



UNIVERSIDAD AUTÓNOMA DE QUERÉTARO
FACULTAD DE INGENIERÍA

MEMORY

CONiIN

XIV INTERNATIONAL ENGINEERING
CONGRESS





2018 XIV International Engineering Congress (CONIIN)

Universidad Autónoma de Querétaro, Santiago de Querétaro, México

From 2018-05-14 to 2018-05-19



ORGANIZING COMMITTEE

2018 XIV International Engineering Congress (CONIIN)

General Chair:

Gonzalo Macías Bobadilla

Program Chair

Saúl Tovar Arriaga

Technical Program Chair:

Juvenal Rodríguez Resendíz

Carlos Villareal Sosa

Advisory Committee:

Margarita Teresa de Jesús García Gasca

Aurelio Domínguez González

Manuel Toledano Ayala

Information Chair

Carlos Torres Hernández

2018 XIV International Engineering Congress (CONIIN)
Facultad de Ingeniería, Universidad Autónoma de Querétaro, Santiago de Querétaro, México
From 2018-05-14 to 2018-05-19



REVIEWER COMMITTEE

Rojas Molina Adrian
Jose Manuel Alvarez Alvarado
Feregrino Perez Ana Angelica
Mendez Lopez Arturo
Alejandro Clemente Chavez
Vargas Vazquez Damián
Talavera Velázquez Dimas
Elizalde Peña Eduardo
Gorrostieta Urtado Efrén
Rico García Enrique
Ortíz Arredondo Felipe
Angel Figueroa Soto
Avatar Flores Gutiérrez
Román García Ramos
Soto Zarazua Genaro
Hernández Padron Genoveva
Jose Marcelino Gutierrez Villalobos
Arroyo Chávez Hiram
Rodríguez Reséndiz Hugo
Rodríguez Morales Jose Alberto
Ríos Moreno José Gabriel
Hernández Zaragoza Juan Bosco
García Trejo Juan Fernando
Esquivel Escalante Karen
Verónica Leyva Picazo

Aceves Fernández Marco Antonio
Contreras Padilla Margarita
Perez Rea María de La Luz
Cuan Hernandez Maria de Los Angeles
Garduño Aparicio Mariano
Trejo Perea Mario
Martínez Prado Miguel Ángel
Martínez Hernández Moises Agustin
Georgina Mota Valtierra
Juan Carlos Moya Morales
Chavez Alegría Omar
Jesus Carlos Pedraza Ortega
Miguel Perez Lara
Gerardo Israel Perez Soto
Juan Manuel Ramos Arreguín
Hector Rea
Jose Luis Reyes
Edgar Rivas Araiza
Erik Rivas Araiza
Carrillo Serrano Roberto Valentín
López Lara Teresa
Suresh Thenozhi
Diana Carolina Toledo Pérez



UNIVERSIDAD AUTÓNOMA DE QUERÉTARO
FACULTAD DE INGENIERÍA

ORAL PRESENTATIONS **MEMORY**

CONiIN

XIV INTERNATIONAL ENGINEERING
CONGRESS





Table of Contents

2018 XIV International Engineering Congress (CONIIN)

Neural Monitoring System for the Characterization of Voltage and Frequency Patterns.

Substrates used in the cultivation of edible mushrooms: Review.

Rhizosphere engineering and its application in agriculture.

Management of stress factors (eustressors) in medicinal plants as an alternative for production of secondary metabolites.

Effect of Polyester Short-fiber on Tensile and Compressive Strength of Tepetate.

Optimal reuse and treatment of grey water through flocculation and granular filtration.

Effect of stocking density on Black Soldier Fly larvae biomass production (*Hermetia illucens*).

Design of a LED module for plant experimentation.

Economic impact produced by differential subsidence in urban areas. Case study Querétaro, Qro.

Improvement of the quality of life through the design of a house by means of clay for rural areas.

Development of a prototype for rainwater reuse.

Geometric design, the solution for Mexico?.

Vibration control in cables of the baluarte bridge with a linear dynamic model.

Characterization of factors that impact academic performance in higher education.

Rainwater catchment system for residential house in Querétaro.

Project proposal for the residential sector using the presented principles in the leed certification system.



Biological Alternatives for Mobilization and Availability of Phosphorus.

Synthesis and characterization of a nanostructured composite for its potential application as a fuel additive.

Evaluation of recycled acrylonitrile-butadiene-styrene/polycarbonate copolymer (ABS/PC) pelletized as fine aggregate in concrete mixtures.

Microalgae relation with nitrate and phosphate concentration in a lentic water body.

Mechanical behavior of subgrade materials for railways through the inclusion of geosynthetics based on recycled expanded polystyrene.

Non-expansive pre-consolidated soil behavior in triaxial test.

Generation of biogas from cattle excrement: A review.

Development of mesoporous matrices of type SBA-16 functionalized with amino groups for the reduction of total chromium in water.

Effect on the concentration of flavonoids in strawberry (*Fragaria anannassa* Duch) by the inoculation of *Rhizophagus intraradices*.

A parallel algorithm for the estimation of missing Normalized Vegetation Index values from satellite images.

Methodology to Quantify the Impact of a Poor Power Quality in an Industrial Robot.

Remote System for the Acquisition of Electric Signals in Parks of Electric Power Production.

Synthesis of CeO₂ thin films by sol-gel method.

Smart system implementation to measure electric consumption, home load and lighting control.

Synthesis and characterization of TiO₂-Au nanopowder.

Rheological characterization of an almond butter.

Neural Monitoring System for the Characterization of Voltage and Frequency Patterns

Luz María Sánchez Reyes

División de Posgrado, Facultad de Ingeniería

Universidad Autónoma de Querétaro

Querétaro, México.

luzmsr@ieee.org

Juvenal Rodríguez Reséndiz

División de Posgrado, Facultad de Ingeniería

Universidad Autónoma de Querétaro

Querétaro, México.

juvenal@ieee.org

Abstract— An EEG pattern is defined as recurrent waveforms that occur regularly and have similar shape and duration. The identification of voltage and frequency patterns for EEG signals can be applied in different areas of medicine such as diagnosis, rehabilitation, and communication with external support devices. This paper presents an investigation performed at the Universidad Autónoma de Querétaro, Facultad de Ingeniería. The objective of the research was the implementation of a BCI (Brain Computer Interface) system for the characterization of voltage and frequency patterns for EEG (electroencephalogram) signals. In the tests carried out, the noise and interference levels were verified. The system was divided into three parts; the first part was the electronic part that helps in the amplification and conditioning of signals, the second part was the signal acquisition system and the implementation of algorithms for processing and the last stage was the Graphical interface to show the obtained results. The graphical interface was developed in LabView and the system for signals acquisition in a DSP (Digital Signal Processor).

Keywords—EEG; BCI; voltage and frequency patterns; DSP; LabView.

I. INTRODUCTION

The brain is the control center of the human being, which receives information from all parts of the body and sends orders. The brain is made up of specialized cells called neurons. Neurons are composed of a cell body, a nucleus, dendrites and an axon. In Fig. 1 is shown the neuron and its interactions.

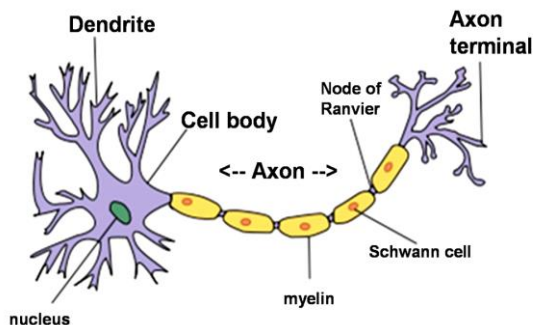


Fig. 1. The neuron and its interactions.

Neurons are electrically excitable cells, process and transmit information via chemical and electrical signals. Although most electrical currents remain within the cerebral cortex, a small fraction penetrates the scalp, which causes different parts of the scalp to have different electrical potentials. These differences vary in amplitudes of 10-100 μ V and are detected by electrodes; these signals are called EEG signals. Electroencephalography (EEG) is one of the techniques of neuroscience, which is based on the recording of brain bioelectrical activity. The EEG is a study widely used in medicine due to its wide field of applications, which is a non-invasive, portable and inexpensive technique compared to other methods. In Fig. 2 is shown the acquisition of EEG signals [2], [3], [7].

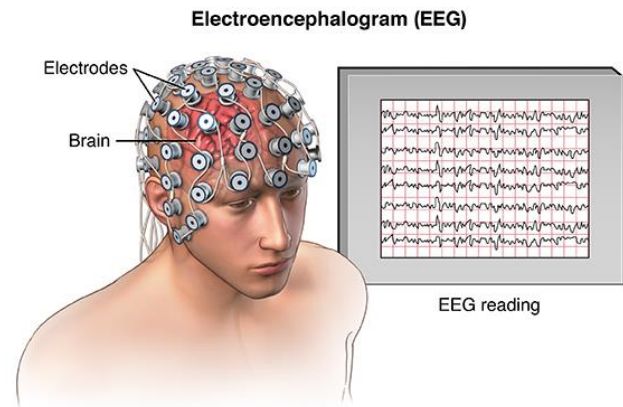


Fig. 2. Acquisition of EEG signals.

Technical characteristics of EEG signals:

- They have amplitudes ranging from 10 μ V in the cortex to 100 μ V in the surface of the scalp.
- Their frequencies are between 0.5Hz and 100Hz.
- They depend on the degree of activity of the cerebral cortex.
- They are non-periodic signals.

- Normal rhythms are often classified as alpha, beta, theta, and delta:
 - Alpha waves (α) have frequencies between 9Hz and 12Hz. They are recorded in normal subjects without activity and with closed eyes, especially in the occipital area.
 - Beta waves (β) have frequencies between 13Hz and 30Hz but can reach up to 50Hz. They are mainly found in the parietal and frontal regions. They are divided into two fundamental types, with very different behavior, beta1, and beta2. Beta1 waves have a double frequency to beta2 waves.
 - Theta waves (θ) have frequencies between 5Hz and 8Hz and occur in childhood, but adults can also present them in periods of emotional stress and frustration.
 - Delta waves (δ) have frequencies below 4Hz and occur during deep sleep, in childhood and severe diseases of brain organs.

Recently a fifth band called gamma (γ) has been found between 22Hz and 40Hz, related to the result of attention or sensory stimulation; which has a very low amplitude (2uV).

A brain-computer interface (BCI) is a means of communication that is mainly based on the acquisition of brain waves using the EEG or some other technique so that later they are processed and interpreted by a computer. One of the primary applications of the BCI is the identification of voltage and frequency patterns of the EEG study since these can help us for the diagnosis, the rehabilitation of disabled people, and communication with external help devices. In Fig. 3 is shown the essential parts of a BCI system [10], [12], [13].

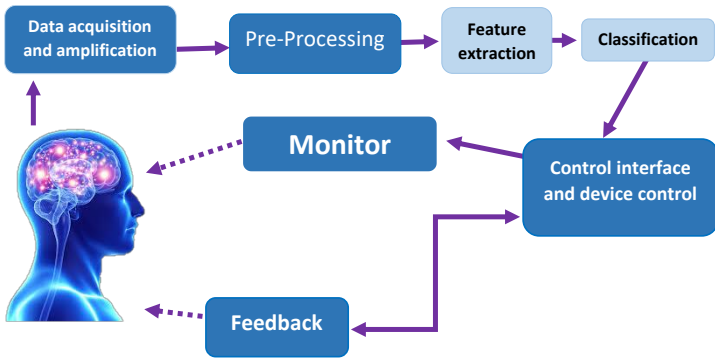


Fig. 3. Parts of a BCI system.

EEG in a system BCI is widely used in compared to other neural techniques. It is a tool of great help for the diagnosis and monitoring of some pathologies, such as epilepsy, encephalopathies, alterations in the state of consciousness or infections of the central nervous system [1], [5], [6].

An EEG pattern is defined based on its:

- Frequency (number of waves per second, Hertz (Hz)).
- Voltage (uV).
- Topography (location).
- Morphology (shape of the wave).
- Symmetry (interhemispheric).
- Character of occurrence (random, continuous, rare, with some sequence of presentation, very frequent).
- Reactivity.
- Modulation (amplitude regulation according to frequency).

However, the most important factors are the amplitude and the frequency of the signals. The objective of this research work is the implementation of a BCI system for the identification of Voltage and Frequency Patterns [1], [8], [9], [11].

II. MATERIALS AND METHODS

The research was done in the facilities of the Universidad Autónoma de Querétaro at the Facultad de Ingeniería, since last year. The main materials to be used for the development of the project are the following: surface mount electrodes with gold discs and shielded cable, electronic card for the acquisition of EEG signals, materials for the application of electrodes (conductive paste, cotton, alcohol, and clamps), and a hp computer (Intel Celeron N3050 processor, 4GB memory, and 1MB hard disk) for the graphical interface.

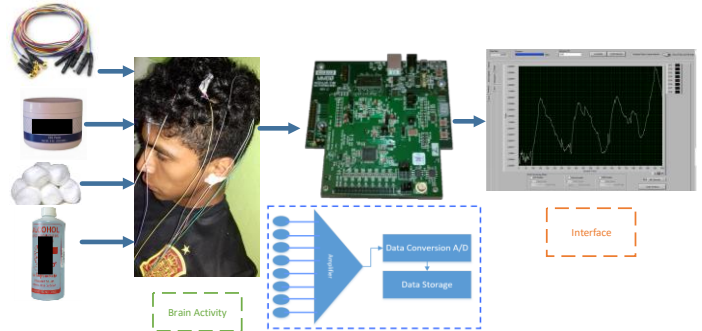


Fig. 4. Stages of the BCI system.

The methodology is divided into four parts; the first part is the bibliographic search that allowed to know the state of the art of BCI systems. The second stage was the implementation of an electronic phase for the amplification and conditioning of the EEG signals. Fig. 4 illustrates the steps of the project.

A. Amplification and Conditioning of the EEG Signals

Recalling some of the properties of the EEG, its amplitude is of the order of uV, and its frequency is between 0-100Hz. According to the above, it is essential that in the second stage conditioning and amplification is added to the signals. The conditioning is integrated by analog bandpass filters and analog band rejection filter using operational amplifiers.

The amplification stage is constituted by instrumentation amplifiers with high noise immunity, and the amplification is adjusted to the voltage levels detected by the ADC. The system is powered by rechargeable batteries to avoid interference from the electrical network.

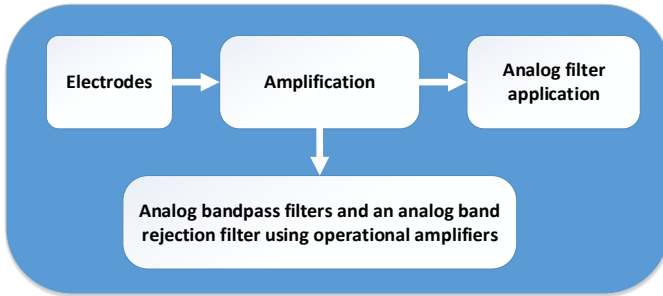


Fig. 5. Conditioning and amplification stage.

The signals are acquired by contact electrodes that are placed on the scalp with the help of a conductive paste; then the signals pass through the conditioning and amplification stage. The number of channels and their location conform to the reduced Ten-Twenty International System. It is important to mention that the electrodes are contact sensors that function as an input element, so there is no risk to the patient and they can be placed even though people have hair or not. A conductive paste is used to position the electrodes; this paste is used to adhere electrodes topically on intact and healthy skin only. The conductive paste is made from a mixture of water, glycerin, calcium carbonate, potassium chloride, white gel, sodium chloride, polyoxyethylene (20) sorbitol, and methylparaben.

B. Signal Acquisition and Processing System

The signal acquisition system has eight channels which were strategically accommodated in the reduced 10-20 International System. The selected positions were frontal, occipital, and parietal. In Fig. 7 is shown the arrangement of the electrodes.

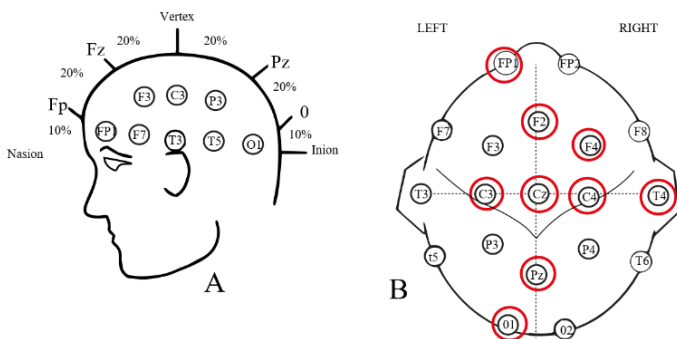


Fig. 7. Arrangement of the electrodes: A. Profile view, B. Top view.

After the signals pass through the conditioning and amplification stage, they are converted from analog to digital signals with the help of an ADC and their information is stored

and processed with a DSP device. The ADC that is used to have a sampling time that can be modified, its communication is through SPI (Serial Peripheral Interface), and it is a specialized device for biopotential applications.

The third stage is the signal acquisition and processing system. This stage contains the reading of the ADC and the implementation of algorithms for the processing of EEG signals. Once the signals are digital, processing techniques are applied to help analyze the signals in the frequency domain and then digital filters are used to eliminate noise due to the equipment and the person.

The Fast Fourier Transform (FFT) is used for the processing of the EEG signals. The FFT helps to pass the time domain information to the frequency domain since having the information in the frequency domain allows identifying the patterns.

After the digital signal was processed, the information is sent to a computer. In Fig. 8 is shown the activities for which the DSP is responsible.

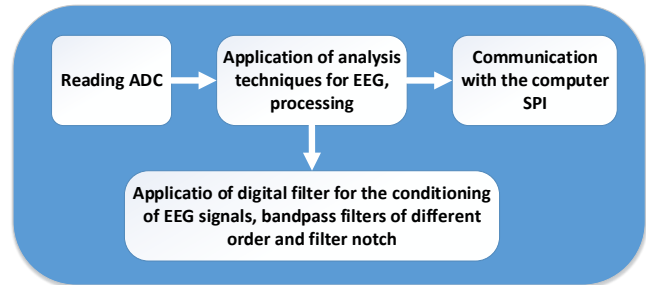


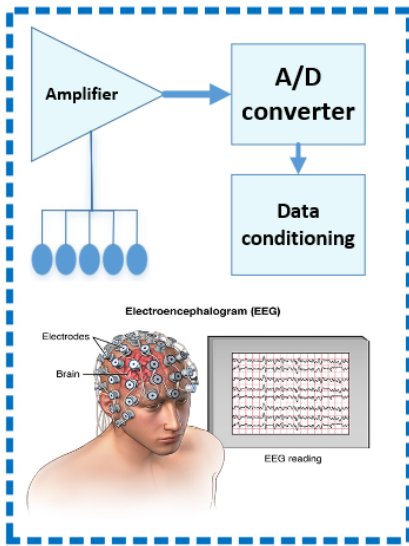
Fig. 6. Internal structure of the BCI system.

C. Application

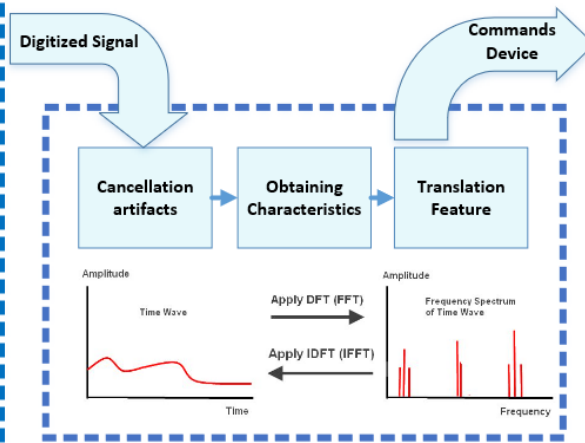
The last stage was the design and implementation of a user-friendly graphical interface that allows to interpret the results and the identification of voltage and frequency patterns. Once the results are shown graphically, the analysis can be quantitative or qualitative, in our case it was qualitatively. Fig. 8 shows the internal structure of the complete system.

The tests were applied to people between 16 and 20 years old and each of the tests lasted from 30 to 45 min. The minimum time for an EEG study is 30 min and a range of ages should be defined to apply the test since according to the corresponding standards for an EEG study, the response of an EEG can vary according to age. In each study it was verified that the noise and interference levels were within the allowed limits. From the studies carried out, a database was generated and compared with databases generated by other equipment.

SIGNAL ACQUISITION



SIGNAL PROCESSING



APPLICATION

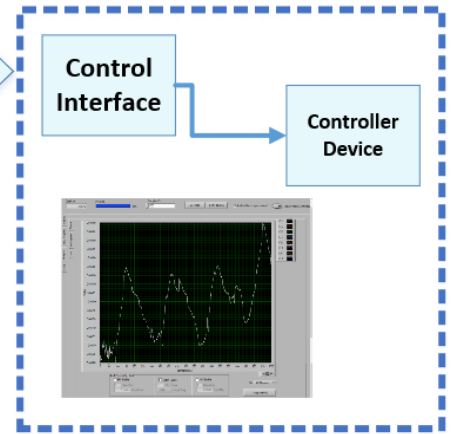


Fig. 8. Internal structure of the complete system BCI.

III. RESULTS AND DISCUSSION

In the identification of patterns, it is important to consider the frequency, amplitude, topography, morphology, symmetry, the level of occurrence, reactivity, and modulation; however, the two most important characteristics are amplitude and frequency. To compare the results of an EEG it is essential to take into account the health conditions of the person, and their age mainly, since according to these characteristics the results are changed. The electrodes were stained in: F2 (frontal 2), F4 (frontal 4), Cz (vertex), C4 (vertex 4), C3 (vertex 3), Pz (parietal), FP1 (frontal parietal 1), O1 (occipital) and T4 (reference, lobes of the ears), Fig. 7.

Once the results of the EEG tests were obtained, they were compared with databases to verify that the noise and interference levels were within the permitted limits according to other similar studies. In Fig. 9 is shown an EEG test performed.

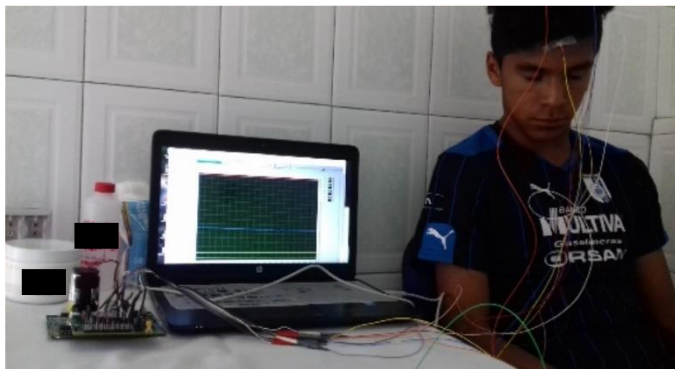


Fig. 9. EEG analysis.

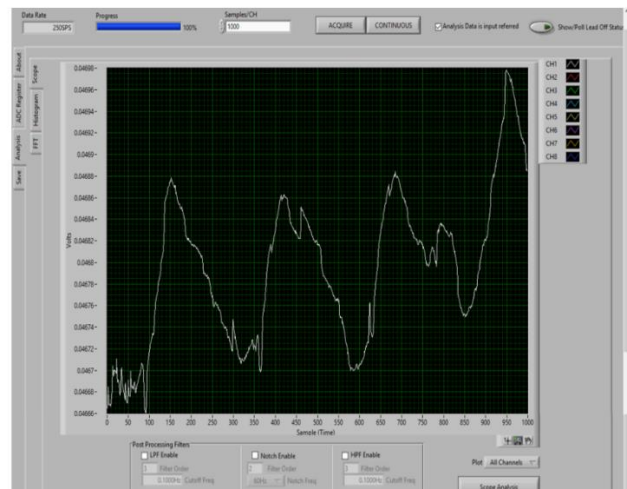


Fig. 10. Graphic interface proposed for EEG analysis.

In Fig. 10 is shown the proposed interface, and the pattern identified when a person closes the right hand. In Fig. 11 is shown the BCI system implemented. According to the analysis of the results, it can be stated that it is possible to identify voltage and frequency patterns of EEG signals by using our BCI system and that can oscillate between 94 and 97% of the data sample. Also, the system has a graphical interface in which it is possible to modify different parameters of the study, such as the sampling frequency, the filter order and the frequency range in which it is applied, among others.

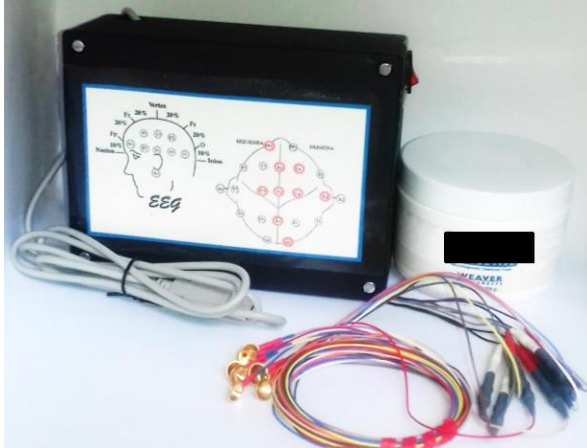


Fig. 11. BCI system.

IV. CONCLUSIONS

According to the analysis of the results, it can be concluded that the identification of EEG patterns is possible through the use of our BCI system. This work constitutes a significant contribution to the improvement of the BCI systems and the implementation of more reliable biofeedback techniques to the same electroencephalographic pattern.

The EEG is widely used in comparison with other neuronal techniques because it is not invasive, dangerous and does not require any surgical intervention. Although the EEG signals are not linear, chaotic or predictive, it has patterns related to the central nervous system which allows us to identify specific brain diseases and communication with external support devices.

BCI systems can be easily affected by the noise generated by the acquisition system or by the noise generated by the person, so it is very important to implement both digital and analog filters for their conditioning. In our case, analog broadband filters and low pass digital filters were added, high passes and notch and notch rejection.

The developed system has the ability to have an open architecture which allows us to make changes in the internal structure, modernize the equipment, and add new tools. Also, it is a portable non-invasive system with a wide field of applications in the area of medicine. As future work will be implemented some other techniques for the conditioning of signals.

V. IMPACT

This work helps future research carried out at the Universidad Autónoma de Querétaro focused on the processing and acquisition of biopotentials.

ACKNOWLEDGMENT

To the Unidad de Investigación en Neurodesarrollo, UNAM and especially to MC. Héctor Belmont Tamayo for his support

during the project. This research was supported by Dr. Juvenal Rodríguez Reséndiz and the UAQ for providing financial and academic support.

REFERENCES

- [1] L. Thu, and N. Hong "Automatic skin lesion analysis towards melanoma detection," *21st Asia Pacific Symposium on Intelligent and Evolutionary Systems (IES) IEEE*, pp. 106-111, 2012.
- [2] V. Bandara, A. Jumpei, and K. Kazuo "Task-based motion intention prediction with EEG signals," *International Symposium on Robotics and Intelligent Sensor, 2016 IEEE*, pp. 57-60, 2016.
- [3] M. Colin, C. King, T. Wang, S. Cramer, N. Zoran, and A. Do "Brain-controlled functional electrical stimulation for lower-limb motor recovery in stroke survivors," *IEEE Journal of Solid-State Circuits*, pp. 1247-1250.
- [4] "Encuesta Nacional sobre Discriminación en México (Enadis)", *Personas con discapacidades, 2014* [Online]. Available: http://conadis.gob.mx/gob.mx/transparencia/transparencia_focalizada/La_Discapacidad_en_Mexico_datos_2014.pdf [Accessed: Jun 22, 2017]
- [5] A. Fares, B. Tong, and K. Masahi, "Stress assessment based on decision fusion of EEG and fmirs signals," *IEEE Journal of Solid-State Circuits*, vol. 5, pp. 19889-19895, 2014.
- [6] M. Jianjun, D. Taylor, M. Kaitlin, S. Nicholas, H. Jeffrey, and H. Bin, "Effects of soft Drinks on Resting State EEG Brain-Computer Interface Performance," *IEEE Journal of Solid-State Circuits*, vol. 5, pp. 18756-18762. doi: 10.1109/ACCESS.2017.2751069
- [7] J. Xu, B. Busze, H. Kim, K. Makinwa, C. Van, and R. Firat "A 60nV/ $\sqrt{\text{Hz}}$ 15-Channel digital active electrode system for portable biopotential signal acquisition," *IEEE Journal of Solid-State Circuits*, pp. 424-426.
- [8] Y. Lin, Y. Xu, and J. Meng, "BCI-implicative ideals of BCI-algebras," *Information Sciences*, vol. 177, pp. 4987-4996, 2007.
- [9] C. Stefano, R. Attux, and G. Castellano, "Can graph metrics be used for EEG-BCIs based on hand motor imagery?" *Biomedical Signal Processing and Control*, vol. 40, pp. 359-365, 2018.
- [10] G. Lange, C. Yee, K. Johar, F. Akthar, and F. Kamaruzaman, "Classification of Electroencephalogram Data from Hand Grasp and Release Movements for BCI Controlled Prosthesis," *Procedia Technology*, vol. 26, pp. 374-381, 2016.
- [11] P. Amorim, T. Moraes, D. Fazanaro, J. Silva, and H. Pedrini, "Electroencephalogram signal classification based on shearlet and contourlet transforms," *Expert Systems with Applications*, vol. 67, pp. 140-147, 2017.
- [12] Z. Iscan, Z. Dokur, and T. Demiralp, "Classification of electroencephalogram signals with combined time and frequency features," *Expert Systems with Applications*, vol. 38, pp.10499-10505, 2011.
- [13] R. Upadhyay, A. Manglick, D. Reddy, P. Padhy, and P. Kankar, "Channel optimization and nonlinear feature extraction for Electroencephalogram signals classification," *Computers & Electrical Engineering*, vol. 45, pp. 222-234, 2015.



Studies on statistical bias in Cosmology

L. Herrera-Zamorano, and A. Hernández-Almada*

Facultad de Ingeniería
 Universidad Autónoma de Querétaro
 Centro Universitario Cerro de las Campanas 76010
 Querétaro, México
 *ahalmada@uaq.mx

Abstract—Based on LambdaCDM model and using Observational Hubble Data (OHD) and Supernovae type Ia (SNIa) sample, we study a possible bias due their limited statistics. We develop an algorithm with the purpose of having the parameters best fits of the Lambda CDM model for several statistics size by selecting with Monte Carlo Methods subsamples with 50%, 75%, and 90% of the OHD and SNIa dataset. We estimate a bias of 5.2% and 9.0% for OHD and SNIa respectively.

Keywords—Computational physics; data analysis; cosmology.

I. INTRODUCTION

Cosmology is the branch of Physics that study the origin and dynamics of the Universe. Currently, the observations provided by Supernovae type Ia, cosmic microwave background (CMB) and baryon acoustic oscillations (BAO) indicate an accelerated Universe [1-6]. The most successful model for understanding the Universe is the well-known *Lambda-Cold Dark Matter* (Λ CDM) [7].

This model considers mainly two dominant components called *dark energy* and *dark matter* that correspond about 96 % of the total. While the latter is postulated to be dust (a pressureless matter) and is the responsible of the structure formation (such as galaxies, clusters of galaxies), dark energy (Λ) is proposed to be a kind of matter with a negative pressure to explain the late accelerated expansion of the Universe.

In this work, we estimate a possible bias due to limited cosmological measurements provided by $H(z)$ and SNIa measurements [8-9].

II. Λ CDM MODEL.

The Friedman equation gives the evolution of the Universe, for Λ CDM model is given by

$$E^2(z) = \frac{H^2(z)}{H_0^2} = \Omega_{m0}(1+z)^3 + \Omega_{r0}(1+z)^4 + \Omega_{\Lambda} \quad (1)$$

where $H(z) = \dot{a}/a$ with a is the scale factor. $H_0 = H(z=0) = 100h$ and z is the red-shift (that can be expressed as function of time). Ω_{m0} , Ω_{r0} , and Ω_{Λ} are the components of matter (baryons and dark matter), radiation, and dark energy

presented in the Universe at the present epoch (today) respectively. In this work, we assume a flat universe that is supported by the observations (see Figure 1) satisfies the following relation

$$\Omega_{m0} + \Omega_{r0} + \Omega_{\Lambda} = 1 \quad (2)$$

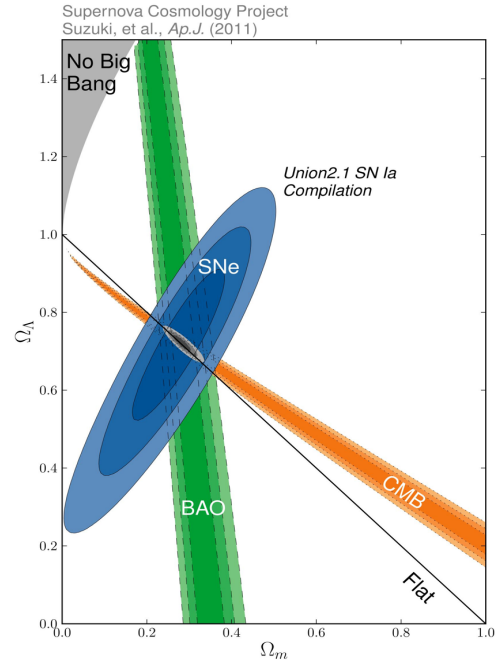


Figure 1: $\Omega_{m0} - \Omega_{\Lambda}$ contour [9].

In addition, one test to probe the late cosmic acceleration comes from the measurements of module distance that is given in terms of the luminosity distance d_L by

$$\mu(z) = 5 \log \left[\frac{d_L(z)}{\text{Mpc}} \right] + \mu_0 \quad (3)$$

Where μ_0 is a nuisance parameter and



$$d_L(z) = (1+z) \frac{c}{H_0} \int_0^z \frac{dz'}{E(z')} \quad (4)$$

Here $E(z)$ is given in equation 1 and c is the speed of light in vacuum.

III. ANALISYS AND RESULTS

In order to search for a possible bias due the statistics size, we fit Λ CDM model to $H(z)$ and SNIa datasets by following the procedure:

- *Case I:* We fit the LCDM model to data coming from.
- *Case II:* We select randomly subsamples containing a 90%, 75%, and 50% of OHD and SNIa datasets.
- *Case II:* We divide $H(z)$ and SNIa datasets into two subsamples by selecting odd and even points respectively.

Then, our strategy is to compare the last two cases with the first one and quantify a possible deviation of the best fit values obtained in the parameters.

The best fit value is obtained by developing an algorithm in python 2.7 based on Minuit module [10]. The figure-of-merit to maximize is the $-\log(L) \approx \chi^2$ where

$$\chi^2 = \sum_i^N \left(\frac{y_i - M(z_i|\Theta)}{e_i} \right)^2 \quad (5)$$

where $M(z_i|\Theta)$ is the model with free parameter Θ , $y_i \pm e_i$ are the measurements with uncertainties at redshift z_i . Notice that for OHD and SNIa dataset, $M(z_i|\Theta)$ is given by equation 1 and 3 respectively.

TABLE I. Values of free model parameters after fitting $H(z)$ data.

Case	Ω_{m0}	h	$\epsilon_{\Omega_{m0}}\%$	$\epsilon_h\%$
$H(z)$	0.251 ± 0.011	0.712 ± 0.007	-	-
$H(z)$ 90%	0.250 ± 0.003	0.713 ± 0.002	0.398	0.140
$H(z)$ 75%	0.250 ± 0.007	0.713 ± 0.004	0.398	0.140
$H(z)$ 50%	0.249 ± 0.011	0.715 ± 0.007	0.797	0.421
$H(z)$ odd	0.253 ± 0.014	0.712 ± 0.010	0.797	$<10^{-3}$
$H(z)$ even	0.238 ± 0.014	0.719 ± 0.010	5.179	0.983

TABLE II. Values of free model parameters after fitting SNIa data.

Case	Ω_{m0}	h	μ_0	$\epsilon_{\Omega_{m0}}\%$	$\epsilon_h\%$	$\epsilon_\mu\%$
$\mu(z)$	0.277 ± 0.019	0.732 ± 0.017	25.096 ± 0.052	-	-	-
$\mu(z)$ 90%	0.277 ± 0.006	0.732 ± 0.004	25.097 ± 0.003	$<10^{-3}$	$<10^{-3}$	0.003
$\mu(z)$ 75%	0.278 ± 0.011	0.732 ± 0.019	25.097 ± 0.008	0.361	$<10^{-3}$	0.003
$\mu(z)$ 50%	0.277 ± 0.019	0.732 ± 0.019	25.097 ± 0.012	$<10^{-3}$	$<10^{-3}$	0.003
$\mu(z)$ odd	0.302 ± 0.029	0.732 ± 0.017	25.106 ± 0.054	9.025	$<10^{-3}$	0.040
$\mu(z)$ even	0.256 ± 0.026	0.732 ± 0.017	25.088 ± 0.054	7.581	$<10^{-3}$	0.032

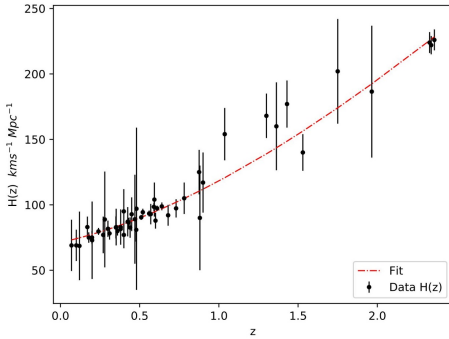


Fig. 1. Best fit (case I) of OHD.

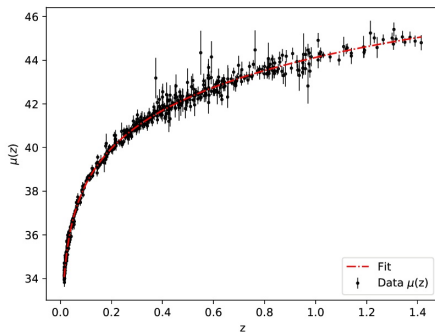


Fig. 2. Best fit (case I) of SNIa data.

IV. SUMMARY AND CONCLUSION

In this paper we estimate a statistical bias due the limited statistics of OHD and SNIa dataset. In order to do this, we develop an algorithm base in Minit module under python environment to obtain the best fit values of the free parameters. Then we take subsamples with 90%, 75 % and 50% of the total dataset. Finally, we compare their corresponding best fit values with respect to the one obtained with the total dataset.

The OHD consist of 51 points that measure the Hubble parameter at several redshifts. In order to get the mean of the parameter best fits (see case II), we consider three cases according to data size. Each one contains 10000 fits by selecting 46, 38 and 25 points randomly. We estimate a bias less than 1% for the case when the data were reduced to 50% for Ω_{m0} and h .

On the other hand, the Union 2.1 Project collects 580 data points coming from the module distance of SNIa. Following a similar procedure of reducing data up to 50%, we obtain a negligible bias (much less than 0.01 %) for both model parameters.

In summary, we expect to have up to 5 % and 9% of deviation for Ω_{m0} (and less than 1% and a negligible bias for h) when OHD and SNIa data are used. This result motivates to increase the size of this samples in order to reduce these uncertainties.

REFERENCES

- [1] Brian P. Schmidt, Nicholas B. Suntzeff, M. M. Phillips, Robert A. Schommer, Alejandro Clocchiatti, et al. The high- z supernova search: Measuring cosmic deceleration and global curvature of the universe using type Ia supernovae. *The Astrophysical Journal*, 507(1):46, 1998.
- [2] S. Perlmutter, G. Aldering, G. Goldhaber, R. A. Knop, P. Nugent, others, and The Supernova Cosmology Project. Measurements of Ω and Λ from 42 high-redshift supernovae. *The Astrophysical Journal*, 517(2):565, 1999.
- [3] Adam G. Riess, Alexei V. Filippenko, Peter Challis, Alejandro Clocchiatti, Alan Diercks, et al. Observational evidence from supernovae for an accelerating universe and a cosmological constant. *The Astronomical Journal*, 116(3):1009, 1998.
- [4] P. A. R. Ade et al. Planck 2015 results. XIII. Cosmological parameters. 2015..
- [5] P. A. R. Ade et al. Planck 2015 results. XIV. Dark energy and modified gravity. 2015.
- [6] Shadab Alam et al. The clustering of galaxies in the completed SDSS-III Baryon Oscillation Spectroscopic Survey: cosmological analysis of the DR12 galaxy sample. *Mon. Not. Roy. Astron. Soc.*, 470:2617–2652, September 2017.
- [7] Planck Collaboration et al. arXiv:1303.5076
- [8] J. Magaña, M. H. Amante, M. A. Garcia-Aspeitia and V. Motta. The Cardassian expansion revisited: constraints from updated Hubble parameter measurements and type Ia supernova data, *Monthly Notices of the Royal Astronomical Society*, vol. 476, n° 1, p. 1036–1049, 2018.
- [9] N. Suzuki, et.al. and The Supernova Cosmology Project. The hubble space telescope cluster supernova survey. v. improving the dark-energy constraints above $z > 1$ and building an early-type-hosted supernova sample. *The Astrophysical Journal*, 746(1):85, 2012.
- [10] Roos M. James F. *Comput. Phys. Commun.*, 10(5):343, 1975.





“Substrates used in the cultivation of edible mushrooms: Review”.

Biol. Byanka Arizbeth Cruz Moreno¹ Dra. Ana Angélica Feregrino Pérez² *¹M. en C. *Engineering of Biosystems*,² *Faculty of Engineering, Universidad Autónoma de Querétaro, Centro Universitario Cerro de las Campanas, S/N, Col. Las Campanas, C.P. 76010 Santiago de Querétaro, Qro., México.*
mibyvis14@gmail.com; *feregrino.angge@hotmail.com

Abstract— Agroindustrial waste is considered to be biomass that is not used or included in the processes of agricultural production, forestry and agro-industry; this vegetal biomass presents a material with high industrial potential called lignocellulose (González-Rentería et al., 2011, Howard et al., 2003). Lignocellulose is a compound difficult to degrade and mineralize, however there is a group of basidiomycete fungi capable of performing this action in a process known as "white rot" disease (Papinutti et al., 2003). Within these degrading fungi are numerous edible species, with high nutritional value. This review focuses on recent advances in the production of edible mushrooms of the genus *Pleurotus*, with special emphasis on substrates composed of profitable agro-industrial waste, that are profitable, provide higher yield, greater biological efficiency (BE) and improve the quality of them.

Keywords— *Mushrooms, waste, bagasse, reuse, agricultural byproducts.*

I. INTRODUCTION (HEADING 1)

Cultivating edible macromycetes is an ecological conversion system, so that what is not useful to man, such as straws, bagasse, husks and pulps, mushrooms transform it into protein food and into a sale product. Once the edible product has been obtained, organic fertilizer can be obtained from the residual substrate for the production of plants and vegetables, conserving and improving the quality of the soils. This type of production has been exploited successfully for years in other countries. Nowadays, the large-scale cultivation of edible fungi represents an agro-industry of great socioeconomic importance, because in addition to providing a food with high nutritional and medicinal value for human consumption, it represents an industry that generates jobs. One of the main challenges for the cultivation of fungi is the growth of the sowing mycelia and the selection of suitable substrates for the development of the mycelium and its fruiting (Maggie et al., 1988). The objective of the present work is to carry out a revision on the substrates useful in the cultivation of edible fungi.

Dr. Sergio de Jesus Romero Gómez³ Faculty of Chemistry, Universidad Autónoma de Querétaro, Centro Universitario Cerro de las Campanas, S/N, Col. Las Campanas, C.P. 76010 Santiago de Querétaro, Qro., México

1. GENERALITIES OF THE FUNGI

Fungi are eukaryotic organisms, belonging to the Fungi kingdom with a cell wall consisting mainly of chitin (Alexopoulos, 1996). They lack of chlorophyll so their nutrition is heterotrophic. They present sexual and asexual reproduction (Tormo, 1996). Their somatic structures are called hyphae and they are usually surrounded by cell walls. Macromycetes are fungi whose carpophores or fruiting bodies can be seen by the naked eye. Commonly they divide into saprophytes when they grow in decomposed matter and absorb organic matter, in symbionts when they form ectomycorrhizae and parasites when they feed on living cells (Pedreros, 2007). Saprophyte fungi growing on lignocellulosic substrates excrete a mixture of hydrolytic enzymes and oxidants that depolymerize the components of the substrate, which according to Valencia and Garin (2001) consist essentially of cellulose (45 to 60 percent), hemicellulose (15 to 20 percent) and lignin (10 to 30 percent). In this group are included parasites of tree destroyers of wood and mushrooms, where most of the species commonly known as edible fungi are found (Sánchez and Royse, 2002).

1.1 REPRODUCTION AND LIFE CYCLE

Two forms of reproduction are observed: sexual and asexual. The sexual phase begins with the stem cells that in the Basidiomycetes are called Basidias. The spores of the basidia are thrown abroad for the propagation of the species. If the spore is deposited in a place whose conditions are favorable, it will give rise to the mycelium. This will grow under the soil or between the leaf litter, it will branch out and intermix with the mycelia of other spores to give rise to the secondary mycelium which will grow and differentiate to form the fruiting bodies. The latter is able to grow and multiply vegetative indefinitely. Therefore, this is the type of mycelium with which edible mushroom growers work (Sánchez and Royse, 2002).





1.2. NUTRIMENTAL, NUTRACEUTICAL AND ECONOMIC CONTRIBUTION OF FUNGI

Fungi have a high nutritional and energetic value, providing beneficial properties for health, which is why they are considered functional foods of high culinary value (Trigos & Suárez-Medellín, 2010). Its dietary value, low carbohydrates and fats, significant protein content (20-40% of dry weight) and vitamins, places them above most vegetables, fruits and vegetables, in addition to being delicious complements in meals for their organoleptic properties (Tormo, 1996). Recent data indicate the presence of compounds that possess high antitumor and anticancer activity as well as activate the immune system, stimulate liver function, contain a potent hypoglycemic, reduce cholesterol level as well as nervous disorders among other properties (Beelman *et al.*, 2003, Wasser and Weiss, 1999, Stamets, 2000, Bobeket *et al.*, 1991, Curvetto *et al.*, 2002, Mau *et al.*, 2002, Baba *et al.*, 2015, Yen *et al.*, 2007, Martínez *et al.*, 2012; Kang, 2013). They contain approximately 30% carbohydrates, 39% crude fiber, 17% crude protein and 2% raw fat (Wang *et al.*, 2014). They present glycemia, antioxidants and vitamins A, C, D, E (Mau *et al.*, 2002, Smith *et al.*, 2002, Baba *et al.*, 2015, Smith *et al.*, 2015); essential vitamins such as B1, B2, B6, B12, riboflavin, niacin, iron, ascorbic acid; minerals such as calcium and phosphorus. Although the lipid content is relatively low, it has essential fatty acids such as linoleic acid (Mendivil-Salmón *et al.*, 2001) and chemical compounds such as lentinan, eritadenine and l-ergothionine. They produce high quantities of hydrolases and oxidases for the bioconversion of lignocellulosic components (Harris-Valle *et al.*, 2014). Due to its capacity to degrade lignocellulosic components, hardwood sawdust with grains is currently used as a nitrogen source (Royse, 1997, Rossi *et al.*, 2003).

1.3. FUNGAL CULTIVATION STRATEGIES

The most commonly used methods for the cultivation of edible fungi are fermentation in solid state (FES), which consists of growing the secondary mycelium of the fungus on a substrate until fruiting, in the absence of free water in the system. And on the other hand the submerged liquid fermentation (FLS) in which a greater quantity of enzymes are produced (Smith, 2002).

Among the factors associated with the substrate are: pH, carbon-nitrogen ratio, particle size, moisture retention capacity, and the amount of carbohydrates, lipids, nitrogen, vitamins and minerals present in its composition. As environmental factors can be mentioned: temperature, relative humidity, aeration and carbon dioxide, lighting, etc.

1.4. USE OF AGROINDUSTRIAL SUBSTRATES FOR FUNGAL CULTIVATION

Although edible fungi are commonly grown in wheat straw or pasteurized rice, they have been grown on a large number of lignocellulosic substrates alone or mixed, most of them

agricultural by-products (Salusso and Moraña, 1997; Darjania *et al.*, 1997; Obodai, 2003; Sánchez *et al.*, 2008)

The substrates most used for the cultivation of fungi are shown in the following table:

TABLE I. SUBSTRATES USED FOR THE CULTIVATION OF *P. ERYNGII* FUNGI.

Substratum	Author and year	Notes
Mixture of wheat straw and cotton waste, Peanut shells, wheat straw.	Philippoussis, 2001	They showed higher rates of colonization of wheat straw and cotton residues than in peanut shells.
Mixture of Mn (50 mg / g) with soybean and cottonseed decolouring mixture with sawdust.	Rodriguez-Estrada y Royse, 2007	Higher yields on substrates containing Mn (50 mg / g) and soybean than on cottonseed / sawdust husk substrate.

TABLE II. SUBSTRATES USED FOR THE CULTIVATION OF *P. PULMONARIUS* FUNGI.

Substratum	Author and year	Notes
Mixture of wheat straw and cotton waste, Peanut shells, wheat straw.	Philippoussis, 2001	They showed higher rates of colonization of wheat straw and cotton residues than in peanut shells.
Mix of wheat straw and grass <i>Lolium perenne</i>	Domondon, 2004	<i>Lolium perenne</i> stimulated fructification and yield of <i>P. pulmonarius</i>
Mixture of coffee pulp and wheat straw	Salmones, 2005	The decrease in caffeine content of the coffee pulp samples during the fruiting phase suggests that part of the caffeine accumulates in the fruiting bodies.
Tomato stubble and a combination with vine wood and wheat straw.	Sánchez <i>et al.</i> 2008	The E.B. varied from 92 to 139.8%, whit the highest value in tomato stubble.

TABLE III. SUBSTRATES USED FOR THE CULTIVATION OF *P. CITRINOPILEATUS* FUNGI.

Substratum	Author and year	Notes
Cotton stalk, coconut fiber, sorghum hay and mixtures of these residues	Ragunathan, 2003	Maximum yields of <i>P. citrinopileatus</i> on cotton stalks.
Water lily	Mukherjee, 2004.	BE of the <i>P. citrinopileatus</i> 79%.





TABLA IV.SUBSTRATES USED FOR THE CULTIVATION OF *P. SAJOR-CAJUR* FUNGLI.

Substratum	Author and year	Notes
Mixture of rice straw and cottonseed powder.	Shashirekha, 2002	When rice and wheat straw are used to grow <i>P. sajorcaju</i> , yields were 10%higher in rice than in wheat straw.
Cotton stalk, coconut fiber, sorghum hay and mixtures of these residues.	Ragunathan, 2003	Maximum yields of <i>P. sajor-caju</i> cotton stalks and <i>P. platypus</i> on sorghum.
Rice straw, banana Straw.	Bonatti, 2004	They presented higher ash content when they are grown in rice straw than when they are grown in banana straw.

TABLA V.SUBSTRATES USED FOR THE CULTIVATION OF *P. FLORIDA*FUNGLI.

Substratum	Author and year	Notes
Water lily	Mukherjee, 2004.	BE of the <i>P. citrinopileatus</i> 79%.
Mixture of rice with cottonseed powder	Shashirekha, 2005	Said substrate increases the yield of total proteins, free amino acids and total lipid content.

TABLA VI.SUBSTRATES USED FOR THE CULTIVATION OF *PLEUROTUS SSP.* FUNGLI.

Substratum	Author and year	Notes
Straw of rice, straw of wheat.	Zhang, 2002	Yields were 10% higher in rice than in wheat straw.
<i>Pinus ssp.</i>	Croan, 2004	<i>Pleurotus</i> spp. It can colonize and produce mushrooms in conifers but they do not always colonize conifers easily.
Coniferous sawdust	Ruan, 2006	Some strains of <i>Pleurotus</i> spp. can be adapted for growing on substrates based on coniferous sawdust.

TABLA VII.SUBSTRATES USED FOR THE CULTIVATION OTHER EDIBLEFUNGLI.

Fungus species	Substratum	Author and year	Notes
<i>Lentinus edodes</i> y <i>Stropharia</i>	Sugarcane bagasse, coffee waste, banana leaves, straw and rice husk, coconut fiber, corn husk, sawdust, sorghum grains.	Grodzinskaya <i>et. al</i> 2002	I report the growth of fungi on these substrates.
<i>P.platypus</i>	Cotton stalk, coconut fiber, sorghum hay and mixtures of these residues.	Ragunathan, 2003	Maximum yields of <i>P. platypus</i> on sorghum.
<i>P. cornucopiae</i>	Mix of grass Panicumvirgatum with 1% ground limestone and Mixture of cotton seed husk with 24% wheat straw and 1% ground limestone.	Royse <i>et al</i> 2004	Higher yields were obtained on the cotton husk substrate / wheat straw substrate. However, maximum yields only reached 46%.
<i>P. columbinus</i>	Various lignocellulosic residues supplemented with fresh chicken manure.	Mandeel <i>et al.</i> 2005	Greater BE was observed in <i>P. columbinus</i> (134%) on paperboard substrate.
<i>P. djamor</i>	Mixture of coffee pulp and wheat straw	Salmones, 2005	The decrease in caffeine content of the coffee pulp samples during the fruiting phase suggests that part of the caffeine accumulates in the fruiting bodies.





TABLA VIII.SUBSTRATES USED FOR THE CULTIVATION OF *P.OSTREATUS* FUNGI.

Substratum	Author and year	Notes
Peanut straw, soy straw, sorghum straw and wheat straw	Yildiz, 1998	Higher and lower yields in peanut straw and sorghum, respectively. Higher protein content with peanut straw.
Wooden log of <i>Quercus humboldtii</i>	Staments, 2000	It generates carpophores of excellent quality.
Mixture of wheat straw and cotton waste, Peanut shells, wheat straw.	Philippoussis, 2001	They showed higher rates of colonization of wheat straw and cotton residues than in peanut shells.
Worn beer grains not pretreated	Wang <i>et al</i> , 2001	Few fruiting bodies formed on the spent grain; however 19% BE was obtained with the addition of 45% wheat bran.
Sunflower seed husks supplemented with N-NH4 + or Mn.	Curvetto, 2002	The addition of mineral nutrients increased the mycelia growth rate. The BE increased in control values and reached 60-112%, depending on the concentration of Mn and N-NH4 +
Sugarcane bagasse, coffee waste, banana leaves, straw and rice husk, coconut fiber, corn husk, sawdust, sorghum grains.	Grodzinskaya <i>et. al</i> 2002	I report the growth of fungi on these substrates.
<i>Tilia</i> spp., European poplar leaves, wheat straw, sawdust and waste paper.	Yildiz, 2002	Increased production of mushrooms in wheat straw and wheat straw mix with waste paper. Lower yield and small diameters of fruit body with <i>Tilia</i> spp. Greater number of fruiting bodies with the mixture of wheat straw, hazel leaves and waste paper.
Waste paper with the addition of chicken manure, peat and rice husks	Baysalet <i>al.</i> , 2003	The greater number of rice husks added to the substrate, the inoculation and formation of the fruit body accelerate. A higher proportion of manure in the peat produces a negative effect on growth.

Mixture of coffee pulp and <i>Digitaria decumbens</i>	Hernández, 2003	This mixture improved the BE, The decrease in the caffeine content of the coffee pulp samples during the fruiting phase suggests that part of the caffeine accumulates in the fruiting bodies.
Banana leaves, corn cob, corn husk, rice husks, elephant grass, rice straw.	Obodai <i>et al</i> ,2003	Rice straw is the best substrate for growing mushrooms.
Fresh sawdust, composted sawdust / bran mixture.	Obodai, 2003	BE in <i>P. ostreatus</i> is lower in fresh sawdust than in composted sawdust / bran mixture
Rice straw, banana straw	Bonatti, 2004	They presented higher ash content when they are grown in rice straw than when they are grown in banana straw.
Oak sawdust	Shanet <i>al.</i> 2004	Biological Efficiency (BE) of 64.9%
Mix of corn and pumpkin straw.	Ancona, 2005	The substrate had no effect on the nitrogen content in the amino acid profile of the fruiting bodies; the nitrogen content increased from the first harvest to the third
Various lignocellulosic residues supplemented with fresh chicken manure	Mandee <i>et al.</i> 2005	Greater BE was observed in <i>P. ostreatus</i> (117%) on paperboard substrate.
Different species of trees.	Pavlik, 2005	The yields of the fruiting bodies vary with the species of trees used, ranging from 21% biological efficiency (BE) for beech wood to 3% BE for alder wood.
Mixture of coffee pulp and wheat straw	Salmones, 2005	The decrease in caffeine content of the coffee pulp samples during the fruiting phase suggests that part of the caffeine accumulates in the fruiting bodies.
Weed (<i>Leonotis</i> spp. Mixed with rice straw, <i>Sida acuta</i> ,	Das, 2007	<i>Leonotis</i> spp. Mixed with rice straw was the best substrate for





<i>Parthenium argentatum</i> , <i>Ageratum conyzoides</i> , <i>Cassiasophera</i> , <i>Tephrosia purpurea</i> y <i>Lantana camara</i>		inoculation and culture, <i>T. purpurea</i> was the least appropriate. Higher protein content in the fungus in <i>Cassiasophera</i> , <i>Parthenium argentatum</i> and <i>Leonotis spp.</i>
Tomato stubble and a combination with vine wood and wheat straw.	Sánchez <i>et al.</i> 2008	The EB varied from 92.0 to 139.8%, with the highest value in tomato stubble.

In Mexico, traditional techniques have been adapted and modified to reduce the crop cycle and lower production costs by using material substrates not previously considered, such as shavings and sawdust from different trees, such as oak (*Quercus spp.*), pine (*Pinus spp.*), palo mulato (*Bursera spp.*) etc., (Mata *et al.*, 1990, Morales and Martínez, 1990, Morales and Martínez, 1991) and several agricultural residues such as corn (*Zea mays*), cane sugar (*Saccharum spp.*) oats (*Avena sativa*) etc., (Soto *et al.*, 1992; Mata and Guzmán, 1993; Mata and Gaitán, 1994; Ashrafuzzaman *et al.*, 2009).

1.5. ECONOMIC AND ENVIRONMENTAL BENEFITS OF USING AGROINDUSTRIAL SUBSTRATES

One example is the profitability of overgrowth on artificial mushroom crops, productions of 3.1 kg / m² are obtained, higher than many agricultural crops (for example, wheat: 0.27 kg / m², meat: 0.69 kg / m² (Schies, 2006).

On the other hand, it is known that the agroindustrial activity generates a large amount of what has been declared as waste, with significant negative impacts on the environment, such as the generation of pests, water pollution, bad odors, among others (Barragán -Huerta *et al.*, 2008). Faced with this concern, interest has been awakened in taking advantage of what had been considered waste and focusing it as a waste that could be used for the production of new products.

Official data from 2006, establish that in Mexico there were 75.73 million tons of dry matter from 20 crops, of which 60.13 million tons correspond to primary waste, obtained at the time of harvest, among which are: leaves and stems of corn, stems and pods of sorghum, tips and leaves of sugarcane, wheat straw, straw of barley and beans, as well as cotton husk.

While, 15.60 million tons correspond to secondary waste obtained from post-harvest processing, among which are: sugarcane bagasse, corncobs and olotes, maguey or agave bagasse, as well as coffee pulp (Valdez-Vázquez *et al.*, 2010).

In general, agroindustrial lignocellulosic residues are mainly composed of cellulose, hemicelluloses and lignin (Deysson, 1982, Hendriks & Zeeman, 2009, Hopkins, 2003), the main compounds necessary for the growth of some edible fungi.

In addition to this, the commercial production of edible fungi represents an agroindustry of great socioeconomic importance, since it not only provides a food of acceptable nutritional and medicinal value for human consumption, but also represents an industry that generates jobs. In China, the main producer of mushrooms cultivated in the world, 25 million people are involved in this activity (Li, 2012), while in Mexico 25,000 direct and indirect jobs could have been generated in 2005 as a result of the production and industrialization of these organisms (Martínez-Carrera *et al.*, 2007).

2. Conclusions

Lignocellulosic compounds present in agroindustrial waste are a valuable resource that can be used in the production of edible fungi, also creating a production line free of waste. The production of edible fungi can become an activity of economic importance, to generate extra incomes in the world.

ACKNOWLEDGMENT

I appreciate the FOPER 2018 project.

REFERENCES

- [1] S. González-Rentería, N. Soto-Cruz, N., Rutiaga- Quiñonez, O., Medrano-Roldán, H., López- Miranda, J. Optimization of the process of enzymatic hydrolysis of a mixture of bean straws of four varieties (Pinto villa, pinto saltillo, pinto mestizo and May flower). Mexican Journal of Chemical Engineering. 2011.10: 17-28.
- [2] R. Howard, E. Abotsi, A. Jansen, E. Van Rensburg, and Howard, S. Lignocellulose biotechnology: issues of bioconversion and enzyme production. African Journal of Biotechnology 2. 2003. 602-619.
- [3] V. Papinutti, L. Diorio and F. Forchiassin. Degradación de madera de álamo por *Fomes sclerodermeus*: Producción de enzimas ligninolíticas en aserrín de álamo y cedro. Revista Iberoamericana de Micología 20.2003 16-20.
- [4] Y. Maggie, Y. Matsubara, T. Shiratori and T. Sasaki. Variation in fruiting body production of protoclones of oyster mushroom. HortScience 23(6). 1988. 1.065-1.066.
- [5] C. J. Alexopoulos, C.W. Mims and M. Blackwell Introductory Mycology. John Wiley and Sons Inc. USA. 1996.
- [6] R. Tormo Molina. Los hongos: generalidades (en línea). Lecciones hipertextuales de botánica, España. 1996.
- [7] J. Pedreros. Evaluación del crecimiento y producción de *Lenitina edodes* (shiitake), en residuos agroindustriales. Pontificia Universidad Javeriana. 2007.





- [8] J. Sánchez, D. Roysse. La biología y el cultivo de *Pleurotus spp.* Colegio de la Frontera Sur (ECOSUR), Chiapas, México, D. F., MX, Editorial Limusa, S.A. 2002. 290p.
- [9] A. Trigos & J. Suárez-Medellín. Los hongos como alimentos funcionales y complementos alimenticios. En D. Martínez-Carrera, N. Curvetto, M. Sobal, P. Morales, & V. M. Mora (Eds.), Hacia un desarrollo sostenible del sistema de producción-consumo de los hongos comestibles y medicinales en Latinoamérica: avances y perspectivas en el siglo XXI. Puebla, México: Red Latinoamericana de Hongos Comestibles y Medicinales-COLPOS-UNSCONACYT-AMC, UAEM, UPAEP, IMINAP. 2010.
- [10] R. B. Beelman, D.J. Roysse, N. Chikthimmah. Bioactive components in button mushroom *Agaricus bisporus* (J. Lge) Imbach (Agaricomycetidae) of nutritional, medicinal, and biological importance (review). International Journal of Medicinal Mushrooms. 2010. 5:321–337.
- [11] S. P. Wasser and A. L. Weiss. Medicinal properties of substances occurring in higher Basidiomycetes mushrooms: current perspectives (Review). International Journal of Medicinal Mushrooms 1. 1999.
- [12] P. Stamets. Growing gourmet and medicinal mushrooms. Ten Speed Press, Berkeley, California. 2000. Pp574.
- [13] P. Bobek, E. Ginter, L. Kuniak, J. Babala, M. Jurcovicova, L. Ozdin, J. Cerven. Effect of mushroom *Pleurotus ostreatus* and isolated fungal polysaccharide on serum and liver lipids in Syrian hamsters with hyperlipoproteinemia. Nutrition. 1991. 7, 105–108.
- [14] N. Curvetto, D. Figlas and S. Delmastro. Sunflower seed hulls as substrate for the cultivation of Shiitake mushrooms. Hort Technol. 2002. 12(4):652–655
- [15] J. L. Mau, H. C. Lin, S.F. Song. Antioxidant properties of several specialty mushrooms. Food Res. 2002 Int., 35 (6), 519–526.
- [16] E. Baba, G. Uluköy, C. Önta. Effects of feed supplemented with *Lentinula edodes* mushroom extract on the immune response of rainbow trout, *Oncorhynchus mykiss*, and disease resistance against *Lactococcus garvieae*. Aquaculture. 2015. 448, 476–482.
- [17] Yen, M. Ming-Tsung, Jeng-Leun. Selected physical properties of chitin prepared from Shiitake stipes. El Servier “LWT - Food Sci. Technol. 2007. 40(3):558-563
- [18] G. M. A. Martínez, D. Sihuana, L. A. Macías, L. Pérez, M. D. Martínez, and O. López. Characterization and production of Shiitake (*Lentinula edodes*) in Mexico using supplemented sawdust. Afr. J. Biotechnol. 2012. 11(46):10582-10588.
- [19] J. C. Kang. The risen of mushroom pharmaceutical industry. In: The 7th International Medicinal Mushroom Conference. 26–29. Chinese Academy of Engineering, Beijing, China, 2013. pp. 826–834.
- [20] X.-M. Wang, J. Zhang, L. H. Wu, Y. L. Zhao, T. Li, J. Q. Li, Y. Z. Wang, H. G. Liu. A mini-review of chemical composition and nutritional value of edible wild-grown mushroom from China. Food Chem. 2014 151, 279–285.
- [21] J. Smith, N. Rowan, R. Sullivan. Medicinal mushrooms: Their therapeutic properties and current medical usage with special emphasis on cancer treatments. 2002. Available at: http://www.academia.edu/305933/Medicinal_Mushrooms_Their_therapeutic_properties_and_current_medical_usage_with_special_emphasis_on_cancer_treatments
- [22] H. Smith, S. Doyle, R. Murphy. Filamentous fungi as a source of natural antioxidants. Food Chem. 2015. 185, 389–397.
- [23] M. Salusso y L.B. Moraña. Cultivo de *Pleurotus laciniatocrenatus* en Argentina. Revista Iberoamericana de Micología. 1997. 14:129–130.
- [24] L. Darjanja, N. Curvetto, M. Schapiro, D. Figlas, D. Curvetto. Sunflower seed hulls as a substrate for cultivation of an oyster mushroom, *Pleurotus ostreatus*. MushroomNews. 1997. 45:6–10.
- [25] M. Obodai, J. Cleland-Okine, K. A. Vowotor. 2003. Comparative study on the growth and yield of *Pleurotus ostreatus* mushroom on different lignocellulosic by-products. Journal of Industrial Microbiology and Biotechnology 30:146–149.
- [26] A. Sánchez, M. Esqueda, R. Gaitán-Hernández, A. Córdova, M.L. Coronado. Uso potencial del rastrojo de tomate como sustrato para el cultivo de *Pleurotus spp.* Revista Mexicana de Micología. 2008. 28:17–24.
- [27] A. Yildiz, M. Karakaplan, F. Aydin, Studies on *Pleurotus ostreatus* (Jacq. ex Fr.) Kum. var. *salignus* (Pers. ex Fr.) Konr. et Maubl.: Cultivation, proximate composition, organic and admniral composition of carpophores, Food Chem. 61.1998.127–130.
- [28] A. Philippoussis, G. Zervakis, P. Diamantopoulou. Bioconversion of agricultural lignocellulosic wastes through the cultivation of the edible mushrooms *Agrocybe aegerita*, *Volvariella volvacea* and *Pleurotus spp.*, World J. Microbiol. Biotechnol. 2001. 17 :191–200
- [29] D. Wang, A. Sakoda, M. Suzuki. Biological efficiency and nutritional value of *Pleurotus ostreatus* cultivated on spent beer grain, *Bioresour. Technol.* 2001. 78 : 293–300.
- [30] A.A. Grodzinskaya, Diógenes Infante H. y Nickolai M. Piven. Cultivo de hongos comestibles utilizando desechos agrícolas e industriales. Agronomía Trop. v.52 n.4 Maracay oct. 2002
- [31] M.N. Shashirekha, S. Rajarathnam, Z. Bano, Effects of supplementing rice straw growth substrate with cotton seeds on the analytical characteristics of the mushroom, *Pleurotus florida* (Block & Tsao), *Food Chem.* 92. 2005.255–259.
- [32] S. Yildiz, Ü.C. Yildiz, E.D. Gezer, A. Temiz. Some lignocellulosic wastes used as raw material in cultivation of the *Pleurotus ostreatus* culture mushroom, *Process Biochem.* 2002. 38:301–306.
- [33] R. Zhang, X. Li, J.G. Fadel. Oyster mushroom cultivation with rice and wheat straw, *Bioresour. Technol.* 2002. 82 :277–284.
- [34] E. Baysal, H. Peker, M.K. Yalinkılıç, A. Temiz. Cultivation of oyster mushroom on waste paper with some added supplementary materials, *Bioresour. Technol.* 2003. 89 : 95–97.
- [35] M. Hernández, M.A. Chávez, R. Báez, C. Carvajal, M. Márquez, H. Morris, R. Santos, J.L. González, V. Quesada y C. Rodríguez. Nueva tecnología para la obtención de un preparado de bromelina de tallo de piña (*Ananas comosus* (L.) Merr). *Biotechnol. Apl.* 20(3). 2003.180–182.
- [36] R. Rangunathan, K. Swaminathan, Nutritional status of *Pleurotus* spp. grown on various agro-wastes, *Food Chem.* 80. 2003. 371–375.
- [37] M. Bonatti, P. Karnopp, H.M. Soares, S.A. Furlan, Evaluation of *Pleurotus ostreatus* and *Pleurotus sajor-caju* nutritional characteristics when cultivated in different lignocellulosic wastes, *Food Chem.* 2004. 88: 425–428.
- [38] S. C. Croan. Conversion of conifer wastes into edible and medicinal mushrooms, *Forest Prod. J.* 2004. 54: 68–76.
- [39] D.L. Domondon, W. He, N.D. Kimpe, M. Höfte, J. Poppe. b-Adenosine, a bioactive compound in grass chaff stimulating mushroom production, *Phytochemistry.* 2004. 65, 181–187.
- [40] R. B. Mukherjee, Nandi. Improvement of *in vitro* digestibility through biological treatment of water hyacinth biomass by two *Pleurotus* species, *Int. Biodeter. Biodegr.* 2004. 53: 7–12.
- [41] D. J. Roysse. Cultivation of shiitake on synthetic and natural logs. 1997.
- [42] Shan, Z. Ashraf, M. Ishtiaq. Comparative study on cultivation and yield performance of Oyster Mushroom (*Pleurotus ostreatus*) on different substrates (Wheat Straw, Leaves, Saw dust). *Pakistan Journal of Nutrition.* Vol. 3. 2004. No 3:158-160.
- [43] L. Ancona, Mendez, C.A. Sandoval-Castro, R. Belmar Casso, C.M. Capetillo Leal. Effect of substrate and harvest on the amino acid profile of Oyster mushroom (*Pleurotus ostreatus*), *J. Food Compos.* 2005. *Anal.* 18:447–450.
- [44] Q. Mandeel, A. Al-Lait, S. Mohamed. Cultivation of oyster mushrooms (*Pleurotus spp.*) on various lignocellulosic wastes, *World J. Microbiol. Biotechnol.* 2005. 21: 601–607.
- [45] M. Pavlik. Growing of *Pleurotus ostreatus* on woods of various deciduous trees, *Acta Edulis Fungi.* 12. 2005.306–312.
- [46] D. Salmones, G. Mata, K.N. Waliszewski. Comparative culturing of *Pleurotus* spp. on coffee pulp and wheat straw: Biomass production and substrate biodegradation, *Bioresour. Technol.* 96.2005. 537–544.
- [47] R.G. Ruan, L.C. Ding, X.H. Pan, H. Chen, Y.F. Luo. Domestication and cultivation of *Pleurotus citrinopileatus* strain Ninghuang No. 16 on a substrate containing pine and fir sawdust, *Acta Edulis Fungi.* 13. 2006. 36–38.
- [48] N. Das, M. Mukherjee. Cultivation of *Pleurotus ostreatus* on weed plants, *Bioresour. Technol.* 98. 2007. 2723–2726.
- [49] A. E. Rodriguez Estrada, D.J. Roysse. Yield size and bacterial blotch resistance of *Pleurotus eryngii* grown on cottonseed hulls/oak sawdust supplemented with manganese, copper and whole ground soybean, *Bioresour. Technol.* 98. 2007. 1898–1906.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

- [50] G. Mata, D. Salmones, and G. Guzmán. Cultivo del Shiitake japonés, *Lentinus edodes*, en bolsas con viruta de madera. Rev. Mex. Micol. 6(1). 1990. 245-251.
- [51] P. Morales, and D. Martínez-Carrera. Cultivation of *Lentinula edodes* in Mexico. Micol. Neotrop. Apl. 3. 1990. 13-17.
- [52] P. Morales, and D. Martínez-Carrera. Bursera sawdust as a substrate for shiitake cultivation. Micol. Neotrop. Apl. 4. 1991. 41-47.
- [53] V.C. Soto, S. Fausto, and L. Guzmán-Dávalos. Cultivo del hongo de encino (*Lentinus* spp.) sobre una mezcla de bagazo de maguey tequilero y bagazo de caña de azúcar. In: Memorias I Congreso Centroamericano de Micología. Guatemala, C. A. 1992.
- [54] G. Mata, and G. Guzmán. Cultivation of *Lentinus boryanus* in wood shaving in Mexico. Cryptogamic Bot. 4(1). 1993. 47-49.
- [55] G. Mata, and R. Gaitán-Hernández. Avances en el cultivo del Shiitake en pulpa de café. Revista Iberoamericana de Micología 11. 1994. 90-91.
- [56] M. Ashrafuzzaman, A. Kamruzzaman, M. Razi-ismail, S. Shahidullah, and S. Fakir. Substrate affects growth and yield of shiitake mushroom. Afr. J. Biotechnol. 8(1). 1994. 2999-3006.
- [57] M. Schiess. Hongos comestibles (en línea). Universidad de Chile, Facultad de Ciencias Agronómicas. La Pintana, Santiago de Chile. 2006. Disponible en : <http://agronomia.uchile.cl/webcursos/cmd/12003/Macarena%20Schiess> /DHCEXport/default.htm
- [58] B. Barragán-Huerta, Y. A. Téllez-Díaz & A. Laguna-Trinidad Utilización de residuos agroindustriales. Revista Sistemas Ambientales. 2. 2008. 44-50.
- [59] I. Valdez-Vazquez, J. A. Acevedo-Benitez, and C. Hernandez-Santiago. Distribution and potential of bioenergy resources from agricultural activities in Mexico. Renew. Sust. Energy Rev. 14. 2010. 2147-2153.
- [60] G. Deysson. Physiologie et Biologie des plantes vasculaires. Tome III. Première partie. Nutrition et metabolisme (5ème ed) France: Societé d'Édition d'Enseignement Supérieur. 1982.
- [61] A. T. W. M. Hendriks & G. Zeeman. Pretreatment to enhance the digestibility of lignocellulosic biomass Bioresource technology. 100. 2009. 10-18.
- [62] W. G. Hopkins. Physiologie Végétale. España : De Boeck & Laicier. 2003.
- [63] Y. Li. Present, development situation and tendency of edible mushroom industry in China. In: Zhang, J., H. Wang, M. Chen, (eds.), Mushroom Science 18, China Agriculture Press. 2012. pp. 3-9.
- [64] D. Martínez-Carrera, P. Morales, M. Sobal, M. Bonilla, W. Martínez. La cadena de valor de los hongos comestibles de México. In: Zulueta R., R., D. Trejo A., A. Trigos L. (eds.). El maravilloso mundo de los hongos. Universidad Veracruzana. Xalapa. 2007. pp. 71-90.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERIA

Rhizosphere engineering and its application in agriculture.

Q.F.B. Betsie Martínez Cano

*Master in Biosystems Engineering
Faculty of Engineering
Autonomous University of Queretaro
Querétaro, Querétaro.
betsiemtz@gmail.com*

Dr. Genaro Martín Soto Zarazúa

*Faculty of Engineering
Autonomous University of Queretaro
Querétaro, Querétaro.
soto_zarazua@yahoo.com.mx*

Abstract- The rhizosphere engineering is based on the design and manipulation of the physical and chemical environment where the interaction between the plant, the soil and the microorganisms takes place to get effects that benefit plants and environment. A part of rhizosphere engineering studies the managing and manipulation of the microbial communities to search the health of plants, according to the role of microorganisms in the source of organic matter in the soil, mineralization and solubilization of nutrients as well as resistance to certain pests. This is applied in the agriculture as a means to get improvement in the crops' yield and quality, aside from to optimize the water retention capacity, the nutrient cycle and the antagonism toward the pathogens.

This work is an investigation of the studies released in recent years about the benefits obtained with the designing microbial communities and the adaptability of the plants to biotic and abiotic stress, so as to implement this knowledge in agricultural soils and increase the production of food and bioenergy.

Keywords - rhizosphere; microbial communities; rhizosphere engineering; biotic factors; abiotic factors.

I. INTRODUCTION

The first habitat where the soil particles and the roots of plants are in contact is the rhizosphere, which is the first contact between soil microorganisms and plants. In this zone exist a very important communication that perform a high impact on carbon flux and its transformation, also other soil components used by the plants like nutrients [1]. Likewise, there is a very close relationship between the composition and abundance of exudates from the roots with the structural and functional properties of the microorganisms that live there [2]. Therefore, rather than to be considered a region, it's cataloged as a gradient of physical, chemical and biological qualities through the root [3].

The composition of the rhizosphere is influenced by the metabolism of plants when they excrete photosynthates and some phytohormones, these compounds participate in communication with the microorganisms. The beneficial interactions of plants with these microorganisms have favorable effects, such as the improvement of diseases, the availability of nutrients and the increase of immunity to biotic and abiotic stress [4]. These includes the drought

[5], salinity [6], high concentrations of CO₂ in the atmosphere [7], changes in temperature [8] and heavy metals [9]. There are many researches that suggest that the rhizosphere composition influences in the department of plants in the presence of these factors [10]. In this way, the rhizosphere engineering appear, it's based on the design and manipulation of the physical and chemical properties of the rhizosphere for obtain benefits in plants and the environment "Fig. 1" [11]. In agriculture this is used as a method to reach improvements in yield and quality of crops [12], in addition to optimize the water retention, the nutrient cycle and the resistance to pathogens [13].

One of the applications of rhizosphere engineering focuses on the management and manipulation of microbial communities for the health of plants, in conformity with the role of microorganisms in the development of organic matter, mineralization and solubilization of nutrients, as well as resistance to certain pests [14]. Currently, the ability to control and manipulate microbial communities in the rhizosphere is reduced, with inoculation being the most direct way to do so. However, although

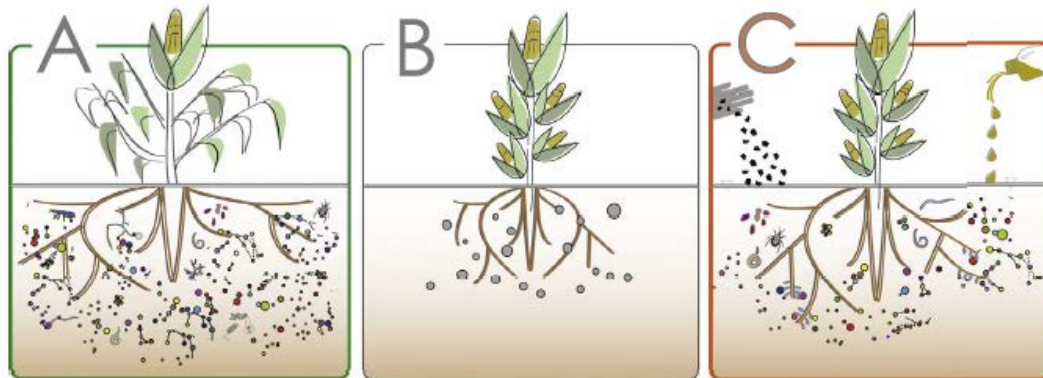


Fig. 1. Rhizosphere engineering (A) natural ecosystems, (B) ecosystems degraded by intensive agriculture and use of fertilizers and (C) rhizospheres designed by inoculations of microbial communities or rhizosphere engineering. Taken from Wallenstein, 2017 [14]

these inoculate give good results under laboratory and greenhouse conditions, are not reproducible under natural state in the field [15]. It's very important to make a research about the benefits of designing microbial communities that improve the adaptability of plants to biotic and abiotic stress, for implement this knowledge in agricultural soils.

II. BENEFITS OF THE MICROBIAL COMMUNITIES IN THE RHIZOSPHERE.

The rhizosphere is the region where chemical communications and the exchange of nutrients between plants and microorganisms of the soil are carried out [16], these relationships play important roles in various vital processes, such as carbon retention and the nutrient cycle [4]. The beneficial interactions between plants and microorganisms include the suppression of diseases [17], the increase in nutrient availability [18], and an improvement in resistance to biotic and abiotic stress [19] these increases the productivity of plants [20]. According to this, a technique to improve health of crops is the selection and modification of microbial communities in the rhizosphere [14].

Several studies have been realize about the inoculation of microbial communities to obtain improvements in agricultural productivity, such as the synergy between *Azotobacter* and mycorrhizal fungi, they improve the height of the plants aside from the number and weight of the fruits [21]. On the other hand, *Azotobacter* and *Bacillus* increase the growth and yield of crop, while they reduced application of chemical fertilizers [22]. A study of the synergy between *Rhizobium* and *Trichoderma*, prove this

increases crop production and the support of the plants [23]. When *Azospirillum*, *Azotobacter*, *Bacillus*, *Enterobacter* and *Pseudomonas* coexist, better results are observed in the recovery of nitrogen, as well as lower incidence of pathogens and finally a good productivity [24]. Furthermore, *Azospirillum* in synergy with *Azotobacter* have shown beneficial results in the growth of plants when inorganic nitrogen is added [25]. The *Azospirillum*, *Azoarcus* and *Azorhizobium* consortium improves root growth, resistance to environmental stress and decreases nitrogen loss in the farmlands [26]. Nevertheless, the rhizosphere engineering dedicated to microbial communities has not only search an increase in production and decrease diseases, it has also reduced the impact of climate change on the health in plants through beneficial mutualism between microorganisms and plants, because these interactions improve the plant's adaptability to biotic and abiotic stress, giving it a certain tolerance [10].

A. Elevated CO₂ levels in atmosphere

CO₂ is a gas that causes the greenhouse effect and it exists naturally in the atmosphere, however, certain human activities increase alarmingly the concentration of this gas and it is already part of global warming [27]. Understand the impact of the increase of CO₂ in the atmosphere, nutrient cycle and the soil has carry to look for alternatives to maintain nutrients in an effective way in the crops. One of them is the addition and use of soil microorganisms to support nutrients in balance [7]. There are researches that study the relationship between CO₂ and soil microorganisms and its benefit to plants. These researches have demonstrated that the CO₂ fluxes in soil and atmosphere are



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERIA

regulated in a very important way by microbial communities like a response to changes of pH, light and they ensure that there are microorganisms with affinity for CO₂ [28].

Studies shows that in a field with high CO₂ and reduced rains, it is altered the composition of microbial communities in the soil, extremely affecting the plants, increases fungal proliferation therefore increases soil C concentration and decreases the amount of N by the few nitrogen-fixing bacterial communities [29]. However, when inoculating with *Pseudomonas* and mycorrhizal fungi in a lettuce crop, in an atmosphere with high CO₂ and limited irrigation, greater soil stability is observed and an increase in biomass of the root, which indicates that the inoculation with these microorganisms can be an alternative to improve soil properties and increase the crops development in semi-arid regions [30]. The microbial communities' functions are altered by the increase in CO₂ because it increases the abundance of functional genes involved in the carbon and nitrogen cycle to feed back into the ecosystem [31]. There is research that suggests that the presence of growth-promoting rhizobacteria benefit terrestrial carbon storage, through an increase in crop yield and decrease in carbon losses due to respiration of soil microorganisms when there is a considerable increase of CO₂ in the environment [32], for this reason it's considered that an increase of this type of rhizobacteria can be beneficial to increase crop yield submitted to high CO₂ levels [1].

B. Heavy metals

Heavy metals are non-biodegradable electronegative elements, usually toxic at high concentrations, because of that, they tend to accumulate in the environment causing diseases to the crops and obstructions in the biogeochemical cycles [9]. The presence of these compounds in the soil causes decrease in mass and composition of microbial communities. Nonetheless, there are microorganisms that can survive because they have cellular mechanisms to tolerate and eliminate toxicity by cellular precipitation, metal transformation and bioabsorption in their cell wall. These microorganisms have application in the soil bioremediation [33]. Some of them are *Aspergillus*, *Penicillium*, *Fusarium*, *Alternaria*, *Geotrichum*, *Scopulariopsis* y *Curvularia*, that have been isolated in polluted places and they are tolerant to heavy metals [34]. The studies carried out about these microorganisms have been

directed principally to the soil bioremediation. In the province of China, microbial communities tolerant to heavy metals composed of *Nitrospiraceae*, *Blastocatella* y *Acidobacteria* were identified, and they are being evaluated for scientific purposes [35]. On the other hand, it was found that *Bacillus megaterium* has a high potential to recover heavy metals and it doesn't and it doesn't cause any pathogenicity in humans, for this reason it is used in water and soil [36]. Investigations have indicate that *Pseudomonas libanensis* y *P. reactans* in stress conditions for drought, they show a beneficial effect on the plants growth and decrease the proline and malondialdehyde concentrations in leaves under metallic stress, therefore, it is suggested that these microbial strains could be used in phytoremediation of contaminated soil with metals in semi-arid places [37]. In the same way, *Pseudomonas azotoformans* has the ability to resist abiotic stress towards heavy metals, drought, salinity, antibiotics and extreme temperature, besides it's a promoter of plant growth. In one study, this bacterium improved the biological accumulation coefficient of Cu, Zn and Ni, and a better plant growth, whereby, it's considered for the protection of crops against abiotic stress and it accelerates the soil phytoremediation process [38]. *Kocuria* sp. is a bacterium resistant to radiation and it has the bioabsorption capacity of Cr through its living cells. It has a maximum efficiency of 82.4% which can be beneficial for soils with this type of contamination [39]. *Rhodococcus pseudoacacia* has the ability to improve crops in the presence of heavy metals compared to controls and other bacterial strains under the same conditions [40]. It has been found that the inoculation of *Streptomyces* sp. increases plant biomass and reduces oxidative stress in plants, as well as the absorption and bioaccumulation of Zn, Cd and Pb [41]. Strategies for soil bioremediation also include microbial consortia, one of which is composed of *Pseudomonas*, *Proteobacteria*, *Flavobacterium* y *Actinobacteria* tested in contaminated soil polluted with As and it was found to promote plant growth and extraction of this metal, suggesting a successful strategy for phytoextraction [42]. *Alcaligenes*, *Bacillus*, *Curtobacterium* y *Microbacterium*, in consortium, they have resistance to high levels of heavy metals, such as As, Pb, Cu and Zn, in addition, they improve the germination and the root development in corn in presence of these metals [43]. As well as these studies there are some others focused on the remediation of soil, based on the activity of bacteria isolated from the



rhizosphere that improving the quality of the soil [44].

C. Salinity

A saline soil has an electrical conductivity in the root zone exceeds 4 dSm^{-1} , with a concentration of 40 mM of NaCl at 25°C approximately, with these conditions the crops yield decreases. Near 20% of the cultivated land in the world is affected by high salinity and it is increasing at a rate of 10% per year because low rainfall, high surface evaporation, erosion, salt water irrigation and wrong cultural practices [45]. However, soil microorganisms can play an important role for the tolerate salinity conditions, genetic diversity, synthesis of compatible solutes, plant growth hormones production, biological control and their interaction with plants [6]. Among the microorganisms used in saline soils for the purpose of improving crop productivity is *Trichoderma harzianum*, growth-promoter of *S. salsa* and it improves soil quality, by increasing beneficial microbial communities [46]. *Pseudomonas chlororaphis* and *Pseudomonas extremorientalis* are able to stimulate plant growth and they act as biological control against *Fusarium solani* in tomato under salt conditions, providing resistance to stress [47]. *Bacillus licheniformis* increases the total nitrogen and total phosphorus in soil by its activity as a nitrogen fixer and phosphorus solubilizer, its auxin production, it stimulates the root growth and the nutrients absorption, also, it reduces the ethylene levels in the plants, which decreases the stress caused by soil salinity [48]. *Rhizophagus irregularis*, *Chryseobacterium humi* and *Ochrobacterium haematophilum* improve the biomass production of sunflower, they improve the K^+ , Mg^{2+} , Ca^{2+} , N y P accumulation, they reduce the Na^+ levels in the tissues and increase the antioxidant response of the plant in saline soil [49]. Arbuscular mycorrhizal fungi improve the nutrient absorption of plants, the photosynthetic capacity, the water efficiency, the osmoprotectors production and antioxidant activity, increasing crop yield under saline conditions [50], they also decrease salt concentration and increase microbial biodiversity in the soil [51]. *Arthrobacter siccitolerans* enhances the aerial and radicular dry matter of wheat under salinity conditions by the indole-3-acetic acid production [52]. The inoculation of a mixture of *Aspergillus* spp., *Alternaria* spp., *Bacillus subtilis* and *Bacillus megaterium* in saline soil significantly increases the saturated hydraulic conductivity, suggesting that these microorganisms have the

potential to improve the water movement through the soil [53]. On the other hand, the microbial consortium between *Azospirillum lipoferum*, *Azotobacter chroococcum* and *Pseudomonas putida* increases the fresh and dry weight of the medicinal hops root in a soil with an electrical conductivity of 20 dSm^{-1} [54]. The application of effective microorganisms in plants cultivated in saline soils significantly increase crop production, membrane stability index, the nitrate reductase activity, the nitrate and protein content, the K^+ concentration and the K^+/Na^+ ratio, which indicates that effective microorganisms improve the adaptation of plant to saline soil [55].

D. Drought

The shortage of water has adverse effects on the plants health as well as their growth and production yield. The water and nutrients transport is limited due to the low hydraulic conductivity, it's for this reason that it diminishes the roots size limiting the absorption of nutrients and their flow through the plant [56]. When there is little water in the soil the microbial activity also decreases, which suggests a negative impact on the availability of nutrients and the absorption by the plant [57].

There are studies of certain drought-tolerant microorganisms, which have been isolated from arid regions affected by drought, such as *Streptomyces coelicolor*, *Streptomyces olivaceus* and *S. geysiriensis*, they show activity as plant growth promoter and tolerance to water stress from -0.05 to -0.73 MPa, additionally they induces the production of auxins and other phytohormones, which promote growth and confer potential for tolerance to water stress in wheat plants in stressed soil [5]. Moreover, *Citrococcus zhacaiensis* improves the onion seed germination under conditions of osmotic stress of about -0.8 MPa, also promotes plant growth and induces the production of some hormones, it generates an adaptability of the plant to drought stress conditions [58]. When tomato roots are infected with *Trichoderma harzianum*, an increase in the biosynthesis of growth regulating hormones is observed such indole acetic acid, indole butyric acid and gibberellic acid, they conferred to the plant drought tolerance [59]. Likewise, the inoculation with arbuscular mycorrhizal fungi and bacteria isolated from dry degraded soil influences the growth of *Trifolium repens* under water stress conditions [60]. In another study, two types of biofertilizers were evaluated: *Azotobacter vinelandii* and *Pantoea*



agglomerans + *P. putida* under water stress conditions, finding that the use of these microorganisms increases the germination and growth of *B. tomentellus*, this grassland improvement [61]. By inoculating the bacterium *Bradyrhizobium* sp. in *Lupinus angustifolius* L. under deficit irrigation conditions, it was found that the plants improve their growth, their absorption of nutrients mainly N and P, providing an alternative to improve growth and symbiosis under stress conditions [62]. On the other hand, by inoculating *Burkholderia phytofirmans* and *Enterobacter* sp. drought stress is minimized, these microorganisms also act on the biomass of shoots, roots, leaf area, chlorophyll content and photosynthesis, increasing them, the water content in the leaves too, which suggests that these microbial strains can protect corn crops from drought [63]. Other research reports that the inoculation of *Pseudomonas putida* + *Pseudomonas fluorescens* in *Hyoscyamus niger* presents positive effects for the growth of the root and stem, increases the water content in the leaves, stimulates the antioxidant compounds activity and increases the proline biosynthesis, which generates a tolerance to water stress in the plant [64]. Likewise, the inoculation of *Pseudomonas putida* individually in corn crops showed better growth in the seedling stage, in the shoots, length of the roots, and dry biomass, also it increased the concentration of cellular metabolites and the conductance of the stomata when subjected to drought, giving an approach in the development of new inoculant for increase the drought tolerance in plants [65].

III. CONCLUSIONS

These studies show that different microbial strains can be used to counteract the crops effects under conditions of abiotic stress, such as drought or in arid areas, environments with elevated CO₂ levels, soils with high concentrations of salts or heavy metals, to increase the tolerance and growth of plants.

The rhizosphere engineering is a promising way to reduce the agrochemicals to improve the quality of soil and crop productivity, bringing with it a benefit in agricultural productivity, aside from being an alternative against global climate change.

REFERENCES

[1] A. H. Ahkami, R. Allen White, P. P. Handakumbura, and C. Jansson,

“Rhizosphere engineering: Enhancing sustainable plant ecosystem productivity,” *Rhizosphere*, vol. 3, no. April, pp. 233–243, 2017.

[2] R. Allen White, M. I. Borkum, A. Rivas-Ubach, A. Bilbao, J. P. Wendler, S. M. Colby, M. Köberl, and C. Jansson, “From data to knowledge: The future of multi-omics data analysis for the rhizosphere,” *Rhizosphere*, vol. 3, no. April, pp. 222–229, 2017.

[3] L. M. York, A. Carminati, S. J. Mooney, K. Ritz, and M. J. Bennett, “The holistic rhizosphere: integrating zones, processes, and semantics in the soil influenced by roots,” *J. Exp. Bot.*, vol. 67, no. 12, pp. 3629–3643, 2016.

[4] X.-F. Huang, J. M. Chaparro, K. F. Reardon, R. Zhang, Q. Shen, and J. M. Vivanco, “Rhizosphere interactions: root exudates, microbes, and microbial communities¹,” *Botany*, vol. 92, no. 4, pp. 267–275, 2014.

[5] M. S. Yandigeri, K. K. Meena, D. Singh, N. Malviya, D. P. Singh, M. K. Solanki, A. K. Yadav, and D. K. Arora, “Drought-tolerant endophytic actinobacteria promote growth of wheat (*Triticum aestivum*) under water stress conditions,” *Plant Growth Regul.*, vol. 68, no. 3, pp. 411–420, 2012.

[6] P. Shrivastava and R. Kumar, “Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation,” *Saudi J. Biol. Sci.*, vol. 22, no. 2, pp. 123–131, 2015.

[7] J. Jin, C. Tang, A. Robertson, A. E. Franks, R. Armstrong, and P. Sale, “Increased microbial activity contributes to phosphorus immobilization in the rhizosphere of wheat under elevated CO₂,” *Soil Biol. Biochem.*, vol. 75, pp. 292–299, 2014.

[8] J. D. Lewis, N. G. Phillips, B. A. Logan, R. A. Smith, I. Aranjuelo, S. Clarke, C. A. Offord, A. Frith, M. Barbour, T. Huxman, and D. T. Tissue, “Rising temperature may negate the stimulatory effect of rising CO₂ on growth and physiology of Wollemi pine (*Wollemia nobilis*),” *Funct. Plant Biol.*, vol. 42, no. 9, pp. 836–850, 2015.

[9] A. J. Das, S. Lal, R. Kumar, and C. Verma, “Bacterial biosurfactants can be an ecofriendly and advanced technology for remediation of heavy metals and co-



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERIA

- contaminated soil,” *Int. J. Environ. Sci. Technol.*, vol. 14, no. 6, pp. 1343–1354, 2017.
- [10] P. P. Mirshad and J. T. Puthur, “Drought tolerance of bioenergy grass *Saccharum spontaneum* L. enhanced by arbuscular mycorrhizae,” *Rhizosphere*, vol. 3, no. P1, pp. 1–8, 2016.
- [11] H. Lambers, C. Mougel, B. Jaillard, and P. Hinsinger, “Plant-microbe-soil interactions in the rhizosphere: An evolutionary perspective,” *Plant Soil*, vol. 321, no. 1–2, pp. 83–115, 2009.
- [12] M. del C. Orozco-Mosqueda, M. del C. Rocha-Granados, B. R. Glick, and G. Santoyo, “Microbiome engineering to improve biocontrol and plant growth-promoting mechanisms,” *Microbiol. Res.*, vol. 208, pp. 25–31, 2018.
- [13] Z. Shen, Y. Ruan, B. Wang, S. Zhong, L. Su, R. Li, and Q. Shen, “Effect of biofertilizer for suppressing *Fusarium* wilt disease of banana as well as enhancing microbial and chemical properties of soil under greenhouse trial,” *Appl. Soil Ecol.*, vol. 93, pp. 111–119, 2015.
- [14] M. D. Wallenstein, “Managing and manipulating the rhizosphere microbiome for plant health: A systems approach,” *Rhizosphere*, vol. 3, no. April, pp. 230–232, 2017.
- [15] E. Verbruggen, “Mycorrhizal fungal establishment in agricultural soils : Factors determining inoculation success Minireview Mycorrhizal fungal establishment in agricultural soils : factors determining inoculation success,” no. April, pp. 1104–1109, 2017.
- [16] V. S. Meena, S. K. Meena, J. P. Verma, A. Kumar, A. Aeron, P. K. Mishra, J. K. Bisht, A. Pattanayak, M. Naveed, and M. L. Dotaniya, “Plant beneficial rhizospheric microorganism (PBRM) strategies to improve nutrients use efficiency: A review,” *Ecol. Eng.*, vol. 107, pp. 8–32, 2017.
- [17] A. Di Francesco, F. Milella, M. Mari, and R. Roberti, “A preliminary investigation into *Aureobasidium pullulans* as a potential biocontrol agent against *Phytophthora infestans* of tomato,” *Biol. Control*, vol. 114, no. August, pp. 144–149, 2017.
- [18] P. J. Criollo, M. Obando, L. Sánchez, and R. Bonilla, “Efecto de bacterias promotoras de crecimiento vegetal (PGPR) asociadas a *Pennisetum clandestinum* en el altiplano cundiboyacense,” *Rev. Corpoica*, vol. 13, no. 2, pp. 189–195, 2012.
- [19] S. Shameer and T. N. V. K. V. Prasad, “Plant growth promoting rhizobacteria for sustainable agricultural practices with special reference to biotic and abiotic stresses,” *Plant Growth Regul.*, vol. 84, no. 3, pp. 603–615, 2018.
- [20] M. H. Abd-Alla, A.-W. E. El-Enany, N. A. Nafady, D. M. Khalaf, and F. M. Morsy, “Synergistic interaction of *Rhizobium leguminosarum* bv. *viciae* and arbuscular mycorrhizal fungi as a plant growth promoting biofertilizers for faba bean (*Vicia faba* L.) in alkaline soil,” *Microbiol. Res.*, vol. 169, no. 1, pp. 49–58, 2014.
- [21] S. Paul, M. S. Rathi, and S. P. Tyagi, “Interactive effect with AM fungi and *Azotobacter* inoculated seed on germination, plant growth and yield in cotton (*Gossypium hirsutum*),” *Indian J. Agric. Sci.*, vol. 81, no. 11, pp. 1041–1045, 2011.
- [22] S. Yasmin, F. Y. Hafeez, M. Schmid, and A. Hartmann, “Plant-beneficial rhizobacteria for sustainable increased yield of cotton with reduced level of chemical fertilizers,” *Pakistan J. Bot.*, vol. 45, no. 2, pp. 655–662, 2013.
- [23] A. Hannan, M. Hasan, and I. Hossain, “Impact of Dual Inoculations with *Rhizobium* and *Trichoderma* on Root Rot Disease and Plant Growth Parameters of Grasspea under Field Conditions,” *Int. Res. J. Agric. Sci. Soil Sci.*, vol. 2, no. May, pp. 1–9, 2013.
- [24] M. T. Abbas, M. A. Hamza, H. H. Youssef, G. H. Youssef, M. Fayez, M. Monib, and N. A. Hegazi, “Bio-preparates support the productivity of potato plants grown under desert farming conditions of north Sinai: Five years of field trials,” *J. Adv. Res.*, vol. 5, no. 1, pp. 41–48, 2014.
- [25] M. Bilal, M. Ayub, M. Tariq, M. Tahir, and M. A. Nadeem, “Dry matter yield and forage quality traits of oat (*Avena sativa* L.) under integrative use of microbial and synthetic source of nitrogen,” *J. Saudi Soc. Agric. Sci.*, vol. 16, no. 3, pp. 236–241, 2017.
- [26] C. Dal Cortivo, G. Barion, G. Visioli, M. Mattarozzi, G. Mosca, and T.



- Vamerali, "Increased root growth and nitrogen accumulation in common wheat following PGPR inoculation: Assessment of plant-microbe interactions by ESEM," *Agric. Ecosyst. Environ.*, vol. 247, no. November 2016, pp. 396–408, 2017.
- [27] FAO, "El estado Mundial de la Agricultura y la Alimentacion," *Cambio Clim. , Agric. Segur. Aliment.*, 2016.
- [28] J. Sauze, J. Ogée, P. A. Maron, O. Crouzet, V. Nowak, S. Wohl, A. Kaisermann, S. P. Jones, and L. Wingate, "The interaction of soil phototrophs and fungi with pH and their impact on soil CO₂, CO₁₈O and OCS exchange," *Soil Biol. Biochem.*, vol. 115, pp. 371–382, 2017.
- [29] M. Dam, L. Bergmark, and M. Vestergård, "Elevated CO₂ increases fungal-based micro-foodwebs in soils of contrasting plant species," *Plant Soil*, vol. 415, no. 1–2, pp. 549–561, 2017.
- [30] J. Kohler, F. Caravaca, M. del Mar Alguacil, and A. Roldán, "Elevated CO₂ increases the effect of an arbuscular mycorrhizal fungus and a plant-growth-promoting rhizobacterium on structural stability of a semiarid agricultural soil under drought conditions," *Soil Biol. Biochem.*, vol. 41, no. 8, pp. 1710–1716, 2009.
- [31] H. Yu, Z. He, A. Wang, J. Xie, L. Wu, J. D. Van Nostrand, D. Jin, Z. Shao, C. W. Schadt, J. Zhou, and Y. Deng, "Divergent responses of forest soil microbial communities under elevated CO₂ in different depths of upper soil layers," *Appl. Environ. Microbiol.*, no. 18, pp. AEM.01694–17, 2017.
- [32] M. Nie, C. Bell, M. D. Wallenstein, and E. Pendall, "Increased plant productivity and decreased microbial respiratory C loss by plant growth-promoting rhizobacteria under elevated CO₂," *Sci. Rep.*, vol. 5, pp. 1–6, 2015.
- [33] E. Mohammadian, A. Babai Ahari, M. Arzanlou, S. Oustan, and S. H. Khazaei, "Tolerance to heavy metals in filamentous fungi isolated from contaminated mining soils in the Zanjan Province, Iran," *Chemosphere*, vol. 185, pp. 290–296, 2017.
- [34] S. Iram, A. Arooj, and K. Parveen, "Tolerance potential of fungi isolated from polluted soil of," vol. 2, no. 10, pp. 27–34, 2012.
- [35] H. Guo, M. Nasir, J. Lv, Y. Dai, and J. Gao, "Understanding the variation of microbial community in heavy metals contaminated soil using high throughput sequencing," *Ecotoxicol. Environ. Saf.*, vol. 144, no. June, pp. 300–306, 2017.
- [36] J. D. García-García, R. Sánchez-Thomas, and R. Moreno-Sánchez, "Bio-recovery of non-essential heavy metals by intra- and extracellular mechanisms in free-living microorganisms," *Biotechnol. Adv.*, vol. 34, no. 5, pp. 859–873, 2016.
- [37] Y. Ma, M. Rajkumar, C. Zhang, and H. Freitas, "Inoculation of Brassica oxyrrhina with plant growth promoting bacteria for the improvement of heavy metal phytoremediation under drought conditions," *J. Hazard. Mater.*, vol. 320, pp. 36–44, 2016.
- [38] Y. Ma, M. Rajkumar, A. Moreno, C. Zhang, and H. Freitas, "Serpentine endophytic bacterium Pseudomonas azotoformans ASS1 accelerates phytoremediation of soil metals under drought stress," *Chemosphere*, vol. 185, pp. 75–85, 2017.
- [39] M. Akbarpour Nesheli, E. Asgarani, and R. Dabbagh, "Biosorption potential of Cr(VI) by *Kocuria* sp. ASB107, a radio-resistant bacterium isolated from Ramsar, Iran," *Chem. Ecol.*, vol. 34, no. 2, pp. 163–176, 2018.
- [40] M. Fan, X. Xiao, Y. Guo, J. Zhang, E. Wang, W. Chen, Y. Lin, and G. Wei, "Enhanced phytoremediation of Robinia pseudoacacia in heavy metal-contaminated soils with rhizobia and the associated bacterial community structure and function," *Chemosphere*, vol. 197, pp. 729–740, 2018.
- [41] M. Zloch, T. Kowalkowski, J. Tyburski, and K. Hryniewicz, "Modeling of phytoextraction efficiency of microbially stimulated *Salix dasyclados* L. in the soils with different speciation of heavy metals," *Int. J. Phytoremediation*, vol. 19, no. 12, pp. 1150–1164, 2017.
- [42] V. Mesa, A. Navazas, R. González-Gil, A. González, N. Weyens, B. Lauga, J. L. R. Gallego, J. Sánchez, and A. I. Peláez, "Use of endophytic and rhizosphere bacteria to improve phytoremediation of arsenic-contaminated industrial soils by autochthonous *Betula celtiberica*," *Appl.*



- Environ. Microbiol.*, vol. 83, no. 8, 2017.
- [43] B. ROMÁN-PONCE, D. M. REZA-VÁZQUEZ, S. GUTIÉRREZ-PAREDES, M. de J. DE HARO-CRUZ, J. MALDONADO-HERNÁNDEZ, Y. BAHENA-OSORIO, P. ESTRADA-DE LOS SANTOS, E. T. WANG, and M. S. VÁSQUEZ-MURRIETA, "Plant Growth-Promoting Traits in Rhizobacteria of Heavy Metal-Resistant Plants and Their Effects on Brassica nigra Seed Germination," *Pedosphere*, vol. 27, no. 3, pp. 511–526, 2017.
- [44] N. Sarwar, M. Imran, M. R. Shaheen, W. Ishaque, M. A. Kamran, A. Matloob, A. Rehim, and S. Hussain, "Phytoremediation strategies for soils contaminated with heavy metals: Modifications and future perspectives," *Chemosphere*, vol. 171, pp. 710–721, 2017.
- [45] L. Otero, A. Francisco, V. Gálvez, M. Roberto, S. Inalvis, L. Martha, V. Mirna, C. Marianela, and R. Luis, "Caracterización y evaluación de la salinidad," *Inst. suelo. Minist. la Agric.*, no. 537, pp. 1–9, 2008.
- [46] L. H. Chen, J. H. Zheng, X. H. Shao, S. S. Shen, Z. H. Yu, X. Y. Mao, and T. T. Chang, "Effects of *Trichoderma harzianum* T83 on Suaeda salsa L. in coastal saline soil," *Ecol. Eng.*, vol. 91, pp. 58–64, 2016.
- [47] D. Egamberdieva, K. Davranov, S. Wirth, A. Hashem, and E. F. Abd Allah, "Impact of soil salinity on the plant-growth – promoting and biological control abilities of root associated bacteria," *Saudi J. Biol. Sci.*, vol. 24, no. 7, pp. 1601–1608, 2017.
- [48] H.-G. PARK, M.-H. JEONG, and Y.-S. AHN, "Inoculation with *Bacillus licheniformis* MH48 to improve Camellia japonica seedling development in coastal lands," *Turkish J. Agric. For.*, vol. 41, pp. 381–388, 2017.
- [49] S. I. A. Pereira, H. Moreira, K. Argyras, P. M. L. Castro, and A. P. G. C. Marques, "Promotion of sunflower growth under saline water irrigation by the inoculation of beneficial microorganisms," *Appl. Soil Ecol.*, vol. 105, pp. 36–47, 2016.
- [50] C. Santander, R. Aroca, J. M. Ruiz-Lozano, J. Olave, P. Cartes, F. Borie, and P. Cornejo, "Arbuscular mycorrhiza effects on plant performance under osmotic stress," *Mycorrhiza*, vol. 27, no. 7, pp. 639–657, 2017.
- [51] W. Zhang, C. Wang, T. Lu, and Y. Zheng, "Cooperation between arbuscular mycorrhizal fungi and earthworms promotes the physiological adaptation of maize under a high salt stress," *Plant Soil*, pp. 1–16, 2017.
- [52] R. Soleimani, H. A. Alikhani, H. Towfighi, K. Khavazi, and A. A. Pourbabaee, "Isolated bacteria from saline-sodic soils alter the response of wheat under high adsorbed sodium and salt stress," *Int. J. Environ. Sci. Technol.*, vol. 14, no. 1, pp. 143–150, 2017.
- [53] U. Sahin s, S. Eroğlu, and F. Sahin, "Microbial application with gypsum increases the saturated hydraulic conductivity of saline-sodic soils," *Appl. Soil Ecol.*, vol. 48, no. 2, pp. 247–250, 2011.
- [54] S. Yousefi, D. Kartoolinejad, M. Bahmani, and R. Naghdi, "Salinity tolerance of *Dodonaea viscosa* L. Inoculated with plant growthpromoting rhizobacteria: Assessed based on seed germination and seedling growth characteristics," *Folia Oecologica*, vol. 44, no. 1, pp. 20–27, 2017.
- [55] N. B. Talaat, "Effective microorganisms modify protein and polyamine pools in common bean (*Phaseolus vulgaris* L.) plants grown under saline conditions," *Sci. Hortic. (Amsterdam)*, vol. 190, pp. 1–10, 2015.
- [56] A. N. M. R. Bin Rahman and J. Zhang, "Preferential Geographic Distribution Pattern of Abiotic Stress Tolerant Rice," *Rice*, vol. 11, no. 1, 2018.
- [57] K. Ahmadi, M. Zarebanadkouki, M. A. Ahmed, A. Ferrarini, Y. Kuzyakov, S. J. Kostka, and A. Carminati, "Rhizosphere engineering: Innovative improvement of root environment," *Rhizosphere*, vol. 3, no. April, pp. 176–184, 2017.
- [58] G. Selvakumar, R. M. Bhatt, K. K. Upreti, G. H. Bindu, and K. Shweta, "Citricoccus zhacaiensis B-4 (MTCC 12119) a novel osmotolerant plant growth promoting actinobacterium enhances onion (*Allium cepa* L.) seed germination under osmotic stress conditions," *World J. Microbiol. Biotechnol.*, vol. 31, no. 5, pp. 833–839, 2015.



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

- [59] S. A. Mona, A. Hashem, E. F. Abd_Allah, A. A. Alqarawi, D. W. K. Soliman, S. Wirth, and D. Egamberdieva, "Increased resistance of drought by *Trichoderma harzianum* fungal treatment correlates with increased secondary metabolites and proline content," *J. Integr. Agric.*, vol. 16, no. 8, pp. 1751–1757, 2017.
- [60] K. Benabdellah, Y. Abbas, M. Abourouh, R. Aroca, and R. Azcón, "Influence of two bacterial isolates from degraded and non-degraded soils and arbuscular mycorrhizae fungi isolated from semi-arid zone on the growth of *Trifolium repens* under drought conditions: Mechanisms related to bacterial effectiveness," *Eur. J. Soil Biol.*, vol. 47, no. 5, pp. 303–309, 2011.
- [61] S. Delshadi, M. Ebrahimi, and E. Shirmohammadi, "Effectiveness of plant growth promoting rhizobacteria on *Bromus tomentellus* Boiss seed germination, growth and nutrients uptake under drought stress," *South African J. Bot.*, vol. 113, no. 2017, pp. 11–18, 2017.
- [62] D. Egamberdieva, M. Reckling, and S. Wirth, "Biochar-based *Bradyrhizobium* inoculum improves growth of lupin (*Lupinus angustifolius* L.) under drought stress," *Eur. J. Soil Biol.*, vol. 78, pp. 38–42, 2017.
- [63] M. Naveed, B. Mitter, T. G. Reichenauer, K. Wiczorek, and A. Sessitsch, "Increased drought stress resilience of maize through endophytic colonization by *Burkholderia phytofirmans* PsJN and *Enterobacter* sp. FD17," *Environ. Exp. Bot.*, vol. 97, pp. 30–39, 2014.
- [64] M. Ghorbanpour, M. Hatami, and K. Khavazi, "Role of plant growth promoting rhizobacteria on antioxidant enzyme activities and tropane alkaloid production of *Hyoscyamus niger* under water deficit stress," *Turkish J. Biol.*, vol. 37, no. 3, pp. 350–360, 2013.
- [65] S. S. K. P. Vurukonda, S. Vardharajula, M. Shrivastava, and A. SkZ, "Multifunctional *Pseudomonas putida* strain FBKV2 from arid rhizosphere soil and its growth promotional effects on maize under drought stress," *Rhizosphere*, vol. 1, pp. 4–13, 2016.



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Management of stress factors (eustressors) in medicinal plants as an alternative for production of secondary metabolites

I. Parola-Contreras, L. M. Montoya-Gómez, E. A. Delis Hechavarria, A. Escamilla García, R. G. Guevara-González*

Facultad de Ingeniería
Universidad Autónoma de Querétaro
Querétaro, México
*ramonggg66@gmail.com

Abstract— This review briefly describes the concept of eustressor, the history of the use of the metabolic routes of plants to cope pathogens and diseases. The review deals with a general overview of the systemic resistance and how it is synthesized through substances that give the plants their medicinal properties. The classification of the eustressors are shown through the subtitles and examples of the doses and elicitors used in other investigations are given. The objective of this article is to briefly introduce some examples of medicinal plants under induced stress and how is the metabolism of the plant responded in the biosynthesis of secondary metabolites.

Keywords— eustressors, medicinal plant, systemic immunity plant, secondary metabolites

I. INTRODUCTION

Plants are continually being affected by stress factors. These stress factors can affect plants positively (eustress) or negatively (distress) depending the stress perception of the plants. This perception can be classified as ‘alarm’, ‘resistance’ and ‘exhaustion’. Alarm trigger the stress signalling, the resistance phase refers to adaptation through the post-translational and transcriptional modifications, and finally, the exhaustion phase is the death. Plants activate their defense mechanism to synthesize substances that help them cope with induced stress [1]. These synthesized substances are developed to improve and adapt in the secondary metabolism of plants, these products have been called secondary metabolites (SM) [2]. The SM with medicinal properties gives the plants their therapeutic use. Wild medicinal plants that are taken out of their habitat to produce them in optimal conditions and with high yields usually have high chemical composition variability and low amounts of the SM of interest [3].

An alternative to maintain the production of SM in medicinal plants is through the elicitation technique. These include treatment with various stress factors (eustressors) of biological (elicitors), chemical and physical nature. Many treatments indeed effectively promote the production of a wide range of plant SM, both in vivo and in vitro [4]. The objective of this review is to show a wide scope on how eustressors can be used

to increase the production of secondary metabolites in medicinal plants.

II. SYSTEMIC PLANT IMMUNITY

Plants are exposed to a great variety of organisms such as insects, bacteria, fungi and viruses that interaction trigger the metabolism of SM. The SM can reduce growth and outweighed by the increased quality by the stress induced [5]. For instance, recognition of conserved pathogen- or microbe-associated molecular patterns (PAMPs or MAMPs) via cell surface-localized pattern-recognition receptors (PRRs) activates pattern-triggered immunity [6]. Plant-derived damage-associated molecular patterns (DAMPs) that are released upon infection or herbivore feeding are recognized similarly to MAMPs and also trigger immune responses. Plants do not possess adaptive immunity like animals, the absence of an adaptive immune response likely forced plants to evolve a multiplicity of PRRs, whereas animals elaborated only few PRRs for recognizing very highly conserved MAMPs [7].

Localized and systemic disease resistance is induced by the interaction with certain types of pathogen or non-pathogen organisms. The induced plants are capable to resist diseases or pest attacks because of an enhanced ability to rapidly express defenses upon infection and, in some cases, an increase in defenses that are expressed in response to the inducing treatment [8]. Systemic acquired resistance (SAR) is a type of systemic plant immunity that comes when a localized pathogen attack elicits broad-spectrum immunity to reinfection throughout the whole body by the induction of a hypersensitive response or moderate symptoms of disease. Different molecules have been identified that participate as a set of SAR signals to the plant which contain salicylic acid (SA), methyl-SA (MeSA), dehydroabietinal, methyl-jasmonic acid (MeJA), glycerol 3-phosphate (G3P) or a glycerol 3-phosphate derivative, and/or azelaic acid (AzA) [6].

Bacteria and fungi, these help the growth and immunity of the host colonize the roots of the plants. The immune response of the plant activated by these organisms is called systemic induced resistance (ISR). The activation of ISR depends on the





sensitivity of the jasmonic acid (JA) and ethylene (ET) hormones without the need for SA. Insect pest and microbial pathogens are repelling by a systemic plant immune response can be induced by insect feeding and egg deposition, or physical injury. This response is called wound-induced resistance (WIR). Some studies revealed that wound-induced systemic defense gene activation can be mediated by JA but exist others that are activated using a distinct via [9]. The biotic and abiotic stress modify the photosynthesis and the transport of respiratory electrons, also increase the production of reactive oxygen species (ROS). As well, reactive nitrogen species (RNS) can damage at cellular structures. ROS and RNS cause 'nitrosative' stress causing distress in the plant. However, ROS and RNS with frequency and low doses can lead to the strengthening of the plant and high tolerance in response to eustress [1].

III. EUSTRESS FACTORS

The first investigations on the protection of the plants to the attack of pathogens by means of the activation of defenses, were made at the beginning of century XIX reported by Ray and Beauverie [10]. In 1959, the first experiment by Kuc et al. were recorded to describe the phenomenon of induce resistance against mangle in the apple [11]. Since 1970, studies have been carried out to demonstrate the defense capacity of the plants of pathogenic agents being this susceptibility as an exception in the metabolic process, a phenomenon known as 'defense' [12]. In genetics, plants possess genes that code in the biosynthesis of substances to avoid or diminish the damage caused by pathogens [13].

The eustress factors (EF) can be of origin or biological nature, chemical or physical. The application of EF can increase the production of SM in crop, fruit and vegetable. Considering their nature of the eustress factors, they can be clasificated in two groups 1) biotic (elicitors) and 2) abiotic factors [14]. Biotic factors as phytohormones like JA, SA, ET, or polysaccharides like chitosan have been found to induce such enzymes in plants involve in SM production [15]. Induction of these enzyme molecules by exogenous application of EF and their role in plant defense activation improve tolerance against salinity, drought, pathogens, and insects has been studied in many plants [16]. The bioestimulants achieve the growth and development on the plants for others mechanism. However it has been seen that molecules like SA and quitosan trigger the immunity and also it shows bioestimulants effects on the plants [17]. According to [18] it has been agreed not to mix the terms eliciting with biostimulants. EF can act as biostimulants of plants because they help to tolerate abiotic stress.

IV. PLANT SECONDARY METABOLITES

Secondary metabolites are low-molecular weight compounds that are produced exclusively by specific plant species or taxa and are structurally very diverse [19]. SM participate in the protection of plants against microbial and viral infections, herbivory, UV radiation, attraction of pollinators, light spectrum, mineral salts, gaseous toxins, heavy metals, water, CO₂, allelopathy and signaling [20]. The content of bioactive SM is modified by several enzymatic pathways which

can be induced by elicitors. The SM produced in plant cultivation are used as pharmaceutical, flavour, fragrances, colouring agents, food additives, and agrochemicals [21].

Recently diverse investigations pointed out that the intake of certain SM will have a positive effect on preventing incidences of cancers and many chronic diseases. The utilization of elicitors have become in a strategy for improve the production of secondary metabolites from plants [22].

V. CLASSIFICATION OF EUSTRESSORS

The chemical composition and therapeutic activity of medicinal plants are determining principally by its bioactive compounds [3]. Stress is an important factor in determinate the chemical composition and therapeutic activity of medicinal plants. A desired chemical response can be inducing by elicitation, leverage the connection between plant stress and phytochemistry. Through utilization and manipulation of the plant stress response, optimal conditions can be determined to advance the development of many potentially beneficial medicinal plants [23].

There are some examples where EF have been probed experimentally in medicinal plants to enhance the production of their chemical compounds.

A. Biotic

a) Fungal

Fungal elicitors can activate a branch of the abscisic acid (ABA) signaling pathway in cells that regulates plasma membrane Ca²⁺ channels. The application of these fungal elicitors have shown an increase in the bioactive compounds of several medicinal plants [24].

Valerian (*Valeriana officinalis* L.), a perennial herb from the Valerianaceae family, produces in its roots a pharmacologically-active sesquiterpene known as valerenic acid (VA). VA have sedative, anticonvulsant, hypnotic effects, and anxiolytic activity. The highest content of VA (3.02 mg g⁻¹ dry weight) was observed after a treatment with 1% of *Fusarium graminearum* extract for 7 days. The levels of VA were 11.06 and 12.31 times higher than that of non-elicited control (0.24 mg g⁻¹ dry weight) at exposure times of 3 and 7 days, respectively [25].

Psoralea corylifolia L. synthesizes diverse phenylpropanoids such as furanocoumarins and isoflavonoids. Psoralen is a furanocoumarin and is important for having broad range of pharmacological activities such as photosensitizing, photobiological and phototherapeutic properties. This extract of at 1.0% v/v increase the significant accumulation of psoralen (9850 µg g⁻¹ dry cell weight) in the cultured cells [26].

Ashwagandha, *Withania somnifera*, contains the bioactive compounds withanolides and withaferin A. *Piriformospora indica* has been used as an elicitor stimulating plant growth and metabolism, the maximum enhancement was achieved with 3 % cell homogenate in 2.04 times, followed by 3 % culture filtrate at 1.78 times and culture disc at 1.46 times [27]. *Lantana camara* is a reservoir of bioactive compounds like monoterpenes, sesquiterpenes, triterpenes and flavonoid. Elicitation in *L.*





camara with *P. indica* at 2.5 % (v/v) increased the concentration of triterpenoids as ursolic acid by 3.5-fold (3869.3 $\mu\text{g g}^{-1}$ dry weight), oleanolic acid by 5.6-fold (1425.7 $\mu\text{g g}^{-1}$ dry weight) and betulinic acid by 7.8-fold (117.02 $\mu\text{g g}^{-1}$ dry weight) [28].

Panax quinquefolius L. (American ginseng) has been used as a health tonic for anti-stress, anti-aging, anti-tumor properties, with tranquilizing, cardio-vascular, and analgesic effects. The bioactive compounds are ginsenosides. *Alternaria panax* extract increase the ginsenoside content (276.0 mg g^{-1} dry weight) and also the ginsenoside productivity after elicitation with an extract concentration of 4 mg/L ; this value was 3.2-fold more than the control group (86.0 mg g^{-1} DW) [29].

Mikania laevigata has been validated as bronchodilator, antimicrobial, anti-inflammatory, antiulcer and anticancer agent, the use of JA from *Botryosphaeria rhodina* fungal extract for 30 days enhance coumarin production. With a fungal extract concentration of 100 and 200 μg the production of coumarin in elicited plants was 1.6 and 2.3 fold higher than control [30].

b) Bacterial

Bacterial extracts consist of biological mixtures from microorganism cultures, without identification of the active compounds. These extracts applied in *P. ginseng* hairy roots achieved the production of ginsenosides. *G. biloba* cell suspension cultures and *Beta vulgaris* hairy roots were sprayed with *Staphylococcus aureus* extracts after 24 h enhanced bilobalide in 2.6-fold and ginkgolide biosynthesis in 2.1-fold and accumulating betalain, respectively [14].

Extracts from microbial-enriched composts stimulated systemic resistance to fungus. LB 5-3 strain is an endophyte bacteria closely related with *Bacillus altitudinis*, the use of this bacteria as elicitor in increase biomass and ginsenoside accumulation in ginseng adventitious root culture. After 6 days elicitation with a 10.0 mL of strain LB 5-3, the content of total ginsenoside increase 2.026 mg g^{-1} which is four times more than that in unchallenged roots [31].

c) Yeast extract

Yeast extracts stimulated ethylene biosynthesis and bacterial resistance. Crude yeast extract at 100 $\mu\text{g/ml}$ concentration was added to Callus and cell suspension of *Calligonum polygonoides* L. for 48 h. It found that the compounds in $\mu\text{g/g}$ dry extract of *C. polygonoides* L. were higher in cell suspension than callus. This concentration enhanced the accumulation of quercetin, taxifolin and gallic acid. The increase of catechin was 4-fold, 2.3 and 1.7-fold in kaempferol-3-O-glucuronide and astragalins levels [32].

Astragalus chrysochlorus was treated at 10 gl^{-1} of yeast extract in the 13th day. The response to this treatment was the increase phenylalanine ammonia lyase (PAL) activity the key enzyme of phenylpropanoid pathway and accumulation of total phenolics in 221 $\mu\text{g g}^{-1}$ value as fresh weight (FW) after 36 h of addition of the yeast extract [33].

d) Polysaccharides

Chitosan is an ideal elicitor for enhancing the speed of germination and seedling invigoration that synchronize with

emergence of radicle and salinity stress tolerance. Also, these help the plant to resist in response to insect attack [34]. *Hypericum perforatum* L. (St. John's wort) is a herbaceous perennial plant naphthodianthrones (hypericin and pseudohypericin), prenylated acylphloroglucinols (hyperforin and adhyperforin), flavonoids (quercetin, hyperoside, rutin, and quercitrin), xanthenes (1,3,6,7-tetrahydroxyxanthone) and essential oil rich in sesquiterpenes. The use of chitosan as elicitor enhance the production naphthodianthrones in *H. perforatum*. A treatment with 200 mg/L , β -1,3-glucan, pectin induced higher cell growth for about 1.3-fold (at day 21) as compared to control. Also, cells elicited with pectin at concentration of 200 mg/L and chitin at concentration of 100 mg/L induced a maximum total flavonoids contents (from 1.6- to 1.9-fold) at day 4 and 14, respectively, compared to corresponding controls [35].

The effect of oligogalacturonic acid (OGA) on stomatal movements were examined in leaf epidermis of *Commelina communis* L. The results were the reduction of the size of the stomatal aperture and inhibited light-induced stomatal opening [36].

B. Abiotic

a) Hormonal

Paris polyphylla Sm. is a perennial herbaceous plant, it is commonly known as "Chonglou", it used as an anti-cancer, activate blood circulation, alleviate pain, detoxification, reduce swelling, inflammation and prevent bleeding, antibiotic and anti-inflammatory drug. The steroidal saponins from *P. polyphylla* have significant biological activities. The highest total steroidal saponins content (87.66 \pm 1.66 mg g^{-1} dry weight) achieve in cultures treated with SA at 50 mg/L after 30 days of elicitation which is 3.6 times higher than the in vivo rhizome [37].

Moringa oleifera Lam. leaves are rich source of carotenoids and α -tocopherol. Highest α -tocopherol content, of 187.5 % increase in comparison to the untreated control, enhance upon foliar application of 0.1 mM SA after 24 h of treatment, which represented a 49.7 $\text{mg}/100$ g fresh weight. Similarly, a maximum of 52.6 $\text{mg}/100$ g fresh weight lutein, and 21.8 $\text{mg}/100$ g fresh weight β -carotene content is obtained in leaves after 24 h of treatment with MeJA, which represented a 54.0 and 20.3 % increasing in comparison to the untreated control, respectively [38].

Artichoke (*Cynara scolymus*) from Asteraceae family, is recognized as medicinal plant with phenols, flavonoids, polyphenols such as caffeic acid (CA), monocatecholonic acid derivatives and other natural antioxidant. SA has significant effect on content of phenol and flavonoids in samples in which a treatment with 200 μM is applied [39].

Eryngium planum L. has been reported with highest concentrations of phenolic acids, flavonoids, saponins, coumarins, essential oils, and acetylenes. MeJA stimulate accumulation of the phenolic acids: rosmarinic, chlorogenic and CA. Treatment with 100 μM MeJA for 48h is an optimum condition of elicitation and results in approximately 4.5-fold





increased content of RA + CGA + CA in plant material compared to the control (19.795 mg g⁻¹ dry weight, 4.36 mg g⁻¹ dry weight, respectively) [40].

The effect of SA foliar application on biomass production and the synthesis of secondary compounds in yarrow (*Achillea millefolium* L.) has been determined. The SA at 0.50 mM induce an increase in biomass accumulation of roots, total dry mass, ratio root/shoot and chlorophyll a and chlorophyll a+b content in yarrow plants. The concentrations at 0.50 and 1.00 mM are most effective in the production of essential oils and total phenols, with a consequent improvement of the antioxidant activity of the plant extract [41].

b) Light spectrum

The UV-B radiation at 400µWcm⁻² achieved the content of anthocyanins, soluble sugar, H₂O₂, chlorophyll, carotenoids, amino acid, flavonoid, chlorogenic acid and total vitamin C that absorbed UV-B with the floral development in medicinal *Chrysanthemum morifolium* flowers [42].

The leaves of *Rosmarinus officinalis* were elicited with microwave radiation and five light qualities. The results showed that the highest fresh and dry weights (2.49 g and 0.177 g respectively) were obtained by treated with 200 watts for 60 sec. The highest significant antioxidant activity (314.326%) was given when the callus were incubated under green light [43].

c) Heavy Metals

Stress with heavy metals in plants causes lipid oxidation processes and led oxylipins generation. Also, the growth and development of plants is affected by high exposures to heavy metals [3]. *Echinacea purpurea* L. Moench. Was sprayed with 10, 25 and 50 ppm of TiCl₄. The best treatment was 10 ppm, because this achieved an increase of 1 order of magnitude (R=0.10, 1000% of control [44].

The composition of Peppermint plant changed their biosynthesis and metabolism of essential oil. The treatment at 15 ppm of cobalt enhanced the greatest fresh and dry herb yield. The oil accumulated of macro (N, P and K) and micro (Mn, Zn and Cu) nutrient content. However the 30 ppm of cobalt increased menthone in 37.84% and isomenthone in 15.19% [45].

d) Gases

The early responses of plant to ozone exposure generate the accumulation of SM and Nitric Oxide (NO). This exposure achieve flavonol accumulation and NO generation of Ginkgo biloba cells [46]. Furthermore, *Taxus chinensis* exposed to ozone lead a rapid increase in the levels of the abscisic acid (ABA) and the embossment of Taxol production [47].

VI. CONCLUSIONS

The biosynthesis of different secondary metabolites which have an economical importance for industries can be reached through activation of systemic plant immunity. Stress factors (eustressors) treatment is an effective strategy to induce the production of secondary metabolites in plants such as alkaloids, terpenoids, flavonoids, and phenolic compounds. There are several studies about the utilization of biostimulants to enhance

the production of bioactive compounds from medicinal plants. The development of new production strategies where include the manipulation of plant stress response should be focused in determine the optimal conditions for medicinal plants to produce secondary metabolites in an intensive cultivation. In addition, these kind of tools can be beneficial for the wild medicinal plants which are overexploited.

REFERENCES

- [1] I. Kranner, F. Minibayeva, R. Beckert, C. Seal, "What is stress? Concepts, definitions and applications in seed science", *New Phytol.*, vol. 188, pp. 655-673, September 2010.
- [2] G. Kacienė, J. Žaltauskaitė, E. Milčė, R. Juknys, "Role of oxidative stress on growth responses of spring barley exposed to different environmental stressors", *J. Plant Ecol.*, vol. 8, pp. 605–616, February 2015.
- [3] J. Gorelick and N. Bernstein, "Elicitation : An Underutilized Tool in the Development of Medicinal Plants as a Source of Therapeutic Secondary Metabolites" in *Advances in Agronomy*, D. L. Sparks, Eds. Elsevier Inc. 2014, pp. 201-230.
- [4] M. Mosihuzzaman, "Herbal medicine in healthcare-an overview", *Nat. Prod. Commun.*, vol. 7, pp. 807–812, June 2012.
- [5] P. Jonnada, L. Jesudas, V. Bobbarala, "Phytopharmaceutical studies of selected medicinal plants subjected to abiotic elicitation (Stress) in industrial area". In *Concepts, compounds and the alternatives of antibacterials*, 1 st ed., ch. 7. Intech Inc., 2015, pp. 153 – 200.
- [6] D. Shaw, L. Graeme, D. Pierre, W. Elizabeth and C. Kelvin. "Pharmacovigilance of herbal medicine", *J. Ethnopharmacol.*, vol. 140, pp. 513–518, April 2012.
- [7] J. Zhao, L. Davis and R. Verpoorte. "Elicitor signal transduction leading to production of plant secondary metabolites", *Biotechnol. Adv.*, vol. 23, pp. 283–333, June 2005.
- [8] M. Berens, H. Berry, A. Mine, C. Argueso and K. Tsuda. "Evolution of hormone signaling networks in plant defense", *Annu. Rev. Phytopathol.*, vol. 55, pp. 401–425, August 2017.
- [9] E. Reimer-Michalski and U. Conrath, "Innate immune memory in plants", *Semin. Immunol.*, vol. 28, pp. 319–327, August 2016.
- [10] A. Angarita, "Moléculas activadoras de la inducción de resistencia, incorporadas en programas de agricultura sostenible", *Manejo Integrado de Plagas*, vol. 6, pp. 4 -11, 2001.
- [11] S. Tuzun, "Terminology Related to Induced Systemic Resistance: Incorrect Use of Synonyms may Lead to a Scientific Dilemma by Misleading Interpretation of Results". In *Multigenic and Induced Systemic Resistance in Plants*. Springer USA, pp. 1 -8. 2006.
- [12] G. Agrios, "Plant pathology", 5th ed. Oxford Academic Press, 2005, pp. 948.
- [13] R. Goodman, Z. Kiraly, K. Wood, "The biochemistry and physiology of plant disease". University of Missouri Press, 1986, pp. 433.
- [14] K. Ramirez-Estrada, H. Vidal-Limon, D. Hidalgo, E. Moyano, M. Golenioswki, R. Cusidó, J. Palazón, "Elicitation, an effective strategy for the Biotechnological production of bioactive high-added value compounds in plant cell factories", *Molecules*, vol. 21, pp. 182, February 2016.
- [15] N. Camarena-Rangel, A. Barba-De la Rosa, J. Herrera-Corredor and M. Santos-Díaz, "Enhanced production of metabolites by elicitation in *Opuntia ficus-indica*, *Opuntia megacantha*, and *Opuntia streptacantha* callus", *Plant Cell Tiss. Org.*, vol. 129, pp. 289–298, March 2017.
- [16] H. Böhm, "The formation of secondary metabolites in plant tissue and cell cultures. In *International Review of Cytology*, A survey of cell biology. 1st ed., ch. 17, vol. 265. Elsevier Inc. 2008, pp. 183 – 208.
- [17] L. Mejía-Teniente, I. Pacheco, M. Chavira, R. Ocampo-Velázquez, G. Herrera-Ruiz, A. María and R. Guevara-Gonzalez, "Use of elicitors as an approach for sustainable agriculture". *Afr. J. Biotechnol.*, vol. 9, pp. 9155-9162, December 2010.





- [18] P. du Jardin, "Plant biostimulants: definition, concept, main categories and regulation", *Sci. Hort.*, vol. 196, pp. 3-14, November 2015.
- [19] P. Shakya, G. Marslin, K. Siram, L. Beerhues and G. Franklin, "Elicitation as a tool to improve the profiles of high-value secondary metabolites and pharmacological properties of *Hypericum perforatum*", *J. Pharm. Pharmacol.*, vol. 18, pp. 12877-12895, May 2017.
- [20] S. Ahmed, J. Kadam, V. Mane, S. Patil and M. Baig. "Effect of different agrowastes on yield and nutritional contents of *Pleurotus florida*", *Nat. Sci.*, vol. 7, pp. 44-48, August 2008.
- [21] A. Aharoni and G. Galili, "Metabolic engineering of the plant primary-secondary metabolism interface", *Curr. Opin. Biotechnol.*, vol. 22, pp. 239-244, April 2011.
- [22] J. Rios and M. Recio, "Medicinal plants and antimicrobial activity", *J. Ethnopharmacol.*, vol. 100, pp. 80-84, August 2005.
- [23] M. Fujita, Y. Fujita, Y. Noutoshi, F. Takahashi, Y. Narusaka, K. Yamaguchi-Shinozaki and K. Shinozaki, "Crosstalk between abiotic and biotic stress responses: a current view from the points of convergence in the stress signaling networks", *Curr. Opin. Plant Biol.*, vol. 9, pp. 436-442, August 2006.
- [24] S. Dowom, P. Abrishamchi, T. Radjabian and S. Salami, "Enhanced phenolic acids production in regenerated shoot cultures of *Salvia virgata* Jacq. after elicitation with Ag⁺ ions, methyl jasmonate and yeast extract", *Ind. Crops Prod.*, vol. 103, pp. 81-88, April 2017.
- [25] M. Torkamani, M. Jafari, N. Abbaspour, R. Heidary and N. Safaie. "Enhanced production of valerenic acid in hairy root culture of *Valeriana officinalis* by elicitation", *Cent. Eur. J. Biol.*, vol. 9, pp. 853-863, August 2014.
- [26] S. Ahmed, M. Baig, "Biotic elicitor enhanced production of psoralen in suspension cultures of *Psoralea corylifolia* L.", *Saudi J Biol Sci.*, vol. 21, pp. 499-504, November 2014.
- [27] S. Ahlawat, P. Saxena, A. Ali and M. Abdin, "*Piriformospora indica* elicitation of withaferin A biosynthesis and biomass accumulation in cell suspension cultures of *Withania*", *Symbiosis*. Vol. 69, pp.37-46, May 2016.
- [28] P. Kumar, R. Chaturvedi, D. Sundar and V. S. Bisaria, "*Piriformospora indica* enhances the production of pentacyclic triterpenoids in *Lantana camara* L. suspension cultures", *Plant Cell Tiss. Org.*, vol. 125, pp. 23-29, April 2016.
- [29] Y. Yu, W. Zhang, X. Li, X. Piao, J. Jiang and M. Lian, "Pathogenic fungal elicitors enhance ginsenoside biosynthesis of adventitious roots in *Panax quinquefolius* during bioreactor culture", *Ind. Crops Prod.*, vol. 94, pp. 729-735, December 2016.
- [30] M. Lourenço, W. Soares, B. Bertoni, A. Oliveira, S. Pereira, A. Pereira and S. Franca, "Eliciting effect of jasmonates from *Botryosphaeria rhodina* enhances coumarin production in *Mikania laevigata* plants", *Plant Cell Tiss. Org.*, vol. 125, pp. 595-598, March 2016.
- [31] X. Song, H. Wu, X. Piao, Z. Yin and C. Yin, "Microbial transformation of ginsenosides extracted from *Panax ginseng* adventitious roots in an airlift bioreactor", *Electron. J. Biotechnol.*, vol. 26, pp. 20-26, March 2017.
- [32] A. Owis, N. Abdelwahab, A. Abul-Soad, "Elicitation of phenolics from the micropropagated endangered medicinal plant *Calligonum polygonoides* L. (Polygonoaceae)", *Phcog Mag*, vol. 12, pp. 465-70, July 2016.
- [33] O. Cakir, S. Ari, "Defensive and secondary metabolism in *Astragalus chrysochlorus* cell cultures, in response to yeast extract stressor", *J Environ Biol.*, vol. 30, pp. 51-5, January 2009.
- [34] S. Sen and P. Mandal, "Solid matrix priming with chitosan enhances seed germination and seedling invigoration in mung bean under salinity stress", *J. Cent. Eur. Agric.*, vol. 17, pp. 749-762, 2016.
- [35] S. Gadzovska Simic, O. Tusevski, S. Maury, A. Delaunay, E. Lainé, C. Joseph and D. Hagege, "Polysaccharide elicitors enhance phenylpropanoid and naphthodianthrone production in cell suspension cultures of *Hypericum perforatum*", *Plant Cell Tiss. Org.*, vol. 122, pp. 649-663, 2015.
- [36] S. Lee, H. Choi, S. Suh, I. Doo, K. Oh, E. Choi, A. Schroeder Taylor, P. Low, Y. Lee, "Oligogalacturonic acid and chitosan reduce stomatal aperture by inducing the evolution of reactive oxygen species from guard cells of tomato and *Commelina communis*", *Plant Physiol.*, vol. 121, pp. 147-52, September 1999.
- [37] S. Raomai, S. Kumaria, M. Kehie and P. Tandon, "Plantlet regeneration of *Paris polyphylla* Sm. via thin cell layer culture and enhancement of steroidal saponins in mini-rhizome cultures using elicitors", *Plant Growth Regul.*, vol. 75, pp. 341-353, July 2014.
- [38] R. Saini, K. Harish Prashanth, N. Shetty and P. Giridhar, "Elicitors, SA and MJ enhance carotenoids and tocopherol biosynthesis and expression of antioxidant related genes in *Moringa oleifera* Lam. Leaves", *Acta Physiol. Plant.*, vol. 36, pp. 2695-2704, August 2014.
- [39] A. Tanoori, A. Ghasemnezhad and M. Alizadeh, "In vitro estimation of antioxidant compounds of artichoke (*Cynara scolymus* L.) as affected by methyl jasmonate and salicylic acid", *J. Chem. Pharm. Res.*, vol. 7, pp. 991-996, 2015.
- [40] M. Kikowska, I. Kedziora, A. Krawczyk and B. Thiem, "Methyl jasmonate, yeast extract and sucrose stimulate phenolic acids accumulation in *Eryngium planum* L. shoot cultures", *Acta Biochim. Pol.*, vol. 62, pp.197-200, April 2015.
- [41] P. Gorni and A. Pacheco, "Growth promotion and elicitor activity of salicylic acid in *Achillea millefolium* L.", *Afr. J. Biotechnol.*, vol. 15, pp. 657-665, April 2016.
- [42] C. Ma, J. Chu, X. Shi, C. Liu, X. Yao, "Effects of enhanced UV-B radiation on the nutritional and active ingredient contents during the floral development of medicinal *chrysanthemum*", *J Photochem Photobiol.*, vol. 158, pp. 228-234, May 2016.
- [43] E. Hussein, M. Aref and M. Ramadan, "Physical elicitation of *Rosmarinus officinalis* callus culture for production of antioxidants activity", *Int. J. Innov. Sci. Eng. Technol.*, vol. 4, pp. 238-247, July 2017.
- [44] S. Kuzel, J. Vydra, J. Triska, N. Vrchatova, M. Hruby, P. Cigler, "Elicitation of pharmacologically active substances in an intact medical plant", *J Agr Food Chem.*, vol. 57, pp. 7907-7911, September 2009.
- [45] E. Aziz, N. Gad, S. Khaled, "Effect of cobalt on growth and chemical composition of peppermint plant grown in newly reclaimed soil", *Aust. J. Basic & Appl. Sci.*, vol. 5, pp. 628-633, November 2011.
- [46] X. Maojun, Z. Yun, D. Jufang, J. Haihong, L. Dan, "Ozone induces flavonol production of *Ginkgo biloba* cells dependently on nitrate reductase-mediated nitric oxide signaling", *Environ. Exp. Bot.*, vol. 75, pp. 114-119, January 2012.
- [47] X. Maojun, J. Haihong, D. Jufang, Z. Ming, Z. Ting, "Abscisic Acid Plays Critical Role in Ozone-Induced Taxol Production of *Taxus chinensis* Suspension Cell Cultures", *Biotechnol Prog.*, vol. 27, pp. 1415-20, September 2011.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Effect of Polyester Short-fiber on Tensile and Compressive Strength of Tepetate

Juan Roberto Muñoz Solís

M. I. de Vías Terrestres y
Movilidad

Autonomous University of
Querétaro
Querétaro, México
jrob.ms@gmail.com

Teresa López Lara

Resarch Professor

Autonomous University of
Querétaro
Querétarro, México
lolte@uaq.mx

J. Bosco Hernandez
Zaragoza

Resarch Professor

Autonomous University of
Querétaro
Querétaro, México
bosco@uaq.mx

Jaime Horta Rangel

Resarch Professor

Autonomous University of
Querétaro
Querétaro, México
horta@uaq.mx

Abstract— Tepetate is an underestimated material (silty sand, in this case), vast an economical, which is used in compacted form in low resistance layer fillings on sidewalks and platforms. This material is found in the central region of Mexico, which has a very low compressive and tensile strength. Soil improvement through the addition and mixing of a selected materials can be applied in this particular case. The selection of the appropriate material is made from de recycling perspective.

There is an abundance of materials that could be used, within this paper it will be given an approach to the use of recycled polyester fibers textile waste product; such fibers will be added and mixed randomly to finally perform the analysis at different aggregate dosages.

Keywords—soil stabilization; soil reinforcement; tepetate; polyester fibers; recycling material.

I. INTRODUCTION

In recent years, the environmental and economical issues have stimulated the interest in the development of alternative materials that can satisfy the design specifications [1]. Large quantities of waste are generated daily from various industries and human activities. The waste materials are defined as any type of by-product material of human and industry activity that has no lasting value [2]. In addition, Foti [3] said that the problem of recycling waste materials of various types is, and will be, without a doubt, one of the issues that most afflicts society and that we must address and resolve in all possible ways.

Therefore, one of the most promising approaches in this area is the use of fiber formed waste materials in the compound material. Materials such as polyethylene terephthalate (PET) or plastic bottles are profusely and widely produced. Though, these materials have been little used for engineering purposes and the overwhelming majority of them have been placed in storage or dumping sites. However, the use of recycled materials instead of virgin ones, helps to relieve the landfill pressures and reduce the extraction demand. This is a way in which the roads construction industry is set on the way to the sustainable construction practice. As outlined in [4] recent research focuses on the use of

waste materials in lower grades (base, sub-base, etc.) of the road as they absorb greater quantities of materials than the upper grades. After that, it is proposed the addition of short polyester fiber to Tepetate and increase the soil's compressive and tensile strength.

II. BACKGROUND

In geotechnical engineering applications, such as load bearing construction, erosion control and vegetation support, the engineering properties of the soil can have a significant influence on site reclamation and development operations, transportation infrastructure construction, and general construction costs and configurations [5]. The soil's components can influence the soil's load bearing capability, stability, resistance to lateral movement, drainage and settling characteristics. Desirable soil characteristics include good compatibility, high shear strength, permeability, ductility, density, low compressibility and weight.

Jones [6] pointed out that the reinforcement consists on the incorporation of a material with the desired properties that the other material does not possess. This is how it has been introduced the geosynthetics, such as geotextiles, geogrid, among others, and even more recently natural and synthetic fibers to soil reinforcement, which have been able to avoid the formation of tension and contraction cracks, besides increasing of resistance and the production of a ductile behavior in brittle soils as reported in [7 & 8].

The polyethylene terephthalate is the most common thermoplastic polyester and is often named "polyester", this frequently causes confusion with the other polyesters [9]. The polyethylene terephthalate exists both as amorphous (transparent) and as semi-crystalline (opaque and white) thermoplastic material. The semi-crystalline has good resistance, ductility, stiffness and hardness. The amorphous has better ductility but less stiffness and hardness. The second absorbs very little water. Among the most widespread uses of this polymer it is emphasized the soft drinks and water bottles production, as well as cosmetics, medicines, oils and jars. Besides these products, are also used to manufacture geotextiles and fibers for the textile industry.





Availability, economic benefits, ease of working, fast handling and the quality of use in all weather conditions are the advantages of fiber compound soils. Nguyen [10] assert that the resistance and the stiffness of compound soils are enhanced by fiber reinforcement. These properties are in function of the characteristics of the fiber and the characteristics of the soil. Due to the above, the properties of the soil can increase dramatically through the addition (or subtraction) of materials to (or from) soil. In many cases, the changes are permanent. This method is usually called soil stabilization, since in many cases the ground turns out more stable, with fewer fluctuations in their mechanical properties.

Several researchers like [11, 12 & 13] have performed resistance test on sand samples reinforced with fabric inclusions. Gray and Al-Refeai [14] ensures that in general the results have shown that the final strength increased with increasing layers of fabric and the axial deformation tended to increase with a decreasing separation between layers of fabric (increase in the number of layers).

Therefore, authors such as Hejazy, Sheikhzadeh, Abtahi and Zadhoush [8] and Nguyen, Hrubešová and Voltr [11] analyze the behavior of several fibers, including those of polyester, mixed with different soils. This investigations perform shear strength and Standard Proctor compaction tests with different percentages of fiber aggregate with randomly inclusion. In addition, Yetimoghu and Salbas [15] affirm that in comparison with the systematically reinforced soils, the soils reinforced with randomly distributed fibers have some advantages. The preparation of such reinforced soils imitates soil stabilization by mixing, since the discrete fibers are simply added and mixed with the soil, like cement, lime and other additives. The randomly distributed fibers provide force isotropy and limit the potential planes of weakness that can be developed in parallel with the oriented reinforcement.

Similar research, as in [16, 17 & 18] speak in favor of the use of synthetic fibers or derivatives thereof (liquid polystyrene fluid, geogrids, polystyrene spheres, among others), that have been shown to improve the mechanical properties of different compound soils. In addition, a number of factors such as the fiber characteristics (content, length, thickness, module, tensile strength and failure) and soil characteristics, grain size distribution and average piece size, influence the behavior of the soil-fiber compound [19]. However, these documents are focused only in some very specific cases, so it is not possible to accurately predict the behavior of the aggregates in each type of soil.

III. METHODOLOGY AND LABORATORY TESTS ON SILTY SAND (TEPETATE)

The soil used in testing was silty sand (Tepetate) from Santiago de Querétaro city. The physical and engineering properties of silty sand used are given in TABLE 1. The characteristics of polyester fibers used as reinforcement are given in TABLE 2. Both soil and fibers were randomly distributed and mixed at variable dosage by mass of fiber.

Effect of randomly oriented fibers on the geotechnical characteristics of silty sand was investigated by conducting proctor compaction tests, unconfined compressive strength (UCS) tests and split tensile strength (STS) tests. The details of the tests performed and discussion of results is given in the following sections (TABLE 3).

TABLE I. PHYSICAL AND ENGINEERING PROPERTIES OF SILTY SAND

Property	Value
Liquid limit (%)	41.43
Plastic limit (%)	37.01
Optimum moisture content (%)	26
Dry UnitWeight (kg/m ³)	1448.23

TABLE II. PHYSICAL AND CHARACTERISTICS OF FIBERS

Property	Value
Type	Polyester (synthetic)
Cut length (mm)	10 - 20 plain
Cross section (mm)	Triangular
Size of cross section (mm)	30-40
Tensile elongation (%)	grater than 100
Specific gravity	1.34-1.40
Tensile strength (N/mm ²)	5800-8700
Color	White

TABLE III. GENERAL INFORMATION OF EACH TEST

Test	Regulation		Description	Minimum amount of material for the test
	ASTM	AASHTO		
Particle-Size Analysis	D 422 & D 1140	T 88	Classification of the material by the size of its particles	8 kg
Atterbert Limits	D 4318	T 89	Determination of consistency for classification	300 g for each test
Proctor Test	D 698	T 99, method C	Density depending on the moisture content	15 kg
Unconfined Compression	D 2166	T 208	Determination of the unconfined compressive strength of cohesive soil	200 g for each test
Split Tensile Strength	C 496	T 198	Determination of the splitting tensile strength of cylindrical specimens	200 g for each test



A. Moisture-Density Properties

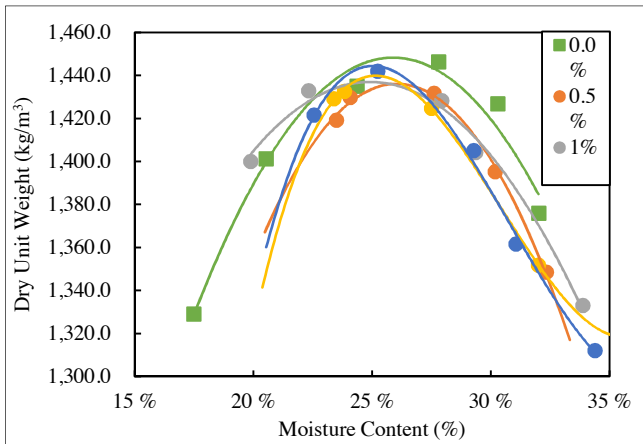


Fig. 1. Moisture-density characteristic of the Tepetate (0 %) and reinforced Tepetate with variable dosages of 10 mm fiber (0.5%, 1.0%, 1.5% and 2.0%)

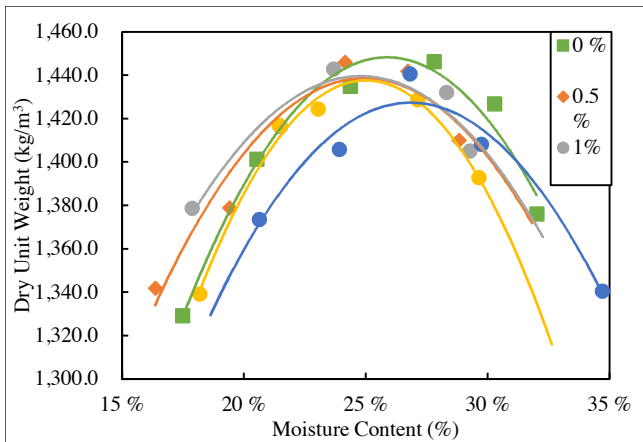


Fig. 2. Moisture-density characteristic of the Tepetate (0 %) and reinforced Tepetate with variable dosages of 20 mm fiber (0.5%, 1.0%, 1.5% and 2.0%)

The tests were conducted in accordance with ASTM D-698 Standard Proctor Test. These tests were carried out for different dosages of fiber, obtaining a minimum variation in the maximum dry density and optimum moisture of the mixtures. From the results, it is observed that by increasing the fiber content, the maximum dry density decreases as well as the optimum moisture of the mixture. This is due to the fact that polyester fiber is not absorbent, although the decrease in the water content of the mixture turns out to be minimal. In the study was just carried out the analysis for polyester fibers in limited dosages. Tepetate characteristics and behavior are exposed in the Fig. 1 and Fig. 2.

B. Unconfined Compression Tests

The unconfined compression tests were carried out in accordance with ASTM D-2166 procedure. Three specimens were molded by each dosage, getting a total of twelve specimens with average size of 37.7 mm in diameter and 78 mm in length. The mixtures were compacted with the optimum moisture in three layers of same length and extruded of the remolding apparatus to subsequently being weighed and tested. The test

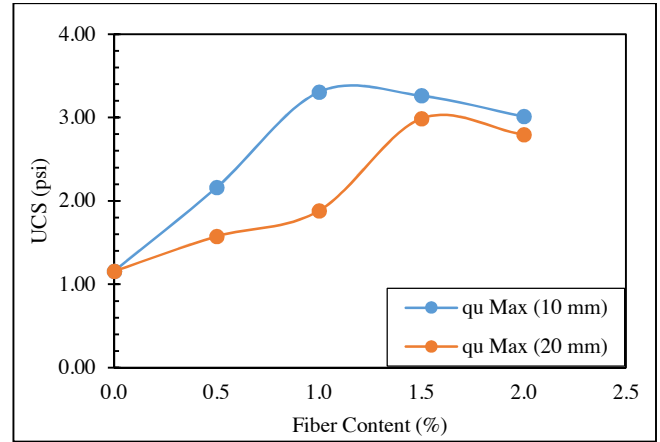


Fig. 3. Variation of unconfined compressive strength for different length and % of fiber

velocity was 1.0 mm/min. Based on the conducted research, it was determined the use of polyester short fiber with length of 10 mm and 20 mm. There were four samples at different fiber dosages: 0.0, 0.5, 1.0, 1.5% and 2.0%. The Fig. 3 shows the maximum UCS value for each length and dosage test.

Generally, the Tepetate samples exhibit quite low UCS values. With the addition of polyester fibers, the UCS values for 10 mm fiber mixtures increases 86.82%, 185.68%, 181.81% and 160.28% for 0.5%, 1.0%, 1.5% and 2.0% for 10 mm fiber mixtures, respectively; and 32.5%, 62.6%, 188.1% and 141.45% for the mentioned dosages of 20 mm fiber mixtures. This implies that as the percentage of polyester fiber increased, the UCS of the reinforced material shows an impressive increase.

C. Splitting Tensile Strength Tests

Normally compressive testing is used for evaluating strength of stabilized soils and there is little information concerning their tensile strength [20]. A knowledge of the tensile strength is needed in the study of stability of earth dams, highways, and airfield pavements. Tensile stresses are set up due to movement of traffic on pavement, shrinkage of soils, seasonal variation in temperature and alternate wetting and drying of soils, etc. One of the tests developed for evaluating tensile strength of soils is the split cylinder test, which is also called the split tensile test, which appears to be the simplest to perform and has been used in this paper.

To perform the STS test on the ground, has been followed the ASTM C-496 standard test procedure. Three specimens were molded by each dosage, getting a total of twelve specimens with average size of 37.7 mm in diameter and 78 mm in length. The mixtures were compacted with the optimum moisture in three layers of same length and extruded of the remolding apparatus to subsequently being weighed and tested. The specimens were placed horizontally between the position blocks of the machine. The test velocity was 0.5 mm/min. There were five samples at different fiber dosages: 0.0, 0.5, 1.0, 1.5% and 2.0%. The Fig. 5 shows the maximum UCS value for each dosage test.

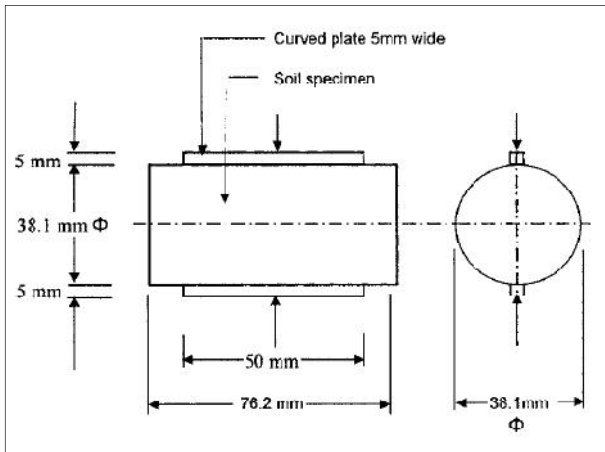


Fig. 4. Schematic sketch of specimen for split tensile test

A schematic sketch of specimen for the split tensile test is shown in Fig. 3. The STS is obtained by the following (1):

$$\text{Split Tensile Strength} = \frac{2P}{\pi td} \quad (1)$$

where P = failure load; t = thickness or length of specimen; and d = diameter of the specimen.

Fig. 4 shows the results of STS of fiber-soil mixtures. The curve display that the split tensile strength increased from 1.54 to 9.19 psi, more than 500% as the amount of polyester fiber increased.

D. Relation Between Split Tensile Strength and Unconfined Compressive Strength

The results show that soil-fiber mixtures develop substantial unconfined compressive strength and split tensile strengths and both of them are closely related. In Fig. 5 it can be observed that the STS/UCS ratio of 10 mm fiber has a smooth increment for 0.5 to 1.5% dosages and then the ratio goes down with the 2.0%, indicating that polyester fibers are more efficient when soil was subjected to tension rather than compression.

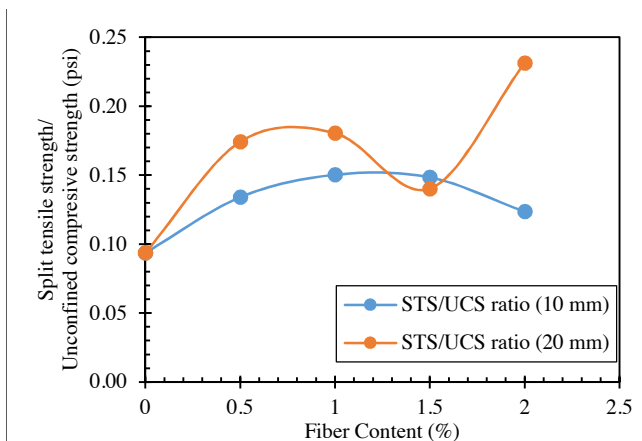


Fig. 5. Variation of split-tensile strength/unconfined compressive strength ratio for different % of fiber

Besides to the above the STS/UCS ratio for 20 mm fiber length had an increment in the first two dosages then, due to an notable increment in the UCS, the ratio for 1.5% decreases in comparison with the other dosages. Nevertheless, in the last dosage, that is 2.0% of fiber content, the ratio increases more than 120% as the virgin soil.

IV. CONCLUSIONS

Based on the findings, the following conclusions can be drawn from the study:

- With the addition of polyester short-fiber the maximum dry density decreases. It implies that the more fiber content the lesser dry density the sample presents.
- Compaction tests showed that limited quantities of polyester fibers (0.5-2.0%), in both 10 and 20 mm of fiber length, had no significant effect on optimum moisture content of soil-fiber mixtures.
- Significant increases in UCS values were achieved for both lengths and all dosages, with a percentage value achieving of 87, 186, 182 and 160%, respectively for each 10 mm fiber dosage. The percentage values for 20 mm fiber achieves the 36, 63, 158 and 141% respectively for each dosage.
- The randomly addition of 0.5-2.0% of 10 mm plain fibers to soil-fiber mixtures increases the STS by 167, 359, 347 and 243% respectively, in comparison to virgin Tepetate; besides the STS values for 20 mm had an extraordinary performance resulting in 153, 213, 286 and 497%, respectively with the mentioned dosages, in comparison to the virgin Tepetate. This means an impressive increment in the STS, property that is not always analyzed and is very important in dams stability, highways and airfield pavements studies.
- The STS/UCS ratio increases in a smooth way with the addition of 0.5 and 1.0% of fiber on both lengths, which shows that polyester fiber are more efficient when soil was subjected to tension rather than to compression. Besides, in 10 mm fiber length to 1.5% of fiber content, the STS/UCS ratio decreases due to an extraordinary increment on UCS. Nevertheless, with 20 mm fiber length the STS/UCS value increases more than four times the virgin Tepetate value.

ACKNOWLEDGMENT

The present paper was supported by the Consejo Nacional de Ciencia y Tecnología scholarship and the Autonomous University of Querétaro. This support is gratefully acknowledged.



REFERENCES

- [1] N. C. Consoli, J. P. Montardo, P. D. Marques P. & G. S. Pasa. Engineering Behavior of Sand Reinforced with Plastic Waste. *Journal of Geotechnical and Geoenvironmental Engineering*. Vol. 128. Pp. 462-471 (2002).
- [2] A. Serpell & L. Alarcon. Construction process improvement methodology for construction projects. *International Journal of Project Management*. Vol 16, No. 4. Pp. 215-221 (1998).
- [3] D. Foti. Use of recycled waste pet bottles fibers for the reinforcement of concrete. *Composite Structures*. Vol. 96. Pp. 396-404 (2012).
- [4] Y. Huang, R. Bird & O. Heidrich. A review of the use of recycled solid waste materials in asphalt pavements. *Resources Conservation & Recycling*. Vol. 52. Pp. 58-68 (2007).
- [5] B. E. Novich, A. Maher & J. A. Neubauer. *Fiber-reinforced Soil Mixtures*. PPG Industries Ohio. (2000).
- [6] R. M. Jones (1999) *Mechanics of Composite Materials* 2nd Edition. Taylor and Francis. Pp. 1-14.
- [7] Ch. Tang, B. Shi & L. Zhao. Interfacial shear strength of fiber reinforced soil. *Geotextiles and Geomembranes* Vol. 28. Pp. 54-61 (2010).
- [8] S. M. Hejazi, M. Sheikhzadeh, S. M. Abtahi & A. Zadhoush. A simple review of soil reinforcement by using natural and synthetic fibers. *Construction and Building Materials*. Vol. 30. Pp. 1-7 (2012).
- [9] L. McKeen. *Fatigue and Tribological Properties of Plastics and Elastomers*. William Andrew. 3rd Edition. Pp. 149-156 (2016).
- [10] G. Nguyen, E. Hrubešová & A. Voltr. Soil improvement using polyester fibers. *Procedia Engineering*. Vol. 111. Pp. 596-599 (2015).
- [11] J. P. Giroud. *Geotextiles and Geomembranes*. *Geotextiles and Geomembranes Journal*. Vol. 1. Pp. 5-40 (1984).
- [12] M. R. Madhav & P. P. Vitkar. Strip Footing on Weak Clay Stabilized with a Granular Trench or Pile. *Canadian Geotechnical Journal*. Vol. 15. Pp. 605-609 (1978).
- [13] A. McGown & K. Z. Andrawes. The Influence of Non-Woven Fabric Inclusions on the Stress-Strain Behavior of a Soil Mass. *Proceedings International Conference on the Use of Fabrics in Geotechnics, L'Ecole des Ponts et Chaussees*, Vol. 1. Pp. 161-166 (1977).
- [14] D. H. Gray & T. Al-Refeai. Behavior of Fabric versus Fiber-Reinforced Sand. *Journal of Geotechnical Engineering*. Vol. 112. Pp. 1-9 (1986).
- [15] T. Yetimoglu & O. Salbas. A study on shear strength of sands reinforced with randomly distributed discrete fibers. *Geotextiles and Geomembranes*. Vol. 21. Pp. 104-109 (2003).
- [16] M.T. Isa, A.S. Ahmed, B.O. Aderemi, R.M. Taib & I.A. Mohammed. Effect of fiber type and combinations on the mechanical, physical and thermal stability properties of polyester hybrid composites. *Composites Part B: Engineering*. Vol. 52. Pp. 217-222 (2013).
- [17] S.M. Haeri, R. Noorzad & A.M. Oskoorouchi. Effect of geotextile reinforcement on the mechanical behavior of sand. *Geotextiles and Geomembranes*. Vol. 18. Pp. 385-400 (2000).
- [18] K.J. Mun, N.W. Choi, S.Y. So & Y.S. Soh. Influence of fine tailings on polyester mortar properties. *Construction and Building Materials*. Vol. 21. Pp. 1335-1341 (2007).
- [19] N. C. Consoli, M. T. Casagrande & M. R. Coop. Effect of Fiber Reinforcement on the Isotropic Compression Behavior of a Sand. *Journal of Geotechnical and Geoenvironmental Engineering*. Vol. 131. Pp. 1434-1437 (2005).
- [20] A. Kumar, B. S. Walia & A. Bajaj. Influence of Fly Ash, Lime, and Polyester Fibers on Compaction and Strength Properties of Expansive Soil. *Journal of Materials in Civil Engineering*. Vol. 19. Pp. 242-248 (2007).





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Optimal reuse and treatment of grey water through flocculation and granular filtration.

Experimental study done in Queretaro

Colín Puig Ricardo
Facultad de Ingeniería
UAQ
Queretaro, México
ricardocolinpuig@gmail.com

Acosta García Daniela
Facultad de Ingeniería
UAQ
Queretaro, México
danielaacostagg@gmail.com

Alvarez Gaona Javier
Facultad de Ingeniería
UAQ
Queretaro, México
jaralgao@gmail.com

Reséndiz Mendoza América Gabriela
Facultad de Ingeniería
UAQ
Queretaro, México
america_resendiz@hotmail.com

Abstract—One of the most important challenges we need to tackle in the upcoming years is water scarcity, and reusing grey water in non-potable water applications (such as irrigation, toilet flushing, car washing, etc.) is one of the most appealing methods to reduce water consumption, due to grey water's relatively low pollution. This project seeks to design an economic and efficient system to reuse grey water from a manufacturing enterprise in the city of Queretaro, Mexico; it will collect grey water (mainly water used for cleaning machinery), and then take it to an underground water tank, capable of supplying it when needed. The use of calcium hydroxide and calcium sulfate dihydrate for flocculation and a granular filter can be used to achieve the type of quality needed for reuse. According to the results, the system is most effective with calcium hydroxide due to its great sedimentation and clarity achieved, but it has the disadvantage of rising the pH.

Keywords— (Grey water, filters, zeolite, water treatment, calcium hydroxide, activated carbon)

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

I. INTRODUCTION

In the past fifteen years the fast economic and industrial growth of many countries has caused several environmental problems, including a global drinking water crisis. This problem has attracted the attention of several scientists and therefore, some gauges have been used to measure the impact of economic activities on water resources. Perhaps one of the most important gauges is Water Footprint which measures the amount of freshwater needed to make a product [1]. Grey Water Footprint is a part of this Water Footprint, and it is measured as the amount of freshwater needed to assimilate the pollutants from a discharge of grey water [2]. It has been proved that most of the growth in GWF has been mainly caused by countries with a fast-

industrial growth, of which BRICS (Brazil, Russia, India, China and South Africa; the 5 economically emergent countries) are responsible for more than 87% of global GWF change [1]. With more and more countries trying to become an industrially growing nation, it is very likely that GWF will grow drastically in the next few decades.

Queretaro being a region with a great industrial growth in the last few years should be already looking for solutions to counteract the imminent GWF increase it will cause in the near future. Otherwise, it will face a difficult water crisis in a few years. Therefore, any type of decentralized water treatment seems like an appealing choice for Queretaro.

However, this water crisis is not an isolated problem: Since all water treatment require a consumption of energy, and at the same time energy production uses huge amounts of water, then we can say a scarcity of water will cause at the same time an energy crisis [3] [4] [5]. This is why, it is really important to design a water treatment system which can be as energy-efficient as possible, so we can tackle both of these problems at the same time.

Grey water is the wastewater obtained from the discharges from the sink, bathtubs, showers, washing machines, and dishwashers, although arguably the discharges from the sink and dishwasher could be omitted [6]. These discharges make up about 75% of all wastewater produced in a regular home, or in a home with a vacuum toilet, about 90% of all wastewater produced [7]. This grey water is composed predominantly of carbohydrates, proteins, fats, detergents and soaps [8]. Due to this relatively low pollution of grey water, it is easier to treat than black water, and therefore, its treatment consumes much less energy.





However, studies have shown that grey water has high concentration of Chemical Oxygen Demand which makes treatment for reuse of grey water a necessity (contradicting the general belief). create these components, incorporating the applicable criteria that follow.

The purpose of this project is to develop a system capable of treating grey water with least amount of energy possible. We achieved this through flocculation combined with a physical filter made of activated carbon, zeolite, fine sand, and fine sieves.

II. MATERIALS AND METHODS

A. Coagulation-Flocculation

Turbidity and water color are mainly caused by very small particles, called colloidal particles. These particles remain suspended in the water for a long time and can pass through a very fine filter medium. On the other hand, although their concentration is very stable, the particles do not have the tendency to approach each other. To eliminate these particles the coagulation and flocculation process are used.

Coagulation is the effect produced by the addition of a chemical to a colloidal dispersion resulting in particles destabilization by the reduction of the forces tending to keep the particles apart. [9].

The objective of coagulation is to destabilize the particles in suspension, that is to say, to facilitate their agglomeration. In practice, this process is characterized by the rapid injection and dispersion of chemical products. The purpose of flocculation is to favor the contact between the destabilized particles with the aid of slow mixing. These particles agglutinate to form a floc that can be easily removed by the decanting and filtration procedures.

Coagulants are chemical products that when added to water are able to produce a chemical reaction with the chemical components of water, especially with the alkalinity of water to form a voluminous, very absorbent precipitate, usual constituted by the metallic hydroxide of coagulant that is using.

To carry out water treatment in this study was used as coagulant calcium hydroxide and calcium sulfate dihydrate.

Calcium hydroxide (hydrated lime, $\text{Ca}(\text{OH})_2$) is a very economical coagulant and gives very good results, working at alkaline pH between 9-11. Some of the advantages that have with respect to other coagulants of this type, is its ability to precipitate heavy metals (arsenic, cadmium, zinc, among others) that are in solution.

Calcium sulfate dihydrate, another economical coagulant, it has a pH of 8.5 or less. But it tends to work better with a pH between 5 and 7.5 [10].

Another benefit of the use of these products is its ability to eliminate odors, as it also reacts with organic matter and microorganisms.

B. Zeolite

Natural zeolites are highly porous materials with bidispersive porosity. The zeolites have a system of voids, channels and cavities in their structure. Due to the unique structure, some molecules under ideal conditions can pass through the channel or cavity to fill the available adsorptive space [11]. Likewise, the large crystal surface area of the zeolites is accessible for adhering microorganisms such as bacteria.

The zeolite has a structure based on volcanic minerals and crystals that function as ion exchangers. In turn, they have channels of microporous materials. It can remove particulate contamination down to $10\mu\text{m}$ and below, it adsorbs dissolved cations such as Fe, Mn, Cu, Zn, and heavy metals such as Pb and As, and it can remove odors and some organic contaminants [12].

In the internal part of the zeolite the presence of oxygen is minimal due to the excess of the external consumption, which causes a settlement of the bacteria and an elimination of the nitrate converting it into nitrogen evaporable by means of carbon.

C. Sand

Sand is a granular medium that is regularly used for water filtration and is the most economical and efficient way of separating suspended solids that are not removed by sedimentation.

Filtration is a very important operation within a water treatment and conditioning system. Generally, the filtration is carried out after the separation of most of the suspended solids by sedimentation, although depending on the characteristics of the water it is possible that it enters directly to the filtration stage, without being settled previously [13]. This can be achieved depending on the amount and nature of the suspended solids. If the amount of suspended solids is not very large, it can be passed directly to the filtration stage. If the concentration of suspended solids in the water is a very high and it is passed directly to the filtration, the filter can saturate quickly, and its cleaning is necessary much more frequently, since the filtration cycles are of short duration. If previously the settling solids are separated, the load in the filter decreases, and it has an operation and a process of removal of suspended solids more efficient.

In the filtration process, cohesive forces intervene between the material formed and the particles in suspension, although electrostatic attraction forces of the London and Van Der Waals forces are also manifested. The water flows through a bed of sand [9]. The properties of the medium, cause the water to take erratic paths and long paths, which increases the probability that the solid has contact with other suspended particles, and with the medium formed on the surface of the granule of gravel or sand, being of this retained between the different layers of filter material.



D. Activated carbon

Activated carbon is a carbonaceous and porous material, which was subjected to a physical or chemical process to increase its internal porosity [14]. Once this procedure has been carried out, coal presents a series of tunnel networks that branch in smaller channels and so on.

In grey water treatment, activated carbon is often used to bring water to higher levels of purity than can be achieved with traditional physicochemical and biological methods.

Activated carbon is able to retain low polar, covalent and non-dissociated contaminants that are usually those of organic origin in any concentration [15]. Activated carbon in technical-economic terms, is competitive with other processes, to bring the levels of organic pollutants from relatively low to very low. It has a high porosity and a large specific surface area (which can range from small areas to areas of thousands of square meters per gram) [15]. This makes this medium suitable for the adsorption process resulting in an optimum water treatment.

E. Filtration system

The filter used in the system has the purpose of retaining any harmful component the water might have that calcium hydroxide is not capable of coagulating. This ensures that the obtained water has a proper quality for reuse. The filter is separated on different layers of materials.

First of all, there is a piece of cloth that prevents any type of solid residue from entering the filter itself. This is important because it makes the filter much easier to clean. The next layer is zeolite; the reason it is here is because it can remove different types of metals that might have dissolved in an industrial process and is relatively good at retaining bacteria. The next layer contains coarse sand which helps retain any lime that might have silt passed. The next layer contains activated carbon; this layer gets the water to a higher level of purity and reduces organic matter that the water might still contain. Finally, there is a thin layer of fine sand, which helps retain limes that might still pass.

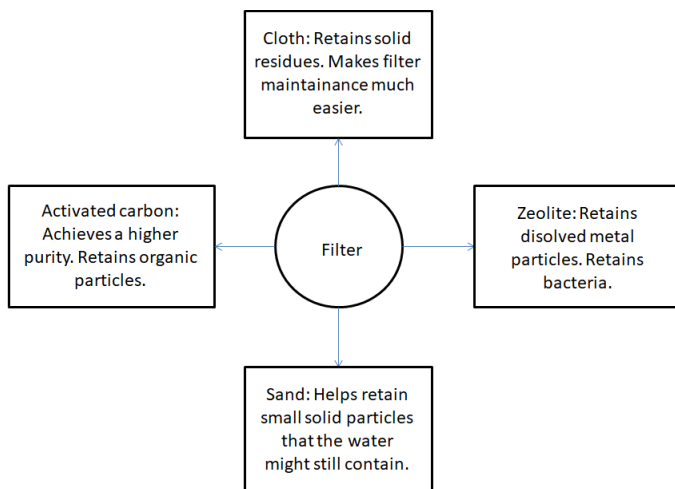


Fig. 1. Filter

F. Setting up the system

The system consists basically of three main stages. The first part is to collect grey water from different sources. In an industrial corporation the sources for grey water will mainly be: water used for mopping floors, for cleaning machinery, and water from the sink. The system will have different pipes for these sources and will take them to a storage tank.

The next stage will be to pump all of the collected grey water into a tank with hydrated lime. The flow generated from the pump will create a whirlpool which will mix the grey water with the lime. When the water reaches a certain level, the pump will stop, and it will leave the water at rest. Then the water must remain at rest for an hour, so the lime and the soap flakes can settle in the bottom of the tank.

When the lime and the soap flakes have finally settled, a valve will open, and it will let the water pass through a series of pipes. Inside of these pipes there will be a filter (described in the last section) and it will retain the rest of the harmful components the water could still have. After passing this filter it will be transported to an underground tank in which it will rest for another hour (to be sure the last of the lime or flakes settle).

At this point, the water will be pumped back to the roof from where it can be sent for its reuse in toilets, irrigation, car washing or it could even be reused to mop floors.

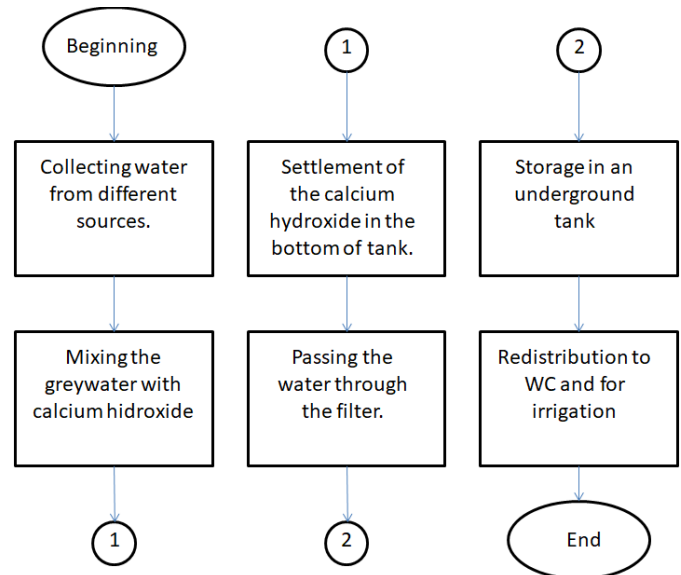


Fig. 2. System

G. Determination of pH

Measuring the pH of the water that has been treated is important since the high and low pH values are toxic and therefore represent a risk when in contact with man. The pH is the most important parameter in the evaluation of the corrosive properties of water. Likewise, it is important for the effective functioning of water treatment process and their control, for example flocculation, which is a process carried out in the filter presented in this work.



TABLE II. COAGULATION

Parameter	Calcium hydroxide	Calcium sulfate dihydrate
pH	13.1	10.85
Electrical conductivity	5.84 S/m	5.26 S/m
Settleable solids	100mL/L	50mL/L

The equipment used to measure the pH of water was pH/COND METER model D-54 brand HORIBA. To measure the pH with the equipment we first turned on the device, then verified that it is calibrated and put in the electrode at a constant height inside the container with the raw water and the water with coagulants, at last pressed the button MEAS and waited for the reading to be recorded. To get a mid-measurement we took three lectures per sample.

H. Determination of electrical conductivity

To measure the electrical conductivity with the equipment we first turned on the device and verified that it is calibrated. We must change the mode to COND. Then put in the electrode at a constant height inside the container with the raw water and the water with coagulants, finally pressed the button MEAS and waited for the reading.

I. Determination of settleable solids

The settleable solids test is the measurement of the volume of solids in one liter of water that will settle to the bottom of an Imhoff cone during an hour.

The determination of settleable solids was done according to the NMX-AA-004-SCFI-2013. The procedure consists in fill the Imhoff cones to the one-liter mark with a well-mixed sample. Wait for sample to settle in the Imhoff cone for 45 minutes, stir the sample with a glass rod to remove matter clinging to the sides of the Imhoff cone. Then, let sample settle for an additional 15 minutes and finally take the measurement in milliliters in the Imhoff cone.



Fig. 3. Jar test

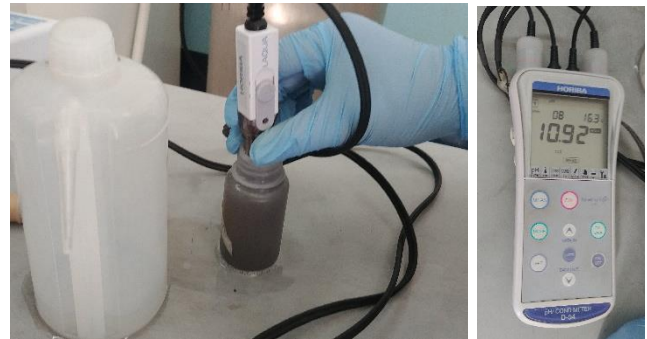


Fig. 4. pH-meter

III. RESULTS

This particular system is going to be installed in an industrial company in the city of Querétaro, in which about 87% of the wastewater is produced by cleaning oils from machinery and the floor with degreasers, detergents, and soaps. Normally, they pay another company to take this waste water (since it has a high concentration of oils, so they can't dispose it like regular water). Because of this, this company finds the system really appealing since installing it would reduce both water consumption, and wastewater production.

Table 1. Characteristics of raw grey water

Because of the type of contaminants this water has, it is a good way to test the limitations of our system (it contains degreaser, grease, oil, and grime, which is the worst-case scenario for grey water). So, we took a sample of the water and ran a simulation of what our system would do to this type of water.

TABLE I. RAW GREY WATER CHARACTERISTICS

Parameter	Raw grey water
pH	10.98
Electrical conductivity	4.12 S/m

The jar test, fig 3, equipment was used for mixing the grey water with 2 g of each coagulant, for 1 minute at a speed of 10 RPM.

The pH analysis, in fig 4, was used as a first parameter and the results showed that calcium hydroxide elevated the pH of the water in comparison with the calcium sulfate dihydrate, as seen in table I and table II. While tap water showed a mid-measurement of 8 and the raw grey water showed a mid-measurement of 10.98, the water obtained post-coagulation with calcium hydroxide showed a measurement of 13.1 and the water obtained post-coagulation with calcium sulfate dihydrate showed a measurement of 10.85. This may be due to an excessive amount of calcium hydroxide in the mixture. The treated water from this process is not suitable for human consumption, but it can be used for cleaning purposes in different industries. Although, calcium sulfate dihydrate as a coagulant does not modify the pH of the water.

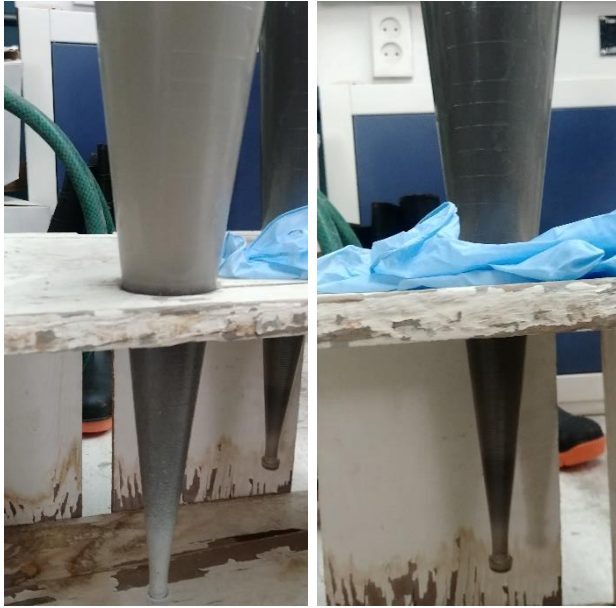


Fig. 5. Imhoff cones

The electrical conductivity, in table I and table II, was used as a second parameter. In comparison with the raw water, with a value of 4.12, the water treated with calcium hydroxide had a value of 5.84 s/m and the water with calcium sulfate dihydrate was 5.26 s/m.

For the Imhoff cones test (fig 5), it is not necessary to do any calculations to determine the settleable solids. The data obtained after the one-hour test is the result. As noted in the table II and the fig 3 left site, the settlement for the calcium hydroxide is better, even the water is clearer, in the case of the calcium sulfate dihydrate (right side of fig 5), the particles were floating, and the settlement was less notorious.

After the settlement we passed the water through the filter, the characteristics remained the same, but the water is clearer in the case of the calcium hydroxide.

However, we think that the system needs to be refined a little bit more before being installed in a real place, as well as studying the concentration of contaminants. But for the moment the best option, to treat the grey water is the calcium hydroxide, even though, it raises the pH.

REFERENCES

- [1] Carrascal Incera, A., Avelino, A. F., & Franco Solís, A. (2017). Gray water and environmental externalities: International patterns water pollution through a structural decomposition analysis. Elsevier, 1174-1187.
- [2] Li, H., Yang, Z., Lui, G., Casazza, M., & Yin, X. (2017). Analyzing virtual water pollution transfer

embodied in economic activities based on greywater footprint: A case study. Elsevier, 1064-1073.

- [3] Wanjiru, E., & Xia, X. (2017). Sustainable energy-water management for residential houses with optimal integrated grey and rain water recycling. Elsevier, 1151-1166.
- [4] Xu, M., Li, C., & Lu, S. (2017). Sustainable water resources utilization on energy industry based on the gray water footprints assessment in Hunan province. Elsevier, 3758-3764.
- [5] Silva Vieira, A., & EneDir, G. (2016). Water-energy nexus in low-income houses in Brazil: the influence of integrated on-site water and sewage management strategies on the energy of water and sewerage services. Elsevier, 145-162.
- [6] Fountoulakis, M. S., Markakis, N., Petousi, I., & Manios, T. (2015). Single house on-site grey water treatment using a submerged membrane bioreactor for toilet flushing. Elsevier, 706-711.
- [7] Hernández Leal, L., Temmink, H., Zeeman, G., & Buisman, C. J. (2010). Characterization and anaerobic biodegradability of greywater. Elsevier, 111-115.
- [8] Chanakya, H., & Khuntia, H. K. (2014). Treatment of gray water using anaerobic biofilms created on synthetic and natural fibers. Elsevier, 186-192.
- [9] AWWA Annual Conference. (2015). Coagulation and Filtration: Pilot to Full Scale. AWWA Seminar Proceeding.
- [10] Hernández, A. (2011). Alternativa de sulfato de calcio di hidratado (Ca SO₄.2H₂O) en el tratamiento primario de aguas residuales para la ciudad de Querétaro. UAQ
- [11] O.Pastore, D. C. (2017). Zeolites for a Sustainable World. Elsevier, 1-2.
- [12] Qiming Sun, N. W. (2017). Applications of Zeolites in Sustainable Chemistry. Elsevier, 477-493.
- [13] P.K. Andy Hong, T. X. (2013). Treatment of oil spill water by ozonation and sand filtration. Elsevier, 641 - 647.
- [14] Amit Bhatnagar, W. H. (2013). An overview of the modification methods of activated carbon for its water treatment applications. Elsevier, 499-511.
- [15] Bacaoui, Dahbi, Yacoubi, & Bennouna. (2002). Experimental design to optimize preparation of activated carbons for use in water treatment. American Chemical Society.



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Effect of stocking density on Black Soldier Fly larvae biomass production (*Hermetia illucens*)

Preliminary results

Ruth Chávez-Jaime, Juan Fernando Trejo-García, Valeria Caltzontzin-Rabell, María de la Luz Sánchez-Estrada, Oscar Alatorre-Jácome.

Facultad de Ingeniería. Universidad Autónoma de Querétaro, Campus Amazcala. Carretera a Chichimequillas s/n Km 1, Amazcala, el Marqués, Querétaro, 76265. Corresponding author: ruth_cha_ja@hotmail.com

Abstract— The soldier fly larva is an insect of economic and nutritional value since it is known that in its larval stage they have a great capacity to convert organic matter into biomass, however there are several factors that influence the development of soldier fly larvae (BSFL).) as the pH, temperature, humidity, food and population density. This last aspect has been little studied, that is why this work focuses on the effect of density on biomass gain in BSFL (*Hermetia illucens*). Three different densities were evaluated, the first density was one larva for each gram of food; the second density was one larva for every two grams of food and the last density was one larva for every 4 grams of food. To measure the production of biomass, three measurements were made throughout the development of BSFL in which the weight, length and width of each larva was taken into account. The treatment that gave us the best results was that of one larva for every four grams of food since a greater weight gain was observed in comparison with the other two treatments.

Keywords— *Black soldier fly larvae (BSFL); yield; stocking density; biomass production.*

I. INTRODUCTION

Due to the rapid growth of the world population, which is expected to reach 9,000 million people by 2050, global food demand will increase by almost 100% between 2005 and 2050 [2,13], while food production is expected for animals and humans through agriculture will increase by 60% [14]. For this reason it is looking for alternative food sources to plants or animals of common human consumption that can provide quality nutrients without compromising the environment and one of these alternatives is the use of insects. Insects are everywhere, reproduce rapidly and have high rates of growth and conversion of feed, as well as a reduced environmental impact during their life cycle. They are nutritious, since they contain high levels of proteins, fats and minerals [14]. They can be reared using various waste streams, such as food waste [3].

The soldier fly (*Hermetia illucens*) is considered an organism of value among insects, since it has a great versatility to transform organic wastes of diverse origins into biomass [6

], which can be used for animal feed or for obtaining macromolecules. However, there are several factors that affect

the performance of this larva, among which are temperature, pH, humidity of the substrate and density of culture [9]. Regarding the density of culture, few studies have been done to know what is the optimum density to improve the yield between these studies is one where a larva density per square centimeter and the feeding rate per day is tested with what it was possible to obtain the optimal variables for the production of biomass from this type of waste [10] and studies of this organism have also been carried out on residues such as manure [9], food residues from restaurants [9] and residues such as rice straw [8]. That is why this study focused on seeing the effect of three different densities on the yield in the biomass generated from a control diet based on wheat bran, corn flour and feed for broiler chicken. We chose this food because it is the one used in the Autonomous University of Querétaro for the production of this larva and it is of great importance to know which is the optimum to be able to improve the production of this organism.

II. MATERIALS AND METHODS

A. Animal Specimen

The soldier fly larvae (BSFL) were obtained from the soldier fly breeding pilot plant (BSF) of the Amazcala campus engineering faculty located in the municipality of Marqués in the state of Querétaro. The larvae used in this work were of an age of 6 days fed on a diet based on corn, wheat bran and feed for broiler chicken mixed with water and kept in conditions of 60% humidity and temperature of 28 ± 1 °C.

B. Experimental Conditions

The experiment was carried out in a memert brand stove with a controlled temperature of 27 ± 10 °C and a humidity of 60%. Plastic bottles of 500 ml capacity were used, in which a known quantity of larvae and diet was placed, which consisted of a mixture of wheat bran, corn flour and feed for broiler chickens. Each container was covered with a blanket of sky to let the air flow inside each one and thus avoid the appearance of fungi. The larvae were only fed once in the whole experiment which lasted 15 days.





C. Treatments

Three different densities of soldier fly larva culture were used as shown in the following table.

TABLE I. TREATMENTS

Treatment	Diet (grams of wet weight)	Number of larvae	Overall initial larvae biomass (grams of wet weight)
1	100	100	0.30995
2	100	50	0.14995
3	100	25	0.08885

Three vials were placed with 100 grams of substrate which consisted of wheat bran (50%), corn flour (20%) and feed for broiler chicken (30%) mixed with water until a pasty consistency was achieved. Different quantities of larvae were added to each bottle, in the first bottle the density was 1 larva for each gram of diet; the second was 1 larva for every 2 grams of diet and the last 1 larva for every 4 grams of diet. Three measurements were made throughout the experiment, which included the length, width and weight of a sample of larvae taken at random from each treatment; the first measurement was made at the beginning of the experiment, the second was done in the middle of the experiment and the last was done at the end of the experiment. The experiment ended as soon as the larvae began to pass to the pre-pupal stage, which happened fifteen days after the beginning of the experiment. Each treatment was done in duplicate.

D. Growth and Feed Conversion

The growth of the larvae was reflected in the increase of their size (width and length) and weight throughout the experiment. The feed conversion was calculated with the formula developed by Scriber & Slansky [11], which is:

$$B = (I-F) - M$$

$$ECD = B / (I - F)$$

Efficiency of Digested Feed, where B is total feed used for growth of larvae, I is the total feed during experiment, F is total feed residue during experiment (undigested food + excretory product), M is total feed metabolized by larvae. All materials were calculated in wet weight (g).

Relative growth rate of larvae was calculated by Waldbauer's formula [15].

$$RGR = \ln W_n - W_o / t$$

Where W_o is initial weight of larvae (mg wet weight), W_n is final weight of larvae (mg wet weight), and t is the time spent in development.

E. Data analysis

The statistically significant differences were determined by ANOVA analysis of variance (using an alpha of .01) to demonstrate the effect of the different treatments applied.

III. RESULTS AND DISCUSSION

The "Fig. 1" shows the increase in biomass over the fifteen days that the experiment lasted, it can be seen that from day seven to day fifteen there was a decrease in the weight of the larva and this is because at that stage the larvae began to move to the stage of pre pupa in which it is known that at the beginning of the metamorphosis they consume a little of their biomass for this process [8]. Another thing that we can notice is that there were significant differences until the fifteenth day in which it is shown that Treatment three is the best in terms of biomass gain. In table two we can see that something peculiar happens with the EDC since in treatment three the value is low, this could be due to the fact that since the larva has enough food, it does not focus on feeding quickly [5], however we can realize that in the RGR treatment three is the one with the highest value, which tells us that the relative growth rate is better when you have a density of one larva for every four grams of food. In "Fig. 2" we observed that there are significant differences on day seven between treatment one and treatment two and three, but this changes to day fifteen in which there is a statistically significant difference in treatment three. In "Fig. 3" we see that as in "Fig. 1" there are no statistically significant differences on day seven but on day fifteen if there are any and in the same way it is in treatment three where we can notice that the length of the larva increased mostly in comparison with the other treatments. As we can see according to the results of this work, treatments one and two did not have statistically significant differences and therefore are not the optimal densities for the correct development of BSFL nor for the biomass gain and this may be due to the scarcity of food [7], since having more larvae creates a competition for food which generates that if there is a higher feeding speed but little biomass gain due to the small amount of food.

TABLE II. FEED CONVERSION GROWTH AND

Treatment	ECD	RGR (mg/mg/day)
1	0.3821	0.0107
2	0.2098	0.01148
3	0.1299	0.1474

It should also be mentioned that the density of culture influences the environment in which the larva develops since in the experiment it was observed that at a higher density of the crop the food was kept humid and homogeneous instead in the containers where there was a density of low culture can be observed that a layer of fungi was generated which could be good because the diet would have a different composition, which could influence the development and composition of the



larva. It was also observed that in the containers with a high density, the food lost moisture very fast which is due to the generation of heat due to the bacteria that cause the decomposition of the food and the metabolism of the larvae [14]. Another important aspect is that a greater number of larvae per gram of food generates cannibalism in this organism and therefore there is a high mortality rate.

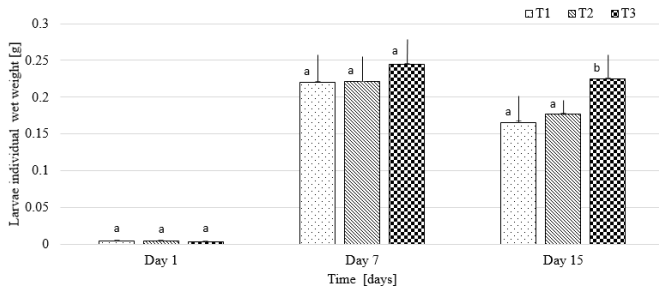


Fig. 1. Increment of individual biomass in *Hermetia illucens* larvae cultivate in three different densities.

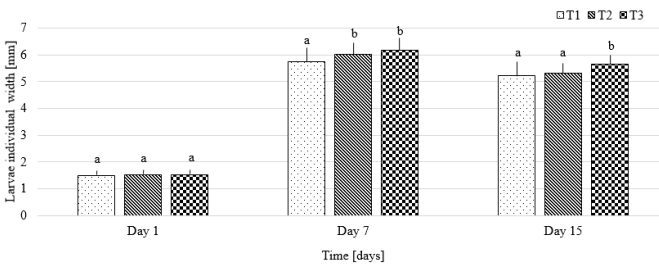


Fig. 2. Increment of individual width in *Hermetia illucens* larvae cultivate in three different densities

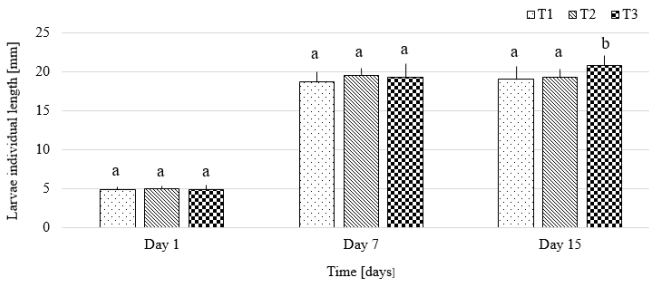


Fig. 3. Increment of individual length in *Hermetia illucens* larvae cultivate in three different densities.

IV. CONCLUSION

In general, an increase in weight is observed over fifteen days. However, there is a decrease in the width of the larvae and an apparent stagnation in the length. This phenomenon is very interesting and shows a peculiar behavior when compared to the growth of other organisms.

The experiment shows evidence that there are density-dependent effects that favor the accumulation of biomass in the density of one larva for every four grams of food, punctually on day fifteen. According to the data obtained in this work, it can be concluded that the higher density of larvae per food the biomass gain is less contrary to what happens when there is a low density of larvae per amount of food, which agrees with previous studies [8,13].

The optimum density for the gain of biomass in larva of fly soldier is one larva for every four grams of food, it is worth mentioning that this optimum is when fed with a mixture of wheat bran (50%), feed for broiler chicken (30%) and corn flour (20%). These results are of importance for the development of fly larva production farms since this can increase the production of biomass and produce an alternative source of protein which is friendly to the environment. It is worth mentioning that it would also be important to assess whether the larval protein composition is affected by density, these studies are intended to be done later, and in other studies it has been found that the composition of the food given to the larva influences the development time, biomass gain and feed conversion efficiency. It is suggested to continue studying the behavior of this insect in different means of feeding to achieve a diet that helps to make more efficient the process of conversion of food into biomass in order to have an alternative generation of protein that is not of animal origin.

ACKNOWLEDGMENT

We thank the support provided by Dr. Juan Fernando García Trejo for advice and also thank the entire team of the Bioengineering Laboratory of the Faculty of Engineering Campus Amazcala of the Autonomous University of Querétaro located in the municipality of Marqués, Querétaro.

REFERENCES

- [1] Allegretti, G., Talamini, E., Schmidt, V., Bogorni, P. C., & Ortega, E. (2018). Insect as feed: An emergy assessment of insect meal as a sustainable protein source for the Brazilian poultry industry. *Journal of Cleaner Production*, 171, 403-412.
- [2] Dmitriev CM. The evolution of growth trajectories: what limits growth rate? *Biological Reviews*. 2011; 86:97-116.
- [3] Halloran, A., & Vantomme, P. (2013). La contribución de los insectos a la seguridad alimentaria, los medios de vida y el medio ambiente. *Edible insects: future prospects for food and feed security*.
- [4] Harris, M., (2002). *Bueno para comer. Enigmas de alimentación y cultura*, Madrid: Alianza Editorial.
- [5] Jiao L, Amunugama K, Hayes MB, Jennings M, Domingo A, Hou C. Food restriction alters energy allocation strategy during growth in tobacco hornworms (*Manduca sexta* larvae). *The Science of Nature*. 2015; 102:40.
- [6] Kroeckel, S., G.E. Harjes, I. Roth, H. Katz, S. Wuertz, A. Susenbeth, and C. Schulz. 2012. When a turbot catches a fly: Evaluation of a pre-pupae meal of the Black Soldier Fly (*Hermetia illucens*) as fish meal substitute - Growth performance and chitin degradation in juvenile turbot (*Psetta maxima*). *Aquaculture* 364–365:345–352.
- [7] Makkar, H. P., Tran, G., Heuzé, V., & Ankers, P. (2014). State-of-the-art on use of insects as animal feed. *Animal Feed Science and Technology*, 197, 1-33.



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

- [8] Manurung, R., Supriatna, A., Esyanti, R. R., & Putra, R. E. (2016). Bioconversion of rice straw waste by black soldier fly larvae (*Hermetia illucens* L.): optimal feed rate for biomass production. *J Entomol Zool Stud*, 4, 1036-1041.
- [9] Paz, A. S. P., Carrejo, N. S., & Rodríguez, C. H. G. (2015). Effects of larval density and feeding rates on the bioconversion of vegetable waste using black soldier fly larvae *Hermetia illucens* (L.), (Diptera: Stratiomyidae). *Waste and Biomass Valorization*, 6(6), 1059-1065.
- [10] Parra, A., Carrejo, N., y Gómez, C., (2015). Effects of larval density feeding rates on the bioconversion of vegetable waste using black soldier fly larvae *Hermetia Illucens* (L.), (Diptera:Stratiomyidae), *Waste Biomass Valor*, 6:1059–1065.
- [11] Scriber JM, Slansky F. The nutritional ecology of immature insects. *Annual Review of Entomology*. 1981; 26:183-211.
- [12] Supriyatna, A., Manurung, R., Esyanti, R. E., & Putra, R. E. (2016). Growth of black soldier larvae fed on cassava peel wastes, An agriculture waste. *Journal of Entomology and Zoology Studies*, 4(6), 161-165.
- [13] Tilman, D., Balzer, C., Hill, J., & Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences*, 108(50), 20260-20264.
- [14] Tomberlin, J. K., Van Huis, A., Benbow, M. E., Jordan, H., Astuti, D. A., Azzollini, D., ... & Chapkin, R. S. (2015). Protecting the environment through insect farming as a means to produce protein for use as livestock, poultry, and aquaculture feed. *Journal of Insects as Food and Feed*, 1(4), 307-309.
- [15] Waldbauer GP. The consumption and utilization of food by insects. *Advances in Insect Physiology*. 1968; 5:229- 288.





Design of a LED module for plant experimentation

H. Aguirre-Becerra^a, J. F. Garcia-Trejo^{a*}, A. A. Feregrino-Perez^a, M. C. Vazquez-Hernandez^b, A. Alvarado-Mariana^b, G. C. Mota-Valtierra^c

^a Cuerpo Académico de Bioingeniería. Facultad de Ingeniería. Campus Amazcala. Universidad Autónoma de Querétaro. México.

^b Doctorado en Biosistemas. Facultad de Ingeniería. Campus Amazcala. Universidad Autónoma de Querétaro. México.

^c Facultad de Ingeniería. Campus Aeropuerto. Universidad Autónoma de Querétaro. México.

*Corresponding author: juanfernando77@gmail.com

Abstract — Light-emitting diodes (LEDs) have marked great advances on horticultural lighting as they allow the control of spectral composition, photoperiod and adjustment of luminous intensity with a low radiant heating power and high useful lifetime. In this article, the description of the method and theoretical considerations for the design of a LED module, that accomplishes plant developmental needs, is presented.

Keywords — LED module, artificial photoperiod, light quantity, light quality

I. INTRODUCTION

During the LED module design procedure, three concepts are considered to accomplish plant's needs: photoperiod, light quantity and light quality. Photoperiod refers to daylength (Light: Darkness) and defines the seasons and latitudes under which, any crop or ornamental plant can be grown, regulating a number of developmental events such as stem and leaf elongation, formation of storage organs, flowering and sex expression [1]. Light quality is defined as the spectral distribution of photons (wavelength) [2], generally referring to the Photosynthetically Active Radiation (PAR), with range of 400 nm λ <math><700\text{ nm}</math> [3], specially red and blue; however current research is being done in Far-Red (FR) and Ultraviolet (UV) ranges because their effect on secondary metabolism as shown in [4], [5], [6] and [7]. Light quantity is related with the amount of photons per unit area per unit time intercepted by a flat surface ($\mu\text{mol m}^{-2} \text{s}^{-1}$) [8]

LEDs are widely used in indoor horticultural farming presenting the next advantages [9]:

- Capability of true spectral composition control, allowing wavelengths to be matched to plant photoreceptors to provide more optimal production and to influence plant morphology and composition.
- They are easily integrated into digital control systems, facilitating special lighting programs such as "daily light integral" lighting and sunrise and sunset simulations.
- They have become economically feasible for even large-scale horticultural lighting applications.

II. LED MODULE DESIGN

A. Wavelengths, light quantity and LEDs

Four wavelengths were considered for the design: UV, FR, red, blue. Each corresponding LED is described in Table 1.

Table 1. LEDs description

	UV	FR	Red	Blue
Wavelength (nm)	410 - 420	710 - 730	625	460
Voltage (Vcd)	3 - 4	1.85	2.1	3.2
Current (mA)	350	350	350	350
Power (W)	1	1	-	-
Viewing Angle (°)	125	150	165	165
Radiant Power (mW)	440	231	-	-
Luminous flux (lm)	-	-	48	25
Model	U70	3S4S-1	ARS01	NNP01

For most plant species, a suitable light quantity ranges from 100 to 200 $\mu\text{mol m}^{-2} \text{s}^{-1}$ distributed in all PAR wavelength [10]. A quantity of 45 $\mu\text{mol m}^{-2} \text{s}^{-1}$ were chose for red, 30 $\mu\text{mol m}^{-2} \text{s}^{-1}$ for blue, 15 $\mu\text{mol m}^{-2} \text{s}^{-1}$ for RF and 10 $\mu\text{mol m}^{-2} \text{s}^{-1}$ for UV.

In order to calculate the amount of LEDs, the energy of a single photon produced for each wavelength was calculated with equation (1), where E_{photon} is the energy of a single photon, h is the plank constant, c is the light speed and λ is the light wavelength [10].

$$E_{\text{photon}} = \frac{hc}{\lambda} \quad (1)$$

The radiant power is needed to calculate the micromoles per second that each LED emits. This value was calculated with equation (2) where R_p is the radiant power and N_A is the Avogadro number. Radiant power of blue and red light can be calculated with the luminous flux and the Relative Luminous Efficiency Function. The number of LEDs were calculated with equation (3) [10].

$$\mu\text{mol} \cdot \text{s}^{-1} = 1 \times 10^6 \frac{R_p}{N_A E_{\text{photon}}} \quad (2)$$

$$\text{LEDs} = \frac{\text{Light Quantity}}{\mu\text{mol} \cdot \text{s}^{-1}} \quad (3)$$



The application of equations (1), (2) and (3) resulted in 31 red, 12 blue, 11 FR, and 7 UV LEDs. In order to accomplish the amount of LEDs, they were divided in two modules of 16 red, 6 blue, 6 FR and 4 UV LEDs each.

B. Circuit and electronic design

Since all LEDs consume 350 mA with different voltage, each color LEDs were placed in series (Figure 1). The block diagram of electronics is shown in Figure 2 and consisted on four 350 mA current sources (LDH-45A-350W) connected to a single voltage source of 12 V_{cd}, each current source has dimmable capability in order to control light intensity. Figure 3 shows the circuit used for the LED module (Figure 4).

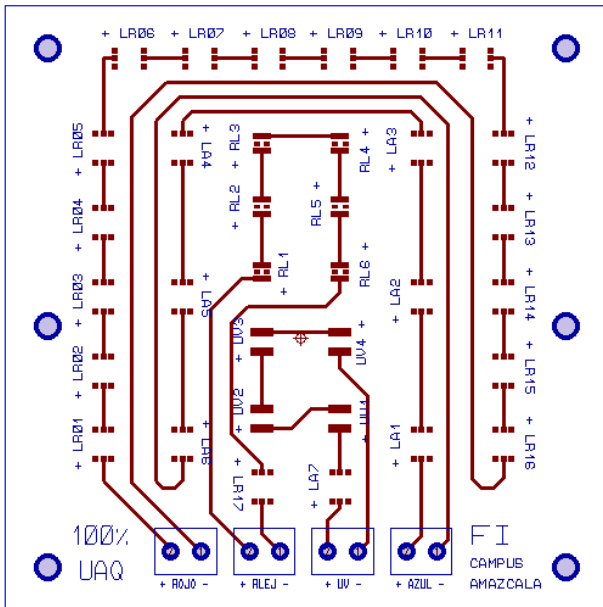


Figure 1. Circuit design of LED module.

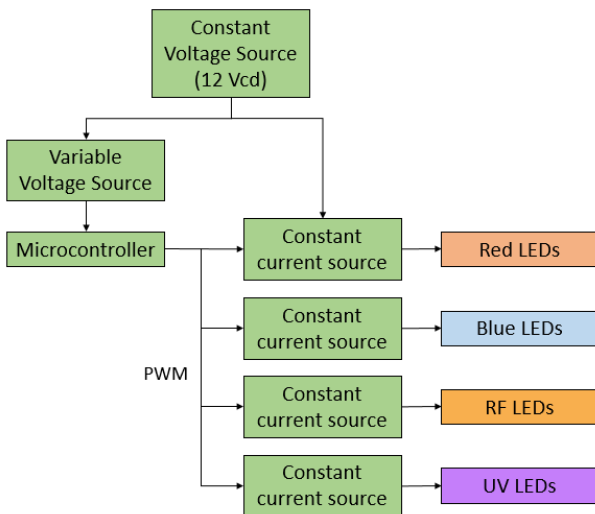


Figure 2. Block diagram of the circuit for the LED module.

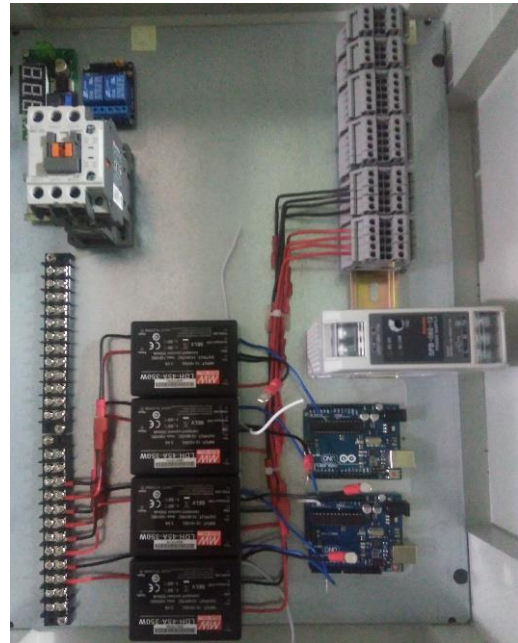


Figure 3. Electronics for module operation

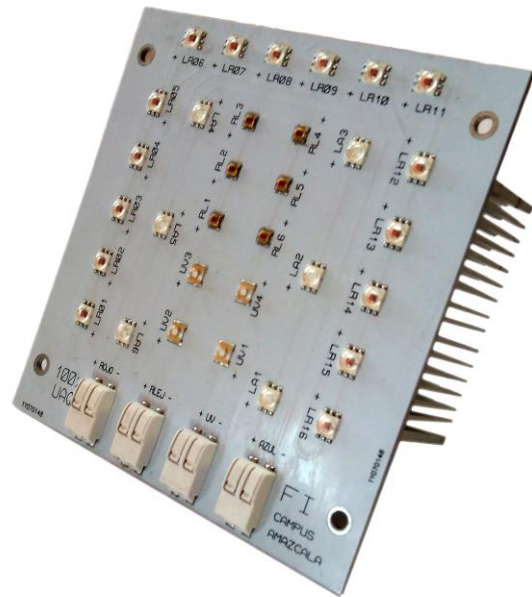


Figure 4. LED module

C. Luminous flux test

A luminous flux test was performed with the red and blue LEDs. This test cannot be performed with RF and UV LEDs since the luxometer (LX1010BS, BeMatik, Barcelona, Spain) only senses visible light. Figure 5 and Figure 6 shows the luminous intensity of the blue LEDs at one and two meters from floor. Figure 7 and Figure 8 shows the luminous intensity of the red LEDs at one and two meters from floor.

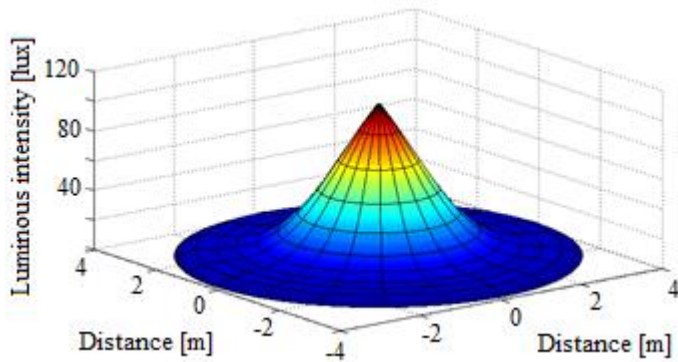


Figure 5. Luminous intensity of blue LEDs (One meter from floor)

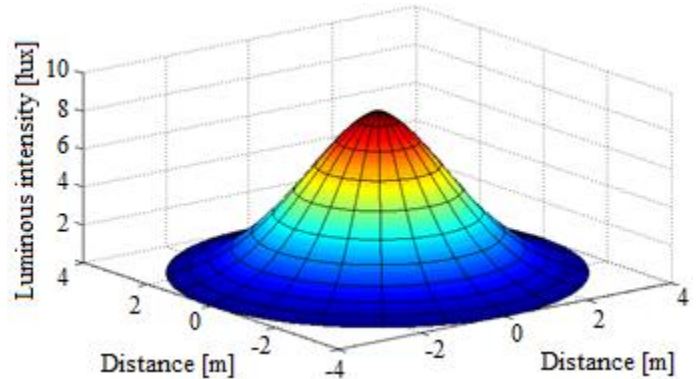


Figure 6. Luminous intensity of red LEDs (Two meter from floor)

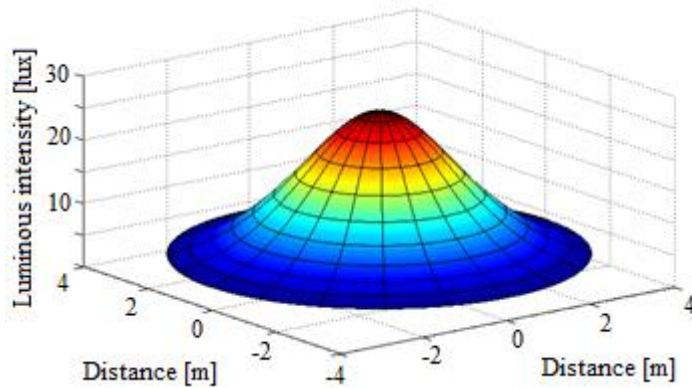


Figure 6. Luminous intensity of blue LEDs (Two meter from floor)

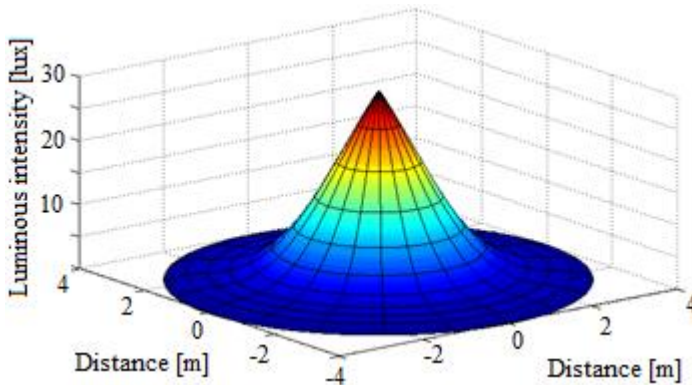


Figure 7. Luminous intensity of red LEDs (One meter from floor)

III. CONCLUSION

The design of a LED module for plant experimentation is presented. This device contains four important wavelengths for plant development and will be used for research in Campus Amazcala of the Universidad Autónoma de Querétaro.

IV. ACKNOWLEDGMENT

Authors want to thank the members of the Bioengineering Laboratory at Campus Amazcala of Universidad Autónoma de Querétaro. This work was partially financed by CONACYT for awarding the scholarship for Doctorate Degree studies and Artículos 100% UAQ projects.

REFERENCES

- [1] Carr, I. A. "Day-length perception and the photoperiodic regulation of flowering in Arabidopsis". *Journal of Biological Rhythms*, vol. 16(4), pp. 415-423. 2001.
- [2] Smith, H. "Light quality, photoperception, and plant strategy". *Annual review of plant physiology*, vol. 33(1), pp. 481-518. 1982.
- [3] Scarascia-Mugnozza, G., Schettini, E., and Vox, G. "Effects of solar radiation on the radiometric properties of biodegradable films for agricultural applications". *Biosystems Engineering*, vol. 87(4), pp. 479-487. 2004.
- [4] Demotes-Mainard, S., Péron, T., Corot, A., Bertheloot, J., Le Gourrierc, J., Pelleschi-Travier, S., ... and Vian, A. "Plant responses to red and far-red lights, applications in horticulture". *Environmental and Experimental Botany*, vol. 121, pp. 4-21. 2016.
- [5] Huché-Thélier, L., Crespel, L., Le Gourrierc, J., Morel, P., Sakr, S., and Leduc, N. "Light signaling and plant responses to blue and UV radiations—Perspectives for applications in horticulture". *Environmental and experimental botany*, vol. 121, pp. 22-38. 2016.
- [6] Robson, T., Klem, K., Urban, O., and Jansen, M. A. "Re - interpreting plant morphological responses to UV - B radiation". *Plant, cell & environment*, vol. 38(5), pp. 856-866. 2015.
- [7] Galvão, V. C., and Fankhauser, C. "Sensing the light environment in plants: photoreceptors and early signaling steps". *Current Opinion in Neurobiology*, vol. 34, pp. 46-53. 2015.
- [8] Mancinelli, A. L. "Interaction between light quality and light quantity in the photoregulation of anthocyanin production". *Plant Physiology*, vol. 92(4), pp. 1191-1195. 1990.
- [9] Morrow, R. C. "LED lighting in horticulture". *HortScience*, vol. 43(7): pp. 1947-1950. 2008.
- [10] Khanna, V. K. "Fundamentals of solid-state lighting: LEDs, OLEDs, and their applications in illumination and displays". CRC press. 2014





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Economic impact produced by differential subsidence in urban areas. Case study Querétaro, Qro.

Luis Oswaldo Morales-Tamayo

Universidad Autónoma de Querétaro

División de Investigación y Posgrado de la Facultad de Ingeniería

Querétaro, México

oswaldostar8@hotmail.com

Abstract

Differential subsidence is a natural and anthropogenic phenomenon that affects the rural and urban infrastructure of an area in the measure of its longitudinal development and influence band, producing physical damages that are translated as economic losses for the owners and that to this date exist very few studies related to its systematized assessment.

The aim of this paper is to assess the economic impact produced by one of the geological aseismic faults or associated to the differential subsidence affecting the city of Querétaro, Qro.; to the extent of its proximity and potential risk. For this, the methodology proposed by Hernández Madrigal [1] was used, methodology which proposes a demerit factor for the concept of belonging and proximity to the fault within a Geographical Information System.

Keywords—Subsidence; Value; Factor

I. INTRODUCTION

Differential subsidence, also known as subsidence of the land, is explained by the overextraction of underground liquids mainly gas, oil and water. For an urban area, the overexploitation of groundwater lowers the phreatic stratum and consequently reduces the pore pressure of the unconsolidated materials that make up the aquifer, increasing the effective effort and consequently a decrease in the fluvio-lacustrine deposit that on the surface is seen as subsidence of the ground [2]. Mexico is one of the main countries with problems of overexploitation of groundwater as a trigger for regional subsidence that affects many cities within the Mexican Republic, including Celaya [3], Mexico City [4], Irapuato, Salamanca [5], Aguascalientes, Morelia [6] and for the purpose of this research Querétaro [7] that links the subsidence models of the Querétaro valley with the increase of effective efforts in the soil mass caused by the loss of hydraulic support that give as result, superficial cracking.

Although its presence in rural and agricultural areas is common because of the natural lines of channels and the formation of escarpments that divide the slope of the land, in urban areas, it has been due to the unconscious extraction of underground liquids used to meet the needs of the population,

increasing the number of extraction wells of liquids and reducing the natural recharge times of the phreatic stratum.

The impact of regional subsidence in urban areas is mainly economic, but it can also represent potential risks of deformation in civil engineering projects with historical significance, ruptures of special facilities at the subsoil level, and in buildings of more than two storeys it can generate collapses that put at risk the population's safety and construction functionality.

In Mexico, losses of several million pesos are assumed, losses derived from the demolition and reinforcement of the structures that have been compromised by the sinking of the ground [8], as well as the aesthetic and structural damage of multiple households and public buildings as a consequence of the unevenness of the land that comes in contact with the buildings. However, these estimates for the case of Querétaro are generalized to subjective knowledge and to the lack of fundamental mathematical and valuation principles in estimating the economic impact of differential subsidence.

Valuation, properly called valuation, is the science that allows us to determine the value of a good by applying a calculation model that involves both the variables that define and distinguish the good and the economic and temporal environment in which that good is located [9].

Being a professional science that requires value analysis under conditions of current situation, it proposes that for an accurate estimate it is necessary to consider all the factors of merit and demerit belonging to the good. One of the most neglected factors of Geography are the failures that surround the real estate, specifically the differential subsidence, when applying the methodology proposed by Hernández Madrigal [1] to calculate this demerit factor it is possible to quantify individually the economic loss of a property through the product of the demerit factor or depreciation factor and the value of the affected property, its sum will be denoted as the total economic impact and the sum of the failure systems as the global economic impact.

Two property values applicable in the methodology can be used: i) cadastral value [10] calculated on street value by region and sector and ii) land value and construction which requires an analysis by surfaces and types of construction of the properties involved that must be compared with the tables



of unitary values of land and buildings of the municipality of Querétaro, Qro., tax year 2018 [10].

One of the main problems of assessing damage to properties that have been affected or are regionally involved with a influence band lies in the methodological ignorance to follow when the phenomenon of subsidence or differential collapse occurs in the valuation of real estate. Although there are different valuation methodologies considered polygonal expressions to assign a value such as future value [11], replacement cost [12] and regression and statistical prediction methods [13] to this date there are only two methods of economic impact assessment, specifically focused on the effect of differential subsidence, the Julio Miranda method [14] that requires the participation of a professional in damaged material in situ and the Hernández Madrigal method [1] product of the value of the property affected by a respective demerit factor. Both considered as methods of linear expressions capable of being applied in the economic impact analysis research work.

Fig. 1 shows an example of apparent physical damage resulting from a difference in terrain associated with the differential subsidence for one of the neighbourhoods of the Metropolitan Zone of Querétaro, Qro.



Fig 1. Subsidence, Social consequences of an induced disaster San Antonio street, Neighbourhood San Pablo [15].

It is for this reason that in the present research work the Hernández Madrigal method [1] will be applied to calculate the depreciation factor by subsidence of the land, which was designed specifically for the geological and cartographic characteristics of the city of Querétaro, the fault systems selected for the study area.

II. STUDY AREA

The city of Santiago de Querétaro, located in the municipality of Querétaro with code 014 of the eighteen municipalities of the State of Querétaro, is located in the center-west of the Mexican Republic and in the south-western part of the State of Querétaro; it is part of the hydrological region number 12 called Lerma-Santiago and according to information from the municipal geostatistical framework of the National Institute of Statistics and Geography (INEGI) [16] it has an urban area of 12,709.40 ha and 65,965.70 ha of

rural area; which means that the 19.20% of the municipal surface corresponds to urban areas and 80.80% corresponds to rural area. However, the intercensal estimate 2015 [17] reveals that the municipality of Querétaro has a population of 878,931 inhabitants, which represents that more than 52.00% of the population is settled in the conurbation zone of the city of Santiago de Querétaro, this is the reason why the State of Querétaro is among the states with the highest population density per square kilometer and, like many States, it also has its own geological faults that affect urban properties at different scales [18].

As for the stratigraphy Fig. 2, in the central part of the Queretaro Valley, alluvial sequences (Q A1) have been identified, these sequences composed mainly of clays, silts and fine sands with variable thicknesses of up to 50 meters. The unit that fills a large part of the valley (Tp Ar Cg) is composed mainly of a sedimentary sequence composed mainly of conglomerates as well as sequences of lacustrine origin formed by gravel, sands, silts and normally graduated clays. These are interdigitated with thin horizons of pyroclastic rocks of silica composition. Below this filling are volcanic rocks that emerge as fissural spills (Tmt AB), the basaltic spill is followed by a sequence of tuffs, gravels, sands and clays moderately consolidated with abundant pyroclastic materials (Tom Py Lac). Below these sediments is a sequence of Tertiary rocks (Tp AB) that lie on a limestone and sandstone unit (Ki CzAr) [19,20,21].

The composition that most favours the phenomenon of differential subsidence is that which complies with the largest amount of fluviolacustrine deposit formed mostly by gravels, sands and silts that give possibility to leave spaces between their pores once the hydraulic sustenance is removed giving as a result superficial cracks [7].

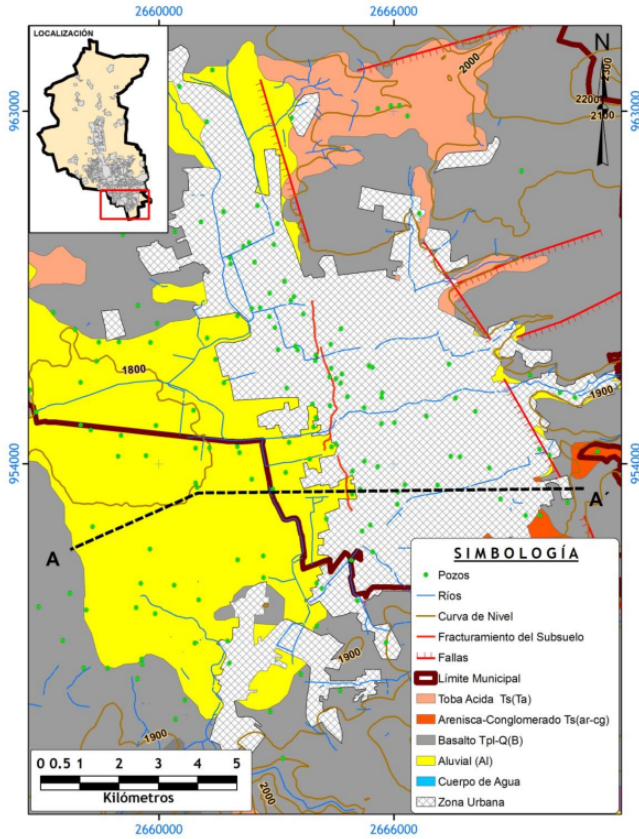


Fig. 2 Geology of the southern area of the municipality of Querétaro [15,20]

The population growth in recent years has generated an urban sprawl in the municipality of Querétaro that produces an increasingly critical water imbalance. Due to the extraction of water necessary to satisfy the demand and the continuous increase of asphalted and paved surfaces that inhibit the infiltration and recharge of the aquifers, the process of differential subsidence is increasingly noticeable in increments of lengths and unevenness as well as increases in the number of aseismic faults in the city. The number of failures of which there is registration and the cartography will depend on the sources of information used. This research project contemplates the failures and fractures of the Partial Plan for Urban Development [22], Atlas of Risks of the Municipio de Querétaro [15] and points of subsidence and cracking of the National Institute of Statistics and Geography [23] downloaded and imported into the ARCMAP 10.4 program for the manipulation of information layers that will later be exported from the shape (.shp) format to the (.dwg) format for its combined manipulation with the other sources of information.

The result of visualizing all faults and fractures in a single map will allow to select the one that is recognized by the three sources of information for an economic impact analysis produced by differential subsidence in urban areas.

III. METHODOLOGY

The methodology for the calculi of Economic Impact (EI), is based on including terms of effect of orientation, proximity and belonging of the failure with respect to an affected property by means of the following equations:

$$EI = EL_1 + EL_2 + \dots + EL_n \quad (1)$$

$$EL_i = PV_i * DF_i \quad (2)$$

Where:

EI: Economic impact for aseismic ground failure (MXN);

EL_i: Economic loss of the property *i* (MXN);

PV_i: Property value *i* (MXN);

DF_i: Depreciation factor (percent).

So far it is said that the Economic Impact (EI) is the result of the sum of each economic loss (EL_i) that covers the area of affection in each property.

For its calculation, the Hernández Madrigal equation [1] defines it as the value of the property (PV_i) by its respective demerit factor (DF_i) that will be calculated by the following expression:

$$DF_i = \frac{(AA_i \cdot \frac{1}{d_i})}{2} \quad (3)$$

Where:

DF_i: Depreciation factor of the property *i* (percentage);

AA_i : Affect area of property *i* (m²)

A_i : Total area of property *i* (m²)

d_i: perpendicular distance from the centroid of the property *i* to the axe of the failure, d_i ≥ 1 m.

Thus, the depreciation factor or demerit factor by the value of a property results in an individual economic impact, while the sum of the impacts obtained will then be the total impact, as the reach of the analysis is required.

The application of the methodology should be repeated for each failure that is wished to include in the global analysis and categorizing the depreciation factors according to the range of influence proposed by Hernández Madrigal [1] with the following table:

TABLE I. SPECTRES DEPRECIATION FACTOR
Hernández Madrigal et al., 2014

Depreciation Factor		
Range	Level ^a	Color
[0.03 - 0.09]	Very low	Dark Green
[0.10 - 0.16]	Low	Bright Green
[0.17 - 0.38]	Medium	Yellow
[0.39 - 0.58]	High	Orange
[0.59 - 0.87]	Very high	Red

^aRisk level Depreciation Factor

The terms of equation (3) represent the effects of ownership and proximity of the property in relation to the axis of the fault associated to the differential subsidence, so that the depreciation factor (DF_i) is estimated according to its spatial relationship from very low to very high risk using Table 1.

IV. RESULTS

The spatial distribution of a failure was obtained from the Atlas of Risks for the municipality of Querétaro with 1.40 km in length and a band of influence of 20.00 m which involves 151 properties in the Residential Italia, Residential Galindas, Neighbourhood Ensueño and Neighbourhood Prados de la Capilla, all belonging to the Felipe Carrillo Puerto delegation. Fig 3 shows the development of the depreciation factor for the study area:



Fig. 3 Spatial distribution of properties affected by Galindas failure [own elaboration]

The following table exemplifies the calculation of 10 properties for the study area corresponding to Residential Italy of Fig. 3 amplified:

TABLE II. CALCULATION OF DEPRECIATION FACTOR [own elaboration]

DEPRECIATION FACTOR							
ZONE	ID	TOTAL AREA (M ²) A _i	AFFECTED AREA (M ²) AA _i	DISTANCE (M) d _i	AA _i /A _i	1/d _i	DF _i
RESIDENCIAL ITALIA	1	356.44	32.36	31.81	0.09	0.03	0.06
	2	198.78	198.78	0.82	1.00	1.22	0.87
	3	201.19	201.19	1.89	1.00	0.53	0.76
	4	268.79	268.79	4.39	1.00	0.23	0.61
	5	337.62	309.24	14.00	0.92	0.07	0.49
	6	246.33	98.78	20.89	0.40	0.05	0.22
	7	206.78	77.55	21.67	0.38	0.05	0.21
	8	213.30	185.16	14.75	0.87	0.07	0.47
	9	193.58	193.58	8.11	1.00	0.12	0.56
	10	213.99	213.99	1.37	1.00	0.73	0.86

The depreciation factor (DF_i) represents ownership and proximity effects for the 151 affected properties regarding the Galindas failure, which multiplied by the values of the property will result in the individual economic loss for each property.

For the value of the property (PV_i) the tables of Unitary Values of Land and Buildings of the Municipality of

Querétaro, Qro., for the tax year 2018 published in the official newspaper of the State Government of Querétaro "La Sombra de Arteaga" December 18, 2017 in volume No.88, valid for the current year of this study.

The land value assigned by sector and area multiplied by the land area will result in the property value (PV_i) to be used in the economic impact methodology.

The value of a property multiplied by the depreciation factor will result in the individual economic loss (EL_i) of a land affected by a fault associated with the differential subsidence. Table 3 shows the summation for land value and economic loss due to failure whose sum will result in the economic impact of the Galindas failure.

TABLE III. ECONOMIC IMPACT [own elaboration]

Economic Impact Failure Galindas			
ID	PV_i	EL_i	
Σ (1-151)	\$617,464,477	\$72,898,593	IE

The economic impact (EI) resulting from the sum of all economic losses (EL_i) of the study area results in \$ 72,898,593 pesos for the Galindas failure, this being a demerit to the value of the land due to land subsidence.

V. DISCUSSION

The method has proven to be effective for the purpose of discretizing and quantifying the economic impact caused by aseismic ground failures in each property, without limiting itself to the fact that important variables that also define the value can be added to the equation, such as the type of construction and geotechnical properties of the soil. Its application promotes mitigation and prevention measures that can be adopted by different government levels and as an analytical factor in the development and planning of new urban areas. Pretending to present and disseminate its application to the reports of valuation experts who are concerned in quantifying the economic damages caused by this phenomenon.

VI. CONCLUSION

The economic impact caused by a failure that affects the city of Querétaro was estimated.

The equation of the methodology can be considered as a standard criterion in the practice of the valuation of an individual property or zone as a whole in a way that allows to change the evaluation from subjective to systematized when establishing the economic loss of a failure.

Likewise, the analysis of Economic Impact by region to promote mitigation and prevention measures by the governmental systems in their different Federal, State and Municipal levels in their tax calculations and damage caused by extractions of fluids in urban areas. As well as an analytical factor in the process of planning and development of new zones of human settlement.



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

REFERENCES

1. Hernández - Madrigal V.M., Muñiz - Jáuregui J.A; Garduño - Monrey V.H.; Flores - Lázaro N. Y Figueroa - Miranda S. (2014). Depreciation factor equation to evaluate the economic losses from groundfailure due to subsidence related to groundwater withdrawal. *Natural Science*.
2. Hernández - Madrigal, V., Flores, N., Villaseñor, C., & Arturo, M. (2015). Impacto económico producido por subsidencia diferencial en zonas urbanas. Caso de estudio Morelia, Mich. (U. Instituto de Investigaciones en Ciencias de la Tierra, Ed.) *Ciencia Nicolaita*.
3. Díaz-Salmerón, J.E. (2010) Geometría y monitoreo con GPS de los procesos de subsidencia-crea-falla (PSCF), en la ciudad de Celaya, Guanajuato, México. Master Thesis, Universidad Michoacana de San Nicolás de Hidalgo, Michoacán.
4. Adrian, O.G., Rudolph, D.L. and Cherry, J.A. (1999) The analysis of long term land subsidence near Mexico City: Field investigations and predictive modeling. *Water Resources Research*.
5. Garduño V.H., Arreygue E. Y Rodríguez G., 2000. Mapa de riesgos de Salamanca. Reporte técnico. Municipio de Salamanca. Universidad Michoacana de San Nicolás de Hidalgo.
6. Garduño-Monroy V.H., Arreygue-Rocha E., Israde-Alcántara I. Y Rodríguez-Torres G., 2001. Efectos de las fallas asociadas a sobreexplotación de acuíferos y la presencia de fallas potencialmente sísmicas en Morelia, Michoacán, México. *Revista Mexicana de Ciencias Geológicas*.
7. Pacheco - Martinez J. (2007). *Modelo de subsidencia del Valle de Querétaro y producción de agrietamientos superficiales Querétaro*. Universidad Nacional Autónoma de México, Posgrado en Ciencias de la Tierra. Tesis Doctoral.
8. Garduño-Monroy, V.H., Rodríguez-Torres, G.M., Israde- Alcántara, I., Arreygue-Rocha, E., Canuti, P. and Chiesa, S. (1999) Efectos del clima (El Niño) en los fenómenos de fluencia de las fallas geológicas de la ciudad de Morelia. *GEOS, Unión Geofísica Mexicana*.
9. Aznar-Bellver, J. (2012). *Nuevos métodos de valoración: Modelos multicriterio* (Segunda edición). Universitat Politècnica de València.
10. Construcciones del Municipio de Querétaro, Qro., para el Ejercicio Fiscal 2018. *La Sombra de Arteaga*.
11. Hu R.L., Yue Z.Q., Wang L.C. y Wang S.J., 2004. Review on current status and challenging issues of land subsidence in China.
12. Yi L.X., Wang J., Shao C.Q., Jia W.G., Jiang Y.X., Bo L., 2010 Land subsidence disaster survey and its economic loss assessment in Tianjin China. *Nat Hazards*.
13. Zhang, A.G. and Wei, Z.X. (2005) Land subsidence in China. Shanghai Science and Technology Press, Shanghai.
14. Julio-Miranda P., Ortiz-Rodríguez A.J., Palacio-Aponte A.G., López-Doncel R. Y Barboza-Gudiño R., 2012. Damage assessment associated with land subsidence in the San Luis Potosí-Soledad de Graciano Sanchez metropolitan area, Mexico, elements for risk management. *Natural Hazards*.
15. Atlas de Riesgos del Municipio de Querétaro 2015. *Fallas y Fracturas*. Querétaro, Querétaro, México.
16. Instituto Nacional de Estadística Geografía e Informática, I. N. (2016). Obtenido de INEGI: <http://www.inegi.org.mx>
17. Geografía, I. N. (2015). Obtenido de Información de México, Encuesta Intercensal: <http://cuentame.inegi.org.mx/monografias/informacion/mex/poblacion/>
18. Civil, U. M. (2015). Atlas de Riesgos del Municipio de Querétaro 2015. *Fallas y Fracturas*. Querétaro, Querétaro, México.
19. Pacheco J. y Arzale J. (2007). Análisis multicapa de la subsidencia en el valle de Querétaro, México. *Revista Mexicana de Ciencias Geológicas*.
20. Carreón-Freyre D., Cerca M., Luna-González L. y Gámez-González F. J., 2005; Influencia de la estratigrafía y estructura geológica en el flujo de agua subterránea del Valle de Querétaro: *Revista Mexicana de ciencias Geológicas*.
21. Alaniz-Álvarez S. A., Nieto-Samaniego A. F., Reyes-Zaragoza M. A., Orozco- Esquivel M. T., Ojeda-García A. C. y Vassallo F. L., 2001; Estratigrafía y deformación extensional en la región San Miguel de allende-Querétaro, México: *Revista Mexicana de Ciencias Geológicas*.
22. Plan Nacional de Desarrollo. (2013-2018). *Gobierno de la República*. Recuperado el 30 de Agosto de 2016, de Plan Nacional de Desarrollo 2013-2018: <http://pnd.gob.mx>
23. Instituto Nacional de Estadística Geografía e Informática, I. N. (2016). Obtenido de INEGI: <http://www.inegi.org.mx>





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Improvement of the quality of life through the design of a house by means of clay for rural areas

L.F. Ortega Servin*, C.N Camacho Álvarez,
A. Rodriguez Vazquez
Department of civil engineering
Universidad Autónoma de Querétaro
Querétaro, México.

lortega23@alumnos.uaq.mx; kamilo_3798@hotmail.com;
ampealf95@gmail.com

Ríos Moreno, G.J.
Department of civil engineering
Universidad Autónoma de Querétaro
Querétaro, México
riosg@uaq.mx

Abstract

The growth of the population increases year after year and with it the demand for space. In rural areas most of the population does not have decent housing, without any planning of any kind, the project aims to design a model of housing in the AutoCad program based on clay materials to improve the quality of life of families as a result shows the design made in the program with the given specifications of each aspect of the house

Keywords: design, rural area, clay materials, quality of life.

I. INTRODUCTION

PLANNING OF THE PROBLEM

Population and settlements are mostly accumulated in pre-mountainous lowlands, river valleys, lower parts of mountainous valleys and plateaus, not equal spatial distribution of population and settlements, big variation of population numbers of rural settlements, uniqueness of demographical processes, big differences in people's occupation and economic functions of settlements, a big diversity of morphology of villages and low level of communication and connections between settlements, (A.H.Potosyan, 2017)

Households that have a settlement in rural areas tend to have a distribution that will be under compliance mainly of their natural and socioeconomic conditions. On the one hand, the natural conditions (First of all, the quality of the land and its attachment to conserving practices for agriculture) will represent a fundamental part for families to take into account at the

beginning of rural settlement, on the other hand, socioeconomic factors (referring to their agricultural practices and migration processes within families) is what will generate a stable idea of the spatial structure of a system that is what will start the settlement in general, therefore begin to create peoples attached to their traditions and way of life.

In the past the essential activity for the rural areas of several countries was agriculture, therefore it is a central axis to give way to the creation of a traditional village, with very particular characteristics, such as the maldistribution of the spaces within a home, were dominated by the installation of pens or farms outside the houses, looking for the way is that their livestock or crops would give better results, so that the members of the families could satisfy several of their basic needs (1).

On the other hand, over the years, the economic development progress and some rural areas were within a range of better quality of life, installed technical and at the same time social infrastructure, the way in which the community works was no longer so similar to the one of years ago, more economic activities were developed, they appropriated some trades, different from agriculture, Due to the constant migration of the countryside to the cities, the number of inhabitants of the urban localities has been increasing; in contrast, that of rural women has declined.

In the mountainous countries, the base for the distribution of the population and the settlements are the valleys and the watersheds, surrounded by dividing ranges. It is an area where the physical-geographical processes interact and interconnect, which differ from the processes in other neighboring physical-geographic regions.

In the upper parts of the river basins, the characteristics of the mountainous terrain (dividing ranges, mountain passages,



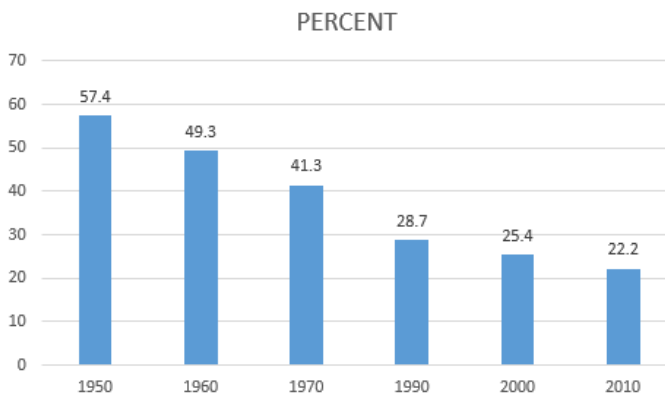


CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERIA

etc.) make up the lifestyle, the language, the dialect and other specific characteristics of particular ethnic groups.

The mountain chains impede the processes of settlement distribution and the consolidation of the territory. For these areas, settlement distribution systems and types of watersheds are more typical, when in a particular basin a certain settlement entity is formed, characterized by a common service system, a transport and infrastructure network, socioeconomic relations between settlements (13).

In 1950, it represented just over 57% of the total population of the country; in 1990 it was 29 percent and for 2010, this figure decreased to 22%. (INEGI, 2017) (Graph 1)



Graph 1. Volume and growth Total population by size of locality for each state,(INEGI, 2010)

Sustainability is a complex term to define enough or practical way to be operational and there is a wide range of ideas about sustainability and its practices (Marcelino-Sádaba et al., 2015). It is a holistic, ambiguous, progressive, global and normative concept. There have been attempts to achieve complex meshed tools for the evaluation of sustainability, by using the many constitutive characteristics of sustainability (Pope, 2006) (3).

In this way it is considered that it gives way to the big cities, with an advance in their way of living, activities they carry out and the same infrastructure. However, not all populations are guided by this form of development, many of them live on the outskirts of cities, others more in mountainous areas. The mountainous zones are generalized by climates with low temperatures, many of them with high vegetation and irregular forms of the land (A.H.Potosyan, 2017).

Generate a housing design from clay materials in most of its structure as well as other elements that allow improving the quality of life in rural populations.

II. THEORETICAL FRAMEWORK

The importance of a study of the homes, or the way in which they are constructed, is of great importance, however, the inhabited spaces in the dominant sectors or with moderately high classes, are the ones that receive the attention regarding these, leaving side to the other population sectors (2). In the same way, cities are those that have the construction studies, their way of life and characteristics of the population (3) This is how they leave aside the sector that lives in rural areas, to the sector with popular peasant housing styles.

Rural housing was characterized by a remarkable use of local building materials, with almost exclusive management of existing elements in the immediate natural environment. The inhabitants of the agrarian communities maintained almost a greater understanding with their habitat, in such a way that the vivandist ecology developed there with more harmony between human beings and the environment, which acquired a weight that is above any cultural motivation. , and even, economic issues (3).

One of the construction practices that facilitated the way homes are designed and built, is the prefabrication that is an old technique, which has different traditional technologies to carry out this practice. We can find various forms of prefabricated roofs from prefabricated mobile roofs in Ethiopia, Vietnam or Mexico or bamboo panels in Asian architecture, to name a few examples (6).

In the last decades, the countries that are in development, have started the use of prefabricated industrial construction systems that mainly import or that they developed on their own (sometimes copied from existing similar techniques) (2) .

The techniques of the use of prefabricated were initially dedicated to people with low incomes in their homes, however, the objective was diverted and they have not addressed that population sector, since the prevaricated ones that are mainly generated are very heavy and of great importance. scale, this means that they only meet the needs of large cities where the results are excellent, in terms of construction time and econo (2) .

The highlights of its failure to population groups with limited resources are (M. Stallen, Y. Chabannes and F. Steinberg, 1994):





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERIA

(a) high costs due to high fixed investments; high transport and assembly costs as the production of the factory is very centralized, heavy cranes are needed at the site; the use of advanced technology and imported inputs, especially expensive construction equipment and construction materials of high energy content such as cement and iron bars are responsible for the production of high-cost prefabricated housing far beyond the limits of affordability;

(b) climatic inadequacy due to improper use of construction materials and due to improper construction;

(c) assembly problems that result in serious inaccuracies and even leakage of assembled components; and finally,

(d) cultural non-portability, since most of the construction systems are only oriented to produce some type of international building type, but never to refer to the local or indigenous construction culture.

Nowadays, precast products are still being used, but mainly they are components or systems that have a large scale, since they are manufactured by specialized factories, factories that are equipped mainly with borders and that possess the necessary resources to develop said methodology (5).

A study developed in Algeria characterized the mechanical behavior of an overconsolidated expansive clay, improved the mechanical properties of a clay treated with hydraulic binders. They establish the relationships between their compaction and their mechanical properties, confirming the improvement of the loading capacity of the clay with the best treatment obtained for a mixture of 4% lime and 8% cement (9).

On the other hand, the countries that are still developing, the use of prefabricated buildings is not as acceptable, since old construction techniques are preserved, which do not allow the generation of this type of systems.

In turn, the realization of prefabricated is going through a time of "stagnation" since it is not accepted and therefore there is a detachment for its acceptance, it would generate several changes in the design of homes, mainly in rural areas, change part of its traditions and other approaches, could be converted into a main activity for the generation of resources.

III. METHODOLOGY

According to the current situation that families live in rural areas, in terms of their home and the needs that needed to be addressed, the first step to start the project was to select the areas and population where it would be feasible to apply it, based on this it was decided to look for rural areas with raw

materials that could be applied in the design and construction process of the homes, in particular the use of clays.

Said zones were studied to know the main characteristics to be treated in the project, such as the type of soil, climatic conditions, vegetation, fauna. This is a very important part in the elaboration of the project, since we look for the areas that have soils with a large amount of clay material, indispensable in the process of construction of the house such as: adobe brick walls and floors of adobe poured that greatly reduce the total cost of the work.

Visits were also made to rural communities to know the socio-economic aspect of the population, this was of great importance for the study, as we were able to notice the shortcomings of the houses and with that information to start designing our house.

The design of the house is based on a family of 5 people, since data offered is the average number of inhabitants per house in a rural area. (INEGI in 2107)

On the other hand, the planning includes, if possible, the placement of a solar heater, take advantage of resources in a large percentage, such as water and natural light since skylights will be placed on the roof of the house as well as reuse the water with a system designed to take advantage of the largest amount of it, based on the basic tools (raw materials) found within the area.

The findings of a study applied in China indicate the advantages of adapting a rural house through the use of passive methods: the annual energy saving for heating is approximately 60% and the interior temperature of the house can be improved compared to its original state. In addition, the environmental cause of the heating fuel source has been mitigated. The results showed the potential for adaptation of rural houses using passive energy-saving methods in northern China (6)

Strictly speaking, the use of clay soil is not unconventional. It only compares unconventionally or in competition with the use and application of more energy-intensive and less ecological materials, such as concrete and steel. The use of clay-based materials has a long and prehistoric background. Their association with mud huts is correct but not sufficient, and they have been seriously reconsidered and modernized, so that clay-based materials can now produce an aesthetically pleasing construction. Good execution can be achieved for both individual and large-scale housing projects using uncooked clay materials, both in developed and developing countries. All these parties have a common interest in low-cost housing, caring for the environment and sustainable development of



community infrastructure, as there is no parallel with the adoption of appropriate technology based on soil (12).

With this design, enough spaces are met to cover the basic needs and thus improve the quality of life of families living in rural areas.

There is pressure on manufacturers of construction materials, due to new government regulations and legislation that point to the use of energy and carbon dioxide emissions in new buildings. Uncooked clay bricks for environmental and sustainable use. They are based on lime or Portland cement as an activator of an industrial by-product (granulated earth slag) to stabilize the lower Oxford clay for the production of uncooked clay bricks. Portland cement was used in the formulation of uncooked clay brick test specimens predominantly as control (10).

Based on the results of the environmental and sustainability analysis, the unburned clay material has demonstrated energy efficiency and suggests a formidable economic alternative to the cooking of clay building components. This study is one of the first attempts to compare the cooked and uncooked clay technologies, and also to combine the use of energy and the emission of CO₂ for the evaluation of clay bricks without cooking in relation to the bricks used in the construction conventional (10).

A coupling between mechanics and physical chemistry was undertaken to explain the mechanical behavior of clay materials treated with lime. The study was carried out in two different clays, a kaolin and a Ca₂ + bentonite. The addition of lime leads to an increase in the mechanical properties of these clays. These improvements are faster with the Ca₂ + bentonite, even if in the long term the performance achieved for the kaolinite is higher. The coupling between the macroscopic and physicochemical aspects shows that these improvements are related to the development of secondary compounds such as calcium silicate hydrates, hydrograne and calcium carboaluminate hydrate phases (11).

IV. RESULTS

Based on a field study, it was decided to carry out a simple design that met all the basic needs of a family, in addition to lowering the construction and maintenance costs of this.

Our house has an area of 62.32 m², with 6.08 m wide x 10.25 m long, this design has 2 bedrooms, 1 bathroom, kitchen and an area for living room (Fig. 1, 2, 3).

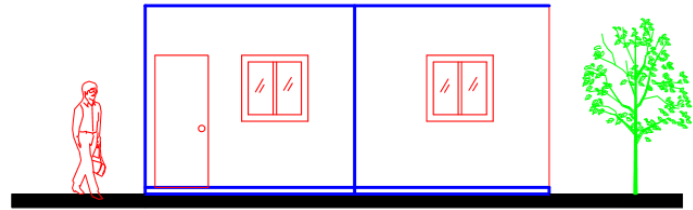


Fig 1. Front Façade

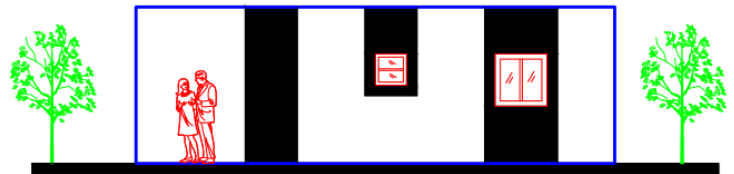


Fig 2. Lateral Façade

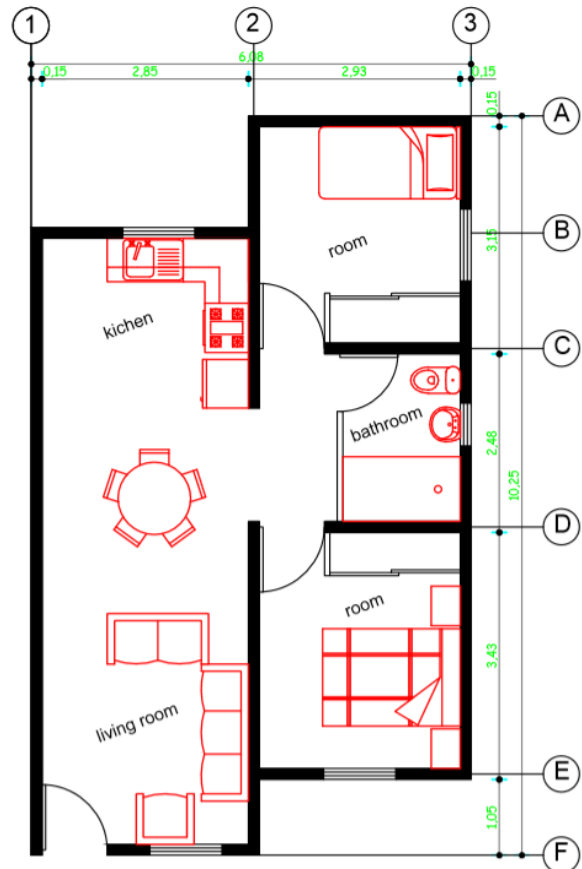


Fig 3. Architectural Plant



The aesthetic aspect is not left aside as a facade was also designed with a simple style, but cheerful to look at, since we believe it is important that it be liked by the people who live there, it gives them a new perspective on his same house (Fig. 4).

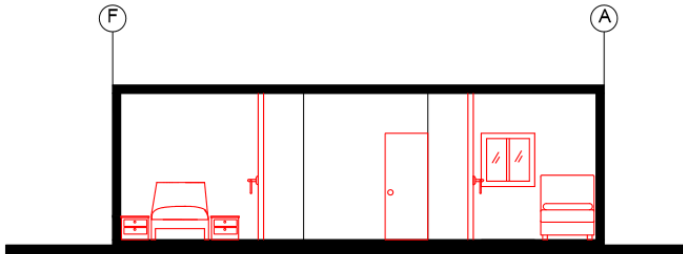


Fig 4. Section A-A'

Likewise, it is necessary to consider placing solar heaters, depending on the area in which the instrument is to be placed, it must be oriented towards the south and for the central zone of Mexico with an angle of inclination of 35-40 degrees (Fig. 5).

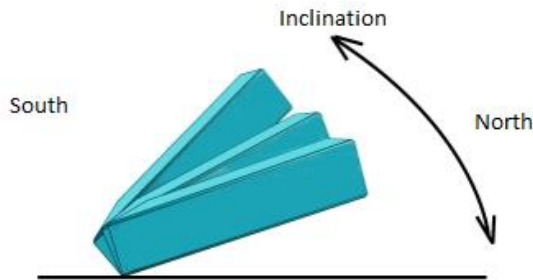


Fig 5. Orientation and inclination of the panel

The house includes a total of four doors, has five windows, one smaller in the bathroom which are located to make the most of natural light.

Use clay blocks of dimensions 15x20x30 cm which allow to have a good temperature regulation thanks to the holes they carry in their body (Fig 6)



Fig 6. Block of 15x20x30 with holes

The house has a height of 2.80 m so that the ventilation and the thermal sensation do not change drastically, the windows are located at a height of 1.20 m.

The large ones have dimensions 1.80x1.40 m as for the bathroom is 0.60x0.60 m



Fig 7. Inside view of the house

V. CONCLUSIONS

Based on our results, we conclude that the design is feasible for a family with average monthly income, so the approach we gave was to guide this sector of the population in the construction of their home, in addition to giving them a space where they feel comfortable and their basic needs are met.

We also conclude that the design as well as the plans are easy to understand for anyone who wants to do it or someone interested in the subject.

VI. REFERENCES

- [1] Jerzy Banski, Monika Wesolowska, "Transformations in housing construction in rural areas of Poland's Lublin region-influence on the spatial settlement structure and landscape aesthetics", Poland, Available on ScienceDirect and www.elsevier.com/locate/landurbplan.
- [2] M. Stallen, Y. Chabannes and F. Steinberg, "Potentials of prefabrications for self-help and mutual-aid housing in developing countries, Habitat INTL. Vol. 18, No. 2, pp 13-39, 1994, Available on ScienceDirect.
- [3] G. Boils Morales, "Las viviendas en el ambito rural", Revista de informacion y analisis, No. 23, 2005.
- [4] S. Marcelino-Sadaba, J. Kimuthia, J. Oti and A. Seco-Meneses, www.elsevier.com/locate/clay
- [5] J. Payne, S. Rissingol, "Identifying the differences between clays used in the brick industry by various methods: Iron extraction and NMR spectroscopy", 2018, Available on www.elsevier.com/locate/clay and ScienceDirect
- [6] X. Liang, Y. Wang, Y. Zhang, J. Jiang, H. Chen, X. Zhang, H. Guo, T. Roskily, "Analysis and optimization on energy performance of a rural house in northern China using passive retrofitting, 2016, Available on ScienceDirect.
- [7] S. Wang, W. Zhu, K. Fei, C. Xu and N. Zhang, "Study on non-darcian flow sand-clay mixtures", Available on ScienceDirect, Vol 151, 2018, pp. 102-108



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

- [8] J.E. Oti, J.M. Kinuthia, R.B. Robinson, "The development of unfired clay building material using Brick Dust Waste and Mercia mudstone clay", *Applied Clay Science*, Volume 102, December 2014, Pages 148-154
- [9] M. Khemissa, A. Mahamedi, "Cement and lime mixture stabilization of an expansive overconsolidated clay", *Applied Clay Science*, Volume 95, June 2014, Pages 104-110
- [10] J.E. Oti, J.M. Kinuthia, "Stabilised unfired clay bricks for environmental and sustainable use", *Applied Clay Science*, Volume 58, April 2012, Pages 52-59
- [11] N. Maubec, D. Deneele, G. Ouvrard, "Influence of the clay type on the strength evolution of lime treated material", *Applied Clay Science*, Volume 137, 1 March 2017, Pages 107-114
- [12] J.M. Kinuthia, "Unfired clay materials and construction", Book chapter, *Nonconventional and Vernacular Construction Materials*, 2016, Pages 251-272
- [13] A.H. Potosyan, "Geographical features and development regularities of rural areas and settlements distribution in mountain countries", *Annals of Agrarian Science*, In press, corrected proof, Available online 11 February 2017.



Development of a prototype for rainwater reuse

Dr. Eduardo Arturo Elizalde Peña, Dra. Karen Esquivel Escalante, Dr. Carlos Guzmán Martínez
Facultad de Ingeniería
Universidad Autónoma de Querétaro
Santiago de Querétaro, Qro., Mex.

Tonantzi Pérez Morneo
Ingeniería en Nanotecnología
Facultad de Ingeniería, UAQ
Santiago de Querétaro, Qro., Mex.

This work shows the development of the prototype of a train system for rainwater reuse. This complex system consists in two phases: first, a photocatalytic reactor that reduce the organic compounds presents in the water stabilizing the biochemical oxygen demand; the second phase is a filtration system that uses the chelating and bacteriostatic activity of chitosan to trap the remaining fats as well as metal ions. A secondary aim of this work is reduced cost, time and energy; the system for rainwater reuse also could be used in wastewater treatment and transferred to domestic level.

Keywords—rainwater; train of treatment; chitosan; titanium dioxide

I. INTRODUCTION (HEADING 1)

One of the most important problems in the world is the shortage of water, climate changes, soil erosion and the growing population have made the expenditure of the vital liquid is greater in urban areas than in rural areas, which is why it is evident that we must take preventive actions and that they provide a solution to this problem and they must be carried out at home or in our workplace.

The pluvial water can be a source of water to solve the deficiency that takes place due to the population growth, action that up to now does not apply very frequently in our environment. Therefore, it is intended to develop and implement a rainwater collection and reuse system in the Amealco campus so that it is self-sustaining and does not require the use of water from the municipal network. Said effluent will be processed by an array of filters and reactors, which will eliminate sediments, bacteria that may be present and heavy metals, thus leaving a water with quality under Official Mexican Standard 003, which establishes the maximum permissible limits of contaminants for waters treated residuals that are reused in public services.

The shortage of water in the homes of our country is increasing, about 20% of households do not have access to water [1], 1,941 wastewater treatment plants can not solve the 3,380,326 miles of cubic meters of wastewater discharged in Mexico [2]. Currently, water reuse is an alternative to the problem of shortage drinking water. Agriculture is the activity that uses the greatest volume of water, that is why using treated water presents a feasible option to improve the global panorama of its use; The inconvenience of clean water is the waste generated during the process, that is the reason of this project is

looking for decrease the production of recalcitrant waste and the production of water with sufficient quality to be reuse.

An alternative that is not new, but to which efforts are being redirected, is the collection of rainwater; This action does not imply the use of advanced technology and can be applied at any level.

Currently both systems, capture rainwater and gray water treatment, represent an efficient alternative to solve the problem of access to water that some communities suffer, and thereby partially over-exploit the water table, especially in the rainy season. , storing rainwater for the dry season [2,3,4].

The advanced oxidation processes consist of the formation of highly oxidizing hydroxyl radicals, which contribute to the total mineralization of the polluting compounds present in industrial effluents. Among the most used processes is photocatalysis, which consists in the acceleration of a photo-reaction using a catalyst: in this case, this research used titanium dioxide as photocatalyst [5]. The mineralization of organic compounds, in addition to contributing to the elimination of waste, contributes to the stabilization of the biochemical oxygen demand which is a laboratory analysis that allows to determine chemically the quantity of oxygen that is required to oxidize the organic matter present in a sample of residual water [4] and that if not controlled can seriously alter aquatic life.

There is titanium dioxide's three types of structures: rutile, anatasa and broquita. The size depends on the stability of the



Fig. 1. Side view of prototype of rainwater treatment system.

titanium dioxide phases; the anatase phase is the most stable for nanoparticles with a size around 11-35 nm [6].

On the other hand, there are currently several systems that seek to remove waste from water, in this project the properties of activated carbon were used together with the properties of magnetic particles with the ability to function at a cellular and molecular level in biological interactions [7] as is magnetite, Fe_3O_4 . At the nanometric scale magnetite is paramagnetic, which means that it is magnetic only in the presence of a magnetic field [8], this leads to the fact that various nanostructured oxides based on magnetite have turned out to be good devices for the manufacture of magnetic materials, sensitive protection films, catalysts, pigments.

To facilitate the manipulation of the magnetite, it was created a nanostructured composite with chitosan as a matrix and magnetite nanoparticles dispersed within it. Chitosan is a linear polysaccharide composed of randomly distributed chains of β - (1-4) D-glucosamine and N-acetyl-D-glucosamine Valderrama, 2000).

Previous studies indicate that chitosan, in the form of gel beads, of 2.5mm diameter have a BET area of 250-800 m^2 compared to 1-2 m^2 that has chitosan in the form of flakes [9]. With a larger surface area, the availability of more active sites for the adsorption of metal ions and organic compounds remaining from the photo reactor is ensured.

Through activated carbon filters, together with a composition of chitosan with magnetite, and the advanced oxidation processes, it is possible to generate water with enough characteristics for domestic reuse that follow the official Mexican standard NOM-003- ECOL-1997.

Therefore, this project seeks build the prototype of a rainwater treatment system that uses nanostructured materials to clean greywater so that it can be reused in the same home that generates it.



Fig. 2. Spheres of Chitosan-QGMA with magnetite nanoparticles.



Fig. 3. Filter with pheres of Chitosan-QGMA with magnetite nanoparticles and activated carbon.

II. METHODS

A. Preparation of the photo-reactor

The PET plates were coated with titanium dioxide as filler in the system to have the active photocatalyst. The TiO_2 was dissolved in ethanol, then the mixture was applied on PET plates, both rough (sanded) and smooth to obtain the active surface.

The reflux system consists of a transparent glass box with a capacity of 80 liters divided into three sections, the first consisting of small and rough PET plates; the second contains soft PET. Finally, an outlet section, as well as reflux, which is achieved by a water pump.

B. Synthesis of GMA chitosan spheres and magnetite nanoparticles

GMA was dissolved in 0.4 M acetic acid with the aid of magnetic stirring at a temperature of 50°C , on the other hand chitosan was dissolved in 0.4 M acetic acid for 50 minutes, also a KOH solution was made. To obtain a 1% chitosan-GMA solution, the chitosan solution was mixed together with the KOH solution and 3 washes of 3 ml of 0.4 M acetic acid were made; subsequently, the GMA solution followed by washing was added. This solution was left in magnetic stirring for 1 h. In a beaker with acetonitrile the previous solution was added dropwise maintaining a temperature of $40 \pm 1^\circ\text{C}$ and a slight magnetic stirring

To the 1% GMA chitosan solution described above, 0.1 g of magnetic was added and taken to an ultrasonic bath for 5 minutes. Previously a pure chitosan solution was made, with a 2: 1 ratio with the chitosan-GMA; to which the previous solution was subsequently incorporated and placed in an ultrasonic bath for 35 minutes. Drop by drop the solution of magnetic chitosan-GMA was added to a 0.5 M NaOH solution.

The Q-QGMA-Magnetite spheres were packaged in PVC tubes with activated carbon to optimize the removal of contaminants. The filters consist of two sections of activated carbon at the ends and a section of magnetic spheres (about 50



Fig. 4. Samples of the cistern with a dilutions of -1.

ml in volume of spheres) in the center, first packed in filter paper and then incorporated in the PVC tube.

C. Bacteriological tests of the treatment system (filters)

Bacteriological tests were carried out with two different culture broths, lactose broth and lauryl sulfate broth. Three solutions of each sample were made, with the notations of -1, -2, -3. For each sample, bacteriological analysis was performed in triplicate for each sample. The incubation of all tubes (samples) was carried out for 2 days.

III. RESULTS

The prototype can be seen in Fig. 1, where you three sections can be distinguish in the system, the first section on the left contains rough PET coated titanium dioxide, the water is introduced into the system in this area, in which comes the contact with the plates that are responsible for carrying out the catalytic photo activity. When the first section is filled, the water begins to fall in the second stage which contains smooth PET coated with TiO₂, where the same catalytic photo mechanism occurs. Finally, the third section collects the water that falls from the second stage and contains a pump that recirculates the water to the first stage.

The total time in which the system was tested was 3 hours, showing a constant circulation. The tests were conducted with 40 liters of water, however, the system can get to work without difficulties up to 60 liters.

On the other hand, about 400 ml in volume of spheres of chitosan-QGMA with magnetite nanoparticles was carried out. The characterization of the nanocomposite could only be performed empirically by means of the coloration, consistency, shape and size of the spheres as shown in Fig. 2, this due to the replicability of the synthesis.

Subsequently, before the spheres being incorporated into the filter (Fig. 3), they were washed with distilled water to remove the NaOH solution. The filter paper is divided into three sections of activated carbon and one in the center of spheres. In addition, the durability of the spheres was proved, and it was obtained that they can resist without disintegrating up to 10 months as long as

they are in a liquid medium, either the NaOH solution or in water.

Finally, the bacteriological tests that were carried out was with the water treated by activated carbon filters, to test its effectiveness.

In tubes with lactosed broth, the three test tubes of the cistern with solution -1 showed turbidity, likewise two of the samples with solution -2 (Fig. 4) showed turbidity. Despite this, no bubbles of gas generated by the bacteria are observed in the Durham hood

On the other hand, in the lauryl sulfate broth samples of the cistern with solution -1 showed turbidity (2 of the 3 tubes), while in solution -2 one of the three tubes presented disturbance.

Because no gas was observed in any of the samples this tubes are not considered like positive. However, because only turbidity appears in the solutions with higher concentration and as the concentration decreases the turbidity disappears (in the samples of the cistern with solution -3 there are no disturbance), we consider that there could be a very small amount from *E. faecalis* ATCC 29212, *P. aeruginosa* ATCC 27853 and *salmonella typhimurium* ATCC 14028, due to these bacterias may or may not produce gas.

IV. CONCLUSION

The materials were synthesized efficiently, in order to make the reactors and filtration systems for the treatment train, the application of the complete system to the Amealco campus was not determined viable because there are no elements that indicate that the water in the containers have a poor quality, so it was determined that only the filter system was sufficient to leave the water with sufficient quality for reuse under NOM-003-ECOL-1997.

The only sample that showed the presence of microorganisms was taken from the building with the highest student density, and possibly the area could have been contaminated and hence have this non-positive result, but it is necessary to emphasize that the present quantity of microorganisms is very low.

ACKNOWLEDGMENT (Heading 5)

To the Autonomous University of Queretaro for the opportunity to carry out the research and the project team of Products 100% UAQ for their support during the time of residence in the laboratory of nanostructured and functional materials.

REFERENCES

- [1] INEGI. *Encuesta Nacional de los Hogares, 2015*. Tabulados básicos. Tabulado 1. 4 Estidades Federativas. (Consultado 08 de marzo 2018). Elaboración propia: Dirección de Estadísticas del Medio Ambiente.
- [2] INEGI. *Censos Económicos, 2014*. Tabulados predefinidos. Sectoriales. *Agua*. México, 2013. Elaboración propia: Dirección de Estadísticas del Medio Ambiente.



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

- [3] Gay Alaníz L., Martínez M., Guevara Escobar A., Luna Zúñiga F. Rain water harvesting and wastewater treatment through constructed wetland in the Soledad basin, *CIENCIA@UAQ*, 3(2):2010
- [4] Ulacia Balmaseda Ramón. La infraestructura verde como sistema de captación de agua de lluvia, *Impluvium*, UNAM, No. 1 (2) 2014.
- [5] Ramírez Edgar. Creando sinergia entre academia y sociedad civil, ¿el pretexto? Captación de agua de lluvia en escuelas de educación básica, *Impluvium*, UNAM, No. 1 (2) 2014.
- [6] Garcés Giraldo, L., Franco, M., Alejandro, E., & Santamaría Arango, J. (2012). La fotocatalisis como alternativa para el tratamiento de aguas residuales.
- [7] Zambrano Franco, D., & Isaza Hinestroza, J. (1998). Demanda química de oxígeno y nitrógeno total, de los subproductos del proceso tradicional de beneficio húmedo del café. *Cenicafé*, 279-289.
- [8] Linsebigler, A. L., Lu, G., & Yates Jr, J. T. (1995). Photocatalysis on TiO₂ surfaces: principles, mechanisms, and selected results. *Chemical reviews*, 95(3), 735-758.
- [9] Karimi Z., (2013). Nano-magnetic particles used in biomedicine: Core and coating materials, En *Material Science and Engineering*, vol. C, no. 33, pp. 2465-2475.
- [10] Besoain E. (1958). *Mineralogía de arcillas de suelos*. Costa Rica: Editorial IICA.
- [11] J. Hennen, W. (1996). *Chitosan*. Orem, Utah. USA: Woodland Health.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Geometric design, the solution for Mexico?

Jycet Monserrat Brizuela Ramírez

Research and Postgraduate Division of the Faculty of
Engineering
Universidad Autónoma de Querétaro
Querétaro, Mexico
monze.br@gmail.com

PhD. Saúl Obregón Biosca

Research and Postgraduate Division of the Faculty of
Engineering
Universidad Autónoma de Querétaro
Querétaro, Mexico
saul.obregon@uaq.mx

Abstract— In Mexico, injuries caused by traffic are among the ten leading causes of death, where the most affected in these situations are the most vulnerable users. This article presents the two solution proposals most studied for this problem, the geometric design and road education, with the aim of studying and comparing them to know the most convenient solution for Mexico. From the above it was obtained as a result that the geometric design alone is not the solution, since the lack of road education means that users, once accustomed to the changes made in the road, return to their previous practices putting themselves in danger, again, to themselves and to others.

Keywords— road accidents, road education, geometric design, road safety, mobility.

I. INTRODUCTION

Mobility is understood as a basic need of the human being, which must be respected and satisfied so that this does not affect the quality of life or the possibilities of their development. Based on the Intercensal Survey 2015 conducted by INEGI, it was estimated that in Mexico we were 119,938,473 people for that year [1] and according to data from CONAPO, by the year 2030 we will be 137,481,336 [2]. Regarding motor vehicles, for the year 2016 there were 42,932,567 vehicles in circulation with projections of an increase of 60% by 2030 [3].

In 2015, the UN in Mexico established a new sustainable development agenda for the next 15 years, where the reduction of injuries and deaths due to traffic accidents was determined as a goal [4]. The STCONAPRA reports that, in Mexico, injuries caused by traffic are among the ten leading causes of death and in 2014 there were 15,886 deaths due to traffic accidents in the country; of which 68.3% of those affected in these situations are the most vulnerable users (pedestrians, cyclists and motorcyclists), pedestrians being the ones that concentrate the highest percentage of deaths among them [5].

II. BACKGROUND

According to the INEGI, in urban areas of Mexico, 360,051 traffic accidents were recorded, of which 4,559 were fatal and 97,614 injured; of these accidents in which fatalities were recorded, 52.3% were at intersections [6]. Table 1 shows the number of deaths in road traffic accidents by type of accident in urban and suburban areas in 2016; it is important to mention that this registry does not take into account the people who were injured in the event and subsequently died.

TABLE I. ROAD TRAFFIC ACCIDENTS IN URBAN AND SUBURBAN AREAS INEGI 2016

Type of Accident	Deaths	Injured
TOTAL	4,559	97,614
Collision with a motor vehicle	940	39,372
Collision with pedestrian	1,033	13,884
Collision with animals	38	275
Collision with fixed object	559	7,978
Rollover	709	5,672
Passenger drop	57	2,316
Exit of road	366	2,854
Collision with motorcycle	539	19,547
Collision with cyclist	197	3,770
Other	121	1,712

It is necessary to observe that in second place of deaths by road accidents are pedestrians, and in third place of injured cyclists; which are considered the most vulnerable users of the road. Therefore, road safety studies are necessary to provide safe mobility for all types of users, especially for the most vulnerable and currently do not have the necessary infrastructure for their safety and, in addition, the level of road safety education in Mexico is very low.

III. GEOMETRIC DESIGN AS A SOLUTION

Several authors such as NACTO [7], World Resources Institute [8], New York City DOT [9], among others, affirm that most cities could become safer and healthier cities only by changing the design of their roads. Arguing that the private car has been given priority at the moment, designing principally or totally for its comfort; if the roads were designed to effectively serve all users of the road, they would be much safer.

According to these authors, road accidents would be reduced by following the following action steps: urban design that reduces the need for vehicle travel and fosters safer vehicle speeds, traffic calming measures that reduce vehicle speeds or allow safer crossings, arterial corridors that ensure safer conditions for all road users, a network of connected and specially designed bicycling infrastructure, safe pedestrian facilities and access to public spaces, and safe access to mass transport corridors, stations, and stops.

In Mexico, at the end of 2017, SEDATU presented the Street Manual: vile design for Mexican cities; The manual aims to





establish technical guidelines and urban design parameters that facilitate the development of safe, inclusive and sustainable road projects [10]. But as it still does not come into force, the Manual of the Highway Geometric Project of the SCT continues to be used despite the fact that it is focused on highways, leaving pedestrians and cyclists in the background.

Tactical Urbanism

As Javier Vergara expresses it, in the book *Tactical Urbanism: Latin American Cases*, this can be understood as a short-term prototype that can provide information to long-term planning and is built from groups of empowered people, which it does citizen urbanism. Tactical urbanism consists of small actions that can have a long-term impact on cities; these actions are initially temporary and it is expected that, when showing their impact, the authorities will decide to convert them into projects that will be implemented permanently [11]. It is necessary to bear in mind that, tactical urbanism would not be necessary if every city had an auditable geometric design.

In Mexico, some citizen groups have made use of tactical urbanism to improve the situation of some roads and intersections throughout the Mexican Republic and in this way make a call to the government. Among them ITDP Mexico and the Liga Peatonal are distinguished with their job of disseminating information on road safety issues and making design improvements in the public space; other groups or collectives such as Zoon Peatón, A Pata, derivé LAB, La Banqueta se Respeta, among others, are engaged in work of citizen empowerment with walks and tactical urbanism work for their cities to inform users of the path of problems that are present.

IV. ROAD SAFETY EDUCATION IN MEXICO

Just as there are authors who consider that the modifications to the geometric design of roads are the solution to end road accidents in Mexico, there are those who believe that this can be solved with an improvement in road safety education.

A study conducted in Florida [12] showed that the majority of road users exhibit unsafe behavior, and a research conducted in Botswana [13] found that 90% of drivers do not yield to pedestrians at not sing intersections and that additionally pedestrians do not feel that the fact that the zebra crossing is marked, gives them greater security.

One of the biggest problems that we face in Mexico, is to believe that road education only concerns users of motorized transport and as a result of this there are documents such as the User Guide of the Streets of Mexico City [14], the National Road Safety Training Program [15], and Technical Publication No. 449 regarding Road Safety Campaigns for the Improvement of Human Factor Behavior [16], where only recommendations are made to drivers, completely forgetting others road users.

Currently in Mexico only road education is provided to those people who are going to apply for their driver's license while the rest of the users of the road pass through it without knowing their rights and obligations.

V. DISCUSSION AND CONCLUSIONS

Mainly, we look for a single action that can solve a problem, in this case we talk about the number of deaths due to road accidents as a problem and two proposed solutions: geometric design and road safety education. As mentioned in the previous sections, it has been proven that the redesign of intersections has caused this problem to decrease, since users perceive a change in the route, respond with a more thorough mobility. Also, there are studies that prove the efficiency obtained by educating citizens so that they know their rights and obligations in the public road depending on their mode of transport.

In Mexico, derived from the problems raised in the previous paragraph, they have taken action on the matter and have begun to make changes in their roads, completely forgetting the issue of education and road safety; resulting in that, once the user is accustomed to this new design, he returns to his previous incorrect practices. Due to the above, the geometric redesign alone does not represent a solution to this problem [17]. In the case of road safety education, courses or compulsory campaigns are lacking in this subject, so under these conditions there is no record that helps us compare a before and after the circumstance in which users received and assimilated this information.

From the above, it generates the need to know the level of road user education of road users and their behavior, this without neglecting the conditions in which are the roads through which they transit. Thus, with these data, we can know what are the parameters that condition the behavior of the users of the road and with this find the most convenient solution to reduce the deaths caused by road accidents in Mexico.

REFERENCES

- [1] Instituto Nacional de Estadística y Geografía, Intercensal Survey, 2015. Recuperado de <http://www.beta.inegi.org.mx/temas/estructura/>
- [2] Secretaría del Consejo Nacional de Población, Proyecciones de la Población 2010-2030. Recuperado de http://www.conapo.gob.mx/es/CONAPO/Proyecciones_Datos
- [3] Instituto Nacional de Estadística y Geografía, Parque Vehicular, 2016. Recuperado de <http://www.beta.inegi.org.mx/temas/vehiculos/>
- [4] Organización Mundial de la Salud, (2009). Informe sobre la situación mundial de la seguridad vial: es hora de pasar a la acción. OMS. Ginebra, Suiza.
- [5] Secretaría de Salud/STCONAPRA, (2016). Informe sobre la situación de la seguridad vial, México 2015. México, Ciudad de México.
- [6] Instituto Nacional de Estadística y Geografía, Estadísticas a Propósito del Día Mundial en Recuerdo de las Víctimas de los Accidentes de Tráfico, 2017.
- [7] National Association of City Transportation Officials, Urban Street Design Guide. New York, 2012.
- [8] Word Resources Institute, Cities Safer by Design: Guidance and Examples to Promote Traffic Safety through Urban and Street Design, 2015.
- [9] New York city Department of Transportation, Making Safer Streets. New York, 2013.
- [10] Secretaría de Desarrollo Agrario, Territorial y Urbano, Manual de Calles: Diseño Vial para Ciudades Mexicanas, 2017.
- [11] Street Plans and Ciudad Emergente, Urbanismo Táctico 3: Casos Latinoamericanos. Creative Commons, 2013.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

- [12] Kourtellis, A., y Lin, P. (2012). Measuring Unsafe Pedestrian Behavior Using Observational Data, Transportation Research Board 92nd Annual Meeting, 2013. Wachinton, D. C.
- [13] Mphele, S. B., M., Selemogwe, M. Kote y S. K. Balogun. (2013). Who Owns the Road? Exploring Driver and Pedestrian Behaviour at Zebra/Pedestrian Crossings in Gaborone, Bostwana. British Journal of Arts ans social Sciences, Vol 13, No 1.
- [14] Secretaría de Moviliad de la Ciudad de México, Guía de Usuario de las Calles, 2007.
- [15] Secretaría de Salud, Programa Nacional de Capacitacion en Seguridad Vial, 2016.
- [16] Secreatría de comunicaciones y Transportes, Publicación Técnica No. 449: Campañas de Seguridad Vial para el Mejoramiento del Comportamiento del Factor Hmano. Sanfandila, Qro., 2015.
- [17] Nina Dragutinovic and Divera Twisk, The Effectiveness of road Safety Education. SWOV Institute for Road Safety Research, The Netherlands, 2008.



VIBRATION CONTROL IN CABLES OF THE BALUARTE BRIDGE WITH A LINEAR DINAMIC MODEL

Esquivel Cruz Javier
Universidad Autónoma de Querétaro
Querétaro, Querétaro
xavitigre@gmail.com

Granados Hernández Fransico

Universidad Autónoma de Querétaro
Querétaro, Querétaro
Frankgranado83@gmail.com

Alan Sinhué Hernández Paredes
Universidad Autónoma de Querétaro
Querétaro, Querétaro
Alan_mess19@hotmail.com

Abstract— Describes the develop of the linear dynamic model, for the behavior of cables of a cable-stayed bridge through of the ANSYS 18.1 software , for develop an active system (intelligent) of deadening for reduce vibrations of the cables of Baluarte bridge's; limited only to cables that are in the position more critical, highlighting the use of mathematical models that significantly reduces costos.

Keywords— behavior, cables, braided , board , charges, shock absorber, cable-stayed, finite element, structure, software

Introduction

The knowledge and the control of natural frequencies of a system help to reduce but don't to remove the forces of dynamic character that give place to occurrence of problems due to vibrations , therefore the introduction of an energy dissipater is intended , that in this case, will be a dynamic shock absorber , face to prevent an excessive system response (large amplitude vibrations), even in the event of a resonance.

The environmental phenomena and the fatigue loads , mainly , they produce great resonances in cable-stayed bridges , therefore , the use of the finite element method is used in the ANSYS 2018 software , since it helps to reduce costs of meaningful manner in the planning of a project .

Mathematical modeling

The modal frequencies , considering the tension , that can be obtained form the equation(1.1), to observe how a structure behaves before dynamic loads.

$$f = \frac{n}{2L} \sqrt{\frac{T}{m}} \quad (1.1)$$

And this to give in tension terms we obtains, the equation(1.2)

$$T = 4L^2 f^2 \frac{W}{g} \quad (1.2)$$

The deformations are considered when we modeling the cable, that this type of structural elemnts could suffer, for this reason we use , the elastic stiffness matrix and the mass matrix , which are related in the equation(1.3).

$$\det[k - w_i^2 [M]] \{\emptyset\} = \{0\} \quad (1.3)$$

For this method , a force is applied at the center of mass, for obtain a unit displacement.

If, we considering the specifications of the cable #9 (of the cable-stayed brifge Baluarte):

- E(elasticity module)=200 GPa
- Total and effective area=2620.47 mm²
- Number of "torones" of steel=27
- Exterior diameter=0.3293 m
- Total mass=2502.03 kg
- Inclination of the cable #9=45.35°
- Length=53.639 m

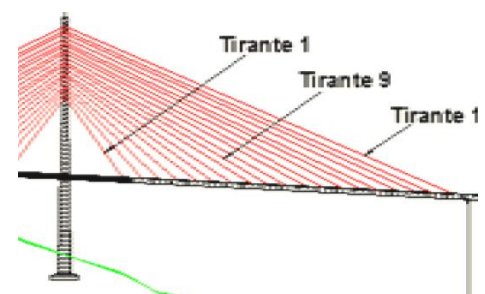


Figure 1. Position of the cables bridge's



We determinate the mass matrix ([M]);

$$M_{xy} = \frac{\rho A h_e}{6} \begin{bmatrix} 2\cos^2\theta & 2\cos\theta\sin\theta & \cos^2\theta & \cos\theta\sin\theta \\ 2\cos\theta\sin\theta & 2\sin^2\theta & \cos\theta\sin\theta & 2\sin^2\theta \\ \cos^2\theta & \cos\theta\sin\theta & 2\cos^2\theta & 2\cos\theta\sin\theta \\ \cos\theta\sin\theta & \sin^2\theta & 2\cos\theta\sin\theta & 2\sin^2\theta \end{bmatrix}$$

$$m = \frac{(7850 \text{ kg/m}^3) \cdot (0.00262047 \text{ m}^2) \cdot (53.639 \text{ m})}{6}$$

0.9877	0.9999	0.4938	0.4999
0.9999	1.0122	0.4999	1.0122
0.4938	0.4999	0.9877	0.9999
0.4999	0.5061	0.9999	1.0122

Figure 2. Mass matrix

The inertial moment , for a circular section, is:

$$I = I_x = I_y = \frac{1}{4} \pi r^4 = 0.000008378 \text{ m}^4 \quad (1.4)$$

The stiffness matrix, Will have 4 liberty grades due to that its will be studied as a beam:

- Displacement unit in a grade of liberty
- Turn unit in grade of liberty 2
- Displacement unit in grade of liberty 3
- Turn unit in grade of liberty 4

And it's determinate of the following way:

$$K = \begin{bmatrix} \frac{12EI}{L^3} & \frac{6EI}{L^2} & -\frac{12EI}{L^3} & \frac{6EI}{L^2} \\ \frac{6EI}{L^2} & \frac{4EI}{L} & -\frac{6EI}{L^2} & \frac{2EI}{L} \\ -\frac{12EI}{L^3} & -\frac{6EI}{L^2} & \frac{12EI}{L^3} & -\frac{6EI}{L^2} \\ \frac{6EI}{L^2} & \frac{2EI}{L} & -\frac{6EI}{L^2} & \frac{4EI}{L} \end{bmatrix} \quad (1.5)$$

$$K =$$

0.13028	3.4943	-0.13028	3.4943
3.4943	124.9538	-3.4943	62.4769
-0.13028	-3.4943	0.13028	-3.4943
3.4943	62.4769	-3.4943	2.3295

Figure 3. Rigid matrix

When we applicated the equation (1.3) , we obtain the natural frequency of the system to solve the resulting equation of the determining:

$$(1.6) \quad \det H = -9527.3w^8 + (1.4362 \times 10^8)w^6 - (6.8124 \times 10^7)w^4 + (2.7191 \times 10^5)w^2 = 0$$

(1.3) So, the solutions was:

$$W_n = -122.777$$

$$W_n = -0.685802$$

$$W_n = -0.0634473$$

$$W_n = 0$$

$$W_n = 0.0634473$$

Now , we aplicate the equation (1.7), for obtain the period:

$$f = \frac{1}{T} \quad (1.7)$$

And we obtained the period for the cable number 9:

$$T = 148146 \text{ s}$$

With the equation (1.2), we obtain the tension that we will be applied to the cable :

$$1380.518836 \text{ KN}$$

After , you have calculated the frequency due to 2 vibration modes, the proportion of shock absorber was of 0.078 , that equal to a coefficient of 7.8 kg/s by node.

Now, we will go to calibrate the model , introducing the dynamics loads , due to action of the wind and the rain.

The rain , is represented by the speed design:

- Middle wind :130 km/h (National meteorological system)
- Bursts exceeding to 200 km/h (National meteorological system)

For determinate the force of drag of the wind middle , we use the equation (1.8)

$$F(y) = \frac{1}{2} \rho C_D A_e v^2(y) \quad (1.8)$$

$$F(y) = .5 \cdot (1.225 \text{ kg/m}^3) \cdot 1.12 \cdot (36.1111 \text{ m/s})^2 = 894.5519 \text{ N}$$



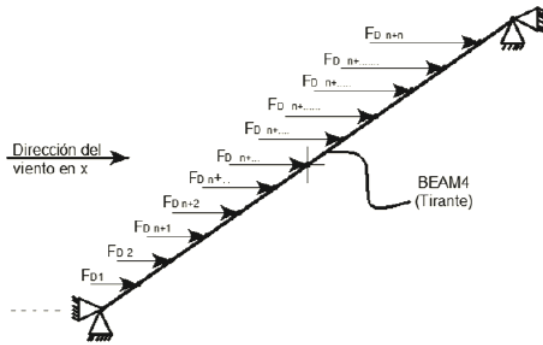


Figure 4. Force of the wind on the beam

In a lot studies we find that the maximal response occurs when the frequency of detachment of the vortices match with the firsts modes of vibration ; so in this bridge , the cables caused biggest displacement ; it's see in the spectrum of Vickery and Clark.

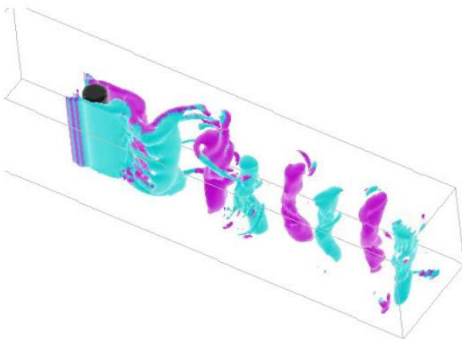
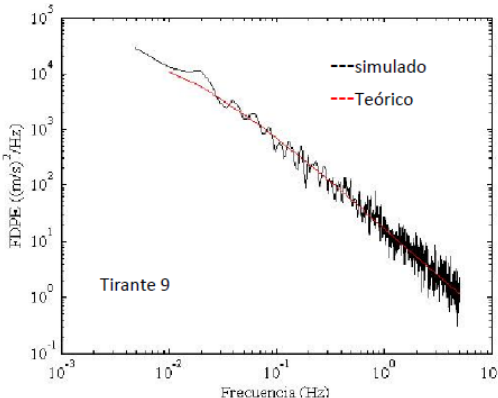


Figure 5. Detachment vortex in a cable

In this types of bridges, largest , is very probable that its mechanism of excitation parameters , is here , due to that the cables and the board have a lot small frequencies.

This can induce biggest oscillations to tension and dynamics tensions.



Graphic 1. Frequency of oscillation of cables over time (ANSYS)

This types of systems should consider various aspects as are the cable and the sink energy (Alvarado 2007), the location and the dynamics characteristics(Alvarado 2008), the types and amount of sensors , also a control strategy (Der Hagopian ,2010),(De Brunner ,2003), Chen(2000), and to finished the dynamic behavior of the cable(Carrion ,2008).

Position of the reducer energy

For the position of the reducer of energy , we make a lot simulations in ANSYS ,as tha that is presented below; we take a element type BEAM-4 , and to submint to loads , this have a behavior very similar to a cable.

We considered the free vibration and its three principals modes of vibration, and we concluded that more critical of the cables could be far of the nodes of the modes of vibration and near of the point of mayor amplitude of the same modes.

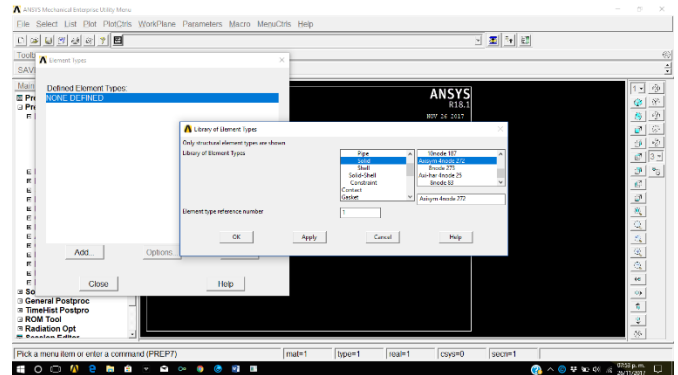


Figure 6. Election of library due to the parameters of study

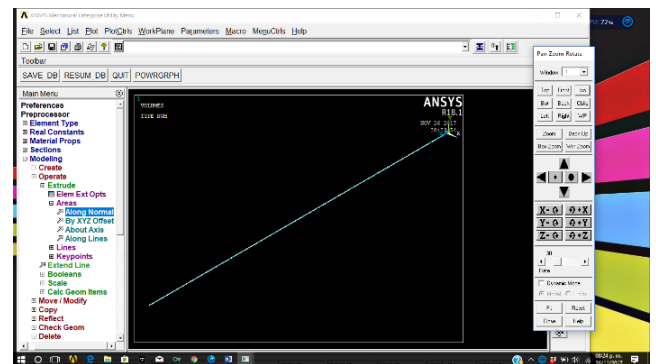


Figure 7. Shape initial of the structural cable

In this moment , we make the meshing

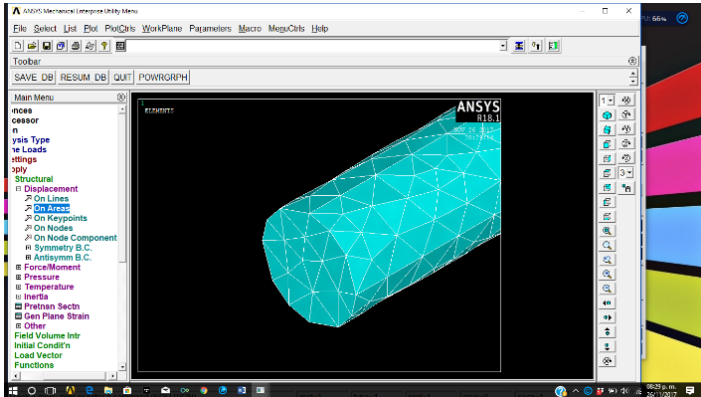


Figure 8. Meshing of the cable by discretization more specific in critical points

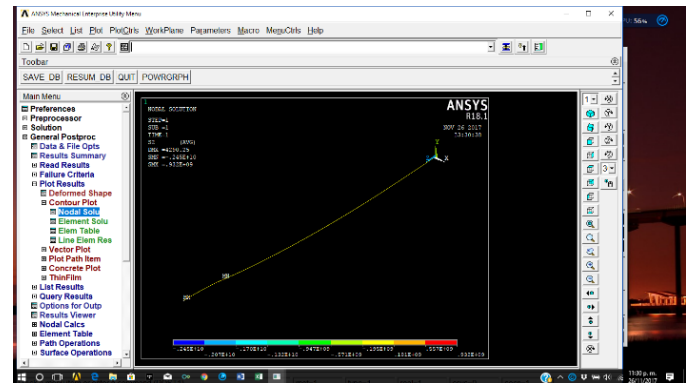


Figure 11. Representation of the second stress principal

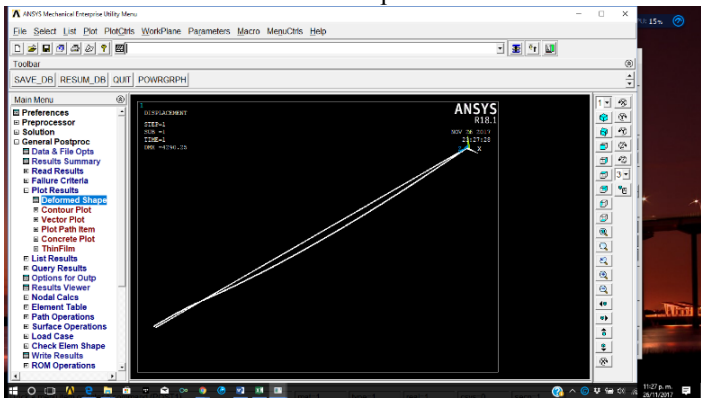


Figure 9. Deformation of the cable (simulation)

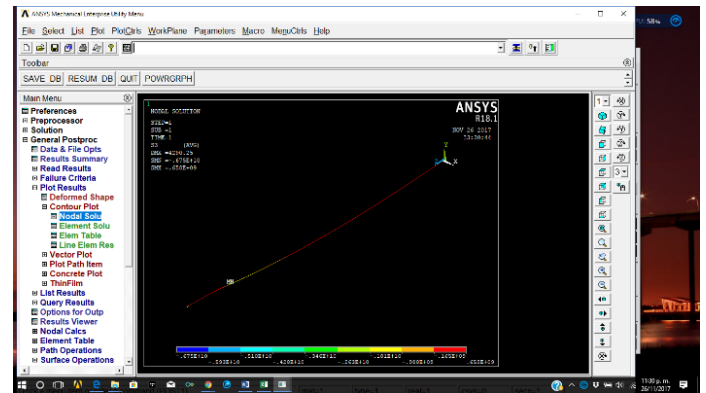


Figure 12. Representation of the third stress principal

RESULTS AND CONCLUSIONS

When the cable is exposed to loads, we obtained the principal stress

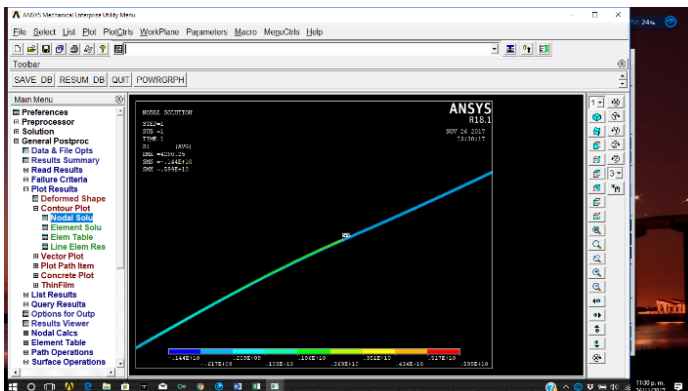


Figure 10. Representation of the first stress

Of the after simulations, we observed that the best position for the reducing of energy, its present 5 meters on the direction of the cable.

Due to the frequency of excitation, now are known, its possible prevent the resonances changes the natural frequency of the system and remove it.

For this type of vibration, and due to the structure, its could use viscoelastic materials, due to this provided values tallest of loss energy.



REFERENCES

- [1] Dominguez, A., Sedaghati, R. & Stiharu, I., 2004. Modelling the hysteresis phenomenon of magnetorheological dampers.. *Smart Materials and Structures*, 13(6), p. 1351.
- [3] Harik, R. W. & Blandford, G., 2004. Roebling Suspension Bridge. I: FiniteElement Model and Free Vibration Response. *Journal of Bridge Engineering*, 9(2), pp. 110-118.
- [4] Liu, M., Song, G. & Li, H., 2007. Non-model-based semi-active vibration suppression of stay cables using magneto-rheological fluid dampers., *Smart Materials and Structures*, 16(4), pp. 1447-1452.
- [5] McDougall, D., Green, M. & Shillinglaw, S., 2006. Fatigue Damage of Steel Bridges Due to Dynamic Vehicle Loads. *Journal Of Bridge Engineering*, 11(3), pp. 320-328.
- [6] Park, K., K. H., Ok, S. & Seo, C., 2005. Fuzzy supervisory control of earthquake-excited cable-stayed bridges. *Engineering Structures*, Issue 27, pp. 1086-1100.
- [7] <http://smn.cna.gob.mx/es/> (servicio meteorológico Nacional)
- [8] <https://www.dropbox.com/recents> [archivo PDF] (intensidad de vientos)
- [9] <https://es.scribd.com/doc/52197523/CFE-Sismo-08> (mapa sísmico de la zona proporcionado por CFE)
- [10] <file:///C:/Users/CentroDeComputo/Dropbox/DESARROLLO%20DE%20PROYECTOS/proyecto%20%20puente/25SI2012V0023.pdf>
- [11] http://www.imem.unavarra.es/EMyV/pdfdoc/vib/vib_control.pdf [archivo PDF](Estudio del amortiguamiento en los cables y los factores que lo afectan)
- [12] <http://durango.com.mx/autopista-durango-mazatlan/> (Datos generales de los costos de construcción de la autopista Durango--Mazatlán-Sinaloa)
- [13] https://www.researchgate.net/publication/313234940_Sistematizacion_bioclimatica_de_la_Sierra_Madre_Occidental_Mexico_y_su_relacion_c_los_pisos_de_vegetacion_Bioclimatic_systematization_of_Sierra_Madre_Occidental_Mexico_and_its_relationship_with_veg.com(Condiciones bioclimáticas de la Sierra Madre Occidental)
- [14] <http://www.inegi.org.mx/geo/contenidos/mapadigital/> (Mapa de relieve [México] detallado(INEGI))
- [15] <http://gaia.inegi.org.mx/mdm6/?v=bGF0OjIxLjg0Mjk0LGxvbjotMTA0Ljk3ODAwLHo6MixsOmMxMTFzZXJ2aWNpb3N8dGMxMTFzZXJ> (Mapa de localización precisa de México)(INEGI)
- [16] <http://smn.cna.gob.mx/es/climatologia/pronostico-climatico/precipitacion-form?view=visproncliprec> (Datos estadísticos de precipitaciones en México)(CONAGUA)
- [17] By Wenjie Wu (2006) "Theoretical and experimental study on cable vibration reduction with a TMD-MR damper" Louisiana State University and Agricultural and Mechanical College
- [18] M. Such, J.R. Jiménez-Octavio, A. Carnicero, C. Sanchez-Rebollo. Simulación de cargas móviles sobre estructuras mediante un mallado móvil de elementos
- [19] J.R. Ockendon, A.B. Tayler, The dynamics of a current collection system for an electric locomotive, *Proceedings of the Royal Society of London, Series A (Mathematical and Physical Sciences)* 322 (1551) (1971) 447–468.
- [20] Fag, I.-K., Chen, C.-R. & Chang, I.-S., 2004. Field Static Load Test on KaoPing-Hsi Cable-Stayed Bridge. *Journal of Bridge Engineering - ASCE*, 9(6), pp. 531-540.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Characterization of factors that impact academic performance in higher education.

Use of statistical tools in the systematic review of the literature.

Vergara-Ayala Edwin Geovanny
Huerta-Manzanilla Eric Leonardo

School of Engineering
Universidad Autónoma de Queretaro (UAQ)
Santiago de Queretaro, Queretaro
eg.vergara28@gmail.com

Abstract—Academic performance is a multifactorial phenomenon, that is difficult to model due to the large number of variables involved in the process. The present research is based on the review of eighty national and international scientific papers, including, articles and theses. The main objective was to obtain a group of representative and significant variables of the state of the art through the use of statistical tools. Following the proposed methodology, it was found that the most used dimensions to characterize the academic performance were the personal and academic profiles. Twenty-seven variables were identified, matching the characteristics established in the objective. Finally, an analysis of variance (ANOVA) was conducted in which it was determined that the number of variables that are included in an article depends significantly on the country in which it is carried out. United States and Mexico are the countries with the highest frequency of research about academic performance in our sample of scientific works.

Keywords—academic performance; systematic review; Pareto chart; analysis of variance; students

I. INTRODUCTION

Academic performance is a multifactorial phenomenon, several authors have studied it and they have highlighted the importance of socioeconomic variables, the breadth of the school program, teaching methodologies, personal characteristics, the student's family environment, financial support, the semester or grade, the health level or the fact of presenting a disease or disability [1]–[4]. Their main findings showed that marital status, gender, age, educational level of parents, work and socioeconomic statuses, as well as the health level were the most significant factors.

A. State of the art

In this systemic review, the state of the art was classified in five main research groups: Psychosocial factors, academic variables, factors associated with health, personal background, professional and family factors, socioeconomic and sociodemographic factors. Some studies included variables of multiple groups; however, they were classified in the groups of the study.

1) Psychosocial factors

A large number of studies have concluded that psychosocial factors play a very important and significant role for the academic success of university students. Krumrei, Newton, Kim & Wilcox in 2013 [5], used a sample of 579 students where the variables were: Self-perceived academic efficiency, organization and attention to study, stress and time management, involvement in school activities, emotional satisfaction with academics and communication with the class; while the response variable was the average grade based on the GPA (Grade Point Average). The authors performed a hierarchical linear regression in order to examine the effects of the variables on the prediction of GPA; finding that the self-perceived academic efficiency is the largest predictor with $\beta = 0.300$, followed by the organization and attention to study ($\beta = 0.220$).

Authors have also chosen to include in their research, variables associated with another descriptive dimension of the student. Such is the case of the work carried out by Reid in 2013 [6] in which the main goals of the study were racial identity, self-efficacy, institutional integration and academic achievement, but the authors decided to involve variables such as the maximum years of schooling of the parents, family income, grade or semester taken at the time of the survey. The analysis showed a weak, but positive and significant correlation between self-efficacy and academic integration ($r = 0.180$, $p = 0.010$).

Other types of studies have been conducted in the clinical areas, finding through correlational design and previously validated psychological tests, that emotional intelligence, psychological empowerment, recovery and spiritual well-being had a significant correlation with the students' academic success [7]. The correlations were significant at 0.050 and 0.010.

2) Academic factors

It has been said that the phenomenon of academic performance is multifactorial, but there is a group of variables that stands out among others and that is the learning styles; Maris, Noriega & Maris [8] studied this factor in 2013, they used a sample of 1501 students of the basic cycle of the School of Architecture, Design and Urbanism of the University of Buenos Aires. The authors conducted a spatial competence test and used





the Motivated Strategies for Learning Questionnaire as evaluation methods. Once the samples were collected, an ANOVA was used to verify significant relationships between academic performance and learning style and levels of spatial competence.

Cheewaparakobkit [9] is one of the recent authors who has combined engineering and computer science with the educational field in 2013. The author published a research using decision trees and data mining to determine the factors that bring variation to the teaching-learning process. The data was analyzed through neural networks and decision trees. Binary, nominal and numeric variables were studied that included attributes such as: Gender, marital status, age, continent, economic support, residence, occupation of parents and English proficiency. The factors that the author found to be significant in academic performance were: The number of hours worked per semester, additional English courses, number of credits taken during the semester and marital status of the student.

Another work reported on the behavior of students having an Internet connection and a computer in the classroom during 2014. The study consisted of 1129 Canadian students and it was found that students' behavior on their computer can be divided into two groups: School-related activities and leisure or non-related activities. Research shows that students with higher academic performance used laptops for academic activities within the classroom [10].

3) *Factors associated with health*

Deliens, Clarys, De Bourdeaudhuij & Deforche [11] conducted a study in 2013 to examine the sociodemographic and health differences among first-year Belgian university students who attended all the final exams of the subjects and the students who did not. However, their research also identified the correlations between academic performance, weight and healthy habits of students. The measurement instruments were elaborated from original questions of existing questionnaires. The researchers used t-test and multiple linear regression to identify the correlations of academic performance. The results obtained by the researchers show that gender did have a significant impact on academic performance, showing that women would achieve better academic outcomes or performance. On the other hand, gaining weight during the study period showed a negative correlation. Similarly, sedentary habits, poor diet and alcohol consumption had a negative effect on the prediction of academic performance.

In 2014, Daswani found that stress, health and school performance maintained a close relationship, concluding that both health and performance tended to be negatively affected when people were exposed to situations of prolonged stress [12].

4) *Personal, professional and family factors*

There are articles that analyze variables corresponding to the professional dimension or work situation of a person and their impact on the student's performance. An example of this is the research carried out by Carrillo y Ríos in 2013 [13]. They determined that two thirds of their sample made up of university students are negatively affected in their academic performance

due to their occupation; the authors highlighted an interesting point of study, since the reasons why the student worked contributed a degree of variation to the student's grades and performance.

Some authors focused on identifying the contribution of nationality and other factors to student performance in 2014. They found that 37% of the variation could be attributed to gender, age and nationality [14].

In 2014, Voyer and Voyer analyzed the impact of gender as a significant factor on the academic performance of the students, their study was remarkable, it consisted of a meta-analysis of the researches related to this factor [15]. The authors determined that there is a small but significant advantage of female students.

Age is a factor related to academic performance that has been the subject of study for many researchers at national and international level. Navarro, García-Rubio & Olivares in 2015 [16] found that age is significant for academic performance. The authors used an ANOVA to analyze the significance.

5) *Socioeconomic and sociodemographic factors*

A study that included 100 students, analyzed the socioeconomic status of the father, student's area of residence, accommodation trend and factors such as age, gender, school of study, daily study hours, etc. The results showed statistical significance due to the father's socioeconomic status, as well as the age and hours of study. It is important to emphasize that the model had an adjustment of $r^2 = 0.312$, which indicates that the model represents 31% of the total variation of the phenomenon, only [17].

A study was conducted at the Bahir Dar University in Ethiopia where 150 questionnaires were answered by the students (120 women and 30 men). The study was conducted by Gile & Atinaf in 2014 [18], focusing mainly on the female population; the results showed that there were three categories of factors that affecting academic performance: Variables related to the university, and socioeconomic and sociocultural variables. The research of these authors showed that the presence of nightclubs, bars, self-service stores and tourist centers around the university affected the academic achievement of the students. The same effect had factors such as the socioeconomic status of the parents, the limited employment opportunities and living outside of the university campus.

We also find articles that, although without a mathematical foundation, are rich in information. The importance of the relationship between socioeconomic status and student achievement has been stressed, saying that teachers should consider how to improve the academic performance of students who encounter difficulties in socio-economic areas [19].

B. *Objective*

Obtain a group of variables that represent the state of the art, based on the factors that have been most studied and, on the other hand, variables that have also been significant at a frequency of 70% in the review of the national and international literature covering the interval of 2011 to 2018.





C. Hypothesis

- H₁: Academic performance can be characterized more frequently by factors pertaining to personal dimensions and academic profiles, because these profiles are the most studied and significant in the systematic review of the literature.
- H₂: There is a significant difference in the number of variables that are used to describe the academic performance according to the year, method of analysis and/or region.

II. MATERIALS AND METHODS

In order to carry out the systematic review of the literature, it was necessary to have the following materials and services: Computer, internet service, access to academic search engines, Microsoft Office® package and RStudio software.

In the first place, a mapping of relevance was carried out, this technique was based on the summary that is made during a review of a specific topic or in its defect in the steps that are followed for the elaboration of a meta-analysis. Initially we proceeded to the selection of academic articles, theses, journals, etc. that had a relevance in the hypothesis and objective of this investigation. The total number of articles consulted was 80, both in English and Spanish and from 2011 to the present.

From each of the articles, the title, its author/s, the year of publication, the method used in the research, the sample size and finally its dependent and independent variable were extracted, concentrating the information in a matrix (Fig. 1) in which the variables included in the studies and with a statistical significance were indicated with a number "1", with a "0" factors included in the works but that did not have a significance; and finally, the independent variables that were not included in the research works were represented with an "NI".

Name of the article	Author	Year	Method	Sample (n)	Y	Independent variables		
						1	2	...
						0	NI	
						NI	1	
						0	NI	

List of articles

Source: Prepared by authors.

Fig. 1 Information matrix of the literature review.

Table I shows the coding of the methods used by researchers to achieve their main objective and to test their hypotheses. As can be seen, there are several statistical methods used to test hypotheses regarding academic performance. In addition, a list of 88 variables covering personal, professional, school, family,

sociodemographic, socioeconomic, cognitive and behavioral dimensions corresponding to the student was made from all 80 articles. The codification of these factors is shown to facilitate their identification in the relevance mapping through the data matrix (Table II and III).

TABLE I. CODIFICATION OF THE METHODS USED IN THE REVIEW OF THE STATE OF THE ART

Code	Method
1	χ^2 test
2	Correlations
3	Multivariable analysis
4	Hierarchical regression
5	Multiple regression analysis
6	Focus group
7	Linear regression and ANOVA
8	Correlations and ANOVA
9	Linear regression
10	Decision trees and neural networks
11	Meta-analysis
12	Conceptual analysis and/or surveys
13	Adjusted probability ratios
14	Student's t test
15	Multivariate analysis of covariance (MANCOVA)
16	Multivariate analysis of variance (MANOVA)
17	Moderation and/or effects analysis
18	Ordinary least squares (OLS)
19	Descriptive statistical analysis
20	ANOVA
21	Analysis of covariance (ANCOVA)
22	Unspecified method

Source: Prepared by authors.

TABLE II. CODIFICATION OF THE FACTORS REPORTED IN THE LITERATURE

Code	Factor
1	Self-academic efficiency
2	Organization and attention to study
3	Stress and time management
4	Involvement in school activities
5	Emotional satisfaction with academics
6	Communication with the class
7	Gender
8	Ethnicity
9	Grade or semester
10	Previous average
11	Family or personal income
12	Higher academic degree of parents
13	Having a specialization
14	Racial identity
15	Weight
16	Computer activities on weekends
17	Video games on weekends
18	Diet
19	Feeding habits
20	Frequency of alcohol intake
21	Average of previous academic level
22	Integration in your social environment
23	Academic environment
24	Attendance at conferences and early review of topics
25	Learning in small groups
26	Mental maps
27	Laboratory learning

Source: Prepared by authors.





TABLE III. CONTINUATION OF TABLE II – CODIFICATION OF THE FACTORS REPORTED IN THE LITERATURE

Code	Factor
28	Learn from mistakes
29	Time management
30	Family support
31	Internal motivation
32	Language barriers
33	Nostalgia and stress
34	Family size
35	Civil status
36	Place where the student lives
37	Family problems
38	Sharing vehicle
39	Responsibility for someone
40	Type of transport
41	Responsibility to transport someone else
42	Spending time in household chores
43	Hobbies
44	Watching television and listening to music
45	Time in social networks
46	Time dedicated to extracurricular activities
47	Smoking
48	Hours of sleep
49	Proficiency in the English language
50	Study habits
51	Time to study
52	Social activities during exams
53	Study material
54	Emotional intelligence
55	Empowerment
56	Resilience and/or procrastination
57	Spiritual balance
58	Age
59	Using of mobile devices in the classroom
60	Type of school
61	Support from friends
62	Teacher support
63	Admission Test
64	Nationality
65	Father's occupation
66	Scholarships
67	Working hours
68	Curricular load
69	Bachelor's degree
70	Behavior and characteristics of teachers
71	Learning styles
72	Socioeconomic level
73	Self esteem
74	Interaction with the teacher
75	Domain of content of the subject
76	Internet habits
77	Expectations
78	Previous bachelor's degree or previous school
79	Previous or current occupation
80	Published articles
81	State of mind
82	Occupation of the mother
83	Commitment
84	Multiple intelligences
85	Origin
86	School schedule
87	Teacher's experience
88	Assistance

Source: Prepared by authors.

Once the data matrix was completed, we proceeded to obtain 4 values for each of the variables: Number of articles where the variable was studied (Nst), number of articles where the variable was significant (Ns), percentage of study of the variable (Pst) (1), percentage of significance of the variable (Ps) (2).

$$Pst = \frac{(Nst)(100)}{80} \quad (1)$$

$$Ps = \frac{(Ns)(100)}{Nst} \quad (2)$$

Once the percentages were obtained, a table of accumulated frequencies was made with the purpose of constructing a Pareto diagram for the percentage of study of the variable and for the percentage of significance, in order to identify which factors were most frequent or also called vital factors [20].

When the vital factors for both percentages were obtained, they were grouped and a Venn diagram was elaborated. For this, it was decided to homogenize the size of the groups.

Finally, in order to be able to contrast the hypothesis number one, a table was created in which the groups of variables, the intercept of both groups, the name of the variable and the dimension to which the factor belonged were enlisted. Subsequently, a table of frequencies by dimensions was made to know which profiles were most studied.

To contrast the hypothesis number two, it was decided to carry out a multifactorial anova of three factors: year, method of analysis used and country of the investigation. The levels of each variable are described below.

- Year: 8 levels with the values 2011,2012,2013,2014,2015,2016,2017,2018.
- Method: 22 levels previously listed in Table I.
- Countries: 27 levels. United States, Belgium, Egypt, Saudi Arabia, Pakistan, Spain, Ethiopia, Australia, Thailand, Iran, Germany, Portugal, Argentina, Nigeria, Norway, Canada, United Kingdom, Singapore, Italy, Taiwan, Sweden, Mexico, Guatemala, Chile, Colombia, Honduras, Peru.

III. ANALYSIS AND RESULTS

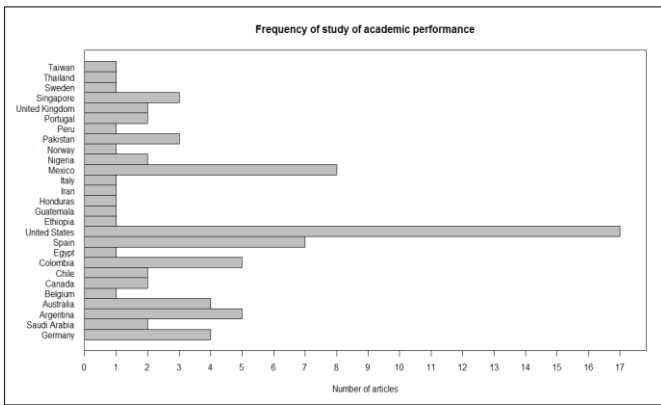
This systematic review was very diverse in results. In the first place, the tendency of the countries to study the phenomenon of academic performance could be analyzed. By making a bar graph it was possible to observe the frequency with which the countries analyze the phenomenon (Fig. 2).

It is not strange that the United States is one of the countries that has spent time and money studying the phenomenon of academic performance. Continuing with the analysis of the bar chart, it is surprising that Mexico occupies the second place on the list, however, with the current educational reforms it was necessary to carry out research on education. In third place is Spain, being one of the most copied educational models by Latin American countries. However, we can relate your position in the graph to the current priorities of the government. Where one of



the main concerns of the leaders is to rejuvenate the Spanish population.

Latin American countries have invested in education to an unprecedented degree, barriers have been broken between nations and knowledge has crossed borders with the premise of an educational and technological revolution. Latin countries such as Argentina and Colombia have decided to study the phenomenon of academic performance continuously and at higher education levels. This fact is seen in the frequency of studies in the review of the literature that make these countries occupy the fourth and fifth position.

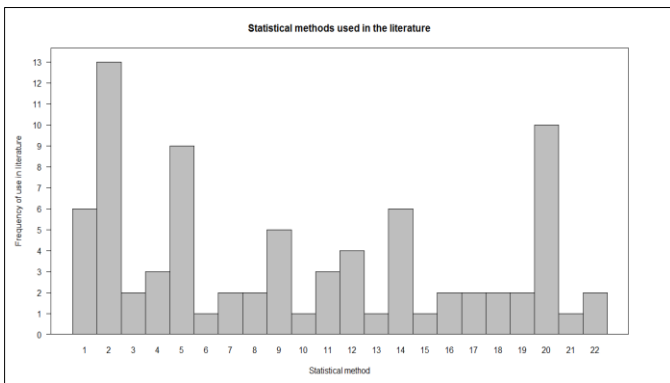


Source: Prepared by authors.

Fig. 2 Frequency of study of academic performance by country.

As it is mentioned in the materials and methods, there are several statistical methods used to contrast hypotheses regarding academic performance, however, in the sample of 80 academic articles, there is a greater tendency to use correlations, ANOVA, multiple regression analysis and the χ^2 test. While the least used methods were the focus groups, decision trees and neural networks, adjusted probability ratios, MANCOVA and ANCOVA (Fig. 3).

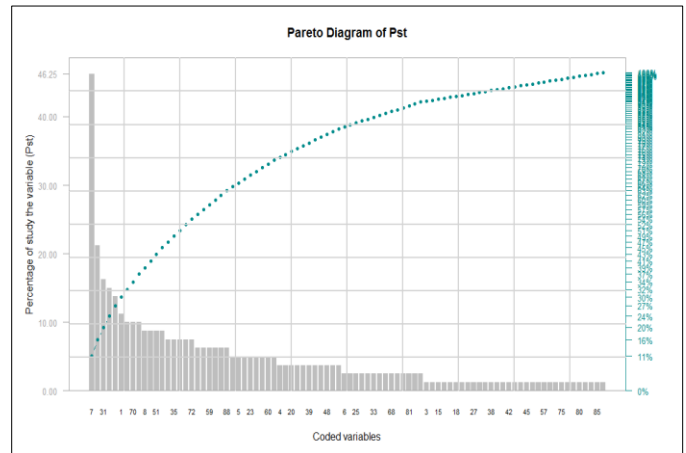
One of the reasons why multivariable methods may not be so common is due to the complexity of the phenomenon and, of course, the cost in time and money of studying multiple variables.



Source: Prepared by authors.

Fig. 3 Frequency of statistical methods used in the state of the art.

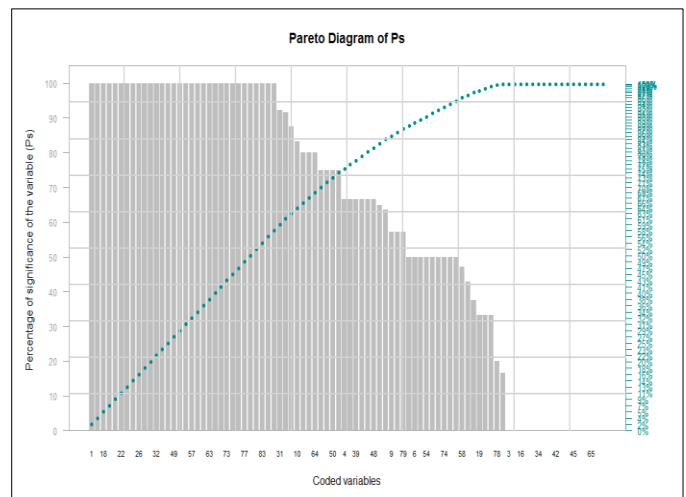
On the other hand, a Pareto diagram and its respective frequency table showed that the variables: 7, 58, 31, 67, 11, 1, 12, 70, 71, 8, 9, 51, 79, 10, 35, 36, 66, 72, 30, 53, 59, 64, 78, 88, 2, 5, 21, 23, 50, 54, 60, 69, 4, 19, 20, 34, 37, 39, 46 and 47 were the factors most frequently studied in the literature (Fig. 4), complying with the Pareto 80-20 rule [21]. Although the number of variables is large, a reduction of 54.54% of elements was achieved.



Source: Prepared by authors.

Fig. 4 Pareto diagram for the percentage of study of the variables in the state of the art.

With another Pareto diagram (Fig. 5), which was elaborated for the significance of the variables, it can be affirmed that the variables: 1, 14, 18, 20, 21, 22, 24, 25, 26, 27, 28, 32, 33, 41, 49, 53, 55, 57, 61, 62, 63, 68, 70, 73, 75, 76, 77, 80, 81, 83, 86, 88, 31, 67, 71, 10, 30, 59, 64, 5, 23, 50, 69, 4, 37, 39, 46 and 47 were the factors with greater significance according to the number of times in which they were studied in the sample of 80 articles. These factors were selected with the use of the Pareto 80-20 rule.



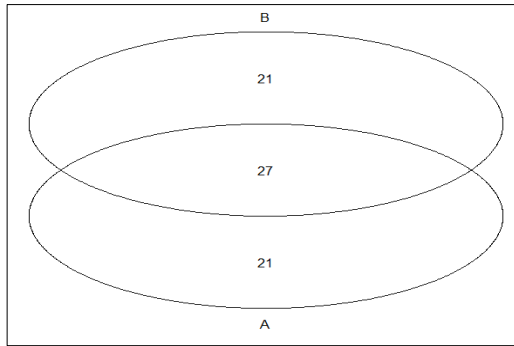
Source: Prepared by authors.

Fig. 5 Pareto diagram for the percentage of significance of the variables in the state of the art.



Once both groups of variables were identified, the intersection could be observed through a Venn diagram (Fig. 6) with the following characteristics:

- Group A: frequently studied variables (21 elements).
- Group B: frequently significant variables (21 elements).
- Intersection: frequently studied and significant variables (27 elements).



Source: Prepared by authors.

Fig. 6 Venn diagram of the variables in the state of the art.

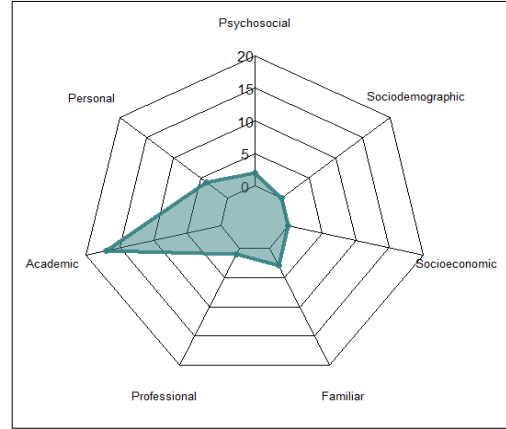
Table IV shows the variables corresponding to the intercept and which were our main evidence to detect which has been the most studied and significant dimension in the literature.

TABLE IV. RESULTING VARIABLES OF THE STATE OF THE ART

Group A	Group B	Group A	Group B	Intersection	Dimension
7	1	69	88	31	Psychosocial
58	14	4	31	67	Professional
31	18	19	67	1	Psychosocial
67	20	20	71	70	Academic
11	21	34	10	71	Academic
1	22	37	30	10	Academic
12	24	39	59	30	Familiar
70	25	46	64	53	Academic
71	26	47	5	59	Academic
8	27	48	23	64	Personal
9	28	49	50	88	Academic
51	32	62	69	5	Academic
79	33	6	4	21	Academic
10	41	13	37	23	Academic
35	49	25	39	50	Academic
36	53	26	46	69	Academic
66	55	32	47	4	Academic
72	57	23	80	20	Personal
30	61	50	81	37	Familiar
53	62	54	83	39	Familiar
59	63	60	86	46	Personal
64	68			47	Personal
78	70			49	Academic
88	73			62	Academic
2	75			25	Academic
5	76			26	Academic
21	77			32	Academic

Source: Prepared by authors.

The results confirm the hypothesis number one, reaffirming that the dimensions that are frequently used to characterize the academic performance are: academic profiles and personal profiles (Fig. 7).



Source: Prepared by authors.

Fig. 7 Spider graph of the dimensions that are used to describe the phenomenon of academic performance.

The effect of the year of the research (X_1), the method used (X_2) and the country (X_3) on the number of variables included in the articles was modeled in Rstudio in order to contrast the hypothesis number two through the proposal of a linear model and its analysis. The first proposed model followed a structure where the three factors and their interactions were considered. However, it was not the best model, because most of its elements were not significant (3).

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_1 X_2 + \beta_5 X_1 X_3 + \beta_6 X_2 X_3 + \beta_7 X_1 X_2 X_3 + \varepsilon \quad (3)$$

The model was reduced to its best optimization (4) and it was found that the number of variables included in the studies varied significantly according to the country in which they were carried out. The results show that the country had a significance less or equal than 0.010 (Fig. 8), the R-squared was 0.532, the Adjusted R-squared was 0.303 and the p-value of the model was 0.005.

$$Y = \beta_0 + \beta_3 X_3 + \varepsilon \quad (4)$$

```

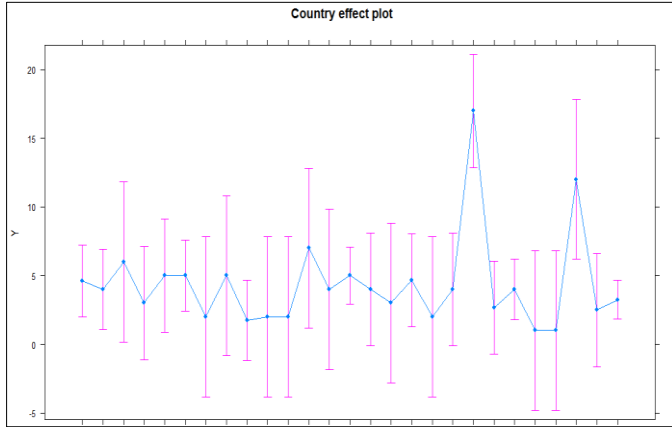
Df Sum Sq Mean Sq F value Pr(>F)
Country 26 508.7 19.566 2.321 0.00473 **
Residuals 53 446.8 8.431
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

Source: Prepared by authors, obtained from RStudio.

Fig. 8 ANOVA of the adjusted model to its best optimization.

Countries tend to differ in the number of variables that are included in the research conducted around the academic performance, however, there are regions of the world in which there are no significant differences, but there are also regions that have very marked differences (Fig. 9).



Source: Prepared by authors.

Fig. 9 Effects diagram of the number of variables that are included in the investigations according to the country.

IV. DISCUSSION AND CONCLUSIONS

The review of the state of the art is one of the main elements during an investigation. During this stage the researcher has to make an exhaustive review of the study phenomenon and usually find a large amount of information. In the educational phenomenon, academic performance is one of the most common variables and it is very easy for researchers to get lost in the literature and start wandering between each of the articles. Employing statistical methods during the systematic review let the researcher be able to delimit and specify the state of the art.

In the educational phenomenon there are a lot of factors that have shown an effect on academic performance. However, these variables cannot be generalized, because educational models must be seen as a suit tailored to each educational institution. This review allowed us to observe a complete picture of the phenomenon as well as the methods used for the analysis.

The use of statistics within the systematic review of the state of the art is a powerful tool that allowed us to reduce the number of variables that affect academic performance. Out of a total of 88 variables, our field of study ended with 27 variables that, at a national and intentional level, showed significance and frequency of study.

The ANOVA helped us to verify if there were significant differences in the number of variables studied according to three factors. This analysis also helped us to verify that a wide investigation of articles has been done, because the factor with the greatest significance was the country. This indicates that, indeed, the country affects the number of variables included in the studies but also tells us that we had a wide range of articles from different regions and not just a homogenization of a single region.

It is very common in educational research to see that researchers only limit themselves to the search and synthesis of background information, but we invite them to perform statistical analysis during the review of the state of the art to enrich their work. The analysis that is proposed to the researchers should not replace the statistical analysis of the

methodology, it should be understood only as a prior analysis of the context and historical information recorded in the literature.

ACKNOWLEDGMENT

This research was supported by UAQ's School of Engineering and The National Council of Science and Technology (CONACYT). We thank Marcela Gaytán Martínez, Phd. for assistance with the writing of scientific documents and research methodologies and also for her comments that greatly improved the manuscript.

REFERENCES

- [1] D. Fonseca, N. Martí, E. Redondo, I. Navarro, y A. Sánchez, "Relationship between student profile, tool use, participation, and academic performance with the use of Augmented Reality technology for visualized architecture models", *Comput. Human Behav.*, vol. 31, núm. Supplement C, pp. 434–445, 2014.
- [2] M. D. Hanus y J. Fox, "Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance", *Comput. Educ.*, vol. 80, núm. Supplement C, pp. 152–161, 2015.
- [3] V. Jiménez y R. M. Valle Gómez, "Factores de salud asociados al desempeño escolar: seguimiento de una generación del bachillerato en la UNAM", en *Tercera Conferencia Latinoamericana sobre el Abandono en la Educación Superior*, 2013, p. 12.
- [4] A. Wald, P. A. Muennig, K. A. O'Connell, y C. E. Garber, "Associations between Healthy Lifestyle Behaviors and Academic Performance in U.S. Undergraduates: A Secondary Analysis of the American College Health Association's National College Health Assessment II", *Am. J. Heal. Promot.*, vol. 28, núm. 5, pp. 298–305, 2014.
- [5] E. Krumrei, F. Newton, E. Kim, y D. Wilcox, "Psychosocial Factors Predicting First-Year College Student Success", *J. Coll. Stud. Dev.*, vol. 54, pp. 247–266, 2013.
- [6] K. W. Reid, "Understanding the Relationships among Racial Identity, Self-Efficacy, Institutional Integration and Academic Achievement of Black Males Attending Research Universities", *J. Negro Educ.*, vol. 82, núm. 1, pp. 75–93, 2013.
- [7] A. M. Beauvais, J. G. Stewart, S. DeNisco, y J. E. Beauvais, "Factors related to academic success among nursing students: A descriptive correlational research study", *Nurse Educ. Today*, vol. 34, núm. 6, pp. 918–923, feb. 2018.
- [8] S. Maris, M. Noriega, y S. Maris, "REDIE. Revista Electrónica de Investigación Educativa", *REDIE. Rev. Electrónica Investig. Educ.*, vol. 15, pp. 29–44, 2013.
- [9] P. Cheewaparakobkit, "Study of Factors Analysis Affecting Academic Achievement of Undergraduate Students in International Program", en *Proceedings of the International MultiConference of Engineers and Computer Scientists*, 2013, p. 5.
- [10] P. Gaudreau, D. Miranda, y A. Gareau, "Canadian university students in wireless classrooms: What do they do on their laptops and does it really matter?", *Comput. Educ.*, vol. 70, pp. 245–255, 2014.
- [11] T. Deliens, P. Clarys, I. De Bourdeaudhuij, y B. Deforche, "Weight, socio-demographics, and health behaviour related correlates of academic performance in first year university students", *Nutr. J.*, vol. 12, p. 162, dic. 2013.
- [12] P. Daswani, "Estrés, salud y rendimiento académico: el afrontamiento como factor modulador", Universidad de La Laguna, 2014.
- [13] S. Carrillo y J. Ríos, "Trabajo y rendimiento escolar de los estudiantes universitarios. El caso de la Universidad de Guadalajara, México", *Revista de la Educación Superior*, México, D.F., pp. 09–34, feb-2013.
- [14] S. Jayanthi, S. Balakrishnan, A. Lim Siok Ching, N. Aaqilah Abdul Latiff, y A. M. A. Nasirudeen, "Factors Contributing to Academic Performance of Students in a Tertiary Institution in Singapore", *Am. J. Educ. Res.*, vol. 2, pp. 752–758, 2014.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

- [15] D. Voyer y S. Voyer, “Gender Differences in Scholastic Achievement: A Meta-Analysis”, *Psychol. Bull.*, vol. 140, 2014.
- [16] J.-J. Navarro, J. García-Rubio, y P. R. Olivares, “The Relative Age Effect and Its Influence on Academic Performance”, *PLoS One*, vol. 10, núm. 10, pp. 1–18, 2015.
- [17] S. Ali, Z. Haider, F. Munir, H. Khan, y A. Ahmed, “Factors Contributing to the Students Academic Performance: A Case Study of Islamia University Sub-Campus”, *Am J Educ Res*, vol. 1, pp. 283–289, 2013.
- [18] P. Gile y W. Atinaf, “Factors affecting female students’ academic performance in Ethiopia:the case of Bahir Dar University”, *African Educ. Res. J.*, vol. 2, pp. 161–166, 2014.
- [19] G. Lam, “A Theoretical Framework of the Relation between Socioeconomic Status and Academic Achievement of Students”, *Education*, vol. 134, p. 6, 2014.
- [20] J. Arthur, *Lean Six Sigma for Hospitals: Improving Patient Safety, Patient Flow and the Bottom Line, Second Edition*. McGraw-Hill Education, 2016.
- [21] R. W. A. Aziz, A. Shuib, W. N. H. W. A. Aziz, N. M. Tawil, y A. H. M. Nawawi, “Pareto Analysis on Budget Allocation for Different Categories of Faculties in Higher Education Institution”, *Procedia - Soc. Behav. Sci.*, vol. 90, pp. 686–694, 2013.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Rainwater catchment system for residential house in Querétaro

Arredondo de Anda, C., Guerrero Jaime, E., Montes Márquez, A

Facultad de Ingeniería civil
Universidad Autónoma de Querétaro
Querétaro, Querétaro

carhum210797@gmail.com; lunnox19@gmail.com;
amontes20@alumnos.uaq.mx.

Ríos Moreno G.J.

Departamento de ingeniería
Universidad Autónoma de Querétaro
Querétaro, Querétaro
riosg@uaq.mx

Imagine one football stadium which capacity is nearly 51,000 people. Well, if the time advance 6 hours, there will be enough births in the world to get another stadium from the same capacity full. Overpopulation it is not a big problem for now, because the world population is growing slowly, the real problem with it is overconsumism. Nowadays, in the world there are many people that consumes a lot of natural resources, so, we are caring about one of the most important resources for life, the one that could finish its existence in the world, even though we are surrounded by it, the water. It is incredible that we have drought problems and lack of water at the same time. The objective of this investigation is the design of a rainwater catchment system (SCALL) based on water catchment in roofs of residential houses for its use principally in bathrooms. This bears to an economic saving as well as option sustainable in the residential house. With a 570 mm / year precipitation, the system of reception of rainwater (SCALL) residential guy is designed for a house with an area of reception of 129.22 m² with a slope of 2 % as a rule and waterproofed, consists in one the 1100 L water tank was placed in the backyard of the home, it consists of two BAP (rainwater down), 100mm (4"), with a strainer to stop large solids, the water will travel through a tube of 100mm (4"), directly to a 4-stage filter with UV light, discharging into the collection tank, then it will come out by means of a 5hp pump, having two outputs with valves, one for garden irrigation / free outlet and another connection to sanitary furniture (wc). With the use of the rainwater catchment system (SCALL) it goes over to a saving of approximately 10 % of the entire consumption of the house, this means an economic saving and an option sustainable.

Keywords—Water catchment, green engineering, Queretaro (key words)

I. INTRODUCTION

Imagine that you are in a football stadium, specifically BBVA stadium in Monterrey where the capacity of assistants ascend to 51 thousand people. The stadium is watching a

match and it is at its full capacity. In 6 hours, the world population will grow the same number of assistants in BBVA stadium, and, past 6 hours more, we will have another BBVA stadium to fill.¹

Actually there is a stage in time in which overpopulation starts to be a problem because we are running out of natural resources. Developed countries have a tendency that consist on have 2 or 3 children on average. But, in the other hand, the life expectancy is growing because of medical advancements. These two situations maintain a balance in the population of this kind of countries and that is why world haven't reached an even higher number of earth habitants.

In another place in the world there are developing countries, in which the birth rate is bigger than in developed countries, but the death rate is big also, so in these countries we have another that help us to maintain a low growing rate of the population.

But that doesn't free the world about this problem, in 2050, some investigators foresee that will be 9 billion people if this grow rate keep being the same or even worse, if this rate grows, we could be almost 11 billion people in the earth [1].

It is usually known that water is used in a lot of house chores as well as for health and hygiene. So, in this investigation the objective is to seek for solutions to save this valuable resource one of this solution for domestic environment are SCALL.

The first sight of water catchment that scientifics have data, is from the fifth millennium when some sedentary villages started to appear, they diverted rivers to deal with drought and in that way, they could have its plantations in arid or semiarid regions. Later, in México, specifically Yucatán, Mayas and Toltecas took advantages of the cenotes to catch and storage water. Then Anaya in 1990 and Herrera in 2010 discovered underground storage called Chultunes used in a lot of prehispanic villages. [2] Nowadays in the world SCALL, as is used to name to pluvial watercatchment systems, took a very important force because some countries are are having problems with water suministration [2]. In Australia 13% of houses already use a SCALL to obtain water for cook or drink, in Tokio is a "plan B" if in the future there is a problem with





water, in Germany they build 50 thousand SCALL every year using buildings or pedestrian paths and in Mexico IMTA have developed SCALLs for the north region in Morelos [2].

Nowadays there are a couple of options to save water in homes of the world. Another alternative that is already studied is the reuse of greywater. Grey water is the waste of washing machines, shower, bath and dishwasher. In other words, water that does not have faecal matter. Some studies revealed that if you reuse greywater, you will save 2400 L/month using 4 taps, a washing machine, a toilet and the shower. [3]

In some countries, there are rainwater tank that are for entire towns and they impulse in a certain way the economy of the town because these tanks represent savings of water for the entire community. There are tanks that are for one house too, for example, in Australia 26% of households save water using a rainwater tank and this SCALL have 100m² [4]

This investigation took this problem because some investigators studied the lack of water and the found that its main reason of this problem, is that there is a big demand of water in urban areas. And in this article, we will analyze the option of porpoise one SCALL for Queretaro in which we have about 555 mm³ of rainwater. This is a big opportunity in the whole world because it represents the main source of fresh water. [5]

Many states of México obtain its water principally from springs. Those projects started with an expectancy of less people than the actual population. [6] That's a problem, because in a near future the world will have troubles due the lack of water. So, are looking to offer another option to save water and reduce the overconsumption in the planet, show its advantages and show that the water is one of the "Precious resources" in the earth.

It is incredible some issues in Mexico [7]:

- The most of the north states have a high index of urbanization, so, they have a higher demand of water. But, in these states, there are the lowest rainfall average in Mexico
- In the other corner of Mexico, in the south, there are the higher rainfall average, the highest marginalization rate in Mexico and a lot of rural zones.

It seems that are two different countries, but, those situations happen in one country, our country. It is so important take this problem very serious, because it is quite important that in some states there are flood problems and other states have a lack of water.

The objective is to design one SCALL that could be installed in roofs of houses already built taking on count that water cannot be stored more than 24 hours pluvial water and focusing on WC and some other domestic tasks.

II. TEORICAL CONSIDERATION

The demand or endowment for person is the water quantity that a person needs every day to expire with the physical and

biological functions of its body. This water need can change of 25 liters per day for person, like minimum, up to 80 l / day.

The World Health Organization (WHO) thinks that the suitable water quantity for human consumption (to drink, to cook, personal hygiene, cleanliness of the hearth) is 50 l/hab-day.

For calculation effects, the quantity assigned by person will depend on the quantity of available water (fallen rainwater and aptitude of reception and storage) and on the quota to which he could adapt himself.

A high percentage of the water that is used in the Metropolitan area of the City of Querétaro comes from the aquifer of the Valle of Querétaro. East finds south-west of the State located in the part, comprising the municipalities of Corregidora, El Marqués and Querétaro. [8]

In the last years the City of Querétaro has developed problems to satisfy its needs, needs sufficient water to cover the demands of the agriculture, industry and domestic use For the city, the problems concerning the handling of the water are related to the increasing increase of the demand, caused principally by the population growth and the economic development of the recent years.

The State of Querétaro splits into three areas in accordance with its climate. The average temperature is of 18°C and the annual average precipitations reach approximately 570 mm. The central region is characterized by the type of dry or semidry climate, including approximately 50 % of the territory, with an average of maximum temperatures of 35°C (in summer) and minimal temperatures of 0°C (in winter), the rains station is contemplated in May to October that 500 mm per year do not exceed. The humid and subhumid warm climate is typical in the regions of the Sierra Madre and Sierra Gorda, with maximum temperatures of 40°C (in summer) and minims of 15°C (in winter), the rains station they are intense between spring and summer with 1500 mm per year. In the high regions of the Sierra Gorda in the state, the climate is moderated humid and subhumid, with maximum temperatures of 25°C and minims below 0°C.

The project focuses in the capital of the state of Querétaro, located in the central region, Santiago de Querétaro presents a semidry climate, annual average temperature of 18°C and with approximately 150 mm of annual precipitation. The station of rains of the capital passes between May and October, which a little more than 75 % accumulates whole of the rains in the city, generally there are rains that take place to the evening, July is the rainiest with 130 mm. [9]

In average, the familiar nucleus Queretano is shaped by 6 members that it depends principally on the area.

The following relation is applied to estimate the consumption of the family:

$$V_{th\ nec} = (n)(c)(p)$$

(1)[10]

V_{th nec}: Necessary water volume

n: Number of persons living in the house



c : Average water consumption for person per day (Liters)
 p : Period of considered consumption (days)

The priorities for the domestic use the family establishes them, considering first of all the feeding; then, the personal hygiene, the cleanliness of the goods, useful and personal objects and of the hearth, etc. The supply must be continuous and the rational and efficient use.

A. Elements of a system of reception of Rain waters [11]

- **Compilation module.** In the compilation module The roof of the house must be adapted to optimize the compilation, a smooth and free obstacles surface is going to allow us a good compilation. One think to have in mind is try to maintain the roof or the covering more possible bootblack to prevent the water from being contaminated and from wrapping up the system of conduction of the water.
- **Conduction module.** The system or network of conduction is in charge of transporting all the water gathered to the receptacles of storage. In these cases channels or canaletas of sewer pipe there are the method simplest to transport the water, the slope of these channels of sewer pipe in general recommends to itself to be of between 2 and 5 %.
- **Filtration system.** This system is important because that will allow to have a cleaner water.
- **Storage.** The tanks and cisterns are the form simplest to store the water, we must protect them from the direct solar light and they must be properly closed.
- **Distribution system.** The distribution systems take the water stored from the storage up to where its use is needed, for it a bomb can be used or it can be also for gravity.

III. METODOLOGY

To do this project, this investigation focused to Queretaro, where we live, because Queretaro it is in the center of Mexico, so it has an average rainfall in Mexico. Also, Queretaro have a moderate weather, nor too much hot neither too cold.

Also, Querétaro had been selected because it is obtaining its water of underground springs, for 2015 the population expected were around 1,600,000 people and we were in 2015 2,038,372 habitants. Overpopulation in Queretaro is appearing as a problem because it forces us to concentrate water in one place and do not deliver this valuable resource in other parts. With this idea, we are looking to get water for every zone of Queretaro to make activities that doesn't need potable water.

In this investigation started proposing a residential house as the target house with area of 129.22 m². The study will reveal if that area is enough to make this system able to save a good quantity of water.

After that, due the research in a page, we expect that in summer we will have better results because we will catch around 350 liters.

IV. RESULTS

A pluvial water collection system was designed for a residential house in the state of Querétaro, the catchment area is 129.2216 m² and a catchment perimeter of 72.5678 m

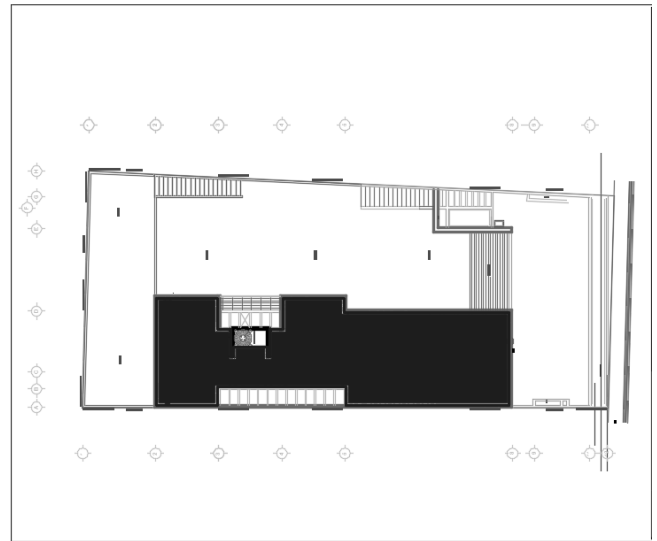


Figure 1. Up view from the model of house planned. The dark side represents the area where we test the catchment area.

Taking into account that the precipitation of water in Querétaro (state) is 570 mm / year, and taking into account our catchment area, a design was obtained, with the help of a web page called "Fundación cántaro azul", the data of catchment.

Número de usuarios	Consumo esperado (L/p/d)
7	20
Área (m ²) de captación	Tipo de almacenamiento
129.22	Plástico Rotomoldeado
Calidad requerida	Entorno
Para riego, limpieza y WC	Urbano
Vol. del almacenamiento (L)	Datos de precipitación
1100	Históricos (SMN 1961-2000)

Figure 2. Expected consumption estimated.

The use of potable water in the state is 200 l / p / d, then with the collection system is expected to have a consumption



of 20 l / p / d, having a water tank of 1100 liters for catchment, in a year would be 32,027.00 l / year.

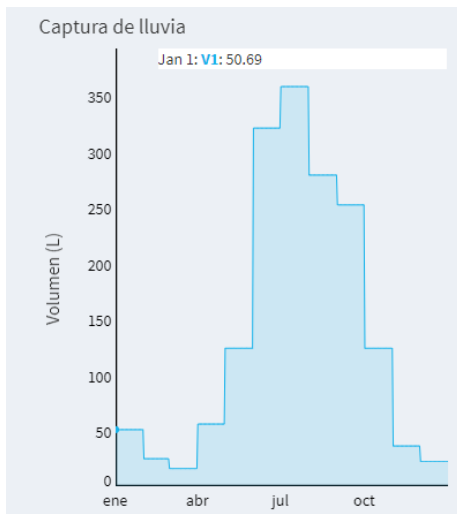


Figure 3. According to “cantaro azul” this graph represents the months vs.liters per month.

This system of water collection will allow to use all the water collected in w.c, for irrigation and cleaning. Having all this we designed a collection system very easy to install and simple, since it was also taken into account that it is economical.

This system starts from the roof slab, waterproofing the entire catchment area, as a rule a 2% slope was applied, without part of the water; since the 1100 L water tank was placed in the backyard of the home, it consists of two BAP (rainwater down), 100mm (4 "), with a strainer to stop large solids, the water will travel through a tube of 100mm (4 "), directly to a 4-stage filter with UV light, discharging into the collection tank, then it will come out by means of a 5hp pump, having two outputs with valves, one for garden irrigation / free outlet and another connection to sanitary furniture (wc).

In case the rain was very intense or the BAP (rainwater fall) were covered, the roof will begin to fill, has two BAP (rainwater fall) for the front of the house, with grid and tube of 100mm (4 "), having fallen by gravity to two pluvial records of 40x60cm of concrete, having discharge to the street, all this to avoid damages in the roof slab or leaks.

V. CONCLUSION

Considering the catchment air of 129.2216 m², a cistern of 1100 l, we can gather 32027 l / year and the expenditure per drinking water consumption standard is 200 l / p / d, in a year it represents 73000 l / p / d . Thanks to this proposed system we can save up to 8.77% of drinking water in one year per house, this system can save a small amount of water in a year,

but it is a considerable amount, taking into account the problems with drinking water.

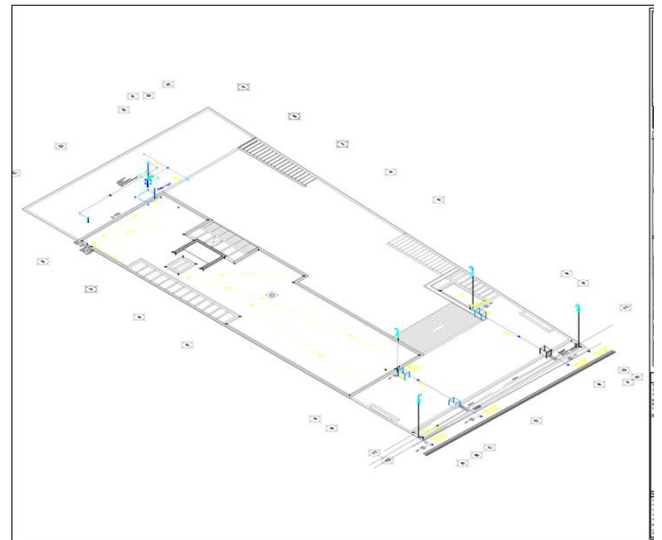


Figure 4. Hydraulic plane of the system proposed.

- [1] Alison, G.. (2009, Septiembre 23). 7 billion and counting.... New Scientist, 203, 34-35. 2018, Marzo 8, De Science direct Base de datos.
- [2] Frost, A. (2011, Mayo). Antecedentes de la captación de agua de lluvia . 2018, Marzo 7, de Universidad Nacional Autónoma de México Sitio web: http://www.agua.unam.mx/assets/pdfs/eventos/aguadelluvia11/1_alberto_frost.pdf
- [3] Wanjiru, E. & Xia, X.. (2017, July 3). Sustainable energy-water management for residential houses with optimal integrated grey and rain water recycling. Journal of cleaner production, 170, 1151-1166. 2018, Marzo 8, De Elsevier Base de datos.
- [4] Thulo, G. & Sharma, A. . (2013, Julio 25). Communal rainwater tanks system design and economies of scale. Journal of cleaner solution, 67, 27 - 36. 2018, Marzo 15, De Elsevier Base de datos.
- [5] Umapathi, S., Chong, M. & Sharma, A.. (2012, Junio 14). Evaluation of plumbed rainwater tanks in households for sustainable water resource management: a real-tima monitoring study. Journal of cleaner production, 42, 205-214. 2018, Marzo 15, De Elsevier Base de datos.
- [6] Ventura, E; Acosta, J; Domínguez, M; Ward, K. ((Desconocido)). *Captación de agua de lluvia*. Marzo 15, 2018, de Fondo de la iniciativa para las américas Sitio web: <http://www.fiaes.org.sv/library/Captaciondeaguadelluvia.pdf>
- [7] Diario oficial de la federación. (2004). Programa nacional hídrico. Marzo 1, 2018, de Secretaría de gobernación Sitio web: http://www.dof.gob.mx/nota_detalle_popup.php?codigo=5339732.
- [8] Manuel M. Urquiza Estada. (2008). Uso sostenible del agua en la ciudad de Querétaro. 2018, de EXPO ZARAGOZA Sitio web: <https://www.zaragoza.es/contenidos/medioambiente/cajaAzul/27S6-P5-Manuel%20UrquizaACC.pdf>
- [9] Climatología, INEGI, (s.f.) Sitio web: <http://www.inegi.org.mx/geo/contenidos/recnat/clima/default.aspx>
- [10] Brito et al. (2007a)
- [11] Jochen Scheerer. (15 de junio de 2011). Aprovechamiento de aguas pluviales: Documento Guía. 2018, de Xarxa Sitio web: http://xarxaenxarxa.diba.cat/sites/xarxaenxarxa.diba.cat/files/ponencia_t_pluviales_diba.pdf



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

- [12] Duran, P.. (2010). Captación de agua de lluvia, alternativa sustentable. CONAMA 10, 1-16.
- [13] Ricardo Radulovich, Roduel Rodríguez A., Orlando moncada G.. (1994). Captación de agua de lluvia en el hogar rural. Turrialba, Costar rica: CATIE.
- [14] Eusebio Jr. Ventura Ramos ; Jorge A. Acosta Gallegos , Miguel A. Domínguez C. y Keith Ward. (Desconocido). CAPTACION DE AGUA DE LLUVIA. 08/05/17, de fiaes Sitio web: <http://www.fiaes.org.sv/library/Captaciondeaguadelluvia.pdf>
- [15] Ilán Adler Gabriela Carmona José Antonio Bojalil . (2008). MANUAL DE CAPTACIÓN DE AGUAS DE LLUVIA PARA CENTROS URBANOS . 08/05/17, de PNUMA Sitio web: https://sistemamid.com/panel/uploads/biblioteca/2014-07-09_06-51-41106740.pdf
- [16] Palacio, N.. (2010). propuesta de un sistema de aprovechamiento de agua lluvia, como alternativa para el ahorro de agua potable, en la institución educativa maría auxiliadora de caldas, antioquia. 08/05/17, de Sistema de Bibliotecas Sitio web: <http://bibliotecadigital.udea.edu.co/bitstream/10495/1325/1/PropuestaSistemaAprovechamientoAguaLluvia.pdf>





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

PROJECT PROPOSAL FOR THE RESIDENTIAL SECTOR USING THE PRESENTED PRINCIPLES IN THE LEED CERTIFICATION SYSTEM.

*Alan E. Alvarado-Soto¹, Abraham R. Nava-Ledesma¹, Luis F. S. Díaz-Escobedo¹,
O. Chavez-Alegría², G.J. Ríos-Moreno²*

¹ CIVIL ENGINEERING DEPARTMENT, Universidad Autónoma de Querétaro, Querétaro, QRO, México.
alan.edgardo.alvarado@hotmail.com; abrahamnala@hotmail.com; felipediaz223@gmail.com.

² SCHOOL OF ENGINEERING, Universidad Autónoma de Querétaro, Querétaro, QRO, México. omarchavez@ yahoo.com.mx;
riosg@uaq.mx.

ABSTRACT

One of the greatest developing sectors in the construction is the residential sector, the more population, the more construction and energy they need. The use of energy produces contamination because of the use of based oil combustible and increases the issue. Many countries have adopted the Energy and Environmental Design (LEED) certification system as a base for sustainable building, this implies that is necessary to develop to obtain this certification and thus create sustainable constructions for different parts of the world. Most of the projects that are carried out are not regulated to be considered sustainable. The objective of this paper is to create a focused in the energy uses and environmental impact project proposal aiming to improve the quality life of people in residential sector, comparing this project proposal with system's qualification points that LEED certification handles. the study is carry on taking on count the following points Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), Interiors Environmental Quality (IEQ), Innovation in Design (ID). Certification system as a base for sustainable building implies that is necessary to develop new ideas in order to obtain this certification in a best possible way and thus create sustainable constructions for different parts of the world. Most of the projects that are developed are not regulated to be considered sustainable.

Keywords—Sustainable construction; residential sector; LEED certification system; environmental impact; energy efficiently.

1. INTRODUCTION

The use of energy produces contamination because of the use of based oil combustible and increases the issue

[1]. According to the World Health Organization (WHO) air quality model confirms that 92% of the world's population lives in places where air quality levels exceed the established limits [2]. Air pollution represents the biggest environmental risk to health. In 2012, one out of every nine deaths was the result of air pollution-related conditions. Of those deaths, around 3 million are attributable solely to ambient (outdoor) air pollution [2]. Air pollution levels in cities is cited as an indicator for urban sustainable development; access to clean energy – particularly clean household fuels and technologies – is highlighted as an indicator for sustainable energy. Current, world population has increased, as a result the number of residential buildings has been increasing. China, India and USA lead the most populous countries ranking respectively [3].

The building sector is the largest energy-consuming sector, accounting for over one-third of the final energy consumption in the world [4], and the societal and economic impacts of a short-term approach to the problem could result in inflated problems for future generations [5]. In a study realized in Italy, it has been estimated that construction sector is responsible of almost 36% of greenhouses gas production; the objective of this study was the refurbishment of existing buildings stock, especially in the residential sector that in this country corresponds to 88% of total buildings [6]. That is why the emergence of green building rating systems was crucial, as they inform people how environmentally a building is through their certification [7]. Leadership in Energy and Environmental Design (LEED), which has played an important role in spreading the green building certificate system approach worldwide, aims to reduce negative environmental effects of buildings and ensure energy efficiency [8]. One example of sustainable constructions are the green vegetation systems, such as





green walls and green roofs, are developed to make the buildings more sustainable [9].

The sustainable construction market is experiencing exponential growth and in 2013 it was valued at 260 billion dollars. Consequently, it also increases the demand for green building materials and it is believed that this market will reach 234 billion dollars in 2019. According to the second annual world ranking of the countries with the highest number of projects approved with LEED certification, obtained that after the United States (53908 projects), there are Canada (4814 projects), China (2022 projects) and India (1883 projects) in the first places [10]. Information that is useful to know the interest that several countries have for continuing to develop construction projects that are friendly to the environment.

Certified projects demonstrate leadership, innovation and social responsibility. Also, LEED certification brings with it tangible benefits, such as:

- Better spaces, conditions for the health and productivity of its occupants.
- Reductions of greenhouse gas emissions.
- Access to tax incentives.
- Lower operating costs.
- Increase in the value of your assets.
- Decrease of waste.
- Conservation of energy and water.

According to a residential real estate commercial study conducted in the city of Querétaro by Grupo Acerta in 2013, it was recorded that on average the houses built have 3 bedrooms, 2 to 3.5 bathrooms and 2 to 3.5 parking spaces and have an approximate of 134.60 m² to 284.35 m² of constructed area [11]. Taking into account the aforementioned, we can have a better dimensioning of the construction sector which will be our objective in the realization of this project.

II. BACKGROUND INFORMATION

The trend in saving resources is driven by the need that collected data shows [1], it is of great importance the current situation of development and population growth. With the purpose of analyzing and measuring the impact that a house has, different points based on the LEED certification have been classified and categorized.

The first parameter to be measured is location and transport (LT), which seeks to reduce the environmental impact and protect areas designated for social development purposes. The agency in charge changes according to the region in which it is located, due to variations of the environment in terms of climatic conditions and for political and social factors [12]. In the United States, the agency in charge of establishing areas that are not suitable for construction is the Federal Emergency Management Agency (FEMA), which is in charge of encouraging the population to carry out development plans focusing on natural disasters, in another approach FEMA coordinates for national security coming from emergencies and disasters, both natural and caused by man [13]. In Mexico, the agency that deals with natural resources, their protection and use is Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) which is also responsible for establishing the national environmental policy for sustainable development, also establishing the national program for urban development and the general law of ecological balance and protection of the environment. In addition, it is responsible for establishing the national environmental policy for sustainable development, it also establishes the national urban development program and the general law of ecological balance and protection of the environment [14].

Sustainable sites (SS), which is related to the last subject LT, aims to reduce pollution caused by construction activities controlling soil erosion, sedimentation of channels and dust in the air. It takes in account the impact that the construction of the project has on the local community and the environment. The use of resources near the location where the project is to be developed greatly reduces the pollutants generated by the transport that is required, in the same way, having the proper machinery and in good condition makes the emission of gases contaminants coming from said machinery is reduced and can be used in an optimal time. Well planned work allows the project to be carried out quickly and efficiently, reducing costs and damaging to the environment. The LEED validation methodology indicates that an erosion and sedimentation control plan should be developed, graphic or written with detailing specifications, if the process produce the best erosion control and sedimentation management practices the bases for the project are close to be done [15].





The third parameter focuses on water efficiency (WE), at this point the optimal use of water is verified, in addition to integrating technologies for an alternative supply and a decrease in demand for it [16]. In Querétaro in the year of 2012, it was determined that the monthly consumption per household which has an amount of 3 to 5 people goes from 13500 to 22500 liters [17].

Wanjiru proposes a system of water collection and reuse of it (Fig. 1) for the different processes of a house, this consists of using 3 water tanks, the first one (Potable water) is connected to the drinking water network, the second (Holding tank) is connected to the rainwater collection system and the third (Gray water tank) separates the gray water from the black water and is connected to a pump that sends the gray water to the third tank for its reuse and the waters black directly to the drain. It was concluded that the proposed system reduces drinking water consumption by 23.5% [18].

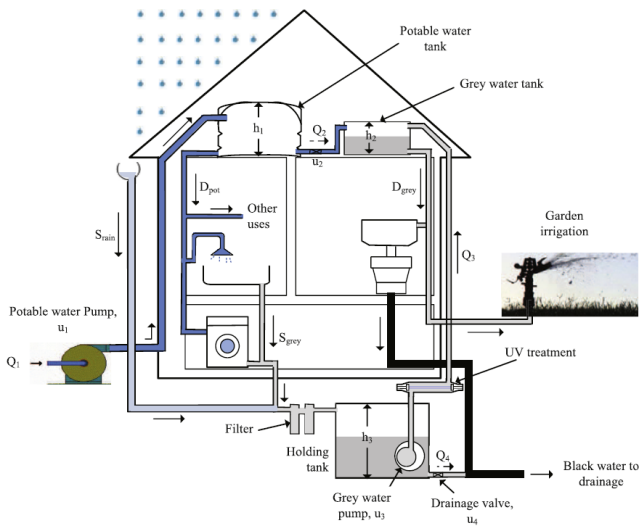


Fig 1. Water collection and reuse system [18].

The Energy and Atmosphere (EA) section refers to an improvement in the fields of demand, efficiency and energy performance in the next construction projects. Buildings and the construction industry consume 39% of the energy produced each year. Therefore, the energy and atmosphere category regulates a wide variety of strategies for reducing energy consumption and increasing the efficiency of buildings: Optimization of energy performance, use of Renewable energies, efficient installations [19]. According to studies conducted in Mexico in the year of 2008, the monthly

consumption per house, which has an amount of 3 to 5 people ranges, is between 1024.801 to 751.241 megajoules [20].

The energy consumption record is managed by different commissions in each country. In the year of 2016 in Mexico, Secretaría de Energía (SENER) conducted an analysis of energy consumption by sector, resulting in industrial consumption with 1680 petajoules, the residential with 756 petajoules, the commercial with 171 petajoules, the public with 31 petajoules and the transport with 2484 petajoules (the percentages are presented in figure 2) [21]. It is important to know this information about the expense involved in the residential sector and thus propose a solution that helps reduce consumption in that sector.

Electric consumption according to each sector, México 2016.

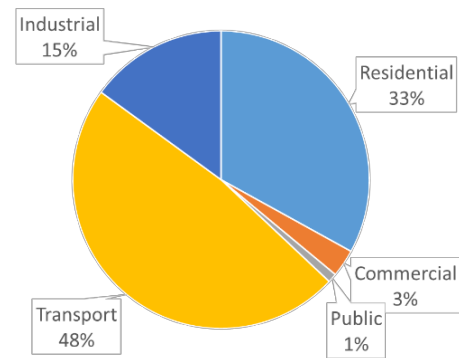


Fig 2. Energy consumption according to sector in Mexico [21].

Materials and resources (MR) includes the conservation, management and reduction of materials for construction, as well as recycling them in order to reduce waste of resources and environmental pollution [22]. Research conducted by the World Business Council for Sustainable Development (WBC SD) has shown that construction and demolition waste (CDW) are important when talking about recycling because they have advantages in terms of: Transportation costs, CDWs are in urban areas close to the construction site, while virgin materials are usually obtained from places close to the construction zone, which indicates a low transportation cost. The life expectancy, the durability of the recycled concrete means a long useful life that can present advantages in sustainability compared to other materials [23].





Interior environmental quality (IEQ) tries to develop a building that has in its interior an optimal environment for the development of the people who are in it, with well distributed and acclimatized spaces, promoting well-being. Every time there is greater limitation in the built spaces, not only because family structures have evolved but because urbanization land is scarce in large cities, where the population density is high in direct relation with industrial development and the supply of employment. The tendency to build dormitory cities that surround the large cities where economic activity develops continues. It is increasingly built for small families and even one-person families, but those spaces must ideally have all the conditions that minimize mechanical risks, with more ergonomic designs and with total control of the ambient factors, such as lighting, noise and air. Several studies indicate that pollutants in indoor air may be in greater quantity than those in outdoor air. These reasons attach importance to these reasons: 1) pollutant concentrations are not significantly reduced when outside air enters buildings, 2) people consume approximately 90% of their time indoors, 3) inside buildings they concentrate new sources of air pollution by hundreds of products that are used in them [24].

Innovation in design (ID) aims to promote ideas or initiatives in addition to those raised in the previous LEED certification qualification categories. In this section points are obtained starting from the innovation presented by the project in each of the categories, with the presentation of quantitative performance improvements comparing them with a standard performance base, taking into account that the processes must be comprehensive (applicable to the entire project) and should be replicable and applied in another project, significantly improving the principles of standard sustainable design [25].

Regional Priority (RP) includes the characteristic needs of the place where the planned project will be developed. This point depends completely on the needs of the population to whom the construction project is directed, taking in count the way in which it will impact the lives of the inhabitants of the property [26].

III. MATERIAL AND METHODS

The methodology to implement begin with the project which is based in the urban development in residential

sector and the statistics on population what is going to let estimate a concrete prototype or ideal of it, this one is object of analysis.

An analysis of this approved project looking forward to the next variables: Location and transport (LT); Sustainable sites (SS); Water Efficiency (WE); Energy and Atmosphere (EA); Materials and Resources (MR); Indoor Environmental Quality (IEQ); Innovation in Design (ID); Regional Priority (RP). According to it, but without look all of them like a unity or part of the same project, propose the idea.

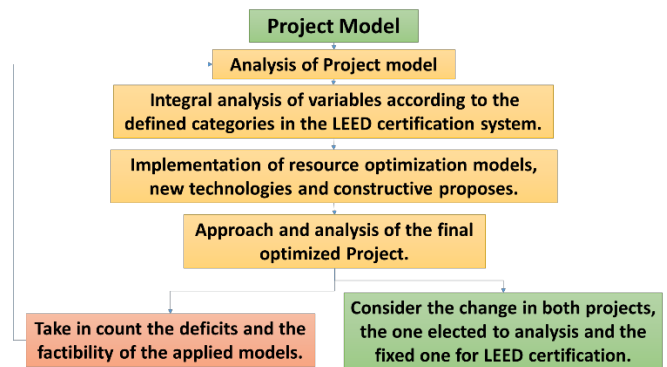


Fig. 3. Methodology for project certification.

This methodology takes in count different concepts according to a local perspective, the methodology takes as main fact the where come from of the resources and where the project is going to be realized.

According to the analysis there are opportunity areas (OA) of the project and according to this analysis is going to be the feasibility of its appliance. The steps to follow will lead the project to obtain LEED certification, if there are anything to change it's just to improve and get a better level. Many facts can be implemented to build a better efficiency between all resources and the optimal use of them, this is the main objective for a residential project. The analysis of project model may be the most important step because the whole project must cover the facts adapting the different implements to reduce the pollution production. Then, variables according the category in the LEED certification system will be subjected to an integral analysis design a proposal to implement a feasible project in which the resources harnessing should be the greatest.

There are a lot of new technologies and those are what project must have, also it is important to implement constructive proposes with the objective of improve the interior and exterior quality, besides it is main to





generate a new constructive technique about green adjustments, building without breaking down the nature balance. Finally, of the optimized project, there are two options, the analysis was well done and consider the change in both projects or return to first analysis of project model and take in count the deficits and the feasibilities of the applied models (fig. 3).

IV. RESULTS AND DISCUSSION

The projects carried out with this perspective are monetarily affordable, the recovery time between the different projects is different. However, considering the useful life of the buildings, the recovery time becomes relatively short.

The adaptability of the project and variations of this depend on the conditions of the site and the needs of the owner, both dimensions and obtaining resources will depend on a previous analysis, based on the information gathered in the present the following considerations are taken into account:

With regard to materials and resources (MR), as well as location and transportation (LT), the choice of local materials is chosen, with the possibility of using recycled materials. It shows that increasing the time or distance of transfer of raw material increases the impact that is on the environment. Not so should the quality of the construction be reduced, studies of the different materials to be used are required as well as technical specifications provided by the different suppliers for the realization of a complete and viable project. It is a practical approach to the origin of the materials, however, it does not stop being a great factor the constructive process that they carry out, their useful life, and above all the impact they have on the environment from its origin and all means and processes involved, their use and termination.

The use and implementation of new technologies and systems will be established for reasons of savings, efficiency and environmental impact. Within these concepts we can locate mainly what refers to sustainable sites (SS), energy and atmosphere (EA) and water efficiency (WE), although its scope is not limited to its independent execution, but to the execution of the different systems as a whole, these systems will be defined with analysis of the environmental characteristics of the area where the project will be developed, in order to know the times and amount of rainfall in different areas of a place and thus decide the

most optimal system to use in the project, as well as the orientation of the residence for the use of solar energy during the day and the amount of energy used by each household on average and thus use a system that helps optimize energy.

V. CONCLUSIONS

The development and implementation of different technologies within the residential sector is a field that is still in expansion, currently looking for alternatives to improve projects in the environmental sense being the residential sector one of the most important, however, the cases applicable to this sector are few and different social factors involved in its development or implementation due to the lack of willingness to make short or medium term investments for the improvement of private housing. LEED is a very complete certification, since it has many categories which are essential when planning a construction project, the acceptance of this certification is reflected in the number of certified projects worldwide, this indicates that more and more people are concerned about the environment and the impact that construction has on it, wanting to achieve higher impact certifications.

VI. REFERENCES

- [1] CO₂ emissions (kt) Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States. <https://data.worldbank.org/indicator/EN.ATM.CO2E.KT>, (accessed 07.02.2018).
- [2] WHO, WHO releases country estimates on air pollution exposure and health impact, <http://www.who.int/mediacentre/news/releases/2016/air-pollution-estimates/en/>, 2016 (accessed 07.02.2018).
- [3] United States Census, U.S. and world population clock, <https://www.census.gov/popclock/>, 2018 (accessed 10.02.2018).
- [4] Dallas, T. et al. Sustainability of a historical building renovation design through the application of LEED rating system. *Energy Procedia*, No. 113 (2017), pp. 382 – 389.
- [5] Champagne, C. & Aktas, C. Assessing the resilience of LEED certified green buildings. *Procedia Engineering*, No. 145 (2016), pp. 380 – 387.
- [6] Jesús Lizana, T. et al. Advances in thermal energy storage materials and their applications towards zero





energy buildings: A critical review. *Applied Energy*, No. 203, (2017), pp 219-239.

[7] El Yamany, S. et al. Applicability and implementation of U.S. Green Building Council Rating System (LEED) in Egypt (a longitudinal study for Egyptian LEED certified buildings). *Procedia Environmental Sciences*, No. 34, (2016), pp. 594 – 604.

[8] Onur, L. & Leblebici, N. An examination of the LEED green building certification system in terms of construction costs. *Renewable and Sustainable Energy Reviews*, No. xxx, (2017).

[9] Gurgun, A., Komurlu, R., & Ardit, D. Review of the LEED category in materials and resources for developing countries. *Procedia Engineering*, No. 118, (2015), pp. 1145 – 1152.

[10] Bühl, G. "El ranking del USGBC de los 10 países que lideran las certificaciones LEED". *ECOCONSTRUCCIÓN*, (2015).

[11] Grupo Acerta, "Estudio Comercial Inmobiliario Residencial Querétaro 2013". Grupo Acerta, 2013.

[12] U.S. Green Building Council. (2015). *Guía de Conceptos Básicos de Edificios verdes y LEED (Core Concepts and LEED Guide)*. Washington, DC: U.S. Green Building Council.

[13] Federal Emergency Management Agency (FEMA), <https://www.fema.gov>, 2018 (accessed 15.03.2018).

[14] Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT), www.semarnat.gob.mx, 2018 (accessed 12.03.2018).

[15] U.S. Green Building Council. (2015). *Guía de Conceptos Básicos de Edificios verdes y LEED (Core Concepts and LEED Guide)*. Washington, DC: U.S. Green Building Council. pp. 50-59.

[16] U.S. Green Building Council. (2015). *Guía de Conceptos Básicos de Edificios verdes y LEED (Core*

Concepts and LEED Guide). Washington, DC: U.S. Green Building Council. pp. 60-63.

[17] Patiño, A. Aumenta 15% consumo de agua en Querétaro. *El economista*, (2012).

[18] Wanjiru, E. & Xia, X. Sustainable energy-water management for residential houses with optimal integrated grey and rain water recycling. *Journal of Cleaner Production*, No. 170, (2018) pp. 1151-1166.

[19] U.S. Green Building Council. (2015). *Guía de Conceptos Básicos de Edificios verdes y LEED (Core Concepts and LEED Guide)*. Washington, DC: U.S. Green Building Council. pp. 64-70.

[20] Sánchez, L. Hogares y consumo energético en México. *Revista digital universitaria*, No. 10, (2012).

[21] Sistema de información energética. (2016) *Balance Nacional de Energía: Consumo final de energía por sector*. México, Secretaría de energía.

[22] U.S. Green Building Council. (2015). *Guía de Conceptos Básicos de Edificios verdes y LEED (Core Concepts and LEED Guide)*. Washington, DC: U.S. Green Building Council. pp. 71-76.

[23] Consejo mundial empresarial para el desarrollo sostenible. (2009) *Reciclando concreto*. Cement sustainability initiative, 2009.

[24] U.S. Green Building Council. (2015). *Guía de Conceptos Básicos de Edificios verdes y LEED (Core Concepts and LEED Guide)*. Washington, DC: U.S. Green Building Council. pp. 77-82.

[25] U.S. Green Building Council. (2015). *Guía de Conceptos Básicos de Edificios verdes y LEED (Core Concepts and LEED Guide)*. Washington, DC: U.S. Green Building Council. pp. 83-84.

[26] U.S. Green Building Council. (2015). *Guía de Conceptos Básicos de Edificios verdes y LEED (Core Concepts and LEED Guide)*. Washington, DC: U.S. Green Building Council. pp. 49-84.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Biological Alternatives for Mobilization and Availability of Phosphorus.

Ana María Arteaga Reséndiz

Engineering of Biosystems, Faculty of Engineering.
Universidad Autónoma de Querétaro
Querétaro, México
anamar_843@hotmail.com

Rosalía V. Ocampo Velázquez

Engineering of Biosystems, Faculty of Engineering.
Universidad Autónoma de Querétaro
Querétaro, México.
rosov05@yahoo.com.mx

Abstract

Due to the frequent application of synthetic fertilizers in agroecosystems, the quality of soil, water and production costs have been affected. Agriculture is the main source of food and part of the economic development of countries. However, day by day, the demand for food is May and there has been a need to accelerate the growth of plants, current practices such as the application of chemical fertilizers that affect the environment. Phosphorus is one of the fundamental nutrients in the development of crops which is added in the form of fertilizer but the reserves are becoming depleted every day, there is a large amount of Phosphorus fixed in the soil that can't be taken by the plants. As an alternative in recent years, strategies have been developed to replace or reduce the use of fertilizers. The microorganisms have been exposed to fulfill functions that maintain the equilibrium in the ecosystem besides promoting plant development using diverse mechanisms, among them the solubilization of phosphates. This nutrient is vital for the development of the plant, but it is not available in the soil.

Keywords— (solubilize microorganisms, Phosphorus, bacteria)

I. INTRODUCTION

Currently, agriculture has the challenge of producing more food per unit area, it is estimated that by the year 2050 the population will be 9100 million people so it will be necessary to increase food production by 70% [1].

Plants need different nutrients to reach their maximum. Most crops are developed by absorbing nutrients from the soil and their ability to do so depends on the nature of the soil where they are established. Soil texture and acidity determine the extent to which nutrients are available to plants. The nutrients, which are demanded by the plants, are naturally in the soil, but most of the time these are added in the form of fertilizers to the soil so that they can be taken by the plants [2]. Phosphorus is

one of the essential elements needed in optimal amounts for the growth and development of plants [3].

Phosphorus is one of the essential elements for the growth of plants. It is estimated that approximately 60% of this element comes from phosphate rocks [4].

II. PHOSPHORUS IN THE PLANT AND SOIL

Phosphorus (P) is an essential nutrient and limiting growth in agroecosystems [5]. However, this limitation could be replaced by external contributions to the soil in the form of phosphate fertilizers. Which are formulated from the reserves of rock phosphate. Therefore, many researchers are concerned about the rapid decrease in Phosphorus reserves due to their constant extraction [6-7]. Recently, there is a contradiction in opinions regarding the availability of global Phosphorus reserves.

A. Phosphorus in the plant

Phosphorus is an essential element for the growth and development of plants, acts in photosynthesis, in the maturation of fruits, is a factor in the formation of roots and flowers, is part of the nucleic acids, ATP and phospholipids that they integrate and give flexibility to the cell membranes, in addition it increases the plant's resistance to low temperatures and diseases [8].

Plant roots absorb phosphorus as either of H_2PO_4^- or $\text{HP}_4\text{O}_6^{2-}$ [8]. Most of the Phosphorus inorganic taken up by roots is loaded into the xylem and subsequently translocated into shoots [9].

Phosphorus is founded in all tissues of the plant in a variable concentration, depending on the part of the vegetative apparatus that is considered, P is essential in the formation of enzymes and proteins [10].

Phosphorus is one of the essential nutrients and is cataloged as macronutrients, because it is required in large quantities by plants [11].



B. Phosphorus dynamic in soil

Phosphorus nutrition is a limiting factor for crop in many soils due to relatively low Phosphorus availability because Phosphorus can be readily adsorbed or fixed by calcium (Ca) aluminum (Al) and iron (Fe) in acid soils [12]. Around 10-30% of Phosphorus applied as fertilizer may become available to plants [13] which aggravates the economic losses due to the excessive use of Phosphorus fertilizers in intensive agriculture [14].

Soil Phosphorus exists in inorganic and organic chemical forms. Principal Phosphorus minerals are variscite, apatites, strengite, and are stable, and the release of available Phosphorus from these minerals by weathering is too slow to meet the crop demand [15]. Contrary the second Phosphorus minerals are iron (Fe), calcium (Ca) and aluminum (Al) phosphates vary depending of soil pH and size of aggregates [16]. If increasing soil pH, solubility of Al and Fe phosphates increases but solubility of Ca phosphate decreases, unless for pH values above eight [12]. The Phosphorus adsorbed as Al and Fe oxides can be released by desorption reactions. These Phosphorus forms exist in complex balances with each other, representing since very stable, sparingly available, to plant-available Phosphorus pools such as labile Phosphorus and solution Phosphorus (Fig. 1) [15].

In acidic soils, Aluminum and Iron oxides and hydroxides, such as gibbsite, hematite, and goethite, can dominantly adsorb Phosphorus. P can be taken up on the surface of clay minerals and Fe and Al oxides by forming various complexes [15]. The complexes may coexist at pH 4 to 9, while complex is predominant acidic soil conditions [17]. Phosphate can precipitate with Ca, making dicalcium phosphate that is available to plants. However, dicalcium phosphate can be transform into stable forms like octocalcium phosphate and hydroxyapatite, which are less available to plants at alkaline pH [17]. Hydroxyapatite dissolution increases with decrease of soil pH [18], rhizosphere acidification can be a good strategy to mobilize soil Phosphorus from calcareous soil [15]. The availability of soil Phosphorus is complex because it is highly associated with Phosphorus dynamics and transformation among various Phosphorus pools (Fig. 1) [15].

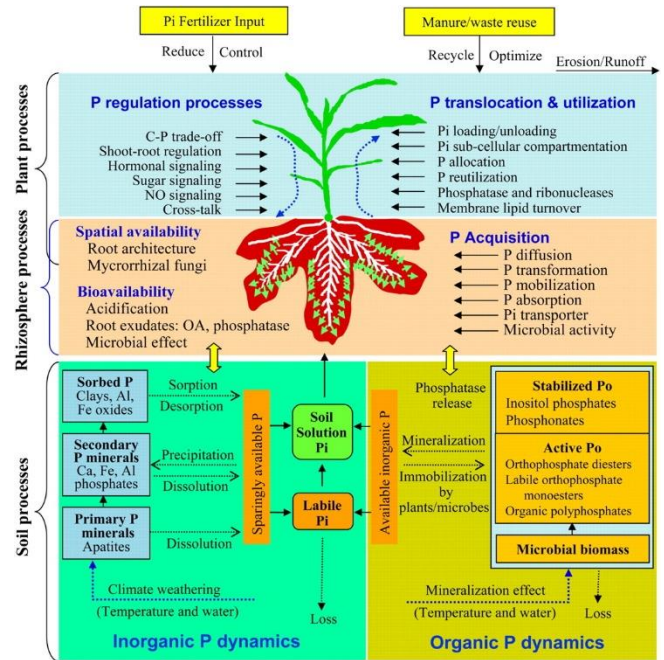


Figure 1. Phosphorus dynamics in the soil / rhizosphere-plant [15].

III. THE PHOSPHORUS AND THE CURRENT SITUATION.

A. Demand for food, demand for fertilizers

According to the FAO (Food and Agriculture Organization of the United Nations) for the year 2050 the production of cereals (for food and fodder) will reach 30000 million tons, while that of meat will double almost 50% to reach 470 million. Producing more food will depend above all on increasing crop yields, not on growing more land. The production of biofuels could also increase the demand for agricultural commodities, depending on energy prices and government policies [19].

The International Association of Fertilizer Manufacturers foresees that for this period 2017-18 the world demand for fertilizers will increase by 1.6% with respect to the previous period. In the case of P_2O_5 , the increase is estimated at 1.5% (up to 43.5 million tons) [20].

B. Phosphorus reserves

The agriculture that is developed today depends on the inputs of phosphate fertilizers derived from extracted rock to replenish the Phosphorus taken by the crop, but the phosphate rock is a non-renewable resource. The reserves of phosphate rock are under the control of China, Morocco, the USA, South Africa and Jordan that control 85% of the world reserves [21], which makes the European Union sensitive, and at volatile prices, as it happened in 2008 with the 800% increase in the price of phosphate rock [22].





China to ensure its domestic supply has imposed a tariff of 135% on the export of phosphate to avoid exports [23]. According to industry analysts, World mine production capacity, except China, was projected to increase to 168 million tons in 2021 [21]. The United States, historically the largest producer, consumer, importer and exporter of rock phosphates, in 2008 its reserves were calculated for a duration of 25 [24-22].

IV. ALTERNATIVES, MICROORGANISMS SOLUBILIZER OF PHOSPHATOS.

Farmers apply phosphate fertilizers on their crops to combat the Phosphorus deficiency in their soil. Plants absorb very few amounts of the fertilizers and the rest quickly becomes insoluble complexes in the soil.

Phosphate fertilizers with P_2O_5 useable when added to the soil are fixed and are not available for plant growth. The role of microorganisms in the solubilization of inorganic phosphates in the soil and its availability to plants is well known. They are called phosphate solubilizers and convert the insoluble phosphates into soluble forms by acidification, chelation, exchange reactions and gluconic acid production [25].

The rhizosphere is the zone of interactions microorganisms, plants and soils. Plant roots can modify the rhizosphere environment due some physiological activities, for example, exudation of organic compounds like mucilage, organic acids, phosphatases, and some specific signaling substances, which are key drivers of various rhizosphere processes [15]. The biological and chemical processes around the rhizosphere not only determine acquisition and mobilization of soil nutrients as well as microbial dynamics, but also control nutrient use efficiency [12]. Phosphorus can be rapidly depleted in the rhizosphere by root uptake, due to its low solubility and mobility in soil. Phosphorus content generally exceeding the plant requirements, but the low mobility can restrict its availability to plants [15]. Soluble Phosphorus in the rhizosphere soil solution should be replaced 20 to 50 times per day [26]. Phosphorus dynamics in the rhizosphere are controlled by plant root growth and function, and highly related to physical and chemical properties of soil [27].

A. Phosphate solubilizing microorganisms

The microorganisms solubilizing Phosphorus, strains become of to the bacterial genera *Bacillus*, *Rhizobium*, *Pseudomonas*, etc. and the fungi for example *Aspergillus*, *Fusarium*, *Penicillium*, *Helminthosporium*, *Alternaria*, etc., are the most potent phosphate solubilizes [28].

Phosphate Moroccan rock inoculated with *Aspergillus niger* for seven and nine days, obtaining as a result a high solubilization index after nine days [29]. Isolated soil samples where found *Deteuromycete*, *Penicillium sp*, *Aspergillus niger*,

Zigomycetes and *Paecilomyces sp* all with solubilizing activity evaluated in calf media. Where the species *Penicillium sp* and *Aspergillum niger* showed a higher solubilizing activity of phosphates [30]. *Gluconacetobacter diazotrophicus* showed a significant mineral phosphate solubilizing potential [31].

Isolated from the rhizosphere of *Saccarum officinarum L.* (sugarcane), a strain of *Citrobacter sp.*, with the facility to grow in medium based on sucrose or fructose and phosphate rock as carbon and Phosphorus sources, respectively. Results by high performance liquid chromatography showed that when the bacteria developed in a culture medium with sucrose produced acetic acid and when it grew in fructose a low level of pyruvic acid was originated. It follows that the solubilization of Phosphorus by means of organic acids of bacterial origin is related to the carbon source [32].

The bacterium *Kushneria sp.* YCWA18 can survive at a concentration of 20% NaCl and, under optimal conditions, solubilized 283.16 $\mu\text{g/ml}$ Phosphorus in eleven days after being inoculated in 200 ml $\text{Ca}_3(\text{PO}_4)_2$ and 47.52 $\mu\text{g/ml}$ Phosphorus in eight days after being inoculated in 200 ml of lecithin [33]. Of 122 soil samples from different crops in Mexico and Guatemala were analyzed to create a liquid biofertilizer such as nitrogen fixative, phosphate and potassium solubilizer, among the solubilizing microorganisms they found were *Pseudomonas fluorescens* from an oil palm crop in Guatemala, *Pseudomonas sp.* a culture of watermelon in Mexico and *Penicillium sp* in a tomato crop also in Mexico [34]. Of the rhizosphere of a corn crop isolated six bacteria, *Paenibacillus sp.* strain B1, *Pseudomonas sp* B10, B14, SX1 and SX2 and one *Sphingobium sp* SX14, quantified the ability to solubilize phosphate in National Botanical Research (NBRIP) as $\text{Ca}_3(\text{PO}_4)_2$, AlPO_4 , FePO_4 and lécitine. Their results report that all isolates solubilized inorganic Phosphorus but SX1 and SX2 having the best results with 493.1 and 529.7 $\text{mg}\cdot\text{L}^{-1}$ respectively in $\text{Ca}_3(\text{PO}_4)_2$ and while strains B1 and B10 solubilized inorganic Phosphorus (lecithin) [35]. The fungus *Penicillium oxalicum* was isolated from the soil of the rhizosphere of the phosphate mines of India and tested for its effectiveness in solubilizing phosphate rock, results showed that *Penicillium oxalicum* effectively solubilized the phosphate rock in a Pikoyskaya medium. The solubilization increased according to the increase phosphate rock concentration of, 0.1, 0.5, 1.0 and 2.0, equivalent to P_2O_5 gr, the soluble Phosphorus was 73.7, 168.8, 457.9, and 586.2 $\mu\text{g/ml}$ [36]. The bacterium *Enterobacter sp* strain P23 as a growth promoter because it produces indole-3-acetic acid (IAA), the solubilization of phosphates, production of siderophores and production of NH_3 [37]. A study of six strains of *Actinomycetes* extracted from the phosphate mines of Morocco, *Streptomyces lividans* TK24 and *Streptomyces griseus s.* M1323 and 2 species of *Streptomyces* (SG^{MPM} , SC SB11) and *micromonospora* species (MA^{MPM}) reported that the *actinomycete* strains isolated from the Moroccan Phosphate Mines, as well as *S. griseus* M1323 and



S. lividans TK24, were all capable of using rock insoluble phosphoric as sole source of phosphate. However, not all were able to release soluble Phosphorus in the growth medium (only the strains MPM and *S. griseus* M1323 released Phosphorus) but not *S. lividans* [38]. Different combinations of phosphate fertilization was tested in wheat grain yield (control, diammonium phosphate DAP 100 kg/ha, rock phosphate 150 kg/ha, phosphate + Phosphorus solubilizing bacteria *Pseudomonas sp.* BR2, and three biological superphosphates BioTRP methodology [39-40], tilemsi rock phosphate inoculating it with *Thiobacillus Thiooxidans* AHB436 BioTRP1, *Thiobacillus thiooxidans* AHB411 BioTRP2 and *Thiobacillus thioparus* AHB717 BioTRP3). The results showed that the best biological treatment was BioTRP1 producing 2840 kg/ha grain yield exceeded by the treatment fertilized with DAP in 260 kg [40]. The *Streptomyces griseoplanus* PSA1 isolated strains from the rhizosphere maize soil from China, which was capable of Phosphorus solubilization from tricalcium phosphate. Release of different phosphates by *Streptomyces griseoplanus* PSA1 from ferric phosphate, aluminum phosphate and rock phosphate indicated its efficient phosphate solubilizing ability. Tested the bacteria in the field and found that with a good combination of *Streptomyces griseoplanus* PSA1 and phosphate fertilizer under field conditions, the amounts of available Phosphorus were increased and improve grain yield 11%. Also were detected acid citric, acid acetic, malic acid, succinic acid and oxalic acid [41]. Fig 2, show the importance of microorganisms to Phosphorus availability in soil [42]. There are biological processes associated with growth promoters activated by microorganisms that can directly or indirectly increase the availability of Phosphorus in the soil and therefore increase the ability of the plant to take it, Fig 3, [42].

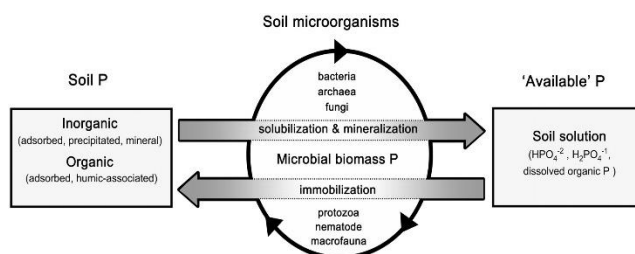


Figure 2. Schematic representation of the importance of microorganisms to P availability in soil [42]

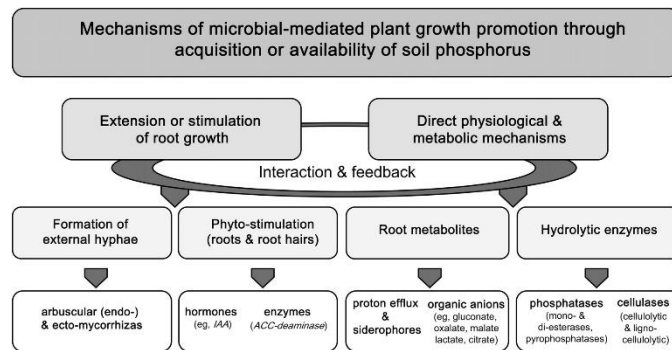


Figure 3. Processes associated with microbially [42].

The organic acids produced by phosphate solubilizing microorganisms includes in great measure gluconic acid, oxalic acid, ketogluconic acid, citric acid, etc. The table 1 shows examples of plant growth regulators synthesized by phosphate-solubilizing microorganisms and organic acids produced by phosphate-solubilizing microorganisms [43]. The solubilization, mineralization of inorganic and organic Phosphorus occurs by three mechanisms: synthesis of enzymes, excretion of H⁺ ions and production of organic acids [44-45]. One of the main mechanism of *diazotrophic endophytic* bacteria to solubilize Phosphorus is the efficient production of organic acids mainly oxalic, citric, succinic and ascorbic acids [46].

Table 1. Organic acids produced by phosphate solubilizing microorganisms and examples of plant growth regulators synthesized by phosphate solubilizing microorganisms [43].

Phosphorus solubilizing microorganisms	Organic acids produced/ Plant growth regulator activities	Initial pH of medium	Final pH of medium	Solubilized (mg/l)
<i>Aspergillus sp.</i> ; <i>Penicillium sp.</i>	Glycolic, malic, Citric, gluconic, oxalic, succinic,	7.0;7.0	3.2; 3.3	392;381
<i>Aspergillus niger</i>	Oxalatic, lactic	ND	ND	3640
<i>Trichoderma harzianum</i>	Lactic, succinic, tartaric, citric	5.4	4.3	ND
<i>Rhizobium tropici</i> , <i>Paenibacillus kribbensis</i> , <i>Acinetobacter sp</i>	Malic, 2-ketoglutaric, lactic, succinic, tartaric, propionic, gluconic	5.0; 7.0	5.0; 4.0	70; 75; 75;
<i>Pseudomonas sp. R7</i>	Lactic, isocitric, tartaric, pyruvic	7.03	4.92	19.5
<i>Pseudomonas fluorescens I228</i>	Gluconic	7.0	4.06	1312



<i>Rhizobium sp. VM-2</i>	Organic acids	7.0	4.93	4799
<i>Rhizobium sp. RASH6</i>	Succinic, gluconic	7.0	3.4	275
<i>Bacillus megaterium</i>	Malic, quinic	7.0	4.0	ND
<i>Trichoderma harzianum</i>	Citric, lactic, succinic	7.2	4.68	9.31
<i>Pantoea agglomerans, Burkholderia anthina, Enterobacter ludwigii</i>	Gluconic, oxalic, citric	7.0	3.2; 3.5; 4.0	575.16; 384.28; 600
<i>Enterobacter hormaechei sub sp. steigerwaltii</i>	Gluconic, succinic, malic, glutamic	7.0	3.5	505
<i>Azospirillum, Bacillus, Enterobacter</i>	Acetic, citric, gluconic	7.0	Reduced pH	218.1; 298.3; 258.6
<i>Burkholderia ambifaria KS 01, B. Tropica KS 04</i>	Acetic, citric, gluconic, lactic, succinic, propionic	6.6	4.86; 4.05	433.81; 499.85
<i>Penicillium sp.</i>	Gluconic, citric	6.25	3.22	39.2; 86.6
<i>Acinetobacter sp. WR 1222</i>	Gluconic	7.0	4.21	414
<i>Pantoea sp. (sedes)</i>	IAA, siderophore, N ₂ fixation			
<i>Burkholderia sp. Enterobacter sp. (rhizosphere)</i>	IAA, siderophore			
<i>Serratia marcescens P. aeruginosa (vegetables rhizosphere)</i>	IAA NH ₄ and HCN	5.05; 4.42;		143.58; 160.34

ND no determinate

Pantoea sp. J49, en un medio liquido NBRIP con un pH inicial de 3.6 y 5.2 de pH final tuvo una solubilizacion de fosforo de 385.4 mg/l [47]. *Pseudomonas fluorescens* K-34 pH inicial de 7.0 y un pH final de 5.9 solubilizo 563 mg/l además de secretar los acids siderophore y IAA [48].

Pantoea sp. J49, in a liquid NBRIP medium with an initial pH of 3.6 and 5.2 of final pH had a phosphorus solubilization of 385.4 mg l [47]. *Pseudomonas fluorescens* K-34 initial pH of 7.0 and a final pH of 5.9 solubilized 563 mg/l in addition to secreting the siderophore and IAA acids [48]. *Bacillus cerus* solubilizo 27 mg/ml, *Bacillus megaterium*, *Bacillus subtilis* 140.44 y 35 mg/ml respectively. *Proteus vulgaris* 27, *Proteus mirabilis* 28, *Micrococcus varians* 26, *Staphylococcus aureus* 18, *Proteus inconstans* 30, *Klebsiella pneumonia* 28, *Pseudomonas mallei* 35, *Enterobacter aerogens* 34 mg/ml the Phosphate solubilization by bacterial isolates in broth using National

Botanical Research Institute's phosphate growth medium (NBRIP) medium [49].

Isoted *actinobacteria* of the different regions that are able to solubilizing phosphate from wild plants of the Eastern Cordillera of Colombia. Used two form to qualitative assays to determine solubilization by measuring the halo of hydrolysis in a Pikovskaya's and National Botanical Research Institute's phosphate growth (NBRIP) medium containing soluble phosphate by *Actinobacteria* was quantified using insoluble Ca₃(PO₄)₂ or AlPO₄ as single sources of Phosphorus. The bets strains were the collected from Fusagasuga area 510 mg/L [50]. Evaluate the effects of a Phosphorus mobilizing plant-growth promoting rhizobacterial strain *Bacillus cereus* GS6, alone or combined with phosphate enriched compost (food waste with addition of single super phosphate) on the symbiotic, found that the combination bettween *Bacillus cereus* GS6 with PEC improve significantly the concentration of nitrogen, Phosphorus, and potassium in grain, shoot, and nodule [51]. The bacterial diversity and Phosphorus dynamics was calculated in the composting process of the sugarcane, inoculated with *Pseudomonas aeruginosa* PSBR12 and *Bacillus sp.* BACBR01. Showed inoculation of bacterial solubilizing Phosphorus reduced the levels of Ca-bound Phosphorus by 21% and increased the labile organic Phosphorus [46]. Twenty phosphate-solubilizing bacteria were isolated, identified as *Bacillus megaterium* (*B. aryabhatai*), *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Rhizobium sp.*, *Acinetobacter sp.*, and *Pseudomonas oryzihabitans*. Seven of them were evaluated with phosphate solubilizing bacteria (NBRIP) plate culture. Results showed that halo zone formation by on NBRIP plates was a good indicator for screening PSB, but not good enough to quantify capability of Phosphorus solubilization [52].

The availability of Phosphorus was quantified in a soil with Phosphorus-enriched compost and together with the inoculation of Phosphorus-solubilizing rhizobacteria. For which isolated the bacterial strain AK-35 showed 99.76% resemblance with *Enterobacter kobei* CIP 105566T, strain AK-35 was deposited in EMBL with accession number LK936515. For the quantitative solubilization of Phosphorus, the bacteria inoculated into the Pikovskaya broth solution containing rock phosphate (5 g/l). The methods are composed of compost, bacteria, and compost plus bacteria, results, total Phosphorus 13.25, 18.33 mg/kg of soil and 0.65ns respectively [53]. Tested on maize and wheat fertilizer (diammonium phosphate, DAP) and phosphate solubilizing bacteria *Pantoea cyripedii* and *Pseudomonas plecoglossicida*, inoculated together with rock phosphate and singly. Inoculation these bacterias together with rock phosphate increased the total Phosphorus uptake in both crops [54]. Eighty-one bacteria with Phosphorus solubilization potential of only four, showed a high capacity to solubilize phosphates. These bacterias were





classified as *ketobacter licuefaciens*, *Acetobacter sp.*, *Pseudomonas gladioli* and PSB 58 (unidentified strain). All showed a maximum solubilization of Phosphorus 72.9, 63.8, 68.8 and 59.0 mg/100 ml of solubilized Phosphorus amount respectively [55]. Quantified the Phosphorus solubilization potential of thirty strains of inoculated bacteria from the Himalayas. The diversity of bacteria found in members of the genera *Serratia*, *Pseudomonas*, *Ochrobactrum*, *Bacillus*, *Agrobacterium*, *Staphylococcus*, *Enterobacter*, *Citrobacter*, *Acinetobacter* and *Pantoea*. The majority of bacteria were viable to solubilize inorganic Phosphorus in the form of tricalcium phosphate in a range of 200-400 mg/l [56]. A bacteria solubilizing phosphate strain *Burkholderia multivorans* WS-FJ9 was tested in six levels of exogenous soluble in phosphate (0, 0.5, 1, 5, 10 and 20 mM). Strain WS-FJ9 showed better growth at high levels of soluble phosphate. The phosphate solubilization activity of WS-FJ9 was reduced as the soluble phosphate increased the concentration [57].

A series of strains of phosphate solubilizing bacteria isolated from the cultivation of *Oryza sativa L.*, where it obtained the phosphate solubilization index (NBRIP-pH 7.0) of putred *Pseudomonas* bacteria AI05, AJ13, 2.41, 2.14. In Arabica coffee (*Coffea arabica L.*) the phosphate solubilization index (NBRIP pH 7.0) with the bacteria *Herbaspirillum sp.* C4, *Herbaspirillum sp.* C8, *Herbaspirillum sp.* C9, and *Azospirillum sp.* C7 the found values were 4.7, 6.37, 4.64 and 3.04 respectively [58]. Obtained a solubilization index of the bacteria *Gluconacetobacter diazotrophicus* PAL5, *Burkholderia vietnaminenses* AR1125, *Burkholderia kuriensis* AR2236, 2.61, 2.88, 2.30 respectively, also quantified the soluble Phosphorus in a liquid medium NBRIP, 239, 226, 206, mg of Phosphorus/l [59]. On the other hand, of a tomato crop (*Solanum lycopersicum L.*) isolated *Enterobacter sp.* TVL1, *Enterobacter sp.* TVL2, *Pseudomonas putida* PSO14, the results obtained were 5.0, 4.26, 4.32 index of phosphate solubilization in NBRIP at a pH of 7.0 and 189.5, 192.5, 144 in the liquid medium mg of Phosphorus per liter [60]. Results from strains of the culture of *Brassica campestris L.* (NBRIP pH 7.0) were 2,333, 1.78, 2.83, 4.33, 1.11, 1.63 and 2.33 in *Pseudonoma poae* CPBE37, CPBE42, CPBE43, *Pseudonoma trivalis* CPBE31, CBPE40, CPBE44 and *Rhizobium radiobacter* CPBE30 and in liquid medium NBRIP 301.3, 299, 440.9, 247.9, 279.9, 282.1, and 326.4 respectively [61]. Quantify the soluble Phosphorus in ornamental plants the values were the following 259, 428, 252, 312 and 170 mg of Phosphorus/l, with *Bacillus cereus* B3 bacteria, *Bacillus thioeparans* B53, *Paenibacillus rhizosphaerae* B89, *Paenibacillus lautus* B96 and *Bacillus subtilis* SR/B-16 [62].

V. CONCLUSIONS

Farmers since the beginning of the green revolution became addicted to the use of Phosphorus fertilizers. The demand for food continues to grow, the demand for phosphate fertilizers

increases. The current and future implications refer to where Phosphorus is extracted from non-renewable sources. If we do not make a change in the way the Phosphorus source is used, crop yields will be affected in the future. This affects farmers and poor consumers in the first stay. In recent years, it has taken advantage of the use of microorganisms as an alternative to solubilize the Phosphorus that is fixed in the soil. The implementation of these alternatives also reduces the long-term use of chemical products in agriculture and the development of agronomic strategies that would preserve the environment. The success of these bacterial inoculants depends on the selection of efficient strains, type of native soil, ability to colonize the rhizosphere and maintain biological activity, culture, pH.

In the studies presented, no bacteria have exceeded the performance of crops with chemical fertilization, however, work must continue to find microorganisms that act alone or together can equal or exceed these yields.

REFERENCES

- [1] Bruinsma J. The resource outlook to 2050. By how much do land, water use and crop yields need to increase by 2050?. FAO Expert Meeting on How to Feed the World in 2050, FAO, 2009.
- [2] Awasthi R., Tewari R., Nayyar H. Synergy between Plants and P-Solubilizing Microbes in soils: Effects on Growth and Physiology of Crops. Int Res J Microbiol, 2011.
- [3] Bagyaraj D, Krishnaraj P. Mineral phosphate solubilization: agronomic implication, mechanism and molecular genetics. Proc. Indian natn. Sci. Acad. 66:69-82, 2000.
- [4] Cooper J, Lombardi R, Boardman D, Carliell-Marquet C. The future distribution and production of global phosphate rock reserves. Resources, Conservation and Recycling 57 (2011) 78–86.
- [5] Smil S V. Phosphorus in the environment: natural flows and human interferences. Annual Review of Energy and the Environment 2000;25:53–88.
- [6] Cordell D, Drangert J-O, White S. The story of Phosphorus: global food security and food for thought. Global Environmental Change 2009a;19:292–305.
- [7] Van P, Bouwman A, Beusen A. Phosphorus demand for the 1970–2100 period: a scenario analysis of resource depletion. Global Environmental Change 2010;20:428–39.
- [8] Navarro G. Química Agrícola. El suelo y los elementos químicos esenciales para la vida vegetal. Ed. Mundi-Prensa, Madrid, 2000.
- [9] Ai P., Sun S., Zhao J., Fan Z., Xin W., Guo Q., Yu L., Shen Q., Wu P., Miller A. Two rice phosphate transporters, OsPht1;2 and OsPht1;6, have different functions and kinetic properties in uptake and translocation. Plant J. 2009, 57: pag 798-809.
- [10] Rodríguez H., Rodríguez J. Métodos de análisis de suelos y plantas, criterios de interpretación, 2002
- [11] Bushman L, Lamb J, Randall G, Rehm G, Schmitt M The nature of Phosphorus in soils. Phosphorus in agriculture environment. University of Minnesota, 2009.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

- [12] Hinsinger P. Bioavailability of soil inorganic P in the rhizosphere as affected by root-induced chemical changes: a review. *Plant Soil*, 2001, 237 173–195.
- [13] Holford I. C. R. Soil Phosphorus: its measurement, and its uptake by plants. *Aust. J. Soil Res.* 1997, 35 227–240.
- [14] Shen J, Yuan L, Zhang J, Li H, Bai Z, Chen X, Zhang W, Zhang F. Review Phosphorus dynamics: from soil to plant. *Plant Physiol.* Jul 2011; 156(3):997-1005.
- [15] Shen J., Yuan L., Zhang J., Li H., Bai Z., Chen X., Zhang W., Zhang F. Phosphorus Dynamics: From Soil to Plant. *Plant Physiology* 2011, 156 (3) 997-1005;
- [16] Pierzynski G., McDowell R, Sims J., Chemistry, cycling, and potential movement of inorganic Phosphorus in soils. In: Sims, J.T. and Sharpley, A.N., eds. *Phosphorus: Agriculture and the environment*. Madison, Soil Science Society of America, 2005. p.53-86.
- [17] Arai Y., Sparks D. Phosphate reaction dynamics in soils and soil minerals: a multiscale approach. *Adv Agron* 2007, 94: 135–179.
- [18] Wang I., Nancollas G. Calcium orthonphosphates: crystallization and dissolution. *Chem Rev* 2008, 108: 4628–4669.
- [19] Organización de las Naciones Unidas para la Agricultura y la Alimentación. *Como alimentar al mundo 2050*. 2009.
- [20] International Fertilizer Association. *Fertilizer Outlook 2017-2021, Production and International Trade and agriculture services*. IFA Annual conference. Morocco 2017.
- [21] U.S.G.S. Mineral commodity summaries 2018. US Geological Survey
- [22] Cordell D, Drangert J, White S. The story of Phosphorus: Global food security and food for thought. *Global Environmental Change* 19, 2009, pag 292–305.
- [23] Fertilizer Week, 2008. Industry ponders the impact of China's trade policy. *Markets Report*, 2008, British Sulphur Consultants, CRU.
- [24] Jasinski, S.M., 2008. Phosphate Rock, Mineral Commodity Summaries, U.S. Geological Survey.
- [25] Vikram A, Hamzehzarghani H. Effect of phosphate solubilizing bacteria on nodulation and growth parameters of greengram (*Vigna radiate L. Wilchek*). *Res. J. Microbiol.* 3:62-72, 2008.
- [26] Marschner H *Mineral Nutrition of Higher Plants*, Ed 2. Academic Press, London, 1995, pag 889.
- [27] Neumann G, Römheld V. Root-induced changes in the availability of nutrients in the rhizosphere. In Waisel Y, Eshel A, Kafkafi U, eds, *Plant Roots, The Hidden Half*, Ed 3. Marcel Dekker, Inc., New York, 2001, pp 617–649.
- [28] Behera C., Singdevsachan .K., Mishra .R., Dutta K. Diversity, mechanism and biotechnology of phosphate solubilising microorganism in mangrove-A review. *Biocatal. Agric. Biotechnol* 2014, 3: 97–110.
- [29] Goenadi, D. H., Siswanto and Y. Sugiarto. 2000. Bioactivation of poorly soluble phosphate rocks with a Phosphorus-solubilizing fungus. *Soil Sci. Soc. Am. J.* 2000, 64:927-932.
- [30] Perez, C., A., de la Ossa, V. Montes, V., D. Hongos solubilizadores de fosfatos en fincas ganaderas del departamento de sucre. *Revista Colombiana de Ciencia Animal*, 2002.
- [31] Alan E. Richardson, Richard J. Simpson. Soil Microorganisms Mediating Phosphorus Availability Update on Microbial Phosphorus. *Plant Physiology* 2011, 156 (3) 989-996.
- [32] Patel K, Archana G, Kumar N. Variation in the nature of organic acid secretion and mineral phosphate solubilization by *Citrobacter* sp. DHRSS in the presence of different sugars. *Curr Micro.* 2008; 56: 168-74.
- [33] Zhu F., Qu L., Hong X. Sun X. Isolation and Characterization of a Phosphate-Solubilizing Halophilic Bacterium *Kushneria* sp. YCWA18 from Daqiao Saltern on the Coast of Yellow Sea of China. *Hindawi Publishing Corporation Evidence-Based Complementary and Alternative Medicine*, 2011.
- [34] Velazquez-Gurrola A., Ramos-Alegria M.P. Beneficios de microorganismos solubilizadores de P y K e la recuperación y mantenimiento de suelos agrícola. *Actas del VIII Congreso Mundial de la Palma* 2015.
- [35] Li Y., Liu X., Hoa T., Chen S. Colonization and maize growth promotion induced by phosphate solubilizing bacterial isolates. *Int. J. Mol. Sci.* 18, 1253, 2017.
- [36] Singh, H.; Reddy, M.S. Effect of inoculation with phosphate solubilizing fungus on growth and nutrient uptake of wheat and maize plants fertilized with rock phosphate in alkaline soils. *Eur. J. Soil Biol.* 2011, 47, 30–34.
- [37] Singh, H.; Reddy, M.S. Effect of inoculation with phosphate solubilizing fungus on growth and nutrient uptake of wheat and maize plants fertilized with rock phosphate in alkaline soils. *Eur. J. Soil Biol.* 2011, 47, 30–34.
- [38] Hamdali H., Smirnov A., Esnault C., Ouhdouch Y., Virolle M. Physiological studies and comparative analysis of rock phosphate solubilization abilities of actinomycetales originating from Moroccan phosphate mines and of *Streptomyces lividans*. *Appl. Soil Ecol.*, 44 (2010), pp. 24-31.
- [39] Swaby R. Biosuper-biological superphosphate. In McLean KD, ed. *Sulphur in Australian agriculture*, 1975, pp. 213-220.
- [40] Babana A, Kassogué A, Dicko AH, Maïga K, Samaké F, Traoré D, Fané R, Faradji FA. Development of a biological phosphate fertilizer to improve wheat (*Triticum aestivum* L.) production in Mali. *Procedia Eng*, 2016, 138:319–324.
- [41] Wang C., Cui J., Yang L., Zhao C., Wang T., Shuxia L. Phosphorus-Release Dynamics by Phosphate Solubilizing Actinomycetes and its Enhancement of Growth and Yields in Maize. *Int. J. Agric. Biol.*, 2018, Vol. 20, No. 2.
- [42] Alan E. Richardson, Richard J. Simpson. Soil Microorganisms Mediating Phosphorus Availability Update on Microbial Phosphorus. *Plant Physiology* 2011, 156 (3) 989-996.
- [43] Khan M., Rizvi A., Saif S., Zaidi A. Phosphate-Solubilizing Microorganisms in Sustainable Production of Wheat: Current Perspective. *Probiotics in Agroecosystem*. Springer, Singapore, 2017.
- [44] Kapri A, Tewari L. Phosphate solubilization potential and phosphatase activity of rhizospheric *Trichoderma* spp. *Braz J Microbiol*, 2010, 41:787–795
- [45] Arcand M, Schneider K. Plant- and microbial-based mechanisms to improve the agronomic effectiveness of phosphate rock: a review. *An Acad Bras Cienc*, 2006, 78:791–807.
- [46] German A. Estrada-Bonilla C., Lopes A., Paulo R., Alves N., Elke J. Effect of phosphate-solubilizing bacteria on Phosphorus dynamics and the bacterial community during composting of sugarcane industry waste. *Systematic and Applied Microbiology*, 2017, Volume 40, Issue 5, pag 308-313.
- [47] Taurian T., Anzuay S., Ludueña M. Effects of single and co-inoculation with native phosphate solubilising





- strain *Pantoea sp* J49 and the symbiotic nitrogen fixing bacterium *Bradyrhizobium sp* SEMIA 6144 on peanut (*Arachis hypogaea* L.) growth. Symbiosis, 2013.
- [48] Parani K., Saha B. Prospects of using solubilizing *Pseudomonas* as biofertilizer. European Journal of Biological Sciences, 2012, 4(2): 40-44.
- [49] Deepika K., Naresh G., Krishnakanth V., Sujatha P. Isolation, screening and identification of phosphate solubilizing bacteria from different regions of Visakhapatnam and Araku Valley. International Journal of Advanced Biotechnology and Research, Vol 4, Issue 4, 2013, pp 518-526.
- [50] Prada D., Prieto C., franco M. Screening phosphate solubilizing actinobacteria isolated from the rhizosphere of wild plants from the Eastern Cordillera of the Colombian Andes. African Journal of Microbiology Research 8, no. 8 2014: 734-742.
- [51] Zhiguang L., Yuncong C., Shouan Z., Yuqing F., Xiaohui F., Jaimin S., Min Z. Characterization of phosphate-solubilizing bacteria isolated from calcareous soils. Applied Soil Ecology, Volume 96, 2015, pag 217-224.
- [52] Sher M., Saleem M., Muhammad R., Riaz M., Tahira Y., Zaheer A., Bragazza L., Buttler A, Bjorn J. Interaction of compost additives with phosphate solubilizing rhizobacteria improved maize production and soil biochemical properties under dryland agriculture. Soil and Tillage Research, Volume 174, 2017, pag 70-80.
- [53] Gurdeep K., Mondem S. Effects of Phosphate-Solubilizing Bacteria, Rock Phosphate and Chemical Fertilizers on Maize-Wheat Cropping Cycle and Economics. Pedosphere. Volume 25, Issue 3, 2015, pag 428-437.
- [54] Stephen J, M.S. Buffering Reduces Phosphate Solubilizing Ability of Selected Strains of Bacteria. World Journal of Agricultural Sciences 5 (1): 2009, pag 135-137.
- [55] Stephen J, M.S. Buffering Reduces Phosphate Solubilizing Ability of Selected Strains of Bacteria. World Journal of Agricultural Sciences 5 (1): 2009, pag 135-137.
- [56] Hayat W., Aman H., Irshad U., Azeem M., Iqbal A., Nazir R. Analysis of ecological attributes of bacterial Phosphorus solubilizers, native to pine forests of Lower Himalaya. Applied Soil Ecology, Volume 112, 2017, pag 51-59.
- [57] Qingwei Z, Xiaoqin W., Wang J., Ding X. Phosphate Solubilization and Gene Expression of Phosphate-Solubilizing Bacterium Burkholderia multivorans WS-FJ9 under Different Levels of Soluble Phosphate. J. Microbiol Biotechnol (2017), 27(4), pag 844–855.
- [58] Restrepo-Franco G., Marulanda-Moreno S., Fe-Pérez Y., Díaz-de la Osa A., Lucia-Baldani V., Hernández-Rodríguez A. Bacterias solubilizadoras de fosfato y sus potencialidades de uso en la promoción del crecimiento de cultivos de importancia económica. Revista CENIC. Ciencias Biológicas 46 (1): 2015, 63-76.
- [59] Jasinski, S.M., 2008. Phosphate Rock, Mineral Commodity Summaries, U.S. Geological Survey.
- [60] Sánchez D., Gómez-Vargas R, Garrido M. Inoculación con bacterias promotoras de crecimiento vegetal en tomate bajo condiciones de invernadero. Revista Mexicana de Ciencias Agrícolas. 2012;3(7): 1401-15.
- [61] Poonguzhali S., Madhaiyan M., SA T. Isolation and Identification of Phosphate Solubilizing Bacteria from Chinese Cabbage and Their Effect on Growth and Phosphorus Utilization of Plants. Journal of Microbiology and Biotechnology. 2008; 18(4): 773-7.
- [62] Orberá T., Pérez I., Ferrer D., Cortés N., González Z. Aislamiento de cepas de Bacillus sp con potencialidades para la bioprotección y la estimulación del crecimiento vegetal. Rev Cub Quím. 2005; XVII(1): 189-95.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA



LABORATORIO DE MATERIALES
NANOESTRUCTURADOS
Y FUNCIONALES

Synthesis and characterization of a nanostructured composite for its potential application as a fuel additive.

Jaime Moroni Mora Muñoz.

Laboratorio de materiales nanoestructurados y funcionales, Facultad de Ingeniería.
Universidad Autónoma de Querétaro.
Querétaro, México
j.m.37295@gmail.com

K. Esquivel.

Laboratorio de materiales nanoestructurados y funcionales, Facultad de Ingeniería.
Universidad Autónoma de Querétaro
Querétaro, México

Abstract—Multi-wall carbon nanotubes (MWCNTs) with a typical diameter of 5-20 nm have been superficially functionalized using an acid hydroxylation reaction and decorated with metallic nanoparticles (Co and Fe) through a chemical deposition assisted with sonochemistry. TEM demonstrates the structural comparison between un-functionalized MWCNTs and the hydroxylated MWCNTs, and the dispersion of the metallic nanoparticles reinforcement. Raman spectra shows the typical peaks for graphene-based materials and a shift in them that indicates an intermolecular interaction between the matrix and the reinforcement of out nanocomposite.

Keywords—Multi-wall carbon nanotubes; Nanocomposite; Metallic nanoparticles; Hydroxylation; Raman; TEM; Nanostructured additives.

I. INTRODUCTION.

In recent years there has been a crescent interest in the use of alternate fuels in the generation of energy. Despite this fact, the use of fuels coming from oil will continue at least for the next 10 years. Regarding this problematic it is born the necessity to increase the performance of the fuels used nowadays and to compensate the deficiencies of the next generation biofuels. Some of the properties that are meant to be modified are the ignition temperature, emission of pollutants and the cetane content that propitiates a short ignition time, and the lower operation noise. [1]

Some of the limitations that had prevented the new generation fuels from positioning as some of the most used fuels in the energy generation industry are focused into two main problems. The first resides in the fact that there exists a top in the quantity of oil crude available in the world. The second is related with the emissions of pollutants that are released to the ambient and can be harmful to the population. A good example of these are the nitrogen oxides (NO_x), carbon monoxide (CO) and polycyclic aromatic hydrocarbons. [2]

To reduce these pollutants emissions and increase the performance of fuels, it is necessary to seek ways to optimize the combustion reaction of the fuels used. [3] This optimization can be achieved through two main approaches, the addition of a

new generation fuel such as ethanol, biodiesel, etc. to create a blend and the use of additives to enhance the combustion properties of the fuel. [4]

The present work is part of a program that aims to evaluate the use of nanostructures as additives for different fuels to enhance their combustion properties and to reduce the emissions they generate during their consumption. Here we discuss the synthesis and characterization of two nanocomposites with potential application as fuels additives. The composite matrix is carbon based in its multi-wall carbon nanotube (MWCNT) allotropic form. [5] The matrix is hydroxylated and doped with metallic nanoparticles (Iron and cobalt). [6] We illustrate the effects on the physical structure of the MWCNTs using TEM as well as the nanoparticulate distribution. [7] Raman spectroscopy was used to confirm the functionalization of the MWCNTs and to confirmed that the metallic species are present in the composite. [8]

II. EXPERIMENTAL.

A. Surface functionalization.

Three grams of MWCNTs (Sigma-Aldrich) were dissolved into 150 ml of nitric acid (HNO_3) at 68 vol%. This solution was then heated to 120°C for 5 hours and then cooled to room temperature. The product obtained was filtered and dried at 60°C in a convection oven for 12 hours.

B. Deposition of the metallic nanoparticles.

The deposition was achieved through a chemical reduction using as precursor salts of the metallic nanoparticles: iron sulfate heptahydrate ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ - Sigma Aldrich) and cobalt acetate tetrahydrate ($\text{Co}(\text{CH}_3\text{COO})_2 \cdot 4\text{H}_2\text{O}$ - Sigma Aldrich). The reduction agent used was sodium borohydride (NaBH_4 - Sigma Aldrich). A 100-ppm dissolution of the correspondent precursor salt for each nanocomposite was stirred for 20 min. Immediately after we obtain the homogeneous dissolution, we incorporate 0.5 g of hydroxylated carbon nanotubes (MWCN-OH) in the dissolution. Later it is removed from stirring and an ultrasonic homogenizer (Hielscher Up200Ht) is used to obtain a high



dispersion of the functionalized carbon nanotubes. Afterwards we add 10 ml of a 0.01 M of NaBH_4 dissolution to the salt-MWCNT-OH solution and it is stirred for an hour without any source of light inciting in it. The resulting blend is taken out from stirring and dried in a convection oven at 60°C for 12 hours. When retired from the oven, a size reduction process is done with the resultant of a sheer powder.

C. Characterization.

A structure comparison between the synthesized nanocomposites and its untreated matrix has been carried out by transmission electron microscopy (TEM) using a JEOL JEM-1010 (Tokyo, Japan), operating at a voltage of 200 kV. The Raman spectra were obtained using a LabRAM HR equipment (Horiba Scientific Kyoto, Japan), which used an NdYGA laser ($\lambda=532$ nm).

III. RESULTS AND DISCUSSION.

The effects on the MWCNTs structure due to the functionalization and the dispersion of the metallic nanoparticles has been studied by TEM. The resulting images selected for the analysis shown in figure 1 shows the characteristic structure of the carbon nanotubes with a central tube diameter of 5-30 nm. The images from the materials functionalized through the hydroxylation reaction, Fig. 1. (b), (c) and (d), indicate that the

MWCNT structure is not disrupted and the multiple layers intact. In the images Fig.1 (c) and (d) shows clearly nanoparticles deposited on the functionalized carbon nanotubes with high dispersion and in low concentrations with a particle diameter of 10 -20 nm.

The Raman spectroscopy's results of the multi-wall carbon nanotubes, the hydroxylated MWCNTs and those doped with metallic nanoparticles are shown in Figure 2. The Raman spectra for all the samples are almost identical but at different intensities. The disorder peaks (D) displays at approximately 1330 cm^{-1} Fig. 2 (A) and the graphite peaks (G) at approximately 1580 cm^{-1} . These two peaks are characteristic for of graphene-based carbon material. The next two peaks Fig. 2 (C) and (D) displayed at 2700 cm^{-1} and 2930 cm^{-1} correspond to the D' and G' peaks. The last peak fig.2 (E) only appears in the functionalized multi-wall carbon nanotube doped with iron (MWCNT-OH-Fe) spectra at 3220 cm^{-1} . This peak could be interpreted as a vibration of the iron nanoparticles; however, the intensity is not high enough to reassure the presence of the nanoparticles and can be related to the low concentration dispersed in the matrix.

A shift is presented in the disorder peaks and the graphite peaks of the MWCNT-OH-Fe and the MWCNT-OH-Co, this can be the result of a change in the interparticle interactions on

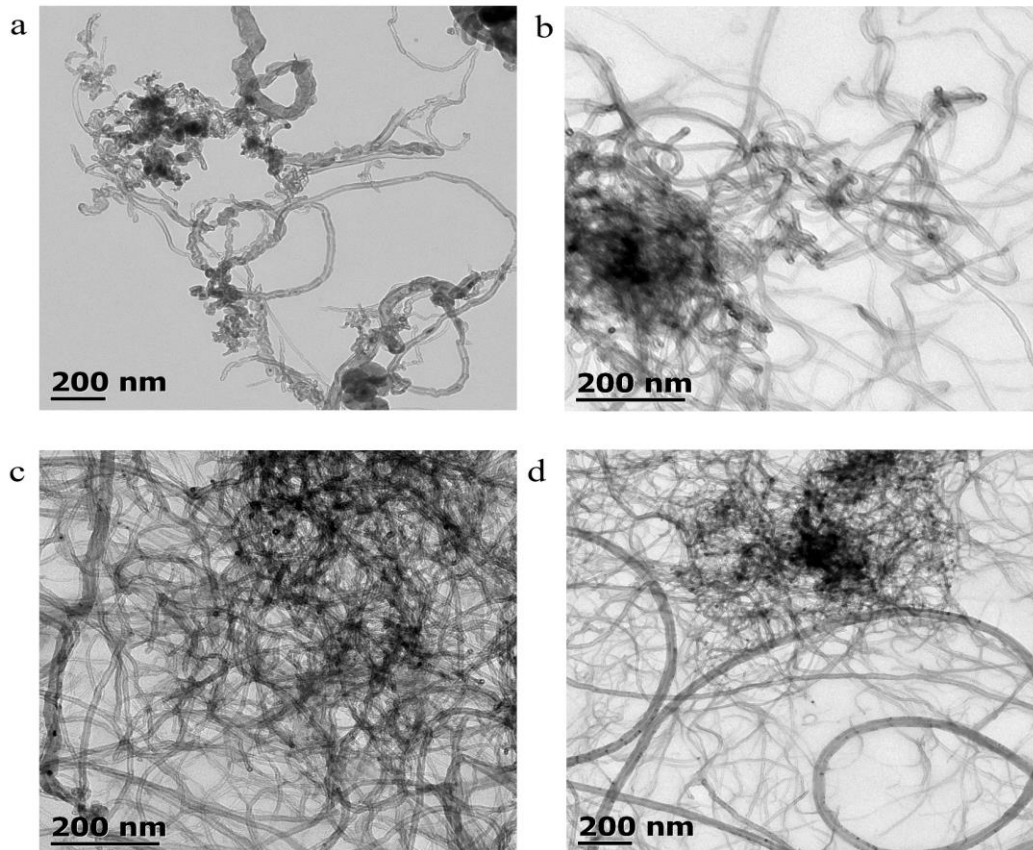


Fig. 1. TEM images of MWCNTs (a), hydroxylated MWCNTs (b) and decorated with Co (c) and Fe (d) MWCNTs-OH.

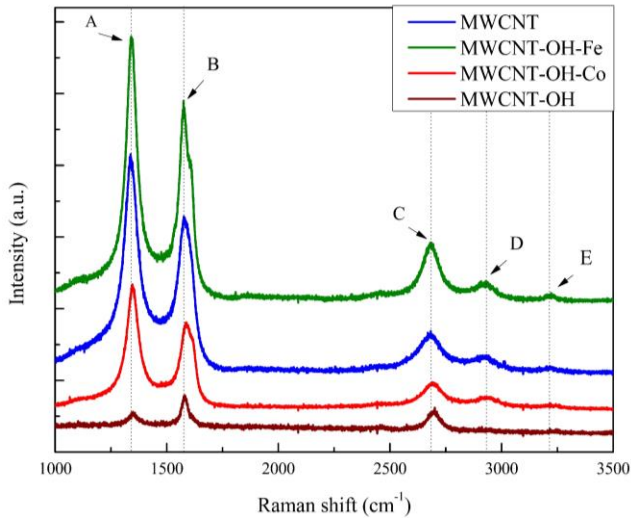


Fig. 2. Raman spectra from: MWCNTs, hydroxylated MWCNTs and decorated (Co and Fe) MWCNTs-OH showing A (1330 cm^{-1}), B (1580 cm^{-1}), C (2700 cm^{-1}), D (2930 cm^{-1}) and E (3220 cm^{-1}).

the vibrational spectra in the material. This is another indicative of the presence of the metallic nanoparticles as this shift represents a modification of the chemical bond of the MWCNTs owed to an interaction with an external force exerted by the reinforcements of the synthesized nanocomposite. It is necessary to do a further characterization of the nanocomposites to determine more accurately the presence of the metallic nanoparticle reinforcement and the crystallin phase in which they are present in the material.

IV. CONCLUSIONS.

The TEM images demonstrate that the MWCNTs structure is not disrupted or damaged during the hydroxylation process, also it shows there is no surface deformation or contamination. It also illustrates the high dispersion of the metallic nanoparticulate, as well as its low concentration presence in the nanocomposite.

The Raman spectra of the synthesized nanocomposites are a good indicative of the presence of the metallic reinforcements (Co and Fe) as it presents a shift in the representative peaks which indicates a modification in the bond length due to an interaction with an external force.

It is necessary to make a complementary analysis of the nanocomposites to determine more of their chemical and physical properties. The suggested technics to clarify the

composition and properties of the composites are: Infrared Spectroscopy (IR-spectroscopy) to confirm the hydroxylation of the MWCNTs and if it exists Van der Waals forces between the MWCNTs and the metallic nanoparticles, X-Ray diffraction (XRD) to confirm the presence of the metallic nanoparticles and the crystallin phase in which they are present, and X-ray photoelectron spectroscopy (XPS) to know the elemental composition of the nanomaterial synthesized. The synthesized nanocomposites are suitable for its application as fuel additives due to its oxygen content that will allow a better oxygenation of the fuel as well as the metallic nanoparticles reinforcement will enhance the combustion properties of the fuel.

ACKNOWLEDGMENT.

The authors gratefully acknowledge the financial support of the UAQ and project PRODEP-FIN201638 and thank Dr. Luis Escobar Alarcon from ININ for the Raman analysis and Q.F.B. Lourdes Palma Tirado of laboratory of Microscopy in CEFATA Querártaro, Qro. for the TEM imaging.

REFERENCES.

- [1] B. R. Moser, "Biodiesel production, properties, and feedstocks", *In Vitro Cell.Dev.Biol.—Plant*, vol. 45, pp. 229-266, 2009.
- [2] A. Guarieiro, J. Santos, A. Eiguren-Fernandez, E. Torres, G. da Rocha, and J. Andrade, "Redox activity and PAH content in size-classified nanoparticles emitted by a diesel engine fuelled with biodiesel and diesel blends *Fuel*, vol. 116, pp. 490-497, 2014.
- [3] H. Venu, and V. Madhavan, "Effect of Al_2O_3 nanoparticles in biodiesel-diesel-ethanol blends at various injection strategies: Performance, combustion, and emission characteristics *Fuel*, vol. 116, pp. 490-497, 2016.
- [4] A. Fayyazbakhsh, and V. Pirouzfar, "Comprehensive overview on diesel additives to reduce emissions, enhance fuel properties and improve engine performance", *Renewable and Sustainable Energy Reviews*, vol. 74, pp. 891-901, 2017.
- [5] A. El-Seesy, A. Abdel-Rahman, A. Bady, and S. Ookawara, "Performance, combustion, and emission characteristics of a diesel engine fueled by biodiesel-diesel mixtures with multi-walled carbon nanotubes additives", *Energy Conversion and Management*, vol. 135, pp. 373-393, 2017.
- [6] V. Saxena, N. Kumarb, and V. Kumar Saxena, "A comprehensive review on combustion and stability aspects of metal nanoparticles and its additive effect on diesel and biodiesel fuelled C.I. engine", *Renewable and Sustainable Energy Reviews*, vol. 70, pp. 563-588, 2017.
- [7] R. H. Bradley, K. Cassity, R. Andrews, M. Meier, S. Osbeck, A. Andreu, and C. Johnston, "Surface studies of hydroxylated multi-wall carbon nanotubes", *Applied Surface Science*, vol. 258, pp. 4835-4843, 2012.
- [8] S. Kanga, D. Yina, X. Li, and J. Mu, "High catalytic activity and selectivity for hydroxylation of benzene to phenol over multi-walled carbon nanotubes supported Fe_3O_4 catalyst", *Colloids and Surfaces A: Physicochem. Eng. Aspects*, vol. 384, pp. 363-367, 2011.



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Evaluation of recycled acrylonitrile-butadiene-styrene/polycarbonate copolymer (ABS/PC) pelletized as fine aggregate in concrete mixtures.

Christopher Garza Calleja
Universidad Autónoma de Querétaro
Faculty of Engineering, Civil Engineering, UAQ
Querétaro, México
chrisgarzaca@gmail.com

Misael de Jesús Vázquez Flores
Universidad Autónoma de Querétaro
Faculty of Engineering, Civil Engineering, UAQ
Querétaro, México

misael.vzq@gmail.com

Carlos Guillermo de Hoyos Gallegos
Universidad Autónoma de Querétaro
Faculty of Engineering, Civil Engineering, UAQ
Querétaro, México
Memo.dhg@gmail.com

Abstract— Our work evaluates the possibility of introducing polycarbonate / acrylonitrile butadiene styrene (PC / ABS) recycled and pelleted as a fine aggregate material in concrete mixtures, for its use and decrease in the environmental effects of water bodies and subsoil, generated by the inadequate final disposal of this, likewise decreasing the demand for raw materials. The 10, 20, 30 and 40% by volume of the fine aggregate was replaced by the pelletized polymer in the mixtures, performing three tests for each percentage of inclusion and three of unmodified concrete, 15 in total. The evaluation was carried out with laboratory tests, mechanical resistance tests. The measurements of the specimens were cylinders 10 cm in diameter and 20 cm in height.

After testing the cylinders, the data of each tested cylinder was captured and the results of each group were compared with different percentage of PC / ABS as fine aggregate.

All specimens containing PC / ABS had a lower strength than unmodified concrete, but the resistance increased as the percentage increased. Anomalous values were obtained in 30%, because the resistance decreased inexplicably, so it is recommended to perform the same type of tests but with a range between 20% and 40%..

Keywords— Aggregates, concrete, polymers, recycling.

I. INTRODUCTION

The protection of the environment and natural resources is one of the most outstanding concerns of contemporary society worldwide, so the recycling of materials arises as an option that involves benefits of ecological improvement in the reduction of the volume of waste and pollution, as in the conservation of

natural resources [Méndez, 2013]. In India, research was conducted on the use of waste products in concrete, each waste product provided by a specific element on the properties of the concrete, which can also help reduce the problems of waste disposal [Siddique et al. 2008].

In 2011, the National Association of the Chemical Industry reported a national production of synthetic resins of 3.2 million tons and an apparent national consumption of 5.3 million tons. Likewise, the National Association of the Plastic Industry reports that in Mexico only 15% of the total is recycled [ANIPAQ, 2011]. Plastic as solid waste is a large part of the total waste that has become a global environmental concern [McCarthy, 1993; Al-Salem et al., 2009].

The small bags generate an environmental impact due, mainly, to factors such as their low density that causes a greater effect than the other materials, and their resistance to degradation that allows them to last for a long time in the final stage of their disposal, also by the presence of additives added to plastics from their synthesis to their transformation to improve and modify their properties [CIQA, 2013].

In Colombia, using recycled polyethylene terephthalate (PET) as a fine aggregate in a research, he concluded that it is possible to use recycled PET in mixtures of mixtures and mixtures that require resistance [Zúñiga, 2015].

In Iraq, they introduced plastic waste in different proportions into concrete mixtures for analysis and demonstration that reduce the spread of alternate microcracks, as well as ensuring the reuse of waste plastic as well as sand in concrete. a good approach to reduce the cost of materials and solve solids problems posed by plastics [Ismail, 2008].





Polycarbonate acrylonitrile butadiene styrene (PC-ABS) is one of the most widely used materials in the thermoplastics industry. This material offers most of the desirable properties of the materials of which it is composed (PC and ABS), the mechanical properties and the heat resistance. Very used in the automotive industry, electronics and telecommunications applications [UNDO Prototypes, 2015].

In Jordan, a study addressed the problem of waste generated in construction fields, such as demolished concrete, glass and plastic. To eliminate or eliminate this waste less, they proposed to reuse some of these waste materials to replace a percentage of the primary materials used in the concrete. Plastics, molds and glass were used to replace up to 20% of fine aggregates in concrete mixtures, while crushed concrete is used to replace up to 20% of coarse aggregates. They were evaluated and the main results revealed that the three types of waste materials could be successfully reused as partial substitutes of fine and coarse aggregates in concrete mixtures [Batayneh et al, 2006]

Our study addresses a method of sustainable use of residual PC / ABS, which is its inclusion (pelletizing) in concrete mixtures as part of the fine aggregate to establish, by means of a compression of the concrete cylinders made with inclusion percentages of the new aggregate, if it is feasible to use it in concrete, contrasting the results with those of the unaltered concrete and if it is the case of a behavior similar or very similar to the unaltered concrete, obtain an inclusion percentage that can improve the performance, for such as reducing the accumulation of PC / ABS generated in Mexico and reducing the use and inclusion of new raw materials used in concrete mixtures. The evaluation was carried out by means of compression tests on the universal machine.

II. THEORETICAL FRAMEWORK

Given that the central focus of this research will be based on the use of Polycarbonate and Acrylonitrile Butadiene Styrene (PC / ABS) pelletizing as an alternative of fine aggregate in concrete mixtures, it is fundamental to understand the importance and importance of concrete as a construction material, as well as the impact that PC and ABS polymers have on our environment and the properties of these, which allow us to be suitable for construction.

On the other hand, we must also address technical concepts which are broken down in the present work, likewise, it will be necessary to propose mechanical tests in the laboratory that serve as conceptual axes on which the research is based.

The resistance to low and high temperatures, permeability, hermeticity, as well as the resistance, durability and versatility allow that the concrete is one of the most competent construction materials, besides its reasonable cost allows it to be the most used construction material and with more transcendence at the international level.

Having said that, we must emphasize a property that has concrete, which we have not mentioned previously, but it is vital for our research, and it is the Workability, it is this property that allows us to add a series of different materials and / or additives to it and that the resulting mixture possesses the physical and mechanical properties that were sought when adding the additives.

Our research focuses on the use of Acrylonitrile Butadiene Styrene (ABS) and Polycarbonate (PC) as additives to a mixture of concrete, both polymers have properties that will contribute to improve the performance and mechanical properties of concrete.

Acrylonitrile butadiene styrene (ABS) is able to withstand high temperatures without losing physical, chemical and mechanical properties, has an excellent chemical resistance, which reduces the possibility of softening or deformation of it when mixed with some other chemical compound, the hardness surface and impact resistance, make ABS an excellent alternative for use in construction.

Similarly, polycarbonate has properties that make it attractive for use in this industry, the PC is one of the polymers with better impact resistance, has a high resistance to thermal deformation extremely high blows, a high level of stability dimensional and is also resistant to moisture.

To verify the performance and optimization of the properties of the new mixture, various compression load resistance tests were performed in a universal press. The use of these two materials in concrete is not only based on the possibility of improving the properties of this, but also on the environmental impact because the large volumes of both plastics become harmful to our environment.

III. METHODOLOGY

A. Test tube design

The characterization of the materials and the adequate proportioning (Figure 1, A, B) of these for the concrete was carried out, which was designed with a compressive strength (f_c) of 250 kg / cm², and a formulation was proposed. experimental, where PC / ABS was used from recycled and pelleted material of standardized size (Figure 1, C) so that it could be used as part of the fine aggregate in the concrete mixes.



Figure 1. A) Characterization and B) Proportion of the aggregates. C) PC/ABS.



B. Addition of the polymer

Once the design of the mixture was done, the PC / ABS was dosed replacing the 10, 20, 30 and 40% of the fine aggregates as experimental formulations (Figure 2, A), and the mixture of each formulation was prepared to later use the mold cylinders and obtain our test specimens, weighed, measured and calculated their densities (Table 1), when the curing conditions were fulfilled (Figure 3, A) defined by the complementary technical norms of the construction regulations of the Federal District (NTC-RC-DF), the mechanical properties of resistance to compression were verified.

Densities of concrete mixtures					
	Test tube	Volume (m3)	mass (Kg)	density (m3/Kg)	Average density
0%	1	0,001570796	3,3	2100,85	2088,11
	2	0,001570796	3,28	2088,11	
	3	0,001570796	3,26	2075,38	
10%	1	0,001570796	3,12	1986,25	2015,96
	2	0,001570796	3,27	2081,75	
	3	0,001570796	3,11	1979,89	
20%	1	0,001570796	3,12	1986,25	2013,84
	2	0,001570796	3,22	2049,92	
	3	0,001570796	3,15	2005,35	
30%	1	0,001570796	3,06	1948,06	2007,47
	2	0,001570796	3,3	2100,85	
	3	0,001570796	3,1	1973,52	
40%	1	0,001570796	3,04	1935,32	1905,62
	2	0,001570796	2,98	1897,13	
	3	0,001570796	2,96	1884,39	

Table 1. Densities of concrete mixtures.

C. Models of test

Five models of test specimens were made, four with the PC / ABS as an aggregate and one without this as a standard sample, to contrast the results of one with the other. The measurements of our specimens (cylinders) are 10x20 cm each (Figure 2, B).

Figure 2. A) Realization of the mixture B) Molds for the specimens.

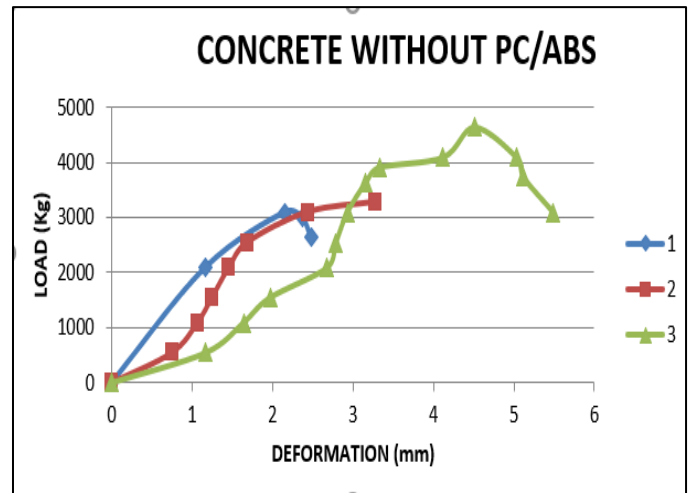
D. Assay of test tubes

The universal machine (Figure 3, B) of the Geotechnical, Materials and Geomatics laboratory of the UAQ Faculty of Engineering was used to perform the compression tests on the specimens, with the results of the tests carried out (Figure 3, C), neoprene pads were used to avoid having to use pitch with sulfur in the cylinders. The conclusions, shown later, on the mechanical and physical behavior of the altered concrete, were compared with the results of the concrete used as a sample pattern.

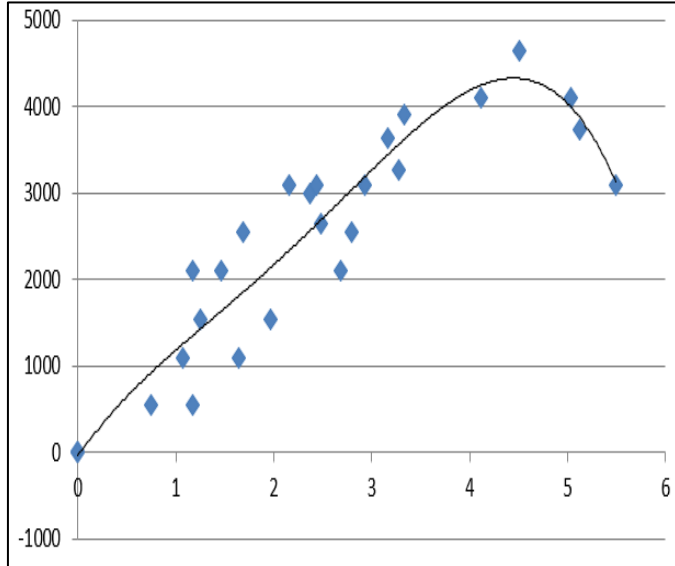
IV. RESULTS

After performing the mechanical tests in the laboratory, the results obtained are shown below. For the mechanical tests of compressive strength, the cylinders were tested in the universal machine of the FI UAQ, as in Figure 3.C, and the results of the tests are shown in load-deformation graphs [Graph 1 -10] comparisons between the behavior of the three cylinders with the same percentage of inclusion and another where a trend line was added which represents the "average behavior" of the specimens, this was done for each inclusion percentage.

Graph 1 shows the behavior of simple concrete samples. The graph describes the behavior of each of the samples without PC / ABS, with a low hardening by plasticity, and little elastic, this condition of the specimens is more noticeable in graph 2.



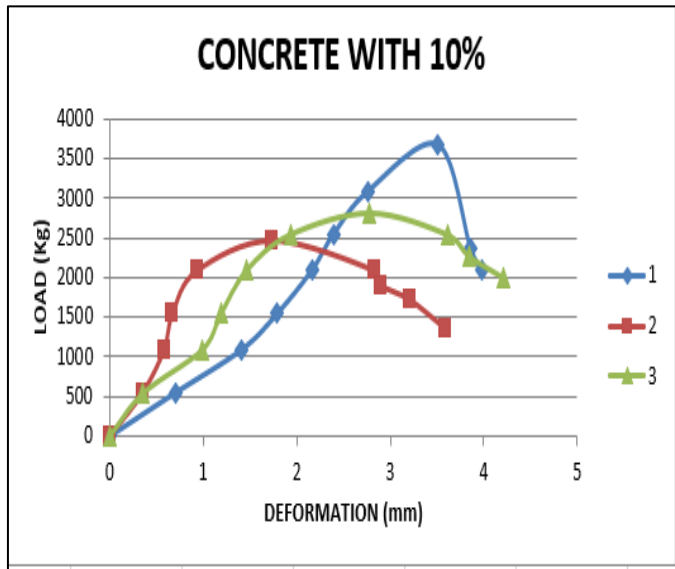
Graph 1. Behavior curves of the concrete without modification to compression, given by each specimen.



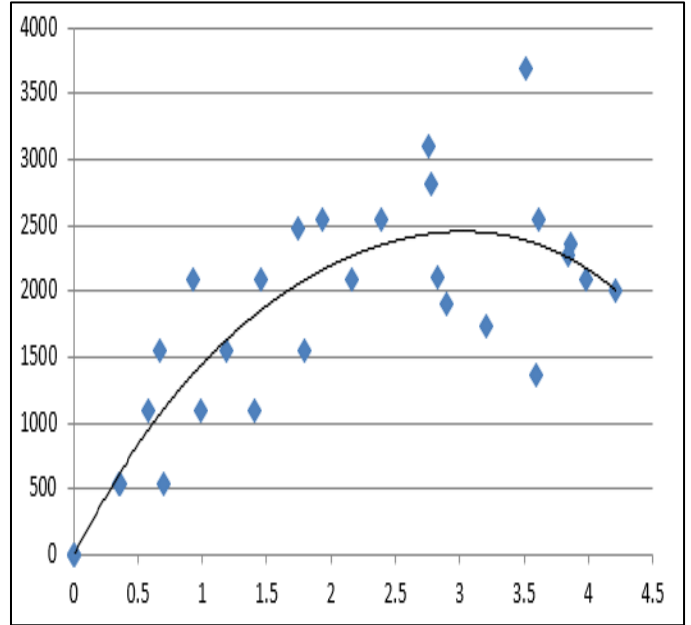
Graph 2. Behavior curve of the concrete without modification to compression, given in general.

On the other hand, in graph 3, the stress-strain curves of the cylinders tested with 10% of the PC / ABS polymer are found, and there is an improvement in the plasticity of each of the cylinders tested.

In addition, in graph 4, a trend curve is presented in which the values obtained in the test (load-deformation) were used and the considerable increase in plasticity is noted, which means that the concrete does not fail as suddenly as the concrete without polymer.

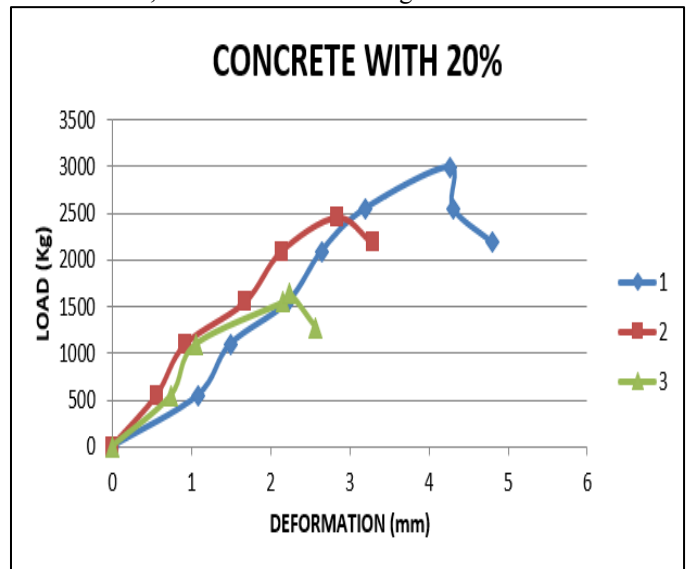


Graph 3. Behavior curves of concrete with 10% PC / ABS at compression, for each specimen.

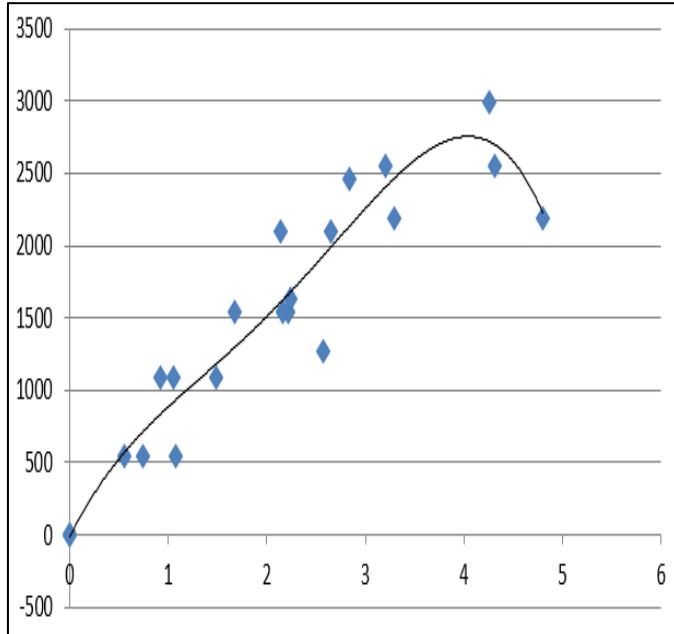


Graph 4. Behavior curve of concrete with 10% PC / ABS at compression in general.

Afterwards, the graphs corresponding to a percentage of 20% PC / ABS in the fine aggregates for the concrete mixture, graphics 5 and 6 were preceded, however, contrary to what one might expect, an increase to plasticity; the plasticity is observed to decrease in all the cylinders (graph 5). On the other hand, the proportional line of the beginning increased significantly, which could mean an increase in the elasticity of the concrete, can be seen in figure 6 more in detail.



Graph 5. Behavior curves of concrete with 20% PC / ABS at compression, for each specimen.

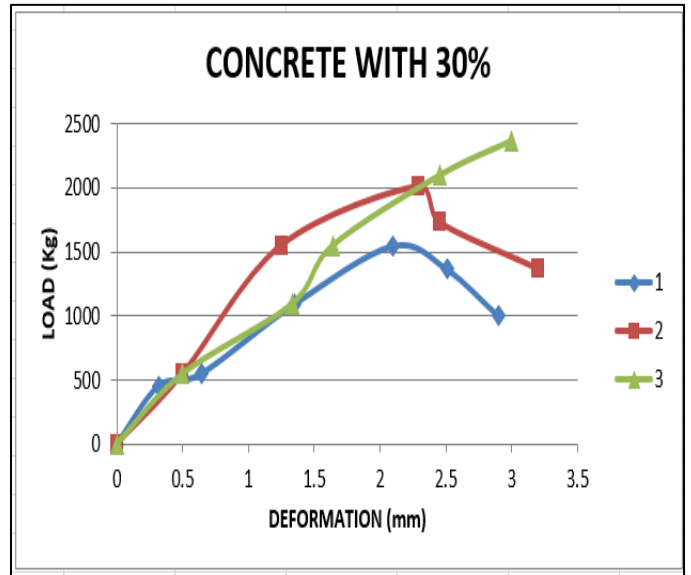


Graph 6. Behavior curve of concrete with 20% PC / ABS at compression in general.

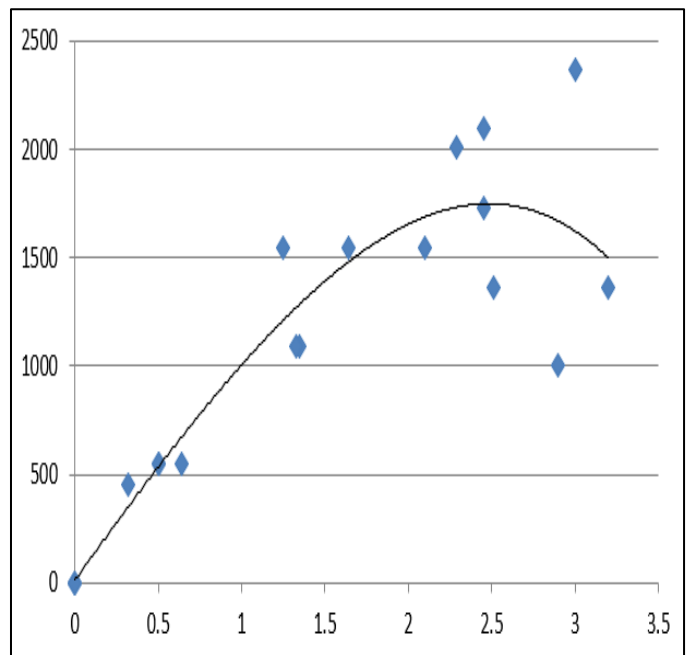
Tests were also carried out on concrete cylinders in which 30% of fine aggregates were replaced with PC / ABS polymer and the results were observed in graphs 7 and 8.

In graph 7, you can find the load-deformation curves of each of the cylinders tested, where you can see that the elements have an increase in the elastic part, or that seems because at the beginning of the test the cylinders behave in a proportional in relation to its load with the deformation that occurs in them.

In graph 8, a trend curve of all the results obtained is plotted and confirms what in figure 7 we concluded, the elasticity is benefited but the plasticity is still less than in graph 4, where 10% of the aggregate Fine is PC / ABS.



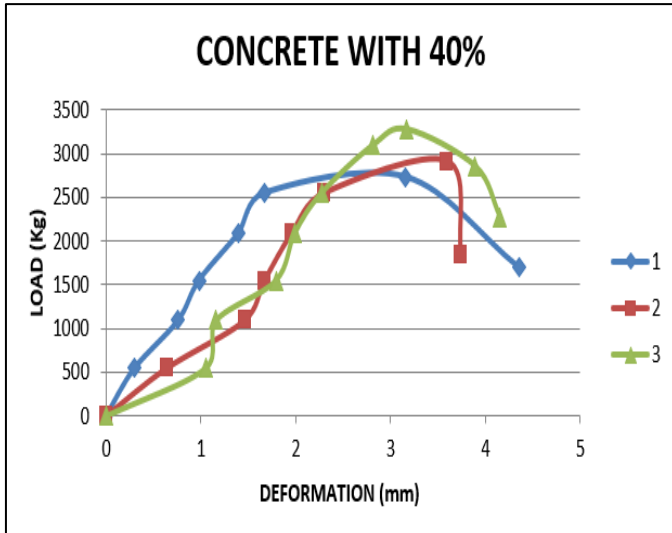
Graph 7. Concrete behavior curves with 30% PC / ABS at compression, for each specimen.



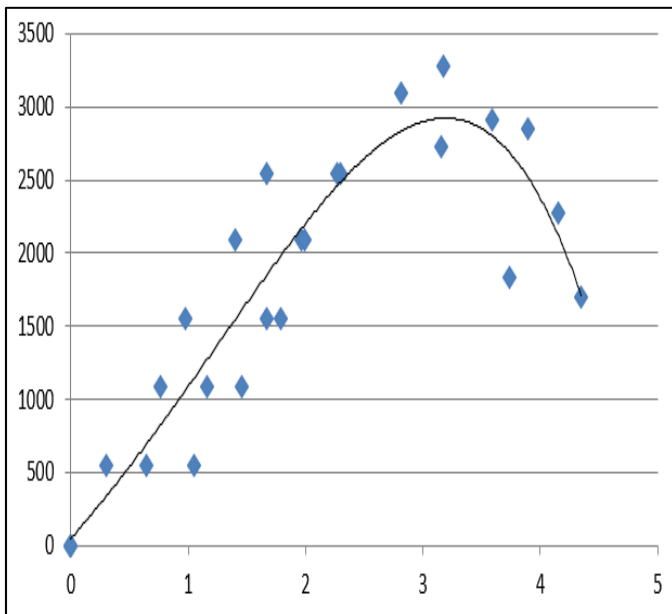
Graph 8. Concrete behavior curves with 30% PC / ABS at compression in general.

Finally, the last test that was carried out was replacing 40% of sand with PC / ABS. The results of each of the tests are shown in graph 9. Something notorious about these last cylinders is that they do not have an abrupt failure, besides that in the individual load-deformation curves of the cylinders there is plasticity and a slight creep over all between

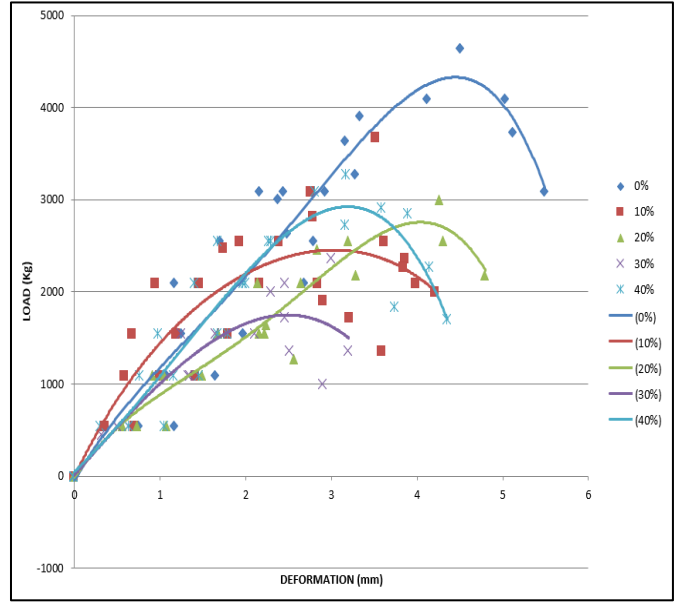
2500 and 3000 kg load. In addition, figure 10 shows that the trend curve has a well-defined elastic zone, a zone of prolonged plasticity, but does not have extensive fluency; on the other hand, it indicates that the concrete behavior is affected by increasing its plastic properties but without affecting the elastic properties.



Graph 9. Concrete behavior curves with 40% PC / ABS at compression, for each specimen.



Graphs 9 and 10. Concrete behavior curves with 40% PC / ABS at compression in general



Graph 11. Concrete behavior curves with different inclusion percentages of PC / ABS compression, comparison in general.

In Figure 11, each of the trend lines is compared with the different percentages of PC / ABS in substitution of the fine aggregates (0%, 10%, 20%, 30%, 40%) generated by the cylinder test. 10cm in diameter by 20cm in height.

In this graph (graph 11), it is observed that the unmodified mixture is the one that supports the highest load, however the plasticity is short compared to its elasticity.

Now, comparing the curve of the unmodified mixture with the curves of the modified mixtures, it is highlighted that the 40% PC / ABS curve (replacing sand) has a lower maximum load than the 0% PC / ABS mixture, without However, the plasticity of both is similar in terms of length, which indicates that despite a lower maximum load on the part of the 40% mixture, the plasticity is benefited significantly.



Figure 3. A) Curing of specimens B) Universal machine C) Cylinder test.

DISCUSSION

The question that was sought to respond with the research, seeks to discover the feasibility of using a recycled



PC / ABS pelletizer as a substitute for fine aggregate in a structural concrete mix.

The strength of the concrete is reduced, with the intrusion of PC / ABS as added. Although as the substitution percentage of the fine aggregate increases, the resistance increases.

In the study carried out in Colombia [Zúñiga, 2015], where the use of PET was considered as an addition to concrete, it was concluded that the use to be given to the concrete should be reviewed in specific cases, in the same way when finding that the resistance decreases it is necessary to evaluate the use that can be given to the concrete with PC / ABS.

Similarly, in Jordan, part of the aggregates was substituted for the concrete, reaching up to 20% of the aggregate [Batayneh et al, 2006], where it was successfully concluded that partial replacement of aggregates by recycled plastic is possible, with the PC / ABS is concluded in the same way that its use as a fine aggregate in concrete is possible.

Comparing the results of the sample pattern with the altered panel, speaking economically, are more expensive, since PC / ABS is a more expensive than traditional aggregates such as sand and gravel.

Ecologically it is much more feasible than conventional methods, since the impact produced by the PC and by ABS is reduced. It is also allowed to wear out the environment by including aggregates extracted from material banks.

It was found that with the increase of the substituted percentage it is proportional to the increase of the resistance, but in this case there is a probability that the data of the substitution of 30% of the fine aggregate, are anomalous data. This is because it is not consistent with the results of the tests on the other cylinders. For this reason it is recommended that another experiment be carried out where variations are made in the percentage of PC / ABS that goes from 20% to 40%, which are the intervals where the highest resistances were obtained.

On the other hand, from 120 ° C onwards, the polymer used starts to melt, which is not very feasible if the design of the work takes into account that a fire could occur at some point. In order to know the behavior, it is recommended that in the future a study be carried out with which the structural behavior that would obtain the concrete with PC / ABS subjected to high temperatures is known.

CONCLUSIONS

From the testing of the specimens, consistent results were obtained, as the percentage of PC / ABS was increased as a substitute for fine aggregate, the resistance obtained increased.

Although for future projects it is planned to make a larger number of samples or specimens by varying the inclusion percentages of the aggregate to obtain more results

and thus make a more accurate comparison, the range of variation will be lower (between 20% and 40%) but will be made more tests, as well as doing a more in-depth statistical analysis to find an optimal PC / ABS inclusion percentage in the mix.

Taking into account the ecological benefits of replacing, as part of the aggregate in concrete mixtures for structural use as proposed, the PC / ABS pelletized and ignoring the fact that pellets from 120 ° C begin to melt, This is a viable alternative, especially if considered from an ecological point of view.

It will be necessary to carry out more experiments with a single percentage of substitution of aggregates, either 20% or 40%, this to confirm the results obtained and continue comparing them with the normal concrete.

It is also proposed that a variation of the expected strength of the concrete be made to determine if it is possible to obtain high strength concrete by including PC / ABS as a substitute for fine aggregates.

In the end it was found that it is possible to use PC / ABS as a substitute for the fine aggregate of the concrete, but the tests were not enough to prove that it could be used structurally.

At the moment it is known that it can be applied in applications that do not require high resistance, such as walls, floors, sidewalks or castles.

REFERENCES

- [1] Al-Salem, S. M., Lettieri, P., and Baeyens, J. (2009). "Recycling and recovery routes of plastic solid waste (PSW): A review." *Waste Manage.* 29(10), 2625–2643.
- [2] Batayneh, M., Marie, I., and Asi, I. (2007). "Use of selected waste materials in concrete mixes." *Waste Manage.* 27(12), 1870–1876.
- [3] Choquechambi J., Cutisaca K., Quispe J. (2013) Informe de investigación presentado en cumplimiento parcial de tecnología de concreto. 5, 6. Juliaca, Perú.
- [4] Ismail, Z. Z., and Al-Hashmi, E. A. (2008). "Use of waste plastic in concrete mixture as aggregate replacement." *Waste Manage.*, 28(11), 2041–2047.
- [5] McCarthy, J. E. (1993). "Recycling and reducing packaging waste: How the United States compares to other countries." *Resour., Conserv. Recycl.*, 8(3–4), 293–360.
- [6] Méndez A. (2013) En el Día Mundial del Medio Ambiente: La apuesta tecnológica y sustentable en el reciclado de plásticos, CIQA. Recuperado de: <https://www.ciqa.mx/index.php/difusion-y-divulgacion/sala-de-prensa/175-la-apuesta-tecnologica-y-sustentable-en-el-reciclado-de-plasticos>
- [7] PC/ABS. (2015) UNDO Prototipos: Materiales. Recuperado de: <http://www.undoprototipos.com/es/materiales/pc-abs>
- [8] Zúñiga A. (2015) Evaluación del tereftarato de polietileno (pet) como agregado en la elaboración de mortero para ladrillos y concreto. 7,8. Bogotá, Colombia.
- [9] Siddique, R., Khatib, J., and Kaur, I. (2008). "Use of recycled plastic in concrete: A review." *Waste Manage.*, 28(10), 1835–1852.





Microalgae relation with nitrate and phosphate concentration in a lentic water body

Jarro-Castañeda Alexandra Edilibeth
Universidad Autónoma de Querétaro
Querétaro, México
Alexa.jarro@gmail.com

García-Trejo Juan Fernando; Félix-Cuencas Leticia;
Escamilla Axel; Cruz-Hernández Andrés
Universidad Autónoma de Querétaro
Querétaro, México
Juanfernando77@gmail.com; andrex1998@hotmail.com

Abstract— A temporary characterization of environmental variables with the composition of microalgal community was studied in Presa Centenario, Tequisquiapan, Querétaro, Mexico. The purpose of this was to identify the occurrence of specific groups of microalgae, and their relationship to the concentration of nitrate and phosphate in the body of water. In order to determine this, the following biological variables were taken into account: the concentration of chlorophyll-a, the application of ecological indices such as relative abundance and autotrophy/heterotrophy index. The identification of microalgae was carried out with taxonomic keys. Physicochemical variables of the water body, nitrates, phosphates and silicates were analyzed by UV-VIS spectrophotometry. The in situ measurements that were taken are as followed: pH, dissolved oxygen, transparency, and water temperature. As for the meteorological variables that were taken into account: precipitation, wind speed, and environmental temperature. Over the course of one year 24 samples were taken from six sampling points to cover different weather seasons. As a result of this project, the first inventory of freshwater microalgae identified by molecular markers for the State of Querétaro was generated. In addition, a distribution map of microalgal species according to the concentration of salts from water was created.

Keywords— (microalgae, environmental variables, nutrient concentration, limnology)

I. INTRODUCTION

Bodies of water are both affected by natural causes, as well as, by human activities. This is due to a number of causes. Among them are the lack of environmental regulations for industrial and domestic wastes, inadequate solid waste disposal and waste management difficult in agriculture. These sources have contributed to the raise of pollutants in water, limiting human or biological consumption. Organic compounds and species of inorganic chemistry in bodies of water can indicate ecosystem deterioration. Ecological management in bodies of water is of utmost importance to governments and researchers because the

results of these studies provide necessary measurements for management of aquifers, rivers and other bodies of water. These studies are also essential in order to reduce the risk of exposure to human populations, aquatic and terrestrial fauna and flora to toxic chemicals [1]. Some of the most common compounds found in industrial, agricultural, and domestic run off are nitrates and phosphorus.

On a biological level these compounds affect the growth, structure, composition, distribution, and function of a great diversity of organisms, including microalgae [2,3]. By using microalgae as bioindicators or biomarkers it allows researchers to monitor the physical and chemical changes in bodies of water [4]. Biomarkers Organizations dependent on environmental conditions, in consequence, any change in Environmental Conditions, you will see reflected in your presence, characteristics and distribution [5].

There several classes or types Biological Indicators, Sensors, batteries, operators and sentries. The detectors are developed in Specific areas, and their response to the variation in the average includes: changes vitality reproductive capacity, as occurs with epiphytic moss. The presence of algae is an indicator of eutrophication processes of water bodies [6].

That is why the aim of our work is to identify groups of microalgae and its relationship with the concentrations of phosphate (PO_4^{3-}) and nitrates (NO_3) in lentic water body.

II. MATERIALS AND METHODS

A. Study site

In Figure 1 the Presa Centenario is located in the southern part of the county Tequisquiapan in Querétaro state. It is located at an altitude between 1880 m and 1900 m, at latitude $20^\circ 39' 50''$ and longitude $99^\circ 50'$. The Presa Centenario, has a capacity of 10.15 million m^3 , the water from this reservoir comes from the San





Juan River, passing through the urban area of Tequisquiapan emptying into the Centenario Reservoir. Afterwards the water flows into Paso de Tablas Reservoir and into the Moctezuma River, located in the state of Hidalgo [7].

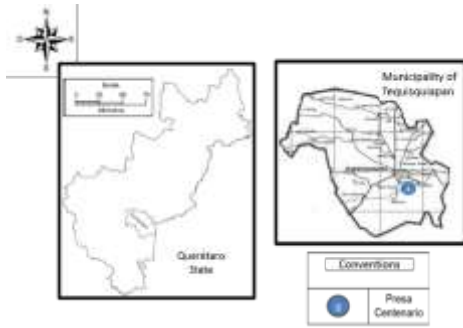


Fig 1. Diagram of location of the sampling site, Presa Centenario in Tequisquiapan, Querétaro [8].

B. Measurements and analysis

Sampling was carried out twice a month, with a total temporal sampling of 12 months in order to obtain variations in nutrient concentrations and speciation of microalgae due to seasonal or climatic variation. Field analysis and the collection of samples was performed according to the sampling proposed by CONAGUA and thus complemented by the continuity and water quality studies conducted in the Presa Centenario.



Fig 2. Diagram of Presa Centenario and the selection on sample points [9].

The physicochemical variables with the respective regulations measured in Presa Centenario, were: pH (potentiometer field, NMX-AA-008-SCFI-2011), dissolved oxygen (Potentiometer with membrane selective electrode, NMX-AA-012-SCFI-2001), temperature (Electrode potentiometer or thermometer, NMX-AA-007-SCFI-2013).

The concentration of each nutrient, nitrates, phosphates, and silicates, in water samples collected were analyzed by colorimetry and spectrophotometry UV-Vis.

Identify applicable sponsor/s here. If no sponsors, delete this text box (sponsors).



For the collection of microalgae, a 35 µm phytoplankton mesh was implemented. In addition to identification by microscopy, several taxonomic keys listed below were used. (Table 1.)

Book/Key	Autor	Year	Entity/editorial
El Plancton de las aguas continentales	Aída González de Infante	1988	OEA
Atlas de los microorganismos de agua dulce: la vida en una gota de agua.	Streble, Heinz; Krauter, Dieter.; Rieradevall, Maria.	1987	OMEGA
Guía para el estudio de los seres vivos de las aguas dulces.	Needham, J.G.; P.R. Needham	1982	REVERTÉ
A manual of the freshwater algae in North Carolina, United States	L A Whitford; G J Schumacher	1969	North Carolina Agricultural Experiment Station.
Identification of freshwater diatoms from live material	Eileen Cox	1996	Chapman & Hall, London

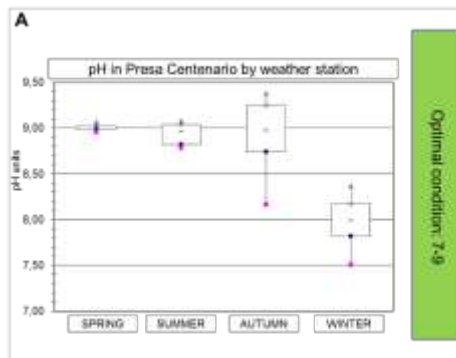
To determine the seasonal distribution of microalgae, ecological indices were conducted measuring the diversity [10], and autotrophy/heterotrophy index [11]. In addition monthly reports published by CONAGUA of the meteorological measurements were used. After all the data was collected principal component analysis and Pearson model of linear correlation were used to evaluate statistically. Posteriorly, a microalgal distribution map by species, was created according to the concentration nutrient medium.

III. RESULTS

A. Results of measurements made

We performed ten samples during one year contemplating the four climatic seasons of the year, the results are presented by weather seasons. All results are presented as the maximum value ± standard deviation and minimum value ± standard deviation for each climatic season.

Following show the results obtained for each in situ analysis in the Presa Centenario (Figure 3a.b.c.d.).



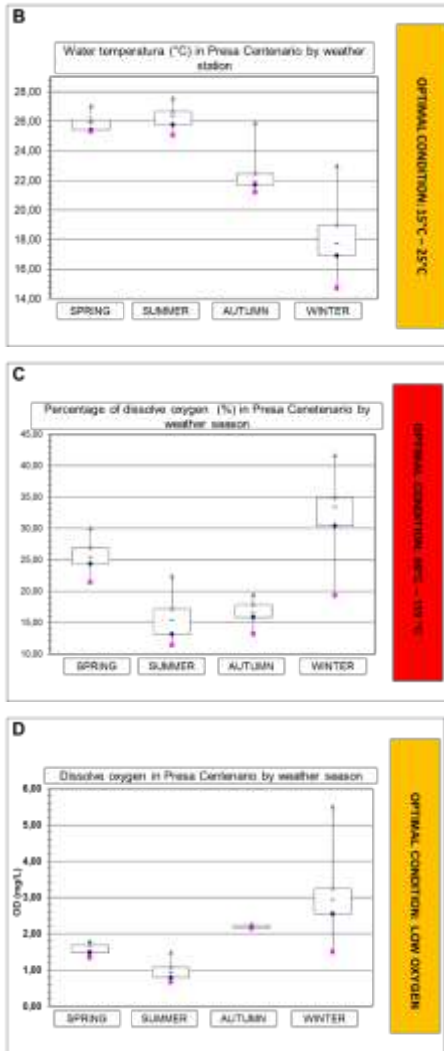


Fig 3. Insitu values in water bodie by weathr station

The figure A, show us the pH behavior throughout the year in the water body. Spring: 9.07 ± 0.11 and 8.96 ± 0.19 ; Summer: 9.08 ± 0.23 and 8.78 ± 0.03 ; Autumn: 9.33 ± 0.23 and 8.17 ± 0.14 ; Winter: 8.37 ± 0.01 and 7.51 ± 0.04 . Thus we can deduce that the contrasting climatic seasons for pH are spring-summer (higher pH values) vs. winter (lower pH values). The figure B,

show us the water temperature Spring: 27.03 ± 6.42 and 25.30 ± 3.00 ; Summer: 27.57 ± 1.17 and 25.07 ± 2.65 ; Autumn: 25.95 ± 4.31 and 21.20 ± 1.70 ; Winter: 23.00 ± 0.10 and 14.70 ± 0.36 . We can see that for the case of temperature contrasting seasons are summer (higher temperature values) vs winter (lower temperature values). The figure C, show us the percentage of oxygen dissolve in the water body, Spring: 30.07 ± 10.34 and 21.37 ± 3.19 ; Summer: 22.47 ± 4.25 and 11.40 ± 8.84 ; Autumn: 33.12 ± 4.64 and 20.50 ± 0.28 ; Winter: 34.97 ± 0.64 and 19.27 ± 0.35 . For the percentage (%) of dissolved oxygen, the contrasting seasons are winter (values of % dissolved oxygen higher) vs. summer (values of % dissolved oxygen lower). The figure D, show the dissolve oxygen behavior in the Presa Centenario, Spring: 1.80 ± 0.69 and 1.33 ± 0.15 ; Summer: 1.50 ± 0.40 and 0.67 ± 0.40 ; Fall: 2.34 ± 2.31 and 2.04 ± 2.18 ; Winter: 5.50 ± 0.10 and 1.50 ± 0.10 . For the dissolved oxygen concentration (mg/L), the contrasting seasons are winter (values of dissolved oxygen (mg / L) higher) vs. summer (lower dissolved oxygen values (mg / L)).

The results obtained from silica, phosphates and nitrate analyzes of the Presa Centenario are presented below, noting that these are theoretically the limiting nutrients for the establishment of microalgae communities in water bodies or ecosystems are present (figure 4.).

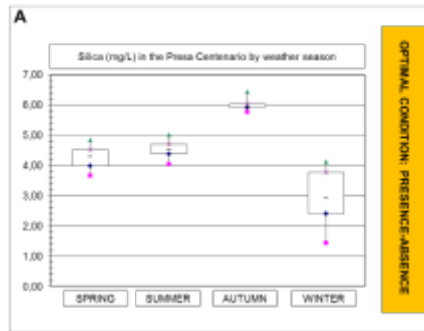


Fig 4. Levels of silica in water bodie by weathr station

In the part A, we show us the silica concentration, Spring: 4.84 ± 0.16 and 3.66 ± 0.79 ; Summer: 5.01 ± 0.05 and 4.04 ± 0.06 ; Autumn: 6.43 ± 0.50 and 5.76 ± 0.53 ; Winter: 4.12 ± 0.008 and 1.43 ± 0.003 . The contrasting seasons are autumn (higher values of silicates (mg/L)) vs. winter (lower values of silicates (mg / L)). The silicates were analyzed because some microalgae (diatoms specifically) depend on the presence of this in the medium to be established, so for all climatic seasons we will find diatoms in different proportion, according to the concentration presented.



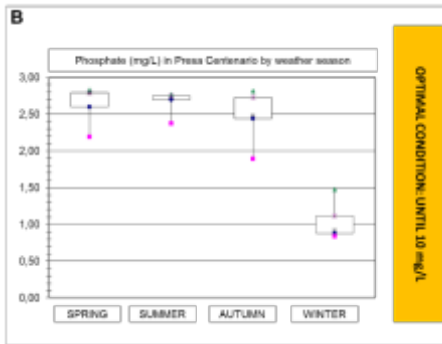


Fig 5. Levels of phosphate in water body by weathr station

The figure B, show us the phosphate concentratio, Spring: 2.83 ± 0.49 and 2.19 ± 1.20 ; Summer: 2.77 ± 0.05 and 2.37 ± 0.09 ; Autumn: 2.82 ± 0.38 and 1.89 ± 0.78 ; Winter: 1.48 ± 0.002 and 0.83 ± 0.001 . For the phosphate concentration (mg / L), the contrasting seasons are spring-autumn (higher phosphate values (mg / L)) vs. winter (lower phosphate values (mg / L)). This nutrient is considered limiting for the establishment of microalgae, and the concentration presented in the body of water favors the establishment of some specific species or groups of microalgae, having as maximum limit bearable by microalgae 10 mg / L.

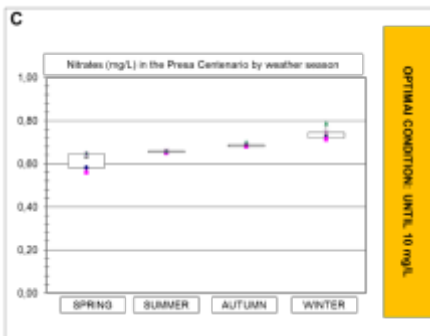


Fig 6. Levels of nitrate in water bodie by weather station

In figure C, we show us the behavior of nitrate concentration in Presa Centenario, Spring: 0.65 ± 0.01 and 0.56 ± 0.15 ; Summer: 0.66 ± 0.01 and 0.65 ± 0.06 ; Autumn: 0.70 ± 0.01 and 0.68 ± 0.01 ; Winter: 0.79 ± 0.002 and 0.71 ± 0.002 . For the concentration of phosphates (mg/L), the contrasting seasons are winter (higher nitrate (mg/L) values) vs spring (lower nitrate values (mg/L)). Despite being one of the limiting nutrients for the establishment and growth of microalgae, there is little difference in reported concentrations of nitrates (mg/L) in the centennial

prey by climatic seasonality, microalgae tolerate up to 15 mg / L of nitrates in The medium, however this low concentration implies that some groups of microalgae, do not appear in the body of water.

B. Identification of microalgae in the Presa Centenario, by taxonomic identification keys of algae species

Five groups corresponding to Cyanophyta, Chlorophyta, Charophyta, Heterokontophyta and Cynobacteria were identified. Of these groups, Chlorophyta was the one that presented a greater number of families and species, being found eleven families and sixteen species; followed by the Cyanobacteria group with nine families and eight species. The other groups presented a smaller number of families and species. Thus for the Heterokontophyta divisions, eight families and eight species were recorded, four species were recorded for Charophyta and four species were identified, and finally the Cyanophyta group presented two families and two species.

The Heterokontophyta group are the most abundant for the season "Spring", while for the second station sampled "Summer", the most frequently encountered are the group Cyanophyta, for the autumn season the group that prevailed was Chlorophyta, as well as for the winter weather station. The cumulative percentages of distribution of microalgae groups for each climatic season (Figure 7).

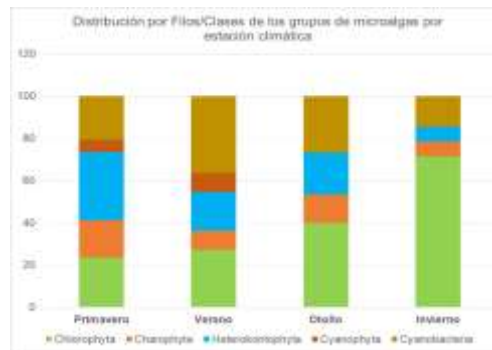


Fig 7. Microalgae class distribution by weather station

In spring were found 36 species distributed in the different edges, being this time the one of greater abundance of microalgae; For the summer season 22 species; For the autumn season 16 species; And finally the winter season where 15 species of microalgae were found, being this the climatic season of smaller abundance of microalgae.





IV. CONCLUSIONS

In the determination of the seasonal distribution of algal groups by Autotrophs index: The following is the data obtained from the relationship between chlorophyll-a and ash-free dry weight, measured as an autotroph index, where values between 0 and 200 also show poor water quality. Presented by means of colors in which the green color represents "Good quality" and are values less than 50, the yellow color "moderate quality" are values between 50 and 500 and the red color "poor quality" in the body of water are values Exceeding 500 (Figure 8.).

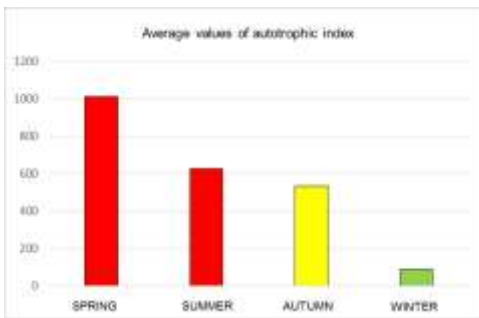


Fig 8. Values of autotrophic index in Presa Centenario by weather station

C. Correlation analysis between PO_4^{3-} and NO_3^- concentrations with abundance and distribution of algal groups identified in the Presa Centenario

We use the principal component analysis (PCA) for determine the physicochemicals variables that directly affect in the biological variables (microalgae), the variables that most influence are pH, phosphate, percentage and concentration of dissolve oxygen.

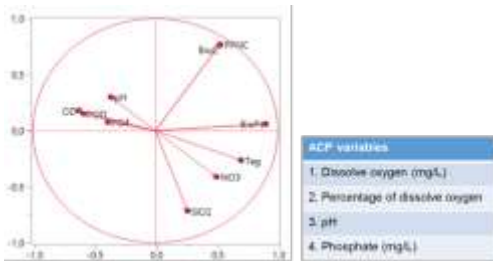


Fig 9. PCA results

Microalgae have the capacity to grow in different environments, We can conclude that the pH of the Presa Centenario is an import seasonality; pH influences the speed of growth, proportion or abundance of microalgae in the body of water, and the availability of important nutrients for microalgae in water; Depending on the species is the ideal pH range, however pH between 7 and 9, as presented in the Presa Centenario, is the optimal range [12].

The dissolve Oxygen in lentic water bodies comes mainly from the process of photosynthesis that depends on the amount of available light [13]. If the population of microalgae is high, the oxygen will decrease more rapidly, this can be seen in contrast in the time of lower oxygen with the one of greater oxygen in our study, comparing with the time of greater abundance of microalgae with the time of Lower abundance; The lowest concentration of oxygen was reported for summer and the highest amount of oxygen in winter, contrasting these data, the summer was the one that registered the second greatest abundance of microalgae in the Presa Centenario, while in winter it presents the lowest abundance Of these microorganisms. In addition, if optimal conditions exist for its establishment, its mass can be doubled, which generates greater demand for oxygen (decrease in water), and when its life cycle is over (death), these go to the bottom of the Water bodies, and decomposing bacteria will intervene in these reservoirs, demanding oxygen and depleting the resource in the rest of the water, and limiting the other organisms that live there [14].

Phosphorus intervenes in the vast majority of cellular energy transfer processes and nucleic acid synthesis (DNA and RNA), especially in the form of phosphate is important for enzymes, lipids, biochemical species and metabolic processes. The required quantity of phosphorus is lower than that of nitrogen, the intake of nutrients by the microalgae is influenced by the N:P and the availability of these in the medium, usually this ratio is 8:1, however the microalgae are adaptable to the environment and can take the nutrient that is found in the highest proportion [15, 16].

At high pH (between 8 and 9) favor the deposition of phosphate in the water body as soluble and available salt [17].

In the study, the climatic season that presented higher concentrations of phosphate was spring, and the time with lower concentration of phosphates was winter. Contrasting with pH, the spring season had a similar behavior among all the sampling points, presenting pH 9, and the winter season oscillated between 8 and 9.5 pH.





REFERENCES

- [1] López, O., & Lechuga, M. (2001). Contaminantes en los cuerpos de agua del sur de Sonora. *Salud Pública de México*, 43 (4), pp. 298-305 pp.
- [2] Becker, E. W. (2004). "Microalgae in Human and Animal Nutrition." *Handbook of Microalgal Culture (Biotechnology and Applied Phycology)*. Edited by Amos Richmond.
- [3] Herbas, R.; Rivero, F., & Gonzales, A. (2006). Indicadores biológicos de calidad de agua.
- [4] Vázquez, G., Castro, G., González, I., Pérez, R., & Castro, T. (2006). Bioindicadores como herramientas para determinar la calidad de agua. *ContactoS* 60, 41-48 pp.
- [5] Cañavate, J. (2011). *Funciones de las microalgas en la acuicultura*. Barcelona: IFAPA Centro El Toruno.
- [6] Arcos, M., & Gómez, A. (2006). Microalgas perfiticas como indicadoras del estado de las aguas de un humedal urbano: Jaboque, Bogotá D.C., Colombia. *NovaPublicación Científica*, 4 (6), 60-79 pp.
- [7] Mercader, F.; Gyves, J.; Rodríguez, E.; Rodríguez, T.; Guardado, A. & Burgos, M. (2004). Simposio de metrología: preparación de un nuevo candidato a material de referencia para la medición de mercurio en sedimentos. CENAM: México.
- [8] INEGI (2010). *Panorama sociodemográfico de Querétaro*. México.
- [9] CONAGUA (2010). *Estadísticas del agua en México, edición 2010*. México: 1-193 pp.
- [10] Ferreiro, N. (2012). *Influencia de la heterogeneidad ambiental de los lechos de macrófitas en los organismos acompañantes en un arroyo pampeano*. Universidad de Buenos Aires-Facultad de Ciencias Exactas y Naturales. Argentina.
- [11] [APHA \(1998\). Standard methods for examination of water and wastewater 20th Edition. American Public Health Association, American Water Works Association and Water Pollution Control Federation, Washington. 1325 pp.](#)
- [12] Baba, M., Y. Shiraiwa (2012). "High-CO2 response mechanisms in microalgae." Najafpour M (Ed) *Advances in Photosynthesis: "Fundamental aspects"*: 299- 305 pp CONAGUA (2010). *Estadísticas del agua en México, edición 2010*. México: 1-193 pp.
- [13] Fernández, A. (2003). *El agua en Iberoamérica: aportes para la integración entre los organismos de gestión y los centros de investigación*. Colombia-CYTED: 1-160 pp.
- [14] Breuer, G., P. P. Lamers, D. E. Martens, R. B. Draaisma, R. H. Wijffels (2013). "Effect of light intensity, pH, and temperature on triacylglycerol (TAG) accumulation induced by nitrogen starvation in *Scenedesmus obliquus*." *Bioresource Technology* 143: 1-9 pp.
- [15] Doucha, J., F. Straka, K. Livansky (2005). "Utilization of flue gas for cultivation of microalgae (*Chlorella* sp.) in an outdoor open thin layer photobioreactor." *Journal of Applied Phycology* 17: 403-412 pp.
- [16] Dragone, G., B. D. Fernandes, A. P. Abreu, A. A. Vicente, J. A. Teixeira (2011). "Nutrient limitation as a strategy for increasing starch accumulation in microalgae." *Applied Energy* 88 (10): 3331-3335 pp.
- [17] Andrade, C.; Vera, A.; Cárdenas, C. y Morales, E. (2009). Biomass production of microalga *Scenedesmis* sp. With wastewater from fishery. *Revista técnica de la Universidad Zulia* 32 (2) 1-9 pp.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Mechanical behavior of subgrade materials for railways through the inclusion of geosynthetics based on recycled expanded polystyrene.

case Colombia

González Mendoza Emmanuel

Maestría en Ingeniería de Vías Terrestres y Movilidad.
Universidad Autónoma de Querétaro.
Querétaro, México
manemcdoza@gmail.com

López Lara Teresa

Posgrado de Ingeniería
Universidad Autónoma de Querétaro.
Querétaro, México
lolte@uaq.mx

Abstract—The speed and loads that most high-speed trains can achieve today need soil structures that can support them, since the backwardness in railway systems has left a competitive gap with other forms of transport. In the same way that in the pavements the lower layers of the structural section are irreparable within a reasonable economic scheme. When there are serious deficiencies in these layers, there are no alternatives other than total rehabilitation, or face prohibitive conservation. One of the many alternatives to this problem are geosynthetics, which are products developed from industrial segments for the transformation of basic polymers which in turn have been transformed to be used to improve the behavior of soils; This research will use the inclusion of a recycled expanded polystyrene geotextile in the California Support Relationship Test (CBR) and simple compression tests. The results obtained show an increase in resistance of the order of 15% in the CBR test, 32% in the Unconfined Compression test and a decrease in the amount of material used of 3.84% versus the unimproved material.

Keywords— *Subgrade, Railways, Geotechnical Properties, Geosynthetics, Polystyrene.*

I. INTRODUCTION

The subgrade is the layer that forms part of the total seating structure of the railway lines, and its relevance is due to its capacity to absorb the stresses coming from upper layers and to defer them homogeneously to the foundation ground; The performance of railway tracks can be greatly affected by the geomechanical behavior of both the embankment and the ground. As it is a large geotechnical structure in a straight line, over most of its length, the geological conditions of the soil vary while the railways cross different areas along its path [1] [2]. On the other hand, the materials used to form the layers are usually obtained from nearby places, which also vary from one area to another [3]. Both embankments and floors used in railway construction are not only subject to the repeated and dynamic nature of train loads (which have been increasing in magnitude due to the requirement of cargo transport), but also to the fluctuations imposed by local climatic conditions [4] [5].

Soil improvement techniques are applied for the inclusion of non-conventional materials in the construction of roads [6]; They are defined as the mechanical and artificial procedures by which it is intended to modify the existing properties of the soil and making them able to achieve the desired requirements, especially that the material that has the minimum requirements of strength, permeability and volumetric stability [7].

The benefits of using structures reinforced with geosynthetics have been previously documented [8] [9] [10] increasing soil strength and reducing settlements, thus achieving reductions in foundation size and / or depth of excavation where these will be placed; which translates into an economic impact reducing costs for materials and labor. In addition to this, it has been shown that reinforcement has an effective impact on the performance of seismic activity [11].

The dynamic responses of road structures induced by the loads of moving vehicles have aroused great interest in the field of geotechnical engineering and related to transport. Early damage caused by vehicle loads reduces road life and degrades travel comfort. The dynamic loads induced by the vehicle are mainly generated by the vibrations of the vehicle and the vehicle-pavement interactions and are supposed to increase the damage to the pavement by approximately 20-30% more than static loads [12] [13].

The current qualities of the materials used in the structural section of the Railways are not suitable for high-speed trains. The hauling and / or stabilization of material suitable for this type of sections generate setbacks and cost overruns so an improvement based on the inclusion of a geosynthetic is a viable option for this type of loads to improve the geomechanical behavior [14] [15]. This work is developed with the objective of achieving an improvement of the geomechanical properties of a subgrade layer, which are analyzed by the specifications that regulate the characteristics of the structural layer in railroads in Colombia.





II. METODOLOGY

A. Characterization of materials

- *Geomechanical Characterization*

The geotechnical characterization of the material consists of the evaluation of the index and mechanical properties of the material, made by the corresponding regulations of the American Society for Testing and Materials (ASTM), the current regulations of the Instituto Nacional de Vías Colombia (INVIAS) and the Secretaría de Comunicaciones y Transportes of México (SCT) that is listed below (Table 1).

Table 1. Tests for characterization of soils.

Source: Self-made.

Test	Normative		
	A.S.T.M.	INVIAS	S.C.T.
Granulometry	ASTM C 136 & ASTM C 117	INVE-123	M·MMP-1-02/03
Liquid Limit	ASTM D 4318	INVE-125	M·MMP-1-07/07
Plastic Limit & Plastic Index	ASTM D 4318	INVE-126	M·MMP-1-07/07
Specific Gravity	ASTM D 854	INVE-128	M·MMP-1-05/03
Humidity	ASTM D 4643	INVE-135	M·MMP-1-04/03
Normal Compaction Test	ASTM D 698	INVE-141	M·MMP-1-09/06
CBR of Compacted Soils	ASTM D 1557	INVE-148	M·MMP-1-11/16
Unconfined Compression	ASTM D 2166	INVE-152	-

- *Polymer Characterization*

To characterize the polymers to be used, it is possible to produce two types of waste: the first is generated during production, in the polymerization process, and the second, at the end of the product life cycle (tubes, bottles, toys, cards, among others).

The handling of the waste can be done:

- **Recycling:** elaborated in the same way as the virgin resin of these.
- **Incineration:** incineration is an effective solution that does not need fuel or energy and can be used in heating or electricity production.
- **Sanitary landfills:** landfills are another solution for the disposal of polymers, but it is not the most feasible and safe for the environment.

In this case, the polymer used was Expanded Polystyrene because it can be used in a large number of applications; In particular, its light character, which allows it to be an excellent filling material, its low thermal conductivity, which makes it an adequate pavement insulation in cold climates, its compressibility, which facilitates its application in the

protection of underground services, and finally, its vibration damping qualities that makes it a potential vibration damper.

B. Geomechanical Tests

- *California Bearing Ratio (CBR) Test*

This test method is used to evaluate the potential strength of subgrade, subbase and base materials, including recycled materials, for use in road pavements and runways. The CBR value obtained in this test is an integral part of several flexible pavement design methods (ASTM D 1557).

Three specimens were carried out for each of the types of geosynthetics used to obtain a decent correlation of the results and to ensure little dispersion of these; all tests were performed at maximum density using the compaction energy of the Proctor compaction test of modified energy, which is what will theoretically be in the field when laying and compacting said material at its optimum humidity. A compression press with a capacity of 5 tons was used automatically and the CBR was performed under conditions without saturating the sample.

- *Unconfined Compression*

The main objective of the unconfined compression test is to obtain, quickly, a value of the compressive strength of those soils that have sufficient cohesion to be tested in unconfined condition. Three specimens were carried out for each of the types of geosynthetics used to obtain a decent correlation of the results and to ensure little dispersion of these.

III. RESULTS

A. Geomechanical Properties

The geomechanical properties of the soil analyzed are shown below:

Table 2. Results of the soils characterization.

Source: Self-made.

Test	Result
Granulometry	Low compressibility Clayey Silt
Liquid Limit	30.67 %
Plastic Limit / Plastic Index	22.71% / 7.96%
Specific Gravity	2.74
Humidity	1.493%
Normal Compaction Test	14.91 kN/m ³ @ 20.5% of moisture
CBR of Compacted Soils	5.651%
Unconfined Compression	31.192 kPa

Based on the tests carried out, it was determined that the material is a low compressibility clayey silt very commonly found in the department of Antioquia with a very low CBR contribution not suitable for the construction of structural layers of railways.



- California Bearing Ratio (CBR).

It was used discs of recycled polystyrene of 10 mm thick, that was placed among the layers of soil as is shown in Figure 1.

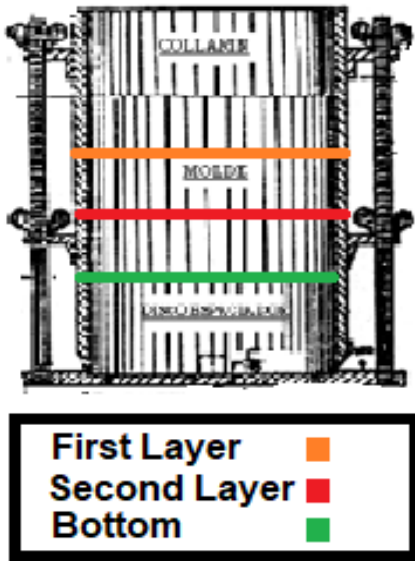


Fig. 1. Arrangement diagram.

Source: Self-made.

Table 3 shows the penetration loads obtained in the CBR test and in figure 3 the graphics of the behavior of the penetration against the stress are shown:

Table 3. Results of CBR tests.

Source: Self-made.

Penetration	Unimproved soil.	Polystyrene in first layer	Polystyrene in second layer	Polystyrene in the bottom
<i>mm</i>	<i>MPa</i>	<i>MPa</i>	<i>MPa</i>	<i>MPa</i>
0	0	0	0	0
0.635	0.187	0.123	0.144	0.178
1.27	0.343	0.178	0.258	0.288
1.905	0.423	0.219	0.336	0.37
2.54	0.471	0.235	0.393	0.455
3.175	0.503	0.258	0.427	0.528
3.81	0.532	0.279	0.45	0.585
4.445	0.560	0.288	0.459	0.633
5.08	0.585	0.292	0.455	0.676
7.62	0.681	0.311	0.423	0.852
10.16	0.786	0.327	0.427	0.992
12.7	0.882	0.35	0.45	1.097

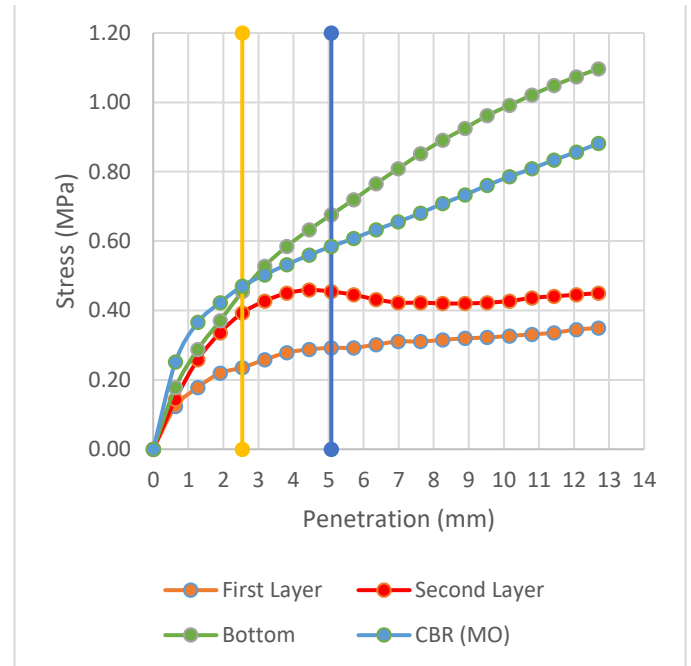


Fig. 2. Comparative between CBRs.

Source: Self-made.

In the previous figure the comparison between the specimens with the inclusion of the geosynthetic and the virgin material (MO) is observed; A reduction in the CBR values of two of the specimens is noticeable due to the height at which the polystyrene layer was placed, since while it is approaching the bottom of the specimen, the material strength will increase due to the volume of material that it is found as it is possible to observe; it is not until the first inch that the polystyrene shows an improvement in the mechanical behavior of the specimen.

- Unconfined Compression

As in the previous test, it was used discs of recycled polystyrene of 10 mm thick, that was placed among the layers of soil as is shown in Figure 1. Table 4 shows the uncorrected penetration loads obtained in the unconfined compression test and in figure 4 the graphs of stress behavior versus unit deformation are shown:

Table 4. Results of Unconfined Compression of Unimproved soil.

Source: Self-made.

Unimproved soil.			
Vertical deformation	Load	Unitary deformation	Stress
<i>mm</i>	<i>N</i>	-	<i>kPa</i>
0	0	0	0
0.159	10	0.00156	5.338
0.318	23	0.00311	12.259
0.484	34	0.00474	18.092



0.643	43	0.00629	22.845
0.81	50	0.00793	26.521
0.976	55	0.00955	29.125
1.142	59	0.01118	31.192
1.316	60	0.01288	31.666
1.482	58	0.01451	30.56
1.663	54	0.01628	28.401
1.852	50	0.01813	26.248

4.324	80	0.04233	40.961
4.483	81	0.04389	41.406
4.649	79	0.04551	40.315
4.762	77	0.04662	39.249

Table 4. Results of Unconfined Compression of Soil with polystyrene in the bottom

Source: Self-made.

Soil with polystyrene in the bottom			
Vertical deformation	Load	Unitary deformation	Stress
<i>mm</i>	<i>N</i>	-	<i>kPa</i>
0	0	0	0
0.174	3	0.0017	1.601
0.347	5	0.0034	2.664
0.513	8	0.00502	4.256
0.68	11	0.00666	5.842
0.864	14	0.00846	7.422
1.012	17	0.00991	8.999
1.179	19	0.01154	10.041
1.345	22	0.01317	11.607
1.504	25	0.01472	13.169
1.67	29	0.01635	15.251
1.844	32	0.01805	16.8
2.003	35	0.01961	18.346
2.176	38	0.0213	19.884
2.343	42	0.02294	21.94
2.509	45	0.02456	23.468
2.675	49	0.02619	25.512
2.849	52	0.02789	27.026
3.015	56	0.02952	29.057
3.181	59	0.03114	30.562
3.348	63	0.03278	32.579
3.514	66	0.0344	34.073
3.673	70	0.03596	36.08
3.839	73	0.03758	37.563
3.998	76	0.03914	39.043
4.165	79	0.04077	40.515

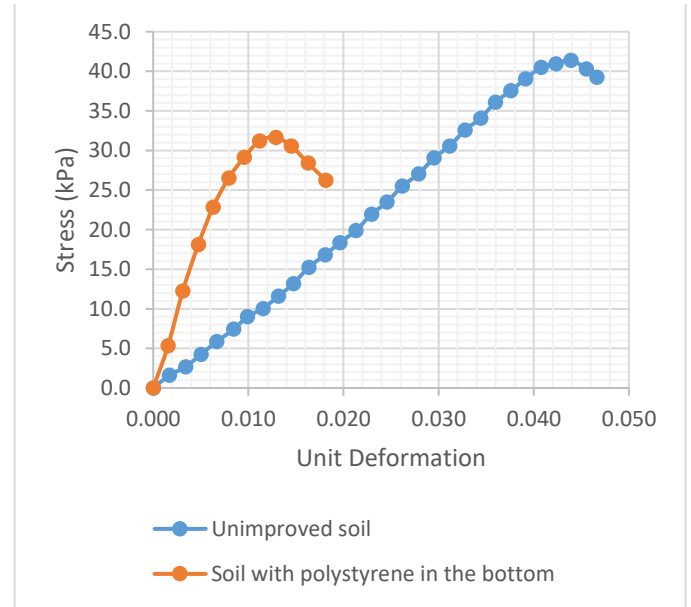


Fig.3. Comparative between tests.

Source: Self-made.

In the previous figure the comparison between the specimens with the inclusion of the geosynthetic and the virgin material (MO) is observed; At the beginning of the test, a decrease in the compressive strength of the material is observed, as well as a greater unitary deformation of the specimen because it is obstructed completely by the geosynthetic. Eventually an increase in the compressive strength that exceeds the virgin material is achieved, showing the improvement that this material can give to soils.

IV. CONSLUSIONS

Although there is a slight decrease, at the beginning of the tests, in the characteristics of support and resistance to compression, these are reversed by improving the material in an order of 24% for CBR and 36% for simple compression; one of the important factors detected in the assays was the location of the polystyrene layer, since the deeper this was, the better was obtained, this because the polystyrene divided the material into two soil masses that did not interact each other, reducing the test support; therefore, placing it in the background of the assay was the best result obtained. The other factor is the size of the particles with which the sheets of expanded polystyrene are formed, since at a smaller diameter there is a greater deformation and a greater tendency to failure by rupture of the geosynthetic. Similarly, the amount of material used in the assays was reduced





by an order of 4%, obtaining a better performance with the inclusion of the geosynthetic.

As for expanded polystyrene, it is a versatile material that can be used in many geotechnical engineering applications, particularly in the construction of road structures. This is possible due to the interesting mechanical properties of PE. Its light character, which allows it to be an excellent filling material, its low thermal conductivity, which makes it an adequate pavement insulation in cold climates, its compressibility, which facilitates its application in the protection of underground services, and finally, its qualities of vibration damping that makes it a potential vibration damper.

REFERENCES

- [1] Sánchez, M., Wanga, D., Briaud, J., Douglas, C., (2014). "Typical geomechanical problems associated with railroads on shrink-swell soils". *Transportation Geotechnics* 1(4), 257–274.
- [2] Mohajerani, A., Ashdown, M., Abdihashi, L., Nazem, M., (2017). "Expanded polystyrene geofoam in pavement construction". *Construction and Building Materials* 157(1), 438-448.
- [3] Fluet, J. (1986). "Geosynthetics and North American Railroads". *Geotextiles and Geomembranes* 3(2-3), 201-218.
- [4] Ahmed Kamel, M., Chandra, S., Kumar, P., (2004). "Behavior of subgrade soil reinforced with geogrid". *International Journal of Pavement Engineering*. 5 (4), 201–209.
- [5] Long, P.V., Bergado, D.T., Abuel-Naga, H.M., (2007). "Geosynthetics reinforcement application for tsunami reconstruction: evaluation of interface parameters with silty sand and weathered clay". *Geotextiles and Geomembranes* 25(4-5), 311–323.
- [6] López-Lara, T., Hernández-Zaragoza, J., Horta-Rangel, J., Coronado-Márquez, A., Castaño-Meneses, V., (2010). "Polímeros para la estabilización volumétrica de arcillas expansivas". *Revista Iberoamericana de Polímeros* 11(3), 159-168.
- [7] Zepeda-Garrido, J.A. (2004). *Mecánica de suelos no saturados*. Sociedad Mexicana de Mecánica de Suelos A.C. (322 páginas)
- [8] Liu, C.N., Yang, K.H., Nguyen M.D., (2014). "Behavior of geogrid reinforced sand and effect of reinforcement anchorage in large-scale plane strain compression". *Geotextiles and Geomembranes* 42(5), 479–493.
- [9] Consoli, C.N., Vendruscolo, M.A., Fonini, A., Rosa D. (2009). "Fiber reinforcement effects on sand considering a wide cementation range". *Geotextiles and Geomembranes* 27(3), 196–203.
- [10] Anvari, S.M., Shooshpasha, I., Kutanaei, S.S., (2017). "Effect of granulated rubber on shear strength of fine-grained sand". *Journal of Rock Mechanics and Geotechnical Engineering*, 1-9.
- [11] Ishihara, K., (1993). "Liquefaction and flow failure during earthquake". *Geotechnique* 43(3), 351-415.
- [12] Kouroussis, G., Vogiatzis, K.E., Connolly, D.P., (2017). "A combined numerical/experimental prediction method for urban railway vibration". *Soil Dynamics and Earthquake Engineering* 97, 377–86.
- [13] Kim, T., Kim, J., Lee, G., (2008). "Mechanical behavior of lightweight soil reinforced with waste fishing net". *Geotextiles and Geomembranes* 26(6), 512–518.
- [14] Lu, Z., Hu, Z., Yao, H.L., Liu, J., (2016). "Field evaluation and analysis of road subgrade dynamic responses under heavy duty vehicle". *International Journal of Pavement Engineering*, 1-10.
- [15] Rodríguez, E.R., Rondón, H.A., Vélez, D.M., Aguirre, L.C. (2006). "Influencia de la inclusión de desecho de PVC sobre el CBR de un material granular tipo subbase". *Revista Ingenierías Universidad de Medellín* 5(9), 21-30.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERIA

Non-expansive pre-consolidated soil behavior in triaxial test

Paulina Lizeth Talamantes Carrillo

“Autonomous University of Queretaro”

Faculty of Engineering Santiago de Querétaro, Querétaro,
México.

pao.talamantesc@gmail.com

Eduardo Rojas González

“Autonomous University of Queretaro”

Faculty of Engineering Santiago de Querétaro, Querétaro,
México.

erg@uaq.mx

Abstract— The behavior of the soil depends on many factors and parameters. The critical state model is used as a reference to obtain several special cases and it has come to the deduction that is a presiso model and useful for soils, with some special features. One of the great disadvantages is that when analyzing a preconsolidated soil the model is no longer accurate and varies considerably. Therefore, this document focuses on the proposition of the adaptation of the critical state model for preconsolidated soils.

Keywords—The critical state model; Preconsolidated soils; OCR

I. INTRODUCTION

The behavior of soils subjected to external loads or other phenomena can be simulated using constitutive models. A model can integrate and simulate the responses of a soil. The mechanical behavior of the geotechnical materials presents phenomena of creep, irrecoverable deformations and dilatancy induced by shear forces (Gens and D.M., 1988).

These characteristics immediately suggest that the plasticity theory could be very suitable for describing the behavior of soils and rocks.

These models are based on stress-deformation relationships that are normally established by elastoplastic theories. However, the constitutive models can be established considering the main phenomena that occur during the application of loads and are sufficiently precise for different engineering purposes.

The constituent models that are used in geotechnics are mainly based on the hypothesis that is a continuous medium. Thus we start from the three constitutive equations of the mechanics of the continuous medium:

- Equilibration of stresses
- Compatibility of deformations
- Constitutive relation that relates tensions and deformations.

Based on the elastoplastic models, the mechanics of soils have been able to develop, and to respond to phenomena of creep, irrecoverable deformations and dilatance produced by

cutting tensions, therefore it is proposed that the application of the theory of pasticity may be adequate, for The explanation of their behavior.

With the criterion of Coulomb (1776), which is known as breaking criterion, which is tested in the analysis of land pressures on walls, which subsequently adapts to several problems in the breakage of soil and the pressures generated by it, However the delimitation of this criterion is that we cannot achieve the complete stress-strain state in the soil, because these methods are restricted to obtaining the tensional state at break.. The critical state models were developed at the University of Cambridge (Drucker 1957), which improves the prediction of soil behavior with a qualitative approach.

The first model that was developed was the Cam-Clay, of which several authors will be based to make improvements or to change them for different special cases.

The critical state model is used as a reference to obtain several parameters in soils, it is an accurate model, its disadvantage is that when working with preconsolidated soils the model varies a lot, and is not precise, which is why an improvement is proposed for This type of soil.

his article presents the behavior of pre-consolidated non-expansive soils

In this research the non-expansive soils are studied, precisely a silty soil. These materials have certain particular characteristics. Through different triaxial assays the behavior of the soil can be obtained. Volumetric changes depending on the applied pressure. Compressibility is the property that determines the degree of consolidation due to the increase in pressure.





Gómez and Lloret (2015) showed that the triaxial test simulates the different soil conditions. With the results of the tests that will be carried out, the deformation and resistance of a pre-consolidated soil can be observed.

The fundamental parameter of this research is the degree of soil preconsolidation (OCR).

In this investigation, slow triaxial tests were performed. The triaxial test is one of the most reliable methods to determine the parameters of the shear strength. The consolidated drained tests are used essentially in granular soils (sands), however, it can be applied in fine soils.

II. MODEL CLAM-CLAY

A. Elastic state to plastic state in soils

When the deformation of the material recovers completely after eliminating the applied load, it is said to have an elastic behavior.

$$K = \frac{E}{3(1-2\mu)} \quad G = \frac{E}{2(1+\mu)} \quad (1)$$

K and G are the elastic behavior is divided into a size change without change of shape (volumetric behavior).

Considering the linear isotropic elasticity ($G = \text{constant}$ and $K = \text{constant}$) is a simple way of obtaining the tenso-deformational behavior of soils subjected to loads.

The classical theory of plasticity, its main foundation is the behavior in this case of a soil after a point of fluce, when a load is applied, which is obtained by consequent a decrease of the resistance as the deformation increases.

This is called plastic softening.

B. Critical Status Line

Critical line of state depends on the type of soil being studied, because it does not have the same behavior. In agreement with the model of Clam-Clay which is focused on clay is represented as follows.

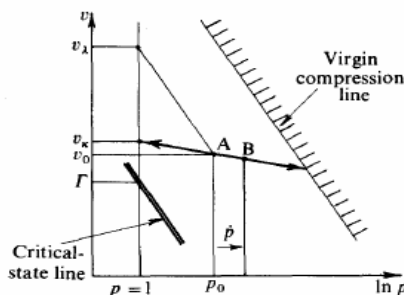


Fig.1 Elastic Change of State (Andrew Schofield)

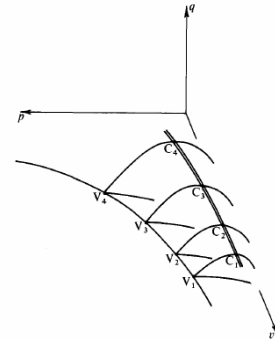


Fig.2 Upper Half of State Boundary Surface for Cam-clay (Andrew Schofield)

The concept of critical state to represent the relationship between the relative density, or index of pores and the pressure of confinement.

C. Plastic Compressibility and the Tests

If we have a simple laboratory with only a water supply, a drying oven, a balance and a simple indentation test equipment (such as the falling cone test widely used in Scandinavia), we can find a value of λ for a silty clay soil. We mix the soil with water and remould it into a soft paste: we continually remould the soil and as it dries in the air it becomes increasingly strong. There will be a surface tension in the water of the menisci in the wet soil surface that naturally compresses the effective soil structure as water evaporates. As long as the soil is continually being remoulded it must remain at the critical state (Andrew Schofield).

D. The Unconfined Compression Strength

The critical state model is the natural basis for interpretation of the unconfined compression test. It is a simple test in which a cylindrical specimen of saturated clayey soil sustains no total radial stress $\sigma_r = 0$, and the total axial stress σ_1 is rapidly increased until the specimen yields and fails. The unconfined compressive strength q_u is defined to equal the ultimate total axial stress σ_1 . No attempt is made to measure pore-pressure, and no sheath is used to envelop the specimen, but the whole operation is so rapid relative to the. (Andrew Schofield).

III. HVORSLEV AREA

Hvorslev found a straight line, which is a good approximation for the rupture envelope for preconsolidated soils. Adapting a straight line as a surface of fluce on the supercritical side using numerical applications of the Cam-clay models, which is often called Hvorslev surface, if associated plasticity is adopted, the result is a high dilatancy.

The flow surface itself moves according to changes in plastic volumetric deformation, but the surface of rupture (supercritical) is fixed. Therefore, softening is not predicted. The model implies associated plasticity.

Fig.3 Comparison of the Hvorslev surface and the modified Cam-clay model as a surface of creep on the supercritical side for the Lower Cromer clay.

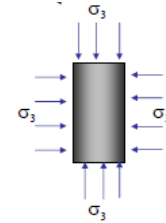


Fig.5 Representation of the soil test piece in the triaxial chamber where (σ_1) deviating effort, confining effort(σ_3).

The confining effort is the one that represents the consolidation of the soil and is the one that will be varied.

IV. LIMIT SURFACE MODEL FOR PRECONSOLIDATED CLAYS

The model of preconsolidated clays has a long history. The critical state model provides a broad framework for describing the stress-strain relationships of preconsolidated and normally consolidated soil and represents a starting point for developing constitutive models (Vukic, 2017).

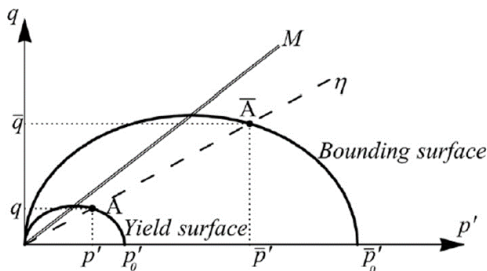


Fig.4 Concept of boundary surface and radial mapping. Hardening State Parameter (HASP)

The Hardening State Parameter (HASP) overcomes many shortcomings of the modified Cam-clay model, while retaining its simplicity and the same set of parameters.

The Hardening State Parameter (HASP) model takes into account the behavior of preconsolidated clays, based on the concept of boundary surface.

V. EXPERIMENTATION TO BE CARRIED OUT

Based on the existing critical state models it is intended to improve, in order to obtain a correlation of the parameters of the critical state model, it is intended to perform triaxial tests.

A. Experimentation

It is expected to perform 6 triaxial tests with the same deviator effort but different confining efforts. In addition to performing several consolidation tests.

B. Explanation of the experimentation to obtain parameters

First make different test pieces using the same soil, which in this case will be a non-expansive soil.

C. Equations

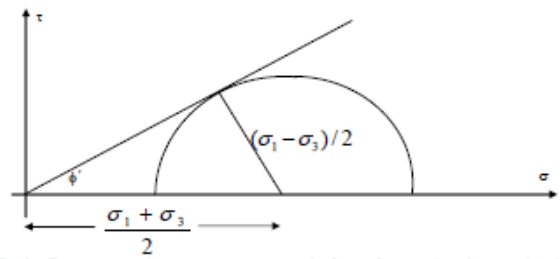


Fig.8 It represents a circle in terms of effective pressures containing the point of failure.

$$(\sigma_1 - \sigma_3) = q \quad (2)$$

$$(\sigma_1 + \sigma_3) = \frac{6p' + q}{3} \quad (3)$$

$$q = Mp \quad (4)$$

$$\Gamma = v + \lambda \ln p. \quad (5)$$

The constants M , Γ , and λ represent basic soil-material properties, and the parameters q , v , and p are defined in due course.

With these equations we can implement a relationship of soil behavior with different confinement efforts.

D. Results

With the accomplishment of these tests, to different efforts of confinement, we will obtain the behavior of the same soil, besides obtaining the volumetric changes, obtaining the different slopes and the different points of origin or critical state.

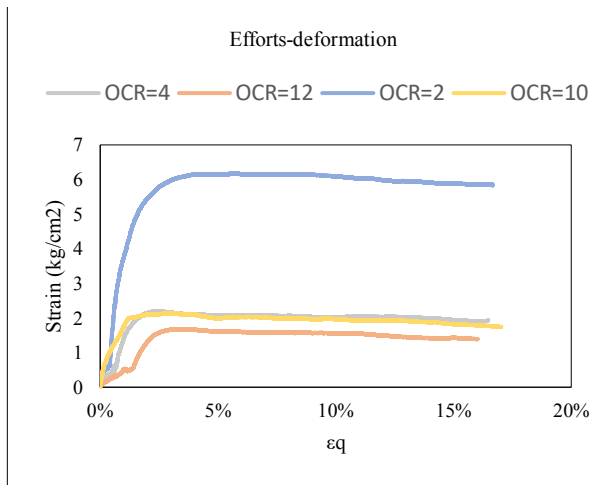


Fig.9 Results of triaxial tests (stress-strain) with Figure 1 shows the deviating stress against the unit axial strain.

En la figura 9 se observan las 3 curvas esfuerzo-deformación de los 4 ensayos triaxiales realizados con los diferentes valores de OCR, el cual es determinado por la presión de confinamiento, la historia de esfuerzos y otros factores. Después de que la tensión vertical aumenta y la presión de poro aumenta, la presión de los poros se reducirá lentamente, llegando eventualmente a cero. Este proceso causará una deformación plástica (disminución permanente del volumen del suelo). Este es un nuevo estado de estrés para el suelo. Se muestra en las curvas que se alcanza un máximo valor de esfuerzo, y posteriormente la resistencia disminuye muy poco y alcanzan un valor donde se mantiene constante, a esta resistencia última se le llama residual.

Se percibe que cuanto mayor es el valor de OCR, menor esfuerzo se tendrá a la falladiferentes grados de OCR.

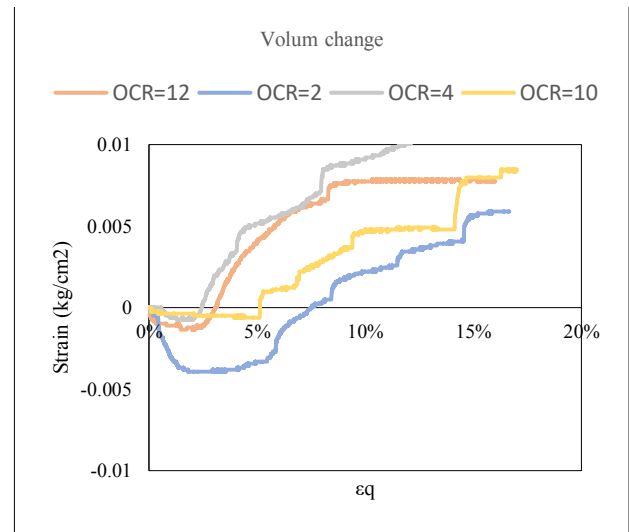


Fig.10 Results of triaxial tests (volumetric deformation) with different degrees of OCR.

Figure 10 shows the volumetric deformation against the axial deformation of the sample. As it is observed in this figure, as the OCR increases, the tendency of the soil to expand and the compression deformations are increased.

It is observed that in the first tests carried out an initial compression of the volume takes place, and when continuing to load it, the dilatant plastic deformations increase (volumetric expansion).

The volumetric change decreases, this is associated to the fact that a large part of the particle breakage is reached in the isotropic consolidation stage, therefore, when a deviating force is applied, the soil arrangement densifies and stabilizes rapidly. observe clearly that the maximum stress ratio decreases with increasing pressure.

VI. CONCLUSIONS

In this article the results of the triaxial assays made with silty material are presented. The graphs of the stress-strain behavior of the different triaxial tests with different OCR values were obtained, as shown in figure 9. Where it was observed that the resistance is reduced as the OCR increases. This result is due to the lower amount of air and water present in the soil sample, because these spaces have been occupied by solid particles, which are reorganized and introduced into the pores during the consolidation process.

In addition, the graphs of the volumetric deformation were obtained in the triaxial tests with the proposed OCR values. Where it is observed that as the OCR increases, the tendency of the soil to expand increases, it is presented in figure 10.



A peak is observed in figure 9 (stress-strain) which corresponds to the contraction-dilation change of the curve (volumetric deformation) of figure 10.

The pressure of confinement is an important factor, that by increasing enough cancels all dilatance, transforming to the most dense in contractive state. This change in the tendency of the volumetric deformation is due to the occurrence of an important breakage of particles, therefore, especially in dense states, the behavior at low pressures differs from that which develops at high pressures.

The critical states become our base of reference. We combine the effective pressure and specific volume of soil in any state to plot a single point: when we are looking at a problem we begin by asking ourselves if the soil is looser than the critical states. In such states we call the soil 'wet', with the thought that during deformation the effective soil structure will give way and throw some pressure into the pore-water (the amount will depend on how far the initial state is from the critical state), this positive porepressure will cause water to bleed out of the soil, and in remoulding soil in that state our hands would get wet. In contrast, if the soil is denser than the critical states then we call the soil 'dry', with the thought that during deformation the effective soil structure will expand (this expansion may be resisted by negative pore-pressures) and the soil would tend to suck up water and dry our hands when we remoulded it. (Andrew Schofield).

With the planned experimentation it is tried to find an improvement for preconsolidated soils in models of critical state, with that to raise a relation and adaptation of the model of the critical state.

There are different constitutive models, which predict the behavior of soils, but each one focuses on specific phenomena.

Some constitutive models that have been developed only apply under certain conditions and with certain types of soils. However, there are many problems where different states and different types of soils are required.

The constitutive models that exist use parameters that were obtained by performing triaxial tests using expansive soils.

Existing models applied to highly preconsolidated soils have important shortcomings.

As mentioned above, we intend to make a constitutive model with non-expansive soil, in triaxial drained tests, with preconsolidated and normally consolidated soils.

REFERENCES

- [1] Roscoe, K. H. and Schofield, A. N. Mechanical Behaviour of an Idealised Wet
- [2] Roscoe, K. H., Schofield, A. N. and Thurairajah, A. Yielding of Clays in States
- [3] Burland, J. B. Correspondence on 'The Yielding and Dilation of Clay',
- [4] Géotechnique 15, 211 – 214, 1965. K. Elissa, "Title of paper if known," unpublished.
- [5] Bishop, A. W., Webb, D. L. and Lewin, P. I. Undisturbed Samples of London Clay from the Ashford Common Shaft: Strength Effective Stress Relationships, Géotechnique 15, 1 – 31, 1965..
- [6] Casagrande, A. Characteristics of Cohesionless Soils affecting the Stability of Slopes and Earth Fills, J. Boston Soc. Civ. Eng., pp 257 – 276, 1936.
- [7] Andrew Schofield and Peter Wroth, Critical Satate Soil Mechanics.



Generation of biogas from cattle excrement: A review

Basilio Carrillo Valdés

Facultad de ingeniería
Universidad Autónoma de Querétaro
Querétaro; México
abu.ca7@hotmail.com

Mario Trejo Perea

Facultad de ingeniería
Universidad Autónoma de Querétaro
Querétaro; México
mtp@uaq.mx

Jose Gabriel Ríos Moreno

Facultad de ingeniería
Universidad Autónoma de Querétaro
Querétaro; México
riosg@uaq.mx

Abstract— Cattle, Biogas, Methane, RE.

Around 20 years ago to date, the demand for products of animal origin has grown exponentially, especially in developing countries. In these countries, population growth is subject to the supply of food; especially those of animal origin. The activity of the livestock sector has a high impact on climate change due to GHG emissions; in particular those of methane (44%), carbon dioxide (27%), and nitrous oxide (29%). Cattle emits the highest, about 65 % of the livestock production emissions; indeed feed processing and production and enteric fermentation from ruminants are the two major sources of emissions, contributing to 45 % and 39 % of total emissions respectively.

I. INTRODUCTION

Assuming that all ruminant animal husbandry are farmed on grassland soils, the overall emissions from the ruminant livestock sector can be estimated at 56% of the total agricultural emissions [1]. Renewable energy sources have the ability to provide energy free of air pollutants and greenhouse gasses by emitting zero or nearly zero percent of these gasses [2]. Currently, renewable energy sources supply about 23.7% of the total world energy demand [3], which was 2% in 1998 including seven exajoules of modern biomass, and two exajoules of all other renewable sources [4]. Currently, some of the renewable energy technologies, hydropower, wind energy, solar energy, biomass energy, biofuels and geothermal energy are now mainstream and contributing. An increase in global temperature near or greater to 2 degrees Celsius could generate quite severe implications such as droughts, famines, extinction of species etc. The fact is that this level is being quickly approached [4]. In this investigation, it is proposed that a study of gas production from cattle excrement should be done with the objective of generating electric energy. As well as reduce the impact of the different gasses produced by cattle excrement.

II. THE MODERN WORLD OF CLEAN ENERGIES

Renewable energy sources have the potential to play an important role in the world's future. Renewable sources can be used to produce energy again and again i.e. solar energy, wind energy, geothermal energy, marine energy, biomass energy, biofuels, and many more [5]. Renewable energy sources have the ability to provide energy free of air pollutants and

greenhouse gasses by emitting zero or nearly zero percent of these gasses [6].

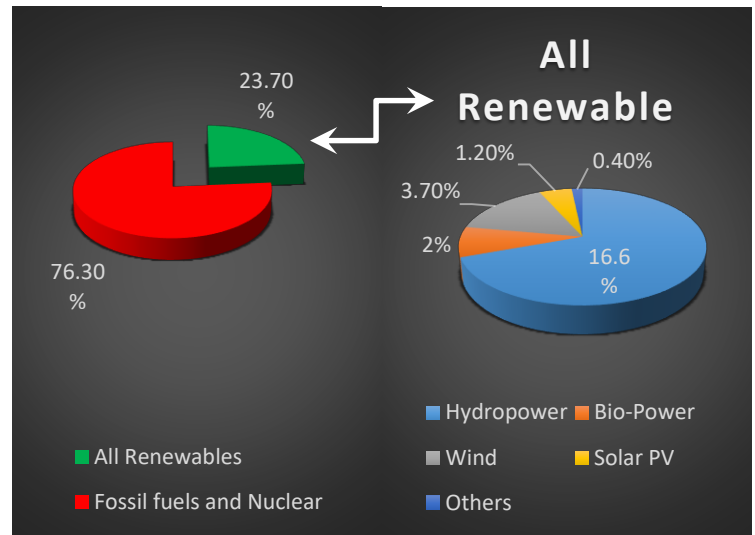


Fig. 1 Estimated Renewable Energy share of Global Energy [7].

Due to global climate change, developed countries have continued to reduce their use of fossil fuels and increase their use of renewable energy (RE). By 2012, as a result of the Kyoto Protocol, RE production reached an estimated 22.1% of global electricity production [9]. Total new investment in renewable power was at least US\$249.4 billion in 2013 [8].

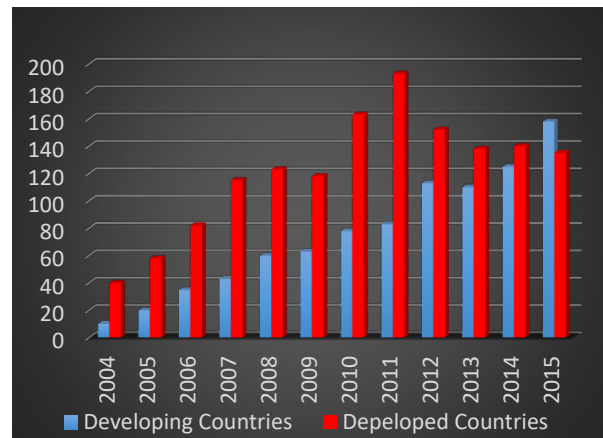


Fig. 2 Developed and developing countries investment in renewable energies [9].



Renewable energy projects in developing countries should provide clean energy supply as well as support sustainable economic development [10]. Due to global climate change, developed countries have continued to reduce their use of fossil fuels and increase their use of renewable energy (RE)[11]. Since 1990, RE generation worldwide has grown by an average of 3.3% per annum: 2.3% among countries in the Organization for Economic Co-operation and Development and 4.5% among other countries [12]. The RE business has created an energy industry boom and has filled a gap in the electricity supply in emerging economies including developing countries in Asia, Africa, and South America [13].

III. A GLOBAL PROBLEM

Today, while it is true that ERs have an important boom, research and the use of biogas derived from the fermentation of livestock manure has not received the attention it deserves; since this type of pollution is a significant part of GHG emissions worldwide and is also a powerful source of economic income. Anaerobic fermentation of structural carbohydrates in the rumen of bovines produces waste products such as volatile fatty acids, fermentation heat, carbon dioxide and methane gas. Methane is a greenhouse gas having several times the global warming potential of CO₂.

Globally, ruminant livestock produce ~80 million tons of CH₄ annually, accounting for ~33% of anthropogenic emissions of CH₄ (Beauchemin et al., 2009). Methane is an end product of rumen fermentation, formed autotrophically by methanogenic archaea from CO₂ and H₂ derived from fermentation of carbon sources, basically structural and storage carbohydrates in plants (Orskov et al., 1968; Kebreab et al., 2006). Typically, about 6-10% of the total gross energy consumed by the dairy cow is converted to CH₄ and released into the atmosphere via the breath (Eckard et al., 2010). Therefore, reducing the enteric CH₄ production could contribute to decrease overall greenhouse gas emissions on a worldwide scale and lead to production benefits for farmers [14].

To figure out the problem we have fig. 3 and fig. 4:

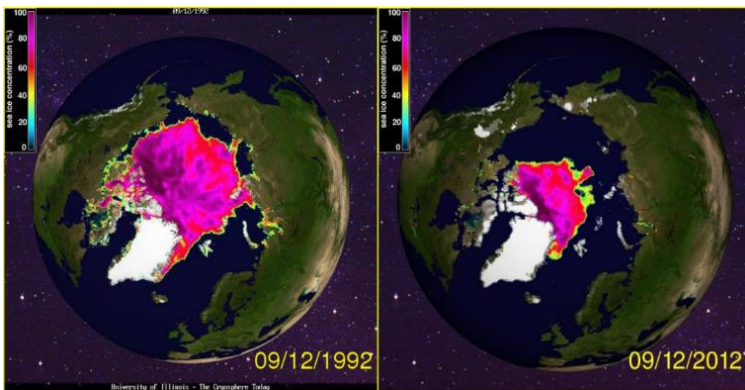


Fig. 3 Comparison of Arctic sea ice concentrations on September 12, 1992 (left) and September 12, 2012 [15]

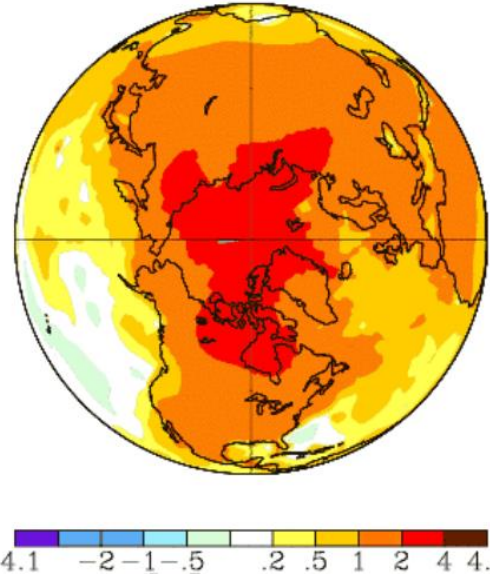


Fig. 4 Change of annual surface air temperatures (°C) over the 50-year period, 1963- 2012. Plotted values are differences between initial and final points of linear regression trend line for each point.[16]

IV. A VIABLE ALTERNATIVE

Agricultural biodigesters are seen as a viable means to reduce greenhouse gas (GHG) emissions while generating clean energy for on-farm and to sell to power companies. Through anaerobic digestion, biodigesters reduce organic compounds in waste material to methane (CH₄) and carbon dioxide (CO₂). The subsequent capture and combustion of CH₄ can result in a reduction in GHG emissions compared to traditional waste management [17]. In storage, anaerobic digestion (AD) of degradable organic matter (OM) in the liquid manure occurs naturally, generating biogas, a mixture of methane (50–75% vol), carbon dioxide (25–50%) and trace amounts of other gases (< 1%) (Gomez, 2013) [18].

In Canada, manure management accounted for 14% of agriculture's GHG emissions in 2014 (Environment and Climate Change Canada, 2016)[18]. It is important to mention that the amount of biogas that a biodigester can generate from livestock manure depends on a number of factors such as the types of feed given to livestock, the temperature of the facility, among others. A specialized biodigester for the fermentation of livestock manure is made up of existing technology which we will only adapt for our use and with the specifications that we need; This is because the use of technology that is already on the market is much cheaper than the innovation and development of it.



Table 1 shows the different findings of different researchers in reference to the area of Generation of biogas from cattle excrement:

Year of publication	Article name	Author or Authors	Useful information
2009	Estimate of the electric energy generating potential for different sources of biogas in Brazil	Karina Ribeiro Salomon, Elected Eduardo Silva Lora	Countries like China, India, Nepal, Thailand, Germany, United States and Denmark have experience in the development of biogas programs and projects.
2018	Methane emissions from storage of digestate at a dairy manure biogas facility.	Lia Maldanera, Claudia Wagner-Riddle, Andrew C. VanderZaagb, Robert Gordonc, Christopher Duked	Conventional manure storages are an important source of methane (CH ₄), a potent greenhouse gas.
2001	Methane emission factors from cattle manure in México.	E. González-Avalos, L.G. Ruiz-Suárez	Methane is produced by anaerobic fermentation of animal manure.
2014	Renewable energy production in Spain: A review	Francisco G. Montoya, Maria J. Aguilera, Francisco Manzano-Agugliaro	The growing need for energy in western societies and, has posed a major challenge to the establishment of new energy policies.
2014	Modeling methane emissions and methane inventories for cattle production systems in Mexico.	Octavio A. Castelán-Ortega, Juan Carlos Ku-Vera, Julieta G. Estrada Flores	Predicted total emission of methane produced by the 23.3 million heads of cattle in Mexico is approximately 2.02 Tg/yr.
2018	On the role of efficient cogeneration for meeting Mexico's clean energy goals.	Armando Llamas, Oliver Probst	After the energy reform in Mexico, efficient cogeneration plants can generate and trade Clean Energy Certificates, to the extent a certain efficiency threshold is exceeded.
2011	Fugitive methane emissions from an agricultural biodigester.	Thomas K. Flesch, Raymond L. Desjardins, Devon Worth	The GHG reduction associated with a biodigester will be affected by fugitive emissions from the facility.
2015	Effects on the biogas and methane production of cattle manure treated with urease inhibitor.	Frauke Hagenkamp-Korth, Susanne Ohl, Eberhard Hartung	In Germany, a large part of the total stored cattle manure is utilized as a substrate in biogas plants.
2016	Nitrous oxide and methane fluxes from cattle excrement on C3 pasture and C4-dominated shortgrass steppe.	Kristopher L. Nicholsa, Stephen J. Del Grossoa, Justin D. Dernerb, Ronald F. Folletta, Shawn L. Archibequec, Catherine E. Stewart, Keith H. Paustian	The potential to mitigate GHG emissions is limited as management options for semi-arid rangeland primarily consist of modifying the stocking rate and the duration of the grazing season.
2018	Carbon dioxide assisted thermal decomposition of cattle excreta.	Sang-Ryong Lee, Jechan Lee, Taewoo Lee, Seong-Heon Cho, Jeong-Ik Oh, Hana Kim, Daniel C.W. Tsang, Eilhann E. Kwon	The generation of CO ₂ , the enhanced generation of H ₂ and CH ₄ in the thermal degradation of cattle excreta in CO ₂ .
2018	Generation of biogas from cattle excrement: A review	Basilio Carrillo Valdés, Mario Trejo Perea, Jose Gabriel Rios Moreno	The use of the gases produced by livestock manure can become an important source of clean energy that without a destination can become an economic generator on a smaller or larger scale.

V. CONCLUSION

It is important to mention that from the economic aspect, this is a viable project in the medium and long term. Also, that with

the correct management of the parts, it is possible to develop farms with GHG emissions much lower than those produced at the present time. It is estimated that in Mexico in 2015 there were around 33.50 million heads of cattle which generated an approximate emission of 2.904 tons of methane this year. Adding 8.72 million heads of goats, 8.71 million heads of sheep and 16.36 million heads of pigs; a total of approximately 67.29 million head of cattle in Mexico for that year; This means that methane emissions in 2015 exceeded 3 tons. It is true that it is an ambitious project, but it is well-founded given the data that supports that ecologically an alternative is needed for the excrement coming from the Cattle.

VI. REFERENCES

- [1] Fiore Mariantonietta, Spada Alessia, Contò Francesco, Pellegrini Giustina, GHG and Cattle Farming: Co-Assessing the Emissions and Economic Performances in Italy. *Journal of Cleaner Production* (2017), doi: 10.1016/j.jclepro.2017.07.167
- [2] Akhtar Hussain, Syed Muhammad Arif, Muhamma Aslame" Emerging renewable and sustainable energy technologies: State of the art" *Renewable and Sustainable Energy Reviews* 71 (2017) 12–28
- [3] REN21. *Renewable energy PolicyNetworkfor the 21st century. Renewables 2014. Global Status Report*; 2016
- [4] UNDP. *World energy assessment 2000—energy and the challenge of sustainability*. New York: UNDP; 2000 (ISBN 9211261260)
- [5] Rathore NS, Panwar NL. *Renewable energy sources for sustainable development*. New Delhi, India: New India Publishing Agency; 1996.
- [6] Panwara NL, Kaushik SC, Kothari Surendra. *Role of renewable energy sources in environmental protection: a review*. *Renew Sustain Energy Rev* 2011;15:1513–24.
- [7] REN21. *Renewable energy PolicyNetworkfor the 21st century. Renewables 2014. Global Status Report*; 2016
- [8] REN21. *Renewables 2014 Global Status Report*. Paris, France: REN21 Secretariat; 2014.
- [9] FS-UNEP Collaboration Center, Frankfurt School. *Global trends in renewable energy investments*; 2016.
- [10] Kyeongseok Kim, Hyoungbae Park, Hyoungkwan Kim; " Real options analysis for renewable energy investment decisions in developing countries" *Renewable and Sustainable Energy Reviews*
- [11] REN21. *Renewables 2014 Global Status Report*. Paris, France: REN21 Secretariat; 2014.
- [12] IEA. *Renewables Information 2014*. Paris, France: International Energy Agency (IEA); 2014
- [13] Kyeongseok Kim, Hyoungbae Park, Hyoungkwan Kim; " Real options analysis for renewable energy investment decisions in developing countries" *Renewable and Sustainable Energy Reviews*
- [14] OCTAVIO ALONSO CASTELÁN-ORTEGA, JUAN CARLOS KU-VERA, JULIETA G. ESTRADA-FLORE; *Modeling methane emissions and methane inventories for cattle production systems in Mexico"*
- [15] University of Illinois, Cryosphere Today, <http://artic.atmos.uiuc.edu/cryosphere/>
- [16] NASA Goddard Institute for Space Studies, <http://data.giss.nasa.gov/gistemp/maps/>
- [17] Climate Action Reserve. *Organic waste digestion project protocol: avoiding methane emissions from anaerobic digestion of food waste and/or agro-industrial wastewater. Version 1.0*. Climate Action Reserve. Available online at, <http://www.climateactionreserve.org/how/protocols/adopted/organic-waste-digestion/current/>; 2009 [accessed 22.06.11].
- [18] Gomez, Claudius da Costa, 2013. 1 – Biogas as an energy option: an overview. *The Biogas Handbook, Science, Production and Applications*. Woodhead Publishing Limited, pp. 1–16. <http://dx.doi.org/10.1533/9780857097415.1>.





Development of mesoporous matrices of type SBA-16 functionalized with amino groups for the reduction of total chromium in water.

Ileri Graciela Segura Gutiérrez, Rufino Nava Mendoza, Viviana Palos Barba

Facultad de Ingeniería
Universidad Autónoma de Querétaro
Querétaro, México

Abstract—In this paper we will talk about the removal of the total chromium in contaminated water, the methods and materials that we will be used for its development as well as the expected results about the adsorption capacity of the SBA-16 to remove the chromium in aqueous solutions.

Keywords—mesoporous materials; SBA-16; synthesis; functionalize; chromium; adsorption

I. INTRODUCTION

One of the most severe problems that exists today, is the water pollution, as it is a resource that is used for various processes [1]. Therefore, there are different methods have been used for the removal of pollutants in water bodies, and one of them is to use the mesoporous materials that can perform this process [1, 2, 3, 4]. The functionalized mesoporous materials have become one of the most important research areas in the field of functional materials [5]. Said the above and knowing that there are various pollutants in aqueous solutions, there is a need to develop research for the removal of these pollutants such as: Chromium, Mercury, Arsenic, Lead, among others. According to the nomenclature of IUPAC (International Union of Pure and Applied Chemistry) mesoporous materials that have a diameter of 2 to 50 nm [6, 7]. The mesoporous silica of type SBA-16 has had good results as an adsorbent since it has pores intercommunicated in its body [1, 8].

II. OBJECTIVES

A. General Objective

Develop nanostructured matrices based on mesoporous silica SBA-16 functionalized with amino groups with high adsorption capacity, to decrease the concentration of total chromium dissolved in water.

B. Particular objectives

- Synthesize the mesoporous silica SBA-16 by the sol-gel method.
- Functionalize the mesoporous material with amino groups.

- Analyze the textural, structural and thermal properties of mesoporous material SBA-16 functionalized with amino groups, for the removal of total chromium dissolved in water.
- Determine the efficiency of the mesoporous materials of type SBA-16 functionalized with amino groups, for the removal of total chromium dissolved in water.
- Establish a functional relationship between the textural, structural and thermal properties of the adsorbent materials with their efficiency in the adsorption of chromium.

III. HYPOTHESIS

Mesoporous matrices of type SBA-16 functionalized with amino groups have adequate textural and chemical properties for the adsorption of Cr and with it the concentration of this transition metal contained in contaminated water will be reduced, due to the formation of coordinated covalent bonds between this metal and the nitrogen atom of the amino group.

IV. BACKGROUND

There are several researches on the removal of lead using mesoporous materials such as SBA-15 [9], in this paper they describe how they synthesized SBA-15 and functionalized it with amino groups. In this study they obtained that the hybrid silica material turned out to be an efficient adsorbent for the removal of Pb (II) ions in aqueous solutions.

Also, Leila Dolatyari et al, used Schiff base functionalized SBA-15 mesoporous silica materials to removal of uranium (VI) ions from aqueous solutions. They obtained that their material are efficient and selective adsorbents for decontamination of water samples, plus, it has shown reasonable adsorption capacities with very fast adsorption kinetics [2].

Plus, in a study used SBA-16 to removal neutral, cationic, and anionic dyes from aqueous medium, they mentioned the synthesis of this material and they obtained the conclusion that their material have a very high surface area, average pore diameter, total pore volume, and higher active sites, which it





means that SBA-16 has a high adsorption capacity in comparison to the other adsorbents [1].

On the other, there are studies for the removal of arsenic, Sneh Lata and S. R. Samadder in its review mentions the elimination of As using various nano adsorbents such as: (1) Iron oxides/hydroxides nanoparticles, (2) Alumina nanoparticles, (3) Copper oxide nanoparticles, (4) Titanium dioxide nanoparticles, (5) Zinc oxide nanoparticles, (6) Mixed metal oxide (MMO's) nanoparticles, (7) Carbon nano tubes, among others [10].

V. METHODS AND MATERIALS

A. Synthesis of the mesoporous material

The synthesis method that will be used to generate the mesoporous silica is the sol-gel method described by Zhao (1998) [11] and Flodström (2003) [12]. It is necessary 8 grams of neutral surfactant are added as the director of the cubic structure, Pluronic F127 (BASF), which is dissolved in 240 ml of a 2M solution of hydrochloric acid and 60 ml of distilled water. This solution is placed in constant agitation at room temperature (28°-30° C) for one hour. Later it is matured for 48 hours at 80°C in a stove without agitation. The next step is to let cool and recover the solid by filtration. Then it is left to dry at room temperature and then it is left in the muffle at 110°C for 18 hours with a speed of 2°C per minute. Finally, it is calcined at 500°C for 6 hours at a rate of 1°C per minute.

B. Functionalization of SBA-16 with amino groups.

The post-synthesis method (ex-situ) will be used for the superficial functionalization of the previously synthesized SBA-16 described by Nava et al [9]. The SBA-16 is dispersed in a solution of 3-aminopropyl triethoxysilane (APTES) (precursor of the NH₂ functional groups) in ethanol. The amount of APTES will be calculated to obtain 0.3 moles of APTES for each mole of TEOS. The reaction will be carried out at room temperature and in an inert N₂ atmosphere for 60 minutes. Subsequently, deionized water will be added and it will remain in agitation for 45 minutes. The solid will be recovered by filtration and left to dry at room temperature and subsequently at 110°C for 18 hours.

C. Characterization of the material.

The physicochemical characteristics of the adsorbents of SBA-16 modified with amino groups before and after the adsorption of Cr will be investigated by elemental analysis, thermal analysis, isotherms of adsorption-desorption of N₂ at 77K (SBET), infrared spectroscopy with Fourier transform (FT-IR), diffuse reflectance spectroscopy in the DRS-UV-vis range, X-ray photoelectric spectroscopy (XPS). Scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

VI. EXPECTED RESULTS

The adsorption capacity of SBA-16 functionalized with amino groups is high for the removal of total chromium in aqueous solutions.

ACKNOWLEDGMENT

The authors would like to thank the financial support of CONACYT.

REFERENCES

- [1] H. Chaudhuri, S. Dash, S. Ghorai, S. Pal and A. Sarkar, "SBA-16: Application for the removal of neutral, cationic, and anionic dyes from aqueous medium.," *Journal of Environmental Chemical Engineering*, n° 4, pp. 157-166, 2016.
- [2] L. Dolatyari, M. Reza Yafian and S. Rostammia, "Removal of uranium (VI) ions from aqueous solutions using Schiff base functionalized SBA-15 mesoporous silica materials," *Journal of Environmental Management*, n° 169, pp. 8-17, 2016.
- [3] H. Chaudhuri, S. Dash and A. Sarkar, "Synthesis and use of SBA-15 adsorbent for dye-loaded wastewater treatment.," *Journal of Environmental Chemical Engineering*, n° 3, pp. 2866-2874, 2015.
- [4] B. Sun, G. Zhou and H. Zhang, "Synthesis, functionalization, and applications of morphology-controllable silica-based nanostructures: A review.," *Progress in Solid State Chemistry*, n° 44, pp. 1-19, 2016.
- [5] M. Ghazizadeh, A. Badiei and I. Sheikhsaie, "Iron-functionalized nanoporous silica type SBA-15: Synthesis, characterization and application in alkene epoxidation in presence of hydrogen peroxide.," *Arabian Journal of Chemistry*, 2013.
- [6] A. Feliczak-Guzik, B. Jadach, H. Piotrowska, M. Murias, J. Lulek and I. Nowak, "Synthesis and characterization of SBA-16 type mesoporous materials containing amine groups.," *Microporous and Mesoporous Materials*, n° 220, pp. 231-238, 2016.
- [7] L. B. McCusker, F. Liebau and G. Engelhardt, "Nomenclature of structural and compositional characteristics of ordered microporous and mesoporous with inorganic hosts (IUPAC recommendations 2001).," *Microporous and Mesoporous Materials*, n° 58, pp. 3-13, 2003.
- [8] Z. Cao, P. Du, A. Duan, R. Guo, Z. Zhao, H. I. Zhang, P. Zheng, C. Xu and Z. Chen, "Synthesis of mesoporous materials SBA-16 with different morphologies and their application in dibenzothiophene hydrodesulfurization.," *Chemical Engineering Science*, n° 155, pp. 141-152, 2016.
- [9] V. Hernández-Morales, R. Nava, Y. J. Acosta-Silca, S. A. Macías-Sánchez, J. L. Pérez-Bueno and B. Pawelec, "Adsorption of lead (II) on SBA- mesoporous molecular sieve functionalized with -NH₂ groups.," *Microporous and Mesoporous Materials*, n° 160, pp. 133-142, 2012.
- [10] S. Lata and S. R. Samadder, "Removal of arsenic from water using nano adsorbents and challenges: A review.," *Journal of Environmental Management*, n° 166, pp. 387-406, 2016.
- [11] D. Zhao, P. Yang, D. I. Margolese, B. F. Chmelka and G. D. Stucky, "Synthesis of continuous mesoporous silica thin films with three-dimensional accessible pore structures.," *Chemical Communications*, n° 22, pp. 2499-2500, 1998.
- [12] K. Flodström and V. Alfredsson, "Influence of the block length of triblock copolymers on the formation of mesoporous silica.," *Microporous and Mesoporous Materials*, n° 58, pp. 3-13, 2003.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Effect on the concentration of flavonoids in strawberry (*Fragaria ananassa* Duch) by the inoculation of *Rhizophagus Intraradices*.

Vázquez-Moreno Gerardo

Faculty of Engineering. Academic body of biosystems
Autonomous University of Querétaro (UAQ)
Querétaro, México
gerard_ovm@hotmail.com

Ocampo-Velázquez Rosalía V.

Faculty of Engineering. Academic body of biosystems
Autonomous University of Querétaro (UAQ)
Querétaro, México
rosov05@yahoo.com.mx

Abstract

Arbuscular mycorrhizae or endomycorrhizae are symbiotic mutualistic associations of various types that are established between certain fungi found in the soil and the roots of a certain plant. The importance of endomycorrhizas has increased in the last decade due to numerous reports of beneficial effects on plants, ranging from increases in the absorption of nutrients in the soil to the plant, its influence on water relations and protection against pathogens. Therefore, in the present study the nutraceutical quality of the strawberry fruit (*Fragaria ananassa* Duch) was evaluated, specifically, the content of total phenols and flavonoids by inoculation with the arbuscular mycorrhizal fungus (AMF), *Rhizophagus intraradices*. The results of the plants inoculated with *R. intraradices* indicate significant statistical differences, which represents a beneficial effect in the concentration flavonoids in comparison with the plants that were not inoculated. Therefore, the use of strains of *R. intraradices* is proposed as a biotechnological tool that can be used within horticultural production practices in greenhouses.

Keywords: soil microbiology, mutualist symbiosis, fertirrigation.

I. INTRODUCTION (HEADING 1)

In recent years, Mexico has increased in deaths associated with chronic degenerative diseases (INEGI, 2016), derived from this, foods such as fruits and vegetables have been taking relevance in the diet by consumers to be aware of the relationship that exists between good nutrition and disease prevention, in this situation, the strawberry turns out to be a very favorable fruit, due to its nutraceutical value, mainly; phenolic compounds, flavonoids and anthocyanins. These compounds, in addition to help to define the organoleptic characteristics and to preserve the nutritional quality of the fruit, can prevent or delay some types of cell damage by stabilizing the oxidations that occur due to its antioxidant capacity (Kuskoski et al., 2004;

Tulipani et al., 2008), so it is important to note that the greater the antioxidant capacity that a food can provide, the greater the benefits it can bring to health. This antioxidant activity is related to the reduction and prevention of certain chronic diseases (diabetes, hypertension and obesity) and degenerative diseases such as cancer (Basu et al., 2010). This nutraceutical value associated with the strawberry can be improved and used to generate an added value to the berries, which would positively impact the strawberry production chain at a national level because the strawberry is one of the most productive berries and export in Mexico. Due to the biotechnological potential of the AMF to improve agricultural practices, we proceeded to test the use of these in the strawberry crop under greenhouse conditions, since this is a crop of economic and social relevance at regional and national level, it is necessary to apply biotechnological strategies to solve some problems faced by their production, among which stand out, environmental pollution and the high cost of production due to the indiscriminate use of agrochemicals. The objective of this work was to determine the effect of AMF on agronomic variables and quality characteristics of strawberry fruits. Plants of *Fragaria x ananassa* Duch were used of the foreign variety Albion, which was inoculated with a single species of AMF (*R. Intraradices*), with the purpose of evaluating its effect on the nutraceutical value (flavonoids and total phenols) of strawberry fruits. The inoculation with *R. Intraradices* promoted statistical superiority in the two variables evaluated with respect to the control. The results showed that the concentration of nutraceutical compounds (total phenols and flavonoids) is more competitive in relation to the plants that were not inoculated. It should be noted that the amount of work is minimal, in which the effect of the AMF on the internal quality characteristics of strawberry fruits is studied, which can be exploited as an added value.



II. MATERIALS AND METHODS

A. Experimental site, substrate and biological material

The experiment was conducted in a greenhouse inside the campus facilities of the Universidad Autónoma de Querétaro located in the town of Amazcala, in the municipality of El Marqués in the state of Querétaro. This place is located at a height of 1920 meters above sea level in the GPS coordinates of longitude (dec): -100.265833 and latitude (dec): 20.703333. It has a mostly temperate-semi-dry climate and an average annual temperature of 21 ° C. This greenhouse is designed under the scheme of a "sierra type" structure, has overhead ventilation and the coating material is made of long-lasting polyethylene with 10% shade. The plant was installed in the greenhouse with its respective pot, for which a substrate with a mixture of coconut powder (*Cocos nucifera*) and peat moss in a 5:3 ratios was used. The design of the plantation was in a cultivation system that consists of vertical tubular steel structures of $\frac{3}{4}$ " in which the PVC tubes were supported where the pots were placed with the crop, each of the structures has a height 2.24 m and are separated from each other at a distance of 1.05 m from base to base. Each of the structures had three levels, the first level, positioned at 0.70 m from ground level, the second at 1.40 m and the third at 2.1 m. In each level, a line of PVC tubes of five inches in diameter positioned parallel to each other with a line length of 10.35 m was placed in each level, in each line a total of 47 holes of four inches in diameter were made and in each one of them was placed a pot of the following dimensions: five inches in top diameter, four inches in bottom diameter and four inches in height.

- *Fragaria X Ananassa* Duch, Variety Albion.

This variety of this plant was purchased with a producer from the municipality of Amealco de Bonfil, Querétaro and moved to the Amazcala campus. At the time of the beginning of the experiment, the plant had 3 months of life.

- *Rhizophagus Intraradices*.

The inocula of *Rhizophagus Intraradices* used in this project were obtained from a collaboration with the experimental field of the Bajío of INIFAP. The donation of the commercial inoculum "Micorriza INIFAP^{MR}" with a concentration of 60 spores per gram of inoculum.

B. Treatments and their application

The following treatments were established: control and 0.5 g *Rhizophagus Intraradices* per plant. The experimental design used was randomized blocks with three repetitions. The experimental unit consisted of 41 plants. The inoculum was applied once the plant installed in the greenhouse. We proceeded to make four perforations in the substrate of each pot, each perforation was two centimeters in diameter and five centimeters in depth approximately. In each of the perforations the mycorrhizal inoculum was sprinkled, and each perforation was covered with the same substrate and the cultural work was continued in a normal manner. For nutrition, the 30% Steiner solution was used, which was supplied to each plant by means

of a drip irrigation system with self-compensating drippers with a flow rate of four liters per hour and using one dropper for every two plants. To cover the demand of 0.6 liters of irrigation per plant, a total of nine irrigations of two minutes each were scheduled per day during each hour, beginning with the first irrigation at eight in the morning and ending at four in the afternoon during a period of four months until the cut of fruit.

C. Variables

The concentration of nutraceutical compounds (total flavonoids) was evaluated in the stage five based on the ripening stage emitted by SAGARPA.



Fig 1. Maturation status of strawberry fruits. Image taken from NMX-FF-062-SCFI-2002 (SAGARPA, 2012)

D. Total flavonoids

The quantification of the flavonoids present in the strawberry extract was carried out by the method of Liu et al. (2002). For this quantification, an aliquot of the methanolic or aqueous phenolic extract (50 μ l) equivalent to 0.0125 g of the extract of the pod was taken. To this sample, as well as to the points of the standard routine curve (0, 0.02, 0.05, 0.1, 0.25 and 0.5 mg / ml) were added 180 μ l of distilled water or methanol and 20 μ l of 2-aminoethyldiphenyl borate solution to the 1%, prepared with methanol, routine and distilled water for each extract. Subsequently, the absorbance at 404 nm was measured with a spectrophotometer (Thermo, Multiskan Ascent). The results obtained were expressed as mg routine equivalents / g of extract.

E. Statistic analysis

The statistical analysis was performed through an analysis of variance, with the ANOVA procedure with the Excel office 2016 software

III. RESULTS AND DISCUSSION

Statistical analysis indicated that inoculation with *R. intraradices* significantly increased the concentration of flavonoids compared to the control where the highest concentration value of this phenolic compound was found in plants inoculated with this microorganism, since the averages of each treatment was 2.78 mg routine equivalents / g of extract for the inoculated plants and 1.78 mg routine equivalents / g of extract for the control giving an F value of 5693.49 and



obtaining a critical value of F at 95 % reliability of 7.70, which shows a statistically significant difference between both treatments. In other studies, it has also been reported that the inoculation of AMF increases the concentration of nutraceutical compounds (phenols, flavonoids, anthocyanins, carotenoids, among others) compared with non-inoculated plants.

IV. CONCLUSIONS

The inoculation of mycorrhizal fungi *R. intraradices* (Micorriza INIFAP^{MR}) to strawberry plants, under a system of fertigation and in greenhouse conditions favored the increase of the concentration of flavonoids in fruit, which therefore increases the nutraceutical value of the strawberry in ripening stage five compared to non-inoculated plants.

REFERENCES

- [1] Adesemoye A., Klopper J. (2009). Plant microbes interactions in enhanced fertilizer-use efficiency. *Applied Microbiology and Biotechnology*. Vol. 85(1). pp. 1-12
- [2] Ban D., Goretá Ban S., Oplanic M., Horvat J. Novak B., Zanic K., Znidarcic D. (2011). Growth and yield response of watermelon to in-row plant spacings and mycorrhiza. *Chilean journal of agricultural research*. Vol. 71(4). pp. 497-502.
- [3] Basu A., Rhone M. (2010). Berries: emerging impact on cardiovascular health. *Nutrition*. Vol. 68(3). pp. 168-177
- [4] Cardoso, Irene M.; Kuyper, Thomas W. (2006). "Mycorrhizas and tropical soil fertility". *Agriculture, Ecosystems & Environment*. 116 (1–2): 72–84
- [5] Carvajal M. J., Mera B. A. (2010). Fertilización biológica: Técnica de vanguardia para el desarrollo agrícola sostenible. *Producción*. Vol. 5. pp. 78-96.
- [6] CONAFRE (2011). Sistema producto fresa. Disponible en: [http://conafresa.com/plan_rector.pdf]
- [7] Contreras Alonso R., Aguilera Gómez L., Arriaga M., Olalde Portugal V., (2007). Micorrizas arbusculares. *Ciencia Ergo Sum*, Vol. 14(3). pp. 300-306
- [8] Cruz Hernandez Y., García Rubido M., León Gonzalez Y., Acosta Aguilar Y. (2014). Influencia de la aplicación de micorrizas arbusculares y la reducción de fertilizante mineral en plántulas de tabaco. *Cultivos tropicales*. Vol. 35(1). pp. 21-24.
- [9] Díaz Franco A., Alvarado Carrillo M., Ortíz Chairez F., Grageda Cabrera O. (2013). Nutrición de la planta y calidad de fruto de pimiento asociado con micorriza arbuscular en invernadero. *Revista mexicana de ciencias agrícolas*. Vol. 4(2). pp. 315-321.
- [10] Instituto Nacional de Estadística y Geografía. (2011). Enfermedades cronicodegenerativas, INEGI, México. Disponible en: <http://www.inegi.org.mx> Instituto Nacional de Estadística Geografía e Informática/Secretaría de Salud.
- [11] Joublan JP., Vergara M. (2003). Desarrollo vegetativo y productivo de la frutilla (*Fragaria x ananassa* Duch.), utilizando una cubierta de agrotexil de diferentes densidades. *Agro sur*. Vol. 31(1). pp. 37-47.
- [12] Kusoski E., Asuero AG., García MC., Troncoso AM., Fett R. (2004). Actividad antioxidante de pigmentos antocianicos. *Investigación en Ciencia y Tecnología de Alimentos*. Vol. 24(4). pp. 2-11.
- [13] Liu M., Li XQ., Weber C., Lee CY., Brown J., Liu RH. (2002). Antioxidant and antiproliferative activities of raspberries. *J Agric Food Chem*. Vol. 50(10). pp.2926–2930. doi: 10.1021/jf0111209
- [14] Neetu Neetu, Ashok Aggarwal, Anju Tanwar, Alpa Alpa. (2012). Influence of arbuscular micorrhizal fungi and pseudomonas fluorescens at different superphosphate levels on linseed (*linum usitatissimum* L.) growth response. *Chilean journal of agricultural research*. Vol. 72(2) pp. 237-243
- [15] SAGARPA (2010). Catálogo nacional de variedades vegetales (C.N.V.V.) Disponible en: <http://snics.sagarpa.gob.mx/somos/Documents/CNVV%202010.pdf>
- [16] SAGARPA (2012). Productos alimenticios no industrializados para consumo humano-fruta fresca- fresa (*Fragaria x ananassa*, Dutch)-Especificaciones y método de prueba (Cancela a la NMX-FF062-1987). Disponible en: http://www.sagarpa.gob.mx/agronegocios/Lists/Instrumentos%20Tcnico s%20Normalizacin%20y%20Marcas%20Colecti/Attachments/90/NMX_FRESA.pdf
- [17] Smith S., Read D. *Micorrhizal Symbiosis* (Edit): Smith S., Read D. (2009). Academic press: London. pp. 144-187



A parallel algorithm for the estimation of missing Normalized Vegetation Index values from satellite images.

Jaime Alberto Arteaga Vargas

Facultad de Ingeniería, Universidad Autónoma de Querétaro
Querétaro, México
jaime_av@outlook.com

Enrique González Sosa

Facultad de Ingeniería, Universidad Autónoma de Querétaro
Querétaro, México
egs@uaq.mx

Abstract—Primary vegetation production is an important process for human beings, in vegetation we found one of the main sources of materials and food, also it is related to the carbon dioxide cycle and implicitly with global warming so its monitoring has become one of the main tasks for remote sensing research, although we have developed better remote sensors and techniques for estimating missing values in data from satellite images we face to the problem of increasing amount of data day by day and with these the increase of processing time of all of this information, using a parallel algorithm for estimating missing information we can make a better interpretation of the data and have a better understanding of hydrological phenomena like interception, water balance and global warming reducing the time spent processing data .

Keywords— Hydroinformatics, NDVI, Remote sensing, Gapfill, Rstudio

I. INTRODUCTION

Remote sensing has had a great development in the last 15 years driven by the need to understand how human activities affect the ecosystems over the world (Turner,2005).

On this discipline the energy from the earth's surface is measured through remote sensors installed on satellites, the amount of energy reflected by the surface is measured and registered as numerical value which is assigned to every pixel forming what we better known as satellite images like the one presented on Fig. 1 (Opriescu and Dumitrescu, 2005).

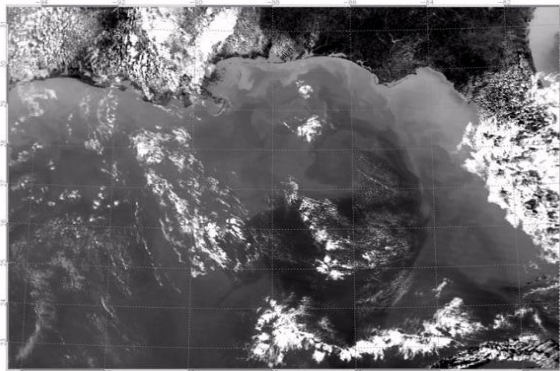


Fig. 1- Example of a Satellite Image.

MODIS or Moderate Resolution Imaging Spectroradiometer is an instrument on the Terra and AQUA satellites that acquires information from the earth's surface with 2330 km wide in 36 spectral bands and three different spatial resolutions 250, 500 and 1000 meters per pixel.

Primary vegetation production is very important for human being because it's one of the main sources of materials and food in addition multiple researches has proven that human activities like deforestation, urbanization and pollution Fig. 2 are related to vegetation quality and the way it changes, for these and other reasons monitoring vegetation distribution and quality has become a priority (Ipcc,1995).

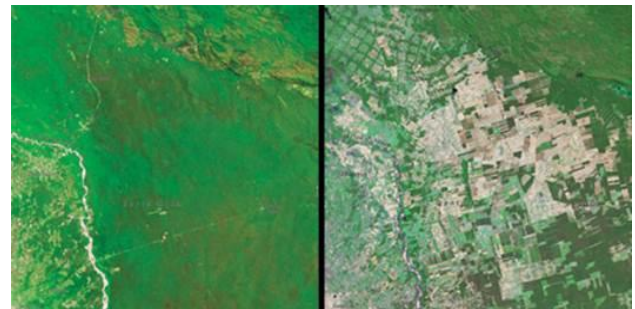


Fig. 2- Land change example detected by satellite images over Bolivia.

In this context the usage of remote sensing has become an efficient and affordable way in which we can perform measurements and keep a constant monitoring of large areas of the earth surface, on the other way we can reach conflict areas that under conventional circumstances would be dangerous (Wulder,1998).

The information obtained through remote sensing will provide us a better perspective of the behavior of the aforementioned phenomena over the earth's surface and in the future, we will be able to elaborate complex models to represents processes such as climate change (Unninayar and Olsen, 2008).

Thanks to the research made on this field, we have tools for the characterization of the vegetal cover using parameters obtained from remote sensed information such as the NDVI or



normalized vegetation index which allows us to characterize the quality and development of primary vegetation (1).

$$NDVI = \frac{IR-R}{IR+R} \quad (1)$$

Where:

IR - infrared band

R – red band

According to the NDVI value measured by the remote sensor we can judge if vegetation over the surface is healthy or unhealthy, values between 0.1-0.3 are measured from unhealthy vegetation, 0.3-0.66 are registered from moderately healthy vegetation while values of 0.66-1 are for healthy vegetation.

One of the main problems we face when we work with remote sensing data is the missing values on satellite images, when we have crossing bands over the image as the one presented on Fig. 3, we can say it means there's a problem with the calibration of the remote sensor on the satellite.



Fig. 3- Satellite Image with banded missing pixel values.

A second reason that explains missing values could be the presence of clouds which is a very common problem not to say the most common Fig. 4, in this case the remote sensor measures NDVI values affected due to the clouds modifying the value reflected by the surface.



Fig. 4- Satellite Image with pixel values affected by clouds.

In recent years lots of algorithms have been developed for the estimation of missing values in satellite images and also for processing databases using physical methods, regressions or a combination of both (Verrelst et al., 2015)

All of these methods mentioned before find their limitation when it comes to processing large databases, which is why methods such as segmentation processing in parts the whole database are used.

Among the wide variety of algorithms used for the estimation of missing values on satellite images this research will focus on the one named Gapfill using RStudio due to the processing advantages and wide variety of geostatistical tools it offers being the most important the possibility to run the algorithm in parallel making more efficient the estimation of missing pixel values of NDVI.

II. MATERIALS AND METHODS

The algorithm Gapfill is based on a 4 dimensions array composed by latitude, longitude, time interval and year of the measurement, all of these are used to estimate de missing values as time series with a correction made with an interpolation method stopping when one of the following two criteria is reached:

- The max number of iterations is reached
- The resulting value is NAN

The estimation of values with the algorithm is based on the selection of a subset of data around the missing value, making the estimation of each missing value independently depending of the surrounding values, an interpolation method better known as nearest neighbor.

The main input for the algorithm is the matrix of NDVI values obtained from processing the corresponding bands mentioned on (1), as we mentioned before the potential of the Gapfill algorithm lies on the possibility to be executed in parallel which means using each core of the computer at the same time, a second reason why we choose gapfill is the possibility to be executed using other interpolation methods selected by the user.

As we mentioned before in order to be able to process this data on RStudio we need to have a four dimensions array Fig.5, for this case we had latitude and longitude, the corresponding day and year of measurement.

Day 345 del 2006																						
Long/Lat	69.1	69.12	69.14	69.16	69.18	69.2	69.22	69.24	69.26	69.28	69.3	69.32	69.34	69.36	69.38	69.4	69.42	69.44	69.46	69.5	69.5	
-153.032																0.417	0.435					
-153.012																0.452	0.464					
-152.992																0.444	0.459					
-152.975																0.448	0.431	0.441				
-152.955																0.458	0.475	0.487	0.482			
-152.935																0.465	0.458	0.451				
-152.915																0.465	0.443	0.465	0.449	0.424		
-152.895																0.453	0.439	0.434	0.409			
-152.875																	0.455	0.434	0.409			
-152.855																	0.455	0.431	0.418			
-152.835						0.4813											0.456	0.392	0.409			
-152.815						0.4813												0.453	0.457	0.382		
-152.795																		0.5026	0.4401			
-152.774																		0.5002	0.486			
-152.754	0.4798	0.4996															0.4955	0.3961	0.5072	0.496		
-152.734	0.489																0.4661		0.4724			
-152.714	0.4958	0.5109															0.486		0.4551			
-152.694	0.4807																					
-152.674	0.4587	0.4837																				
-152.654	0.465	0.45																				
-152.634	0.4829																					

Fig. 5- four dimensions array of values for day 345 of 2006.



For the last matrix we can see the missing values as a NA values which means there was no measurements, column 1 corresponds to the first dimension of longitude, row1 for the latitude dimension and the las two where the day which was 345 and the year 2006.

For this research it was used a database obtained from NDVI images downloaded from the MODIS website, it was composed by images of four days, may 24, June 09, June 24 and July 11 with a resolution of 21x21 pixels for the years which means we had 442 daily values for the years 2004, 2005, 2006 and 2007 which means that our database had 7056 values and after a first inspection we found that we had 1643 missing values.

As we mentioned before in order to be able to process this data on RStudio we need to have a 4 dimensions array, for this case we had latitude and longitude, time interval and the corresponding year of measurement.

III. RESULTS

After we prepare our data and deploy it on Rstudio we got dispersion graphs as the one shown on Fig.6 where we can have a first look of the data, each point is a measured value and we can see each break between one day and another one, in this case is shown the data for the four days of 2005, on the y axis we have the value of NDVI reached meanwhile on the x axis we have their respective n index.

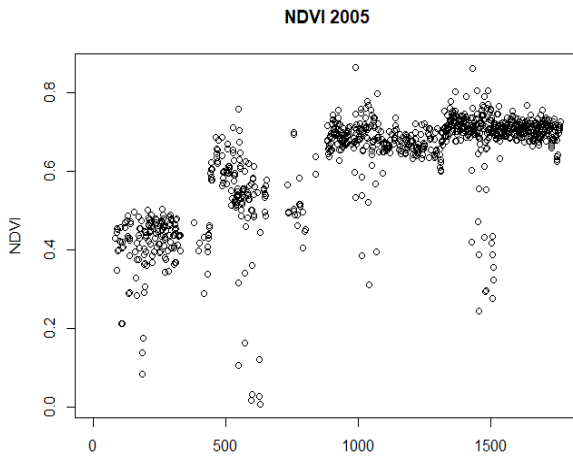


Fig. 6- NDVI data plot for the year 2005.

This graph was selected because we can see clearly which the year with less measurements and the same to identify the day with less density of points, in addition we are able to see the points out of the line of tendency and identify these extreme values.

If we had a graph for a whole year of measurements we could see the characteristic behavior of the parameter with an increasing tendency all over the year which is a behavior already studied by other research.

The graph presented before helped us to identify extreme values and see if we need another filter for these values, in this case these values were caused because the remote sensor was measuring the NDVI value from a river whose values of

reflectance rounds between 0.01 and 0.1 whose color corresponds to the blue tones on Fig. 7.

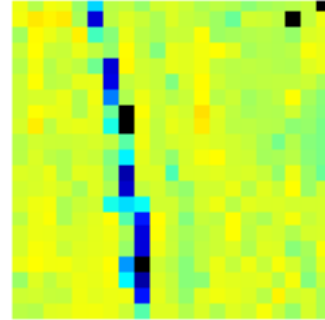


Fig. 7- NDVI Image where green pixels are vegetation measurements and the blue ones are the pixels that corresponds to the river.

After loading the database and once we extract pixel to simulating the presence of clouds, we were able to plot each matrix as we can see on Fig.8 where each column corresponds to a different year, each row for a different day and the pixels inside are the measurements of NDVI.

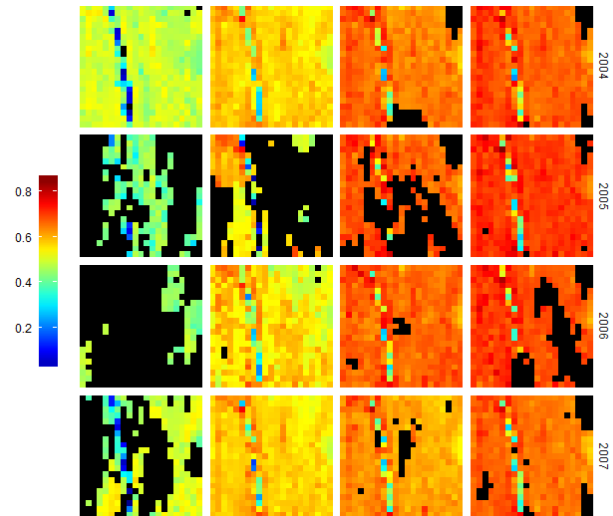


Fig. 8- NDVI database array.

We can appreciate that missing values appears as black pixels, the ones that corresponds to the river are on blue and the rest of the data are NDVI from the vegetation found on the surface.

Now that we have finished our first inspection we have loaded the data we have to proceed to estimate the missing values, we apply the algorithm under the scheme of a function shown in Fig 9.

```
Gapfill(data, fnSubset = Subset, fnPredict = Predict, iMax = Inf,
nPredict = 1L, subset = "missings", clipRange = c(-Inf, Inf),
dopar = FALSE, verbose = TRUE, ...)
```

Fig. 9- Scheme of the algorithm Gapfill.

This algorithm makes the estimation of missing pixel values in two steps, on the first one it select the missing pixel value an make an interpolation by the nearest method with the neighbors around this pixel, when we declare the conditions for the algorithm we can select how many pixels around the algorithm is going to take into account, for this research we use five pixel on every direction, forming a 11x11 matrix to interpolate, this would be an easy task if leave things like that so the second step is to go back to the other measurements and select the ones for the same location, row and column in order to build a time series of NDVI values for that position and make an adjustment according to the values measured before and after that day.

After having run the algorithm for the database the same kind of array will be returned by RStudio but this time with the estimates missing values already substituted Fig. 10 we can observe the data matrix shown in previous figures but this time with the results after executing the algorithm and interpolating the missing NDVI values.

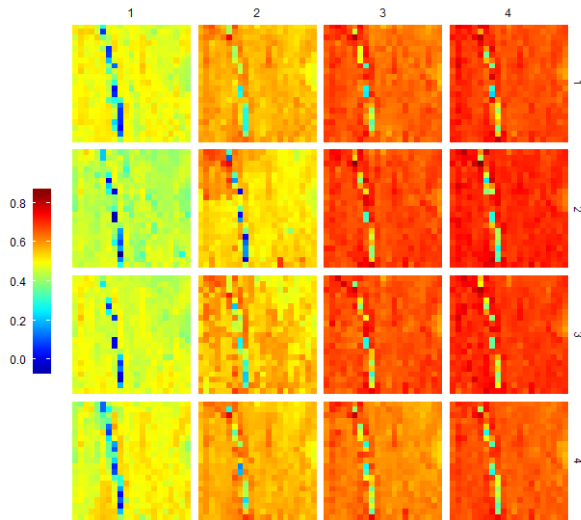


Fig. 8- NDVI database array.

The results of the algorithm were validated through a cross validation, removing from the matrix of known values, certain samples replacing the values of pixels by NA to estimate them in another run of the algorithm, estimating the absolute error that was obtained in the estimation of values in the center of the image we have from 80-94% accuracy and but we move away to the corners the precision on our estimations falls until 23%, when the number of data is less than 50% on the corners, absolute error can reach 77%.

Once we have identified the accuracy from the algorithm, we continue to test the processing times before and after being implemented in parallel, for this test the algorithm was run fifty times under the same conditions and for the same situation in order to get a controlled environment for the same case of study.

The computer used for this test was a desktop with 16 Gb of RAMM at 2400 GHz with a Intel Core i7-6700 HQ CPU at 2.6

GHz with an NVIDIA GeForce GTX 1060, executing the algorithm as predetermined we got a processing time of.

IV. DISCUSSION AND CONCLUSIONS

Ten simulations where made to review the consistency of the algorithm extracting known values reassigning NA values for them, once we estimate this missing but known values we found that the accuracy of the algorithm round 80-90% but it depends on how many pixels are missing because as we said before it may fall until 23% of accuracy at the corner under specific situations, this fall is generated by nature of the algorithm procedure, having a just a little pixel values near the estimation location and also missing historical values the algorithm can't make a accurate estimation.

Another thing we can mention is the advantage we got with the possibility to run the algorithm using the entire potential from our computer dividing the process between each of the cores available no matter if they are from the CPU or GPU.

It is necessary to consider that the algorithm starts from the assumption of a spatial-temporal relationship between the variables in order to apply the method and obtain good results.

Being a method, based on interpolation, we cannot estimate extreme values that have not been recorded within the measurements, that is, the estimated values will have as limits the minimum and maximum values that have been recorded by the sensor.

As an interpolation method, the nearest neighbor was maintained by default, but each user could select or enter his own routine according to experience to obtain better results in terms of accuracy that could improve it in border values due to edge effects.

Talking about processing times the algorithm was run forty times were made for each method until there was little variation between the processing times, making the processing more efficient, reducing the execution times from 0.1815 seconds to 0.0048 second for each estimated value reducing processing time in 70%.

The estimated NDVI values will allow us to have a better understanding of the processes on the earth's surface with the possibility of making a better estimate of evapotranspiration as part of the water balance due to the urgency of the situation to make better designs that adapt to the present conditions that occur in the atmosphere that affect the intensity and duration of the rains as well as the periods in which they occurred, in the same way we will have a better understanding of the relationship between the quality of the vegetation and the time of year in which we find ourselves as well as its relationship with the concentration of CO2 in the atmosphere.

Finally, as a recommendation to obtain an improvement in the results should be considered the run of the algorithm with larger databases that will allow us to have longer time series for the estimation of the missing values, although those that are close to the date will give us a better approximation if we do not



have recent information, the historical ones will allow us better approximations.

REFERENCES

- [1] Linke, J., G. J. McDermid, A. D. Pape, A. J. McLane, D. N. Laskin, M. Hall-Beyer, and S. E. Franklin, "The influence of patch-delineation mismatches on multi-temporal landscape pattern analysis", 2009.
- [2] Oprisescu, S., and M. Dumitrescu, "On the regularization of segmented satellite images", 2005.
- [3] Turner, M. G., "Landscape Ecology: What Is the State of the Science?". 2005.
- [4] Unninayar, S., and L. Olsen, "Monitoring, Observations, and Remote Sensing", 2008
- [5] Verrelst, J., G. Camps-Valls, J. Muñoz-Mari, J. P. Rivera, F. Veroustraete, J. G. P. W. Clevers, and J. Moreno, "Optical remote sensing and the retrieval of terrestrial vegetation bio-geophysical properties", 2015.
- [6] Ippc, "Second Assessment Synthesis of Scientific-Technical Information relevant to interpreting Article 2 of the UN Framework Convention on Climate Change", 1995.
- [7] Wulder, M., "Optical remote-sensing techniques for the assessment of forest inventory and biophysical parameters", 1998.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Methodology to Quantify the Impact of a Poor Power Quality in an Industrial Robot.

Ing. Luis Alberto Ángeles Hurtado

Facultad de Ingeniería, Universidad Autónoma de Querétaro

Universidad Autónoma de Querétaro, UAQ
Querétaro, México

e-mail langesl1@alumnos.uaq.mx

Dr. Juvenal Rodríguez Reséndiz

Facultad de Ingeniería, Universidad Autónoma de Querétaro

Universidad Autónoma de Querétaro, UAQ
Querétaro, México

e-mail juvenal@uaq.edu.mx

Abstract— Modern electric power supply and delivery systems consist of a complex grid of multiple electrical components including power generation supply, transmission, voltage control, and power delivery with multiple points of supply and use. Many businesses suffer economic losses when electric power interruptions occur or even when there are voltage or current abnormalities present in the power delivery. This paper explores the power quality sensitivity of the power quality disturbances in the robot Nachi and examines a methodology as a tool based on machine learning and design of experiments in which measure the impact of a poor power quality in the industrial robot and how can be characterized when connecting and disconnecting electrical loads.

Keywords—Power quality; classification; machine learning; power quality disturbances.

I. INTRODUCTION

The estimate of robots installed in companies worldwide is around 294,000 only for 2016. China has significantly expanded its leading position as the biggest market with a share of 30% of the total supply in 2016. Between 2011 and 2016, the average annual growth rate was 15%. The automotive industry is still the major customer of industrial robots with a share of 35% of the total supply in 2016. The electrical/electronics industry has been catching up, specially in 2015 and 2016, reaching a share of 31% of the total supply in 2016, sales to the metal and machinery industry slightly decreased by 3% to 28,700 units, the food and beverage industry also increased robot orders in 2016 by 20% to almost 8,200 units, accounting for a share of 3% of the total supply. Mexico has become an important emerging market for industrial robots. Robot sales further increased to about 5,900 units in 2016, eighth worldwide. With a forecast for 2018 of 2.323 million worldwide in stock of industrial robots [1], These data give us a global panorama to carry out the research and maintain the growth of this industry in our country.

In Mexico, numerous works are carried out in the area of retrofitting research with the aim of reducing the technological gap we have with respect to other growing countries. In the 90s,

this line of research aimed at older robots began to adapt to new technologies [2], the mechanical parts of the robot are reused, only those that are in good condition, together with the electronic and electromechanical components. In this work we will analyze the Nachi robot, which at the end of its life cycle was discarded and recovered by the Autonomous University of Querétaro, is currently located in the Mechatronics laboratory.

The demand for electricity is growing and the problems arise with computers, microprocessors, fluorescent light ballasts, sensitive medical imaging equipment, variable speed drives, computer directed design and manufacturing, critical communications equipment, nuisance trips on circuit breakers, overheating of equipment, etc. [4].

These electric charges are considered sources of power quality disturbances (PQD) [3]. The large number of inductive loads connected in the different industries demand a good capacity of the power systems to provide signals without distortion of voltage, current and frequency, to this capacity of the electrical network is called power quality (PQ) [4].

The signals with distortions of voltage and current can damage the electrical equipment, these distortions occur frequently in the electrical supply network, therefore, it is necessary to increase the generation of energy and improve the use of the systems that consume high amounts of energy. power [5], [6], ensuring that the PQ disturbances are minimized.

In accordance with the recommendations of the IEEE Std 1159 [7] some of the different electromagnetic phenomena that affect the quality of energy are transient (impulsive and oscillatory), short duration variations (interruption, sag and swell) and steady state variations (harmonics, notch and flicker), see “Fig. 1”, commonly caused by the switching of large electrical loads such as motors, transformers and capacitor banks or faults in the network, these are the most important due to their significant negative impact on the equipment.



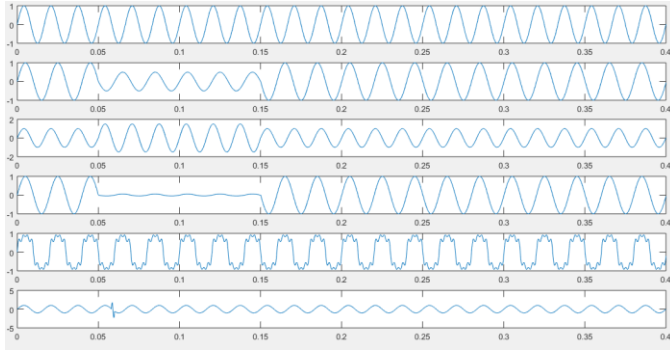


Fig. 1. Normal sinusoidal signal, sag, swell interruption, harmonics, transient.

The importance of being able to correctly classify the electromagnetic phenomena is that once the PQ events can be identified in an electrical system, a solution can be given that is more in line with the problem in the energy consumption.

The extraction of electromagnetic phenomena is also known as perturbation detection, this extraction is used to classify the PQ events, therefore, the appropriate selection of PQ events characteristics is crucial for a good classification [4], [8], among the most commonly used methods are the Fourier transform method, the S transform method, the Hilbert Huang transform method and the Wavelet transform method [8]. SVM (support vector machine) are introduced for the classification of the PQ events. SVM has the robust ability to classify PQ events considering the theory of statistical learning and the principle of minimum structural risk [13], [15].

The proposed methodology is 1) the data of the Nachi robot motors are obtained with the PW3198-90 analyzer 2) the statistical tool of main components is implemented to quantify the impact on the robot motors, 3) the factors that impact on the energy consumption of the robot motors are defined, 4) Simulate different loads to define the characteristics of a poor power quality and the method is applied of the Wavelet transform with support vector machine to sorting the PQ events, 5) the design of experiments is applied to identify the conditions in the that the robot can have a better performance, 6) the improvement is checked again applying the tool of main components.

II. THEORECAL BACKGROUND

A. Characteristics of voltage variations.

The “TABLE I” shows how voltage variations are classified according to function and magnitude [9].

TABLE I. CATEGORIES AND TYPICAL CHARACTERISTICS OF VOLTAGE VARIATIONS [7], [9], [10].

Category	Typical duration	Typical voltage magnitude
Short duration variations		
Instantaneous Sag	0.5-30 cycles	0.1 – 0.9 pu

	Swell	0.5-30 cycles	1.1 – 1.8 pu
Momentary	Interruption	0.5 cycles-3s	< 0.1 pu
	Sag	30 cycles -3s	0.1 – 0.9 pu
	Swell	30 cycles -3s	1.1 – 1.4 pu
Temporary	Interruption	3s – 1min	< 0.1 pu
		3s – 1min	0.1 – 0.9 pu
		3s – 1min	1.1 – 1.2 pu

Long duration variations

Interruptions sustained	> 1 min	0.0 pu
Low tensions	> 1 min	0.8 – 0.9 pu
Overvoltage	> 1 min	1.1 – 1.2 pu

a. per unit

B. Mathematical models of power quality disturbances.

The “TABLE II” shows the equations that describe the signals of the electromagnetic phenomena these equations will be used for the methodology that is being proposed.

TABLE II. EQUATIONS FOR THE TYPES OF POWER QUALITY EVENTS [9], [11], [13].

PQD	Expression
Normal	$\mu(t) = \sin\omega t$
Swells	$\mu(t) = \{1 + \alpha[u(t - t1) - \mu(t - t2)]\}\sin\omega t$
Sag	$\mu(t) = \{1 - \alpha[u(t - t1) - \mu(t - t2)]\}\sin\omega t$
Interruptions	$\mu(t) = \{1 - \alpha[u(t - t1) - \mu(t - t2)]\}\sin\omega t$
Harmonics	$\mu(t) = \{1 - [u(t - t1) - \mu(t - t2)]\}\sin\omega t$
Pulse	$\mu(t) = \sin\omega t + \alpha3\sin\omega t + \alpha5\sin\omega t + \alpha7\sin\omega t$
Oscillation	$\mu(t) = \sin\omega t + \alpha e^{-c(t-t1)}[\mu(t - t1) - \mu(t - t2)]\sin\beta\omega t$
Flicker	$\mu(t) = \left[1 + m \sum_{i=1}^3 \frac{1}{i} \sin(2\pi i f t)\right] \sin\omega t$

C. Wavelet transform (WT)

In the literature, the signal processing techniques are available for analyzing PQ disturbance, the most important of those are Fourier transform (FT), short-time Fourier transform (STFT) and wavelet transform (WT) for useful feature extraction from signals [18].

Comparative study of PQ events detection techniques to detect PQ disturbances and the comparison of main PQ disturbance analysis methods is detailed in “TABLE III” [8]. Discrete wavelet transforms represent the computational efficiency of mayor power quality disturbance detection technique provide local representation in both time and frequency. These features make the WT well suited for the



analysis of the power system transients caused by various disturbances [18].

TABLE III. COMPUTATIONAL EFFICIENCY OF PQ DETECTION TECHNIQUES [8].

No.	PQ disturbance	Percentage efficiency of PQ detection techniques.			
		Hilbert Huang transform	S-transform	Discrete wavelet transform	Fast Fourier transform
1	Sag	100	100	98.67	95
2	Swell	100	100	99.33	98
3	Harmonic	95	100	99.33	100
4	Flicker	100	100	98.67	89
5	Notch	100	83	97.33	-
6	Spike	95	77	-	-
7	Transient	98	100	98.67	100
8	Sag+ harmonic	98	100	98.18	-
9	Swell+ harmonic	89	100	98.18	-
10	Sag+ transient	-	-	96.36	-
11	Swell+ transient	-	-	98.18	-

Due to its ability to extract time and frequency information of signal simultaneously. WT can be continuous or discrete. Discrete WT (DWT) can be viewed as a subset of Continuous WT (CWT). In practical applications, the DWT is commonly used. DWT uses the low-pass $h(k)$ and the high-pass $g(k)$ filters to divide the frequency-band of the input signal $f(k)$ into respective low- and high-frequency components into octave bands.

The low-pass filter $h(k)$ is determined from the scaling function. The high-pass filter $g(k)$ is determined from both the wavelet and scaling functions. The wavelet and scaling functions are, respectively, given as:

$$\psi(k) = \sqrt{2} \sum_n g(n) \phi(2k - n), \quad (1)$$

$$\phi(k) = \sqrt{2} \sum_n h(n) \phi(2k - n), \quad (2)$$

Where n is integers and represent the number of samples. On the left-hand side of see “Fig. 2”, the frequency band levels and frequency divisions of levels are shown for a signal which has 10 kHz sampling rate.

On the right-hand side Fig. 2”, the typical PQ phenomena are listed. It can be seen that the harmonic features appear at levels 5–6 because of having the bandwidth between 100 Hz and 250 Hz of dominant harmonics which are 2nd, 3rd, 4th and 5th. Oscillation frequency of a transient is typically between 300 and 1000 Hz. Therefore, transient features are viewed at levels 3–4. High-frequency transient features sight upper levels

so high-frequency transients fall within a bandwidth between 2 kHz and 3 kHz [19], [22].

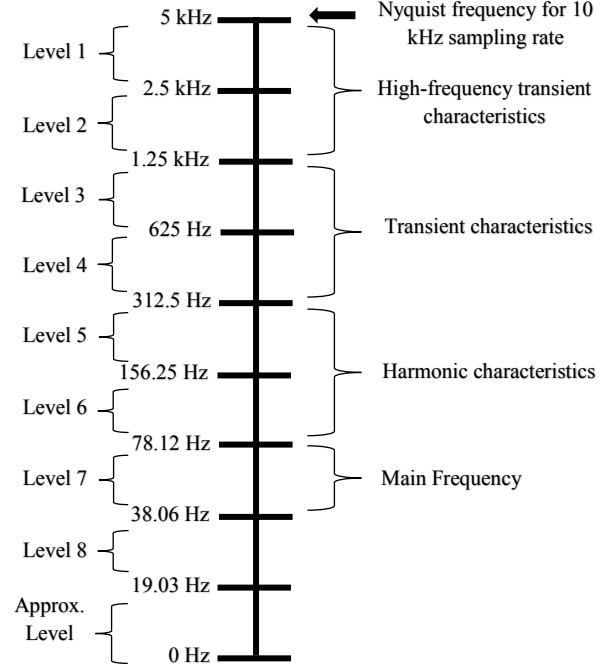


Fig. 2. Frequency division of DWT filters for 10 kHz sampling rate [27].

D. Support vector machine (SVM)

SVM algorithm was proposed by Vladimir N Vapnik. It is a kind of supervised learning classification [8], where the model is built based on the training data to predict the given test data. SVM provides a hyperplane to distinguish between various class of data. SVM can be used to classify two classed data (binary classification) or can also be used to classify multi-class data [11]. In [15] SVM is the powerful tool for identification and classification of voltage signals, images as well as music signals.

The basic idea of SVM is maximizing the boundary hyperplane (maximal margin hyperplane) [16], SVM can classify the data that has more than two classes, for example to specify polynomials of any fixed order d , one can use the following functions for the inner product in the corresponding feature space:

$$K(x, x_i) = ((x \cdot x_i) + 1)^d \quad (3)$$

Radial basis function machines with decision functions of the form

$$f(x) = \text{sign} \left(\sum_{i=1}^n y_i \alpha_i \exp \left\{ \frac{|x-x_i|^2}{\sigma^2} \right\} \right) \quad (4)$$

Can be implemented by using a function of the type



$$K(x, x_i) = \exp \left\{ -\frac{|x-x_i|^2}{\sigma^2} \right\} \quad (5)$$

In this case the SVM will find both the centers x_i and the corresponding weights α_i . The SVM possesses some useful properties. The optimization problem for constructing an SVM has a unique solution [17].

E. Principal Components Analysis (PCA)

PCA uses mathematical principles to transform correlated variables into a smaller number of variables. The principal component analysis uses to describe variation in a set of correlated variables. PCA has several advantages such as lack of redundancy, reduced complexity, small database and reduction of noise. The disadvantages are difficult to be evaluated of the covariance matrix and the simplest invariance could not be captured.

PCA can analyze the main elements of multi-things, expose the nature of things, and shorten difficult problems. Projecting large data in a small space is the main objective of PCA.

Steps to decrease the dimension of the matrix with PCA see “Fig. 3” (1) to determine the covariance matrix $S_{n \times n}$ of the sample matrix $X_{m \times n}$ (2) to determine the eigenvectors of covariance matrix $S_{n \times n}$ and the eigenvalues of the eigenvectors. The eigenvalues are arranged from larger to smaller. The eigenvectors are e_1, e_2, \dots, e_N , and the eigenvalues are x_1, x_2, \dots, x_N , for $i = 1, 2, \dots, N$. (3) to determine the influence rate and the cumulative influence rate of the covariance matrix, then the formulas are as follows [14].

$$\theta_i = x_i / \sum_{n=1}^N x_n, i = 1, 2, \dots, N \quad (6)$$

$$\Theta_r = \sum_{i=1}^r \theta_i, r = 1, 2, \dots, N \quad (7)$$

Where θ_i is the influence rate of the i -th column-vector of the covariance matrix $S_{n \times n}$ where Θ_r is the cumulative influence rate of the first r column-vectors. (4) to decide the dimension of the prediction matrix (or it is called PCA matrix), and the dimension is r if $\Theta_r > 70\%$, $r < n$. (5) to consider the first r -dimension of the covariance matrix as the prediction matrix $S_{n \times r}$. $T_{n \times n}$ is the covariance matrix of the needed to down-dimensional matrix $Y_{s \times n}$, and the outcome of $T_{n \times n}$ multiplied by $S_{n \times r}$ to get the final matrix, Namely, $T_{n \times n} \times S_{n \times r}$.

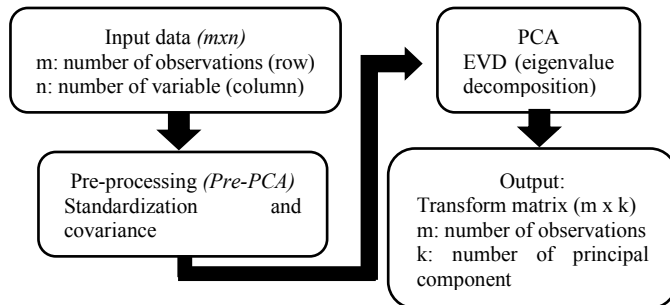


Fig. 3. General steps of PCA.

The matrix of principal components is the product of the matrix of eigenvectors with the matrix of independent variables. The first component represents the largest percentage of the total variation of the data. The second component represents the second highest percentage of the total data variation, and so on [13], [14].

F. Robust design of experiments.

The objective of the robust design of parameters is to achieve products and processes against the causes of variability (noise), which cause the functional characteristics of the products to deviate from their optimal values causing quality costs, this concept was developed and proposed by Taguchi.

The Taguchi methodology establishes three goals: 1) robust designs (insensitive) to the environment for products and processes. 2) Design and development of products, so that they are robust to the variation of components. 3) Minimization of variations with respect to a target value. These three goals are specified with three stages of the development of a product: 1) System design: the experimenter develops scientific principles to determine the basic configuration. 2) Parameter design: the specific values for the parameters of the system are determined, minimizing the variability provided by the noise variables. 3) tolerance design: the best tolerances for the parameters are determined. The function of loss see equation 8 implies that the quality characteristic, y , must be closer and closer to its ideal value, t , and everything that deviates from the ideal is considered a loss.

$$L(y) = k(y - t)^2 \quad (8)$$

Where k is a constant that depends on tolerances and repair costs of the product. The robust design is an experiment in which non-controllable noise factors exist, whose effect is intended to be minimized indirectly, in order to find the combination of levels of the process factors that can be controlled, and where the effect of said noise factors is minimal [24].

G. Improving power quality.

A range of technologies can be used to improve the power quality at a site. These technologies can help to insulate the customer from variations in PQ in utility supplied power or to mitigate PQ disturbances emanating from the customer’s own equipment. These technologies are often used as individual components of an overall PQ control strategy and include: transient voltage surge suppressors; VAR compensators; dynamic voltage restorers; isolation transformers; motor-alternators (motor-generators); and various types of UPS. A facility may choose to protect its entire load (at the electric service entrance), sensitive sub-facilities (individual circuit protection), or individual operations (controls or individual equipment protection.) The protection level depends on the size and type of critical load [4] [25].

III. METHODOLOGY

The three-phase 220V supply network was analyzed at a frequency of 60 Hz, to check whether the voltage source has sufficient characteristics to maintain reliable performance in the robot. We considered 17 variables in the first stage that affect the operation of the robot, see “Fig. 4”, the variables that define the quality of energy according to [20], [21].

To obtain the data of the electrical network we used the Hioki PW3198-90 this is an analyzer of the quality of the energy to monitor, save anomalies of power supply and to evaluate the problems such as voltage drops, flicker, harmonics among others besides having a high degree of precision and accuracy.

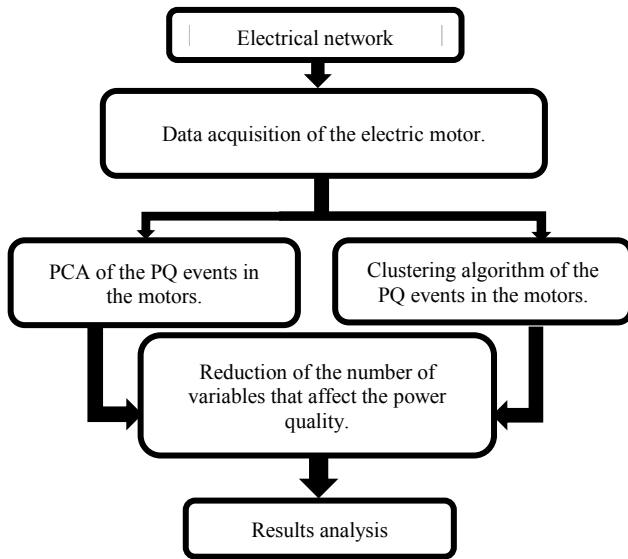


Fig. 4. Analyzing process with PCA.

A. Data acquisition of PQ disturbances.

The measurement instrument of the HIOKI brand was used to measure the quality of the energy of which the main parameters of energy quality are described: frequency, RMS voltage, flicker, voltage interruptions, over transient voltages, voltage imbalance, voltage harmonics, inter-harmonic voltage, voltage signal and fast voltage fluctuations.

B. Principal component analysis of the PQ events in the motors.

We considered the Kaiser criterion and the Montecarlo studies where the cut-off points of 0.7 defining the number of main components required for the analysis obtained the first diagnosis of the motors with respect to PQ disturbances see “Fig. 5”. Each factor that throws was assigned a number depending on the factors that were analyzed.

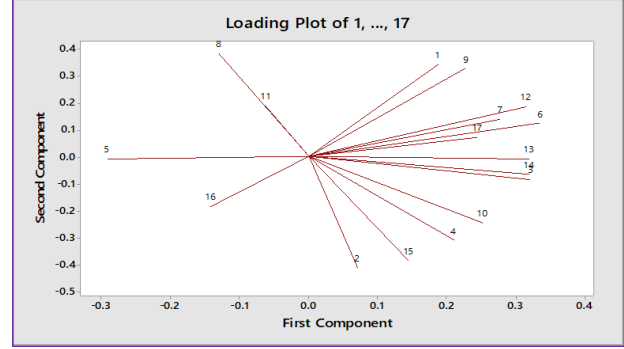


Fig. 5 First component vs second component in Minitab.

C. Clustering algorithm of the PQ events in the motors.

With the conglomerate analysis see “Fig. 6”, a dendrogram was obtained from the variables that represent the most significance in the variation based on the eigenvalues and eigenvectors of the data obtained from the main components. With this conglomerate analysis it was easier to make a decision as to which variables were candidates to be eliminated due to the degree of variation that they represent in the data.

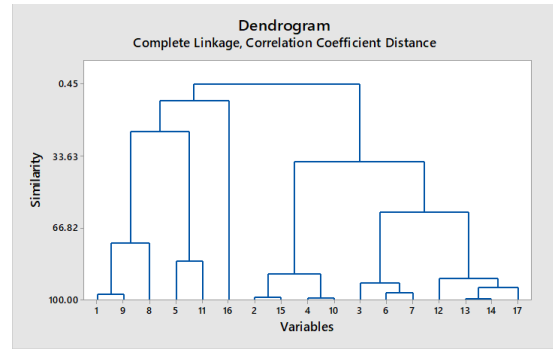


Fig. 6. Dendrogram in Minitab.

D. Reduction of the number of variables that affect the power quality.

The number of dimensions was reduced to facilitate the interpretation of the data. The variables showing data magnitudes above 95% were grouped and eliminated, comparing the results the Matlab software was also used to obtain the proportion of the eigenvalues that represent the greater variability in the main components and select those eigenvectors as those that mainly affect the engines see “Fig. 7”. Each main component is considered as an index of the PQ disturbances.



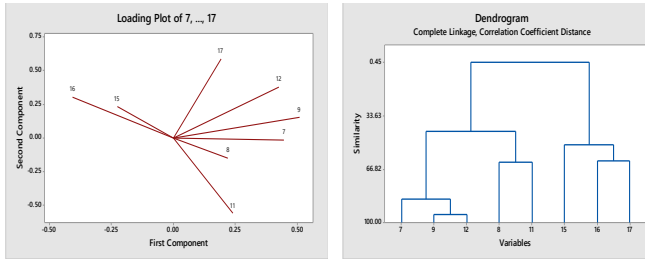


Fig. 7. PCA and clustering to reduction of factors.

E. Simulation of the PQ disturbances.

We considered twelve energy quality disturbance signals swell, sag, interruptions, fluctuations, flicker, transients and oscillating harmonics see “Fig. 8” and two complex power quality disturbance signals (swell with harmonics, sag with harmonics, sag with transient and swell with transient).

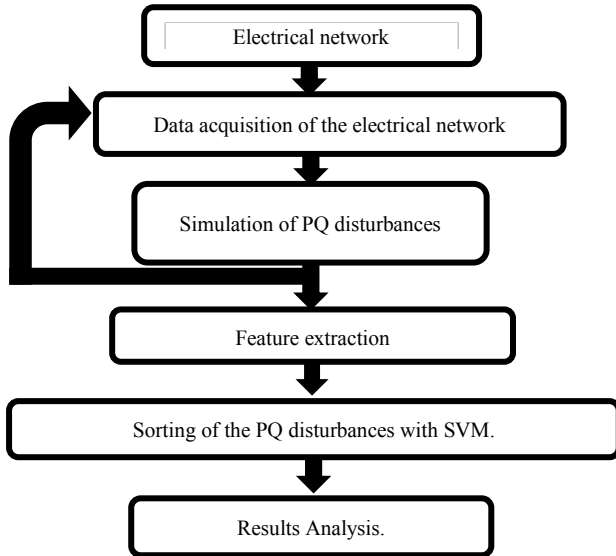


Fig. 8. Analyzing process with SVM.

Once the matrix of principal components is obtained, the PQ disturbances will be simulated so that they have a better precision in the matrix of main components. The training matrix will be based on simulations to analyze them through PCA, these matrices will simulate the number of loads that could be connected in the electrical network. With the objective of quantifying the impact when connecting new electric charges. The “TABLE IV” shows us the mathematical equations that will be added to the matrix of main components.

TABLE IV. PQD MATHEMATICAL MODELS [12], [13], [26].

Power Quality Disturbances		
1. Sag	$(1 - \alpha[u(t - t_1) - \mu(t - t_2)]) \sin(2\pi ft)$	$0.1 \leq \alpha \leq 0.9;$ $t_1 < t_2$

2. Swell	$(1 + \alpha[u(t - t_1) - \mu(t - t_2)]) \sin(2\pi ft)$	$0.1 \leq \alpha \leq 0.8;$ $t_1 < t_2$
3. Harmonic	$\alpha_1 \sin(2\pi ft) + \alpha_3 \sin(3 * 2\pi ft) + \alpha_5 \sin(5 * 2\pi ft) + \alpha_7 \sin(7 * 2\pi ft)$	$0.1 \leq \alpha_i \leq 0.25 \text{ pu for } i = 3, 5, 7$ $0.1 \leq \alpha_j \leq 0.1 \text{ pu for } i = 2, 9, 11$
4. Flicker	$(1 + \alpha \sin(\beta * 2\pi ft)) \sin(2\pi ft)$	
5. Notch	$\sin(2\pi ft) - \text{asign}(\sin(2\pi ft)) \sin(2\pi f_2 t)$	$0.1 \leq \alpha \leq 0.4;$ $100 \leq f_2 \leq 500$
6. Fluctuations	$(1 + \alpha \sin(2\pi ft)) \sin(2\pi ft)$	
7. Transient	$\sin(2\pi ft) + A[u(t - t_2) - \mu(t - t_1)] e^{-t/\tau} \sin(2\pi f_n t)$	$K=0.7 \tau=0.0015$ $900 \leq f_n \leq 1300$
8. Sag+ harmonic	$(1 - \alpha[u(t - 0.05) - \mu(t - 0.15)]) \alpha_1 \sin(2\pi ft) + \alpha_3 \sin(3 * 2\pi ft) + \alpha_5 \sin(5 * 2\pi ft) + \alpha_7 \sin(7 * 2\pi ft)$	
9. Swell+ harmonic	$(1 + \alpha[u(t - t_1) - \mu(t - t_2)]) \alpha_1 \sin(2\pi ft) + \alpha_3 \sin(3 * 2\pi ft) + \alpha_5 \sin(5 * 2\pi ft) + \alpha_7 \sin(7 * 2\pi ft)$	
10. Sag+ transient	$(1 - \alpha[u(t - t_1) - \mu(t - t_2)]) \sin(2\pi ft) + A[u(t - t_2) - \mu(t - t_1)] e^{-t/\tau} \sin(2\pi f_n t)$	
11. Swell+ transient	$(1 + \alpha[u(t - t_1) - \mu(t - t_2)]) \sin(2\pi ft) + A[u(t - t_2) - \mu(t - t_1)] e^{-t/\tau} \sin(2\pi f_n t)$	
12. Interruption	$\mu(t) = \{1 - \alpha[u(t - t_1) - \mu(t - t_2)]\} \sin \omega \theta t$	

The above mentioned signals are simulated using MATLAB as show in “Fig. 9” to “Fig. 14”. These waveforms with base frequency is 60 Hz.

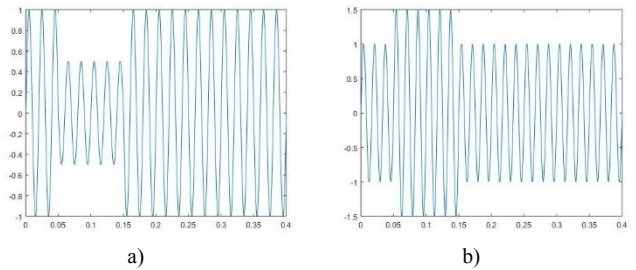


Fig. 9. a) voltage sag, b) voltage swell.

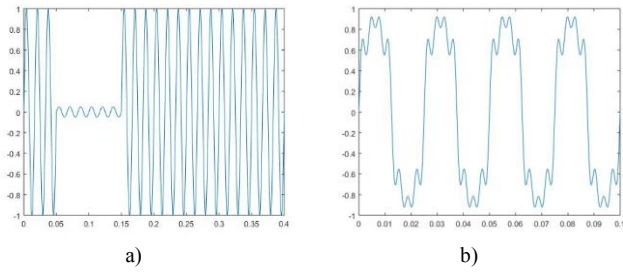


Fig. 10. a) interruption, b) Harmonic.

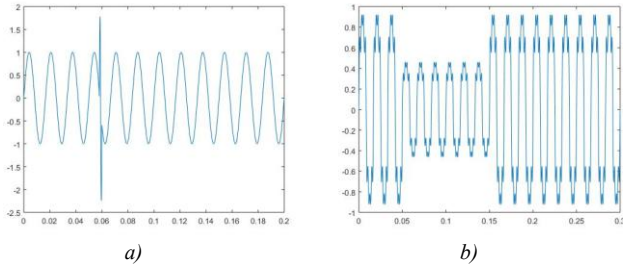


Fig. 11. a) Transient, b) Sag + harmonic.

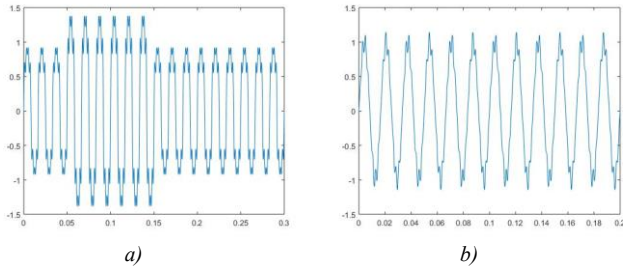


Fig. 12. a) swell + harmonic b) notch.

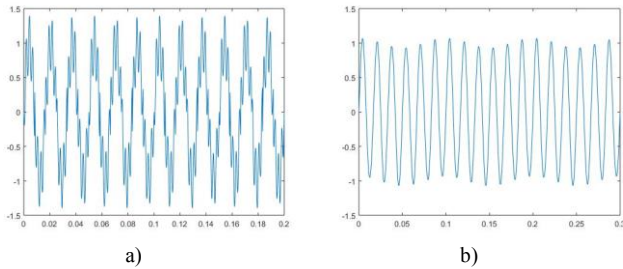


Fig. 13. a) Flicker, b) fluctuations.

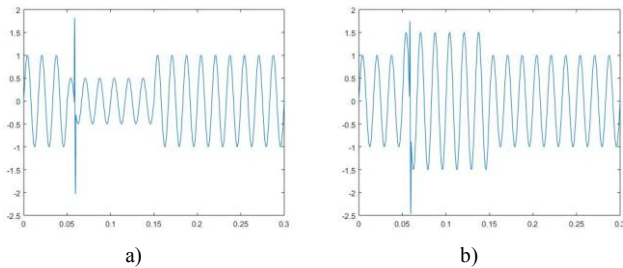


Fig. 14. a) sag + transient, b) swell + transient.

F. Feature Extraction

Due to its ability to extract time and frequency information of signal simultaneously see “Fig. 15”. Starting from a signal s of length N , two sets of coefficients are computed: approximation coefficients CA_1 , and detail coefficients CD_1 . These vectors are obtained by convolving s with the low-pass filter for approximation and with the high-pass filter for detail, followed by dyadic decimation [23], [27].

a) Discrete Wavelet Transform

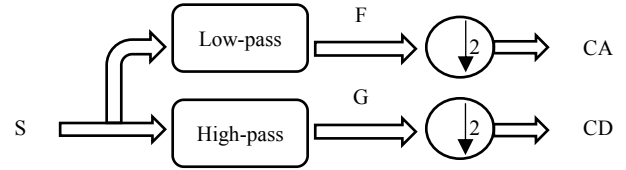


Fig. 15. DWT Algorithm, signal s of length N [23], [27].

Twelve types of disturbances i.e., voltage sag, voltage swell etc. are shown in “Fig. 9” to “Fig. 10” and its wavelet transform are shown in “Fig. 16” to “Fig. 17” respectively, and so on with the others disturbances.

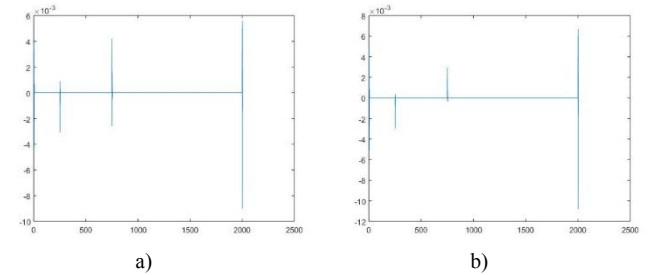


Fig. 16. Wavelet transform of a) voltage sag, b) voltage swell.

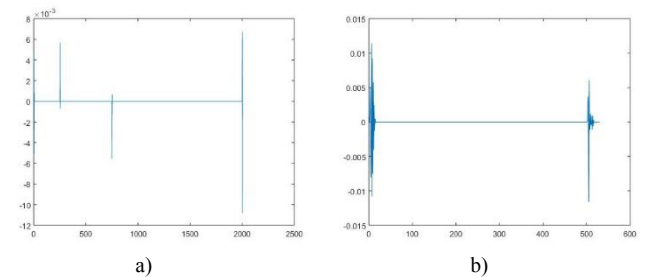


Fig. 17. Wavelet transform of a) interruption, b) Harmonic.

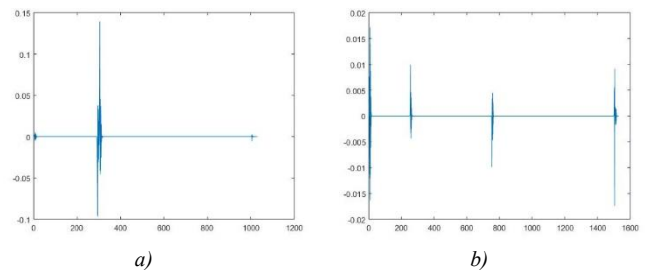


Fig. 18. Wavelet transform of a) Transient, b) Sag + harmonic.

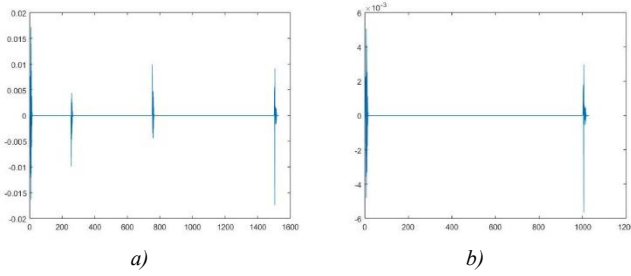


Fig. 19. Wavelet transform of a) swell + harmonic b) notch.

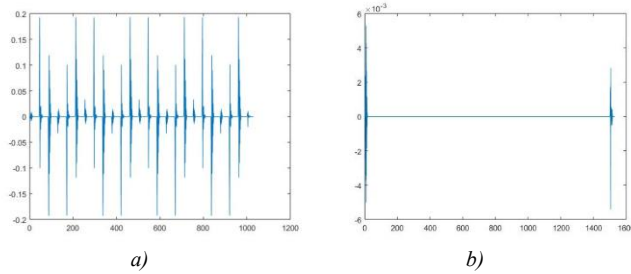


Fig. 20. Wavelet transform of a) Flicker, b) fluctuations.

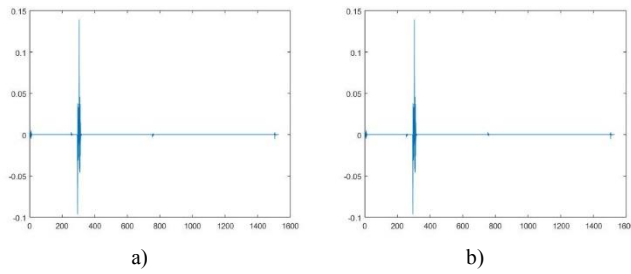


Fig. 21. Wavelet transform of a) sag + transient, b) swell + transient.

b) Support Vector Machine

SVM can classify the data that has more than two classes, continuing. There are two options for implementing multiclass SVM is to combine several binary SVM or combine all of the data that consist of multiple classes into an optimization problem format [14].

Training

$$\min_{\theta} C \sum_{i=1}^m [y^{(i)} \text{cost}_1(\theta^T x^{(i)}) + (1 - y^{(i)}) \text{cost}_0(\theta^T x^{(i)})] + \frac{1}{2} \sum_{i=1}^n \theta_j^2 \quad (9)$$

With SVM we will obtain the PQ events number, this data will help us to predict the impact that would have and what kind of loads the electrical network would support without affecting the operation of the robot's motors.

Once the simulations were found with the differences loads that affect the energy consumption of the robot, you can deduce an index of energy consumption in the robot, in "Fig. 22" there is the methodology to robust design of experiments.

G. Robust design of experiments.

The test bench was an induction motor, capacitor bank and a transformer to generate real voltage variations as a factors noise and as a Factors we have, 1) Fault conditions, large loads that require high starting currents, 2) switching on a large capacitor bank, 3) load that has significant current variations, especially in the reactive component can cause voltage fluctuations, 4) Arc furnaces, 5) to the nonlinear characteristics of devices and loads on the power system.

The variables to be considered as factors that affect the energy consumption of the engines.

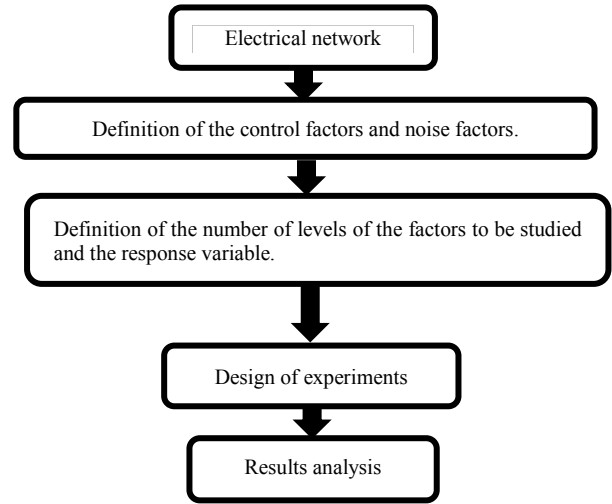


Fig. 22. Analyzing process with robust design of experiments.

For the analysis of the design with internal and external arrangement, Taguchi proposes a performance statistic, which he calls signal to noise ratio see "TABLE V".

TABLE V. SIGNAL NOISE RATIO FOR THE DIFFERENT TYPES OF RESPONSE VARIABLES [24].

Type of feature	Signal / noise ratio
The smaller is the best	$-10 \log \left[\frac{1}{n} \sum_{i=1}^n Y_i^2 \right]$
The bigger is the best	$-10 \log \left[\frac{1}{n} \sum_{i=1}^n \frac{1}{Y_i^2} \right]$
Its nominal value is the best (type I)	$10 \log \left[\frac{\bar{Y}^2}{S^2} \right]$
Its nominal value is the best (type II)	$10 \log[S^2]$
Defective proportion	$-10 \log \left[\frac{p}{(1-p)} \right]$

Regarding the two statistics for nominal type responses, type I is recommended for non-negative responses ranging from



zero to infinity, which have value goal different from zero and that the variance is zero when the answer is also zero. For its part, the type II statistic is for responses that can take both positive and negative values, and where zero can be the nominal value [24].

In the experiment of “TABLE VI” the electrical charges are a response of the nominal type is best to want to have less impact on the robot but without having to disconnect many electrical charges.

TABLE VI. DESING WITH INTERNAL ARRANGEMENT AND EXTERNAL ARRANGEMENT.

		External arrangement											Signal to noise
		M	1	1	2	2						S^2	
Noise factors		N	1	2	1	2							
		O	1	2	2	1							
		Control factors											Signal to noise
		A	B	C	D	E	F						
Internal arrangement		1	1	1	1	1	1	10	4	3	1	15	-11.7
		1	1	1	2	2	2	4	10	1	3	8	-11.5
		1	2	2	1	1	2	6	4	5	6	0.91	0.37
		1	2	2	2	1	1	13	1	9	4	28.2	-14.5
		2	1	2	1	2	1	5	2	2	4	2.25	-3.52
		2	1	2	2	1	2	2	5	4	1	3.33	-5.22
		2	2	1	1	2	2	4	9	6	1	11.3	-10.5
		2	2	1	2	1	1	5	4	1	2	4	14.9

IV. EXPERIMENTATION AND RESULTS

A. Analysis of clustering algorithm and Principal component Analysis.

When the variables were reduced, the principal components analysis was carried out again and an analysis criterion was assigned to each main component. It was observed see “Fig. 23” the relationship it has in the engines with respect to the variables that were considered.

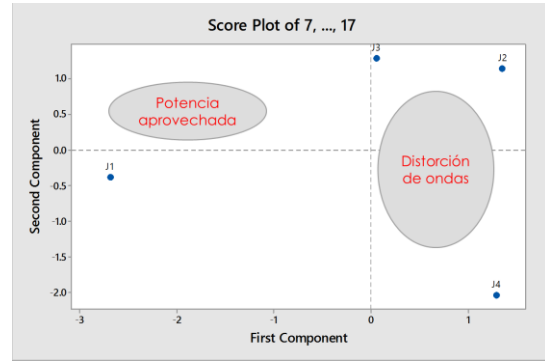


Fig. 23. PCA with the motors in Minitab.

Each component represented the performance of the motor, analyzing the 4 motors starting with the motor of axis 1, it was observed that the motor that represents less distortion in the electrical signals and that shows a low performance of the supplied power. The motor of axis 2 showed us that it is the motor that represents the greatest distortion of waves and at the same time it is the second motor that takes advantage of the electric energy supplied. The motor of axis 3 is within the limits of representing the number one component, but it is the best engine that uses the power. Finally, the motor of axis 4 is the one that behaves worst when causing the greatest wave distortion and the one that uses less power.

B. Análisis de los efectos en el brazo robótico Nachi.

Four types of factors are distinguished: 1) affects the mean and variability, 2) affects only the variability, 3) affects only the mean, 4) does not affect the mean or variability [24].

The factors that are more significant and cause PQ disturbance [25], which affect the robot's motors are the devices that are seen on the “Fig. 24”, these factors only affect the average and avoid that these devices are connected would help to have a good quality of the energy

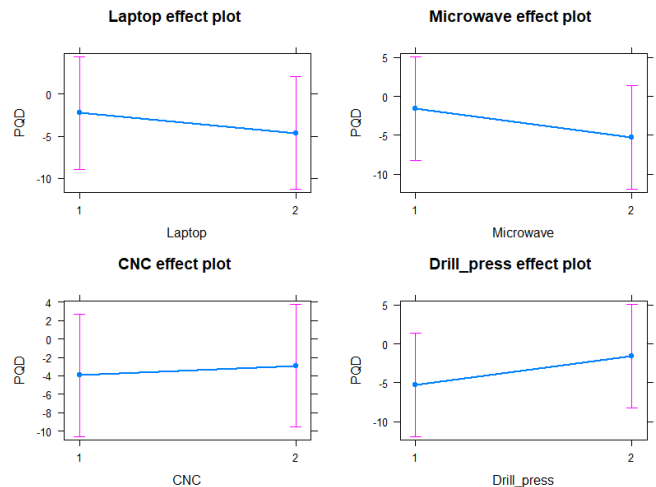


Fig. 24. Effects of factors in R studio.





V. CONCLUSIONS

To get to the root of PQ related problems, the engineers had to install monitoring equipment and identify and diagnose the problems themselves. In this paper the proposed methodology is a tool based on the statistics and design of experiments so that the impact of a poor power quality in the industrial robot can be characterized when connecting and disconnecting electrical loads. Short duration sags, in particular, cause numerous process disruptions. Often, the sag is sensed by electronic process controllers equipped with fault-detection circuitry, which initiates shutdown of other, less-sensitive loads. A common solution to this problem is to serve the electronic controller with a constant-voltage transformer, or other mitigating device, to provide adequate voltage to the controller during a sag. The application challenge is to maintain the electronic controller during sags that will not damage process equipment protected by the fault circuitry, while simultaneously reducing nuisance shutdowns. Electronic devices with battery backup should be unaffected by short duration reductions in voltage. Equipment such as transformers, cable, bus, switchgear, CTs and PTs should not incur damage or malfunction due to short duration sags. A slight speed change of induction machinery and a slight reduction in output from a capacitor bank can occur during a sag. The visible light output of some lighting devices may be reduced briefly during a sag.

ACKNOWLEDGMENT

To **CONACYT** for the support that they gave me in order to study a master degree.

REFERENCES

- [1] IFR. 2017. How robots conquer industry worldwide. IFR Press Conf. 27 Sept. 2017 Frankfurt. Available from: <https://ifr.org/>
- [2] Bomfim, M. H. S., R. A. Gontijo, A. Q. Bracarense, and E. J. Lima. 2012. Overhauling of a ASEA robot IR6 with open architecture. Proc. 11th IEEE Int. Conf. Trust. Secur. Priv. Comput. Commun. Trust. - 11th IEEE Int. Conf. Ubiquitous Comput. Commun. IUCC-2012. 482–489. doi:10.1109/TrustCom.2012.217.
- [3] Thakur, P., and A. K. Singh. 2015. Signal Processing and AI Based Diagnosis of Power Quality Disturbances : A Review. 2015 Int. Conf. Energy Econ. Environ. 1–6. doi:10.1109/EnergyEconomics.2015.7235071. Available from: <http://ieeexplore.ieee.org/document/7235071/>
- [4] Darrow K, Hedman B, Bourgeois T, R. D. 2005. The Role of Distributed Generation in Power Quality and Reliability. Final Report, prepared for: New York State Energy Research and Development.
- [5] IEEE, I. of E. and E. E. 2001. Protection and Coordination of Industrial and Commercial Power Systems, IEEE Std 242-2001TM.
- [6] Piumetto, M., and J. C. Gomez Targarona. 2013. Characterization of voltage sags and its impact on sensitive loads in a mv system with distributed generation for single-phase fault.
- [7] IEEE. 2009. IEEE Std 1159 - IEEE Recommended Practice for Monitoring Electric Power Quality. Available from: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5154067&isnumber=5154066>
- [8] Mahela, O. P., A. G. Shaik, and N. Gupta. 2015. A critical review of detection and classification of power quality events. Renew. Sustain. Energy Rev. 41:495–505. doi:10.1016/j.rser.2014.08.070. Available from: <http://dx.doi.org/10.1016/j.rser.2014.08.070>
- [9] Rodríguez, M. V, L. A. M. Hernández, J. P. B. Rangel, and A. D. González. 2016. Real-Time Monitoring of Voltage Variations Using Mathematical Morphology. Ieee Lat. Am. Trans. Vol. 14, No. 5, May 2016. 14:2138–2145.
- [10] Subtirelu, G. E., M. Dobriceanu, and M. Linca. 2017. Power quality analyzer. 2017 10th Int. Symp. Adv. Top. Electr. Eng. ATEE 2017. 909–914. doi:10.1109/ATEE.2017.7905043.
- [11] Shilpa, R. 2015. Analysis of Three Phase Power Quality Disturbances. In: IEEE. p. 1–5.
- [12] Martínez-figueroa, G. D. E. J., D. Morinigo-sotelo, A. L. Zorita-lamadrid, L. Morales-velazquez, R. D. E. J. Romero-troncoso, and S. Member. 2017. FPGA-Based Smart Sensor for Detection and Classification of Power Quality Disturbances Using Higher Order Statistics. IEEE. 14259–14274.
- [13] Arun Kumar, P. K., V. J. Vijayalakshmi, J. Karpagam, and C. K. Hemapriya. 2016. Classification of Power Quality Events Using Support Vector Machine and S-Transform. 2016 2nd Int. Conf. Contemp. Comput. Informatics. 7:279–284.
- [14] Rizanti, N. A., Arini, and A. H. Setyaningrum. 2016. Colon detection using Principal Component Analysis (PCA) and Support Vector Machine (SVM). Proc. 2016 4th Int. Conf. Cyber IT Serv. Manag. CITSM 2016. 1–6. doi:10.1109/CITSM.2016.7577526.
- [15] Pune, W. 2016. Identification and Sorting of Power Quality Disturbances Using Signal Processing with GUI. 60–63.
- [16] Vapnik V. the nature of statistical learning theory. New York springer verlag: 1995
- [17] Vapnik, V. N. 1999. An Overview of Statistical Learning Theory. 10:988–999.
- [18] Eristi Huseyin, Demir Yakup. A new algorithm for automatic classification of power quality events based on wavelet transform and SVM. Expert Syst Appl 2010;37:4094–102.
- [19] Chen, S., & Zhu, H. Y. (2007). Wavelet transform for processing power quality disturbances. EURASIP Journal on Advances in Signal Processing, article ID: 47695, 20pp.
- [20] Apetrei, D., G. Chicco, R. Neurohr, M. M. Albu, and P. Postolache. 2010. Power quality monitoring. Data relevance and usefulness. Proc. Mediterr. Electrotech. Conf. - MELECON. 1630–1635. doi:10.1109/MELCON.2010.5476319.
- [21] Elphick, S., V. Gosbell, and S. Perera. 2007. The effect of data aggregation interval on voltage results. 2007 Australas. Univ. Power Eng. Conf. AUPEC. doi:10.1109/AUPEC.2007.4548029.
- [22] Dehghani, M., M. H. Khooban, and T. Niknam. 2016. Fast fault detection and classification based on a combination of wavelet singular entropy theory and fuzzy logic in distribution lines in the presence of distributed generations. Int. J. Electr. Power Energy Syst. 78:455–462. doi:10.1016/j.ijepes.2015.11.048. Available from: <http://dx.doi.org/10.1016/j.ijepes.2015.11.048>
- [23] <https://la.mathworks.com/help/wavelet/ref/dwt.html>
- [24] Pulido. 2008. Análisis y diseño de experimentos. Segunda ed. (Humberto Gutiérrez Pulido, editor.).
- [25] Karuna Nikum, Rakesh Saxena, A. W. 2016. Power Quality Analysis of Energy Efficient Residential Load. IEEE. 1:470–471.
- [26] Karthikeyan, M., and V. Malathi. 2009. Wavelet-support vector machine approach for classification of power quality disturbances. Int. J. 1:1–4. Available from: <http://ijrte.academypublisher.com/vol01/no03/ijrte0103290293.pdf>
- [27] Jain, B., S. Jain, and R. K. Nema. 2013. Investigations on Power Quality Disturbances Using Discrete Wavelet Transform.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERIA

Remote System for the Acquisition of Electric Signals in Parks of Electric Power Production

Rodolfo W. Vega-Hernández ,
CA Mecatronica Facultad de Ingeniería
Universidad Autonoma de Queretaro,
Campus San Juan del Rio
rodolfo.walid@gmail.com

Roque A. Osornio-Rios
CA Mecatronica Facultad de Ingeniería
Universidad Autonoma de Queretaro,
Campus San Juan del Rio
Daniel Morfínigo-Sotelo
Departamento de Ingeniería Eléctrica
Escuela de Ingenierías Industriales
Universidad de Valladolid
Valladolid ,España

R. J. Romero-Troncoso
CA Mecatronica Facultad de Ingeniería
Universidad Autonoma de Queretaro,
Campus San Juan del Rio

Abstract— At present there are several equipment to monitor the quality of energy available in the market and the importance of maintaining a good quality of energy is increasingly At a high cost, with the PQ-UAQ card you can get these benefits at a fraction of the cost of commercial devices, this work have the goal of expanding its capabilities with the new paradigm internet of things generating a remote monitoring system allows us to have access to data from anywhere in the world.

Keywords—Power Quality; Raspberry Pi; Remote Monitoring; FPGA

I. INTRODUCCION

A. Quality of Energy and its Monitoring

In recent years there has been an exponential growth in the interest of energy quality, one of the main reasons for this is the increase in the cost of electricity globally, energy quality problems affect consumers in various ways, such as economic penalties in terms of power losses, equipment failure and malfunction, production process disruption, in view of these facts, several terms and definitions are used to quantify energy quality problems in terms of different performance indices.

The term energy quality is used to evaluate and maintain the good quality of energy at the generation, transmission, distribution and utilization of the electric power of AC. As the contamination of power supply systems is at the consumption level, where it is much severe, it is important to study the end points of the distribution systems. There are a number of reasons for contamination of AC supply systems, including natural ones like lightning, flashover and equipment failures (about 60%) and such as distortions in voltage and notches (approximately 40%), consumer equipment also contaminates the supply system, since the consumption of non-sinusoidal current and the behavior of equipment as non-linear loads. Therefore, the quality of energy is quantified in terms of voltage, current or deviation of the generation frequency in the delivery system [2].

B. Remote monitoring

Remote monitoring has become an integral part of day-to-day operation in many manufacturing industries and process plants. Remote monitoring and intelligent control is an important criterion in increasing production in certain processes, allowing the operator to monitor with better conditions and less personnel. While remote monitoring contributes to lowering costs and improving production, there are considerations to ensure the safety and reliability of the system[4].

The Internet of Things, Smart Energy, Smart Grid are an ongoing development of the internet where every day things have the ability to communicate to send and receive data, more than 50 billion devices are expected to be connected by 2020 under this new paradigm, allowing new applications to be launched in high impact fields such as health, agriculture, security, production and energy distribution[1][7].

II. SYSTEM OVERVIEW

A. PQ-UAQ System

The PQ-UAQ System as show in Fig.1 is a proprietary equipment developed by the Universidad Autónoma de Querétaro with open architecture based on a Xilinx Spartan 6 Field Programmable Gate Array (FPGA), which has 8 channels of measurement, four channels dedicated to measure voltage and the other four channels for the measure current, these are connected to an 16bits Analog to Digital Converter (ADC) Texas Instrument ADS130E08 for the data acquisition, the card can be configured to measure AC or DC with ranges of 400V RMS and 1000V DC respectively, the readings data is stored on an unformatted SD card at a frequency of 8K samples per second , all under the coordination of a microcontroller embedded in the FPGA[3].





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERIA



Fig.1 PQ-UAQ System Card

PQ-UAQ system it is used to measure variables with energy quality applications. In any electrical installation is fundamental, as the quality of it represents direct and indirect costs in the products or services offered. One of its features is the flexibility to include analytical algorithms (through IP cores), and its cost is approximately 10% of the price of a similar commercial system.

B. Raspberry Pi

Raspberry Pi is an SBC (single-board computer) created by the Raspberry Pi Foundation, and Cambridge University, the organization formed with the primary purpose of reintroducing low-level computer skills to children in the UK, The goal was to rekindle the revolution of the microcomputers of the 1980s, which produced a whole generation of skillful programmers. Even before the computer went on sale in February 2012, it was clear that the Raspberry Pi had gained many followers around the world and so far the official website reports that it has sold over 12.5 million cards[5].

The Raspberry Pi has been increasing its popularity among the academics due to its low cost. Between the different models available we used the Raspberry Pi 2 model B with the Broadcom BCM2837Arm7 Quad Core Processor running at 900MHz, 1GB of RAM, 40pin extended GPIO, 4 USB ports, 4 pole Stereo output and Composite video port, full size HDMI port, Micro SD port for loading your operating system and storing data and Ethernet port.

The Pi support many flavors of linux distributions, from where we chose raspbian wheezy as is the foundation's official supported Operating System. Being a linux computer, has a large suite of programming languages at your disposal. Pre-installed in the GCC compilation software, its supports basically tens if not hundreds of programming languages, just have to get the required files for the install in the repositories if it's not installed.

III. SYSTEM DESIGN

A. System Main Configuration

The system configuration as shown in Fig. 2 consists of four parts the PQ-UAQ system, the Raspberry Pi, Google

Drive and a PC. The Raspberry Pi functions as the bridge of the data obtained by the system PQ-UAQ and Goggle Drive is the off-site storage system, the PC is used to review the data in Google Drive and remotely connect to the Pi for the System start-up and system monitoring.

The raspberry pi communicates with the PQ-UAQ card through the Serial UART port at a baud rate of 460800, then initiates the synchronization routine, which establishes the date and time at which the monitoring starts, then sends the signal of the beginning, after this every second we asked the samples obtained to be saved in a file which are stored only ten minutes of each channel, when the file limit is reached, a new file is generated this generates 6 files per channel in one hour, when this happens another folder is generated to save the files of the next hour, so until we have 24 folders per day.

This way we can update the data obtained in google drive in intervals of one day, one hour or every 10 minutes, according to the need.

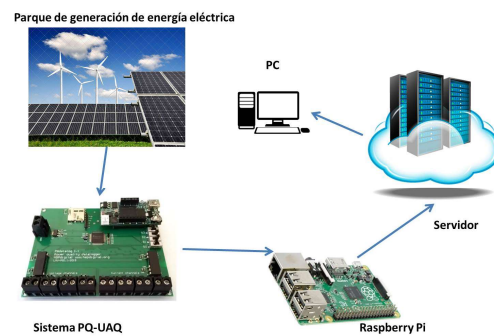


Fig.2 Proposed System Architecture

B. Raspberry Pi Control System

Python Is one of the main programming languages supported by raspberry pi, which were aggravated by two libraries for the control of the PQ-UAQ card, Pyserial is used for the interaction with the Serial UART port available, the other is Pydrive wrapper library of google-api-python-client that simplifies many common Google Drive API tasks.

1) *UART control script*: This script is the one that interacts directly with the PQ-UAQ card through the serial port, this is responsible for making the card sync, start and stop Fig. 3. The synchronization consists in sending the hour, minute and second in the format suitable to be interpreted by the embedded microcontroller, to begin with the acquisition of the data and the creation of the files where the data obtained is saved.



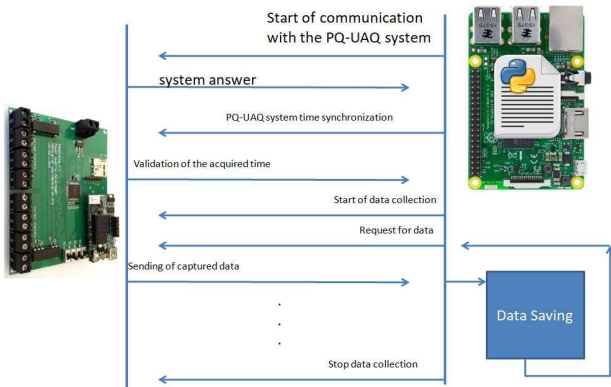


Fig. 3 UART control script diagram.

2) *Google Drive update script*: With the library of Pydrive is made the transfer of the files to google drive to have access to them remotely Fig. 4.

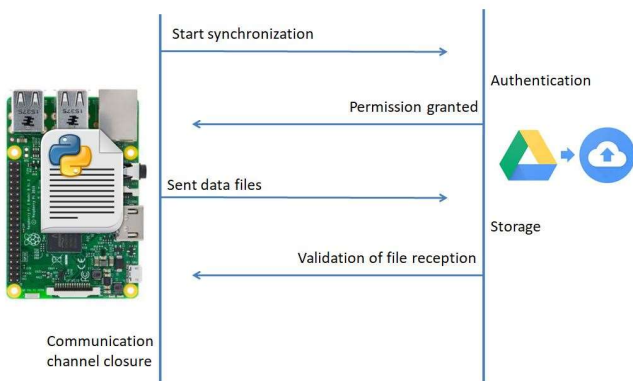


Fig. 4 Google Drive update script diagram.

C. PC remote access

The PC is used for the configuration of the control scripts mentioned above, this is done from a terminal with the SSH protocol in some linux distribution or some SSH client like PuTTY in Windows.

Also to access the files in Google Drive for later analysis.

IV. TEST PROCEDURE

In Fig. 5 shows the test bench used, which consists of a three-phase inverter, a induction motor connected to an electromagnetic brake, two PQ-UAQ cart, a raspberry pi and a PC with an SSH client in this case PuTTY.

One of the cards is used to monitor the three voltages and currents in the induction motor, the other is connected to the control panel of electromagnetic brake, which has two analog outputs which the Torque in N-m and the speed in RPM.

The test consisted in obtaining the data remotely from the starting of the induction motor at different frequencies produced by the inverter. A 220V sinusoidal signal was produced with the following frequencies 10 Hz, 20Hz, 30Hz, 40Hz, 50Hz, 60Hz.

The test was carried out for 10 minutes enough to generate a complete file for each monitored channel.

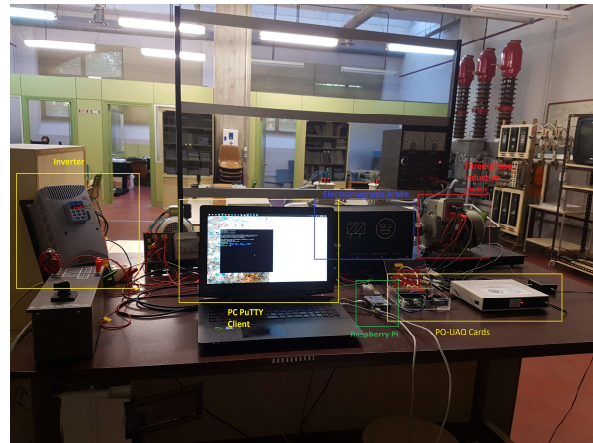


Fig.5 Test Bench

V. RESULTS AND DISCUSSION

Then we will see the results of the test at a frequency of 40Hz, plotted the three faces of current and voltage, a zoom was made to be able to see the engine start ramp, plotted torque and speed as well.

In Fig. 6 we have the three faces of the current the 10 minutes of the test,

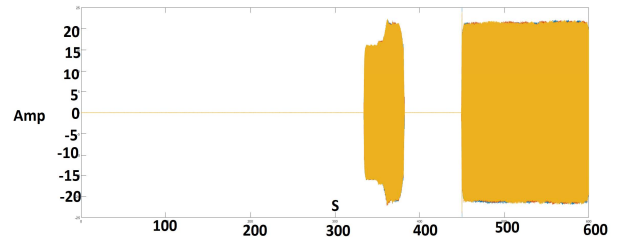


Fig. 6 Currents 10 minutes test file



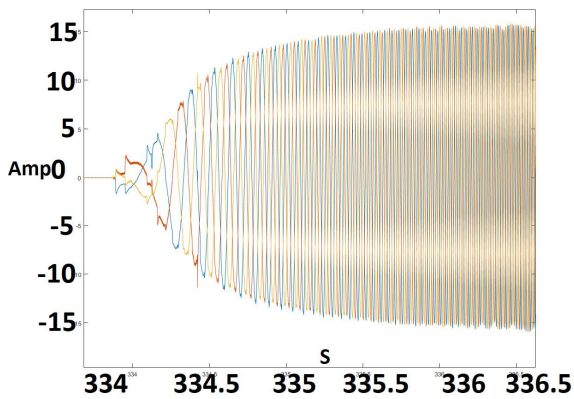


Fig.7 Zoom of Currents from seg. 334 to seg 336.5.

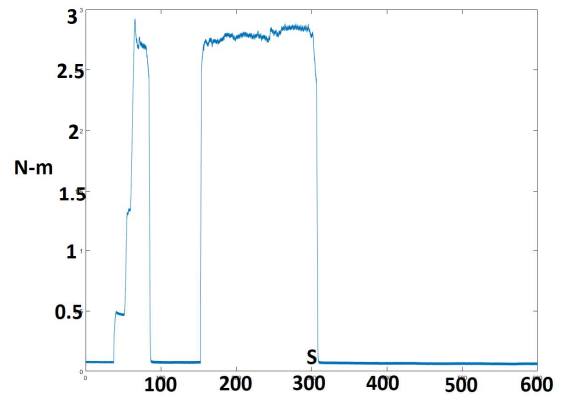


Fig.10 Torque in N-m for the test.

In Fig. 8 we have the three faces of the voltage

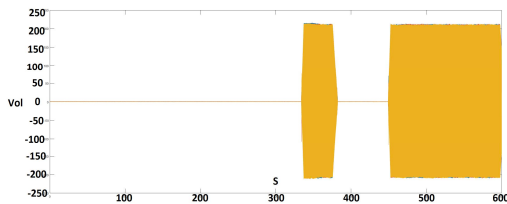


Fig. 8 Voltages on the 10 minutes test file.

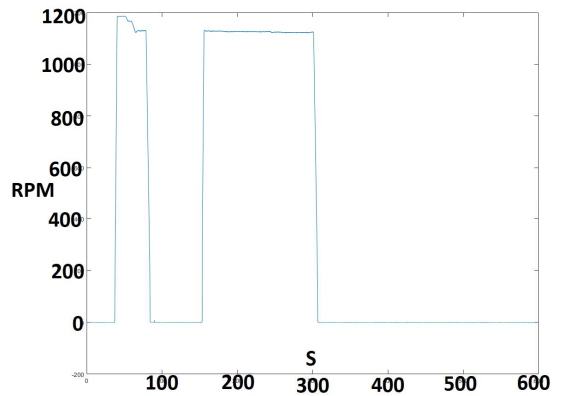


Fig.11 Speed in RPMs for the test.

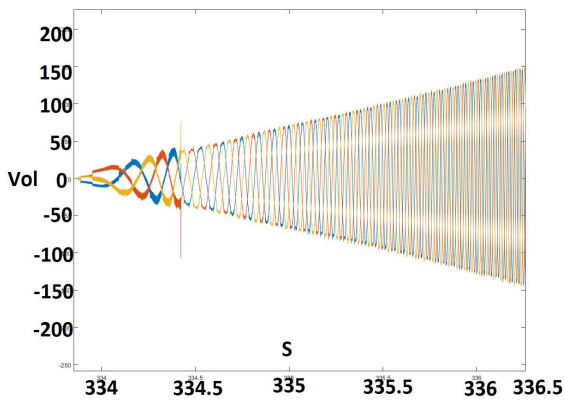


Fig. 9 Zoom of Voltages from seg. 334 to seg 336.5.

Next we have in Fig.10 the torque and in Fig.11 the speed

VI. CONCLUSIONS

As we can see the system works, but more rigorous tests are necessary to test the stability of the communication between raspberry pi and the PQ-UAQ system, since in the field you can have noise that could interfere or even cut the communication between the devices.

Put more devices connected to the same network to see what would be the limit of connected devices for a given bandwidth could be another future test.

It is also intended to process on site the data obtained by calculate the following power quality indicators, RMS for voltage and current, Power factor and THD. In this way, adding even more versatility to the system, we have confidence in the computing power that the Raspberry pi has.

REFERENCES





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERIA

- [1] Ansari, A. N., Sedky, M., Sharma, N., & Tyagi, A. (2015, January). An Internet of things approach for motion detection using Raspberry Pi. In *Intelligent Computing and Internet of Things (ICIT), 2014 International Conference on* (pp. 131-134). IEEE.
- [2] Pan, J., Jain, R., Paul, S., Vu, T., Saifullah, A., & Sha, M. (2015). An internet of things framework for smart energy in buildings: designs, prototype, and experiments. *IEEE Internet of Things Journal*, 2(6), 527-537.
- [3] Deshmukh, A. D., & Shinde, U. B. (2016, August). A low cost environment monitoring system using raspberry Pi and arduino with Zigbee. In *Inventive Computation Technologies (ICICT), International Conference on* (Vol. 3, pp. 1-6). IEEE.
- [4] Fernández Negroe, B., Osornio-Ríos, R.A., Morales-Velásquez, L., Zorita Lamadrid, A.L., Romero-Troncoso, R. de J. (2016). Statistical Calibration and Reliability Analysis of a Power Quality Device Based on FPGA. *CIINDET 2016-ID:74*
- [5] Sangeetha, A. L., Bharathi, N., Blesson, D. G. M., Girish, S. V., & Ganesh, A. B. (2016, March). CC3200 based real-time remote monitoring and control of an industrial process. In *Wireless Communications, Signal Processing and Networking (WiSPNET), International Conference on* (pp. 729-732). IEEE.
- [6] Chandra, P. A., Vamsi, G. M., Manoj, Y. S., & Mary, G. I. (2016, May). Automated energy meter using WiFi enabled raspberry Pi. In *Recent Trends in Electronics, Information & Communication Technology (RTEICT), IEEE International Conference on* (pp. 1992-1994). IEEE.
- [7] Preethi, V., & Harish, G. (2016, August). Design and implementation of smart energy meter. In *Inventive Computation Technologies (ICICT), International Conference on* (Vol. 1, pp. 1-5). IEEE.
- [8] Sahani, M., Rout, S. K., Sharan, A. K., & Dutta, S. (2014, April). Real time color image enhancement with a high regard for restoration of skin color by using Raspberrv Pi. In *Communications and Signal Processing (ICCSP), 2014 International Conference on* (pp. 335-339). IEEE.

(references)





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Synthesis of CeO₂ thin films by sol-gel method

Y.J. Acosta-Silva
División Industrial
Universidad Tecnológica de Querétaro
Querétaro, México
yuliana.acosta@uteq.edu.mx

I. G. Segura-Gutiérrez, J. E. Rubio-Jerezano, A. E.
Mendoza-Rojas, A. Méndez-López
Division de Investigación y Posgrado, Facultad de
Ingeniería, Universidad Autónoma de Querétaro,
Querétaro, Qro., Mexico
lovely-vena2005@hotmail.com, eduardorj18@gmail.com,
clair.de.lune.14.11@gmail.com, arturo.mendez@uaq.mx

Abstract—This CeO₂ thin films were deposited on corning substrates by dip-coating technique and annealed at 250 °C and 550 °C in air atmosphere. X-ray diffraction studies indicated that the prepared thin films are polycrystalline with cubic fluorite structure. AFM images revealed that the surface roughness of CeO₂ films increased when the annealing temperature were increased.

Keywords—thin film; CeO₂; sol-gel; properties.

I. INTRODUCTION

Ceria (CeO₂), as one of the most useful rare earth metal oxide, has the high oxygen storage capacity, redox properties, and metal support interactions. These unique properties make CeO₂ a promising candidate for using as adsorbents, catalysts, luminescence, fuel cells, UV blocking and shielding materials, polishing powder, etc [1]. Various nanostructures of CeO₂ and its based composites such as nanoparticles, microspheres, nanofibers, nanosheets, nanotubes, thin films have been reported [2].

There are many reports for the deposition of CeO₂ films using magnetron sputtering, pulsed laser deposition (PLD), e-beam evaporation, metal-organic chemical vapor deposition (MOCVD), molecular beam epitaxy (MBE), and sol-gel process [3]. The sol-gel method has some advantages over others. A high degree of homogeneity of the films can also be achieved in multicomponent systems, and additionally allows large-area coatings to be prepared at low cost [4].

In the present work, we studied CeO₂ films obtained by the sol-gel dip-coating method. The influence of annealing temperature on the structure, morphological and optical properties was investigated.

The films were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), and atomic force microscopy (AFM) and

II. EXPERIMENTAL

2.1. Preparation of the CeO₂ thin films

A sol of the CeO₂ precursor was prepared by dissolving cerium nitrate hexahydrate Ce(NO₃)₃·6H₂O in a mixture of lactic acid and ethanol. The transparent sol was stable for several days at room temperature, and thereafter gelled by reaction with moisture in air. All films were deposited by the dip coating technique on corning glass substrates.

The as-deposited films were subsequently dried at 250 °C and sintered at different temperatures in the range from 250 and 550 °C, in both cases in open atmosphere for 1 h. Finally, the thin films were allowed to cool to room temperature in the oven.

2.2. Characterization methods

The crystal structure of the cerium oxide films was analyzed by XRD (Rigaku D/max-2100) using Cu-K α radiation in the 2 θ range from 20 to 90°. The surface structure of the thin films was observed by atomic force microscopy (AFM) using a Park Scientific Inst. System.

The surface morphology of the thin films was examined by scanning electron microscopy (SEM) by means of an XL 30ESEM Philips microscope at 100 000x.

III. RESULTS AND DISCUSSION

3.1. X-ray diffraction (XRD)

The X-ray diffraction patterns of CeO₂ thin films sintered at different temperatures (250-550 °C) are showed in Fig. 1 (a). As can be seen in Fig.1 The XRD patterns of the sintered thin films showed (111), (200), (220), (311), (222), (400), (331), (420) and (422) reflections corresponding to crystallographic planes of the fluorite cubic structure (space group Fm3m) of CeO₂ (PDF# 43-102), no additional reflections are detected, indicating high purity of the films.



When the sintering temperature increased to 550 °C, the intensities of the peaks increased due to improvement of crystallinity [5].

(b) $T_A = 550\text{ }^\circ\text{C}$

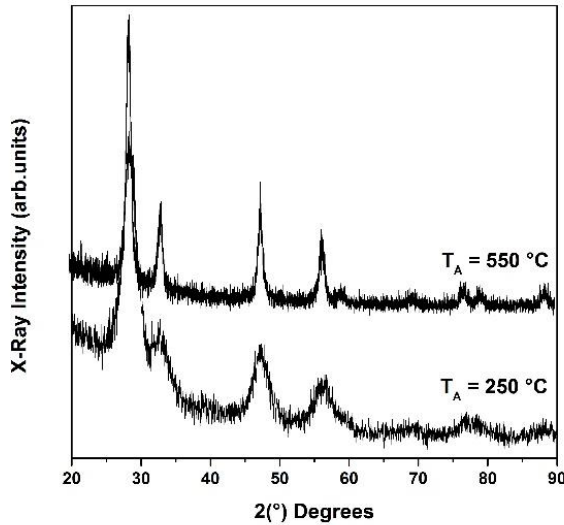


Fig 1. XRD patterns of CeO_2 thin films deposited on glass substrate sintered at 250 °C and 550 °C.

3.2. Scanning electron microscopy (SEM)

Figure 2 shows SEM images showing the surface morphologies of the films annealing at 250 and 550 °C. The SEM micrograph of CeO_2 thin film sintered at 250 °C (Fig. 2a) showed a smooth surface, homogeneous and crack free. When the annealing temperature increased at 550 °C (Fig. 2b) the film exhibited a granular morphology [6].

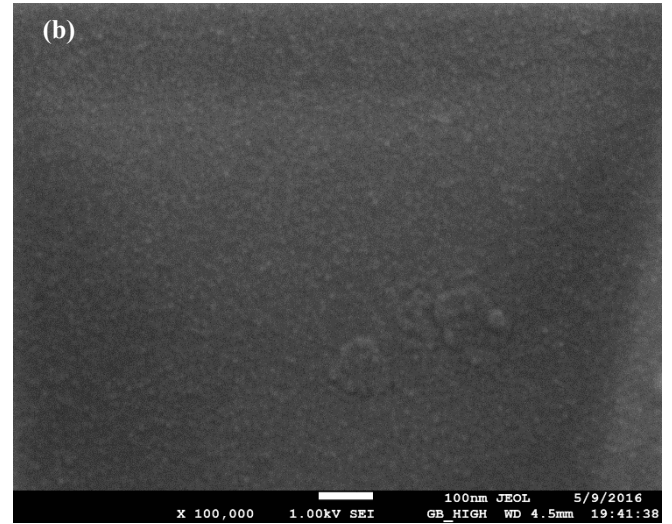


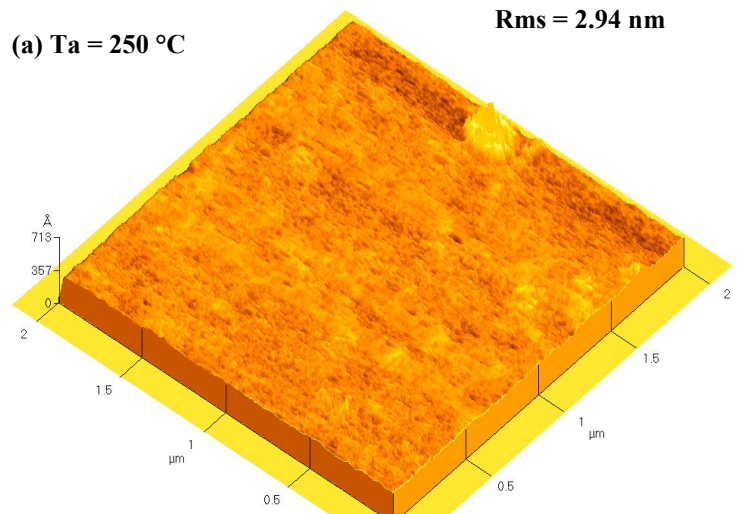
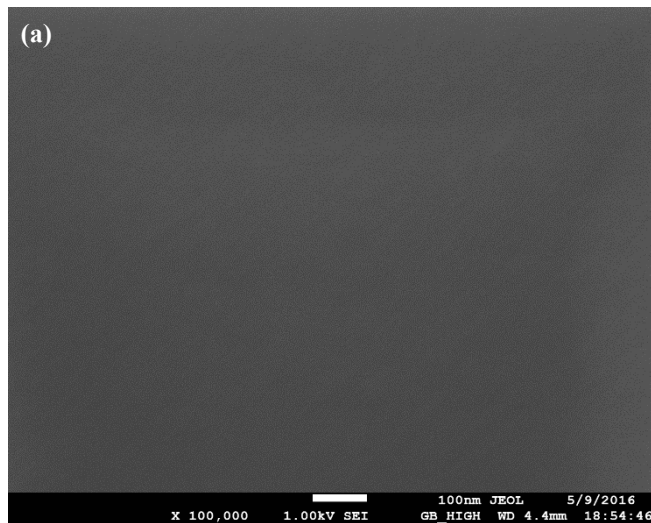
Fig 2. SEM micrographs of CeO_2 thin films annealed at (a) 250 °C and (c) 550 °C.

3.3. Atomic force microscopy (AFM)

The surface morphology of the CeO_2 thin films were also investigated by atomic force microscopy (AFM). Fig.3. shows 3D images of the CeO_2 thin films annealed at 250 and 550 °C, respectively.

In Fig. 3a, the AFM image of the CeO_2 thin film annealed at 250 °C showed that its surface is smooth and uniform. When the sintering temperature increased, on the surface of films sintered at 550 °C (Fig. 3b) appear small grains agglomerate together and randomly distributed.

The measured RMS surface roughness of the CeO_2 thin films annealed at 250 and 550 °C were 2.49 and 6.27 nm, respectively. The RMS values increased because the grains size increased with increasing sintering temperature [7].



[2] I.K. Skofic, S. Sturm, M. Ceh, N. Bukovec, "CeO thin films obtained by sol-gel deposition and annealed in air or argon", *Thin Solid Films*, vol. 422, pp.170-175, 2002.

[3] L.H. Jinn, C.S. Li, J.Q. Feng, Y. Wang, Z.M. Yu, S.N. Zhang, H. Wang, P.X. Zhang, "Influences of Ag nanoparticles on the microstructure and texture of CeO₂ films prepared by chemical solution deposition", *Ceramic International*, vol. 40, pp. 605-609, 2014.

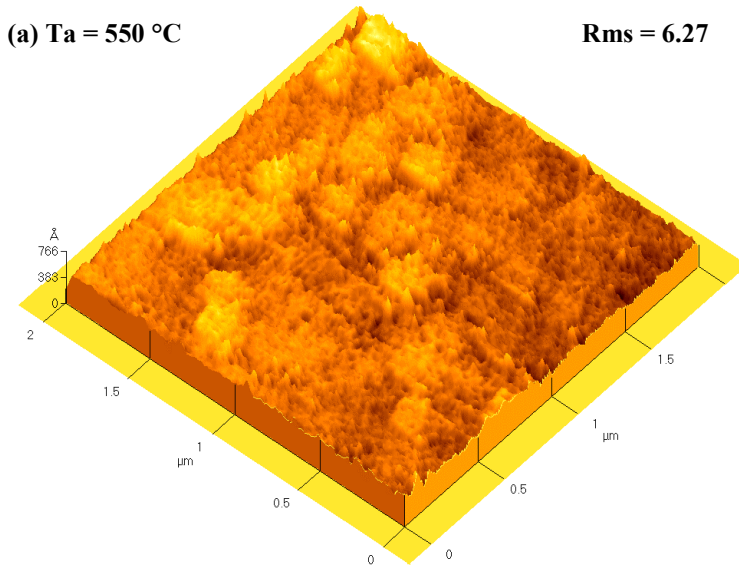


Fig.4. 3D images of CeO₂ thin films annealed at (a) 250 °C, and (b) 550 °C.

[4] W.E. Mahmoud, A.A. Al-Ghamdi, F.A. Al-Agel, E. Al-Arfaj, F.S. Shokr, S.A. Al-Gahtany, A. Alshahrie, M. Hafez, L.M. Bronstein, G.W. Beall, "Structure and properties of the Mn doped CeO₂ thin film grown on LaAlO₃ (001) via a modified sol-gel spin-coating technique", *Journal Alloys and Compounds*, vol. 640, pp.122-127, 2015.

[5] K. Wang, Y. Chang, L. Lv, Y. Long, "Effect of annealing temperature on oxygen vacancy concentrations of nanocrystalline CeO₂ film", *Applied Surface Science*, vol. 351, pp.164-168, 2015.

[6] P.J. King, M. Werner, P.R. Chalker, A.C. Jones, H.C. Aspinall, J. Basca, J.S. Wrench, K. Blanck, H.O. Davies, P.N. Heys, "Effect of deposition temperature on the properties of CeO₂ films grown by atomic layer deposition", *Thin solid films*, vol. 519, pp. 4191-4195, 2011.

[7] P. Singk, K.M.K. Srivatsa, S. Das, "Effect of substrate temperature on nanocrystalline CeO₂ thin films deposited on Si substrate by RF magnetron sputtering", *Advanced Materials Letters*, vol. 5, pp.371-376, 2015.

CONCLUSIONS

The structural, morphological, and optical properties of CeO₂ thin films prepared using a simple precursor solution were influenced by the annealing temperature. The crystalline size of the CeO₂ thin films, increased as a function of the sintering temperature indicating improved crystallinity.

The surface morphologies of the CeO₂ thin films showed that rms roughness of the films increases with the increase of annealing temperature

REFERENCES

[1] B.B. Patil, S.H. Pawar, "Structural, morphological and electrical properties of spray deposited nano-crystalline CeO₂ thin films", *Journal of Alloys and Compounds*, vol. 509, pp. 414-420, 2011.



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Smart system implementation to measure electric consumption, home load and lighting control

Gutierrez-Villalobos Jose M¹.
Faculty of Engineering,
Mechatronic Department.
Autonomous University of
Queretaro,
Queretaro, Mexico
marcelino.gutierrez@uaq.mx

Bautista-Villalon M. M.
Faculty of Engineering,
Mechatronic Department.
Autonomous University of
Queretaro,
Queretaro, Mexico
melizambv@gmail.com

Rivas-Araiza E. A.
Faculty of Engineering,
Mechatronic Department.
Autonomous University of
Queretaro,
Queretaro, Mexico
erivas@uaq.mx

Talavera-Velazquez Dimas
Faculty of Engineering,
Mechatronic Department.
Autonomous University of
Queretaro,
Queretaro, Mexico
dtalavera@upgto.edu.mx

Abstract — *Recently, Electricity consumption and monitoring have become a priority. This work presents a load and lighting control system. Lately, Electricity price per kW/h has increased and this proposal is a helpful tool, which allows to measure power consumption, individually monitor home loads and disconnect electric devices by means of a bluetooth cellphone interface. With a low cost embedded platform and easy to implement system. A friendly android interface is developed for any user. This smart system can record the historical electrical consumption for a term and determine the bill that user has to pay at the end of period.*

Keywords: *Optimization; smart system; electrical load monitoring; home energy management.*

I. INTRODUCTION

The emergent need to save electricity and reduce expenses because of the bills, has encouraged the development of smart systems to measure and monitor power consumption. In this meaning, it has become important to be aware how expensive electricity generation has become and the environment pollution produced by fossil fuels.

The amount of energy used by buildings or households has increased 30% in the past 3 decades. This growth until 2010 is presented in figure 1, taken from the Energy data via World Energy Council, where global home electricity consumption has surged. It has been noticeable that researches for managing energy consumption have helped to save energy and reduce bills. For this task, some Energy Management System (EMS) have emerged to control and monitor load consumption. Never the less, for residential applications the needs are different depending on the user needs, these systems are called Home Energy Management Systems (HEMS). Such systems have evolved with time, now they are a hardware and software combination, with friendlier human machine interfaces (HMI). According to Flores in [1], they are define as, “A system dedicated for a residential load which enables the user to control, monitor and optimize his energy consumption”.

Its main function is to let user know how much electricity they have consumed, in order to create a conscience and user can establish a strategy and try to avoid unnecessary consumption or detect if there is a home appliance, which can be causing an extra electricity use. Besides that, these systems can prevent disasters

by disconnecting electrical loads when they should be already off such as heaters, irons, ovens or lighting.

Household Electricity Consumption (kWh/year)

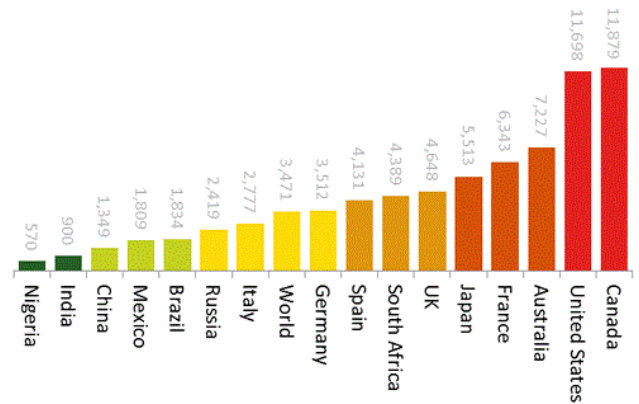


Figure 1. - Averages for household electrical consumption until 2010.

The household electric consumption is basically divided in specific home appliances, these are refrigeration, lighting, washing and drying, office equipment, cooking, entertainment and others. In figure 2, percentages per each one are shown, according to De Almeida in [2]. Electricity consumption breakdown in the residential sector in the countries participating in the REMODECE.

Refrigeration and lighting are the two more demanding electrical loads, households spend about 18% of their incoming in lighting, while schools, stores and businesses spend more than 50% of theirs in lighting. Secondly washing and office equipment. Every energy saving in this 4 factors can mean a representative money save.

This work presents a HEMS with a cell phone application, so users can be aware at all time of their electrical load behavior. In section I, HEMSs are introduced. In section II, a brief HEMS State-of-art is presented. In section III, the proposal is presented and explained. In section IV, the experimental results are shown and finally in section V, conclusions and results are discussed.



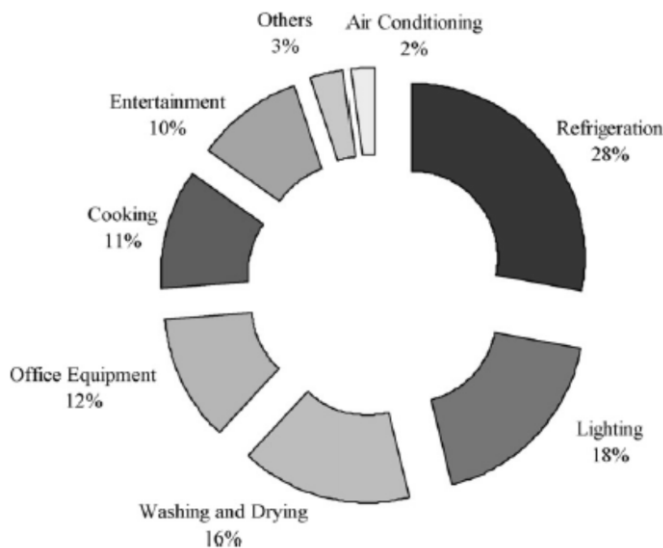


Figure 2. - Electrical consumption percentages by household appliances.

Load behavior can be optimized if users monitor how frequently they are connected or remind on when they should be off.

II. SMART LOAD CONTROL SYSTEMS

HEMS classification is based upon factors and their features for the user, by [1]. By functionality: information based and control based. By technology: user interface, smart hardware and software platform. By network communications: home communications general architecture. By benefits of HEMS adoption: information, energy management, efficiency diagnosis and improvement, remote control, energy storage and emergency management, other benefits. By challenges to HEMS adoption: awareness and knowledge of HEMS, implementation and maintenance cost and fees, security and privacy risks, lack of HEMS standards and infrastructure. In a survey conducted by PG&E (2015) found that 37% of the people do not know HEMS exist, 27% knew HEMS exist and 35% knew HEMS exist but they have no idea exactly the HEMS main purpose.

Before HEMS existed, the form to regulate power consumption, linear programming was used, as explained in [3], with technology growth, electronics system started to occupy this place, trying to optimize residential load management strategy. In [4], another non electronic HEMS is suggested, however this idea is more to help electric power generation companies by redirecting their capacity according to the sector priority, it is to say, if demand is needed by industrial sector or commercial rather than residential, power distribution is reconfigured. As mentioned, grid needs its own HEMS and several works have been presented such [5] and [6].

There also exist works [7], in whose strategy is to commute line, it means that with one acquisition system all loads are motor, but this means that of instant no monitoring is happening and information can be lost. In [8], there is a HEMS based on price prediction, it basically measure power consumption continuously and establish the amount of money user has to pay based on the actual electricity cost and the possible price electricity can have, so user has to analyze their habits to reduce costs. With the introduction of HEMS to house, security protocols must be taken into account [9]. Indeed, the more security is required, more expensive HEMS will be.

Wireless HEMS are other options. ZigBee and PLCs are combined by Han in [10], to establish a wireless land. ZigBee are interconnected to main server and PLC takes action depending on appliance demands but this system can result expensive, thinking in how many ZigBee boards and its circuitry are needed to monitor an entire house. A similar work [11], using ZigBee is implemented but no results are shown. Thuang in [12] presents other idea, which results attractive, establishing small ZigBee monitoring and controlling units, single unit is designed to control and monitor the load from a complete room including contacts and lighting. Besides, each room is activated by a PIR sensor and sends an alarm to the main interface to know if there is people or not in the room.

Sánchez in [13], has a domotic implementation using an Arduino Uno board. But it is only to control variables such as temperature, human presence and illumination but no load control is achieved. A similar form in [14], where environment variable control is sought. But only interface is shown and no platform is displayed. With [15] a LabVIEW smart house control is implemented, so LabVIEW is a helpful tool to develop HEMS. Also is possible to combine ZigBee and LabVIEW as in [16], never the less, control is not implemented, only monitoring the total power consumption. A proposal that help to work this project was the one presented in [17], using Arduino and monitoring variables from an application, with good results.

III. PROPOSED MONITORING AND CONTROL SYSTEM

From what mentioned before, the main purpose of this HEMS must be monitor, save data and allow user to activate or deactivate electrical appliances when they must be off. During this section, an explanation for each part of the proposal will take place.

The entire home load monitoring system is formed by an Arduino Mega board with a set of voltage and current sensors, which are connected to loads in series with an 8-relay module to disconnect them when required, a recording system interface for historical event save implemented in LabVIEW 2015 and USB-linked to the Mega board, an Android application on a mobile devise developed in *MIT App Inventor*, to monitor and control household appliances connected, which is bluetooth-linked to the Mega board. Mounted equipment is shown in figure 3. The current sensors are ACS712 and voltage sensor is ZMPT101B.

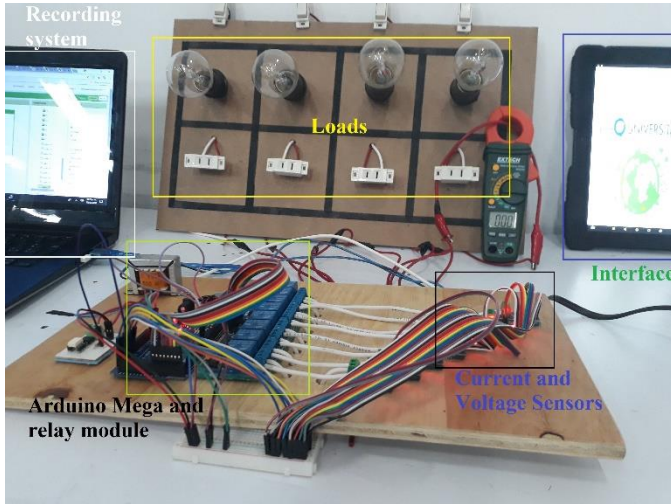


Figure 3. - Entire system setup.

The main control algorithm is implemented in the Mega board, but at the same time it has to interact with the other system parts to accomplish the task. It is to say, a list of steps is block-diagram-presented in figure 4. Mega board, voltage and current sensors are in charge of instrumentation and signals processing to send them via bluetooth to the Android application and at the same time send data to computer in order to save them in the LabVIEW interface.

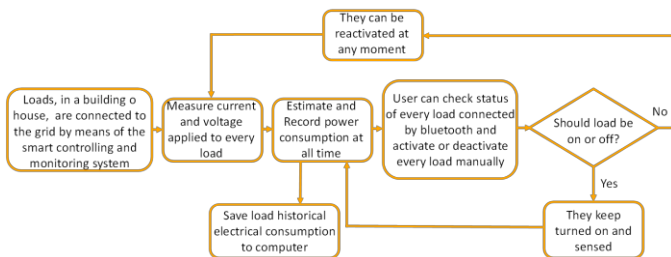


Figure 4. - Monitoring and controlling process block diagram.

A part of the Arduino code, containing the sensed value transformation to rms values, is presented in figure 5. Each auxiliary variable is used to transform every peak value sensed with the current sensor, and transferred via bluetooth. This values are also sent to computer.

Measured current is converted by the ADC integrated in the Atmel Microcontroller embedded in the Mega board, which is a 10-bit converter. Since the current can go from 0 to 30 Amp (maximum sensor capacity), the quantization noise converter is calculated by equation (1).

$$QN = \frac{I_m}{2^{N-1}} = \frac{30}{2^{10-1}} = 0.05865 \text{ mA} \quad (1)$$

```
//APAGAR CARGAS
if (input=="J") {digitalWrite(L0,HIGH); Aux0 = 0;}
if (input=="K") {digitalWrite(L1,HIGH); Aux1 = 0;}
if (input=="L") {digitalWrite(L2,HIGH); Aux2 = 0;}
if (input=="M") {digitalWrite(L3,HIGH); Aux3 = 0;}
if (input=="N") {digitalWrite(L4,HIGH); Aux4 = 0;}
if (input=="O") {digitalWrite(L5,HIGH); Aux5 = 0;}
if (input=="P") {digitalWrite(L6,HIGH); Aux6 = 0;}
if (input=="Q") {digitalWrite(L7,HIGH); Aux7 = 0;}
//APAGAR TODAS LAS CARGAS
if (input=="I") {
  STR=1;
  Aux0 = 0; Aux1 = 0; Aux2 = 0; Aux3 = 0; Aux4 = 0; Aux5 = 0; Aux6 = 0; Aux7 = 0;}

//MUESTREO DE LECTURAS
if (Aux0==1) {
  float I0= get_corriente0(200);
  Irms0=I0*0.707; //Intensidad RMS = Ipico/(2^1/2)
  //P0 = Irms0 * V;
  Serial.print("A"); Serial.println(Irms0);
  //Serial.print("I"); Serial.println(P0);
  delay(700);
}
if (Aux1==1) {
  float I1= get_corriente1(200);
  Irms1=I1*0.707; //Intensidad RMS = Ipico/(2^1/2)
  //P1 = Irms1 * V;
  Serial.print("B"); Serial.println(Irms1);
  //Serial.print("J"); Serial.println(P1);
  delay(700);
}
if (Aux2==1) {
  float I2= get_corriente2(200);
  Irms2=I2*0.707; //Intensidad RMS = Ipico/(2^1/2)
  //P2 = Irms2 * V;
  Serial.print("C"); Serial.println(Irms2);
  //Serial.print("K"); Serial.println(P2);
  delay(700);
}
.
.
.
```

Figure 5. - Arduino Mega code.

Android application has buttons to activate or deactivate all appliances connected to the HEMS system. Indicators in the form of a small lamp to illustrate which loads are on. Voltage, current and power display of every load. Two configuration buttons, one to select the bluetooth transmitter device and a second one to connect or start transmitting.

Application interface is implemented in *MIT App Inventor* and is shown in figure 6. Part of the code is presented in figure 7, containing the instructions to read the mobile bluetooth device and capture data sent from Arduino. *MIT App Inventor* is an easy and intuitive tool to program Android applications. From here, user control and monitor home loads. If a load should not be on, it can be deactivated. It helpful because user can observe if an electrical device is consuming more power than manufacturer says in its owner manual or electric specifications.



Figure 6. - Mobil android application.

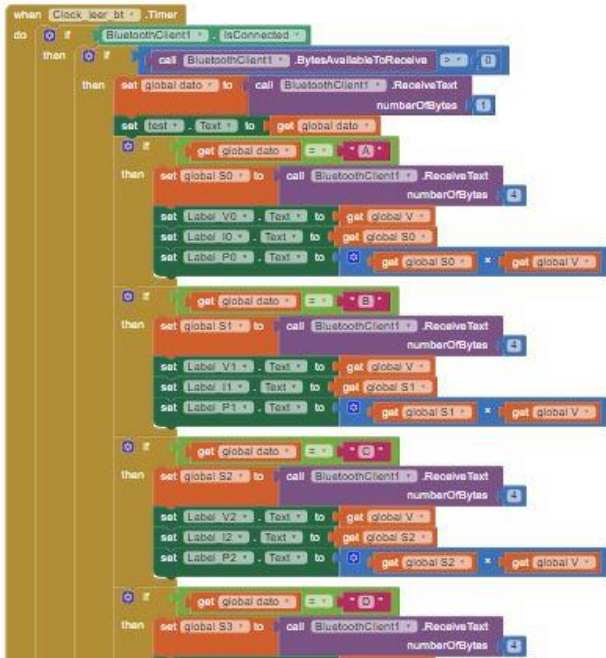
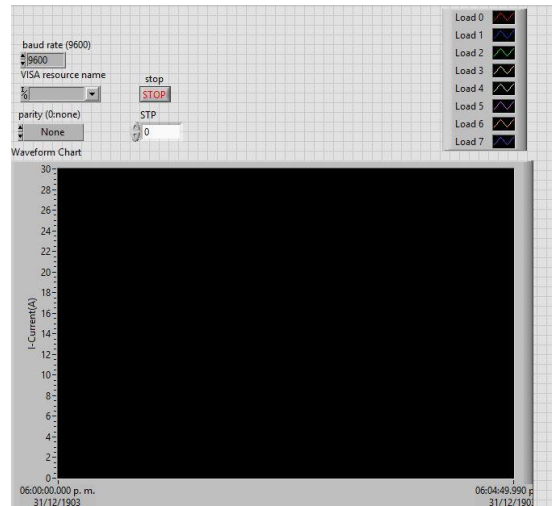
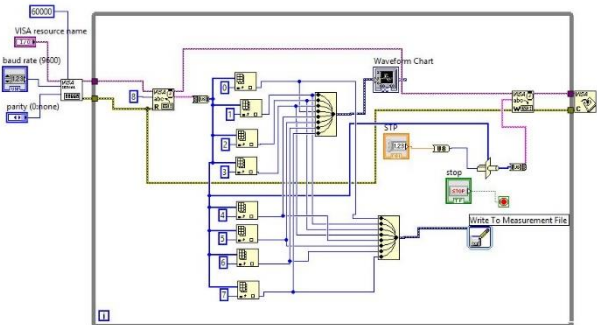


Figure 7. - Monitoring and controlling process block diagram.

Data are stored in the LabVIEW interface, so user will analyze them and determine if there are electric devices demanding more energy or take actions respect to disconnect them. Interface has a COM selector to detect Arduino Mega, baud rate, and a graphic display to show data meanwhile they are sent to a excel file for later graphing and analysis. Interface and block diagram are shown in figure 8 respectively.



a)



b)

Figure 8. - a) LabVIEW interface and b) its block diagram.

While serial port is open with LabVIEW visa tool, all values are sent to an array builder to be display, data are also sent to a excel file. From the waveform graph is possible to select

IV. RESULTS

At the test moment, 4 lamps were connected and activated and deactivated, they were 60-Watt loads. Interface is showing which load are demanding, date are being saved and connection is stable during all time. Even loads were the same size, in reality they present differences in their performance and one is load is higher than the other. It can be observed in the mobile application and in the graphic. Activated loads and its respective electric values are show in figure 9. It is important to say that once the system was running readings and data transmissions kept working at the same speed.

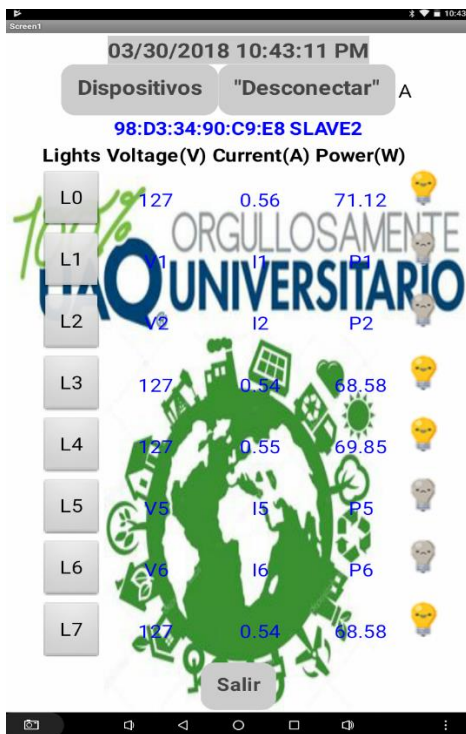
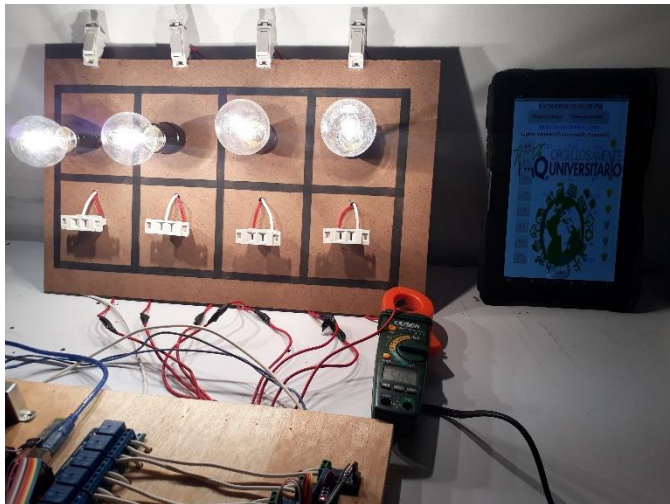


Figure 9. - Proposed HEMS under test.

A key part of the system is the mobile device, a faster equipment can handle the MIT applications more properly. At the beginning during first tests, a smaller capacity cell phone was used presenting a poor performance. It was thought communication was responsible for that, but a more powerful mobile device was used later, presenting better behavior. In the case a tablet with 2 GB in RAM

V. CONCLUSIONS

In this paper a proposed HEMS showed to be reliable and stable during long time periods, household appliances were controlled individually, mobile interface showed device electric values, and data were saved. Both the Arduino application and the mega program were easy to implement.

Future works for this project include, no need for LabVIEW to save data, the idea is to store them in the cell phone itself, to remove computer. Other work is to upload data to a server service to check data by internet and also control the monitoring system through internet. Finally the alarm insertion and timers to disconnect programmed appliance. Measured values were accurate to those measured with the validation instruments.

System needs to be connected to a real house and performance a comparison between the building without the HEMS and with it, to establish and say the system helped to save money by alerting the users about their habits,

If more loads need to be added Mega board still has more analogical inputs and I/O port to connect more relays and voltage and current sensors. And more important, it has the computational speed to achieve several readings and send data by bluetooth.

ACKNOWLEDGMENT (Heading 5)

The authors would like to thank to CONACYT, CONCYTEQ and the Autonomous University of Queretaro for the support received and the facilities where this project could be accomplished.

REFERENCES

- [1] Franco Cano Flores, Saurabh Ranalkar and Ayodeji Amoo, "Home energy management system", October 2016. .
- [2] Anibal de Almeida, Paula Fonseca, Barbara Schlomann, Nicolai Feilberg, "Characterization of the household electricity consumption in the EU, potential energy savings and specific policy recommendations", Energy and Buildings, August 2011, Vol. 43, Issue 8, p.p. 1884-1894.
- [3] N. Javaid, I. Khan, M. N. Ullah, A. Mahmood and M. U. Farooq, "A Survey of Home Energy Management Systems in Future Smart Grid Communications", Eighth International Conference on Broadband, Wireless Computing, Communication and Applications, 2013
- [4] Young-Sung Son, Topi Pulkkinen, Kyeong-Deok Moon and Chaekyu Kim, "Home Energy Management System based on Power Line Communication", IEEE Transactions on Consumer Electronics, August 2010, Vol. 56, No. 3.
- [5] Ye Yan, Yi Qian, Hamid Sharif, and David Tipper, "A Survey on Smart Grid Communication Infrastructures: Motivations, Requirements and Challenges", IEEE Communications Surveys & Tutorials, Vol. 15, No. 1, 2013



- [6] I. Khan, A. Mahmood, N. Javaid, S.Razzaq, R.D. Khan, M. Ilahi, "Home Energy Management Systems in Future Smart Grids", Journal of Basic and Applied Scientific Research 2013, Vol. 3, Issue 3, p.p. 1224-1231.
- [7] Chia-Hung Lien, Hsien-Chung Chen, Ying-Wen Bai and Ming-Bo Lin, "Power Monitoring and Control for Electric Home Appliances Based on Power Line Communication", IEEE International Instrumentation and Measurement Technology Conference, I2MTC 2008.
- [8] Danping Ren, Hui Li and Yuefeng J, "Home energy management system for the residential load control based on the price prediction", Online Conference on Green Communications (GreenCom), 2011 IEEE.
- [9] David Irwin, Anthony Wu, Sean Barker, Aditya Mishra, Prashant Shenoy, and Jeannie Albrecht, "Exploiting Home Automation Protocols for Load Monitoring in Smart Buildings", Conference: Proceedings of the Third ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Buildings, November 2011.
- [10] Jinsoo Han, Chang-Sic Choi, Wan-Ki Park, Ilwoo Lee, and Sang-Ha Kim, "Smart Home Energy Management System Including Renewable Energy Based on ZigBee and PLC", IEEE Transactions on Consumer Electronics, May 2014, Vol. 60, Issue: 2, pp. 198-202.
- [11] J. Rajendhar and Srujana. M, "Smart Home Energy Management System by Using Zigbee", International Journal of Professional Engineering Studies, July 2015, Vol. 5, Issue 2.
- [12] . Hnin Nu Thaug, Zaw Myo Tun and Hla Myo Tun, "Automatic Energy Control and Monitoring System For Building", International Journal of Scientific & Technology Research, June 2016, Vol. 5, Issue 6.
- [13] Camila Sánchez, Alejandra Mesa, Carolina Manrique, Herbert Calderón, Luis Cobo, Rubén Dorado and Camilo Mejía, "Diseño e implementación de un prototipo de vivienda domótica basado en las plataformas arduino y Android", Ontare, December 2014, [Vol. 2, Núm. 2.](#)
- [14] Enrique A. Sierra, Alejandro A. Hossian, Ramón García Martínez y Pablo D. Marino, "Sistema experto para control inteligente de las variables ambientales de un edificio energéticamente eficiente", XI Reunión de Trabajo en Procesamiento de la Información y Control RPIC 2005.
- [15] Basil Hamed, "Design & Implementation of Smart House Control Using LabVIEW", International Journal of Soft Computing and Engineering (IJSCE), January 2012, Vol. 1, Issue 6.
- [16] F. Baig, A. Mahmood, N. Javaid, S. Razzaq, N. Khan and Z. Saleem, "Smart Home Energy Management System for Monitoring and Scheduling of Home Appliances Using Zigbee", Journal of Basic and Applied Scientific Research 2013, Vol. 3, Issue 5, p.p. 880-891.
- [17] Mohannad Jabbar Mnati 1,2,*, Alex Van den Bossche 1,3 and Raad Farhood Chisab, "A Smart Voltage and Current Monitoring System for Three Phase Inverters Using an Android Smartphone Application", Sensors 2017, Vol.17, Issue 4





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Design of mortar mix using magnesium oxide as an additive in coating storage tanks inside swine facilities.

Ing. Carlos Eduardo Hernández Arreguín

Student of Masters in Sciences (Construction)

Engineering Faculty, Universidad Autónoma de Querétaro
Querétaro, Qro.

carlos91_54@hotmail.com

Dr. Juan Bosco Hernández Zaragoza

Teacher- Researcher, Engineering Faculty

Engineering Faculty, Universidad Autónoma de Querétaro
Querétaro, Qro.

Abstract— Within the agricultural sector, different constructions have been developed for agricultural production growth; the most outstanding feature of this type of construction is that they always work with living beings and these are affected by environmental factors. For this reason, it must compile a construction material selection that is resistant, innovative and that contribute to the development of agricultural production. This work focuses on the use of magnesium oxide as an additive in the design of a low permeability mortar mixture; to be used as a coating in the storage pits used as drains in the pig sheds and with this to reduce the excreta filtrations which cause contamination in the soil and groundwater.

Keywords—Agricultural constructions, swine facilities, magnesium oxide, mortar, concrete, permeability.

I. INTRODUCTION

Agricultural constructions are all those structures, which function is associated to the works of agricultural production in its broad meaning, that is, in the production of crops or agriculture proper; in the production of various animal species; in the management (storage or processing) of crops and livestock products; as well as in the protection of machinery and equipment for the work of handling the species and control of environmental factors.

As an example of agricultural constructions, greenhouses, grain warehouses, silos, crop packers, stables, poultry farms and swine constructions can be cited.

The most notable feature of agricultural constructions, unlike industrial constructions, is that they are systems that almost always work with living beings, and these are affected by environmental factors such as space, temperature, humidity, radiation and wind, among others. For this reason, its study is interdisciplinary and its design includes functional and structural aspects.

From a technical and economic point of view, agricultural constructions have the following fundamental objectives:

1. Provide and / or control the environmental conditions required by the plant species in exploitation and agricultural products, for optimal production and conservation.

2. Facilitate and make more efficient the operations of work, by man, during the production process; thus increasing the yield of the inputs and the capital invested.
3. Provide hygienic and safe conditions on farms.

In Mexico, one of the agricultural activities that has shown the highest growth is the production of pork. Currently our country is consolidated as the ninth producer worldwide with a share of 1.3% of the world production of pork, with a production of 1.45 million tons [1].

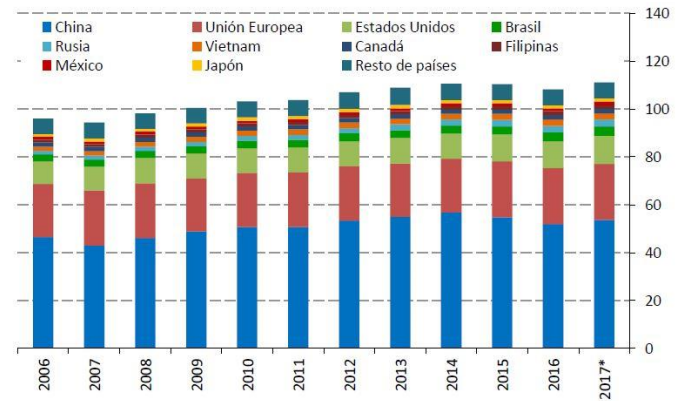


Figure 1. World production of pork (Thousands of tons) [1].

The increase in the production of pork has been matched to an increase in the size of pig farms; this situation resulted in an increase in the polluting capacity of this type of facility. The pollution generated by a swine farm affects the microenvironment (the farm itself) and the environment in general. In regards to the microenvironment, it has been shown that exposure to the gases produced (ammonia, hydrogen sulphide, methane and carbon dioxide) represents direct risks to the health of the workers and the pigs in exploitation.

However, the main problem with this type of facilities is the contamination caused by excreta (feces + urine), since they represent a high risk of contamination of soil and groundwater,



mainly due to the contribution of nitrates, which increases the process of eutrophication of aquifers.

The contamination produced by the excreta is caused by the runoff or filtrations that take place in the constructions that are made for its storage [2].

II. BACKGROUND

Storage pits under grilled soil is a fairly simple but effective system, since its function is to store the excreta to be subsequently emptied by gravity. The emptying of pits by means of gravity is the simplest and most economical method, although it is also emptied by pumping or by water jet.



Figure 2. Storage tank drained by gravity used as drainage in a house for sows in maternity stage in the area of El Márquez, Querétaro.

It is the obligation of the engineers or any authority involved in the design and construction of these storage pits, to use materials for their construction that avoid or minimize leaks or runoff of excreta that may occur in the pits; since in essence they are structures for the retention of liquids.

Nowadays, storage pits under grilled soil (slats of concrete or plastic) is the most used system as drainage for the evacuation of excreta inside the swine houses or sheds; this system consists of tanks with variable capacity, generally built with partition or reinforced concrete for the side walls and concrete bottom, all covered with mortar with a polished finish to facilitate the movement of the excreta at the moment of being evacuated of the shed or shed.

As mentioned before, one of the main elements for the construction of the pits is the mortar lining that is made to the whole pit. The mortar is a compound of inorganic binders, fine aggregates, water and possible additives.

The basic regulations regarding mortars can be found in the complementary technical standards for design and construction

of masonry structures of the federal district construction regulations, which are essentially the same as those used in all the construction regulations of the different federal entities. Make up our country the specification of the minimum compressive strength in mortar for masonry of artificial stones is 40.0 kg / cm², while for masonry of natural stones it is 15.0 kg / cm² [3].

We also have the Mexican regulation NMX-C486-ONNCCE-2014, which establishes the specifications and test methods that must be met by mortar based on cement and / or hydrated lime; for the construction of masonry elements for structural use. It is important to mention that this Mexican norm is applicable to mortar for structural use in masonry element, either pre-dosed or made on site [4].

Permeability in concrete or mortar is the amount of water that migrates through the mixture, while water is under pressure, or, in other words, permeability is the ability of the mixture to resist water penetration or other substances [5].

To obtain concrete mixtures or in this case of low permeability mortar, two stages must be considered [6]:

1. Reduce the ratio of water and cement (W / C), which increases the density of the mixture.
2. Block remaining capillary pores with permeability reducing additives (ARP)

The American Concrete Institute (ACI) divides the permeability reducing additives into two subcategories:

1. ARP for concrete exposed to non-hydrostatic conditions (ARPN).
2. ARP for concrete exposed to hydrostatic conditions (ARPH)

Depending on the manufacturer, ARPs include, but are not limited to, materials from families of one or more chemical products [7].

In 2017, in a study conducted at the Universidad Autónoma de Querétaro, some of the mechanical properties of a concrete mixture were investigated by destructive and non-destructive methods, in which magnesium oxide was used as additive and recycled expanded polystyrene from Waste packaging and packaging of electronic devices, the latter was used as a substitute for sands and gravel [8]. In the tests carried out, all the samples had the same amount of cement, water and expanded polystyrene, with magnesium oxide being the component that had a variation in the percentage of each of the samples, which ranged from 0% to 8%.

For the absorption tests at 24 hours, the results shown in Figure 3 were obtained.

Absorción a 24 horas			
Muestra	Peso Sumergido (gr)	Peso Seco (gr)	Absorción (%)
Ox0	195.20	182.3	7.08
Ox2	173.82	164.2	5.86
Ox4	170.82	162.93	4.84
Ox6	166.03	158.98	4.43
Ox8	179.81	172.97	3.95

Figure 3. Results obtained in the absorption test at 24 hours [8].

The results shown in figure 2 indicate that the behavior of the mixture is inversely proportional when adding larger amounts of magnesium oxide, which indicates that if the mixture contains a higher percentage of magnesium oxide the absorption is lower.

In the simple compression tests, the results shown in Figure 4 were obtained.



Figure 4. Average efforts obtained in simple compression test [8].

It can be seen that adding a greater amount of magnesium oxide to the mortar mixture directly affects the compressive stress, that is, the greater the amount of magnesium oxide, the lower the effort (kg / cm²) that supports

Figure 5 shows a reduction in the densities of the different mixtures, the behavior shown is inversely proportional to increasing the amount of magnesium oxide in the mixture.



Figure 5. Average densities obtained from the samples used in the experiment [8].

It is important to mention that magnesium oxide is a white, odorless, water-insoluble powder material, also known as magnesia, obtained from a controlled calcination process product of the combination with oxygen, its chemical formula is MgO and consists of a lattice of Mg²⁺ ions and O²⁻ ions joined by an ionic bond, its boiling point is presented at 3,600 °C and its melting point at 2,852 °C [9].



Figure 6. Sample of magnesium oxide used in the tests carried out in the Universidad Autónoma de Querétaro.

The current amount of magnesium oxide in nature is sufficient to satisfy all our needs, because magnesium is a mineral that is easily found in nature, its present in ocean water, is the third most common ion in the sea water [9].



III. WORK DESCRIPTION

In this work we seek to obtain a mixture of mortar incorporating as sole additive the magnesium oxide and that the latter provides the mixture with little permeability and that the compressive strength is not affected and meets at least 40.0 kg / cm², as it indicates in the complementary technical norms for design and construction of masonry structures of the regulation for constructions of the federal district.

It is also sought to contribute with the mortar mixture that obtains the best results in the tests that will be carried out, to the agricultural sector. Helping with this to reduce the pollution that causes the production of pork.

Destructive and non-destructive tests will be carried out on mortar mixtures where magnesium oxide is used as an additive and the same tests will be carried out in a conventional mortar mix. The results obtained in the samples should be compared with magnesium oxide and in the sample without magnesium oxide.

IV. METHODOLOGY

- Obtaining materials.

To begin, we will proceed to purchase the base materials for the preparation of the mortar to subsequently extract the sufficient amount of material to carry out the evaluation of it. The Portland Cement shall comply with the norm N-CMT-2-02-001-02 [10]. For the sands, it must comply with the NMX-C-111-ONNCCE-2004 standard [11].

- Evaluation of aggregates.

To evaluate in some way the quality of the materials, a series of tests will be made to the aggregates [12].

- Obtaining moisture from materials.
- The determination of the volumetric weight, this in dry and loose conditions.
- Content of organic matter in sands.

- Mix design.

Four mix designs will be tested, varying only the percentage of magnesium oxide, which will go from 2% to 8%. The dosages for mortar will be made based on the Complementary Technical Norms for Design and Construction of Masonry Elements for a type III mortar.

- Preparation of specimens.

Once having the design of mixtures will proceed to the elaboration of specimens; which will be:

- Cubes of 5 cm of base and 5 cm of height, standardized by the ASTM standard.

- Specimen testing.

- Fluency.

By determining this property, you can measure the plasticity and workability of the mortar in its fresco state, this property tells us how easy the mortar can be distributed on a work surface or be expelled fluidly.

The test consists of filling a standardized flow cone with the mortar, placing it on a flow table and on the table with a mechanical system it is raised and dropped 25 times from a height of 12.7 mm in a time of 15 seconds, all This is in accordance with the provisions of standard NMX-C-061-ONNCCE [13].

- Density.

This property is obtained by dividing the weight between the specimen volume, to obtain the weight a digital scale will be used and to obtain the volume the dimensions of the specimen will be measured using a vernier.

- Absorption at 24 hours.

This test will be performed only on 28-day specimens for each type of mixture. It consists in submerging the 3 pieces in a container with water at room temperature for 24 hours. Absorption at 24 hours is performed according to ASTM-C-67-03 [14] and equation 1 is used.

$$Absorption = \frac{W_{24h} - W_s}{W_s} \times 100 \quad (1)$$

Where:

- W_{24h} = Weight of the specimen after being submerged in cold water for 24 hours, (kg).
- W_s = weight of the specimen in the dry state, (kg).

- Simple Compression.

For each mixture, 3 specimens will be tested at 7 days, 3 to 14 days and 3 to 28 days. The entire procedure will be executed under the parameters of standard NMX-C-083-ONNCCE-2002 [15]. To obtain the compressive strength of the specimens, equation 2 is used.

$$R_c = \frac{F_c}{S} \quad (2)$$

Where:

- R_c = compressive strength of the specimen, (kgf/cm²).
- F_c = maximum load supported during the test, (kgf).
- S = cross section of the specimen, (cm²).





V. EXPECTED RESULTS

When using magnesium oxide as an additive in the mortar, it is sought to reduce the permeability, since it is expected to obtain a mortar with a denser pore structure compared to a regular mortar.

In addition, it is expected to obtain a minimum compressive strength of 40.0 kg / cm² so that it complies with what is specified in the applicable building regulations in our country and thus be able to be used in the lining of a storage pit used as drainage in swine facilities.

VI. REFERENCES

- [1] SAGARPA. (2017). Panorama agroalimentario. Dirección de investigación y evaluación económica y sectorial. Pág. 3.
- [2] Landin, G. (2005). Producción de excretas porcinas y contaminación ambiental. Universo porcino. http://www.aacporcinos.com.ar/articulos/manejo_porcino_03-2013_produccion_de_excretas_porcinas_y_contaminacion_a_mbiencial.html
Fecha de consulta 01/11/2017).
- [3] Del Distrito Federal, G. (2004). Normas técnicas complementarias para diseño y construcción de estructuras de mampostería. Reglamento de Construcciones del Distrito Federal. México D.F.
- [4] NMX-C486-ONNCCE-2014 (2014). Industria de la Construcción. Mampostería. Mortero para uso estructural – Especificaciones y Métodos de ensayo.
- [5] Sika Mexicana. (2013). Concreto Impermeable, una mirada reciente. Corregidora, Querétaro, México. <https://mex.sika.com/dms/getdocument.get/82b80616-e74b-323e-80fb-0d5f2f96f19f/concreto-impermeable.pdf>
Fecha de consulta 12/05/2017).
- [6] ACI 212. 3R. (2010). Report on Chemical Admixtures. Michigan, EE UU: American Concrete Institute.
- [7] ACI 212. 3R. (2010). Report on Chemical Admixtures. Michigan, EE UU: American Concrete Institute.
- [8] Castro-Miranda, O. M., Hernández-Zaragoza, J.B. (2017). Diseño de un concreto de baja densidad con EPS reciclado a través de aditivos poliméricos y óxido de magnesio.
- [9] Rayner-Canham, G., R.E. García, H.E. García and S.B. Garcés. (2000). Química inorgánica descriptiva. Pearson Ed. México.
- [10] N-CMT-2-02-001-02 (2002). Características de los materiales. Materiales para estructuras. Materiales para Concreto Hidráulico. 001 calidad del Cemento Portland.
- [11] NMX-C-111-ONNCCE-2004 (2004). Industria de la Construcción. Agregados para Concreto Hidráulico, especificaciones y métodos de prueba.
- [12] ASTM C 39. (2009). Standard Specification for Concrete Aggregates. West Conshohocken, Pensilvania, EE UU: American Society for Testing and Materials.
- [12] ACI 211.1-97 (2002). Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete.
- [13] NMX-C-061-ONNCCE-2015 (2015). Industria de la Construcción. Cementos Hidráulico. Determinación de la Resistencia a la Compresión de Cementantes Hidráulicos.
- [14] ASTM-C-67-03 (2003). Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile.
- [15] NMX-C-083-ONNCCE-2002 (2002). Industria de la Construcción. Concreto Hidráulico. Determinación de la resistencia a la compresión de cilindros de concreto. Método de Prueba.





CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

Synthesis and characterization of TiO₂-Au nanopowder

R. Hernandez^{1†}, C. Guzman¹, L. Escobar-Alarcón², E. A. Elizalde-Peña¹, K. Esquivel^{1‡}

¹Facultad de Ingeniería, Universidad Autónoma de Querétaro, Cerro de las Campanas, C. P. 76000, Santiago de Querétaro, Qro., México

²Departamento de Física, Instituto Nacional de Investigaciones Nucleares, Carr. México-Toluca, C. P. 52750, Ocoyoacac, Edo. De México, México

[†]rafa.hd2109@outlook.com

[‡]karen.esquivel@uaq.mx

Abstract— Titanium dioxide has been widely investigated, attempts to extend its photocatalytic activity include adding metallic elements on the crystalline structure. TiO₂-Au nanopowders have been synthesized by a microwave sol-gel assisted method and characterized by means of spectroscopic methods such as X-ray diffraction and Raman spectroscopy. Anatase phase was detected after the calcination process and no rutile phase was found.

Keywords— Titanium dioxide, sol-gel, TiO₂-Au, Raman spectroscopy, X-ray diffraction.

I. INTRODUCTION

Titanium dioxide (TiO₂) has been widely used and investigated due to the stability of its chemical structure, biocompatibility and its physic, optic and electric properties. Its photocatalytic properties have been utilized in many environmental applications to remove pollutants in water and air. The main feature of the photocatalytic process is that it breaks the complex organic molecules into simple molecules such as carbon dioxide and water, this process has been used for a variety of applications such as decomposition of organic pollutants [1].

TiO₂ exists as three different polymorphs: anatase, rutile and brookite. The most stable form of TiO₂ is rutile. Anatase form has a crystalline structure corresponding to a tetragonal system and is used mostly in photocatalytic applications due to its photocatalytic activity under UV radiation. Rutile form of TiO₂ has a tetragonal structure and brookite an orthorhombic structure [2].

The application of TiO₂ is limited due to its low photoactivity under visible light. Therefore, attempts to extend its photoactivity to the visible region have been made by substitution of Ti⁴⁺ on the crystalline structure for metallic ions such as Fe, Ni, Co, Ag, Au, Pt, etc [3]–[8].

To design and develop TiO₂-based photocatalysts that can operate under visible-light irradiation, modification of the electronic structure of the photocatalyst is indispensable. Two approaches are considered to control the electronic structure of TiO₂, namely (1) modification of the electronic structure of TiO₂ by metal doping and (2) formation of a new valence band by the addition of proper atoms into the lattice of TiO₂ by nonmetal doping or formation of new binary oxides[9].

Sol-gel synthesis technique has been widely used for catalysts development, such as TiO₂ nanopowders. In comparison to traditional techniques, it offers many advantages. For instance, in supported metals catalysis, the active metal and support can be prepared in a single step. This allows an economy in the catalyst preparation [10].

II. EXPERIMENTAL

A. Synthesis of titanium dioxide

The synthesis of the TiO₂ powder was carried out by dissolving the titanium precursor (titanium isopropoxide, 97% Aldrich, TTIP) in an organic solvent (isopropanol, 99.9%, J. T. Baker), the titanium solution was magnetically stirred for 20 min under nitrogen atmosphere. The hydrolysis process was then performed by adding water into the precursor/solvent solution and was magnetically stirred for 1 h in a dark box. For the gold modified TiO₂, the precursor (Gold(III) chloride hydrate, 99% Aldrich) was added by dissolving it into the water used for the hydrolysis process. The obtained sol was transferred into teflon vessels and placed on a microwave reaction system. The heating procedures were carried for 30 min at 210 °C. The obtained product was filtered and dried at room temperature for 12 h. A calcination process was carried out at 450 °C for 3 h to promote the anatase form of TiO₂.

B. Physicochemical characterization

X-ray diffraction analysis (XRD) were obtained using a Bruker D8 advanced diffractometer equipped with a Cu seal tube to generate Cu K α radiation ($\lambda = 1.5406$ Å) within the Bragg angles $10 < 2\theta < 80^\circ$ in steps of 0.01° . Raman

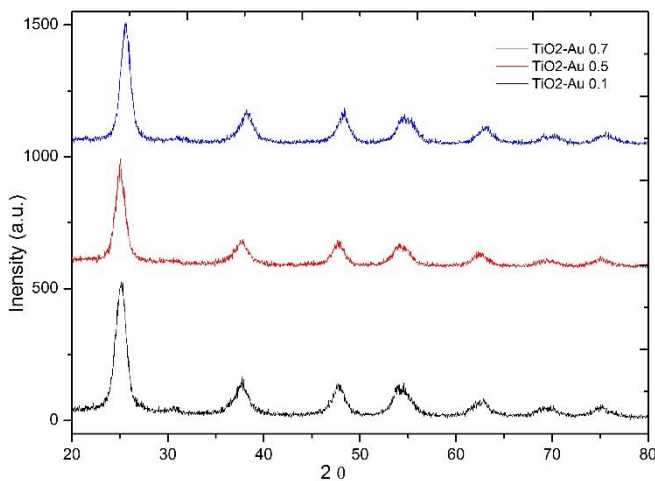


spectroscopy measurements were acquired with LabRAM HR, Horiba Scientific equipment with a Nd:YAG laser ($\lambda = 532$ nm, output power of 80 mW). The samples were analyzed with a power of 6 mW over an area with a diameter of 1.5 μm using a microscope on 10X objective. The laser spot was focused on the sample surface using a long working distance 50x objective. All spectra were recorded over several regions and were referenced to the silicon line at 520 cm^{-1} .

III. RESULTS AND DISCUSSION

A. X-ray diffraction (XRD)

X-ray diffractions patterns were recorded to study the formation of TiO₂ crystalline species. The diffraction peaks detected after the calcination process indicates the presence of the crystalline anatase phase ($2\theta = 25.33^\circ, 37.82^\circ, 48.08^\circ, 53.93^\circ, 62.75^\circ$) and no presence of rutile phase ($2\theta = 27.46^\circ, 36.11^\circ, 41.27^\circ, 54.37^\circ, 69.07^\circ$) was observed. For the Au-TiO₂ samples (Fig 1), no peaks of metallic gold in 2θ ($38^\circ, 44.2^\circ, 64.4^\circ, 77.2^\circ$) were detected. As can be seen from the XRD patterns crystallinity of the photocatalyst decreased on gold doping.



B. Raman Spectroscopy

Another technique widely used to characterize the various polymorphs of TiO₂ is Raman spectroscopy. Some advantages of using this technique are the sample preparation and the simplicity with which each spectrum is collected [11]. For anatase, characteristic vibration modes are located at 144, 197, 399, 515, and 639 cm^{-1} . For rutile, there are four modes at 143, 235, 447, and 612 and a broad band at 826 cm^{-1} . Brookite has 36 vibration modes, some of them located at 132, 138, 152, 197, 212, 245, 278, 325, 370, 406, 457, 500, 550, 587, and 630 cm^{-1} . The most in-tense vibration mode for anatase is at 144 cm^{-1} , and the weakest for rutile is at 143 cm^{-1} .

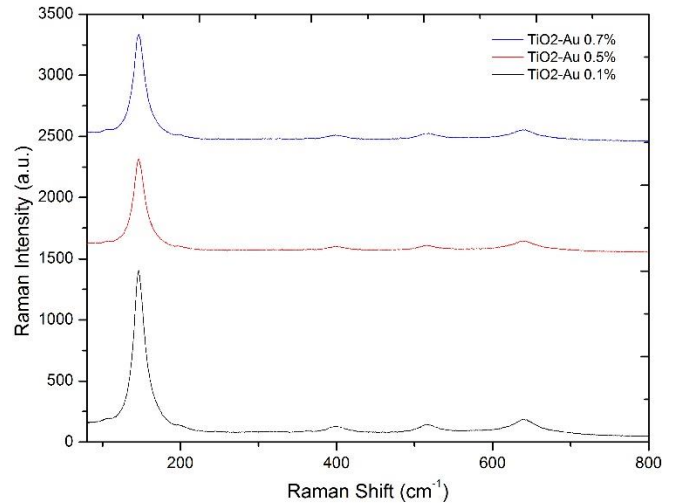


Figure 2 shows the Raman spectra for samples synthesized at different dopant load. In order to make identification of the vibration modes easier, the spectra were arbitrarily displaced on the vertical axis. Au-loaded samples show a spectrum with well-defined vibration modes assigned to anatase (144, 197, 399, 515 and 639 cm^{-1}) and no characteristic vibration modes of rutile or brookite were observed.

IV. CONCLUSIONS

It is possible to synthesize a crystalline and highly oriented TiO₂-Au powder via microwave assisted sol-gel synthesis, besides, according to the characterization, the samples contain only anatase phase.

ACKNOWLEDGMENT

The authors thanks to the CONACyT for the doctorate's scholarship, and to the Queretaro University.

REFERENCES

- [1] D. P. Macwan, P. N. Dave, y S. Chaturvedi, "A review on nano-TiO₂ sol-gel type syntheses and its applications", *J. Mater. Sci.*, vol. 46, núm. 11, pp. 3669–3686, jun. 2011.
- [2] M. Pelaez *et al.*, "A review on the visible light active titanium dioxide photocatalysts for environmental applications", *Appl. Catal. B Environ.*, vol. 125, pp. 331–349, agosto 2012.
- [3] Alamgir, W. Khan, S. Ahmad, M. Mehedi Hassan, y A. H. Naqvi, "Structural phase analysis, band gap tuning and fluorescence properties of Co doped TiO₂ nanoparticles", *Opt. Mater.*, vol. 38, pp. 278–285, diciembre 2014.
- [4] Y. Kobayashi *et al.*, "Fabrication of TiO₂/Pt core-shell particles by electroless metal plating", *Colloids Surf. Physicochem. Eng. Asp.*, vol. 448, pp. 88–92, abril 2014.
- [5] X. F. Lei, X. X. Xue, y H. Yang, "Preparation and characterization of Ag-doped TiO₂ nanomaterials and their photocatalytic reduction of Cr(VI) under visible light", *Appl. Surf. Sci.*, vol. 321, pp. 396–403, diciembre 2014.
- [6] Q. Liu, D. Ding, C. Ning, y X. Wang, "Black Ni-doped TiO₂ photoanodes for high-efficiency photoelectrochemical water-splitting", *Int. J. Hydrog. Energy*, vol. 40, núm. 5, pp. 2107–2114, feb. 2015.



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

- [7] H. Park, Y. Park, W. Kim, y W. Choi, "Surface modification of TiO₂ photocatalyst for environmental applications", *J. Photochem. Photobiol. C Photochem. Rev.*, vol. 15, pp. 1–20, jun. 2013.
- [8] C. Fu, M. Li, H. Li, C. Li, X. guo Wu, y B. Yang, "Fabrication of Au nanoparticle/TiO₂ hybrid films for photoelectrocatalytic degradation of methyl orange", *J. Alloys Compd.*, vol. 692, pp. 727–733, enero 2017.
- [9] J. Zhou y X. S. Zhao, "Visible-Light-Responsive Titanium Dioxide Photocatalysts", en *Environmentally Benign Photocatalysts*, M. Anpo y P. V. Kamat, Eds. Springer New York, 2010, pp. 235–251.
- [10] E. Sánchez, T. López, R. Gómez, Bokhimi, A. Morales, y O. Novaro, "Synthesis and Characterization of Sol–Gel Pt/TiO₂Catalyst", *J. Solid State Chem.*, vol. 122, núm. 2, pp. 309–314, mar. 1996.
- [11] J. Zhang, M. Li, Z. Feng, J. Chen, y C. Li, "UV Raman Spectroscopic Study on TiO₂. I. Phase Transformation at the Surface and in the Bulk", *J. Phys. Chem. B*, vol. 110, núm. 2, pp. 927–935, enero 2006.



COMPARISON OF EVOLUTIONARY METHODS FOR OPTIMIZATION

Aurelio Domínguez-González^{1}, Abraham Gastélum-Barrios^{2*}, Rafael Hernández-Rangel^{3*},
Alejandro Moreno-Gómez^{4*}, Rebeca Visairo-Méndez^{5*}, Norma Angélica Rodríguez-Guzmán⁶*

** División de Investigación y Posgrado, Facultad de Ingeniería, Universidad Autónoma de Querétaro,*

Cerro de las Campanas S/N, Querétaro, Qro, C.P. 76010, México.

1. auredgz@uaq.mx 2. abraham.gastelum.b@gmail.com 3.

4. yosomaperron@gmail.com 5. rvisairom@gmail.com 6. hypatya.riguez@gmail.com

ABSTRACT

In this work we present four methods for evolutionary algorithms; Memetic Algorithms, Evolutionary Strategy Algorithm, Differential Evolution and Evolutionary Programming. The main purpose is to show a comparison between these methods to optimize a function. We present a brief description of each method, as well as the graphs obtained and a comparative table of time and the number of generations carried out to achieve the desired optimization, in order to choose one to solve a problem that you want.

KEYWORDS: methods; evolutionary; algorithms; memetic; strategy algorithm, differential evolution; evolutionary programming.

I. INTRODUCTION

Evolutionary algorithms are methods used for optimization and they try to find solutions. These methods are based on the theory of evolution, start with a random set of individuals, called first generation, that represent a possible solution to the problem posed. Individuals can be modified through operations commonly called crosses or mutations. The crosses consist of the mixture of the information of two or more individuals and the mutation is a random change in the information of the individuals. To generate a new generation we proceed to a selection of original individuals, crossed or mutated, this new generation, represents a possible solution to the problem. The selection also obeys the theory of evolution, so the new generations represent more appropriate solutions to the problem, in this way the set tends to improve gradually.

In this work we present four methods for evolutionary algorithms; Memetic Algorithms, Evolutionary Strategy Algorithm, Differential Evolution and Evolutionary Programming. The main purpose is to show a comparison between these methods to optimize a function. We present a brief description of each method, as well as the graphs obtained and a comparative table of time and the number of generations carried out to achieve the desired optimization, in order to choose one to solve a problem that you want.

II. THE METHODS

MEMETIC ALGORITHMS

Memetic Algorithms are based on metaeuristic populations composed of an evolutionary framework and a collection of local search algorithms that are activated with each generation of the external framework.

The functionality is based on the term "meme", which denotes the equivalent to the evolutionary context of the genes. Some examples of memes are: ideas, fashion, melodies, slogans or sayings, among others. These memes are propagated in brain-to-brain populations, using imitation(Neri and Cotta, 2012).

This characterization of meme proposes a cultural evolutionary process, information is not simply transmitted; it is improved depending on the communication between the pairs. This improvement is achieved through techniques of local search algorithms, specialized in recombination operators. In general terms, memetic algorithms can be interpreted as search strategies in which the population is optimized by agents of cooperation and competition(Neri and Cotta, 2012).

ALGORITHM IN PSEUDOCODE

```
1  Function Memetic_Algorithm (in P: Problem, inpar: Parameter): Solution;  
2  start  
3  |   population  $\leftarrow$  Start (par, P);  
4  |   repeat  
5  |       |   newpop1  $\leftarrow$  Cooperate (pop, par, P);  
6  |       |   newpopo2  $\leftarrow$  Improve (newpop1, par, P);  
7  |       |   pop  $\leftarrow$  Compete (pop, newpop2);  
8  |       |   if Converge (pop) then  
9  |       |       |   pop  $\leftarrow$  Restart (pop, par);  
10 |   end if  
11 |   while Term_criterion (par);  
12 |   return Get_best (pop, 1);  
13 end
```

Created by Neri and Cotta, 2012.

Line 3 of Algorithm, represents the function to initialize the population of the first generation, agents are usually generated (as individuals are called in memetic algorithms) in a random manner. The agents are evaluated according to their cost function (health function). Local search procedures can be included at this time to debug the first generation. Subsequently (line 7) crossing algorithms are integrated between the best selected parents using recombination or mutation (or even both). At this time, a new population is obtained, with agents already improved, the previous population is replaced, generating the second generation. The mutation algorithms can be random or endowed with information that depends on the same problem to solve. Subsequently, the population is reconstructed to obtain a complete population, and the population is evaluated to see if it was degraded (line 8), if so, it is restarted. A typical strategy in this step is to maintain a fraction of the current population, generating new solutions (random or heuristic), to complement the population. All the above procedure is repeated until a term criterion is met (line 11). At the end of the algorithm, an optimized population is obtained.

EVOLUTIONARY STRATEGY ALGORITHM

On July 1, 1858, Darwin presented his controversial *Theory of Natural Evolution* at the Linnean Society of London. Currently, the neo-Darwinian paradigm of evolution holds that the evolutionary mechanism of species and individuals is supported by four main processes: reproduction, mutation, competition and selection, often summarized in the phrase "survival of the fittest and strongest" (Hernández *et al.*, 1998a).

The method of evolutionary strategies was developed in 1964 by a group of German engineering students led by Ingo Rechenberg and Hans-Paul Schwefel. Its objective was to solve hydrodynamic problems of a high degree of complexity.

The original version $(1 + 1) - EE$ he used only one father and with him one son was generated. This son was maintained if he was better than the father, otherwise it was eliminated (his type of selection is called extinctive, because the worst individuals have a zero probability of being selected).

In the version $(1 + 1) - EE$, a new individual is generated using the algorithm:

$$x_{t+1} = x_t + N(0, \sigma),$$

Where, t refers to the generation (or iteration) in which we are, and $N(0, \sigma)$ is a vector of independent Gaussian numbers with a mean of zero and standard deviation σ (Hernández *et al.*, 1998b).

In 1973 Rechenberg introduced the concept of population, by proposing an evolutionary strategy called $(\mu + 1) - EE$, in which there are μ parents and a single child is generated, which can replace the worst father of the population (Botello *et al.*, 2007).

REPRESENTATION

Chromosomes are made up of three parts:

Target variables: x_1, x_2, \dots, x_n

Control variables: $\sigma_1, \sigma_2, \dots, \sigma_n; \alpha_1, \alpha_2, \dots, \alpha_n$

Full size: $\langle x_1, x_2, \dots, x_n, \sigma_1, \sigma_2, \dots, \sigma_n, \alpha_1, \alpha_2, \dots, \alpha_n \rangle$

MUTATION

The mutation is the main operator of the evolutionary strategies, consisting in altering a variable by means of a random number, and it is these mutations that carry out the essential search. First the control variables must be mutated, and then the target variables.

Mutations of the target variables are made by adding a random number with normal distribution with zero mean and standard deviation corresponding to the value of the control variable. The use of mutations with normal distribution has the purpose that small changes are more likely than large ones (Bartholomew, 2008).

RECOMBINATION

The recombination operators of the evolutionary strategies can be:

Sexual: the operator acts on randomly chosen individuals from the parent population.

Panmíticos: a single father is chosen at random, and it remains fixed while a second father (from the entire population) is chosen at random for each component of its vectors (Cuevas *et al.*, 2016).

For the two forms of recombination the same numerical variants are available to make them. These are:

Discrete recombination: Each parameter takes the value of one of the parents chosen at random.

Intermediate: We have x_1 and x_2 parents, then, the son is given by

$$x = \frac{(x_1 + x_2)}{2}$$

Generalized: We have x_1 y x_2 parents, then, the son is given by $x = x_1 + \eta(x_1 + x_2)$, where η is a random number in the range $[0,1]$.

Intermediate widespread panmítica: they take $n + 1$ parents randomly from the population, considering the parents x_{r2in}, x_{r1i} and they generate n values of X :

$$x'_{i} = x_{r1i} + X_n * (x_{r2in} - x_{r1i}), i = 1,2, \dots, \lambda \text{ y } n = 1,2, \dots, d$$

SELECTION OF SURVIVORS

It is applied once λ children of the μ parents are created using mutation and recombination.

Deterministically the worst are eliminated. The basis of the selection is any of:

The set of children only: *selection* – (μ, λ)

The set of parents and children: *selection* – $(\mu + \lambda)$

ALGORITHM IN PSEUDOCODE

- 1 Configure algorithm parameters
- 2 Initialize and evaluate initial population
- 3 While (criterion is not met)
 - 4 Select p parents, strategy parameters.
 - 5 Select p parents, decision parameters.
 - 6 Recombine strategy parameters
 - 7 Recombine decision variables
 - 8 Mutate strategy parameters
 - 9 Mutated decision variables
 - 10 Select the new parents from the population of children and from the parent population.
 - 11 Show result

DIFFERENTIAL EVOLUTION

The Differential Evolution optimization algorithm is a direct and simple search population algorithm, which is able to optimize until reaching the global optimum in multimodal, non-

differentiable and non-linear functions. It was proposed by Keneth Price and Rainer Storn in 1995.

The differential mutation is initiated when starting a generation of parameter vectors; A new vector of parameters is generated by the addition of the weighted difference between two members of the population with a third member.

This evolutionary algorithm attacks the initial point of any problem by sampling the objective function on multiple randomly selected pieces.

The stages for the development of the algorithm are: initialization of a population, mutation difference, crossing between the mutant individuals and non-mutant individuals to increase the diversity of the population and finally, the selection process commonly using a Greedy criterion.

The population is realized with real values. The algorithm will mutate at random, selecting vectors to produce an intermediate population of N_p mutant vectors vi . Each vector in the current population will then be recombined with a mutant vector to produce a test population P_u of N_p mutant vectors vi .

INITIALIZATION

It is required to establish the lower and upper limits for each parameter. A random number generator is established:

$$x = b + rand(0,1) * (b_{sup} - b_{inf})$$

MUTATION

The mutation operator is used to provide exchange information among the different candidate solutions found, in order to recombine the previous population to produce a new population of N_p test vectors, this procedure is known as differential mutation.

The differential mutation adds the difference scaled and randomly sampled, between two vectors belonging to the population, to a third vector of the same:

$$vi = \begin{cases} x0 + F(x1 - x2) & \text{if } rand(0,1) \leq M \\ xi & \text{otherwise} \end{cases}$$

The mutation parameter must always be equal to $1 - CR$, where CR is the crossover parameter. If the number is less than or equal to the value of M , the test parameter is inherited from the mutant vector vi , if this is not fulfilled, then the parameter is copied from the original vector xi .

The scaling factor controls the proportion in which the population will evolve. A value of 0.4 to 0.8 is suffered.

CROSS

The crossover operation between the mutant vector vi and the original individual xi is applied. As a result, the test vector u is obtained:

$$ui = \begin{cases} vi & \text{if } rand(0,1) \leq CR \\ xi & \text{otherwise} \end{cases}$$

If the number is less than or equal to the value of CR the test parameter is inherited from the mutant vector vi , if this is not fulfilled, then the parameter is copied from the original vector xi .

SELECTION

Finally, a Greedy selection method is used to find the best solutions by determining if the new element produced by the mutation and crossing operations is better than its previous one:

$$xi = \begin{cases} ui & \text{if } f(ui) \leq f(xi) \\ xi & \text{otherwise} \end{cases}$$

ALGORITHM IN PSEUDOCODE

```

1 Parameter initialization:  $g \leftarrow 0, M \leftarrow 0.2, CR \leftarrow 0.8$ 
2 Initialization of the population in the function limits:  $x1 \leftarrow random, x2 \leftarrow random$ 
3 While ( $gmax$ )
4 For ( $i = 0; i = Np; i++$ )
5  $r1 \leftarrow rand(Np), r2 \leftarrow rand(Np), r3 \leftarrow rand(Np)$ 
6 if  $rand(0,1) < M$ 
7  $ui \leftarrow x0 + F(x1 - x2)$ 
8 else ( $ui \leftarrow xi$ )
9 if ( $rand(0,1) < CR$ )
10  $yi \leftarrow uiz$ 
11 else ( $yi \leftarrow xi$ )
12  $g \leftarrow g + 1$ 

```

EVOLUTIONARY PROGRAMMING

Evolutionary programming (EP) was invented by Lawrence Fogel, along with his companions Al Owens and Jack Walsh in the 60's. The method evolves a population of individuals, but does not involve recombination, the new individuals are created only by mutation. The original evolutionary programming method makes use of uniform random mutations based on discrete alphabets. This approach remained unused for approximately thirty years. Then, in the 80's, Fogel extended the evolutionary programming for applications involving problems of optimization of continuous parameters.

Evolutionary programming to optimize continuous parameters has many similarities with evolutionary strategies: the mutations are normally distributed and the more elaborate versions of evolutionary programming incorporate the variances of mutations, facilitating the self adaptation of these parameters.

There are five variants of evolutionary programming, in this work we will use a program based on continuous evolutionary programming.

PROGRAMACIÓN EVOLUTIVA CONTINUA

Suppose we want to minimize $f(x)$, where x is a vector from n dimension. Assume that $f(x) \geq 0$ for all x . An EP starts with a randomly generated population of individuals $\{x_i\}, i \in [0, N]$. Children are created with the equation:

$$x'_i = x_i + r_i \sqrt{\beta f(x_i) + \gamma}, i \in [1, N]$$

where r_i is a vector from n random elements, where each element is taken from a Gaussian distribution with an average of 0 and a variance of 1, β and γ they are tuning parameters. The variation of the mutation of x_i is $(\beta f(x_i) + \gamma)$. With $\beta = 0$, all individuals have the same average magnitude of mutation. With $\beta > 0$ an individual with a low cost does not change as much as an individual does with a high cost. Usually $\beta = 1$ y $\gamma = 0$ are used as predetermined magnitudes. After the equation generates N new individuals, we have $2N$ individuals: $\{x_i\}$ y $\{x'_i\}$. The best ones are selected N of these $2N$ individuals to form the population of the next generation.

ALGORITHM IN PSEUDOCODE

Select non-negative EP parameters β and γ .

Nominally $\beta = 1$ and $\gamma = 0$

$\{x_i\} \leftarrow \{\text{randomly generated population}\}, i \in [1, N]$

While not (termination criterion)

 Calculate the cost $f(x_i)$ of each individual in the population

 For each individual $x_i, i \in [1, N]$

 Generate a random vector r_i with each element $\sim N(0,1)$

$$x'_i \leftarrow x_i + r_i \sqrt{\beta f(x_i) + \gamma}$$

 Next individual

$\{x_i\} \leftarrow \text{best } N \text{ individuals from } \{x_i, x'_i\}$

Next generation

SELECTION OF THE NEW GENERATION

We will use the selection by rank, this selection orders individuals in the population from best to worst and make the selection using the classification instead of the absolute values of adjust.

III. RESULTS TO MINIMIZE THE FUNCTION

A function with restrictions, shown below, will be minimized. The algorithm will be implemented in the Matlab software (Mathworks, R2016b).

Minimize:

$$f(\vec{x}) = (x_1 - 10)^3 + (x_2 - 20)^3 \quad (1)$$

restricted to:

$$g_1(\vec{x}) = -(x_1 - 5)^2 - (x_2 - 5)^2 + 100 \leq 0 \quad (2)$$

$$g_2(\vec{x}) = (x_1 - 6)^2 + (x_2 - 5) - 82.81 \leq 0 \quad (3)$$

where:

$$13 \leq x_1 \leq 100 \text{ y } 0 \leq x_2 \leq 100 \quad (4)$$

MEMETIC ALGORITHMS

To exemplify the use of memetic algorithms. The program developed in the software interface is given by the code described below:

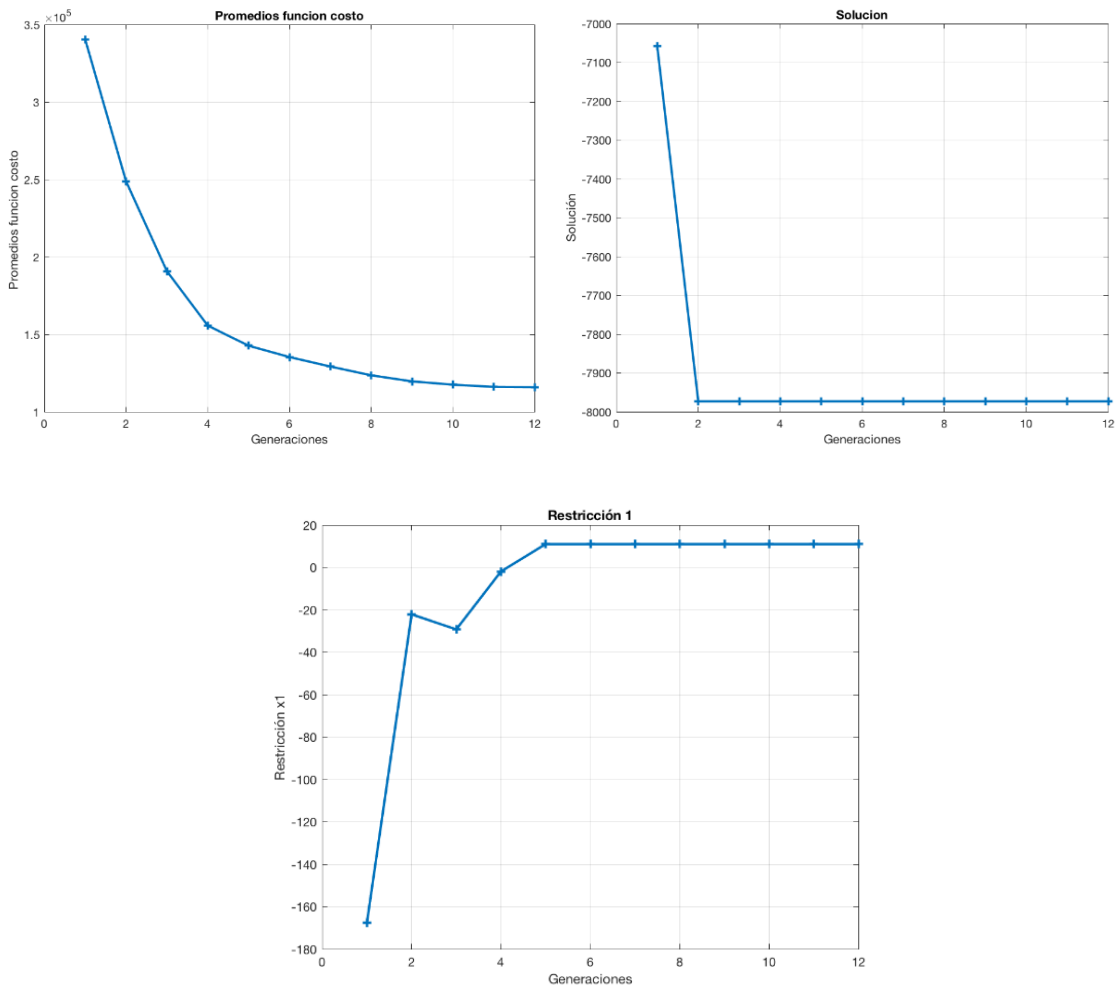
We can emphasize that the design parameters consisted of a population of 100 individuals, 100 points for each unit of the range of values that the independent variables can take, the variables will be subject to penalties according to the violations of the restriction functions.

The results of the execution of the algorithm are shown.

Minimization results.

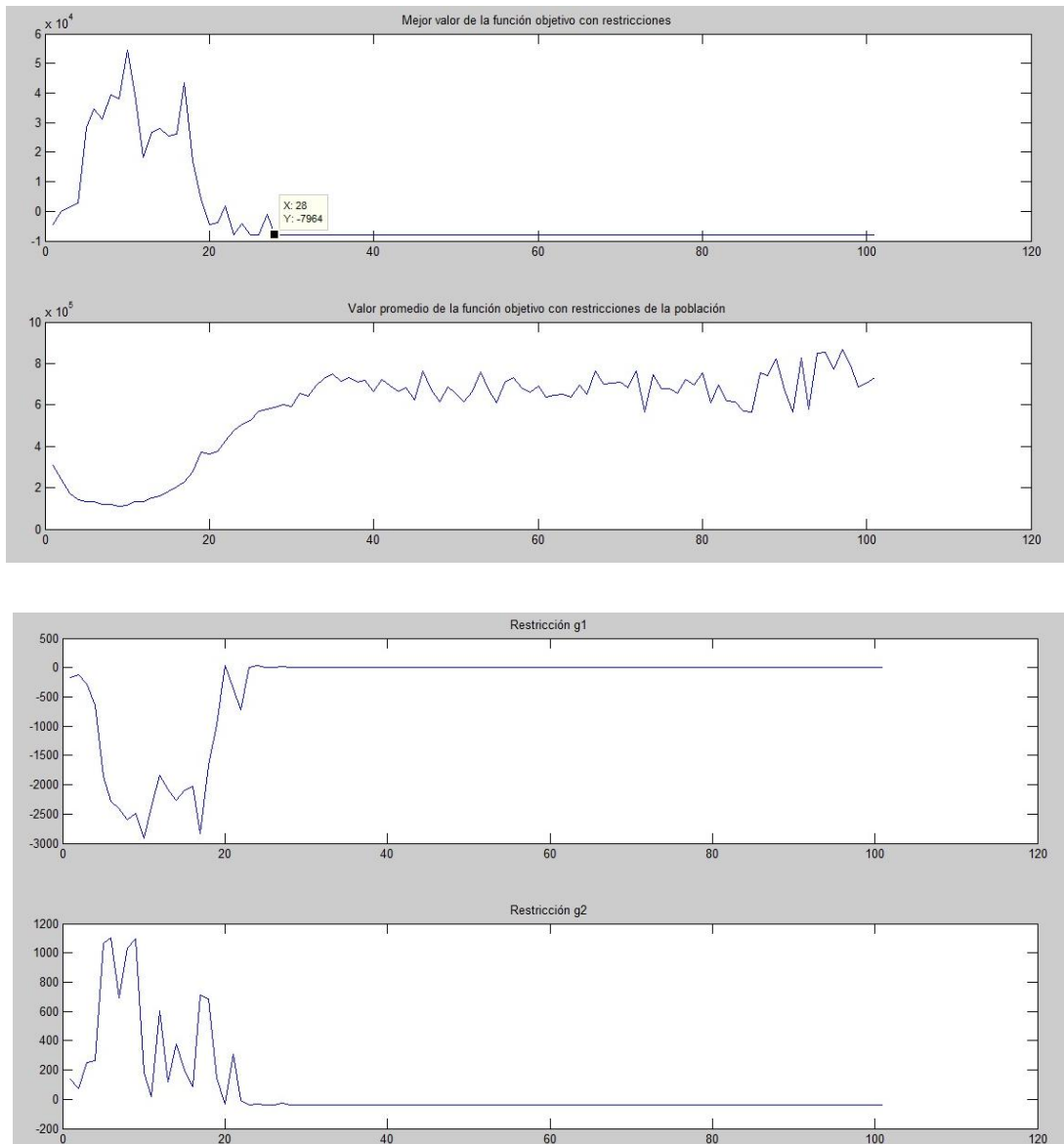
Solution	-7973
Parameters	13 0
Time of processing	0.0724 s

Some graphic results of the implemented algorithm are shown in the following images:



EVOLUTIONARY STRATEGY ALGORITHM

Some graphic results of the implemented algorithm are shown in the following images, the best value of the function with restrictions is: -7964 which is presented in iteration # 28.



DIFFERENTIAL EVOLUTION

The parameters are the following data:

$gmax = 150;$	Number of iterations / Generations
$NP = 100;$	Number of individuals / Population
$d = 2;$	Dimension of the solutions space
$l = [13 \ 0];$	Lower limits of the variables
$u = [100 \ 100];$	Upper limits of the variables

Differential Evolution, Values of constants

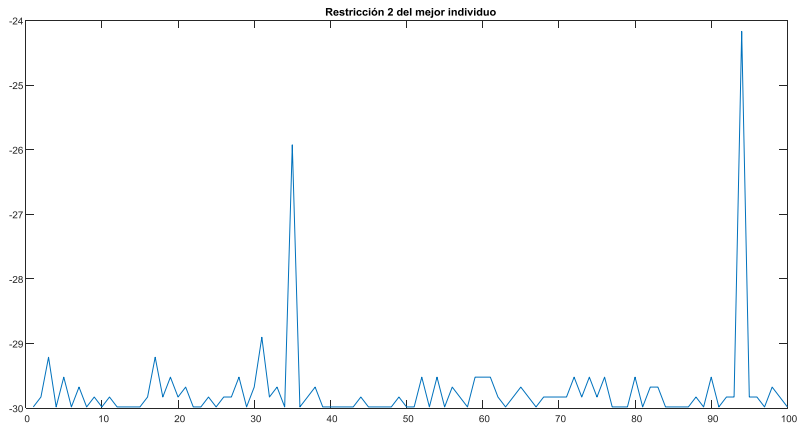
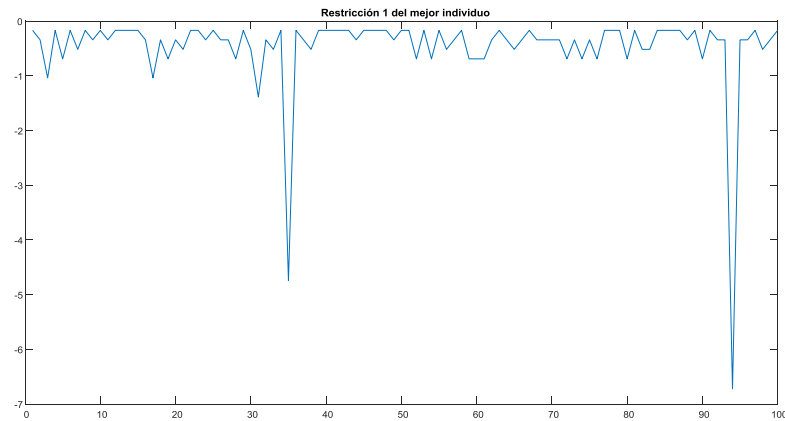
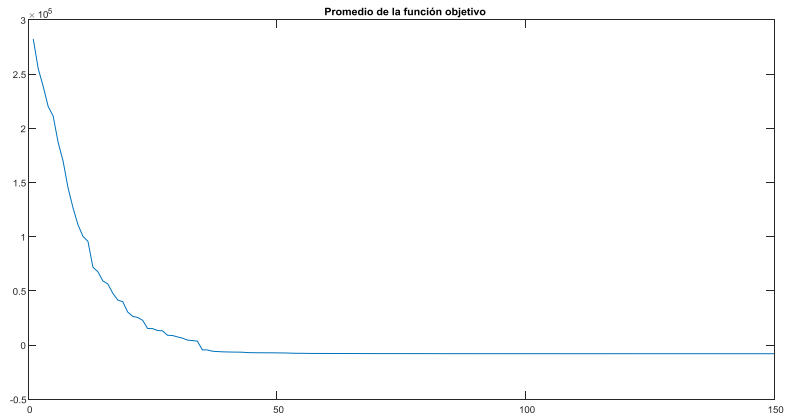
$F = 0.8;$	Escalation factor
------------	-------------------

$CR = 0.8;$ Cross Rate
 $M = 1 - CR;$ Mutation rate

The results in Matlab were the next numbers:

Solution for x_1, x_2 : 13.67, 0
 $f(x)$: -7951

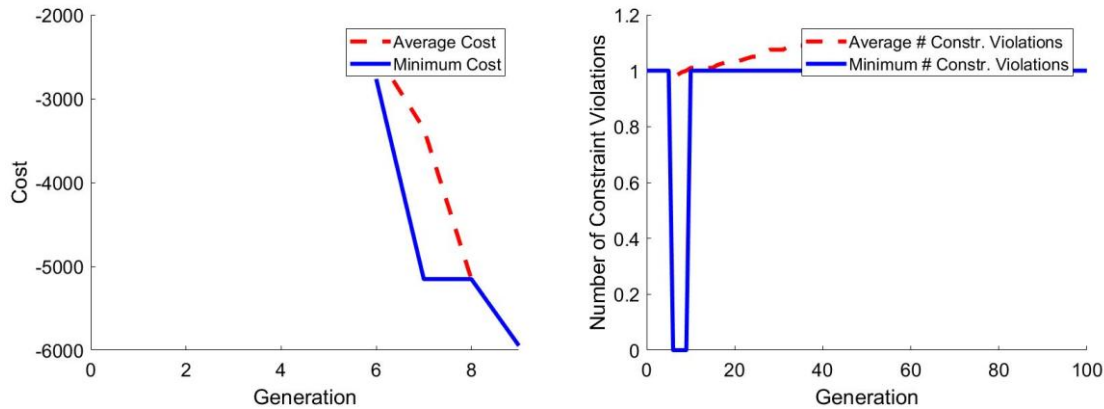
The results are represented in the following drawings:



EVOLUTIONARY PROGRAMMING

Using a population of 200 individuals and 100 generations of calculation, with a calculation time of 29.68 seconds, the following results were obtained.

The behavior of the cost of the function throughout the generations obtained the following graphs.



It is possible to observe that a solution which complies with the restrictions is obtained only in generations 6 to 8, period in which the best solution is obtained with a minimum value of the function for -5946.51. It is observed that the solution diverges when using this type of selection by ranking, where it is observed that the average of violations increases with increasing generations, while the minimum value of violated restrictions is 1 in practically all generations. So it was not possible to obtain a functional solution using a smaller number of generations for this function.

IV. REFERENCES

- [1] Eiben, E., J. E. Smith, and B. History. 2012. Evolutionary Algorithms. 9–27
- [2] Neri, F., and C. Cotta. 2012. A Primer on Memetic Algorithms. In: Handbook of Memetic Algorithms. Vol. 379. p. 43–52. Available from: <http://www.springerlink.com/content/0504353660230jpkp>
- [3] Bartholomew M. 2008. Nonlinear Optimization with Engineering Applications. Springer
- [4] Botello S., Esqueda H. and Hernández A. 2007. Estrategias evolutivas aplicadas en la optimización de problemas con interacción fluido-sólido. Revista Internacional de Métodos Numéricos para Cálculo y Diseño en Ingeniería. 23(4):415–428.
- [5] Cuevas E., Osuna J., Oliva D. and Díaz M. 2016. Optimización. Algoritmos programados con Matlab
- [6] Hernández A., Coello C. and Buckles B. 1998. Estrategias Evolutivas: La Versión Alemana del Algoritmo Genético (Parte I). Soluciones Avanzadas. Tecnologías de Información, 6(62):38–45.
- [7] Hernández A., Coello C. and Buckles B. 1998. Estrategias Evolutivas: La Versión Alemana del Algoritmo Genético (Parte II). Soluciones Avanzadas. Tecnologías de Información, 6(64):47–53.
- [8] Sotelo Figueroa, M., Hernández Aguirre, A., Soria Alcaraz, S., & Soria Alcaraz, J. (2015). Evolución Diferencial con perturbaciones Gaussianas. Research in Computing Science, 94, 111–122.
- [9] Wang, G.-G., Gandomi, A. H., Alavi, A. H., & Hao, G.-S. (2014). Hybrid krill herd algorithm with differential evolution for global numerical optimization. Neural Comput&Applic, 25, 297–308.
- [10] Cuevas Jiménez, E., Osuna Enciso, J., Oliva Navarro, D., Díaz Cortés, M. (2016). Optimización, Algoritmos programados con Matlab. Alfaomega, 83-98.
- [11] Simon, D., *Evolutionary Optimization Algorithms. Biologically Inspired and Population-Based Approaches to Computer Intelligence.*, John Wiley & Sons, Inc., 2013. New Jersey.
- [12] Bäck, T., *Evolutionary Algorithms in Theory and Practice.*, Oxford University Press, 1996. New York.
- [13] Fogel D.B., Fogel L.J. (1996) An introduction to evolutionary programming. In: Alliot JM., Lutton

E., Ronald E., Schoenauer M., Snyers D. (eds) Artificial Evolution. AE 1995. Lecture Notes in Computer Science, vol 1063. Springer, Berlin, Heidelberg



Rheological characterization of an almond butter.

Edgar J. Cruz-Bautistaa

Master's degree in Design and Innovation. Faculty of Engineering

Universidad Autónoma de Querétaro
Santiago de Querétaro, Qro., México.
e-mail: edgar_joel1112@hotmail.com

Margarita Contreras-Padilla

Faculty of Engineering
Universidad Autónoma de Querétaro
Santiago de Querétaro, Qro., México.
e-mail: margarita.contrerasp@uaq.mx

ABSTRACT

The rheological characterization of an almond butter in order to know the type of fluid that it belongs was done. This almond butter was also compared with a similar product present in the market. Studies were made in a rheometer in the steady state for the samples as well as the shear stress tests. The product presented a non Newtonian behavior that correspond a pseudoplastic fluids. The comparison with the commercial product, indicate a similar behavior for the both. The rheological characteristics that show the prototype of almond butter suggest that the organoleptic attributes will be acceptability to the consumer public.

Keywords— Rheology; almond butter; pseudoplastic fluid

I. INTRODUCTION

The nuts and seeds are mainly composed of oils, which in a grinding process can be released [1] [2]. Almonds belong to the genus *Prunus* and the subgenus *Amygdalus* within the family Rosaceae. Almond cultivated is designated as *Prunus dulcis* (Miller). The almonds contain dietary fiber, vitamin E, phytosterols and several micronutrients that contribute to a healthy nutritional profile [3][4][5].

The rheological characteristics of a fluid are one of the essential criteria for product development in industry [6], Which determine the functional properties of some substances and are involved in controlling the quality of products. For oil-based butters is essential to know the behavior of those present because depend on the organoleptic characteristics of the same [7]

The objective of the present work is to analyze the rheological parameters of an almond butter and comparing it with a commercial product with similar characteristics.

II. MATERIALS AND METHODS

A. Development of almond butter

We used a almond butter (MA) which was prepared based on the methodology proposed by Lima and Guraya [8], for the creation of a sunflower seed butter.

The almonds are crushed with a food processor HamiltonBeach at high speed. The samples were stored in plastic bottles at a temperature of 4°C for later analysis. It was used as a control for the comparison a hazelnut cream with chocolate (NMC).

B. Rheological analysis of almond butter

Rheological measurements were performed in a Modular Compact Rheometer Anton Paar, with the RheoplusmV3.62 program using parallel plate geometry PP25 / P2 at a constant temperature of 25 ° C.

C. Viscosity measurements constant shear (steady state)

The behavior of shear viscosity of almond butter and the commercial product was studied as a function of increasing shear rate in the range 0.5 to 30 s⁻¹.

III. RESULTS AND DISCUSSION

A. Rheological analysis of almond butter.

Rheological tests steady state

Fig. 1, shows the results of the rheological tests of steady state for almond butter, as can be seen the viscosity of the samples tend to decrease with increasing shear rate, typical behavior of fluids non-Newtonian. As reported in [5][6][9]. Similar behavior to the sample used as control.

The initial viscosity of the commercial sample is higher compared to the sample MA (fig.1), this is maybe that products are used various additives, thickeners and emulsifiers for increasing the viscosity and thus it is more desirable to the consumer. The almond butter used for this study was not added any type of additive to improve its characteristics.



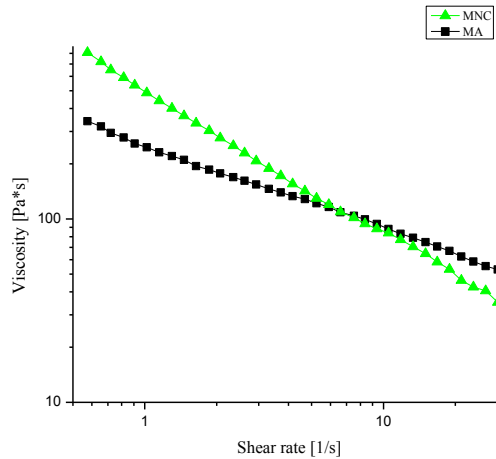


Fig. 1. viscosity of the samples of sample MA and NMC Control

Fig. 2 shows the shear stress and the deformation rate which is known as flow curve where indicate, according to the form of the curve, fluid type to which the samples belong, as can be observed the behavior of the sample MA presents a similar behavior to the sample used is shown NMC as control. Based on the types of fluid behavior reported by [7][9] it was observed that the behavior of samples matches to pseudoplastic.

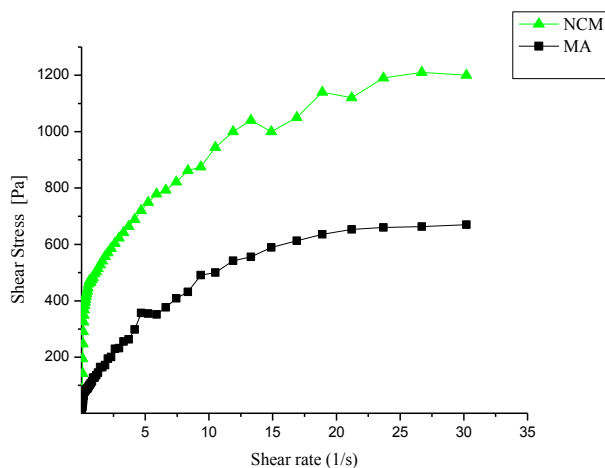


Fig. 2. Test shear stress applied to the MA and the NMC.

The relationship between shear stress and shear rate for non-Newtonian fluids is not linear [7]. The almond butters present a pseudoplastic behavior belonging to the non-Newtonian fluids. Such fluids are characterized by a decrease in viscosity and shear stress with respect to strain rate. These characteristics being important for acceptance and product quality [10].

IV. CONCLUSIONS

The rheological study showed that the almond butter is a non-Newtonian fluid and it corresponds with the behavior of a pseudoplastic fluid. The prototype of the almond butter that is done and the NMC presented a similar behavior in the rheological tests.

The above explain, suggest that the prototype presents the organoleptic characteristics of texture similar to existing products on the market. The texture is a very important attribute for this type of food products.

ACKNOWLEDGMENT

We would like to thank the CAIDEP of the Faculty of Engineering of the Autonomous University of Queretaro, as well as the CFATA for the support of these project.

REFERENCES

- [1] E. D. Co, A. G. Marangoni, „Organogels: An Alternative Edible Oil-Structuring Method,” *Journal of the American Oil Chemistry Society* 89, pp. 749–780, 2012.
- [2] A. Rabadán, et al., „Suitability of Spanish almond cultivars for the industrial production of almond oil and defatted flour,” *Scientia Horticulturae* 255, pp. 539-546, 2017.
- [3] S. Yada, et al., „A review of composition studies of cultivated almonds: Macronutrients and micronutrients,” *Journal of Food Composition and Analysis* 24, pp. 469-480, 2011.
- [4] P. García-Pascual, et al., „Influence of Storage Conditions on the Quality of Shelled and Roasted Almonds,” *Biosystems Engineering* 84, pp. 201-209, 2003.
- [5] B. W. Bolling, et al., „Polyphenol content and antioxidant activity of California almonds depend on cultivar and harvest year,” *Food Chemistry* 122, pp. 819-825, 2010.
- [6] L. Pérez-Trejo, et al., „Determinación de la viscosidad de fluidos newtonianos y no newtonianos (una revisión del viscosímetro de Couette),” *Latin-American Journal of Physics Education* 4, pp. 237-245, 2010.
- [7] J. S. Ramírez-Navas, „Fundamentos de Reología,” *primera edición*, 2006.
- [8] I. M. Lima, H. S. Guraya, „Optimization analysis of sunflower butter,” *Journal of food science* 70, pp. 365-370, 2005.
- [9] G. Tabilo-Munizaga, G.V. Barbosa-Cánovas, „Rheology for the food industry,” *Journal of Food Engineering* 67, pp. 147-156, 2005.
- [10] L. Li, et al., „Effect of Sorbitol on Rheological, Textural and Microstructural Characteristics of Peanut Butter,” *Food Science and Technology Research* 20, pp. 739-747, 2014.



CONiIN
XIV CONGRESO INTERNACIONAL
DE INGENIERÍA

