GROWTH OF VEGETATION ON MINING JALES TO RECOVER GREEN AREAS OF POLLUTED COMMUNAL OPEN SPACES

[1]Contreras López, Christhopher; [2]López de Juambelz, Rocío
[1]Student of master in architecture from the "Programa de Maestría y Doctorado en Arquitectura" of Universidad Nacional Autónoma de México; [2]Tutoress of the "Programa de Maestría y Doctorado en Arquitectura" of Universidad Nacional Autónoma de México.
[1,2]Circuito de Posgrados, Ciudad Universitaria, Unidad de Posgrado, Building "H" first level, Delegación Coyoacán, C.P. 04510, México D.F.
e-mail: christhophercl@hotmail.com

ABSTRACT

Some mining cities in Mexico have recently undergone a rapid demographic expansion which has led to its urban spots expand to places where there are deposits of mining waste (jales) and occupy these places for human settlement. This causes, among many problems, this type of soils causes dust storms of toxic dust particles to health, vegetation does not develop due to the soils because the structure is not suitable due to the lack of organic material, the compactness of soils preclude roots develop, in addition to the physical and chemical characteristics of soil present heavy metals that affect plant growth. These causes, the green areas of the communal open spaces provided in this settlement, are abandoned because they only can be built without vegetation or non-permeable materials that ward off water seepage to the mining jales.

The vegetation in the communal open spaces on these settlements prevents dust storms and improves soil characteristics by re-vegetation processes, so the main objective is obtained by factorial bioassays of plants against the concentration of jal, a palette of plant species capable of growing on deposits of *jales* to mitigate their harmful effects. The experiment species are Carpobrotus edulis and Sedum Praealtum.

These bioassays allow evaluate the plant species against four soil mixtures. One of these with polluted soil another with natural soil as a control and two more with mixed soils in different percentage to improve the quality of polluted soil. Each mixture was compared to establish which species could be adapted to the jal soils and what kind of mixed soils is the fittest to develop plant species.

The first results show that even though the plant species present some morphological changes, these plants are able to establish themselves in substrates polluted. Therefore this type of vegetation can begin recovery the green areas of forgotten communal open spaces, plus get habitability and give dignity to these places.

Keywords: Mining jales, pollution, bioassays, re-vegetation, land reclamation.

1. The tailings as *oblitopías* [1]

About two-thirds of Mexico's territory is formed by metasomatic rocks, with the right characteristics to the existence of mineral geological features, so in 28 states nationwide mining activities are recorded, which are dispersed in about 300 municipalities throughout the territory, of which 7 were founded by mining work and were subsequently elevated to the state capital. [2] As for the variety of mineral production 47 different minerals are extracted, of which in his most are precious metals like gold and silver. [3]

The mining sector has a great importance in the history of Mexico, the diversity and abundance of minerals in the country has always been one of its greatest assets, mining has its history from pre-Hispanic times, the viceroyalty and peaked in the early nineteenth century. [4] This activity has been centered in extractive metallurgy, mainly gold and silver, which has given result as waste water sludge mine where solids are transported and accumulated minerals, who are left without any processing known as tailings or "jales" which are residues of beneficiation processes of mining, have been the result of three periods with different methods to benefit the material: the first sixteenth to the nineteenth century known as “Beneficio de Patio” based on the separation of minerals by the use of mercury as a vehicle amalgamation, followed on par with it in the nineteenth century in a period of approximately 50 years through the method of Freiberg which is derived for “Beneficio de Patio”, and since the early twentieth century to date the benefit with cyanide, which is used mainly due to the large volume of cyanide ion to form complexes with silver and gold. [5]

The environmental impact caused by the tailings is associated with factors such as beneficiation methods used and climatic conditions of the site. Among the most significant problems is the spread of the finest particles of “jal” caused by wind, producing wind erosion in the deposits they are willing to open, this occurs mainly in arid areas; and the generation of acid mine drainage and dispersion to produce surface runoff water erosion in rainy areas. [6]

The city of Pachuca in the state of Hidalgo is the mining town closest to the capital of Mexico, is located approximately 100km from it, due to its proximity, received a special interest in the search for precious metals, base the colonial economies and independence, and became the producer mining center closest to the capital of the territory silver, which facilitated the continued exploitation of silver. [7]

The rapid population growth of the next country's capital cities has led to urban sprawl grow rapidly, particularly the city of Pachuca in their development, first surrounded and subsequently occupied mining waste deposits, so these areas are currently dealing for settlement causing further instability of the structures due to the clay soil, different types of diseases caused by mineral contaminants in soil and water [8] regardless of spaces without green areas, forming *oblitopías*, due to soil composition, this contributes to the spread of dust minerals that can cause health problems.

The soil is not routinely renewed as rain or sunlight; this is a slow process and it must be balanced with the development of vegetation covering it and who sustains, as they form an inseparable pair, where the existence and evolution of one depends on the other. [9] For this reason it is essential to assist in the reclamation and vegetation of the site, so that the process of regeneration of space begins.

2. Objectives

Identify the areas allocated for green areas within human settlements on mine tailings deposits.

Define plant species capable of growing on mining waste deposits to mitigate their harmful effects, and begin the recovery of open spaces.
Perform the factorial bioassay whit different concentrations of contaminated soil and improve soil.

3. Urban growth of the city towards tailings deposits

In 1912 the tailings are not deposited in tailing heap but are spilling into Avenidas river, spreading over a wide area, close of south of Pachuca. So a company that considered convenient to deposit the tailing in tailing heap was formed in which converge all waste in hopes of improving the technique that allows to recover the mineral they contained. This company was called "Asociación de Compañías Beneficiadoras de Pachuca, S.C.L", who took the tailings of the Avenidas river; however it was not possible to recover all tailings from the river, especially during the rainy season, so it was possible to recover only part of them. [10]
In the same year the tailing heaps of "Santa Julia" planned five miles south of Pachuca, began with a tailings from the various benefits plants of the major mining companies working in the district began. For 1924, the company Real del Monte and Pachuca and San Rafael sent their tailings from the mill of Loreto and San Rafael, respectively, through a glazed clay pipe to the south of the city; from that year, total tailings from both mills were deposit on this heap. [11]
By 1961, the tonnage cubed by the company Real del Monte and Pachuca was 57 million tons by the year 1984 it already had two reservoir dams, "Sur 1" and "Sur 2" occupying 391 hectares with more than 65 million tons. [12]
Finally, from 1985 as a result of the earthquakes of Mexico City, has seen a strong growth in the city covering a conurbation with the nearby municipalities and tailings heaps, who were on the outskirts of the city in the middle of century. [13]
Between 1970 and 1990 the population increased considerably in Pachuca, take this period because the 1980 census had many shortcomings in its survey, which is considered a lost census so there only until 1990 results density population, for this period the city of Pachuca considerably expands the boundaries of the city, especially south toward to Mexico city. Start the same way the emergence of adjoining subdivisions with mine tailings, including: Infonavit Venta Prieta (1974) Ampliación Santa Julia (1975), San Javier (1981-1992), Juan C. Doria (1986) Unidad Minera (1987) and a Bus Station (1977) and Supply Center (1980). [14]
From this period begins property speculation to the tailings from the south of the city of Pachuca, especially to meet the needs of a growing population due to migration of people from Mexico City and State of Mexico to Pachuca, so the state government of Hidalgo, start by donating land in boundary with the tailing heap the Tecnológico de Monterrey, coupled with the first building on the grounds of "jal" for the headquarters of the Centro Minero Nacional, with the village called Unidad Minera in 1988. 1994 is built on what was the tailing heaps of Santa Julia, the Hidalgo Stadium and Plaza del Valle, situation took a turn to the use of this type of soils, because they are privately owned by the Compañía Real del Monte y Pachuca, which saw the decline of mining, and the favorable location of these lands, decided to undertake the work of building two subdivisions on what was left of tailing heap of Santa Julia and Presa Jales Norte, these divisions are now called the Moraleja and Puerta de Hierro, occupy in 2000; 2005, built the CRIT Teleton Hidalgo and a Gym near the stadium; This takes up the idea of converting the tailing heaps for housing and urban infrastructure. In 2013 they was authorized to occupy the tailings heaps called Presa Jales Sur and Dos Carlos to build two subdivisions and thus occupy the entire area of mining waste in the city. [15] (fig.1)

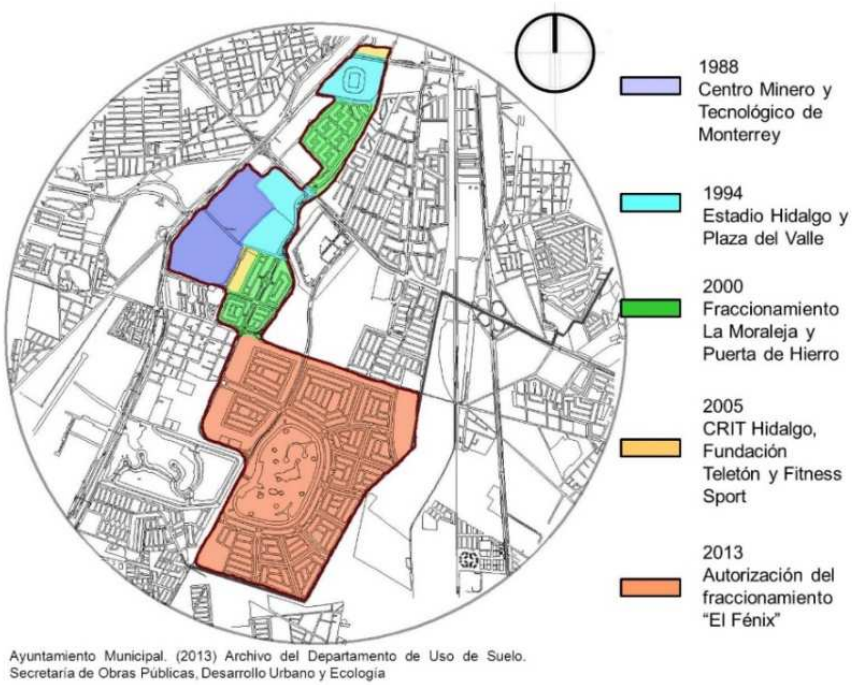

Fig. 1: "Urban intervention in tailing heaps". Source: City Council

4. Case Study

4.1 Visual analysis

A visual analysis was performed in the area of Presa Jales Sur in the city of Pachuca, Hidalgo, which led to analyze one of the subdivisions called "Puerta de Hierro" located above the tailing heaps in the area of Santa Julia, for locate the different communal open spaces forgotten in place.

The place is the division "Puerta de Hieero" located at latitude 20°5'26.51"N and 98°45'46.53"O, located at south of the city of Pachuca, Hidalgo, on the tailings called "Presa Jales Norte of Santa Julia, which has parallel access to primary roads; has a BSW climate classification E. García from the Köpen, which is warm dry with gusts up to 75km/hr ranging from northeast to southwest. [16]

We identify deterioration of the urban image, uninhabited spaces, a large spatial segmentation, plus, spaces untreated or any design is identified; is also identified a large environmental degradation, little or no vegetation, in addition to some rude species and maintenance groundcover; fractionation is residential so a vehicle capacity is noticed, and dust storms in the next avenue to this subdivision. (fig. 2 and 3 and 4 and 5 and 6)

Fig. 2 and 3 and 4 "visual analysis" Source: Christhopher Contreras, October 2014

4.2 Diagnosis Site

The growth of the city of Pachuca to the south mainly due to its proximity to the City of Mexico, has the consequence that the urban area surrounding the tailings heaps, prompting the establishment of housing units and urban equipment on them.

We found communal open spaces without design and not capable to stablishment of vegetation, because of that, without development of human outdoor activities, what makes them forgotten spaces.

Some negative aspects of these areas is the presence of heavy metals in living spaces, dust storms cause respiratory problems, spaces without design and abandoned, homes with cracks due to soil instability, forgotten spaces, introduced species without environmental criteria and contaminated soils.

However there are some positive aspects to be considered in the same way as the presence of some vegetation, some experiments have introduced species such as Dahlia, Tagetes and Cosmos that represent an alternative to cover vegetation and recover contaminated tailings areas; soil characteristics allow the establishment of certain species that are able to reduce the disposal of toxic elements in the soil and mitigate dust and that these spaces enable habitability in these places.

5. Selection of species for the experiment

The city of Pachuca in the state of Hidalgo presents different human settlements were established on tailings heaps called "Presa Jales Norte" that is located at south of the city with approximately twelve hundred acres. [17] On this place, Chapingo, studied physical and chemical characterization of soils, and parameters of vegetation, so they found 25 plant species belonging to seven families were identified was performed, being the most representative Asteraceae nine species and Poaceae seven species, in relation to this study concluded that the physical and chemical properties of waste mine permit the establishment of plant species capable of reducing the disposal of potentially toxic elements in the soil and air, to favor the accumulation of them in their tissues, so suggest using the studied species for vegetation of mine tailings deposit. [18]

Another independent publication conducted the study in the same place on the growth of ornamental plants, in which the objective was to evaluate the effect of heavy metals contained in mining waste deposits in the emergence and development of the species of dahlia, Tagetes and Cosmos, for the purpose of evaluating your use as plants that facilitate vegetation. The result showed that these three species accumulated in their high tissue concentrations of heavy metals in Tagetes and Cosmos and the emergence decreased in Dahlia with the highest percentage of emergency, besides presenting very similar percentages to the above with the growth dynamics, so although these species present physiological and morphological changes, can be established in contaminated substrates [19] however, the study does not show the effect of the species throughout its lifecycle, to really know their behavior and usefulness in soil vegetation.

This reports says that it is possible to introduce species ability to emerge on substrates of mining waste and start its growth and accumulate different metals, however, species introduced in earlier works are not ornamental and cannot covering the floors throughout the year, so you should look for plants, first having resistance to any type of climate, soil and temperature, plus it can serve as floor coverings throughout the year.

The choice of the two species is given by their physical characteristics and adaptability to extreme conditions, where most plants would not survive. Species selected are *Carpobrotus edulis* (L.) L. Bolus and *Sedum praealtum* A. DC. [20] (Table 1)

Cientific name	Common name	family	type	measures cm		flowering	Necessity	
				h	diameter		soil	Sun
Carpobrotus edulis (L.) L. Bolus	dedomoro	Aizoaceae	Evergreen	15	30	divers	any	direct
Sedum praealtum A. DC.	siempre viva	Crassulaceae	evergreen	80	50	yellow	any	direct

Table 1 “Selection of species”

6. Bioassays

6.1 Description of the experiment

The main problem in this type of soils is the dust storms generated with toxic dust particles health. So it is imperative to avoid dust devils and improve soil characteristics through processes of vegetation. In this sense a factorial experiment which allows observing the development of *Carpobrotus edulis* and *Sedum praealtum* and its relation to four concentrations of soil was designed.

- Soil contaminant (jal)
- Substrate as improvement
- 80% of jal and 20% improvement substrate
- 60% of jal and 40% improvement substrate

6.2 Location of the experimental site

The experimental station is located in Mexico City, on the roof of the building "J" Unidad de Posgrado, Posgrados street circuit, Ciudad Universitaria, Coyoacán, CP 04510, Mexico DF, with geographical coordinates 19th 18'33.36 "North and 99 ° 11'5.70" West.

Although the villages with the problem of contaminated soil are located in the city of Pachuca, Hidalgo, the experiment is in a place with a very similar climate, so this variable does not change the result because the average temperature both in Ciudad Universitaria as Pachuca ranges between 14.5 ° C and 16.0 ° C and annual rainfall between 450 and 600mm in both cities. Also was chosen Ciudad Universitaria for periodic measurement and data capture experiment.

6.3 Factorial Experiment

To prepare the factorial experiment and measuring the results the following materials were used: (Table 2)

No	Material	Marca / Procedencia
1	Hydropic tray	AVELOP prefabricados de plástico
2	Jal soil	Presa Jales Norte, Pachuca
3	Black soil	Jardines Flotantes Xochimilco
4	Oak leaves	Jardines Flotantes Xochimilco
5	Fertilizer sheep	Jardines Flotantes Xochimilco
6	Agrolita	Hidro environment SA de CV
7	River sand	Jardines Flotantes Xochimilco
8	*Carpobrotus edlilus*	Vivero bajo UNAM
9	*Sedum praealtum*	Vivero bajo UNAM
10	Drill	Makita
11	Broach	Trupper
12	Shovel	Trupper
13	Tray	S/M
14	Scissors	Barrilito
15	Geotextil	IML Ingeniería

Table 2 “Materials”

Once all materials obtained proceeded to make the substrate mixtures improvement which comprises:

- Mineral: black earth
- Organic Matter: oak leaves and sheep manure
- Draining: agrolita and river sand (Table 3)

1/3 Mineral	1/3 Organic matter	1/3 Draining
Tierra negra	2/3 Oak leaves	1/2 Agrolita
	1/3 Fertilizar sheep	1/2 River sand

Table 3 “Proportions for improving substrate” [21]

Then for the mixture to the substrate 18 improvement measures, of which 6 measures were black earth, 4 oak leaf measures 2 measures sheep manure, 3 measures 3 parts perlite and sand were used, after adding all the materials are stirred with a shovel to five volts to ensure a homogeneous mixture. (fig. 7 and 8)

Fig. 7 and 8 "soil mixes." Source: Christhopher Contreras, January 2015

We cut 48 pieces of 80cm x 80cm of geotextil, which are placed between the substrate and the tray to prevent loss of fines during irrigation, plus we made an average of 25 holes in the grid 20x20cm on trays for the purpose of drain and remove excess water produced by rain. (fig. 9 and 10)

Fig. 9 “Placing geotextile”

Fig. 10 “grid of holes”

6.4 Mixtures

The first mixture is based exclusively on JAL to test the plant growth without any improvement. (Fig. 11 and 12)

Fig. 11 and 12 “First mixture” Source: Christhopher Contreras, January 2015

The second mixture is the base which has the necessary elements for plant growth and is composed of a mixture of materials mentioned above (fig. 13 and 14)

Fig. 13 and 14 “Second mixture” Source: Christhopher Contreras, January 2015

The third mixture is a mixture jal with 80% and 20% improvement that a 5 volt stirred to ensure homogeneity. (fig. 15 and 16)


Fig. 15 and 16 “third mixture” Source: Christhopher Contreras, January 2015

The fourth composition is a blend of 60% and 40% jal development being stirred with the same procedure as the third. (fig. 17 and 18)


Fig. 17 and 18 “fourth mixture” Source: Christhopher Contreras, January 2015

The mixtures were of 20% and 40% improvement because the 50% mixture of improvement with jal, would be unaffordable for the inhabitants of the subdivisions on mine tailings deposits.

6.5.- Plantation

The density of plants per tray is calculated based on the adult size of the species, allowing planting a real frame 9 plant per tray, thus the total coverage of the tray avoiding competition is guaranteed. (fig. 19, 20 and 21)



Fig. 19 and 20 and 21 “*Sedum praealtum* plantation” Source: Christhopher Contreras, January 2015

Each tray has 9 species and 6 replicates per each of the four mixtures are performed, making a total of 24 trays and 216 plants per species. (fig. 22, 23 and 24)

Fig. 19 and 20 and 21 “*Carpobrotus edulis* plantation” Source: Christhopher Contreras, January 2015

For plant growth is recorded in a table field by measuring monthly behavior of each individual taking into account the height and width in centimeters.

7. Conclusions

For the first month of plant growth we obtained only the survival of both species at mixtures one, three and four, the number two mixture has adequate growth. The plants have ability to begin growing in contaminated soils. It suggests that it use to cover soils of jal with green areas in communal open spaces on these settlements. However the long-term experiment, considering the entire life cycle of plants, and more species will help us understand their behavior and usefulness in vegetation, in addition to obtaining more plants able to adapt to these soils and to have different options vegetation to project the green areas of communal open space.

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REFERENCES

[1] Oblitopía, neologism used by Dr. Rocío López de Juambelz to name to the forgotten spaces: López de Juambelz, R. (2004). Taludes: Aspectos formales y técnicos. México: UNAM.

[2] León Portilla, M., Gurría Lacroix, J., Moreno, R., & Madero Bracho, E. (1978). La minería en México, Estudios sobre su desarrollo histórico. México: Dirección General de Publicaciones UNAM.

[3] Ibid.: pag. 168

[4] Muro Riuz, E. (2002). La minería mexicana, su evolución, retos y perspectivas. México: Instituto de Investigaciones Jurídicas UNAM.

[5] Hernández Ávila, J. (2012). Caracterización de la escombrera de Velazco en el estado de Hidalgo y uso industrial alterno como material de construcción. V encuentro de investigación del AACTyM
[6] Ángeles Chávez, D. (2012). Estudio de características geológico-ambientales del depósito de jal Dos Carlos, distrito minero Pachuca-Real del Monte. Pachuca: Instituto de Ciencias Básicas UAEH.
[7] Saavedra Silva, E. E., & Sánchez Salazar, M. T. (2008). Minería y Espacio en el distrito minero de Pachuca-Real del Monte en el siglo XIX. Boletín del Instituto de Geografía. UNAM(65), 82-101.
[8] Rodriguez Elizalde, M., Delgado Alvarado, M., González Chávez, A., Carrillo González, R., Mejía Muñóz, J., & Vargas Hernández, M. (2010). Emergencia y crecimiento de plantas ornamentales en sustratos contaminados con residuos de mina. INTERCIENCIA 35(1).
[9] Cabeza Pérez, A. (1993). Elementos para el diseño de paisaje. México: Trillas.
[10] Ángeles Chávez, D. (2012). Op. cit.: pags. 3-5
[11] Ibid.: pag. 5
[12] Ibid.: pag. 7
[13] Lorenzo Monterrubio, A. (1995). Evolución Urbana de la Ciudad de Pachuca. Pachuca: Consejo Estatal para la Cultura y las Artes de Hidalgo. Pag.:11
[14] Hidalgo, G. d. (noviembre de 2013). Enciclopedia de los municipios de México. Obtenido de Estado de Hidalgo. Pachuca de Soto: Intranet.e-hidalgo-gob-mx/enciclomuni/municipios/13048a.htm
[15] Ibid.
[16] López de Juambelz, R., & Cabeza Pérez, A. (1998). La vegetación en el diseño de espacios exteriores. México: Facultad de Arquitectura UNAM.
[17] Hernández Ávila, J. (2012). Op. Cit.: pags.: 3-4
[18] Hernández Acosta, E., Mondragón Romero, E., Cristóbal Acevedo, D., Rubiños Panta, J., & Robledo Santoyo, E. (2009). Vegetación, residuos de mina y elementos potencialmente tóxicos de un jal de Pachuca, Hidalgo, México. Revista Chapingo Serie Ciencias Forestales y del Ambiente 15(2).
[19] Rodríguez Elizalde, M. (2010) Op.Cit.: pag.: 31
[20] Snodgrass, E. (2006). Green Roof Plants. Portland: Timber Press. Pag.: 53
[21] Palomino Ramírez, B. (2012). Aplicaciones paisajísticas del género sedum para el aligeramiento de sustratos sobre azoteas verdes. México: Facultad de Arquitectura UNAM.