

# Oregano and Composite Substrates: A Mitigation Alternative for Heavy Metals Emission from Tailings Deposits in Parral, Chihuahua, México

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**Abstract:** The Mexican oregano "*Lippia berlandieri Shauer*" is a versatile plant, for multiple purposes and high potential adaptative capabilities. To evaluate the possibility to use oregano as a cover surface on tailings deposits and thereby mitigate the emission of particulate material with metals content, an experiment was carried out comparing the plant growing rate over a period of six-month in four substrates: tailings, vermicompost, "soil" of the region and a mixture of "tailings plus vermicompost". The statistical analysis shows a significant difference between treatments, resulting in the "soil" substrate with the best performance, followed by the mixture of "tailings plus vermicompost" treatment. The low permeability of tailings strongly affects the adaptability and growth of the oregano plant; however, the adaptation possibilities increase in the mixture of tailings with vermicompost or "soil" of the region.

Key words: Oregano, tailings, mining activity, heavy metals.

## **1. Introduction**

In Mexico, there have been many States with a great development in mining industry. Identified as miner districts, different little cities on current States of Guerrero, Queretaro, Guanajuato, Zacatecas and Hidalgo, have been built and their communities has testified their growth, success and prosperity, all because of the exploitation of their regional soil richness between XVII and XIX centuries [1]. In the same case is Hidalgo del Parral city, on Chihuahua State.

The study of processes and activities representing a potential damage due to its environmental alteration has been more relevant on the last decades because of their impact caused on the human being health and its environment [2-5].

The mining industry is one of the commercial activities that strongly contribute to the economic development in Mexico [1]. The mining industry in Mexico is mostly metallic, and currently focuses its production on cooper, zinc, silver and lead [6].

The mining industry involves many pollution sources. The primary process is mineral beneficiation, and the mining waste, better known as tailings, represents one of the most important pollution sources. The chemical composition of mining tailings makes them toxic for living organisms, specifically cyanided ones, those who come from the precious metals obtaining processes [7].

The damage caused to soils by mining activity, is remarkable, causing anomalies such as absence or presence of soil low structure, anomalous chemical

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properties, toxic compounds presence among others [8].

With over three centuries of history, the mining industry on Parral brought not only prosperity on economic issues and urban development [9], but also environmental troubles which have been latent from the very beginning of working operations for one of the most important mines on the region and worldwide, La Prieta mine. With about 1,500 tons of pure mineral production per day, it generated a huge amount of waste occupying today an approximately area of 80 hectares, representing the waste generated during over three centuries of mine working operations [10].

Studies conducted before on the depicted area, make clear the presence of heavy metals concentration levels, which in some cases are above the limits established by current regulations, on superficial soils from populated zone, which suggests that the main source of generation for this pollution, is precisely the zone tailings deposits [11].

The potential risks for population health [12, 13] and its environment damages [14, 15], in addition to being one of the main sources for particulate material emission with heavy metals content to the city and its surroundings, strongly encourage the search for strategies allowing to mitigate the adverse effects produced by the emission of particles with heavy metals content to the atmosphere, which may be available to be inhaled, ingested or deposited on the skin of people living on the limits that surrounds tailings deposits.

Oregano has been used since ancient times on many application fields, from alternative medicine [16-18], to its use on alimentary and pharmaceutical industries [19-22].

The plant versatility and its resistance to extreme conditions environments, poor soils, low water supplies and extreme weathers, make authors think it is a plant with potential to grow in high heavy metal content soils, and can be used as a cover surface on tailings deposits in order to mitigate the particulate material emission with heavy metals content.

## 2. Experimental Methods

#### 2.1 Area on Study Process Characterization

As the mining activity grows, population explosion is a natural phenomenon. Today, not only La Prieta mine's tailings deposits are located inside the urban limits, which have shown recently similar conditions to other deposits located in different places around the country [23-25], but also some other more recent deposits which present the same lack of attention than the mentioned ones, as it shows in Fig. 1. This is a determinant factor to quantify the shape and magnitude of potential impact generated by these tailings on the ecosystem.

Intense dust storms generated by winds oscillating between 21 km/h and 50 km/h, classified as moderate to strong according to Beaufort scale, become more relevant due to different zone locations of tailings deposits, and the fact that predominating winds circulate on Northeast direction. The deposits locations and weather conditions make it easy to transport particulate material with heavy metals content to populated zone and a fraction of its surroundings. The air-transported particle size can become a problem from local to regional scale, existing possibilities that such particles can have a larger reach, from tens or even hundreds of kilometers [26].



Fig. 1 Area on study process depiction.

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## 2.2 Sampling Plan

Samples were collected from both tailings and regional soil, in addition from vermicompost, as a substrate for the experimental units building where the oregano adaptation and growing tracking process was carried out [27].

Taking as a reference the characterization results from La Prieta mine tailings deposits, the tail samples were taken from the point identified as P5, because it has the bigger concentration of arsenic, lead and zinc, mainly as Fig. 2 shows.

# 2.3 Retreatment and Characterization of Collected Samples

Before atomic absorption analysis technique, the samples were dried and sieved until obtaining a sample fraction with particle size  $< 75 \mu m$ , called slit, in according to the ASTM C136 (American Society for Testing and Materials C136) method [28].

The elemental determination for As, Pb, Cd, Cr, Zn, Ag, Fe and Cu was carried out using Atomic Absorption Spectrophotometry Analysis Technique [29], using EPA (Environmental Protection Agency) 3010A and 7000B methods [30, 31], with an Avanta  $\Sigma$  model equipment from GBC Scientific Equipment brand, and coupled to an HG300 model hydride generator from GBC brand.

## 2.4 Permeability Coefficient

The permeability coefficient determination was performed according to specifications provided by Badillo, J. and Rodríguez, R. [32].

## 2.5 Experimental Units: Oregano Care and Watching in Four Experimental Substrates

30 flowerpots were used with an approximately 5 kg sample capacity, distributed as it follows: 10 for "tailings" substrate, 10 for "soil" substrate, 5 for "vermicompost" substrate and 5 for compound substrate (tailings + vermicompost).

Seed germination was carried out in a tray for the



Fig. 2 Sampling points location on La Prieta mine's tailings deposits.

production of oregano seedlings and later transplanted to the experimental units. It was poured 200 mL of water on every experimental unit every third day, in according to recommendations made from personnel working at CIRENA (Research Center for Natural Resources). The tracking process took an approximately six-month period, in which were taken both height and leaf diameter readings once a week.

## 3. Results and Discussion

Figs. 3-6 show the differences between the oregano plant growing behaviors on different substrates used for this experiment. The results reflect a marked difference between the presented behavior on "soil" substrate and those obtained for "tailings" called substrate and a very similar oregano plant growing behavior for the "vermicompost" and "tailings + vermicompost" substrates.

The data was processed using Minitab ® software, through an ANOVA (Analysis Of Variance), using a 95% confidence level (5% significance level), which is shown in Tables 1-3 and Chart 1.

# 3.1 Unidirectional ANOVA: Height Soil, Height Tailings, Height Vermicompost, Height Tailings + Vermicompost

The initial hypothesis established to analyze the four substrates, states that "the oregano plant presents the same behavior on every used substrates,  $\mu 1 = \mu 2 = \mu 3$  $= \dots = \mu a^{"}$ . The alternative hypothesis, on the other hand, states that "at least one of the observed behaviors

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Table 1 ANOVA results.	<b>Fable</b> 1	I AN	IOVA	results.
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Source	DF	SS	MS	F	Р
Factor	3	25,492.9	8,497.6	109.7	0.000
Error	596	46,156.7	7.4		
Total	599	71,649.7			

S = 8.800, R-Sqrt. = 35.58%, R-Sqrt. (adjusted) = 35.26%.

Table 2 Means.

Level	Ν	Average	Std.Dev.
Height soil (HS)	200	22.968	14.053
Height tailings (HT)	200	7.888	3.648
Height vermicompost (HV)	100	10.550	4.901
Height tailings + Vermicompost (HT + V)	100	11.260	4.300

\*Grouped Std.Dev. = 8.800.



Chart 1 ICs of 95% individual for the average based on Std.Dev. grouped.

Table 3Grouping information using the method ofFisher.

Level	Ν	Average	Group
Height soil	200	22.968	А
Height tailings	100	11.260	В
Height vermicompost	100	10.550	В
Height tailings + Vermicompost	200	7.888	С

The averages not sharing a letter are significantly different.

on substrates, is different,  $\mu i \neq \mu j$ ". The Fisher distribution value for the observed data (F = 109.73. y P >> 0.05), exceeds the critical statistic value from Fisher's (Fc = 2.6), obtained from Tables for a 5% significance level ( $\alpha = 0.05$ ), three degrees of freedom for (a-1) factor, and the error freedom degrees bigger than 120. Therefore, the difference is significant for at least one of evaluated treatments.

The first approximations of permeability coefficient (K) on samples taken from La Prieta mine's tailings deposits, obtained a value result of 2.55 E-4 cm/s, placing the analyzed substrate on "impermeable soils", with a 1E-7 a 1E-2 cm/s range, in accordance to values chart of permeability coefficient for different kinds of soil [33].



Fig. 3 Observances on "Soil" substrate.





Fig. 4 Observances on "Tailings" substrate.



Fig. 5 Observances on "Vermicompost" substrate.

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Fig. 6 Observances on "Tailings + Vermicompost" substrate.

The pH determination process on "tailings" samples, and on substrate called "soil" ones was carried out using the AS-02 method of NOM-021-SEMARNAT-2000 (Official Mexican Standard 021 of the Ministry of Environment and Natural Resources of the year 2000) regulations, obtaining a mean value of  $7.7 \pm 0.01$ .

## 4. Conclussion

The results for the oregano plant growing tracking on different substrates provided for this experiment show a marked difference. The substrate with highest growing rate was "soil", as it shows on Fig. 3, with values oscillating between 40 cm and 55 cm, 291.17% higher than observed on the "tailing" substrate, 217.70% higher than "vermicompost" substrate and 203.98% higher than mixture "tailings + vermicompost", being with this the best substrate and therefore which is used as a reference to evaluate the plants growing potential on another substrate. Analysis of variance showed enough evidence to conclude that there exists significant difference between at least a couple of treatments (substrates), being the most significant for the main purposes of this study the observed between the plant growing on "soil" and "tailings" substrate, which could discard oregano for its use as a surface cover directly on tailings deposits. However, the use of a compound substrate, such as "tailings + vermicompost", enables its application.

The low performance showed by the oregano plant on tailings is mainly due to the low permeability coefficient calculated for this substrate. The permeability coefficient for each substrate is a very important factor on plant performance.

It was corroborated the data obtained on previous researches that involved tailings characterization process of La Prieta mine where P5 (Point 5) was identified as the highest concentration of heavy metals, with values oscillating from 800 ppm to 900 ppm of

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arsenic, 7 ppm to 18 ppm of chrome, 97 ppm to 102 ppm for cadmium, 5,200 ppm to 6,800 ppm for lead, 1,700 to 14,000 of zinc, 870 ppm to 990 ppm of copper, 21,000 ppm to 29,000 ppm for iron, and from 36 ppm to 45 ppm of silver.

Although the plant does not properly develop being directly cultivated on tailings, it survives and grows reasonably on a compound substrate, such as the one used in this work, "tailings + vermicompost". This is still a substrate with high heavy metals content given the characteristics of the waste. Therefore, there is a possibility to classify oregano as a phyto-stabilizer, which has an acceptable development on polluted soils. The preceding allows to raise a possibility of building a compound substrate in which can be added the bigger possible amount of tailings, for which oregano has the best performance, in order to establish the proper cover surface to mitigate the particulate material emissions with heavy metals content from tailings deposits on Parral, Chihuahua.

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