

PRISMA ODS
REVISTA MULTIDISCIPLINARIA
SOBRE DESARROLLO SOSTENIBLE
ISSN: 3072-8452

**EVALUATION OF HEAVY METALS
(LEAD, CADMIUM AND ARSENIC) IN
SOILS OF BORDERING ZONES TO
MINES OF THE STATE OF
ZACATECAS**

*EVALUACIÓN DE METALES PESADOS (PLOMO,
CADMIO Y ARSÉNICO) EN SUELOS DE ZONAS
COLINDANTES A MINAS DEL ESTADO DE ZACATECAS*

AUTOR/AS

**CLAUDIA HERMINIA
MALDONADO TAPIA**

UNIVERSIDAD AUTÓNOMA DE
ZACATECAS
MÉXICO

**HÉCTOR EMMANUEL
VALTIERRA MARÍN**

UNIVERSIDAD AUTÓNOMA DE
ZACATECAS
MÉXICO

**MARÍA ALEJANDRA
MORENO GARCÍA**

UNIVERSIDAD AUTÓNOMA DE
ZACATECAS
MÉXICO

SOCORRO ARTEAGA

EL PASO COMMUNITY COLLEGE
MÉXICO

**ELSA GABRIELA
CHÁVEZ GUAJARDO**

UNIVERSIDAD AUTÓNOMA DE
ZACATECAS
MÉXICO

**NITZAYE YETANELY
BRACAMONTES MALDONADO**
RESPIRATORY CARE CENTER
MÉXICO

Evaluation of Heavy Metals (Lead, Cadmium and Arsenic) in Soils of Bordering Zones to Mines of the State of Zacatecas

**Evaluación de Metales Pesados (Plomo, Cadmio y Arsénico) en Suelos de
Zonas Colindantes a Minas del Estado de Zacatecas**

Claudia Herminia Maldonado Tapia

hermimt85@gmail.com

<https://orcid.org/0009-0007-5419-3628>

Universidad Autónoma de Zacatecas
Zacatecas – México

María Alejandra Moreno García

amoreno_29@hotmail.com

<https://orcid.org/0009-0005-9818-5887>

Universidad Autónoma de Zacatecas
Zacatecas – México

Elsa Gabriela Chávez Guajardo

elsagaby@gmail.com

<https://orcid.org/0000-0002-2046-5177>

Universidad Autónoma de Zacatecas
Zacatecas – México

Héctor Emmanuel Valtierra Marín

hectorv@uaz.edu.mx

<https://orcid.org/0000-0002-9635-3577>

Universidad Autónoma de Zacatecas
Zacatecas – México

Socorro Arteaga

marteagl@epcc.edu

El Paso Community College
El Paso TX

Nitzaye Yetanely Bracamontes Maldonado

brani_12@hotmail.com

Zacatecas – México

Artículo recibido: 07/09/2026

Aceptado para publicación: 07/10/2026

Conflictos de Intereses: Ninguno que declarar

ABSTRACT

The objective of the study was to evaluate the presence of heavy metals specifically arsenic (As), cadmium (Cd), and lead (Pb) in soils near mining areas in the state of Zacatecas using ICP atomic absorption spectrophotometry. Heavy metals occur in ecosystems at varying concentrations; centuries of mining, industrial activity, and smelting constitute the primary anthropogenic sources of these metals, potentially disrupting the balance of environmental systems. Upon reaching high concentrations in water, soil, and air, these metals impact human health (Kochubovski, 2011; López et al., 2010) and accumulate in organisms such as plants and animals, thereby altering the human food chain and causing skin disorders or diseases, liver damage, and neurological conditions (Adriano, 2001). Lead (Pb), whether ingested, inhaled, or absorbed through the skin, is toxic to living organisms in general. The concentrations of the analyzed metals (As, Cd, Pb) were determined using the ICP method. It was found that Pb concentrations in the soil exceeded the limits established by current Mexican Official Standards (NOM). The study results were subjected to analysis of variance (ANOVA) using Tukey's mean comparison test at a 95% confidence level, indicating statistical significance. This study reports beyond those allowed by the government of Mexico NOM, As, Cd and Pb, as shown above heavy metal accumulation in soils of mining areas or in areas close to the populations affecting the welfare of the inhabitants, or to be taken a package of mining companies, in order to achieve clean production and improve their remediation goals, thus helping the environment, consequently the safety of humanity

Keywords: heavy metals, Pb, Cd, As, Mining Zones

RESUMEN

El objetivo del estudio fue evaluar la presencia de metales pesados, específicamente arsénico (As), cadmio (Cd) y plomo (Pb), en suelos cercanos a zonas mineras del estado de Zacatecas mediante espectrofotometría de absorción atómica con plasma acoplado inductivamente (ICP). Los metales pesados se encuentran en los ecosistemas en concentraciones variables; siglos de minería, actividad industrial y fundición constituyen las principales fuentes antropogénicas de estos metales, los cuales pueden alterar el equilibrio de los sistemas ambientales. Al alcanzar concentraciones elevadas en el agua, el suelo y el aire, estos metales afectan la salud humana (Kochubovski, 2011; López et al., 2010) y se acumulan en organismos como plantas y animales, alterando así la cadena alimentaria humana y provocando trastornos o enfermedades cutáneas, daños hepáticos y afecciones neurológicas (Adriano, 2001). El plomo (Pb), ya sea ingerido, inhalado o absorbido a través de la piel, es tóxico para los organismos vivos en general. Las concentraciones de los metales analizados (As, Cd, Pb) se determinaron mediante el método ICP. Se encontró que las concentraciones de Pb en el suelo superaban los límites establecidos por las Normas Oficiales Mexicanas (NOM) vigentes. Los resultados del estudio se sometieron a un análisis de varianza (ANOVA) utilizando la prueba de comparación de medias de Tukey con un nivel de confianza del 95%, lo que indicó significancia estadística. Este estudio documenta la acumulación de metales pesados (As, Cd y Pb) en suelos de zonas mineras o áreas cercanas a poblaciones —superando los límites permitidos por las NOM de México—, lo cual afecta el bienestar de los habitantes; asimismo, sugiere la implementación de medidas por parte de las empresas mineras para lograr una producción limpia y mejorar sus objetivos de remediación, beneficiando así al medio ambiente y, por consiguiente, a la seguridad de la humanidad.

Palabras clave: metales pesados, Pb, Cd, As, zonas mineras

INTRODUCTION

The problem of contamination in soils is due to the presence of heavy metals which are natural components of the globe either mineral or salts. These metals do not degrade naturally they do not exercise metabolic functions specific to living things (Rumenova Todorova E. and Kircheva Zhiyansk M. 2023. Prieto Méndez et al., 2009, FDA 2001., Valdez et al., 1999., Doichinova V. et al., 2006. Kachova V.G. Atanassova I.D., 2017).

Heavy metals such as mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl) and lead (Pb), and others become toxic even in low concentrations (Rumenova Todorova E. and Kircheva Zhiyansk M., Harmanesco M. et al., 20011., Castelli et al., 2005).

In ecosystems have been present for many years heavy metals in different concentrations and in the mining, so this may cause a transformation of equilibrium in environmental systems, reach high concentrations in water, soil and air these metals, affecting the health human (Kochubovski M., 20011., Lopez et al., 2010). They may even accumulate in plant and animal organisms, and thus can modify the human food chain as a result giving disorders, skin diseases, liver damage and neurological diseases (Adriano, 2001), Pb is ingested, inhaled or absorbed through the skin, turns out to be toxic to living things in general. (Valdez et al., 1999. Kochubovski M. 2011., Radi Nora., et al., 2023).

A global problem is poisoning from heavy metals which arises from various causes. In Mexico a negative performance effect is due to adjacent mining communities in the state of Zacatecas (Manzanares et al., 2006), and this coupled with the population explosion that is taking place, houses are built in areas near abandoned mines (Gonzalez et al., 2008), which consequently brings heavy metal poisoning among children mainly As, Cd and Pb (Damian F., et al. 2008., Valdez et al., 1999).

Moreover, these generated wastes contribute to the degradation of the surrounding soil environment, which commonly accumulate in the vicinity of the mining operation and transform fertile soils into wastelands (Li, 2006).

This often occurs without the local farmers' knowledge which reinforces the dangerousness of this insidious pollution. The mining operations remain polluting during the exploitation and even after the closure of the mine. These exploitations concerned several metals, and some of

these metals such as copper (Cu) and zinc (Zn) are essential to life, but in high concentrations, they can be toxic (Allan, 1997).

AIM: Evaluation of Heavy Metals (Arsenic, Cadmium, Lead) in Soil in Mining Areas around the state of Zacatecas, using the technique of ICP atomic absorption spectrophotometry

METHODOLOGY

This study was conducted in the state of Zacatecas during the period September to April. The state is located in the central-north, at an average altitude of 2,100 m., With 2,420 meters, in the capital city and 2,690 msn. Cerro del Grillo in the northwest of the capital city. Bordered on the north by the state of Coahuila, on the east by San Luis Potosi, Aguascalientes to the southwest, south to Jalisco, Durango to the west and southwest with Nayarit. It has an area of 74,669 km² equivalent to 3.7% of the total land area, occupying the eighth national extension. The state coordinates are: Latitude North 25 ° 08 'and 21 ° 03' west longitude 100 ° 48 'and 104 ° 21'. The climate is semi-dry with the exception of the northwest where the climate is dry and arid, the average temperature is 16 degrees and rainfall of 510mm per year (Zacatecas Mining Program., 2012).

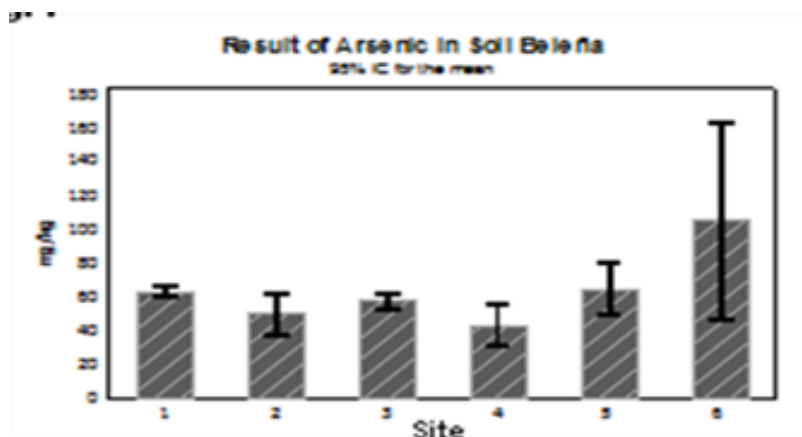
Sampling sites: Beleña, Vetagrande and Calera. Six soil samples were taken from each study site, giving a total of 54 soil samples. In collaboration with the laboratory of Paso Community College, which conducted the evaluation of heavy metals (As, Cd and Pb) using the technique of atomic absorption spectrophotometry, ICP (052 PPS), which consists in making soil sample 15 cm deep in triplicate for each of the samples, the sample dried in an oven at 95 ° C for 24 h, the sample preparation digestion with artificial initiating and continuing the testing of samples.

ANALYSIS

The results of the study was carried out analysis of variance (ANOVA) using Tukey comparison of means. With a reliability index of 95%, indicating that it is statistically significant.

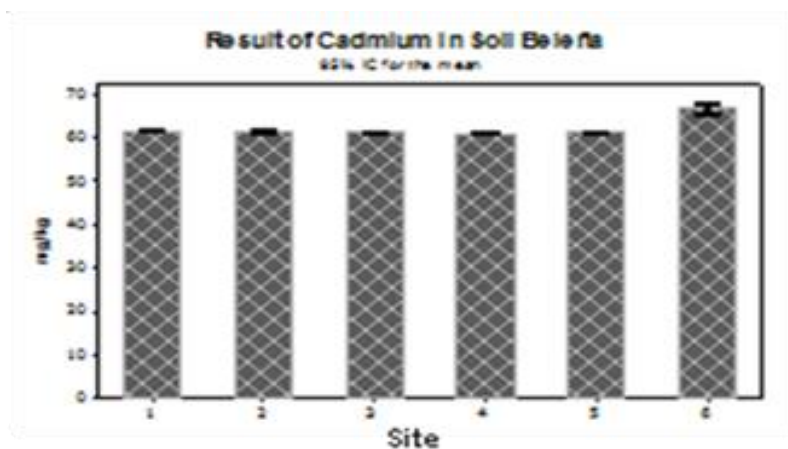
RESULTS

Figure 1. Results on the concentration of heavy metals in soil Beleña during the study period, taking into account indicates that the values reflected in the present site 6 As concentration of 104 mg/kg, for sites 1, 2, 3 4, 5 are found in amount of 43 to 64 mg/kg



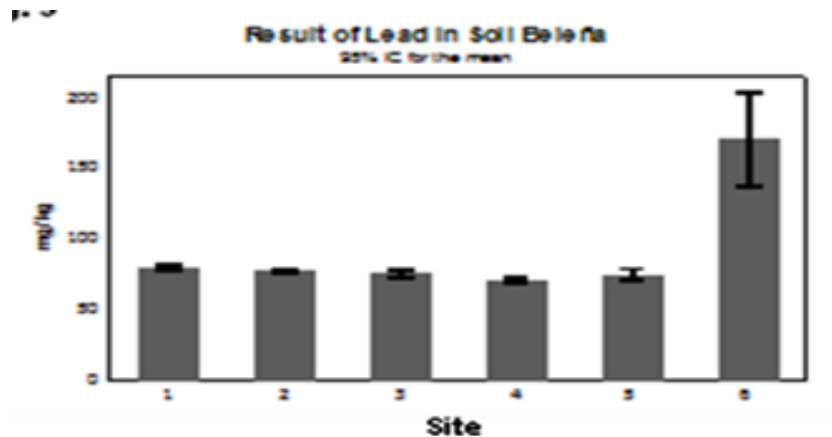
Source: own elaboration.

Figure 2. With respect to Cd the concentration of the 6 study sites, was 60 mg/kg



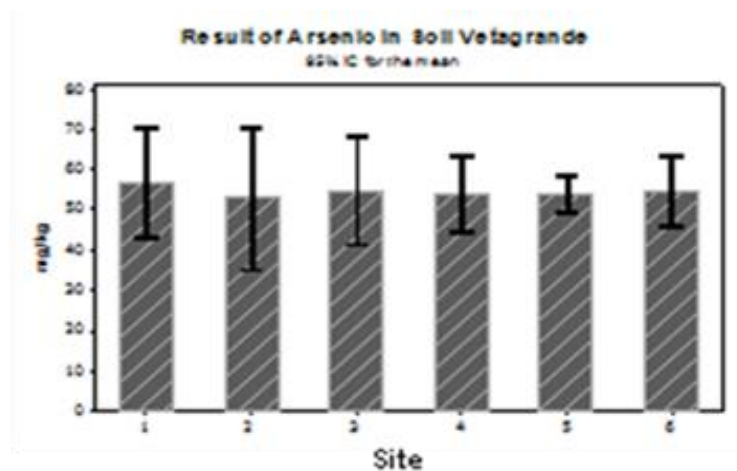
Source: own elaboration.

Figure 3. Pb 160 mg/kg, but not in sites 1, 2, 3, 4, 5 which concentration remained 80mg/kg



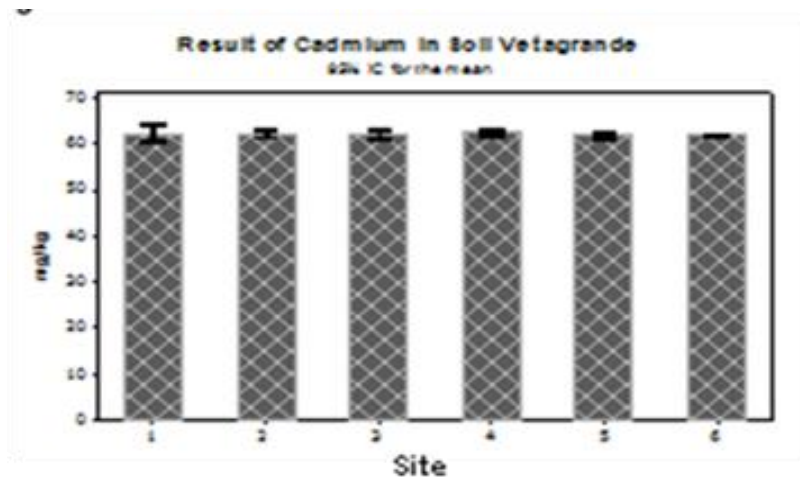
Source: own elaboration.

Figure 4. Shows the results of the heavy metals in soil Vetagrande during the study period. As regards the site 1 obtained concentration of 211 mg/kg for sites 2,3,4 and 5 found in quantities of 70 to 145 mg/kg,



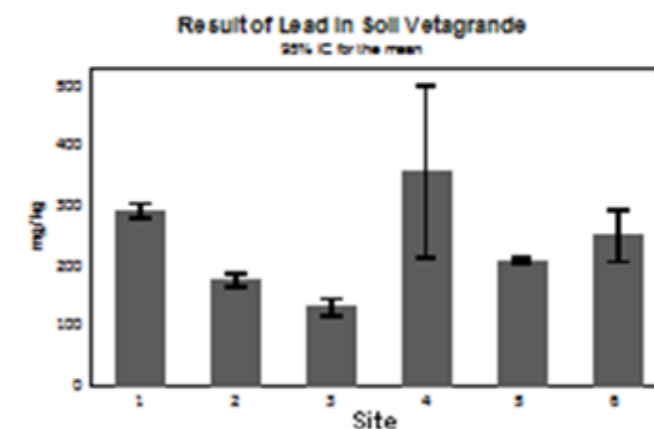
Source: own elaboration.

Figure 5. for the Cd was similar in the 6 study sites having concentrations of 80 to 130 mg/kg



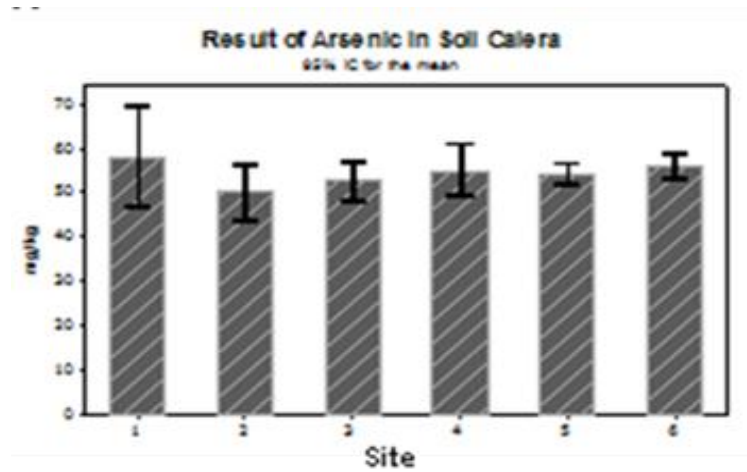
Source: own elaboration.

Figure 6. Indicate that the Pb 1 received site concentration of 2978 mg / kg, the site 6, 2669 mg/kg, and site 2, 1894 mg/kg, with higher concentrations of Pb, followed by site 3: with 907 mg/kg, after 4 to 854 mg/kg



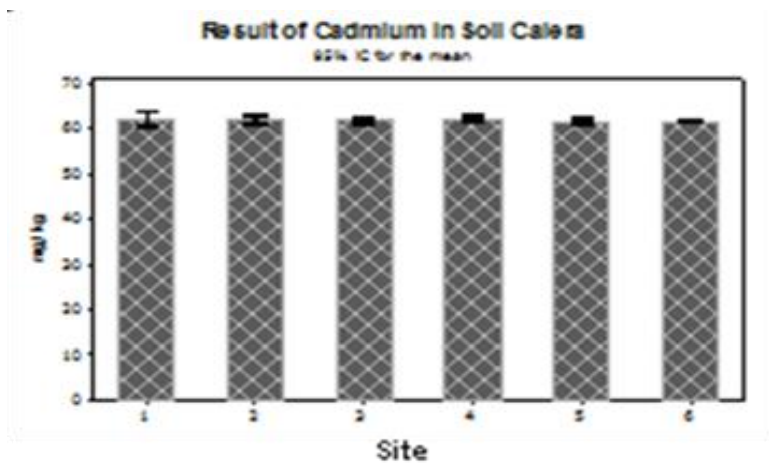
Source: own elaboration.

Figure 7. Show the results of metal content in soil of tobacco industry indicates that as in the 6 site concentratio was 54 mg/kg



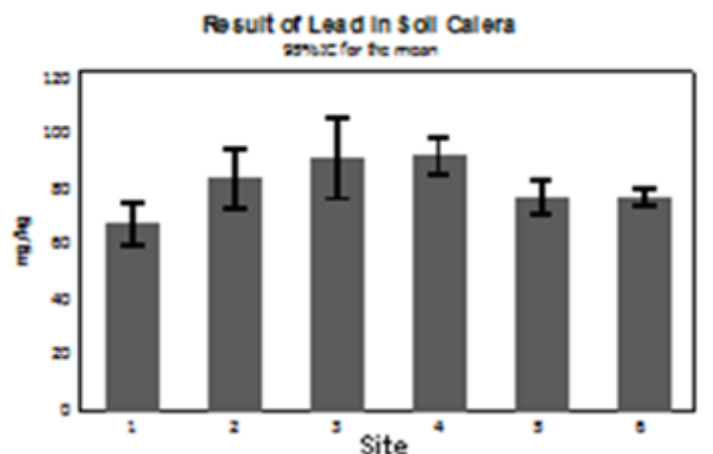
Source: own elaboration.

Figure 8. For the Cd was similar in the 6 study sites having concentrations of 62 mg/kg



Source: own elaboration.

Figure 9. Shows a greater concentration of 90 mg/Pb/kg, in sites 1, 2, 3, 5, 6 concentration was maintained at 70 to 80 mg/kg



Source: own elaboration.

Limits

Analyzing the concentrations of heavy metals in these figures can be said that the heavy metals tested, was located above the permissible values for soils.

DISCUSSION

In the present study we observed that the heavy metal concentration was high, exceeded the limits allowed by the NOM. Concentrations of heavy metals from soils present variations in the statistical analysis, which may be due to the strategies undertaken by the mining industry regarding the cleanliness of the areas.

The mining area near the town of Vetagrande obtained higher concentrations in As, Cd and Pb during the study, with respect to Belenía and Calera, but the concentration of lead was higher in the different sampling sites. Importantly, the accumulation of heavy metals in the study area is due to the accumulation of heavy metals by mining industries have been exploited for over 100 years, causing large-scale negative effects on the environmental conditions of the site, leading to a general environmental deterioration (Martin 2000; [2017]).

When the concentration of heavy metals in soil reach levels that exceed the maximum permissible limits cause effects such as inhibition of normal growth, plant development, a functional disturbance in other components of the environment and the decline in soil microbial populations because the soil acts as a filter for these toxic elements, which can reach the water

table. Among the main soil contaminants, Pb, Cd and As, present in the environment and industrial waste can affect important biological processes, because they are not biodegradable as organic components ([2017]).

The study of the presence and quantification of heavy metals in contaminated soil is important, since some of these contaminants are degraded by naturally (such as nutrients), others (such as heavy metals) are not degraded, therefore, represent a constant threat to the environment (Valdez et al., 1999).

In Mexico state mining companies comply with environmental standards in the country, however the Mexican normatives often lax, and sorely needed standards. No Mexican Official Standard on heavy metal concentrations in soil or on heavy metal emissions into the atmosphere, there is only the Mexican Official Norm (NOM-043-ECOL-1993), which establishes the maximum permissible limits for the issuance of total suspended particles (TSP) to the atmosphere. The PST includes metals such as lead (Valdez et al., 1999).

In general, heavy metals incorporated into the soil can take four different ways: first, be retained in the soil, either dissolved in the aqueous phase of soil or occupying exchange sites; second, specifically adsorbed on inorganic soil constituents; third associated with soil organic matter and fourth solid precipitated as pure or mixed. On the other hand, can be absorbed by plants and incorporated into food chains, may pass into the atmosphere by volatilization and can be mobilized into surface waters or groundwater (Garcia and Dorronsoro, 2005).

To elucidate the behavior of heavy metals in soils and prevent potential toxic risks requires an evaluation of the availability and mobility of these (Benat et al., 2005) the toxicity of metals depends on their concentration, mobility and reactivity with other ecosystem components (Abollino et al., 2002).

Agricultural soils irrigated with wastewater and plants are a significant risk in the accumulation of heavy metals is a problem that affects agriculture and human health. According to these results, the concentration of metals detected in agricultural soils Mixquiahuala, Hidalgo; lead concentration exceeds maximum allowable levels by 40% of water samples analyzed (Flores HM, 2011).

Note: Some parts of the references/citations are very unclear in the image (especially where something like “2017” appears), so I have kept them as faithful as possible to what is legible.

CONCLUSIONS

This study reports on the accumulation and concentration of heavy metals (As, Cd, and Pb). The results reveal significant variations among samples—depending on their specific locations in mining zones or areas near human settlements—with levels exceeding the limits established by official Mexican standards (NOM). There is no specific Official Mexican Standard regarding heavy metal concentrations in soil or their atmospheric emissions; the only relevant standard is NOM-043-ECOL-1993, which sets maximum permissible limits for the emission of total suspended particles (TSP) into the atmosphere. TSP includes metals such as lead and arsenic (Valdez et al., 1999). Analysis of soil in Vetagrande showed a lead (Pb) concentration of 2,978 mg/kg.

Lower concentrations of Pb and As had been anticipated, given their impact on the environment as well as on animal and human health—factors that affect the concept of "One Health." The high levels of lead and arsenic found in the soil correlate with past and present mining activities, demonstrating the significant impact of mining on the well-being of local inhabitants. Soil contamination by metals such as Pb and As is an environmental issue that persists in the vicinity of mining zones long after operations have ceased. This highlights the need for mining companies to adopt comprehensive measures to achieve cleaner production and improve remediation goals, thereby contributing to environmental protection and, consequently, human safety. Analyzing the concentrations of heavy metals in these figures can be said that the heavy metals tested, was located above the permissible values for soils.

REFERENCES

- Abolino Ornella., Aceto Maurizio., Malandrino Mery., 2002. *Havy metals in agricultural soils from Piedmont, Italy. Distribution, speciation nd chemometric data treatment. PubMed. DOI:10.1016/S0045-6535(2)00352-1*
- Banat, K. M., Howari, F. and Al-Hamad, A. A. 2005. *Heavy Metals in Urban Soils of Central Jordan: Should we worry about Their Environmental Risks. Environmental Research, V. 97: pp. 258-273.*

- Castelli M., Rossi B., Corsetti A., Mantovani G., Spera C., Lubrano L., Silvestroni M., Patriarca F., Chiodo A., Menditti. 2005. *Levels of cadmium and lead in blood: an application of validated methods in a groups of patients with endocrine/metabolic disorders from the Rome area* " *Microchemical Journals*. Vol. 79. pp. 349-355.
- Damian F, Damian G, Lacatusu R, Lepure G 2008. *Heavy metals concentration of the soils around Zlatna and Cops a Mic a smelters Romania*. *Carpath Journal of Earth and Environmental Science*, 3:65-82.
- Doichinova Vania, Sokolovska Maria, Velizarova Emilia. 2006. *Heavy metals contamination of soils under oak ecosystems in the Sofia region*. *Environmental Chemistry Letters*. 4(2): 101–105.
- FDA (Food and Drug Administration). 2001. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. Report of the Panel on Micronutrients. National Academy Press, Washington, DC, Food and Drug Administration. Dietary supplements. Center for Food Safety and Applied Nutrition
- Flores Héctor Magdaleno, Mancillas Oscar Raúl Villa, Mejia Enrique, Saenz Ma. Del Carmen, Bolaños Olmedo and Bautista Olivas Ana Laura. 2011. *Heavy metals In agricultural soils and Irrigation Wastewater of Mixquiahuala, Hidalgo, Mexico*. *African Journal of Agricultural Research* Vol. 6(24), pp. 5505-5511. Available online at <http://www.academicjournals.org/AJAR> DOI: [10.5897/AJAR11.414](https://doi.org/10.5897/AJAR11.414) ISSN 1991-637X
- García, I. and Dorronsoro, C. 2005. *Contaminación por Metales Pesados*. En *Tecnología de Suelos*. Universidad de Granada. Departamento de Edafología y Química Agrícola <http://edafologia.ugr.es>.
- González Valdez E., González Reyes E., Bedolla Cedeño C., Arrollo Ordaz E L., Manzanares Acuña E., 2008. *Niveles de Plomo en sangre y factores de riesgo por envenenamiento de plomo en niños Mexicanos*. *Rev. Fac. Ing. Univ. Antioquia*. No. 43. pp. 114.119.
- Harmanescu Monica, Alda Liana Maria, Bordean Despina Maria, Gogoasa Ioan and Gergen Iosif. 2011. *Heavy metals health risk assessment for population via consumption of vegetables grown in old mining area; a case study: Banat County*,

Romania. Chemistry Central Journal 2011, 5:64

<http://journal.chemistrycentral.com/content/5/1/64>

Kachova. V.G., I. D. Atanassova I.D. 2017. Heavy metal pools in urban soils from city parks of Sofia, Bulgaria. AGRICULTURAL SCIENCE AND TECHNOLOGY, VOL. 9, No 2, pp , 2017 DOI: [10.15547/ast.2017.02.026](https://doi.org/10.15547/ast.2017.02.026)

Kochubovski Mihail. 2011. Heavy Metals as Persistent problem for Balkan countries. Institute of Public Health of the FY Republic of Macedonia., 50 Divizija No. 6, 1000 Skopje, FY Republic of Macedonia. Pp. 217- 243.

López-Ceballos, C. R.; García, N.; Valdez, R. 2010. Evaluación de la presencia de metales en residuales líquidos y su efecto potencial para una comunidad. Avances en Investigación Agropecuaria, Red de Revistas Científicas de América Latina, el Caribe, España y Portugal V. 14, núm. 3. pp. 33-46. <http://redalyc.uaemex.mx/src/inicio/ArtPdfRed.jsp?iCve=83715746003>

Martin, Charles W. 2000. Heavy Metals Trends in Floodplain Sediments and Valley Fill River Lahn, Germany. Catena ELSEVIER. V. 39, pp. 53-68.

Niveles y límites máximos permisibles en Normas Oficiales de Mexicanas. 2002. Secretaria de medio ambiente y Desarrollo de Jalisco Sustentable.

Prieto Méndez Judith, González César A, Ramírez Alma D. Román Gutiérrez and Prieto García Francisco. 2009. Contaminación y Citotoxicidad en Plantas por Metales Pesados Provenientes de Suelo y Agua. Revistas Científicas de América Latina, el Caribe, España y Portugal. Vol. 10, Núm. 1, sin mes, pp. 29 - 44

Programa Minero de Zacatecas., 2012. Generación del Conocimiento geológico – económico para Vivir Mejor. Gobierno Federal. pp 1-61. www.sgm.gob.mx.

Radi Nora., Boutaleb Abdelhak., Hirche Azziz., 2023. Assessment of soil contamination by heavy metals and arsenic in Tamesguida abandoned copper mine area, Médéa, Algeria. Environ Monit Assess 195:247 <https://doi.org/10.1007/s10661-022-10862-7>

Rumenova Todorova Elena., Miglena Kircheva Zhiyansk., 2023. Study on soil quality in different functional zones of Sofia región. One Ecosystem 8: e101381. <https://doi.org/10.3897/oneeco>.

Valdéz Perezgasga F., Cabrera Morelos VM., 1999. En defensa del Ambiente La contaminación por metales pesados en Torreón Coahuila, México. Texas Center for Policy Estudios.

© Los autores. Este artículo se publica en Prisma ODS bajo la Licencia Creative Commons Atribución 4.0 Internacional (CC BY 4.0). Esto permite el uso, distribución y reproducción en cualquier medio, incluidos fines comerciales, siempre que se otorgue la atribución adecuada a los autores y a la fuente original.



doi : <https://doi.org/10.65011/prismaods.v5.i5.360>

Cómo citar este artículo (APA 7ª edición):

Maldonado Tapia, C. H., Moreno García, . M. A., Chávez Guajardo, E. G., Valtierra Marín, H. E., Arteaga, S., & Bracamontes Maldonado, N. Y. (2026). Evaluation of Heavy Metals (Lead, Cadmium and Arsenic) in Soils of Bordering Zones to Mines of the State of Zacatecas *Prisma ODS: Revista Multidisciplinaria Sobre Desarrollo Sostenible*, 5(5), 265-279. <https://doi.org/10.65011/prismaods.v5.i5.360>