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ORIGINAL

Assessment of soil contamination by leachates from the municipal landfill in the district of San Pablo

Evaluación de la contaminación del suelo por lixiviados del botadero municipal del distrito de San Pablo

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ABSTRACT

The present investigation, it had as general aim evaluate the pollution of the soil affected for lixiviados of the municipal botadero of San Paul's District, by means of a descriptive investigation of type, in which they were analyzed to the metals weighed as Cadmium (CD), Lead (Pb), Chrome the VIth (Cr+6) and Total Chrome (Cr Total) in soil, in addition they are established in the D. S N ° 002-2013 MINAM, standards of Environmental Quality (ECA) for soil. The samples were obtained of the soil and later sent to the laboratory of soils of San's Martin National University. The investigation concludes that it was reached to evaluate the pollution of the soil affected for lixiviados of the municipal botadero of San Paul's District, realizing two samplings in different dates, they were sampled to the Cadmium (CD), Lead (Pb), Chrome the VIth (Cr+6) and Total Chrome (Cr Total), the sampling was realized in three different points of the municipal botadero (P1: Agricultural Soil, P2: central Soil of the botadero, P3: Soil of control or initial soil of the botadero), Likewise it was achieved to find the presence of the Cadmium, Lead and Total Chrome in three points of sampling with the exception of the Chrome the VIth. The comparison of the levels of concentration of the heavy metals evaluated with the Standards of Environmental Quality for soil - ECA allowed to establish that the levels of Cadmium (CD) in three sampled points overcome the values established by the ECA for an agricultural soil, with regard to the Lead (Pb) in three sampled points they do not overcome the values established by the ECA for an agricultural soil.

Keywords: Pollution of the Soil; Lixiviados; Botadero Municipal.

RESUMEN

La presente investigación, tuvo como objetivo general evaluar la contaminación del suelo afectado por lixiviados del botadero municipal del Distrito de San Pablo, mediante una investigación de tipo descriptiva, en el que se analizaron a los metales pesados como Cadmio (Cd), Plomo (Pb), Cromo VI (Cr+6) y Cromo Total (Cr Total) en suelo, además se encuentran establecidos en el D. S N° 002-2013 MINAM, estándares de Calidad Ambiental (ECA) para suelo. Las muestras fueron obtenidas del suelo y posteriormente enviadas al laboratorio de suelos de la Universidad Nacional de San Martin. La investigación concluye que se alcanzó evaluar la contaminación del suelo afectado por lixiviados del botadero municipal del Distrito de San Pablo, realizando dos muestreos en diferentes fechas, se muestrearon al Cadmio (Cd), Plomo (Pb), Cromo VI (Cr+6) y Cromo Total (Cr Total), el muestreo se realizó en tres diferentes puntos del botadero municipal (P1: Suelo Agrícola, P2: Suelo central del botadero, P3: Suelo de control o suelo inicial del botadero), así mismo se logró encontrar la presencia del Cadmio, Plomo y Cromo Total en los tres puntos de muestreo a excepción del Cromo VI. La comparación de los niveles de concentración de los metales pesados evaluados con los Estándares de Calidad Ambiental para suelo – ECA permitió establecer que los niveles de Cadmio (Cd) en los tres puntos muestreados superan los valores establecidos por el ECA para un suelo agrícola, con respecto al Plomo (Pb) en los tres puntos muestreados no superan los valores establecidos por el ECA para un suelo agrícola.

Palabras clave: Contaminación del Suelo; Lixiviados; Botadero Municipal.

INTRODUCTION

The problem of soil contamination is one of the most significant environmental challenges today, especially in contexts where solid waste is disposed of without adequate technical control or treatment measures. In many municipalities, open dumps are the main form of waste management, generating significant negative impacts on the environment and public health.(1) Among these impacts, the infiltration of leachates loaded with organic and inorganic pollutants, particularly heavy metals, is one of the highest risk factors, given their potential for bioaccumulation and toxicity in ecosystems and the food chain.(2)

The district of San Pablo, located in the province of Bellavista, San Martín region, faces this situation due to the presence of a municipal landfill that receives solid waste generated by the local population on a daily basis.(3) The absence of a comprehensive waste management system and specialized infrastructure for the safe confinement of waste has led to the formation of leachates that percolate into the soil, potentially generating physical-chemical degradation processes and contamination by heavy metals such as cadmium (Cd), lead (Pb), and chromium (Cr), elements known for their adverse effects on human health and the environment.(4)

Given this reality, there is a need to assess the state of soil contamination in the area surrounding the landfill, not only as a technical and scientific exercise, but also as a tool to inform mitigation and prevention policies.(5) This study is part of a descriptive research approach, with a non-experimental design, in which soil samples were collected at different strategic points for subsequent laboratory analysis.(6) This procedure made it possible to determine the concentrations of heavy metals and compare them with the Environmental Quality Standards (ECA) for soils established in Peruvian regulations, in order to identify possible exceedances and establish the level of environmental risk.(7)

The research also seeks to contribute to technical knowledge on the relationship between solid waste management and soil quality in rural and peri-urban areas, where resources for environmental management are often limited.(8) The results obtained are intended to serve as a basis for the development of a mitigation plan that includes corrective and preventive actions, integrating the active participation of the municipality, the competent authorities, and the local community.(9)

In this sense, the study is not limited to a diagnosis, but proposes a contribution to decision-making and the formulation of strategies aimed at minimizing soil contamination, protecting natural resources, and promoting environmental sustainability in the district of San Pablo.(10) The commitment to preserving the environment and the health of the population requires research such as this, which combines scientific rigor with social relevance, within the framework of compliance with current environmental legislation and the search for viable and sustainable solutions.(11)

General Problem

Is there soil contamination from leachates from the municipal landfill in the District of San Pablo – 2018?

Specific Problems

What will be the concentration levels of heavy metals (lead, cadmium, and chromium) in soils affected by leachate from the municipal landfill in the District of San Pablo – 2018?

Will the concentration levels of the heavy metals evaluated be within the values permitted in the Environmental Quality Standards for Soil (ECA)?

Will it be feasible to implement a Solid Waste Mitigation Plan for the municipal landfill in the District of San Pablo – 2018?

General Hypothesis

Leachates generate contamination in the soil of the municipal landfill in the District of San Pablo – 2018.

General Objective

To evaluate the contamination of soil affected by leachates from the municipal landfill in the District of San Pablo – 2018.

METHOD
Type and Design of Research
Type of research

The type of research, according to the nature of the information, is considered descriptive research.

Research design

The type of research design was non-experimental, “the characteristics of these studies is that they are carried out without the deliberate manipulation of variables and in which only the phenomena in their natural environment are observed for analysis.”

O: Observation.

M: Measurement.

O → M

Variable, Operationalization of variables
Variables

Dependent variable: soil contamination.

Independent variable: leachates from the San Pablo Municipal Landfill.

VARIABLE	DEFINICIÓN CONCEPTUAL	DEFINICIÓN OPERACIONAL	DIMENSIÓN	INDICADOR	ESCALA DE MEDICIÓN
Independiente: Lixiviados del Botadero Municipal	“Aquel suelo que han entrado en contacto con los desechos de un botadero, y se producen por la disolución de uno o más compuestos de los residuos sólidos urbanos en contacto con el suelo, o por la propia dinámica de descomposición de los residuos.”	Su característica principal es de contener compuestos de alta peligrosidad que perjudican y/o contaminan el ambiente y especialmente los cuerpos de agua y suelos.	Efectos nocivos en la salud de las personas. Contaminación del suelo.	• Persistentes • Bioacumulables. • Afecta la calidad del agua, aire y suelo.	Intervalo
Dependiente: Contaminación del Suelo.	“El aumento en los niveles de contaminación del suelo hace que exista la necesidad de monitorear el suelo para detectar su grado y/o nivel de contaminación, esto conduce a obtener una inmensa cantidad de datos de varios parámetros.”	El Estándar de Calidad del Suelo (ECA), indica los niveles que no debe de exceder o superar el suelo con presencia de alguna sustancia o compuesto para que no esté siendo considerado como contaminado.	Permite conocer y/o establecer el grado o nivel de contaminación del suelo, mediante el ECA para agua.	▪ Número de compuestos encontrados en el suelo. ▪ Cantidad en PPM. ▪ Tipo de compuestos.	Intervalo

Figure 1. Operationalization of variables

Population and sample
Population

Soil from the municipal landfill in the town of San Pablo.

Sample

Three points of soil belonging to the municipal landfill in San Pablo.

1 kg of soil (for each parameter collected in bags)

Unit of analysis: 250 g of soil

Selection criteria

Point 1: Area with anthropic activity and/or affected. (Lower part of the landfill)

Point 2: Area with anthropic activity and/or affected. (Central part of the landfill).

Point 3: Area adjacent to an agricultural crop. (Control point)

Sampling

Non-probabilistic.

Data collection techniques and instruments, validity, and reliability
Techniques

- Sampling.

- Checklist.
- Guide.

Tools

- Data collection form.
- Environmental Quality Standard for soil (ECA).

Data analysis methods

The data will be presented objectively using experimental statistics, which will be through the analysis of the parameters under study.

This design will be carried out in three stages.

Stage 1: initial cabinet

The following activities will be carried out in this stage:

- Compilation of bibliographic information.
- Consultation with professionals involved in research topics.
- Preparation of equipment and materials necessary for sampling.
- Compilation of information and bibliographic material on the study area.

Stage 2: laboratory and field

- Location of the project and sampling points.
- Georeferencing of sampling points in UTM WGS 84 18S coordinates.
- Soil sampling from the municipal landfill according to the (Guide for Soil Sampling. 2014, p9) applying "identification sampling, which aims to investigate the existence of soil contamination by obtaining representative samples in order to establish whether or not the soil exceeds the Environmental Quality Standards and/or background values in accordance with the provisions of D.S. No. 002-2013-MINAM."
- Analysis of soil samples, which will be carried out in the soil laboratory of the National University of San Martin, prepared by Engineer Carlos Verde Girbau, located in the city of Tarapoto.

Stage 3: final report

- Systematization of the information collected in the field in the previous stages.
- Analysis and interpretation of results.
- Printing of the final research report.
- Presentation of the final report.
- Defense of the final project.

Ethical considerations

In order to carry out this study, approval had to be obtained from the District Municipality of San Pablo in order to obtain the necessary permits to visit the municipal landfill and also to inform them that this research will be presented to their institution, with the aim of producing a document that can be applied and proposing alternatives and/or strategies to minimize soil contamination in this part of the district.

This authorization was accepted, and an agreement was reached that this research will be provided to the District Municipality of San Pablo and that the sources used in this research will be cited according to their authors.

RESULTS

Location

The municipal landfill of the district of San Pablo is located 2 kilometers from the town center of Consuelo, 5 kilometers from the district of San Pablo.

Puntos de muestreo	Datum WGS 84	
Punto	Este	Norte
P1 Final/pendiente	0323745	9245233
P2 Parte Central	0323740	9245198
P3 Punto Control	0323716	9245093

Figure 2. Location of sampling points

Policy

Region: San Martin.
Province: Bellavista.
District: San Pablo.

Political boundaries

- To the north: Town of Fausa Lamista.
- To the south: Town of Dos Unidos.
- To the east: Town of San Pablo.
- To the west: Town of Huingoyacu.

Geography

The district of San Pablo is geographically located between the following coordinates:

- North: 0323700 to 0323154
- East: 9245095 to 9245822
- Datum: WGS-84
- Zone: 18
- Area: 362,49 km^2

The affected area is located within the town of Consuelo. The location of the districts is determined according to the National Institute of Statistics and Informatics 2007.

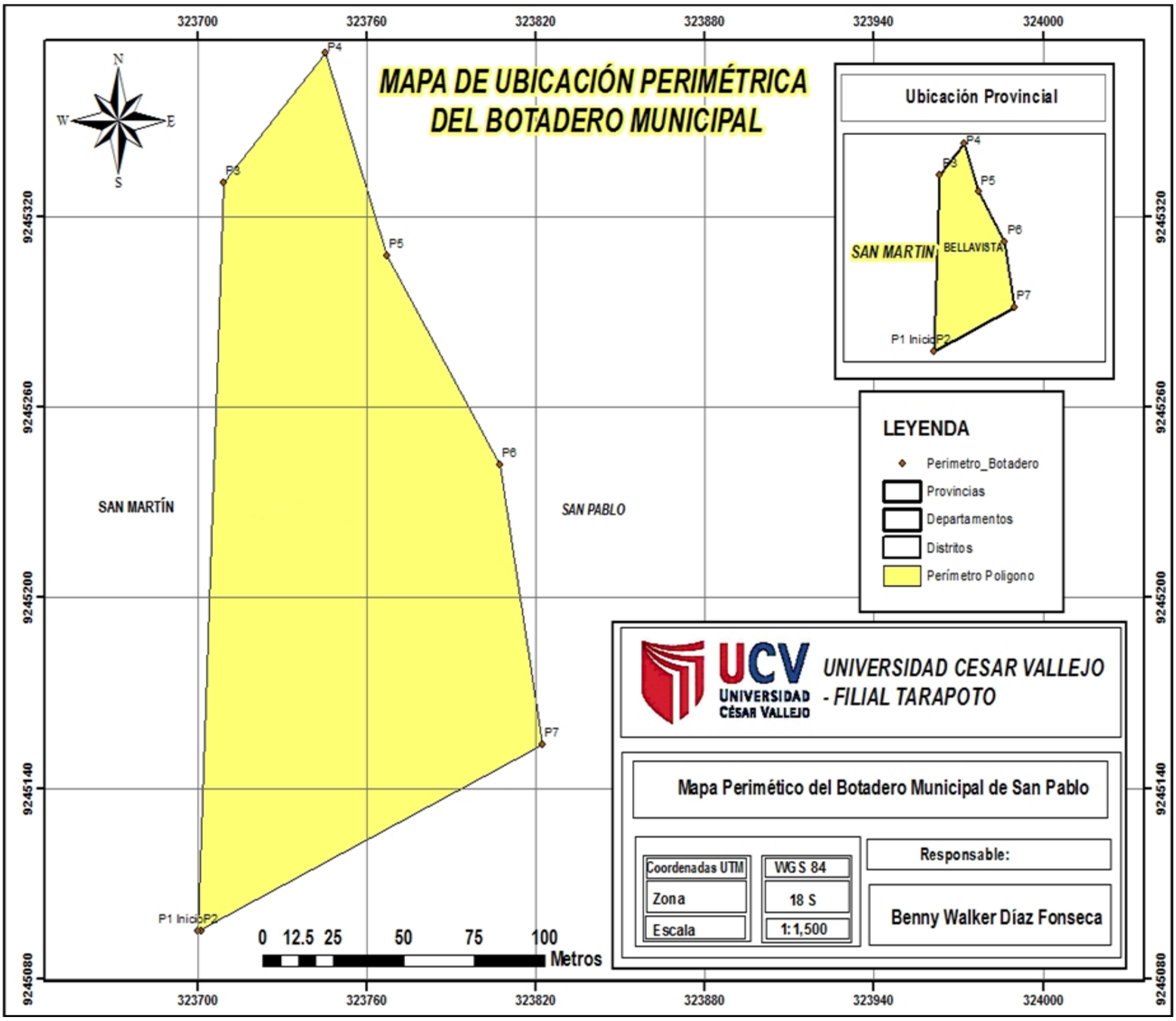

Figure 3. Perimeter Location Map of the Municipal Landfill

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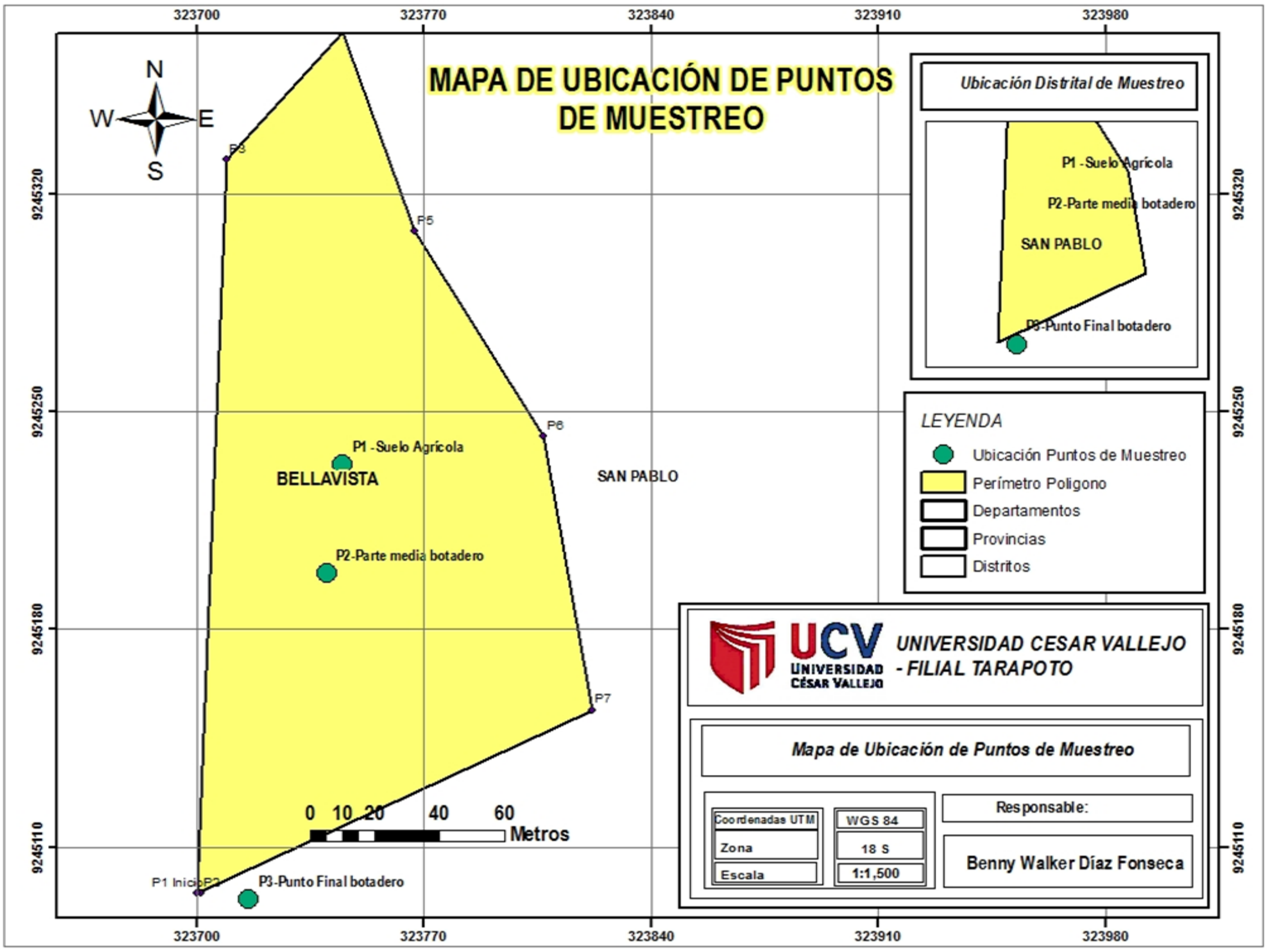

Figure 4. Map of sampling point locations

Results of the first heavy metal test

RESULTADOS PRIMER MUESTREO				
Muestra	Parámetros de Campo (mg/kg)			
	Cd	Pb	Cr VI	Cromo Total
P1	18,752	16,255	nd	0,0363
P2	15,126	12,037	nd	0,0231
P3	6,321	11,123	nd	0,0123

Figure 5. General results of first sampling

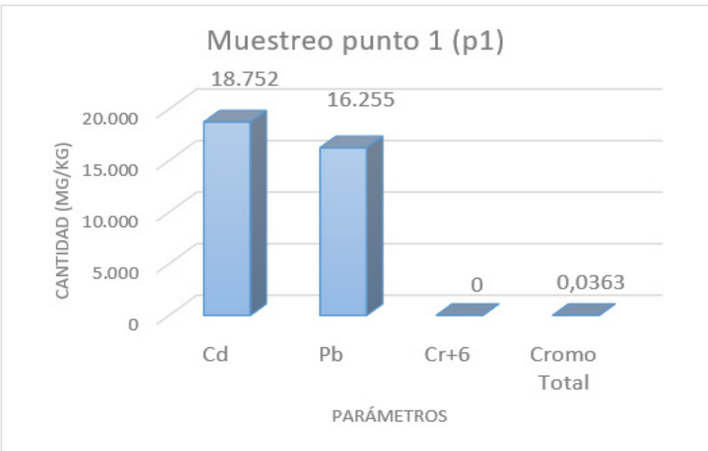

Figure 6. Heavy metal test results, point 1

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Interpretation: figure 6 shows that the highest levels in mg/kg (ppm) are cadmium (Cd), with 18,752, followed by lead (Pb) with 16,255 mg/kg. Chromium VI (Cr+6) could not be detected in the soil; however, traces of total chromium were found, with levels of 0,0363 mg/kg. The analyses correspond to Point 1.

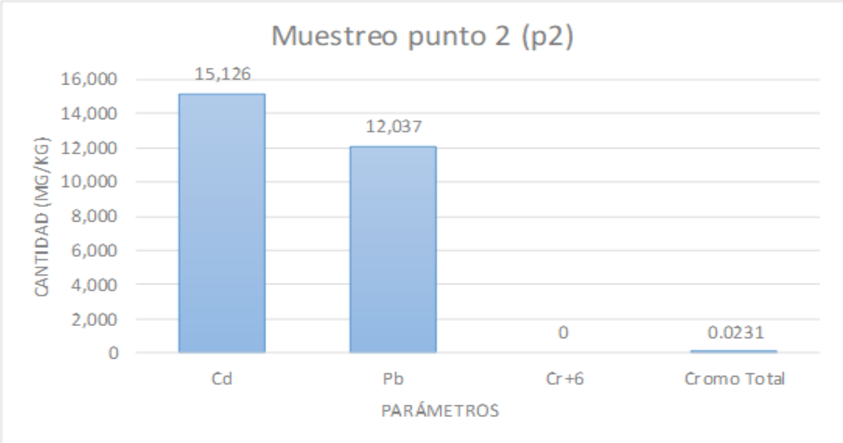

Figure 7. Heavy metal test results, point 2

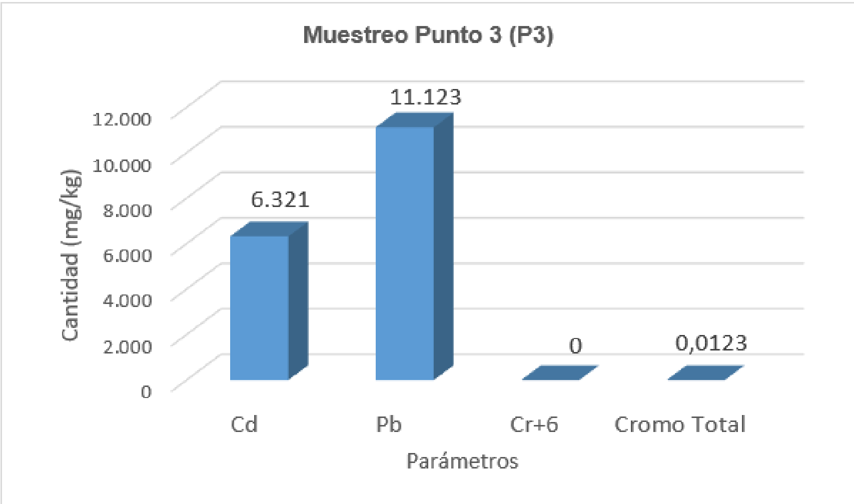

Figure 8. Heavy metal test results, point 3

Interpretation: according to the results shown in figure 7, the heavy metal with the highest presence in the sampled soil is cadmium (Cd), with a value of 15,126 mg/kg (ppm), followed by lead (Pb) with 12,037 mg/kg. Finally, the presence of chromium VI could not be determined in the sampled soil; however, traces of total chromium were found at a level of 0,0231 mg/kg. The analyses correspond to Point 2 (central soil of the landfill).

Interpretation: According to the results presented in figure 8, a higher presence of lead (Pb) was found in the sampled soil with a value of 11,123 mg/kg (ppm); the heavy metal cadmium (Cd) was found in lower quantities with a value of 6,321 mg/kg. Finally, it was not possible to determine the presence of chromium VI in the sampled soil; however, traces of total chromium were found at a level of 0,0123 mg/kg. The analyses correspond to Point 3 (control point of the landfill).

Results of the first heavy metal test compared with the ECA in agricultural soil.

Cuadro comparativo del Cd y Pb con el ECA de los 3 diferentes puntos de muestreo				
Metales Pesados	**ECA - Suelo Agrícola**	**P1**	**P2**	**P3**
Cadmio (Cd)	1.4	18.752	15.126	6.321
Plomo (Pb)	70	16.255	12.037	11.123

Figure 9. General results for lead and cadmium from the first sampling

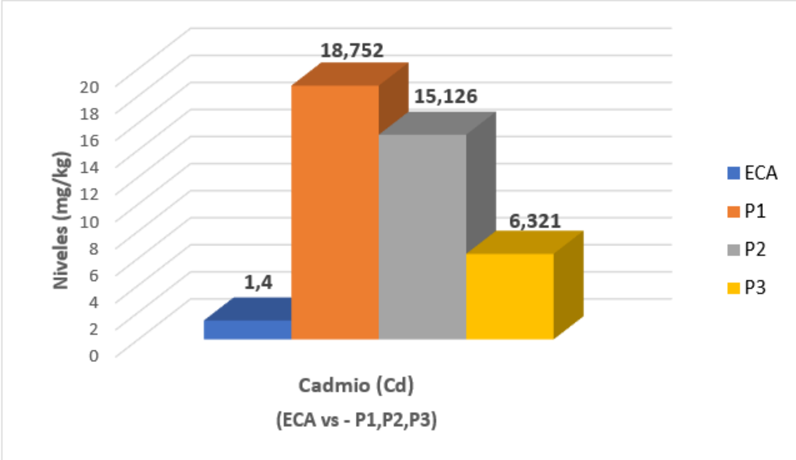

Figure 10. Results of cadmium (Cd) concentrations with the ECA

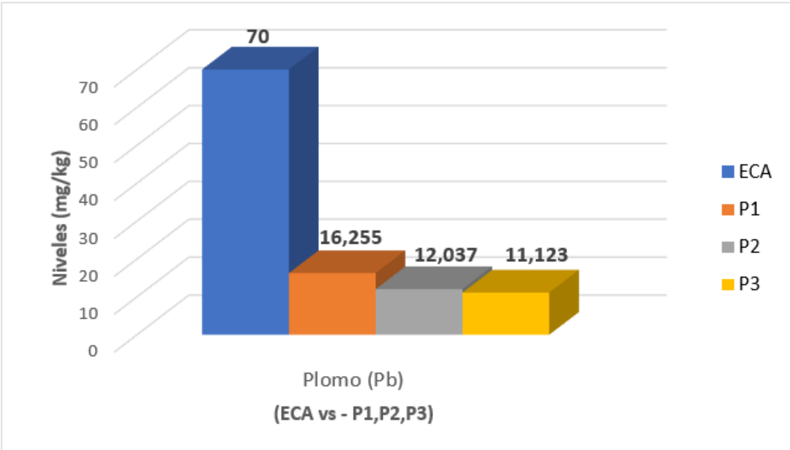

Figure 11. Results of lead (Pb) concentrations with the ECA

Interpretation: according to figure 10, the levels of cadmium (Cd) at the three sampling points exceed the values established by the ECA for agricultural soil, with point 1 having the highest concentration of this metal, with a value of 18,752 mg/kg, followed by point 2 with a value of 15,126 mg/kg; Finally, point 3 has the lowest concentration of this metal, with a value of 6,321 mg/kg.

Interpretation: according to figure 11 the levels of lead (Pb) at the three sampling points do not exceed the values established by the ECA for agricultural soil, with point 1 having the highest concentration of this metal, with a value of 16,255 mg/kg, followed by point 2 with a value of 12,037 mg/kg; Finally, point 3 has the lowest concentration of this metal, with a value of 11,123 mg/kg.

Comparison of the results of the first sampling with the ECA Soil

Table 1. Comparison of results obtained with the ECA for soil, first sampling

	ECA			Analysis result		
	Agricultural soil	Park Soil	Industrial extractive soil	P1	P2	P3
Cadmium (Cd)	1	10	22	18,752	15,126	6,321
Lead (Pb)	70	140	800	16,255	12,037	11,123
Chromium VI (Cr)	0,4	0,4	1,4	nd	nd	nd
Total chromium (Cr)	-	40	100	0,036	0,0231	0,0123

Interpretation: the table 1 below shows the results obtained in comparison with the ECA for soil, according to soil type, for each sampling point and compound (cadmium, lead, chromium VI, total chromium). It should be noted that Chromium VI was not detected at any sampling point, and Total Chromium is not established in the ECA for agricultural soil.

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Results of the second heavy metal sampling

RESULTADOS SEGUNDO MUESTREO				
Muestra	Parámetros de Campo (mg/kg)			
	Cd	Pb	Cr VI	Cromo Total
P1	19,36	17,36	nd	0,045
P2	16,21	14,25	nd	0,036
P3	7,45	11,69	nd	0,024

Figure 12. General results of the second sampling

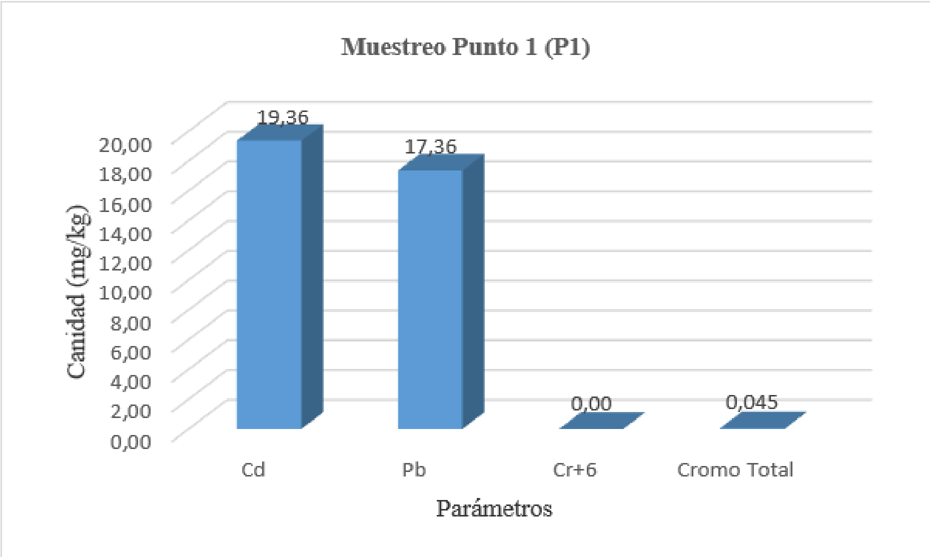

Figure 13. Heavy metal test results, point 1

Interpretation: figure shows that the highest levels in mg/kg (ppm) are cadmium (Cd), with 19,36, followed by lead (Pb) with 17,36 mg/kg. Likewise, Chromium VI (Cr+6) could not be detected in the soil; however, traces of Total Chromium were found, with levels of 0,045 mg/kg. The analyses correspond to Point 1 (agricultural soil).

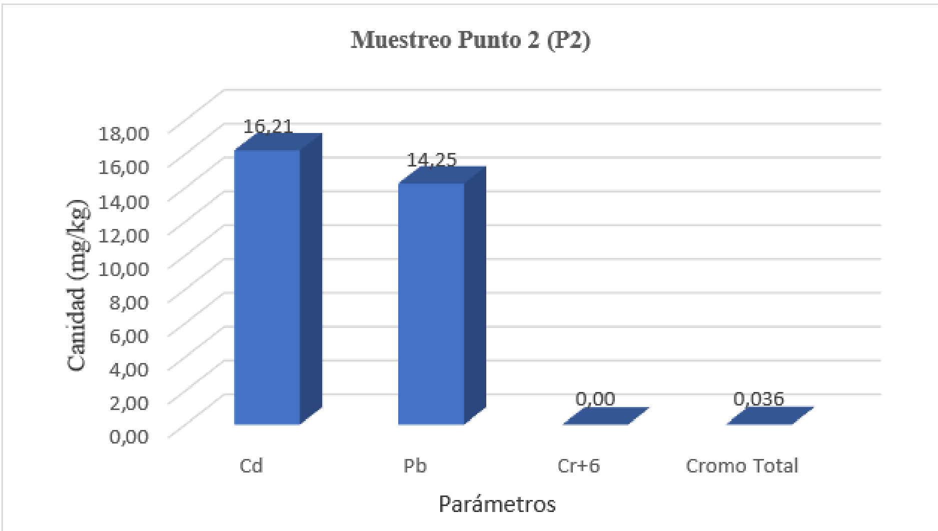

Figure 14. Heavy metal test results, point 2

Interpretation: according to the results shown in figure 14, the heavy metal with the highest presence in the sampled soil is cadmium (Cd), with a value of 16,21 mg/kg (ppm), followed by lead (Pb) with 14,25 mg/kg. Finally, it was not possible to determine the presence of chromium VI in the sampled soil; however, traces of total chromium were found at a level of 0,036 mg/kg. The analyses correspond to Point 2 (central soil of the landfill).

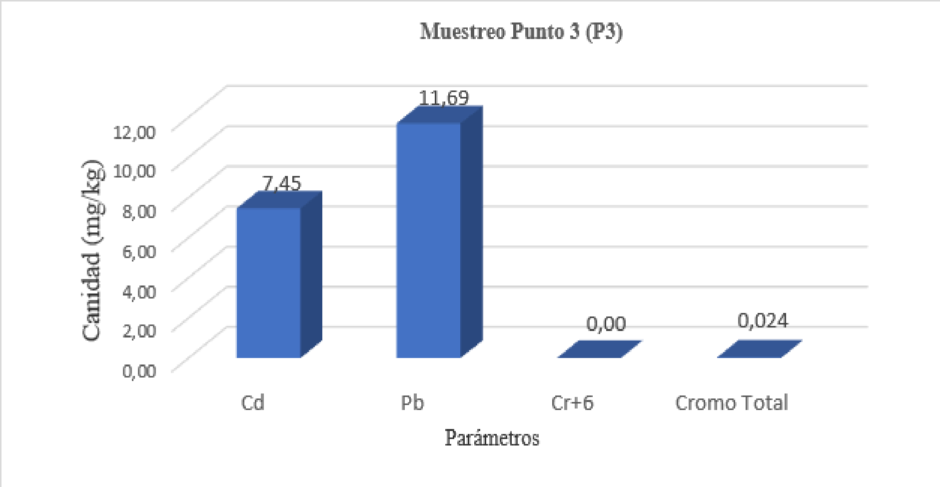

Figure 15. Heavy metal test results, point 3

Interpretation: according to the results presented in figure 15, a higher presence of lead (Pb) was found in the sampled soil with a value of 11,69 mg/kg (ppm); the heavy metal cadmium (Cd) was found in lower quantities with a value of 7,45 mg/kg. Finally, no chromium VI was detected in the soil samples, although traces of total chromium were found at a level of 0,024 mg/kg. The analyses correspond to Point 3 (control point of the landfill).

Results of the second heavy metal test compared with the ECA in agricultural soil

Cuadro comparativo del Cd y Pb con el ECA de los 3 diferentes puntos de muestreo				
Metales Pesados	**ECA - Suelo Agrícola**	**P1**	**P2**	**P3**
Cadmio (Cd)	1.4	19.36	16.21	7.45
Plomo (Pb)	70	17.36	14.25	11.69

Figure 16. General results for lead and cadmium from the second sampling

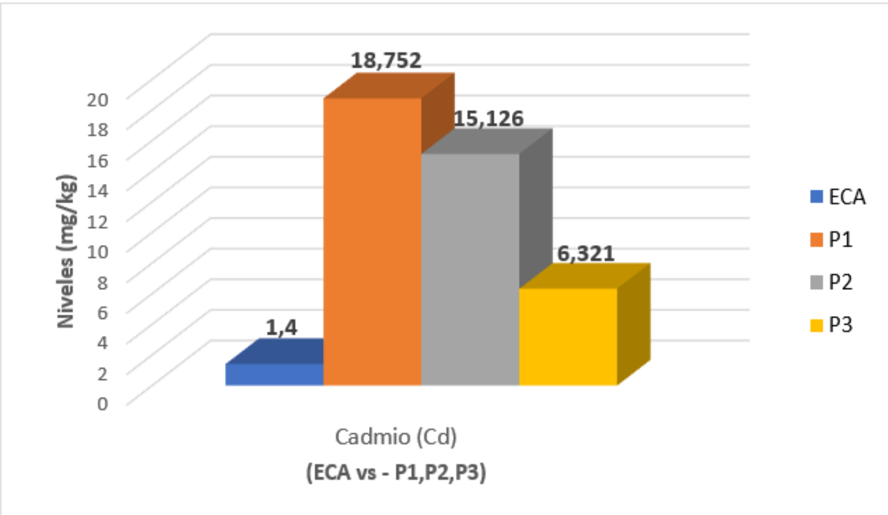

Figure 17. Results of cadmium (Cd) concentrations with the ECA

Interpretation: according to figure 17, cadmium (Cd) levels at the three sampling points exceed the values established by the ECA for agricultural soil, with point 1 having the highest concentration of this metal, with a value of 19,36 mg/kg, followed by point 2 with a value of 16,21 mg/kg. Finally, point 3 has the lowest concentration of this metal, with a value of 7,45 mg/kg.

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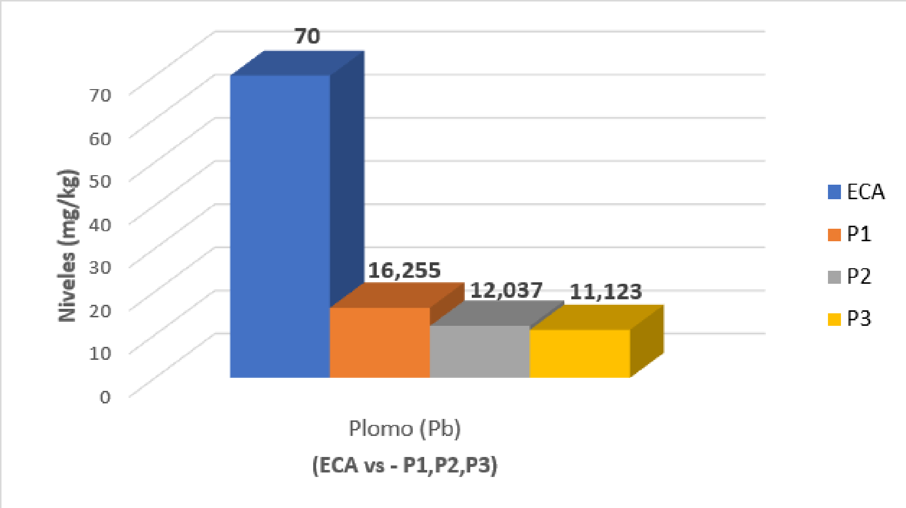

Figure 18. Results of lead (Pb) concentrations with the ECA

Interpretation: according to figure 18 the levels of lead (Pb) at the three sampling points do not exceed the values established by the ECA for agricultural soil, with point 1 having the highest concentration of this metal, with a value of 17,36 mg/kg, followed by point 2 with a value of 14,25 mg/kg; Finally, point 3 has the lowest concentration of this metal, with a value of 11,69 mg/kg.

Comparison of the results of the second sampling with the ECA Soil

Results of comparison of heavy metals with the ECA for soil

	ECA			Resultado Análisis		
	Suelo Agrícola	Suelo Parques	Suelo Inds. Extractivo	P1	P2	P3
Cadmio (Cd)	1.4	10	22	19,36	16,21	7,45
Plomo (Pb)	70	140	800	17,36	14,25	11,69
Cromo VI (Cr)	0.4	0.4	1.4	nd	nd	nd
Cromo Total (Cr)		400	1000	0.045	0,036	0,024

Figure 19. Comparison of results obtained with the ECA for soil, second sampling

Interpretation: the attached figure 19 shows the results obtained in comparison with the ECA for soil, according to soil type, for each sampling point and compound (cadmium, lead, chromium VI, total chromium).

It should be noted that Chromium VI was not detected at any sampling point, and Total Chromium is not established in the ECA for agricultural soil.

Results of the second sampling for soil pH

Table 2. pH results obtained in the second sampling

Second sampling results	
Sample	**pH**
P1	7,8
P2	7,12
P3	7

Interpretation: the table 2 shows the pH results obtained, with point 1 (agricultural soil) measuring 7,68, which is the most basic of the three points, while point 2 (center of the landfill) and point 3 measured 7,12 and 7,32, respectively. Point 2 is slightly neutral and point 3 tends to be more alkaline or basic.

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Impact Mitigation Plan

The solid waste impact mitigation plan was developed to ensure the proper management of solid waste generated by residents of the District of San Pablo, which is disposed of at the municipal landfill located in the town of Consuelo. It was carried out in compliance with the legal framework (Legislative Decree No. 1278, Legislative Decree approving the Comprehensive Solid Waste Management Law - D.S No. 014-2017 MINAM). To this end, it is important that the residents of the town of San Pablo (District) and Consuelo participate in order to comply with the provisions of this Solid Waste Mitigation Plan.

General Objective

Establish an impact plan to minimize soil contamination resulting from the generation of solid waste in the District of San Pablo.

Place of application

San Pablo District, Bellavista Province, San Martín Region.

Responsible

The Environmental Management Department of the District Municipality of San Pablo.

Aspecto Ambiental	Impacto Identificado	Medida Propuesta	Medio Verificación	Etapa
Generación de Residuos convencionales	Sobrecarga del botadero municipal	Educación Ambiental a todos los pobladores del distrito de San Pablo en coodinación con la municipalidad distrital, con el objetivo de minimizar el uso de residuos sólidos	Municipalidad Distrital de San Pablo	SIN PROYECTO
Generación de Residuos peligrosos	Contaminación del Suelo	Contratar a una EPS para el manejo adecuado de los residuos peligros	Municipalidad Distrital de San Pablo	SIN PROYECTO
Generación de Residuos Especiales	Contaminación del Suelo	Contratar a una EPS para el manejo adecuado de las llantas	Municipalidad Distrital de San Pablo	SIN PROYECTO
Generación de derrames	Contaminación del recurso hídrico	Diseñar un plan de manejo	Municipaldiad Distrital de San Pablo	SIN PROYECTO
Generación de emisiones atmosféricas	Afectación al aire	Charlas de Sensibilización a los pobladores del distrito de San Pablo en coodinación con la municipalidad distrital, con el objetivo de reducir la quema de combustibles por vehiculos	Municipalidad Distrital de San Pablo	CON PROYECTO
Almacenamiento de Residuos	Contaminación del Suelo	Almacenar los residuos en contenedores en puntos estratégicos de la ciudad	Municipaldiad Distrital de San Pablo	CON PROYECTO
Recolección y transporte	Contaminación del Suelo	Caracterizar los residuos en dos grupos, orgánicos e inorgánicos	Municipalidad Distrital de San Pablo	CON PROYECTO
Disposición de residuos	Contaminación del Suelo	Disponer en el botadero unicamente los residuos plásticos, vidrio, metal y otros, además de realizar capacitación y talleres de minimización	Municipalidad Distrital de San Pablo	CON PROYECTO

Figure 20. Impact Mitigation Matrix

DISCUSSION

This study evaluated soil contamination caused by leachates from the municipal landfill in the district of San Pablo. Contamination levels were determined based on the main heavy metals present in the leachates from solid waste landfills (lead, cadmium, and chromium VI), to determine the concentration levels, two monitoring sessions were carried out (one per month),[12,13] in September and October of this year, considering three sampling points, two of which are located within the landfill, called P1 and P2, and one in the area where there is no direct impact from municipal solid waste, called P3, i.e., the control point.[14]

According to the study, organic waste (food scraps, fruit peels and waste, tree branches and leaves, etc.) and inorganic waste (batteries, paint and insecticides, batteries, varnishes, PVC pipes, photographs, cement, ink, and plastics) were found at P1 (end/slope) and P2 (central part) of the landfill. and inorganic waste (batteries, paint and insecticides, batteries, varnishes, PVC pipes, photographs, cement, ink, and plastics).[15,16] In Medellín, "it was determined that soil contamination in the Moravia landfill is caused by waste from batteries, paints and insecticides, batteries, batteries, paints, varnishes, leather tanning waste, stainless steel, PVC pipes, as well as photographic waste, wool preservatives, pyrotechnics, anti-corrosion agents, cement, textile dyes, inks, and plastics. All of these wastes determine the presence of heavy metals such as lead, cadmium, and chromium VI."[17]

The results presented in relation to the concentration of cadmium (Cd) in this study are similar to the research carried since in both studies the levels of cadmium (Cd) exceed the values established by the ECA for agricultural soil (1,4 mg/kg), with the highest cadmium value in the aforementioned study found at the end point of the landfill with a value of 3,16 mg/kg compared to 19,36 mg/kg in this study.[18]

The results presented in relation to the concentration of Chromium VI (Cr) in this study differ from the results of the research study conducted since in the cited study, the levels of Chromium VI (Cr) exceed the values established by the ECA for agricultural soil (0,4 mg/kg), with the highest value found at the initial point of the landfill with a value of 1,810 mg/kg, compared to this research study, where the presence of this metal could not be determined.[19]

The results presented in relation to the concentration of Lead (Pb) in this study differ from the results of the research study since in the cited study, the levels of lead (Pb) exceed the values established by the ECA for agricultural soil (70 mg/kg),[20] with the highest value found at the Central Point of the landfill with a value of 88,09 mg/kg compared to 17,36 mg/kg in this study.[21]

The results presented in relation to the concentrations of lead (Pb) and chromium (Cr) in this study are similar to the research carried out since in the aforementioned study, the levels of lead (Pb) and chromium (Cr) did not exceed the values established by the ECA for agricultural soil (70 mg/kg) and (0,4 mg/kg), respectively,[22] with the highest concentrations of lead (Pb) were found in the Lamay and Calca dumps, with values of 0,01 mg/kg in both cases, compared to 17,36 mg/kg in the present study. With regard to chromium VI (Cr), the highest concentration was found in the Calca dump, with a value of 0,06 mg/kg, compared to my research, in which the presence of this metal could not be determined.[23]

The results presented in relation to the concentration of cadmium (Cd) in this study differ from the results of the research carried out by since in the cited study, cadmium (Cd) levels did not exceed the values established by the ECA for agricultural soil (1,4 mg/kg), and no trace of this metal was found, compared to the highest value (19,36 mg/kg) in this study.[24]

CONCLUSIONS

An assessment of soil contamination affected by leachates from the municipal landfill in the District of San Pablo was carried out, finding concentrations in mg/kg of the following heavy metals (cadmium, lead, and total chromium) at the three sampling points.

The concentration levels of heavy metals (lead, cadmium, and chromium VI) in soils affected by leachates from the municipal landfill in the District of San Pablo were determined, finding concentrations of cadmium (Cd) at a level of 18,752 mg/kg in the first sample, followed by lead (Pb) at 16,25 mg/kg, corresponding to point 1. At point 2, 15,126 mg/kg of cadmium (Cd) was found, followed by lead (Pb) at 12,037 mg/kg. Finally, at point 3, it was determined that lead (Pb) in the soil had a concentration of 11,123 mg/kg. Finally, the heavy metal cadmium (Cd) was found in smaller quantities, with a value of 6,321 mg/kg. Likewise, in the second and last sampling, cadmium (Cd) was found to have a concentration of 19,36 mg/kg, followed by lead (Pb) with 17,36 mg/kg, both reports corresponding to point 1. At point 2, the heavy metal with the highest concentration in the soil was cadmium (Cd), with a value of 16,21 mg/kg, followed by lead (Pb) with 14,25 mg/kg. Finally, at point 3, lead (Pb) had the highest concentration with a value of 11,69 mg/kg, followed by cadmium (Cd) with a value of 7,45 mg/kg. With regard to chromium VI (Cr), its presence was not detected at any of the sampling points.

Comparison of the concentration levels of the heavy metals evaluated with the Environmental Quality Standards for soil – ECA established that the levels of cadmium (Cd) at the three sampling points exceed the values established by the ECA for agricultural soil, while lead (Pb) and chromium VI (Cr) at the three sampling points do not exceed the values established by the ECA for agricultural soil.

The solid waste mitigation plan was carried out with the aim of achieving adequate management of solid waste generated by the inhabitants of the District of San Pablo, which will improve the functioning of the municipal landfill and reduce environmental pollution. It was carried out in compliance with the legal framework (Legislative Decree No. 1278, Legislative Decree approving the Law on Integrated Solid Waste Management).

RECOMMENDATIONS

It is recommended to increase the number and frequency of samples so that the new samples provide greater statistical weight and consistency.

Due to the high concentration of cadmium at the sampling points in the municipal landfill, it is recommended that measures be taken to improve the treatment of solid waste and prevent contamination from heavy metals in the soil of the municipal landfill.

It is recommended to implement a medium- and long-term educational process to raise environmental awareness among the emerging population, which will have an impact on the maintenance and/or improvement of environmental conditions at the municipal landfill in the District of San Pablo, especially in the proper management of soil resources.

Further soil quality studies should be conducted to assess contaminant concentrations and consider the environmental, social, and economic implications for nearby populations.

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CONFLICT OF INTEREST

Authors declare that there is no conflict of interest.

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