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SOIL HEAVY METAL CONTAMINATION (Pb, Cd, Cu, Zn, As) FROM WASTE LEACHATES IN RESIDENTIAL AREAS NEAR WASTE-PROCESSING SITES IN THE PHILIPPINES: A SYSTEMATIC REVIEW

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ABSTRACT
Heavy metals in soil is one of the environmental concerns in which there is a problem of excessive amounts of hazardous heavy metals such as Pb, Cd, Cu, Zn, As, and Cr, which are more than the defined and indicated in the DENR, FAO, and WHO guidelines and standards. The lack of linings in open dump sites in the Philippines such as Payatas, Smokey Mountain, and Carmona is one of the contributing factors to this problem of heavy metals in soil. Raised levels of heavy metals (Pb: up to 1,200 mg/kg, Cr: up to 1,480 mg/kg) exceeding standards at large sites are related to waste leachates; pose high/moderate PERI and health risks, including neuro- and carcinogenic effects via food chain and dust. This problem contributes to environmental problems such as increased values of the Potential Ecological Risk Index (PERI). This systematic review aims to provide a comprehensive overview of the existing literature on heavy metal contamination near waste processing facilities like residential areas' dump sites and landfills in the Philippines.

Keywords:
Dumpsites, landfills, soil pollution, waste leachates, health risk, ecological risk.

INTRODUCTION
Rapid urbanization and population growth in the Philippines have significantly increased the generation of municipal solid waste. A substantial proportion of this waste is disposed of in open or inadequately managed dumpsites, many of which are located in close proximity to residential and agricultural zones. These sites have become a growing environmental and public health concern, primarily due to the contamination of soils with heavy metals such as lead (Pb), cadmium (Cd), copper (Cu), arsenic (As), chromium (Cr), and zinc (Zn). The presence of these heavy metals in the environment has a great ecological impact due to certain reasons including toxicity, translocation through food chains and non-biodegradability, which are responsible for their accumulation in the biosphere according to Aekola et al. (2008) as cited in Jyothi et al. (2017).

Dumpsite is an old traditional method of waste disposal similar to landfill method of waste management and is often established in disused quarries, mining, or excavated pits away from the residential areas. Improper dumpsite management could lead to adverse environmental impacts such as leachate that possibly contains toxic heavy metals that pollute the underground soil bed (Shittu et al., 2016). According to Ali et al. (2019), open dumpsites are common in developing countries like the Philippines because of the low budget allotted for waste disposal management and the non-availability of trained manpower.

Heavy metals that are released from poorly managed dumping sites can thus penetrate adjacent soils, which may, in turn, spread into adjacent ecosystems and human populations. Heavy metals can thus spread from the dumping site into adjacent ecosystems and human populations through various routes, including leaching, runoff, and atmospheric fallout. Heavy metals possess a severe risk because they tend to bioaccumulate, which means an increase in chemical concentration in a biological organism over time compared to the chemical concentration in

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the environment (Helmenstine et al, 2021). Once heavy metals are present in soils, they are difficult to eliminate due to their persistence and non-biodegradable characteristics. These characteristics enable heavy metals to accumulate over time, thus increasing their potential to penetrate the food chain either through crops that are grown in soils containing heavy metals or through exposure routes such as ingestion, inhalation, and dermal contact.

Despite the fact that some research works have been undertaken to assess the heavy metal contamination of soils within dumpsite areas in the Philippines, the research works undertaken so far have been fragmented and mostly site-specific in nature. Most of the research works undertaken have been based on the measurement of heavy metal concentration in soil samples from specific locations such as dumpsite areas, landfill sites, and urban soils within the surrounding communities. For instance, research works undertaken within the surroundings of the Payatas dumpsite in Quezon City and the former Smokey Mountain dumpsite in Manila have all revealed high concentrations of heavy metals within the soils within these areas, thus pointing out the possible environmental hazards associated with the improper disposal of waste. These research works have all been undertaken independently and have utilized diverse research methodologies, thus limiting the development of a comprehensive understanding of the heavy metal contamination of the environment within the various waste processing sites within the Philippines (Cruz et al., 2015; DENR, 2021).

Most of the research works undertaken have also been limited in the sense that a comprehensive assessment of the environmental implications of the contamination of the environment within the surrounding communities of the waste processing sites has not been undertaken due to the diversity of the waste disposal practices within the Philippines. The fact that some areas within the Philippines still have open dumpsites despite the passing of the Ecological Solid Waste Management Act of 2000 (Republic Act 9003) also points out the possible heavy metal contamination of the environment within these areas, thus exposing the surrounding communities to the possible hazards of heavy metal exposure.

In this regard, a synthesis of the available literature becomes essential in order to integrate the current literature on the heavy metal contamination of soils in waste-processing sites in the Philippines. By understanding the literature on the various studies conducted in different places and different waste-processing activities, it becomes possible to identify the patterns of heavy metals found in the environment, the environmental and health concerns, and the gaps in the current literature. This will not only help in understanding the environmental impacts of waste-processing soil contamination but will also be beneficial in understanding the impacts of waste management policies.

OBJECTIVES

The primary objective of this study is to conduct a systematic review of the extent, sources, and human health risks of soil heavy metal contamination in residential areas located near waste-processing sites in the Philippines, with a particular focus on assessing potential risks to residents and the environment. This study seeks to evaluate the occurrence of heavy metals in the soils of residential communities located near waste-processing sites in the Philippines, where heavy metals have been reported to be present. It also seeks to evaluate the various waste-processing activities that contribute to the occurrence of heavy metals in the soils of the said communities. Additionally, this study seeks to evaluate the human health risk assessment approach used in the literature, the exposure pathways, the risk assessment approach used, and the populations at risk of exposure to heavy metals. By using this approach to evaluate the literature, this study seeks to contribute to a better understanding of the occurrence of heavy metals in the soils of the said communities. This, in turn, will contribute to a better understanding of the risk of exposure to heavy metals, which will be beneficial to the community.

METHODOLOGY

The research was conducted as a systematic review, utilizing the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework. This provided a structured protocol for the systematic identification, selection, and critical appraisal of publications from 2016 to 2026 concerning the heavy metal contamination in soil from waste leachates in residential areas near waste-processing sites in the Philippines.

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Data Sources
The literature search for this systematic review was conducted using a rigorous, multi-database approach to ensure comprehensive coverage. Key academic databases, including Web of Science, Scopus, PubMed, ScienceDirect, and Google Scholar, were searched to identify relevant studies.

All identified publications were systematically evaluated in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. This structured process ensured methodological consistency and enhanced the reliability of the review, which focuses on the heavy metal contamination in soil from waste leachates in residential areas near waste-processing sites.

Literature Search
A comprehensive search strategy was executed across selected academic databases using a structured combination of keywords and Boolean operators (AND, OR). Multiple search strings were employed to ensure a thorough retrieval of pertinent literature. The search terms were designed to capture the core concepts of the review. Keywords used in the search included combinations of the following terms:

1. Soil pollution
2. Dumpsites
3. Landfills
4. Waste-processing sites
5. Heavy metals in soil near landfill
6. Risk assessment in soil

To maintain a focus on contemporary research, the search was initially filtered to prioritize peer-reviewed journal articles published between 2016 and 2026. However, to provide foundational context on heavy metal contamination in soils associated with waste disposal areas, select books and technical reports were also considered without strict publication date limitations. The screening process involved multiple stages. Initially, all identified records were assessed based on their titles and abstracts to remove duplicates and clearly irrelevant studies. The remaining publications then underwent a rigorous full-text review to definitively determine their eligibility based on the study's pre-defined inclusion and exclusion criteria.

Inclusion Criteria:
Studies were included if they:
1. Investigated heavy metal contamination in soils associated with dumpsites, landfills, or waste-processing facilities.
2. Conducted within the Philippines or in locations with comparable waste-management conditions relevant to Philippine dumpsites.
3. Reported quantitative concentrations of heavy metals such as Pb, Cd, Cu, Zn, As, or Cr in soil samples.
4. Examined environmental impacts, ecological risks, or human health risks related to heavy metal exposure.
5. Were published in English and within the period 2016 to present to ensure contemporary relevance.

Exclusion Criteria:
Studies were excluded if they:
1. We're reviewing articles, editorials, conference abstracts, or opinion pieces without original data.
2. Studies that focused on contaminants other than heavy metals, such as organic pollutants, plastics, or microbiological contaminants, without reporting quantitative data on heavy metal concentrations in soils.
3. Studies that examined environmental compartments other than soil, including water, groundwater, air, sediments, or biota, unless soil contamination data were also explicitly reported.
4. Articles that did not involve waste-processing sites, dumpsites, landfills, or similar waste disposal areas as the primary source of contamination.
5. Studies conducted in locations unrelated to residential areas near waste-processing sites, particularly those focusing solely on industrial zones, mining sites, or agricultural lands with no link to waste disposal activities.

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6. Research that lacked clear methodological descriptions, such as sampling procedures, analytical methods, or study locations, which made it difficult to evaluate the reliability of the findings.
7. Were published before 2016, to maintain contemporary relevance.
8. Were not available in English or as full-text publications.

Search Results

A total of 54 records were initially identified through a systematic search of five academic databases: Web of Science, Scopus, ScienceDirect, PubMed, and Google Scholar. The search was limited to peer-reviewed articles published in English between 2016 and 2026, that investigated soil heavy metal contamination associated with dumpsites, landfills, and waste-processing facilities, particularly in residential areas. This initial search excluded 32 records for being outside the date range, not in English, or lacking direct relevance to landfills and their assessment on soil contamination.

After the removal of 12 duplicate records, 42 studies advanced to the title and abstract screening phase. Screening was performed using predefined inclusion criteria, which required studies to: (1) investigate heavy metal contamination in soils, particularly in areas influenced by dumpsites, landfills, or other waste-processing facilities ; (2) report quantitative measurements of heavy metal concentrations, including metals such as lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn), arsenic (As), and chromium (Cr); (3) examine the environmental or human health implications of soil contamination, including exposure pathways, ecological impacts, or risk assessment; and (4) be primary research articles. Based on these criteria, 27 studies were excluded for reasons such as focusing solely on water or sediment contamination, investigating pollution sources unrelated to waste-processing or disposal sites, lacking quantitative heavy metal concentration data in soils, or being reviewed articles without original experimental findings.

The remaining 16 full-text articles were thoroughly assessed for eligibility. Of these, 6 were excluded due to incomplete data sets, insufficient methodological detail regarding soil sampling and heavy metal analysis, or a primary focus on environmental monitoring without evaluating potential environmental or human health risks associated with heavy metal contamination. Ultimately, 8 studies satisfied all inclusion criteria and were included in the qualitative synthesis. The identification, screening, eligibility, and inclusion process is summarized in the PRISMA flow diagram (Figure 1).

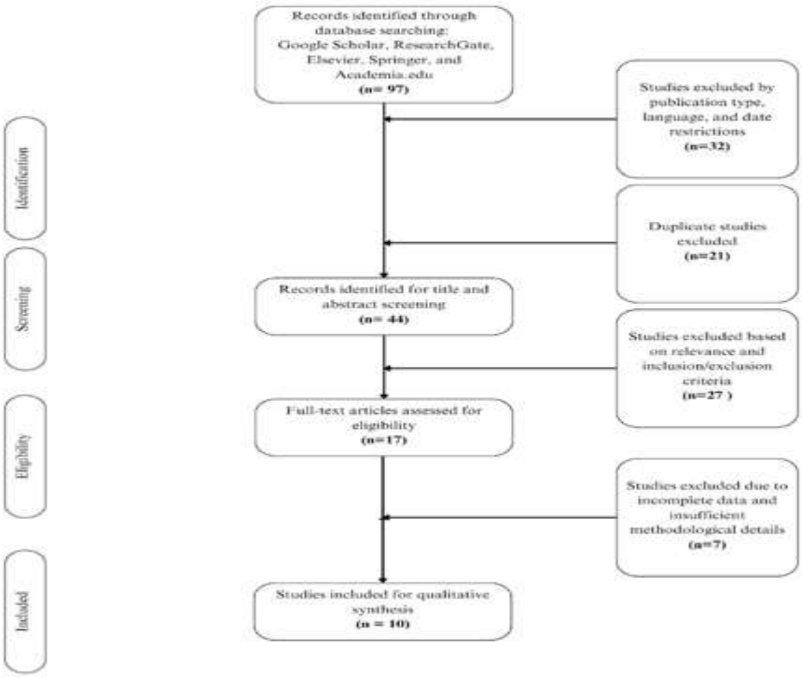

Figure 1. Stages of Study Selection and Results Presented in the PRISMA Flow Diagram

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RESULTS AND DISCUSSION

The final set of 8 included studies was subjected to qualitative synthesis. This research adopted a narrative synthesis approach that entailed the clustering of the identified data to identify patterns of soil contamination with heavy metals and the environmental health risks associated with such contamination. This synthesis approach brought together the findings of both field-based research and environmental assessments to compare the kinds of heavy metals identified in the soils at different locations within the dumpsite, as well as the exposure routes to these metals and the potential effects on the human population within the environs. The main goal was to identify patterns of heavy metal contamination in the soil and to identify the gaps in the existing knowledge to provide a scientific basis for improving the monitoring of the environment around the waste-processing sites.

Table 1. Study Characteristics

Study	Study Location	Health Effects	Environmental Effects	Author and Year
The assessment of the genotoxicity of e-waste leachates from e-waste dumpsites in Metro Manila, Philippines.	Smokey Mountain, Tondo	Exposure to heavy metals such as Pb, Cd, Cu, and Zn from contaminated soils and crops may cause neurological damage, kidney dysfunction, and other chronic health effects among nearby residents consuming contaminated food or inhaling polluted dust.	Elevated heavy metal concentrations in dumpsite soils may accumulate in plants grown in the area and contaminate surrounding soil ecosystems, potentially entering the food chain and affecting vegetation and soil organisms.	Alam, Z.F., Riego, A.J.V., Samson, J.H.R.P. *et al.* (2018).
Heavy metal concentrations in soils and vegetation in urban areas of Quezon City, Philippines.	Payatas Dumpsite, Quezon City	Exposure to Pb, Cd, and Cr from contaminated soil or plants may affect human health including neurological and kidney damage.	Heavy metals accumulate in soil and plant leaves in disturbed urban areas such as landfills, residential, and commercial zones.	Navarrete, I. A., et. al. (2017).
Existing land use and extent of lead (Pb) contamination in the grazing food chain of the closed Carmona sanitary landfill in the Philippines.	Carmona Sanitary Landfill, Cavite	Exposure to heavy metals such as Cr, Hg, and Ni may cause non-carcinogenic and carcinogenic health risks. Children are vulnerable to toxic effects from metal exposure.	Heavy metal contamination in soils and sediments creates very high ecological risk, especially from Ni, Hg, Cr, and Mn affecting aquatic ecosystems and surrounding environments.	Altarez, R. D., & Sedigo, N. A. (2019).
Heavy Metal Contamination in Soil and Phytoremediation Potential of Naturally	Bagong Silang Dumpsite, Talavera, Nueva Ecija	Long-term exposure to contaminated soil can lead to heavy	Soil contamination with Pb and Cr was detected in the dumpsite, showing potential	Santos, A., et. al. (2021).

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Growing Plants in Bagong Silang Dumpsite, Talavera, Nueva Ecija, Philippines.		metal accumulation in crops that may affect human health when consumed.	environmental pollution and metal uptake by plants.	
Cadmium, Nickel, and Lead Concentration of Municipal Dumpsite in Western Samar, Philippines.	Santa Rita Municipal Dumpsite, Western Samar	Long-term exposure to Cd, Pb, and Ni may lead to metal accumulation in the food chain and potential toxicity in humans.	Dumpsite soils contain detectable heavy metals which may accumulate and contaminate nearby soil ecosystems.	Varona, M. B., Amistoso, J. L., & Bobon-Carnice, P. A. (2022).
Heavy Metal Concentration of Dumpsite Soil and Accumulation in Zea mays (corn) Growing in a Closed Dumpsite in Manila , Philippines.	Manila Dumpsite, Philippines	Consumption of crops grown in contaminated dumpsite soils may expose residents to heavy metals such as Pb, Cd, Cu, and Zn, potentially causing toxic effects including neurological damage and other health complications from long-term exposure.	Elevated concentrations of Cu, Zn, Cd, and Pb were detected in dumpsite soils and were absorbed by corn plants, with the highest accumulation observed in plant roots. This indicates that heavy metals from dumpsite soils can enter the food chain through crop uptake.	Leah Amor S. Cortez and Johnny A. Ching. (2016).
Analysis of Heavy Metals in Cebu City Sanitary Landfill, Philippines. Journal of Environmental Science and Management (JESAM).	Cebu City Sanitary Landfill	Pb and Cd contamination in groundwater may cause neurological damage and kidney toxicity when consumed.	Leachate from landfill can contaminate groundwater and surrounding water systems.	Van Ryan Kristopher R. Galarpe & Richard Parilla. (2020).
Chromium and arsenic in an abandoned open dumpsite soil in Iligan, Philippines: A comprehensive ecological and health risk analysis.	Iligan City Dumpsite, Mindanao	Exposure to arsenic and chromium from contaminated soil may pose potential health risks through ingestion, inhalation of dust, or dermal contact.	Soil samples from the abandoned dumpsite showed significant arsenic contamination exceeding regulatory limits, indicating environmental pollution and potential ecological hazards.	Manupac, S.R., et. al. (2025)

Table 1 presents a summary of the characteristics of the eight studies that were included in the systematic review. This table provides a summary of the locations of the studies, the health effects reported in the studies, and the environmental effects of soil contamination with heavy metals near the waste processing sites in the Philippines. Dumpsites or landfills have been found to contribute to the pollution of the surrounding environment due to the

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presence of heavy metals. Heavy metals like lead (Pb) tend to remain in upper soil layers and can be metabolized into plant tissues especially since heavy metals have a high attraction for certain organic materials. An excessive amount of this heavy metal may cause serious problems (Altarez, 2019). These have shown to pose risks and hazards to humans and the ecosystem via direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animalhuman), drinking contaminated groundwater, reduction in food quality (safety and marketability) via phytotoxicity, reduction in land usability for agricultural production resulting in food insecurity, and land tenure issues (Manupac et al, 2025). It can accumulate in fatty tissues, influence the central nervous system, be deposited in the circulatory system, and disturb the proper functioning of internal organs. For instance, chromium (Cr) compounds can be absorbed by the lungs, gastrointestinal tract, and, to a limited extent, intact skin. This absorption can lead to respiratory tract irritation, an increased risk of lung cancer, and various health issues affecting the kidneys, liver, stomach, and blood (Bacosa et al, 2025). Children in the surrounding areas of the dumpsites have shown to have a higher risk of being affected. Other than the effects on humans, the studies have shown the effects of the heavy metals on the environment. Some of the effects include the accumulation of heavy metals in the soils. The most common pathway for human exposure to hazardous metals is through food consumption. Heavy metals are easily absorbed by vegetable roots and can build up to large levels in the edible sections of vegetables, even at low levels in the soil. Moreover, low-level chronic exposure to heavy metals can have long-term health consequences (Nolos et al., 2022). This will increase the dietary exposure of the people in the surrounding environment. Heavy metals such as As and Cr in dumpsites and their toxic nature and persistence in the environment further raise environmental concerns (Manupac et al., 2025).

Environmental contamination has the capacity to migrate across land surface and underground porous media. Due to the essential characteristics of heavy metals such as accumulation, bioavailability, and low mobility in soils, heavy metal pollution poses both potential ecological and health risks (Agarin et al., 2022). From the studies included in the review, it is evident that the soil in the surrounding environment of the waste-processing sites is a significant environmental and public health concern.

Table 2. Heavy Metals Concentrations in Soil near Landfills

Dumpsites	Heavy Metals	Concentrations
Smokey Mountain, Tondo	Pb,Cd	Pb: 450-1,100mg/kg Cd: 1.2-2.4 mg/kg
Payatas Dumpsite, Quezon City	Cr,Cu, Pb, Cd, Ni	Cr: 520–780 mg/kg Cu: 180–300 mg/kg Pb: 800–1,200 mg/kg Cd: 2.1–4.5 mg/kg Ni: 80–150 mg/kg
Carmona Sanitary Landfill, Cavite	Cr, Cu, Hg, Ni, Pb, Zn	Cr: 205–1480 mg/kg Cu: 50.7–116.9 mg/kg Hg: 1.6–397.2 mg/kg Ni: 362–2531 mg/kg Pb: 10.5–36.4 mg/kg Zn: 37–114 mg/kg.
Bagong Silang Dumpsite, Talavera, Nueva Ecija	Pb, Cr, As, Cd, Hg	Pb: 13.8699 ppm Cr: 2.6309 ppm As: 0.2576 ppm Cd: 69.6386 ppm Hg: 0.0343 ppm
Santa Rita Municipal Dumpsite, Western Samar	Cd, Pb, Ni	Cd: 0–0.1 mg/kg Pb: 0.09–3.7 mg/kg

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		Ni: 0.09–3.7 mg/kg.
Manila Dumpsite, Philippines	Cu, Zn, Cd, Pb	Cu: 150–300 mg/kg Zn: 400–950 mg/kg Cd: 0.9–1.6 mg/kg Pb: 300–700 mg/kg
Cebu City Sanitary Landfill	Pb, Cu, Cd, Cr, Hg	Pb: 0.0926–0.2898 mg/L Cu: 0.1812–1.1048 mg/L Cd: 0.0029–0.0145 mg/L Cr: 0.0562–0.1752 mg/L
Iligan City Dumpsite, Mindanao	As, Cr	As: 26.14-28.55 mg/kg Cr: 19.01-29.48 mg/kg

Table 2 shows the concentrations of heavy metals identified in the soils of various dumpsites and landfill sites in the Philippines. The Payatas dumpsite in Quezon City was identified to have the highest concentration of lead (Pb) at a level of up to 1,200 mg/kg. This was followed by the Smokey Mountain dumpsite in Tondo, which was identified to have a Pb level of between 450 to 1,100 mg/kg. The Manila dumpsite was identified to have a Pb level of between 300 to 700 mg/kg. On the contrary, the Carmona sanitary landfill site was identified to have a low level of Pb at a level of between 10.5 to 36.4 mg/kg. The Santa Rita municipal dumpsite in Western Samar was identified to have the lowest level of Pb at a level of between 0.09 to 3.7 mg/kg. Heavy metal concentrations in soils can reflect either the natural condition or the effects of anthropogenic activities, which lead to heavy metal pollution (Navarrete et al., 2017).

For chromium (Cr), the highest concentration was recorded in Carmona Sanitary Landfill with values reaching up to 1,480 mg/kg, followed by Payatas Dumpsite which reported concentrations ranging from 520–780 mg/kg. Meanwhile, Iligan City Dumpsite showed lower chromium concentrations ranging from 19.01–29.48 mg/kg, and Bagong Silang Dumpsite recorded relatively minimal levels at approximately 2.63 ppm. Nickel (Ni) also showed a similar trend, with Carmona Sanitary Landfill having the highest recorded concentrations ranging from 362–2,531 mg/kg, compared with Payatas Dumpsite which reported lower concentrations between 80–150 mg/kg. The adverse effect of contaminants such as heavy metals on health and the environment is linked to their availability in soil. Also, pollution of soil with heavy metals undermines its properties (Ojuri et al., 2018). Nonetheless, when heavy metals are released into the soil, they are retained, accumulated, and concentrated since the soil acts as a natural sink; therefore, deposits the contaminants in elemental, ionic, molecular and oxide forms (Maphuhla et al., 2021).

Other metals, including copper (Cu) and zinc (Zn), were also widely found in the soils of the dumpsites. The Manila Dumpsite had relatively high concentrations of Zn in the range of 400–950 mg/kg. Payatas Dumpsite and Manila Dumpsite had significant concentrations of Cu in the range of 150–300 mg/kg. Cadmium (Cd), although found in smaller amounts compared to the other metals, was found in all the dumpsites. Payatas Dumpsite had the highest concentration of Cd in the range of 2.1– 4.5 mg/kg. Smokey Mountain Dumpsite and Manila Dumpsite had Cd concentrations of 1.2–2.4 mg/kg and 0.9–1.6 mg/kg, respectively. Santa Rita Municipal Dumpsite had the lowest concentration of Cd in the range of 0–0.1 mg/kg. Singh and Chandel (2020) established that age of deposited waste has significant effects on dumpsite waste properties. However, most of the studies reviewed showed that information on depth of distribution of heavy metals at the dumpsites, and the effect of aging of deposited waste on heavy metals distribution is limited (Gyabaah et al., 2023).

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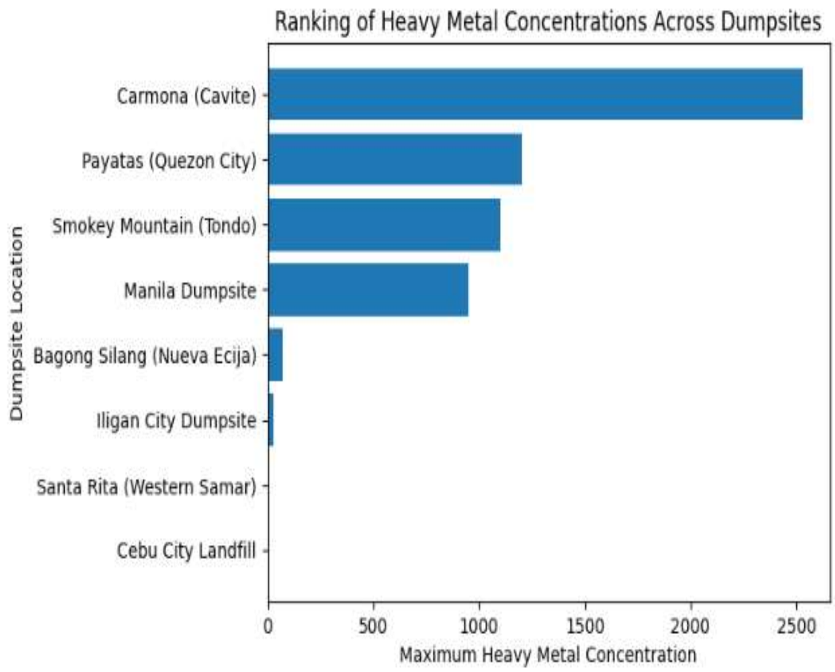

Figure 1: Proportional Distribution of Maximum Heavy Metal Concentrations Across Selected Philippine Dumpsites, Indicating Dominant Contaminant Metals per Site

The bar graph presents a clear ranking of heavy metal concentrations across selected dumpsites, emphasizing the variation in contamination levels among locations. The Carmona Sanitary Landfill shows the highest concentration, primarily driven by nickel (Ni), indicating severe contamination compared to other sites. This is followed by the Payatas Dumpsite and Smokey Mountain, both dominated by high levels of lead (Pb), which pose significant environmental and health risks.
Moderate contamination levels are observed in the Manila Dumpsite, largely due to zinc (Zn), while the Bagong Silang Dumpsite and Iligan City Dumpsite exhibit lower but still notable concentrations of cadmium (Cd) and chromium (Cr), respectively. In contrast, the Santa Rita Municipal Dumpsite and Cebu City Sanitary Landfill show minimal concentrations, suggesting relatively lower contamination levels.
Overall, the bar graph highlights a significant disparity in heavy metal accumulation across dumpsites, with a few sites contributing disproportionately high concentrations. This suggests that differences in waste composition, landfill management practices, and local environmental conditions strongly influence the extent of contamination, underscoring the need for site-specific mitigation strategies

Table 3 – Processing Activities and Sources of Soil Heavy Metal Contamination

Location	**Type of Waste-Processing Activity**	**Waste Characteristics**	**Heavy Metals**	**Possible Source of Heavy Metals**
Smokey Mountain, Tondo	Closed Dumpsite	Mixed municipal solid waste	Pb, Cd	Batteries, paints, electronic waste
Payatas Dumpsite, Quezon City	Controlled Dumpsite	Household waste, plastics, metals	Cr,Cu, Pb, Cd, Ni	Metal scraps, industrial waste

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Carmona Sanitary Landfill, Cavite	Sanitary Landfill	Controlled landfill waste	Cr, Cu, Hg, Ni, Pb, Zn	Industrial waste residues
Bagong Silang Dumpsite, Talavera, Nueva Ecija	Open Dumpsite	Municipal solid waste	Pb, Cr, As, Cd, Hg	Lead paint and old gasoline spills
Santa Rita Municipal Dumpsite, Western Samar	Open Dumpsite, Sludge Dumping	Municipal solid waste, clinical waste, and industrial waste.	Cd, Pb, Ni	Gasoline, industrial processes, batteries, electronic products
Manila Dumpsite, Philippines	Closed Dumpsite	Municipal solid waste	Cu, Zn, Cd, Pb	Mining, smelting of metalliferous ores, metal scraps, electroplating, fertilizer and pesticides
Cebu City Sanitary Landfill	Sanitary Landfill	Medical waste, electronic waste, mixed municipal solid waste	Pb, Cu, Cd, Cr, Hg	Abundance of wastes scrap metals, paints, pigments, plastics, cleaners, and batteries
Iligan City Dumpsite, Mindanao	Open Abandoned Dumpsite	Municipal solid waste	As, Cr	Dyes, pigments, medical waste, pesticides, and ash from hospital waste incineration

Table 3. shows the different categories of waste processing activities, as well as the prospective sources of heavy metals responsible for soil pollution at the sites of dumpsites and landfill facilities. Solid waste disposals such as dumpsites represent a significant source of heavy metals released into the environment (Santos et al., 2021). From the results, it is clear that both dumpsites and landfill facilities are responsible for the pollution of soils at the sites due to the decomposition of waste, which leads to the production of leachates. Its source can include domestic refuse, which is typically generated by households; agricultural waste from animal farms and farmlands; industrial waste produced by construction and industrial sites; and clinical and toxic waste, which is mainly generated by the petrochemical industry and hospitals (Igwegbe et al., 2024).

According to Santo et al. (2021), open dumpsites are common in developing countries like the Philippines because of the low budget allotted for waste disposal management and the non-availability of trained manpower. Several specific sources of heavy metals were also identified in the literature such as mining and smelting of metalliferous ores and metal scraps, electroplating, application of fertilizer and pesticides, sludge dumping and municipal waste have been identified as the sources of heavy metal contamination of the soil (Cortez et al., 2016). This also includes industrial waste materials, lime, fertilizer, and sewage sludge contributing to the significant nickel sources in the soil (Das et al., 2018).

Furthermore, these materials often contain toxic metals such as lead, cadmium, copper, and chromium that can leach into the soil as the waste degrades. The abundance of wastes scrap metals, paints, pigments, plastics, cleaners, and batteries were found in Cebu City Sanitary Landfill, which can be the potential sources of these metals (Galarpe et al., 2017).

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Table 4 – Health Risks of the Heavy Metal Contamination near different Dumpsites

Location	Heavy Metals	Exposure Pathways	Risk Assessment Method	Health Risk Indicators	Vulnerable Population
Smokey Mountain, Tondo	Pb, Cd	Dermal contact, inhalation	Hazard quotient (HQ) & hazard index (HI)	Cognitive impairment, neurological, haematological, kidney dysfunction	Children and some adults
Payatas Dumpsite, Quezon City	Cr,Cu, Pb, Cd, Ni	Dermal contact, inhalation, ingestion	Genetic assays, genotoxicity assays, micronucleus assay	DNA damage, changes in thyroid function, adverse neonatal outcomes	E-waste recyclers, pregnant women, infants
Carmona Sanitary Landfill, Cavite	Cr, Cu, Hg, Ni, Pb, Zn	Ingestion	US FDA Tolerable Daily Intake (TDI)	Lung cancer, diarrhea, neurotoxicity, chronic respiratory issues	0-6 years old, 7 years old to young adults, and pregnant women
Bagong Silang Dumpsite, Talavera, Nueva Ecija	Pb, Cr, As, Cd, Hg	Ingestion, dermal contact, inhalation	Comparison with USEPA soil quality standards	Cancer, cognitive impairment, fetal brain damage, bone fragility	Residents living near the dumpsite, farmers, children
Santa Rita Municipal Dumpsite, Western Samar	Cd, Pb, Ni	Ingestion, groundwater consumption, dermal contact	Pollution Load Index (PLI)	Kidney dysfunction, cognitive impairment, chronic respiratory issues	Local residents, children, agricultural workers
Manila Dumpsite, Philippines	Cu, Zn, Cd, Pb	Inhalation, dermal contact	Comet Assay	Increased DNA damage (tail length, tail moment)	Scavengers, waste pickers, women and children
Cebu City Sanitary Landfill	Pb, Cu, Cd, Cr, Hg	Ingestion, inhalation	Interviewer-administered questionnaire using Statistical Package for the Social Sciences (SPSS)	Dengue fever, respiratory-related, diarrhea, and chest pains	Waste pickers, children
Iligan City Dumpsite, Mindanao	As, Cr	Ingestion, dermal contact, and inhalation	Hazard quotient, hazard index, exposure	Skin lesions, hyperkeratosis, cancer,	Children

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			assessment, dose-response analysis, and risk characterization	cardiovascular disease	

Table 4 summarizes the potential human health risks that may occur as a result of exposure to heavy metals in soils near the dumpsites and landfill areas. From the reviewed studies, there are several exposure routes that may facilitate the contact between humans and the mentioned environmental contaminants. The main sources of Pb poisoning in our environment include lead paint and old gasoline spills resulting in dust and soil contamination of food and water, which can cause severe health effects at relatively low levels of exposure (Santos et al., 2021). For instance, chromium (Cr) compounds can be absorbed by the lungs, gastrointestinal tract, and, to a limited extent, intact skin. This absorption can lead to respiratory tract irritation, an increased risk of lung cancer, and various health issues affecting the kidneys, liver, stomach, and blood (Manupac et al., 2025). Similarly, arsenic can lead to severe health effects such as chronic arsenic poisoning and an elevated risk of skin cancer through prolonged exposure to contaminated soil, food, and water (World Health Organization).

The bioaccumulation process occurs in all living organisms as a result of exposure to metals in food and the environment, including food animals such as poultry, poultry, fish and humans (Altarez et al., 2019.) Several techniques like genotoxicity assays used to detect compounds that induce genetic damage have been employed in the clinical diagnosis of disease. Genetic assays like the micronucleus assay have gained widespread acceptance as indicators of DNA damage and carcinogenicity (Berame et al., 2020). As described by Zhang et al. (2022), the health risk assessment comprises hazard identification, exposure assessment, dose-response analysis, and risk characterization.

In Barangay Payatas, Quezon City, Manila, the majority of residents are involved in collecting and selling used electronic gadgets/appliances such as cell phones, TVs, radios, refrigerators, batteries, and other end-of-life materials. In areas where these e-waste activities take place, environmental harm is evident by the presence of unhealthy soil coming from waste materials junked along the roads and dumpsites, adversely affecting the health of recyclers living in this area (Berame et al., 2020). In addition, e-waste toxins that have carcinogenic and genotoxic effects from organic pollutants including brominated flame retardants, hexavalent chromium, polycyclic aromatic hydrocarbons and heavy metals like lead (Pb), mercury (Hg), arsenic (As), cadmium (Cd), selenium (Se), and aluminum (Al) disperse into the environment and contaminate the soil (Noguera et al., 2020).

Table 5 – Environmental Risks of the Heavy Metal Contamination near different Dumpsites Dumpsites

Location	Heavy Metals	Soil Standard (WHO/FAO/ USEPA) (mg/kg)	Sources of Contamination	Causes in Environment	Assessment Method	Risk Level
Smokey Mountain, Tondo	Pb, Cd	Pb: 50–300 Cd: 1–3	Municipal solid waste leachate, e-waste residues, open burning	Soil Contamination	Potential Ecological Risk Index (PERI)	High Risk (Pb = 366%)
Payatas Dumpsite, Quezon City	Cr,Cu, Pb, Cd, Ni	Cr: 100–300 Cu: 100–150 Pb: 50–300 Cd: 1–3 Ni: 30–75	Household hazardous waste, batteries, e-waste, landfill leachate	Soil-vegetation exchanges of contamination	Pollution Load Index (PLI)	Moderate Risk (Pb = 180%)

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Carmona Sanitary Landfill, Cavite	Cr, Cu, Hg, Ni, Pb, Zn	Cr: 100–300 Cu: 100–150 Hg: 1–2 Ni: 30–75 Pb: 50–300 Zn: 200–300	Industrial waste inputs, landfill leachate	Soil Contamination	Geoaccumulation index, enrichment factor and potential ecological risk index	Moderate Risk (Ni = 190%)
Bagong Silang Dumpsite, Talavera, Nueva Ecija	Pb, Cr, As, Cd, Hg	Pb: 50–300 Cr: 100–300 As: 20–30 Cd: 1–3 Hg: 1–2	Mixed municipal waste, minor leachate seepage	Dust and Soil Contamination	Geoaccumulation Index	Low Risk (Pb = 4.6%)
Santa Rita Municipal Dumpsite, Western Samar	Cd, Pb, Ni	Cd: 1–3 Pb: 50–300 Ni: 30–75	Domestic waste, biodegradable waste leachate	Soil Pollution	Two-way analysis of variance (ANOVA)	Low Risk (Pb = 1.23%)
Manila Dumpsite, Philippines	Cu, Zn, Cd, Pb	Cu: 100–150 Zn: 200–300 Cd: 1–3 Pb: 50–300	Urban solid waste, industrial waste, e-waste	Air, soil pollution and contamination	Allium cepa assay	Moderate Risk (Zn = 180%)
Cebu City Sanitary Landfill	Pb, Cu, Cd, Cr, Hg	Pb: 50–300 Cu: 100–150 Cd: 1–3 Cr: 100–300 Hg: 1–2	Landfill leachate, liquid waste effluents	Soil Contamination	Risk Quotient (RQ)	Low Risk (<1%)
Iligan City Dumpsite, Mindanao	As, Cr	As: 20–30 Cr: 100–300	Industrial residues, waste leachate	Soil Contamination	Geoaccumulation Index, Potential ecological risk (PERI)	Moderate Risk (As = 143%)

Table 5 shows the environmental risks of heavy metal contamination in soils collected from different dumpsites in the Philippines. The table indicates that there is a possibility of ecological risks in different environments due to the presence of various types of toxic metals, including lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), and zinc (Zn), which might be present in soils collected from different dumpsites in the country. The presence of these metals is usually attributed to processes of waste decomposition, disposal of electronic wastes, as well as mixed municipal solid wastes. Potential ecological risk (PERI) is an ecological risk factor proposed by Hakanson (1980) to quantify the ecological risk potential for a contaminant like heavy metal. The potential ecological risk index (PERI), developed by Hakanson (1980), was used to assess the negative effects of pollutants on the environment and individuals (Manupac et al., 2025).

The presence of heavy metals in the soil surrounding the dumpsites can have significant effects on the quality of the soil and the stability of the environment. Heavy metal inputs into soils, which are eventually taken up by plants, can be transferred throughout the ecosystem via food-chain transfer and other ecological mechanisms, resulting in human and/or ecosystem risks (Gabiana et al., 2017). For example, the presence of high concentrations of cadmium and lead in the soil is often associated with the inhibition of microbial processes, the

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reduction of fertility, and the inhibition of plant growth. Moreover, the presence of these materials in the soil can be transferred to the plants in the surroundings, thereby enabling the spread of the heavy metals into the crops and the subsequent transfer of these materials into the food chain. Navarrete et al. (2017) argued that the quantification of heavy metals in soils must be included in the assessment of environmental quality because it can reveal potential risks, whether of the long-term plant nutrient deficiency or the unacceptable levels (i.e., toxicity) of heavy metals in soils and plants.

The results of the analysis of the risks associated with the contamination of the environment due to the presence of heavy metals in the soil samples obtained from the various dumpsites and waste disposal sites in the Philippines were based on the assessment of the ecological risks using various pollution indicators. For example, the results of the analysis of the ecological risks in certain locations were categorized as moderate and high due to the presence of certain heavy metals in the environment. It poses a severe environmental risk due to its continued usage in every part of the world due to the abundance of gasoline, industrial processes, lead-based painting, lead-containing pipes, and lead-acid batteries (Varona et al., 2022).

The ecological risks of heavy metal contamination in dumpsite environments in the Philippines, as well as in different parts of the world, are of serious concern, especially in those dumpsites located in residential communities, agricultural, or water environments. Heavy metals such as As and Cr in dumpsites and their toxic nature and persistence in the environment further raise environmental concerns (Bacosa et al., 2025). The ecological risks of heavy metal contamination in dumpsite environments in the country highlight the need to improve the management of wastes in order to prevent ecological risks of contamination in soil environments. These findings underscore the diverse contamination profiles of heavy metals in different regions, emphasizing the need for targeted environmental management strategies (Manupac et al., 2025).

LEGEND:
Percentage Exceedance = (Measured Concentration / Soil Standard) × 100
High Risk = percentage exceedance ***>200%,*** *indicating strong evidence of environmental and ecological risk*
Moderate Risk = percentage exceedance between ***101% and 200%***, *indicating potential environmental risk*
Low Risk = percentage exceedance ***≤100%*** *indicating minimal or no significant environmental risk*

A. Risk Level

Significant environmental risks associated with heavy metal contamination in Philippine dumpsites, as shown in Table 5, range from high to low risk levels based on WHO/FAO/USEPA soil standards. The high risks found in Smokey Mountain, for instance, include high levels of lead at 366% via PERI, which result from leachate and residues of e-waste and municipal waste, coupled with open burning. Moderate risks, on the other hand, were found in Payatas, with 180% PLI from household hazardous waste, batteries, and e-waste; in Carmona, with 190% Ni via geoaccumulation, enrichment factor, and PERI from leachate; in Manila, with 180% Zn via Allium cepa assay from urban and industrial waste; and in Iligan, with 143% As via PERI and geoaccumulation from residues of industrial waste.

Low risks are found in Bagong Silang, with a geoaccumulation value of 4.6% for Pb, originating from mixed municipal waste; Santa Rita, with an ANOVA value of 1.23% for Pb originating from domestic/biodegradable leachate; and Cebu City Sanitary Landfill, with an RQ value < 1% for heavy metals originating from landfill effluents. The high concentration of heavy metals, including Pb, Ni, Zn, and As, has exceeded the threshold levels due to the decomposition of waste, as confirmed by the PERI, PLI, and geoaccumulation methods, which have damaged the ecosystem through soil degradation, loss of fertility, inhibition of microorganisms, bioaccumulation, and the food chain, as well as the crops around the residential areas.

The worst cases of risks associated with the proximity of mixed waste can be seen at the urban dumpsites, including the Smokey Mountain dumpsite, while the dumpsites with strong influence from industries, including Carmona, require specific interventions. These cases require site-specific actions, as mentioned in RA 9003, including monitoring, which is beyond the simple methods of ANOVA and RQ, due to the high levels of PERI, which exceed 200% as well as the balance of the ecosystem.

B. Causes

The environmental risks associated with heavy metal pollution in Philippine dumpsites are primarily driven by human activities, particularly poor waste management practices. Municipal solid waste, e-waste residues, and

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open burning significantly affect sites such as Smokey Mountain and Payatas Dumpsite, releasing hazardous metals like lead (Pb) and cadmium (Cd) into the soil. Similarly, the Carmona Sanitary Landfill receives industrial waste and landfill leachate, contributing to elevated concentrations of nickel (Ni) and other toxic elements. Additional sources such as household hazardous waste, batteries, and mixed municipal refuse further enhance the movement of contaminants through soil and vegetation systems.
Environmental processes also play a crucial role in the dispersion and persistence of heavy metals. Leachate seepage, soil contamination, and air–soil interactions facilitate the spread of pollutants beyond the original disposal sites. In areas like Manila Dumpsite, contamination is intensified by the combination of urban and industrial waste, while industrial residues significantly affect locations such as Iligan City Dumpsite. These processes, coupled with inadequate waste segregation and disposal practices, lead to the accumulation and long-term persistence of heavy metals in soil environments.
As a result, the continuous buildup of these toxic metals poses serious ecological and environmental concerns. Heavy metals can degrade soil quality, disrupt microbial activity, and reduce soil fertility, ultimately affecting plant growth and productivity. Moreover, their ability to enter the food chain through plant uptake increases the risk of human exposure and long-term health effects. These conditions highlight the importance of improving waste management systems and implementing effective remediation strategies to reduce the environmental risks associated with heavy metal contamination.

C. Effects

The presence of heavy metals in soils surrounding dumpsites poses significant ecological and human health risks. High and moderate risk levels observed in sites such as Smokey Mountain and Payatas Dumpsite indicate severe contamination that can degrade soil quality, reduce fertility, and inhibit plant growth. Toxic metals such as lead (Pb), cadmium (Cd), and chromium (Cr) can disrupt microbial activity, resulting in impaired nutrient cycling and long-term soil degradation.
In addition, these contaminants can be absorbed by plants and transferred through the food chain, increasing the risk of human exposure. Crops grown in contaminated soils may accumulate heavy metals, which can eventually affect human health through consumption. The persistence and bioaccumulative nature of these metals further intensify their impact, as they remain in the environment for long periods and gradually increase in concentration within organisms.
Even sites classified as low risk, such as Santa Rita Municipal Dumpsite and Cebu City Sanitary Landfill, still require continuous monitoring due to the potential for gradual accumulation over time. Overall, prolonged exposure to contaminated soils may lead to ecosystem imbalance, biodiversity loss, and heightened health risks, emphasizing the need for improved waste management practices and effective environmental remediation strategies.

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CONCLUSION

The researchers conducted a comprehensive analysis of the outcomes from eight distinct studies concerning soil contamination in proximity to landfills located in the Philippines. The studied dumpsites encompassed renowned locations such as Payatas, Smoky Mountain, and Cebu City Sanitary Landfill, among other prominent sites within the Philippines. The investigations revealed that the soil exhibited significant concentrations of heavy metals. Specifically, the level of lead attained a concentration of 1200 mg/kg. Similarly, the chromium concentration was recorded at 1480 mg/kg. These concentrations of heavy metals frequently surpassed the permissible limits established by the Department of Environment and Natural Resources, the Food and Agriculture Organization, and the World Health Organization.

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Waste from the production of harmful substances derived from various materials, including kitchen waste, obsolete waste, old electronic devices, equipment, expired batteries, leftover residual paints, industrial scrap, waste and medical waste. This waste generates hazardous substances. These dangerous substances can infiltrate into the soil. It is important to differentiate whether a distinction should be made between open dumpsites and landfills; the former liners lacked the containing liners to prevent leaching of waste into the ground. Subsequent to groundwater rainfall acts as a medium for transporting these substances into the broader wider environment. Humans can encounter people who may come into contact with these hazardous substances through multiple exposure pathways, including the consumption of food cultivated grown in contaminated soil, inhalation of dust containing these contaminants, or the ingestion of tainted contaminated water. The ecological environmental integrity of the environment is also compromised at risk. An increased level of potential environmental risk is observed in the areas around the Smoky Mountains, with similar increases in geoaccumulation indices. The results of the pollution load index from Payatas show alarming metal concentrations. The presence of high metal concentrations in the soil is a harmful condition which may threaten flora and fauna and disturb the ecological balance. In addition, heavy metals tend to migrate into adjacent streams and lakes.

Researchers have identified certain patterns in the locations they've studied. Urban areas characterised by electronic waste disposal, such as Payatas and Smoky Mountain, have had high levels of lead and cadmium. Conversely, areas such as Carmona have shown higher concentrations of chromium and nickel. Santa Rita reflected the general prevalence of metal concentrations throughout the world. However, researchers acknowledged that there is a considerable gap in the knowledge on the mechanisms by which heavy metals enter deeper soil strata and their long-term residence. In addition, there is still insufficient understanding of how metal concentrations in soil and the surrounding environment affect the bioaccumulation of these substances by living organisms. Long-term monitoring of these sites is lacking and there is a lack of effective methodologies to assess the impact on the environment. Individuals residing in low-income communities are disproportionately affected by the challenges associated with waste collection. These research deficiencies present opportunities for further studies, including the mapping of pollution sources and monitoring human exposure, conducting investigations of waste in controlled environments, and developing improved methodologies for differentiating between anthropogenic contaminants and naturally occurring soil substances. The Philippines is experiencing an increase in waste production, necessitating urgent remedial actions. In order to advance, the nation must adhere to the legal framework established by Republic Act 9003, which mandates the closure of existing dumpsites and the establishment of new, safer landfill sites.

In regions where soil contamination is prevalent, it is imperative to conduct thorough environmental assessments. The Department of Environment and Natural Resources is tasked with evaluating areas identified as high-risk, while local governments must enhance their waste management systems. It should be facilitated for individuals to effectively segregate their waste, and electronic waste must be securely stored. Furthermore, the government should advocate for remediation methods, such as phytoremediation, to effectively extract harmful contaminants from the soil. Initiatives have been implemented in certain locales, such as Bagong Silang. Health clinics within the community should routinely monitor the health status of residents residing in high-risk zones, and farmers should receive timely warnings and instructions regarding potential soil contamination that may impact their agricultural production. Through collaborative efforts, the community can mitigate their exposure to hazardous substances. The Philippines must enhance its waste management practices and safeguard the environment to foster sustainable growth.

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