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Existing land use and extent of lead (Pb) contamination in the grazing food chain of the closed Carmona sanitary landfill in the Philippines

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ABSTRACT

The sanitary landfill located in Carmona, Cavite, Philippines operated from April 30, 1993, to March 31, 1998, is now closed and abandoned. Abandoning sanitary landfill without proper remediation and rehabilitation efforts pose risks to both humans and the environment. At present, only grasses and shrubs thrive in the area, and no rehabilitation efforts were made in this area. The closed landfill is nonfunctional except to the nearby inhabitants who use the abundant vegetation for grazing of animals such as cows, goats, and chicken. The possibility of heavy metal accumulation in the area is expected but is yet to determine. Likewise, its utilization into productive use remains a question. Hence, this study was conducted to investigate the existing land use, extent of lead (Pb) contamination in the soil and the grazing food chain of the area and, recommend the most practical and appropriate use of the place. Understanding the dangers it can bring to nearby communities can be used as a reference for putting forward plans and policies to protect people's welfare. Although the soil has an average of 1.36 ppm that is within the standard set by the US EPA, the level of Pb observed in plants, insects and chicken's liver are unsafe as compared to the Tolerable Daily Intake (TDI) for Pb set by the US FDA. The soil can be converted into non-play areas such as a recreational park, but the planting of edible crops and fruit-bearing trees is not recommended.

1. Introduction

Sanitary landfill is a waste disposal site designed, constructed, operated and maintained in a manner that exerts engineering control over significant potential environmental impacts arising from the development and operation of the facility [1]. Construction of sanitary landfills should be located on geologically suitable sites away from lakes, rivers, floodplains, and aquifer recharge zones [2]. Development of such should meet an impact mitigation plan from the first stage of construction up to abandonment phase. Failure to follow planned mitigation measures usually result in the degradation of the environment and consequently affect the human health of nearby communities in the area. A study on heavy metal contamination of foods in a refuse dumpsite in Akwa, Southeastern Nigeria, revealed that dumpsites could substantially contaminate agricultural produce [3].

The Carmona sanitary landfill owned by Metropolitan Manila Development Authority (MMDA), located at Sitio Paligawang Matanda, Barangay Lantic, Carmona, Cavite in the Philippines had been in operation from April 30, 1993, to March 31, 1998. It received over 23 million cubic meters of wastes, which generated leachates and continuously contaminated the groundwater due to treatment system failure [4]. A wide range of unsorted refuses such as household products, electronic equipment, paints, chemicals, and others have been dumped in the landfill, which is why large quantities of heavy metals including Pb are expected to be contained.

The closed sanitary landfill at present is devoted to grasses and shrub growth. It has not utilized except by the nearby community who used the abundant vegetation as a grazing area for animals such as cattle, goat, and chicken. The possibility of heavy metal contamination in the area is expected but undetermined. As such, the conversion of the area to productive land-use poses a problem and need to be determined.

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

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this heavy metal may cause serious problems [5]. These heavy metals can be of great concern to biological organisms since they can react with many chemicals essential for biological processes [6]. Plants absorb the Pb through their roots. Heavy metals tend to concentrate on leaves and the outer part of roots. When contaminated plants are eaten, a fraction of Pb entering the body will be absorbed into the bloodstream and will accumulate in body tissues, primarily in the blood, liver, kidney, and bones. Pb contamination in humans affects a wide range of sublethal effects; higher level could cause death [7]. A study on accumulation of cadmium (Cd) and Pb to cabbage, carrots and lettuce [8], heavy metals uptake of lettuce and mustard rape in sewage sludge and effluent contaminated soil [9] and other several studies such as the uptake of heavy metals by a variety of plants in embanked floodplains of the rivers in Rhine and Meuse [10], contamination in earthworms, snails, spiders and insects [11, 12, 13], and assessments of the risk of contaminant accumulation in mammals and birds [14, 15, 16] reinforce the need to investigate the contamination of heavy metal in the present food chain of a closed landfill. More so, there is a growing concern to evaluate and assess food safety and identify the consequences of the contamination of the food chain [17].

This study could help identify if the place is contaminated with a heavy metal such as Pb and determine the most practical and suitable land use for the area. Converting abandoned landfills to more productive use will be of great help to the Local Government Unit of Carmona, Cavite, in the Philippines. Also, this study was performed to determine the concentration of heavy metal level in the grazing food chain of the study site. Hence, this study aimed to assess the existing land-use and extent of Pb contamination in the grazing food chain in the closed sanitary landfill in Carmona, Cavite. Specifically, it sought to determine the current land use of the study site; assess the extent of Pb contamination in the grazing food chain; and, recommend the most practical and appropriate land use of the area.

2. Materials and methods

2.1. The study site

The study was conducted in Sitio Paligawang Matanda, Brgy. Lantic, Carmona, Cavite. It lies geographically at 14° 15′ 53″ N and 121° 01′ 51″ E and bounded by Silang, Cavite and Sta Rosa, Laguna (Fig. 1). The site is in a hilly agricultural area where the soil is predominantly clayey with silt or gravel to bedrock. Its bedrock is sandy tuff (adobe). The average depth of overburden soil is 1.60 m with a minimum of 1.5 m and a maximum of 2.80 m. The landfill consists of different phases. Phase I is the operational interim landfill with an average dimension of 500 × 22 m high, having a total compacted waste capacity of about 88 percent (968,000 m^3) and total soil cover which is about 12 percent (132,000 m^3) for its service life of three months. Phase II was subdivided into two areas: Phase IIA and Phase IIB. Phase IIA measures 4.4 ha which was used for landfilling operations with an average volume of waste of about 72,424.20 m^3 at an average disposal rate of 7,000 m^3 per day for its service life of five months. Phase IIB has an area of 8.9 ha for its service life of five months at 7,000 m^3 of waste per day. Phase IV has an average dimension of about 490 m × 30 m high and a total volume of wastes dumped of 2,849,039 m^3 [18].

The closed Carmona landfill located at Sitio Paligawang Matanda, Brgy. Lantic, Carmona, Cavite is bounded by various spring wells. The area is indicated by the bold solid line which follows the streams along its north and south limits. The site is 1,320 m long x 820 m wide at the east end, and 200 m wide at the west end. The site has a definite slope downward from west to east as well as steep slopes towards the two streams/creeks along the north and south borders. The highest elevation is 200 m above sea level while the lowest is 110 m. The site is characterized by a series of low hills between the two streams/creeks with minimal level areas. Land of about two (2) hectares was devoted to the

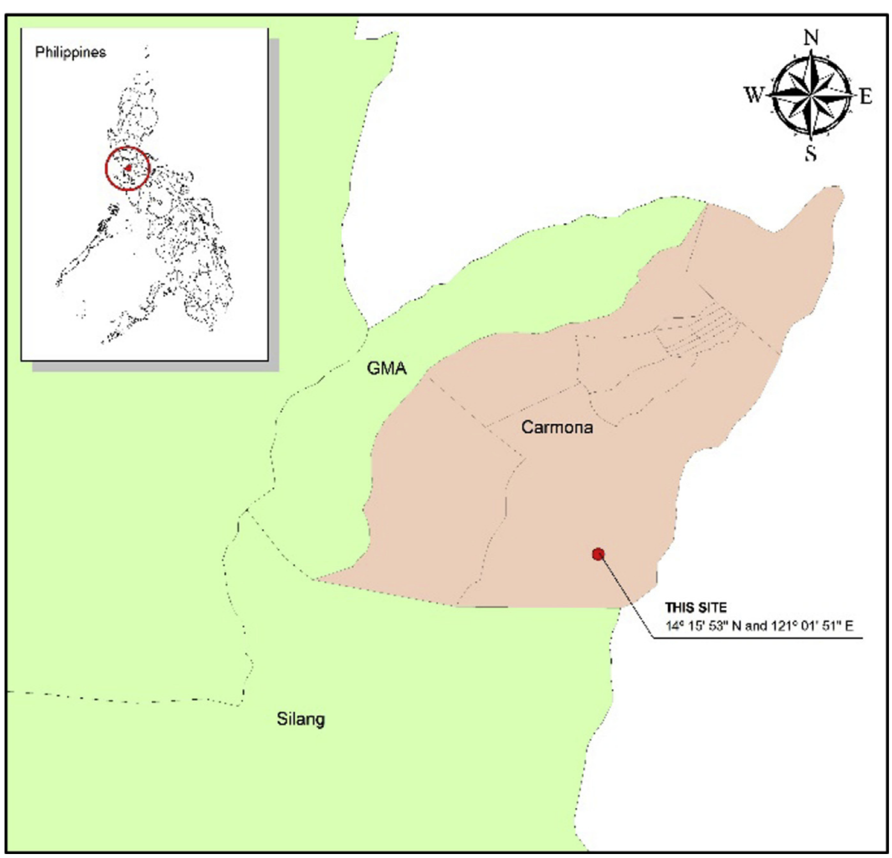

Fig. 1. Location site of the study area.

resident's resettlement area [19].

2.2. Bio-physical description and identification of land use of the area

The biological and physical characteristics of the area were described through a transect walk. These were supplemented with the municipal and barangay profiles of the place. The one (1) km transect line was laid in south and north direction. The transect line was divided into five parts measuring 200 m. Flags were used as an indicator of the stations. Only the flora and fauna species and things observed within the transect line were listed.

2.3. Soil, plant, insect and chicken liver sampling

The composite soil sample was gathered using a shovel. The samples were obtained from 15 – 20 cm below the soil surface. Three (3) soil samples placed in a flexible plastic bag were taken from the composite soil sample for analysis. Similarly, a composite weed sample was taken. Insects, on the other hand, were gathered through insect nets. Three (3) 50–100 g of weed and insects samples placed in a flexible plastic bag were taken from the composite weed and insect sample. Insects samples were frozen to preserve its biophysical condition.

On the other hand, six chickens known to forage for food in the area were bought from the residents. A composite liver sample was gathered from the liver obtained from the chickens. Three (3) 50–100 g liver samples placed in a zipper seal plastic were taken from the composite sample and frozen. The liver was chosen because Pb is involved in bio-accumulation in biological organisms' tissues and organs, and mainly in the liver, gizzards, and bones that lead to several diseases [7].

The assessment for Pb contamination in each sample was limited to three (3) samples per soil, weeds, insects and chicken livers primarily due to the cost of sample analysis in the laboratory.

2.4. Soil, plant, insect and chicken liver analysis

The soil, weed, insect, and liver samples were sent to JEFCOR laboratories Inc., Philippines for chemical analysis. Preparation of samples was done through dry ash technique and analyzed through Lead-Flame Atomic Absorption Spectroscopy test method. This method plays a vital role due to its defined advantages such as significant accuracy, excellent sensitivity and detection limits than other methods [20].

2.5. Data analysis

An independent sample t-Test was conducted to compare the level of Pb detected in the samples of soil and chickens' livers against the set standard in the soil in non-play areas and tolerable daily intake for different age groups as established by US Environmental Protection Agency (EPA) and US Food and Drugs Authority (FDA) respectively.

3. Results and discussion

3.1. Biophysical profile of the study area

The topography of the study site is hilly and consisted mainly of plants dominated by *Imperata cylindrica, Achyrantes aspera, Paspalum conjugatum, Ludwigia hyssopifolia, Lantana camara, Momordica charantia L. var. abbreviate Seringe,* and *Crotalaria mucronata.* The abundance and growth of such plants showed the ability of the natural ecosystem to recover after disturbance. No trees were observed thriving in the former landfill, but few were seen flourishing along the nearby community settlement. There were numerous depressions and half covered refuses along the transect line. Paved road, street lights, and uncovered gas vents were also observed along the transect line.

3.2. Existing land-use and existing food chain of the area

Field observation revealed that the former landfill became a grazing area for the community's domesticated animals such as jungle fowl or native chickens (*Gallus gallus*), cows (*Bos taurus*) and goats (*Capra aegagrus hircus*). These farm animals enormously graze on the study site. Likewise, this indicates that that the area has a grazing type food chain because vegetation grew abundantly and foraged by the various consumer. More so, a collection of wild bitter melon (*Momordica charantia L. var. abbreviate Seringe*) by the community was also observed. The said plants are sold to nearby markets according to the residents.

3.3. Soil contamination level

The Pb content of soil samples analyzed in the JEFCOR laboratory, Inc is presented in Table 1. According to US EPA as cited by the Agency for Toxic Substances and Disease Registry (ATSDR) of the US Department of Health [21] Pb soil standard for non-play areas should not exceed 1,200 ppm. Soil analysis revealed an average of 1.36 ppm which is within the standard set by EPA. The independent sample t-Test analysis showed a significant difference between the Pb level present in the soil samples and the standard set by the US EPA. It can be inferred that the quality of soil concerning Pb contamination is suitable for non-play areas. Therefore, the area could be converted to any purposes such as a recreational park, playground, among others. However, the area should be treated for other heavy metals and toxic chemicals that may be present in the soil.

3.4. Plant, insect and chicken's liver contamination level

Laboratory tests revealed an average Pb content in plants at 0.20 ppm (Table 2). Since Pb has a high affinity to life form, it tends to bio-accumulate to plants. The presence of Pb in plants indicates that planting of edible crops in the area is not advised. This also supports the result of a study of the accumulation of some heavy metals in plants and soils in which plants absorbed Pb on its different parts from the soil [22, 23]. Similarly, farm animals are not encouraged to graze to avoid possible transmission of Pb to humans. Plants in the area pose risks and should be remediated.

Insects are typically the most dominant faunal group of invertebrates and are widely used in biomonitoring and bioassessment programs worldwide [24]. Insects belong to the second trophic level of the grazing food chain. For this reason, Pb is expected to accumulate in their body. This is possible because they feed on contaminated plants and insects [24]. Laboratory analysis for insects revealed an average Pb content at 0.05 ppm (Table 2). This confirmed that plant consumers absorb Pb.

Similarly, predators of these insects will be contaminated, and other higher trophic levels will most likely experience similar contamination.

The bioaccumulation process occurs in all living organisms as a result

Table 1
Level of Pb in soil samples and its significant difference against the US EPA standard in the soil for the non-play area.

Medium	Average Pb level (ppm)	Standard (ppm)	t stat	P value
Soil (Sample 1)	0.82	1,200	-4150.29	0.000 s
Soil (Sample 2)	1.44			
Soil (Sample 3)	1.81			
Average	1.36			

Table 2
The average level of Pb in weeds, insects and chicken's liver.

Medium	Average Pb level (ppm)
Plant	0.20
Insect	0.05
Liver	0.08

of exposure to metals in food and the environment, including food animals such as poultry, poultry, fish and humans [25, 26]. Chicken belongs to the third trophic level because it consumes both insects, and plants as well as its other parts such as seeds and roots. Sampled chickens were found roaming freely and feeding in the area. Laboratory analysis revealed an average Pb level of 0.08 ppm in the chicken's liver (Table 2). It also confirmed the study that heavy metals tend to accumulate in higher trophic organisms [26].

The analyzed level of Pb in the livers of the chicken is not suitable to be eaten by almost all age groups based on US FDA tolerable daily intake for Pb. The independent sample t-Test analysis revealed that there is a significant difference between the Pb level present in the liver samples and the set standard, except for the adults (Table 3). These results suggest that the chicken's liver is contaminated with Pb and is strictly prohibited to most age groups, to include the adults, despite the low P-value result. Also, there is a possibility that other parts of the chicken are contaminated with Pb. Hence a separate study can be done to detect if Pb is present in other parts of the chicken. Likewise, animals aside from chicken are probably contaminated with Pb and hence should not be eaten as well. It can be perceived that raising farm animals should not be engaged in the area. Likewise, farm animals found grazing in the area must not be eaten or sold to nearby communities, as it poses a health risk to those who will consume them.

Table 3
The average level of Pb in chicken's liver samples and its significant difference against US FDA Tolerable Daily Intake (TDI) for Pb in different age groups.

Medium	Pb level (ppm)	Standard (ppm)	t stat	P value
Liver (Sample 1)	0.10	0.006 (0–6 y/o)	7.40	0.02s
Liver (Sample 2)	0.07	0.015 (7-young adults)	6.50	0.02s
Liver (Sample 3)	0.07	0.025 (pregnant women)	5.5	0.03s
Average	0.08	0.075 (adults)	0.50	0.67ns

3.5. *Summary of findings*

Pb contaminated the grazing food chain in the study area. Results show that there is an average Pb contamination in plants, insects, chicken's liver at 0.20 ppm, 0.05 ppm and 0.08 ppm respectively. These findings also strongly indicate possible Pb contamination in other untested farm animals such as goats and cows. Mean Pb level in soil at 1.36 ppm is within the standard of the US EPA for non-play areas which indicates suitability conversion to land uses such as recreational park or playground.

3.6. *Possible land-use for the closed landfill of Carmona*

Removal of dangerous substances such as heavy metals should be employed in the abandoned landfill before conversion into other land use. Since Pb, once in the environment, a non - degradable and persistent metal, environmental regulations are required to prevent further contamination of Pb [4]. Aside from non-play purposes, the results of the study revealed that the area could be converted into other land use. However, there are still risks if the site is converted for agriculture purposes since Pb contaminated the study area's food chain. Hence, conversion of the landfill into a park or playground planted with trees and plants that do not bear edible parts is highly recommended.

4. Conclusion

The area is highly devoted as a grazing area for animals such as *Gallus gallus sp.*, *Bos taurus*, and *Capra aegagrus hircus.* The said grazers, owned by the community, are sold to nearby markets. Grazing type food chain is the observed food chain in the area, and its different levels are contaminated with Pb. The extent of Pb contamination in the area reached the first, second and third trophic levels of the grazing type food chain. The area is suitable for conversion into a recreational park or playground, but not for the cultivation of edible crops.

The area may be converted into a recreational place. However, it should undergo either or both physicochemical or biological treatments such as conventional remediation and biological treatments before any conversion. Since results showed the presence of Pb contamination in plants, planting edible crops should not be practiced to avoid contamination of Pb in humans and prevent health degradation of consumers. It is also necessary to increase the number of samples to determine the precise level of Pb in each specimen. Farm animals such as cattle and goat should be tested to identify if Pb accumulates in their body system. Other heavy metals like cadmium and mercury should also be analyzed to assess if it also contaminates the food chain. Lastly, a policy should be crafted to prevent the people from utilizing the abandoned area for grazing and planting edible crops.

Declarations

Author contribution statement

Richard Dein A. Altarez: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Noel A. Sedigo: Conceived and designed the experiments; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

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