Impacts of Waste Dumping on Pomona Medium Sand Clay Loam Soils and Surface Water Quality in Harare, Zimbabwe

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ABSTRACT

Municipal and industrial waste generated in Harare is dumped at Pomona dumpsite which is not lined to prevent seepage. The concentration of various heavy metals (Lead (Pb), Iron (Fe), Zinc (Zn), Cadmium (Cd) and Chromium (Cr)) in soils and surface water was measured with a view of determining potential ecological and public health risks. Soil samples were collected from above dump site (control), within the dumpsite and below dumpsite (down slope) at depths of 0-5, 10-20 and 30-40 cm using an auger. Water samples were obtained from shallow dams at Pomona dumpsite. At Pomona, the soil concentrations of Fe and Pb pollutants were apparent ($P<0.05$) and surpassed the prescribed threshold limit. There was no significant difference in soil microbial biomass among treatments ($P>0.05$) at Pomona dumpsite. These results imply phyto-toxicity risk of crops cultivated within the vicinity of dumpsites and downstream due to possible bio-magnification of heavy metals in crops and their proliferation up food chain and subsequent health hazard for all living species. It was recommended that the responsible authorities must construct an engineered landfill so as to prevent further environmental contamination.

Keywords: *waste dumping, heavy metals, soil quality*

1. INTRODUCTION

Indiscriminate disposal of industrial and municipal waste can potentially contribute to elevated levels of various heavy metals (Fe, Pb, Zn Cr and Cd) in the soil environment [30, 24; 26]. These metals are known to accumulate in soil and have long persistence time through interaction with soil component and consequently enter food chain through plants or animals .Similarly, continuous disposal of these wastes and particularly in unlined surfaces can enhance their mobility at environmentally hazardous levels [26; 9]. The concentrations of heavy metals in soil and around dumps are influenced by type of wastes; topography, runoff and level of scavenging and are eventually introduced to the ecosystem through infiltration or disposal of leachates.

Common sources of heavy metal pollution include discharge from electroplating and plastic manufacturing, batteries, ceramics, light bulbs, house dust-paints chips lead foils such as wince closures, used motor oils, some inks, glass, fertilizer producing plants and wastes left after mining and metallurgical processes [26, 18, 28].

The non-degradability characteristic of heavy metals shields them from rapid detoxification and removal by metabolic activities accounting for their prolonged presence in the soil environment. Migration of contaminants from waste disposal sites to surrounding ecosystems constitutes a complex process, involving bio-physico-chemical processes and has profound influence on metal mobility and bioavailability [31]. The presence of complexing agents such as organic acids, chlorides, sulphates and carbonates along with redox potential also influence solubility [30, 6].

Heavy metal contamination can inflict multiple effects on the ecosystem [21, 29] imparting negatively on bio-physico-chemical properties of the soil. Changes in pH regime with dumping have implications on solubility and uptake of metals by plants and microorganisms. Reductions in microbial biomass with high accumulations of metal pollutants have been reported. Microbial biomass carbon is not a requirement for crop growth but has profound influence on soil processes and is an indicator of soil quality. In crop and livestock agro-ecosystems, bio-magnification potential of metal pollutants reduces their productive capacities including quality and presence major risk to humans through possible proliferation of toxic pollutants in the food chain as humans consume produce from areas contaminated and irrigated with polluted water [19, 23, 18].

In Zimbabwe the information on common values of heavy metals in soil is limited and therefore it is not possible to make an accurate assessment on soil contamination. Sound scientific assessment is therefore required to determine extend of possible soil contamination from dumpsites and delineate strategies of site remediation [13].

Several studies used the background content of heavy metals (BGV) and or uncontaminated soil as an indicator to ascertain whether or not a soil is contaminated [30, 22, 5, 17, 20, 16]. In many developing countries including Zimbabwe, this BGV has not been used.

The heavy metals under investigation are among metals considered of importance by the Global monitoring system [27]. This study was conceived to evaluate (i) the impact of dumps on the ecosystem by determining the presence and concentrations of heavy metals (Fe, Zn, Pb, Cd and Cr) around industrial and municipal solid waste dumpsite in Pomona site in Harare, Zimbabwe. The specific objectives were to (ii) determine variation in levels of heavy metals from the surface to a depth of 40 cm at each dump site; (iii) assess the impact of heavy metal concentration on leachates (iv) and assess the effect of heavy metals on soil microbial biomass. In the current study the BGV is based on heavy metal concentrations from an area above the dumpsite (control) which was isolated from waste contamination.

2. MATERIALS AND METHODS

2.1 Study Site

Pomona dumpsite is located between 17°43'42"S and 31°4'33"E (Figure 1). Pomona is about 9 km north from Harare city centre. It receives more than 700 tonnes of solid waste daily and dumping has occurred for nearly 12 years. There is no liquid waste dumped at Pomona. Pomona dumpsite sits on red clay soils (Chromic Luvisol [12]).

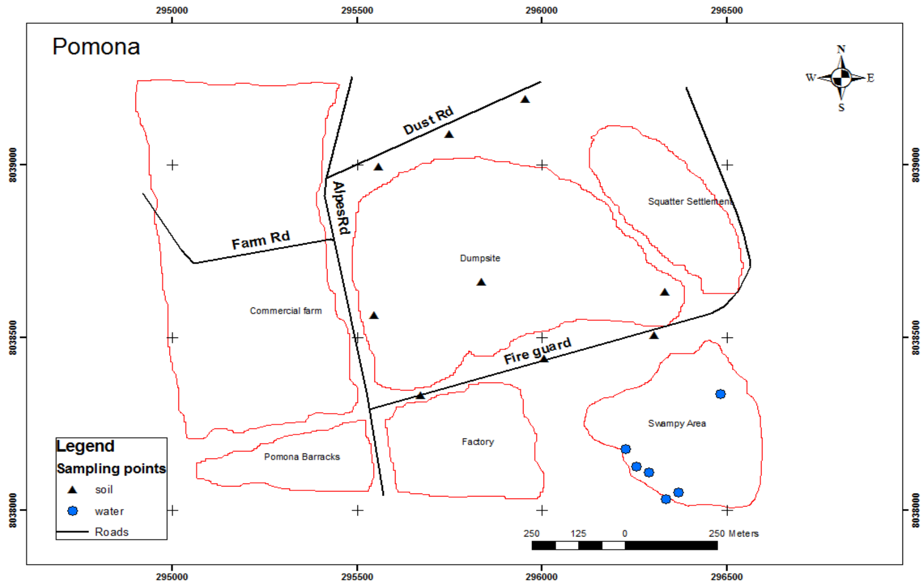

Fig 1: Pomona dumpsite sketch map

2.2 Sample Preparation

Soil samples were obtained using soil augers in triplicate at depths of 0-5, 10-20 and 30-40 cm. Soil samples for chemical analysis were air-dried, ground and sieved through a 2 mm sieve and weighed for different analysis. Soil samples for microbial analysis were kept at temperatures below 4°C prior to analysis within four weeks after sampling.

Water samples were collected from ponds and shallow wells into 2 litre plastic containers held horizontally in the water and half submerged to collect water. Surface water samples from the shallow ponds and trenches were immediately transported to the laboratory for storage in a cold room before analysis. The samples were filtered through a whatman No. 41 filter paper and were preserved with 2 ml nitric acid to prevent the precipitation of metals. They were analyzed using the atomic absorption spectrometer.

2.3 Soil Sample Analysis

The hydrometer method as described by [2] was used to measure proportions of the various sizes of soil particles. Heavy metal (Pb, Cr, Cd, Zn and Fe) analysis was done in volumetric flasks using nitric acid (HNO_3) digestion method as described by [1]. Soil pH was measured in water on 2.5:1 water to soil suspension ratio as described by [2]. Soil microbial activity was determined by the chloroform fumigation / extraction method as described by [2].

2.4 Water Sample Analysis

Surface water samples as a result of surface runoff during the rainy season were collected from sampling sites (shallow ponds) which were downslope of the dumpsite at 534 m. To ensure the removal of organic impurities from the samples and thus prevent interference in analysis, the samples were digested with concentrated nitric acid. Ten milliliters (10 ml) of nitric acid was added to 50 ml of water in a 250 ml conical flask. The mixture was evaporated to half its volume on a hot plate after which it was allowed to cool and then filtered. The digested water samples were analyzed for the presence of Fe, Cd, Zn, Cr and Pb using an atomic absorption spectrophotometer [4].

2.5 Statistical Analysis

Analysis of variance (ANOVA) using Genstat 8 statistical package was used to check the effect of treatments (upslope, midslope and lower slope) on soil properties. Correlation coefficients were calculated to show relationship between heavy metals and the microbial biomass carbon. Data were treated independently between the two sites and all the analyses were done. Least significant difference (LSD) was used to separate treatment means that were significantly different ($P<0.05$). The graphs were plotted using Sigma plot statistical package from the averages obtained during statistical analysis.

3. RESULTS AND DISCUSSION

3.1 Soil texture at Pomona dumpsite soil

Textural analysis done showed that the soils at Pomona are medium sand clay loam (mSaCL) (Table 1).

Table 1: Soil texture of Pomona dumpsite soil

Position	Depth	% +Si	Clay	%Clay	%Silt	%cSa	%mSa	%fSa
Above dumpsite	0-5cm	33		24	9	34.1	16.2	25.7
	10-20cm	38		28	10	27.4	14.9	17.8
	30-40cm	54		40	14	21.9	12.8	11.3
Dump	0-5cm	20		11	9	72.1	8.8	10.4
	10-20cm	28		16	12	61.4	7.9	2.7
	30-40cm	32		16	16	45.3	4.6	6.7
Below dumpsite	0-5cm	29		17	12	23.7	21.6	27.8
	10-20cm	41		24	17	18.8	19.5	20.7
	30-40cm	52		31	21	15.2	13.5	16.2

3.2 Heavy Metal Concentrations in Soil

Iron (Fe) concentrations in soil ranged from 221.1mg/kg in the control to 432.5 mg/kg in the dump soil (Fig 2). Fe concentration at the dump were significantly ($P<0.05$) high against the Upslope of dump treatment, however dump concentrations were not significantly ($P>0.05$) different with the Lower slope of dump treatment. Iron concentrations at Pomona dumpsite can be attributed to the effect of dumping as is shown by the graphical trend (Fig. 2).

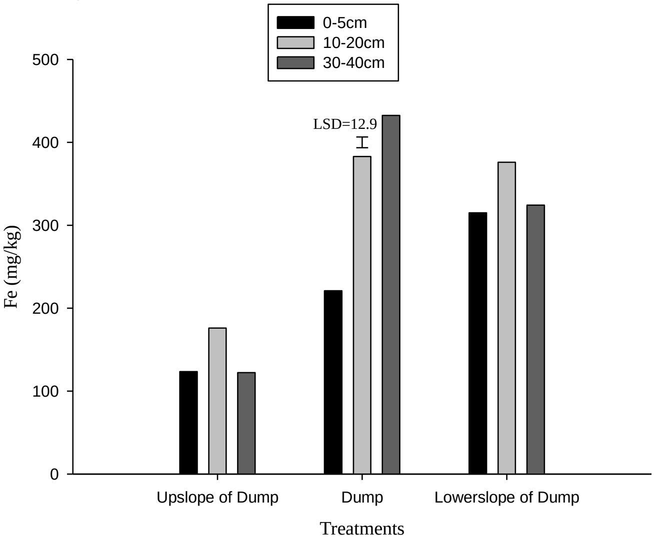

Fig 2: Iron concentration in soil at Pomona dumpsite

There was no significant differences ($P>0.05$) of Zn concentration among treatments. These results concur with other studies [28] that observed that Zn is typically a high concentration pollutant of industrial waste. At Pomona dumpsite, mainly municipal and domestic wastes constitute a major component of the disposed waste and hence low concentrations were anticipated.

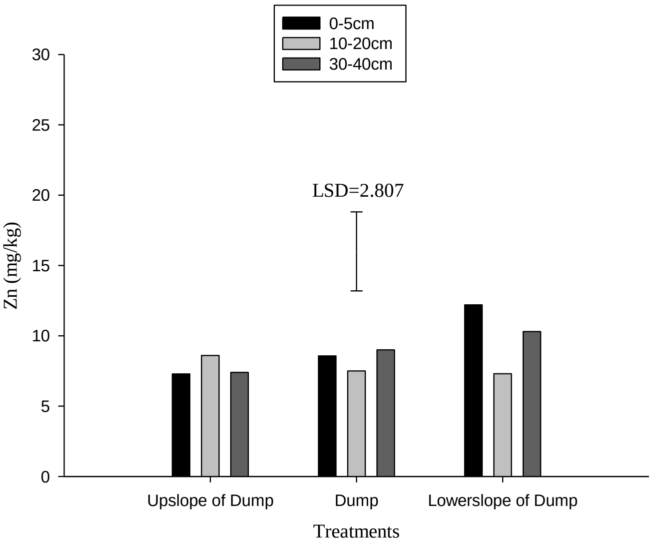

Fig 3: Zinc concentration in soil at Pomona dumpsite

Statistically, Cr levels are lessly influenced by dumping. At Pomona dumpsite, there was no significant treatment difference ($P>0.05$). However, whilst Cr levels across depths currently fall within the maximum permissible level, [7], there is a potential to increase the build up and accumulation of metal chemical contaminant if proper disposal of industrial wastes is not immediately affected.

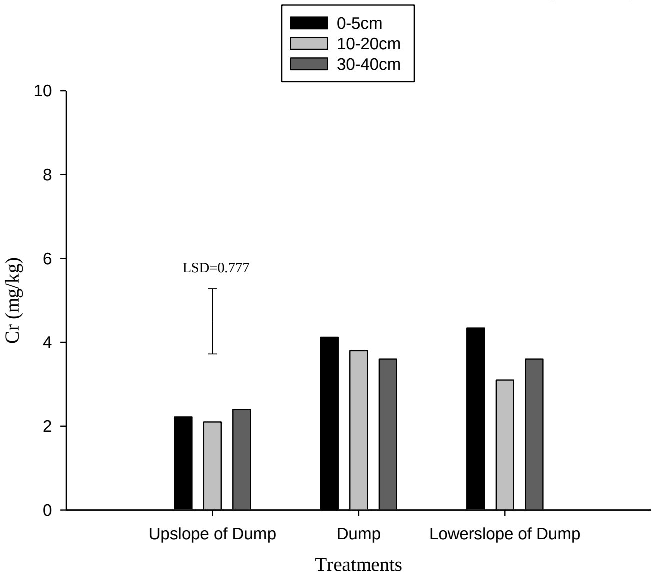

Fig 4: Chromium concentration in soil at Pomona dumpsite

Lead concentrations were increasing as one move from upslope to downslope. At Pomona dumpsite there was significant effect ($P<0.05$) of treatments. At the dump, increase in Pb levels can be attributed to dumping; however increase in the Lower slope of dump treatment can be attributed to lateral migration of the metal. [26] found Pb to be very mobile with more than 50% in the non-residual fraction while 15.85-65.92% of the total extractable fraction contributed to the mobile phase. High Pb levels at Pomona may have been facilitated by large disposal of used batteries, accumulators, used plastic materials as well as used lubrication oils. Similar observations have been reported on Eyagi dumpsite in Bida, Niger State Nigeria [28]. The heavy metal enrichment exceeding the normally expected distribution values in soil give rise to concern over suitability of the soil for growing crops.

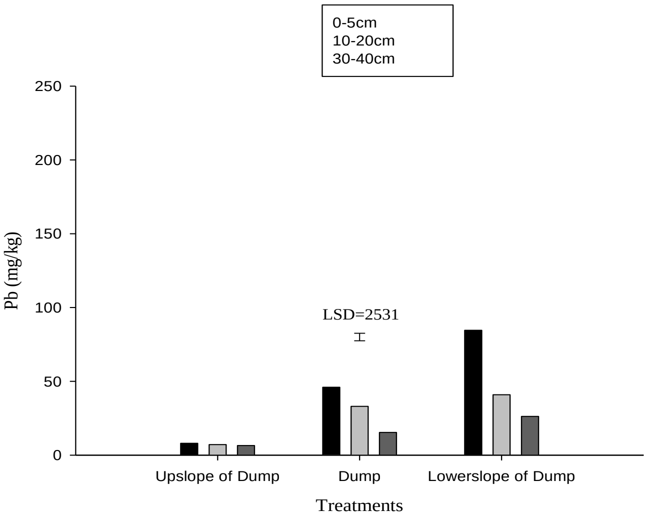

Fig 5: Lead concentration in soil at Pomona dumpsite

There was no significant difference ($P>0.05$) among treatments at Pomona dumpsite, a marked reduction in Cd concentrations in soil was observed (0.96 to 1.5 mg/kg) (Fig 6). Dumping effect was therefore not significant ($P>0.05$).

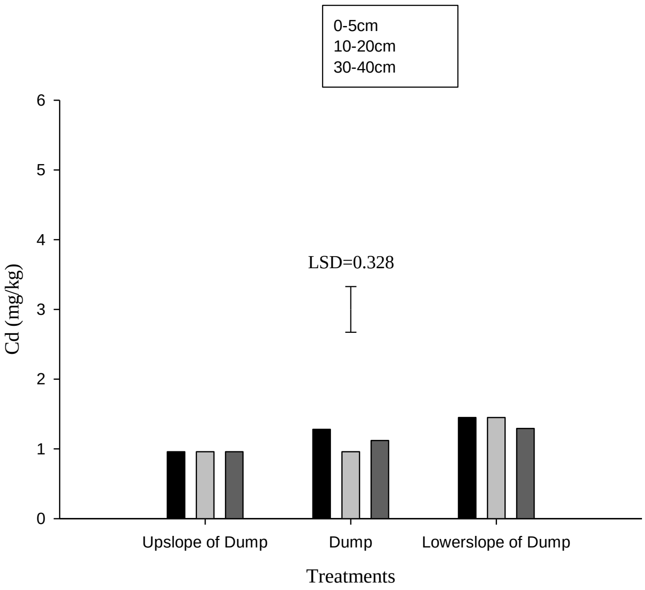

Fig 6: Cadmium concentration in soil at Pomona dumpsite

3.2 Soil pH

The pH values at Pomona were slightly lower and ranged between 6.1 to 6.6 (Fig 7).

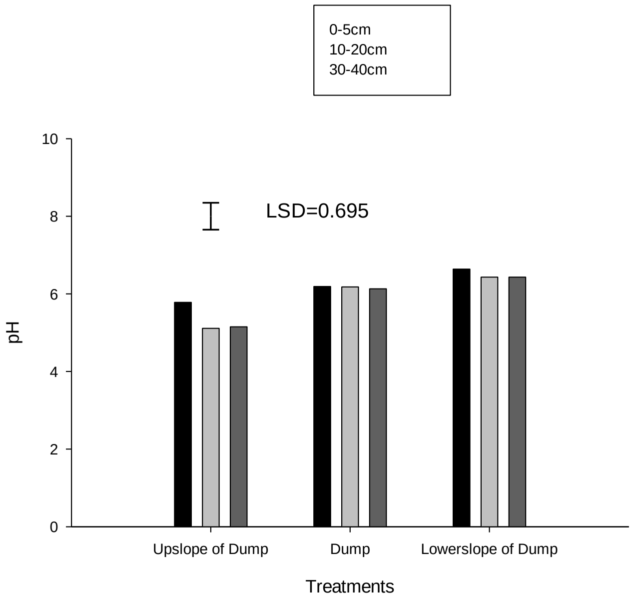

Fig 7: Soil pH level in soil at Pomona dumpsite

3.3 Soil Microbial Biomass

At Pomona, soil microbial biomass C ranged between 6.7 to 13.3 mg/kg (Fig 8). There was treatment effect on soil microbial biomass (P>0.05).

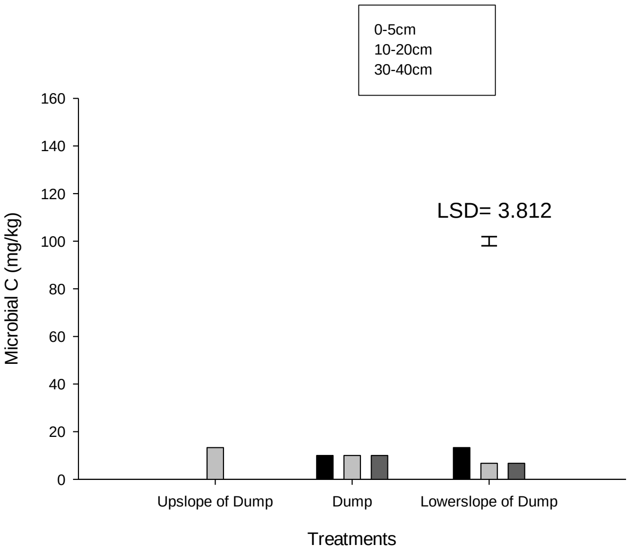

Fig 8: Soil microbial biomass carbon concentration in soil at Pomona dumpsite.

The high component of organic and plastic materials disposed at Pomona dumpsite which is naturally under medium clay loam soils, possibly resulted in soil compaction, which subsequently reduced soil microbial activity due to limited aeration and water movement. Water movement through soil pores could also have been minimized by plastic material deposits at the site accounting for low soil microbial.

However, some metals had no effect on the soil microbial activity shown by the correlation matrix. According to [14], soil microbial C has been proposed as a useful measure of soil pollution by heavy metals and a reduction in soil microbial C as a result of metal pollution has been reported from other studies [8; 11, 3]. In these studies the number of heterotrophic bacteria in the soil was affected by the introduced metal concentrations.

3.4 Surface Water Heavy Metal Concentration

Heavy metals concentration in the surface water collected from the sampling locations were analyzed and found to be in low levels (Table 2). This may be attributed to the pH and concentration of complexing agents. The concentrations of metals in surface water samples at Pomona ranged from: Fe (0.11-2.43 ppm) and Cr (0-1.08 ppm) whilst Pb; Zn and Cd were not detected (Table 2). The high degree of leachate contamination could reduce crop growth in the short to medium term as leachate strength increases [25]. Metal solubility generally decreases with increasing pH [15]. This is due to the precipitation of metal ions as insoluble hydroxides at high pH values (7.6-8.3).

Table 2: Heavy metal levels in leachates downslope of Pomona dumpsite.

	Pomona					
Sample	Fe(ppm)	Cr(ppm)	Pb(ppm)	Cd(ppm)	Zn(ppm)	pH
Pond 1	0.114±0.006	0.412±0.138	ND	ND	ND	5.64±0.34
Pond 2	0.138±0.073	ND	ND	ND	ND	6.26±0.78
Pond 3	0.646±0.343	0.936±0.546	ND	ND	ND	7.34±0.46
Pond 4	2.427±0.716	ND	ND	ND	ND	5.93±0.51
Pond 5	0.161±0.086	0.74±0.52	ND	ND	ND	6.56±0.67
Pond 6	0.128±0.093	.082±0.758	ND	ND	ND	6.42±0.18

Sedimentation of the heavy metals can also result in low metal concentration in water bodies such as ponds at Pomona dumpsite. Runoff water is the main contributor of pollution to these water bodies and only takes place during the rainy season.

4. CONCLUSION

The study revealed that disposal of industrial and municipal wastes in unlined earth surfaces contaminated the soil environment as depicted by higher and spatial variation in metal concentrations above the natural BVG in both the dump and lower slope across dump sites. Iron, Pb and Zn considerably contaminated the dumpsites with concentrations beyond threshold values. The high concentration of these metals is an indication of an occurrence of the exchangeable species of these metals in soil from dumping and has both natural and anthropogenic implications. There is a potential toxicity risk, since the exchangeable species in soil are readily soluble in water leading to surface water pollution. In rainy months, the quality of water bodies can be significantly affected.

Due to high persistence of the metal pollutants once present in the soil, the probability of their bio-magnification in agro-ecosystem products (crops and livestock) is high. This will have adverse effects on the human system by inducing long-term biochemical and toxicological effects upon proliferation through the food chain. A waste management and treatment policy is strongly recommended to the Environmental Management Agency (EMA) along with periodic monitoring of the soil environment for chemical pollutants at all industrial and municipal waste dump sites.

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