

Assessment of Heavy Metals Contamination at Cape Town Landfill Sites

Adelaja O. Osibote and Ademola M. Rabi

Abstract—Heavy metals (HM) contents of municipal solid waste (MSW) are of immense concern in their management and disposal system around the world. Landfilling (and in worse case dumping) remains the preferred disposal method for MSW in majority of Africa countries. Consequently, the HMs, also found in household, medical and industrial waste, ends up in landfills and dumpsites. Over time, if not properly managed, these metals present a contamination risk to the nearby soil, ground and surface water, as well as the biodiversity that depends on these resources; this may contaminate the food chain. This paper reported the spatial distribution of heavy metal concentrations in the topsoil from Cape Town landfill sites using the Inductively-Coupled Plasma Optical Emission Spectrometry (ICP-OES). The results show that the concentrations of the heavy metals found decreases with distance from the landfill sites except for Cd which have the concentration to be high close to the road. Recommendations on proper management and monitoring systems of the existing waste sites that will limit the exposure of the populations to these elements were made.

Index Terms—Municipal solid waste, heavy metals, leachate, cape town landfills.

I. INTRODUCTION

Heavy Metals (HM) well-known for their toxic effects on humans and the environments are found in industrial, construction, medical and even general household wastes. Some heavy metals like mercury, lead, and cadmium are added to certain consumer and industrial products such as batteries, switches, circuit boards, and certain pigments. Mercury was once widely used in pharmaceutical products, agricultural chemicals, dry cell batteries, and paints. Many of these uses have been phased out, although others continue, e.g. chlor-alkali production, switches and electrical apparatus, fluorescent light bulbs, and dental amalgam. These ongoing uses of mercury too are declining. In 2004, world mercury production was estimated to be 1260 metric tons per year, which was significantly less than the 2200 t/y average world mercury production from 1990 to 2000 [1]. Cadmium was at one time widely used in electroplating processes to coat iron and steel. In recent years, cadmium has been used increasingly for the production of rechargeable batteries, and this is now the dominant use of the metal. The frequently used option for many products containing heavy metals is

disposed in a municipal solid waste or hazardous waste landfill or dumpsite [1]. Landfilling involves disposing of waste on land in a series of compacted layers and covering it up with soil and other material. In Cape Town, the major process being used at present for solid waste management is landfill disposal. About 1.6 million tons of waste was landfilled in the city's three landfill sites in 2010.

Electronic waste particularly computers parts contain small amount of toxic heavy metals. And also wastes from battery manufacturing, petrochemical, electroplating industries, etc. contain toxic heavy metals such as cadmium, chromium, lead, nickel, zinc, mercury, copper, arsenic. The presence of these toxic metals in landfilled wastes poses serious threats to the environment.

Landfilling of solid wastes releases greenhouse gases [2] and volatile organic compounds [3] along with leachable toxic heavy metals [4] to the surrounding environment [5].

HM contents of Municipal Solid Waste (MSW) which therefore ends up in landfills and dumpsites are of immense environmental and public health concern. Over time, and when not properly managed, these metals present a contamination risk to the nearby soil, ground and surface water [5]-[7], the biodiversity that depends on these resources as well as the microbial ecophysiological indicators [6] of the surrounding soils. The HM-rich leachate may percolate into soils underlying the disposal site [8], [9]. Soils are usually considered as a sink for trace/heavy metals, it also known that heavy metals are not biodegradable, they therefore are able to move towards a water column or accumulate in plants and consequently contaminate the food chain. There is therefore, the need to analyse the distribution of HMs content in soil samples from landfills in order to ascertain natural and artificial levels of HM in and around the sites.

Landfill disposal is still the major process being used because it is simple, practical and cheap. However, because of more rapid exhaustion of the landfill sites in use and because of the impacts it has on ecology, health and environment, people have become aware of the need to develop alternative waste disposal technologies. Landfilling in particular is increasingly being globally recognised as an unsustainable method for waste management.

The National Waste Management Strategy (NWMS), the White paper on Integrated Pollution and Waste Management for South Africa, and the National Environmental Management: Waste Act (NEMWA, No 58 of 2009) are the national policy and regulatory instruments governing municipal solid waste management. The current MSW management systems include waste collection and sorting for materials recovery followed by landfilling. The city operates

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three landfill sites and transfer stations; two materials recovery facilities and 25 public drop-off sites. Landfill sites are licensed in accordance with the requirements of the National Water Act, and the Department of Water Affairs and Forestry guidelines. Historic problems experienced with MSW disposal facilities in South Africa include poor and inadequate design and operation which impacts negatively on both the environment and quality of life. In South Africa, domestic waste is disposed of at approximately 1 200 landfills out of which only 524 are permitted and hazardous waste on 77 disposal sites of which 41 are permitted (DEAT, 2006a). The fact that only about 40 per cent of waste disposal sites in South Africa are permitted makes control and enforcement of minimum requirements/standards difficult.

As yet, very few published work can be found regarding the contamination levels of heavy metals in and around South African landfill sites, and none for Cape Town's landfill sites. This study aims to establish the magnitude of waste-derived heavy metals contamination in the management and disposal of MSW in Cape Town, South Africa. Specific objective include detailed analyses and assessment of the HM load at some of the City of Cape Town landfill sites.

II. EXPERIMENTAL METHOD

A. Description of the Landfill Sites

The landfill sites in this study are Bellville Landfill site, Vissershok Landfill Site and Coastal Park Landfill Site located in Cape Town. The total areas covered by the landfill sites are 0.60 km², 1.17 km² and 0.75 km² respectively while ages of the landfill sites are equally important for the assessment heavy metals distribution. Two of the landfill sites are approaching the design capacity on or before year 2022.

TABLE I: LANDFILL SITES IN CITY OF CAPE TOWN

Landfill Site	Location	Area m ²	Height m	Age	End
Bellville	SN EW	600,000	35	-	2013
Coastal Park	SN EW	750,000	35-45	-	2016-2022
Vissershok	SN EW	1,170,000	30 65	-	> 2022

The area and the proximity map of the landfill sites is describe and shown in Fig. 1 a) & b) respectively.

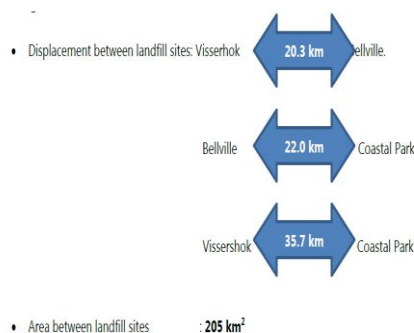


Fig. 1 a). The area between landfill sites.

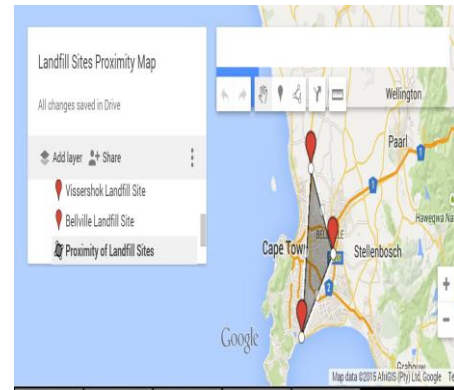


Fig. 1 b). The landfill sites proximity map.

B. Site Mapping and Samples Collection

A mapping of the landfill sites that reflect the topography was carried out, (Figure 2) which is about 50 m from the site. To ensure the integrity of the samples obtained, the surface soil samples were collected using a AMS regular step soil probe (5/8" threaded, nickel plated 33" plated step probe) at a sampling depth of 15 inch. A chrome-plated trowel was first used to remove surface debris before inserting the soil probe.

The collections were done between the months of February and March, that is, summer time in Cape Town. This period is described as hot and dry with no rain. The samples were transferred into sterilized 2-litres plastic containers and tightly sealed. The required amount was then transferred into soil sample bags.

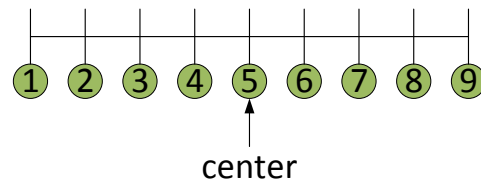


Fig. 2. Site grid layout (10m between nodes).

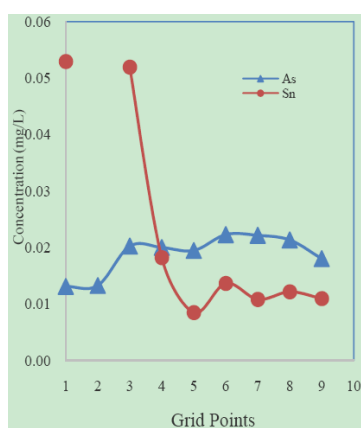
C. Soil Samples Analysis

The collected samples were grinded, homogenized, sieved to a specific size then dried for a period of time (24 hr). The Inductively-Coupled Plasma Optical Emission Spectrometry (ICP-OES) technique was used to determine the samples metals content. The technique allows multi elemental analysis because of its wide dynamic range and sensitivity. The samples were digested using reagents with high purity deionized water and analyzed in triplicate. All reagents used were of analytical grade and from which standard solutions were prepared. Glassware was thoroughly washed with detergent and rinsed with distilled water. With regards to heavy metals, the major elements that were analyzed are As, Sn, Cd, Al, Cu, Pb, Zn, Fe and Si.

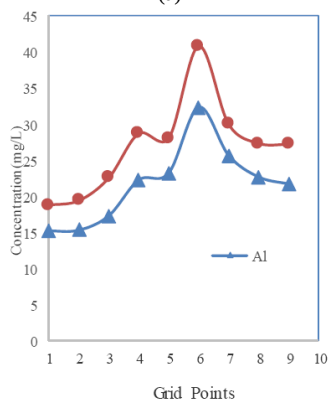
III. RESULTS AND DISCUSSIONS

The concentrations of the different metals detected and measured in the samples are presented in Fig. 2 a)-d) as a function of the sampling points. The concentrations of Al and Fe give high range values of 15.17 – 32.35 and 18.74 – 40.83 mg/L and means of 19.60 and 24.32 mg/L respectively, as compared to range values of Pb, Cu and Zn (0.12 - 0.16, 0.16

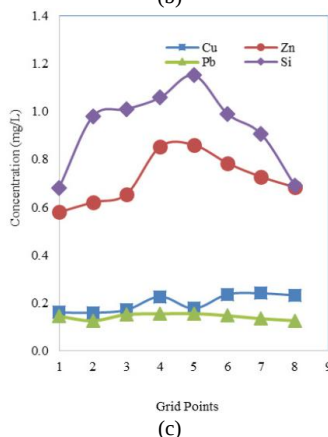
– 0.24, 0.64 – 1.16) respectively. The values of Pb, Cu and Zn are low as compared to some previous works which gives ranges of 44.09 – 291.29 and 42.9 – 1833.5 mg/kg for Pb and 4.53 – 75.52 and 11 – 186.6 mg/kg for Cu respectively [10], [11] From Figure 2, it can be concluded that the metals concentrations for Al, Fe, Sn; Si, Zn in surface soil decreases with distance from the landfill site. The Cu, As and Pb contents seems fairly constant. In the case of Cd, the range value of 0.01 – 8.01 mg/L was measured, the level was found to be highest close to the road, and fairly constant at other points. The percolation mechanism for each of these metals is being investigated to account for this trend. The level of cadmium measured was found to be relatively low as compared to other metals detected. Living organisms even though requires some of the trace elements or HM for proper functioning of the organs and systems; also, with no clear boundary between the benefits and toxicity for these elements, the amount should be minimized because they are not metabolized by the body system thereby resulting in accumulation in some organs such as the liver.



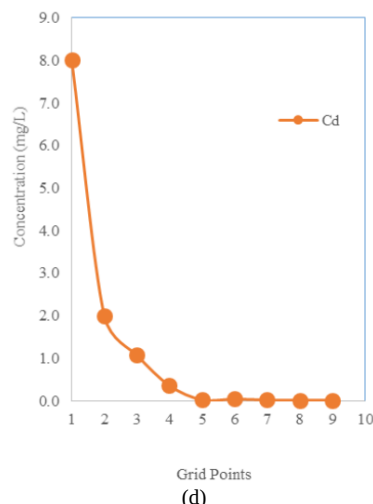
(a)



(b)



(c)



(d)

Fig. 2. Plot of spatial distribution of various metals.

IV. CONCLUSION

The concentrations of the different metals detected and measured in the samples are presented. It can be concluded that the soils from the landfill sites revealed contaminations by trace and heavy metals. Landfilling is increasingly being recognized globally as an unsustainable approach to handling waste. Other waste processing and treatment initiatives such as waste-to-energy conversion technologies need to be considered by municipalities all over the world.

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