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Assessment of Heavy Metal Status in Groundwater around a Dumpsite in Ibadan, South-Western Nigeria

[1]Akintola O. O., [2]Adeyemi, G. O. and [3]Ariyo, S. O.*
[1]Federal College of Forestry, Ibadan. Oyo State
[2]Department of Geology, University of Ibadan. Oyo State
[3]Department of Earth Sciences, Olabisi Onabanjo University, Ago-Iwoye, Ogun state
Corresponding author: soariyo@gmail.com

Abstract

Groundwater contamination within the vicinity of dumpsites has elicited public health concern in recent time. The study assessed the impact of waste dump on the groundwater quality with special reference to heavy metal contamination. Twenty five composite groundwater samples were collected within and some distances from the vicinity of dumpsite at different axes (downslope and upslope) location. Water samples were analyzed for heavy metal (Zn, Cu, Pb, Fe, Ni, Cr, Co, Mn, As and Ni) concentrations using ICP-AES instrumentation techniques. Data were analyzed using descriptive statistic, graphics and contamination indices (Contamination factor and Degree of Contamination). Water samples from downslope location revealed high metal concentrations in comparison to upslope location. Heavy metal concentrations showed reductions with increased in distances from waste dumpsite. The Contamination Factors (CF) of heavy metal concentration in water were Fe (1.04), Zn (1.14), Cu (1.07), Pb (1.07), Cd (0.95), Ni (0.99) and Co (0.87); and Degree of Contamination (Cd) in water was 8.0 indicating groundwater in study area was moderately contaminated. The study showed that toxic heavy metals from waste materials in the dumpsite had contaminated the groundwater. Resident in this location may in future be exposed to greater risk, hence re-designing of the dumpsite construction to sanitary landfill with clay or plastic liners and adoption of clean-up technology for heavy metals are recommended.

Key words: Contamination indices, Dumpsite, Groundwater, Heavy metal concentration

Introduction

Environmental contamination has been lingering the human world in the recent times and is still growing due to excessive growth in developing countries of the world. Solid waste usually termed‘‘garbage’’ is an inevitable by-product of human activity from population growth and economic development (1, 2). Open dumpsites are the common practice for solid waste disposal in developing country of the world due to low funds for waste disposal and non-availability of trained manpower [3]. Open dumping of wastes is a common practise in Nigeria and poses serious risk to soil, groundwater resources and may have continuing effect on environment. Over the last few decades, consequences of increased environmental contamination from industrial, agricultural and municipal sources have led to considerable deterioration in groundwater and soil quality. This is largely due to increase in the concentration of heavy metals presence in the waste. Groundwater water contamination by heavy metals has received attention in recent decades because of their potential risks to man and other organisms when accumulated within a natural system [3, 4]. Suitability of water is dependent on its physical, chemical and biological characteristics, which in turn depends on the geology of the area and the impacts of human activities. Water contamination thus occurs, when its quality is degraded and its usefulness, to human and other organisms are impaired because of the presence of certain harmful substances [4]. However, the contamination of water body by waste from dumpsites depends on several factors such as rainfall waste disposal method, reactions taking place within the dumpsites. Leachates containing toxic substances may be generated from dumpsites, these may eventually pollute the surface and groundwater especially where the underlying geology is composed of un-compacted soils such as coarse sands [4-6]. Infiltration of rain water, water already present in the waste, or water generated by biodegradation, enable the leachates from waste dump to move laterally or vertically and find its way into the groundwater thereby causing contamination. Heavy metals such as copper, lead, nickel, cadmium arsenic, chromium etc when presence in high concentration due to anthropogenic inputs can cause contamination which may be detrimental to humans and animal health.. Studies have shown that human (domestic, agricultural and industrial) activities are the major anthropogenic sources of contaminants (heavy metals) in the environment [7-10]. In an attempt to mitigate environmental pollution within the city, Lapite waste disposal site was located strategically at the outskirt of the city. However, the selection, design, construction and operational activities of this site did not consider the geology of the area and impacts on the adjacent environment. The dumpsite may pose threats to human health through groundwater and soil pollution and its attendant effects on the entire ecosystem.

The study area, Lapite waste dump, is one of the largest among the dumpsites established by Ibadan Waste Management Authority. The site which came into use in 1997 has no record of environmental evaluation as regard its usage in terms of site selection, design and management but was established based on its remoteness from the habitable area [11]. This study aims at assessing the impact of waste dump if any, on the groundwater quality with special reference to heavy metal contamination.

Study Area Description

The study area was located in Lapite village, within Akinyele Local Goverment area, Ibadan. It is situated between old Oyo road and newly constructed Ibadan- Oyo express road (Fig.1). The dumpsite covers an area of 200 by 400 meters, sited on high elevation; weathered and fractured rocks. Tones of wastes generated and collected from various locations in Ibadan and its environs are deposited on a daily basis onto the dumpsite, giving rise to large heap of waste of varying composition, up to 3.0 m high relative to the ground surface. Dumping at the site is unrestricted and industrial, agricultural, domestic and medical wastes (including used syringes) are strewn all over the dumping site. The long axis of the dumpsite or the length is oriented in the East–West direction. On the northern side of the dump site is a small stream which runs in the South West direction. Some of the waste from the dump ends up into the stream thus extending environmental and health risks to the communities living within the vicinity as well as those living downstream who could be using the water for domestic and agricultural purposes like irrigation. Surrounding the dumpsite are villages such as Lapite, Baiyegun, Shogunro, Ketepe, etc existing few hundred meters away from the site.

The study area forms part of the area underlain by Basement Complex rocks of southwestern Nigeria. The major rock types in study area and it’s environ are migmatite and bandedgneisses.

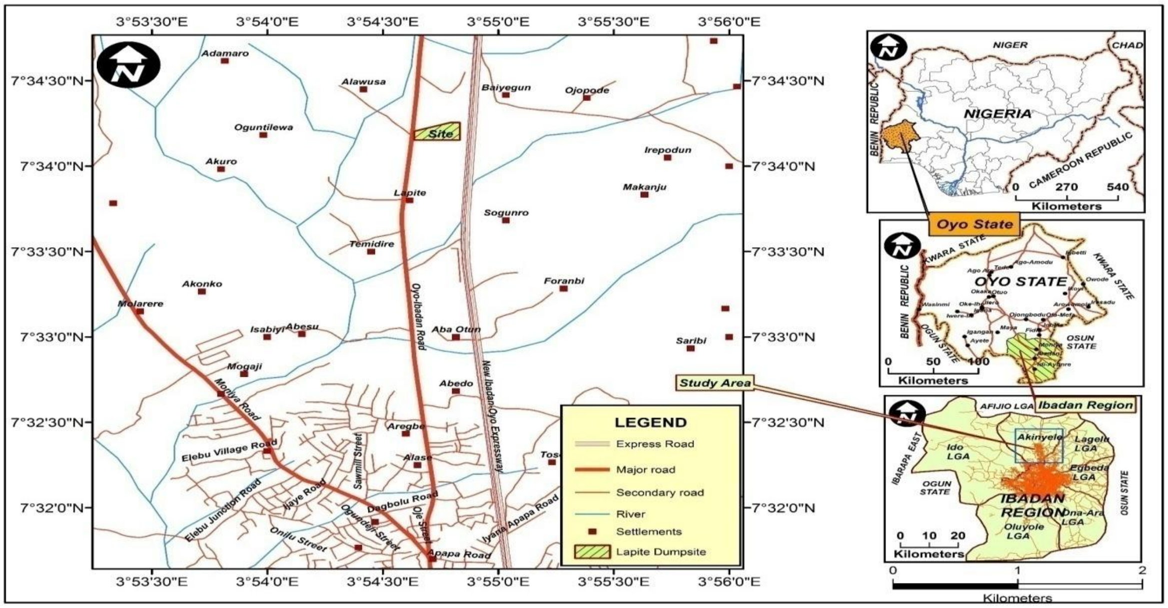

Figure 1. Location map of lapite dumpsite

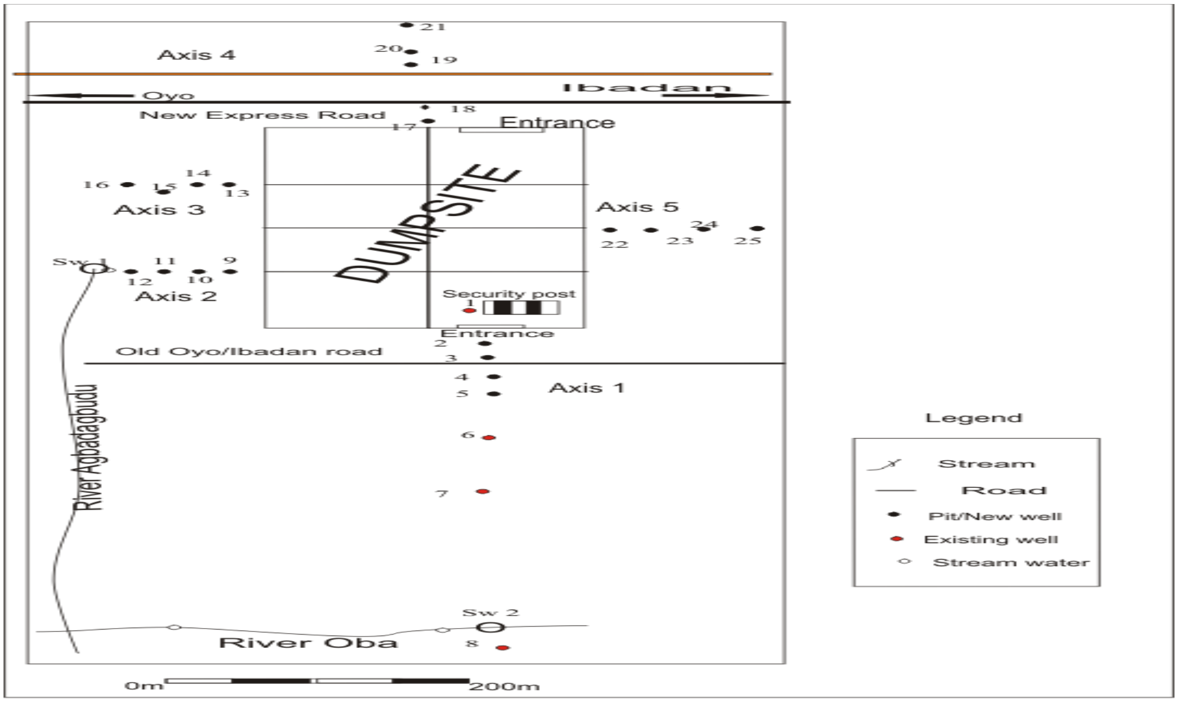

Figure 2. Location of Hand Dug Wells AroundLapite Dumpsite

Table 1. Site specification of the water samples

Distance from dumpsite(m)	**Sample location**				
	Downslope side of the dumpsite			Upslope side	
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5
0	Gw 1				
20	Gw 2	Gw 9	Gw 13	Gw 17	Gw 22
40	Gw 3	Gw 10	Gw 14	Gw 18	Gw 23
60	Gw 4	Gw 11	Gw 15	Gw 19	Gw 24
80	Gw 5	Gw 12	Gw 16	Gw 20	Gw 25
150				CS21	
170	Gw 6				
320	Gw 7				
500	Gw 8				

GW indicates Groundwater at Location 1 to 25

CS indicates, Control

Materials and Methods

The choice of the axis locations for groundwater sampling was based on previous geophysical and geotechnical studies carried out on the dumpsite. Water samples were collected from both downslope (axis1, 2 and 3) and upslope side (axis 4 and 5) of the waste dumpsite. Details of the sampling points are presented in table 1. Three water samples per well were collected from 21 new and 4 existing hand dug wells within the five axes established in the vicinity of dumpsite as shown in figure 2. The depth of the wells ranged between 1.80 and 7.50m. Groundwater samples were randomly collected from hand- dug wells around and within the dumpsites with the aid of plastic bucket that has been previously washed and rinsed thoroughly with distilled water and suspended at one end by rope. The sampling bottlers (plastic bottles of one litre and 60 ml capacity) were first soaked with nitric acid and washed with distilled water before sampling to avoid potential contamination from the sampling materials.

At the identified sampling points, sampling bottles of one litre capacity were washed three times with each water sample before collection. Collection of water samples were done with avoidance of air bubbles during collection. After collection of samples, the pH of the samples was adjusted to about 2 with 3 drops of concentrated nitric acid to inhibit metabolic processes and reduce adsorption of metal compounds to the surface of the container. Sampling bottles were tightly covered and proper labelled. They were then transported in an ice cooler from the field. Composite samples were gotten from the three samples collected from each well into 60ml bottles and labelled as groundwater (GW) 1-20 and control sample (CS 21) as shown in table1. Samples were preserved in the refrigerators for some days before taking to the laboratory. Heavy metal analysis was done at Acme laboratory Ontario, Canada using inductively coupled plasma- atomic emission spectrometry (ICP-AES) instrumentation technique.

Data were analyzed using descriptive statistics, graphical representation and indices of contamination. The indices of contamination used in this study are contamination factor (Cf) and degree of contamination (Cd). Contamination Factor (Cf)has been used to assess contamination status through comparison of the concentrations in the sample to background (control sample) values by the expression given by [12] while Degree of Contamination (Cd) can be defined as the sum of all contamination factors.

Result and Discussion

The mean heavy metal concentrations of water samples collected from 25 hand dug wells at different axes location are presented in Table 1.Heavy metal concentrations in the water samples at distances 20m to 80m from the five axes location are presented in figures 3a-h. Levels of heavy metals in water samples from downslope (axis 1, 2 and 3) location were generally observed to be higher than those observed in the downslope except the case of GW8 in axis 1 at 500m distance from the dumpsite where the heavy metal concentration were found to be lower (figs. 3a-h and 4a-h). The high levels of heavy metals in water samples from downslope side of the dumpsite may be attributed to the topographic condition and to some extent the hydrogeology of the area.

Mean heavy metal concentrations in all the location were found to be higher than that of control sample (table 1). Similarly, the levels of heavy metals in most of the water sampkes were found to exceed the guidelines [13, 14]. The increase in the concentrations of heavy metals in the water samples may be due to the infiltration and percolation of contaminants from the waste dump into the groundwater.

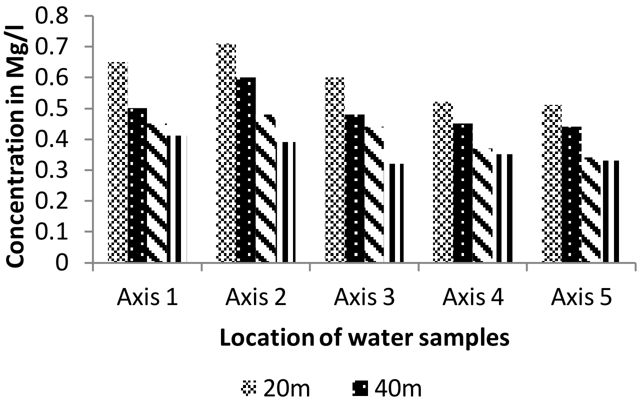

Figure 3a. Reduction in Fe concentration in water sample at different axes location

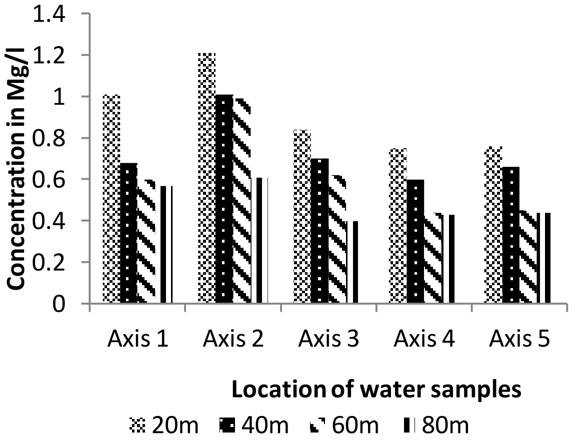

Figure 3b. Reduction in Zn concentration in water sample at different axes location.

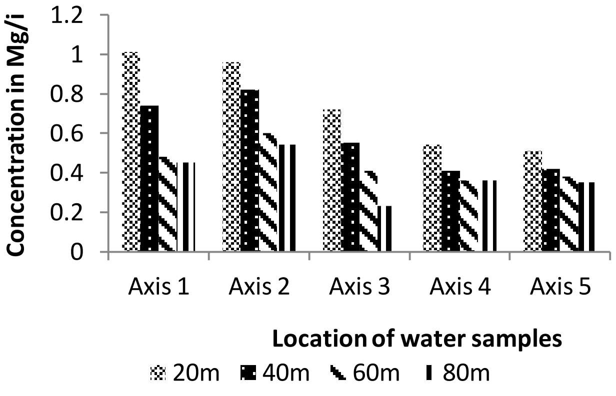

Figure 3c. Reduction in Pb concentration in water sample at different axes location.

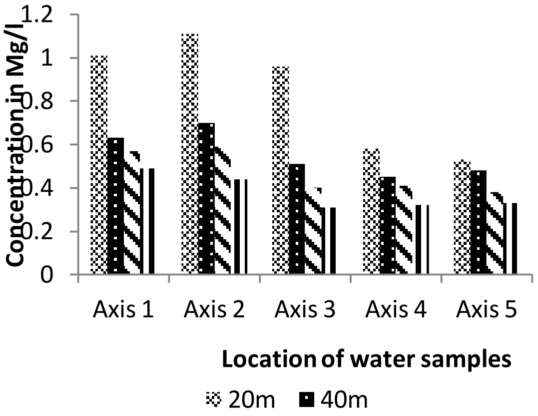

Figure 3d. Reduction in Cu concentration in water sample at different axes location.

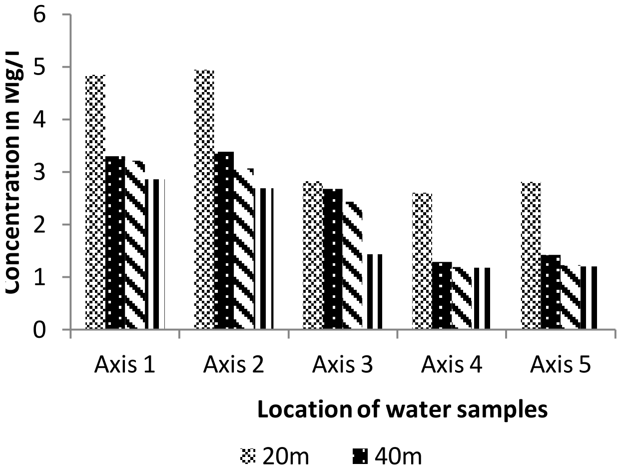

Figure 3g. Reduction in Cd concentration in water sample at different axes location.

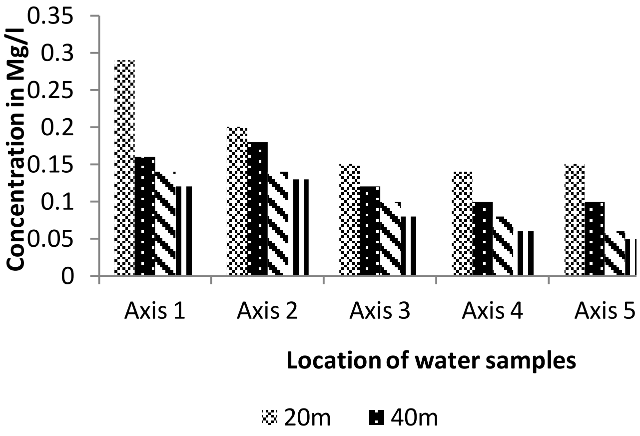

Figure 3e. Reduction in Ni concentration in water sample at different axes location.

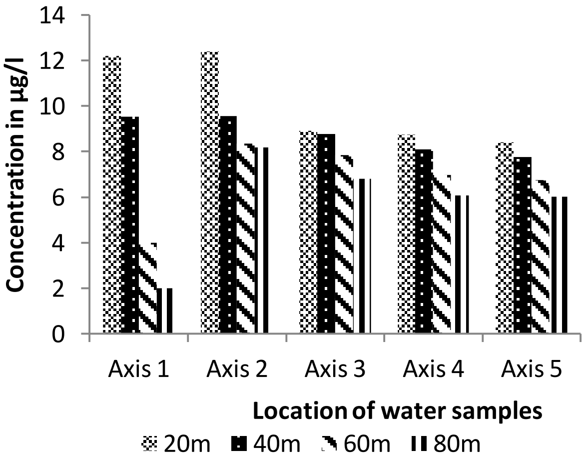

Figure 3h. Reduction in Cr concentration in water sample at different axes location.

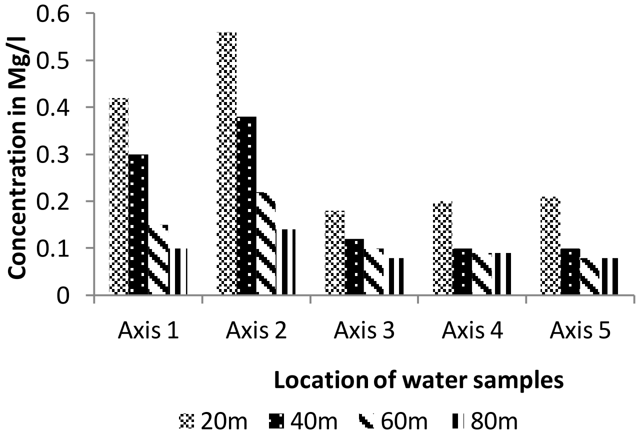

Figure 3f. Reduction in Mnconcentration in water sample at different axes location.

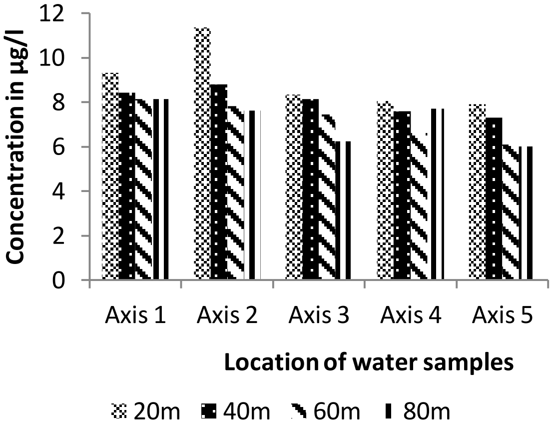

Figure 3i. Reduction inCo concentration in water sample at different axes location.

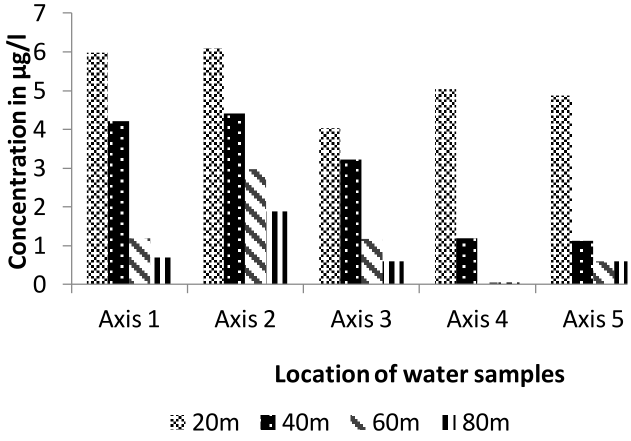

Figure 3f. Reduction in Mo concentration in water sample at different axes location.

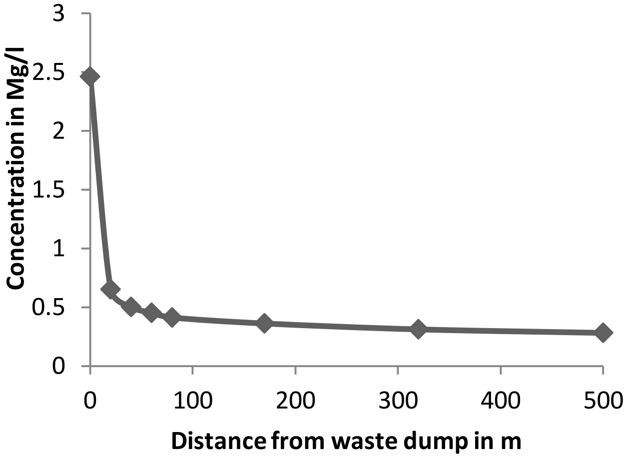

Figure 4a. Fe concentration showing impact of the dumpsite at different intervals.

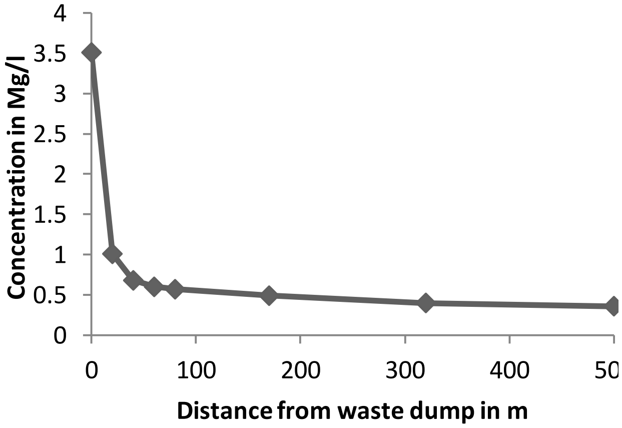

Figure 4b. Zn concentration showing impact of the dumpsite at different intervals.

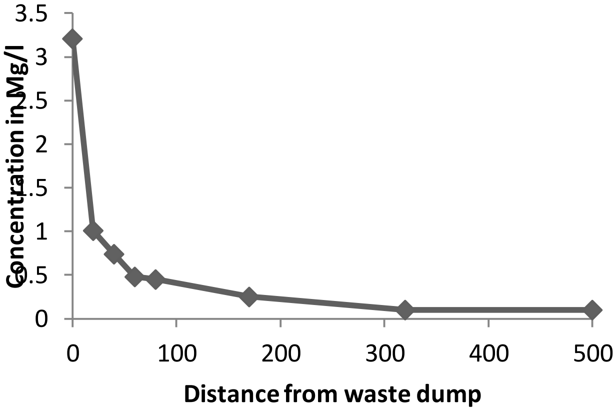

Figure 4c. Pb concentration showing impact of the dumpsite at different intervals.

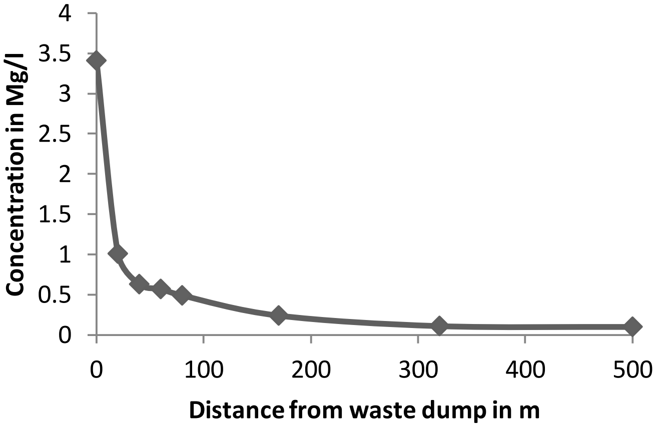

Figure 4d. Cu concentration showing impact of the dumpsite at different intervals

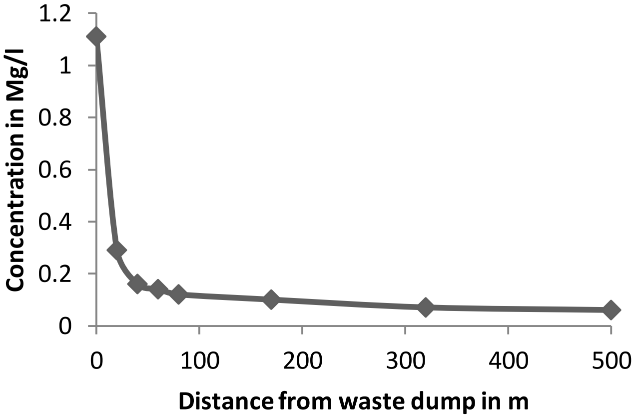

Figure 4e Ni concentration showing impact of the dumpsite at different intervals

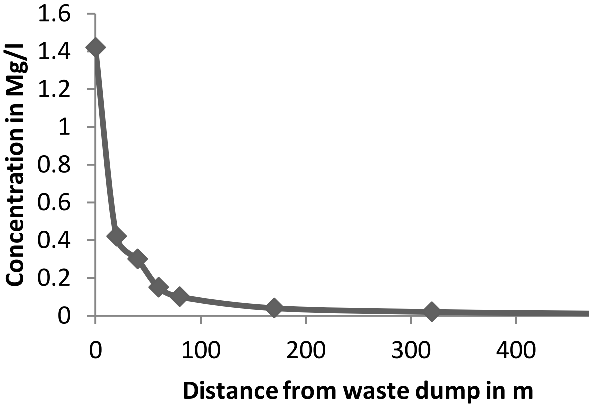

Figure 4f. Mnconcentration showing impact of the dumpsite at different intervals

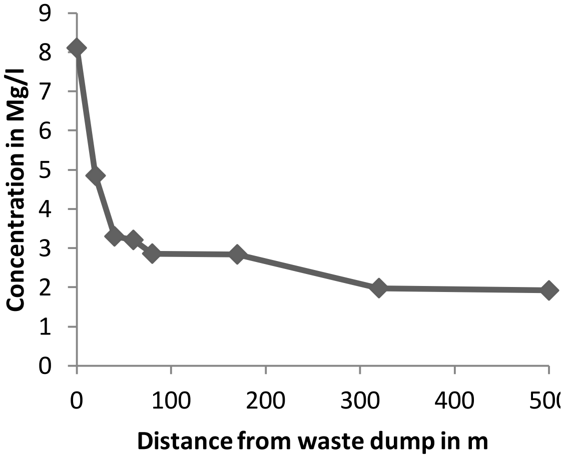

Figure 4g Cd concentration showing impact of the dumpsite at different intervals

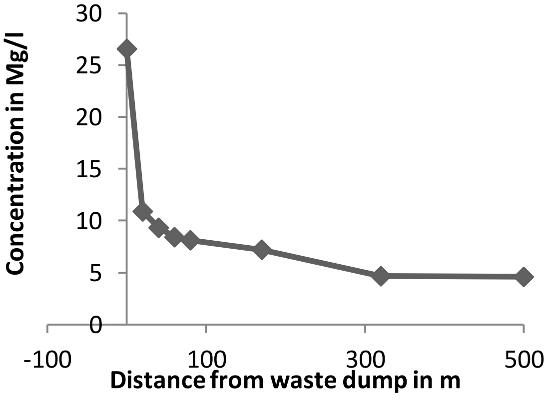

Figure 4h. Co concentration showing impact of the dumpsite at different intervals

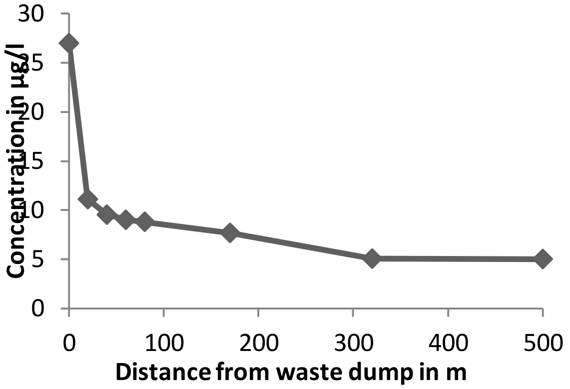

Figure 4i. Cr concentration showing impact of the dumpsite at different intervals.

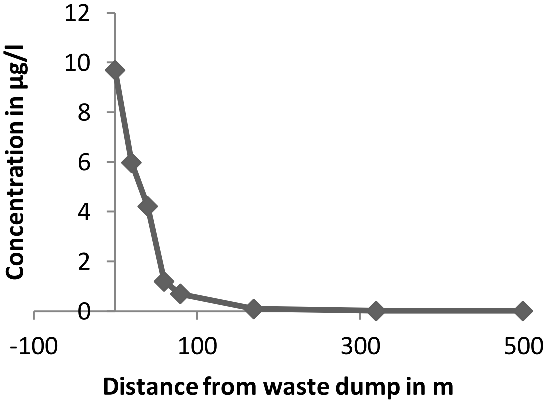

Figure 4h. Mo concentration showing impact of the dumpsite at different intervals.

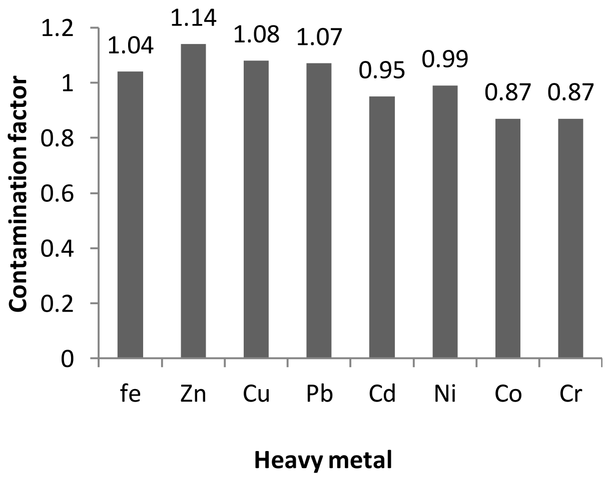

Figure 5. Contamination factors of the heavy metal in the water samples

Generally, concentrations of heavy metals in the water samples were higher than similar work conducted by some researchers [15-17]. This may be attributed to the study location, physiographic condition and geology of the area, type, state and age of the dumpsite. Levels of heavy metals in the studied samples were in the order of Zn> Fe>Pb>Cu>Cd>Ni>Mn>co>Cr> Mo>As (table 1). This may be attributed to the presence of the waste materials such as disposed battery cells, used aerosol cans, and other materials with a certain degree of toxicity [18].

Axis 1 that has the largest number of wells and distances up to 500 m away from dumpsite were considered by establishing plots of heavy metal concentrations in each of the wells against their corresponding distance (figs. 4a-h). It was observed that level of heavy metals in the water reduces with increase in distances from waste dumpsite. The enunciate presence of heavy metal concentrations in the water samples were noticed between 20 m to 170 m away from the dumpsite (Gw1-Gw6), indicating contamination.

Contamination factors used in assessing the heavy metal contamination status of the groundwater in the study area is presented in figure 5. Contamination factors (CF) of heavy metals in water showed the order of Zn > Cu>Pb> Fe> Ni > Cd > Co > Cr in water. Degree of contamination which is the sum of all the contamination factors of heavy metals in the waters was 8.01 indicating moderately degree of contamination (12). This study buttresses the report which stated that landfills are one of the sources of groundwater contamination due to the production of leachates and transportation of the contaminants to farther points in the ecosystem [19]. The contaminations of heavy metals even at low concentration have potential effect on environment and human health.

Conclusion

The study showed that toxic contaminants from waste materials in the dumpsite had analytically contaminated the groundwater. The consequence of such contamination as determined from the study decreased away from the anthropogenic source (dumpsite). The implication of this was that the contamination of the groundwater was more dependent on the closeness to the dump sites. Lesser dependence has been attributed to topography and hydrogeology of the area, type, state and age of dumpsite. The moderate degree of contamination of heavy metal in the water further suggests anthropogenic influence of dumpsite on the surrounding groundwater, which course for concern. There is a future risk to the people living in the study area. Therefore, re-designing of the dumpsite to sanitary landfill with clay or plastic liners to prevent future risk and adoption of clean technology for heavy metals are recommended.

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