Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.12, No.12, 2022

Hydrochemical Assessment of Groundwater Around Osogbo Central Dumpsite, Onibu-Eja, Osun State

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Abstract
Groundwater sources around Oshogbo central dumpsite in Osun state, Nigeria, have been evaluated with the aim of detecting possible influence of dumpsites on nearby aquifers and suitability for domestic use. The site covers an area of 79 200m^2 with an undulating surface. Being part of Ilesha Schist Belt, the major rock types in the area include amphibolites, pegmatites and quartzites. Preliminary tests were conducted on the water samples to determine some parameters, such as PH, Oxidation-reduction potential, Conductivity, Total Dissolve Solids, (TDS), E. *Coli*, etc, as investigative markers. To detect the presence of Heavy Metals and other parameters, there was random collection of a total of thirty (30) samples of leachates/water, using sterilized bottles. At dried areas, soil samples were collected and distilled water was introduced to extract leachates. The samples were then tested for the following heavy metal pollutants: Cadmium, Iron, Lead, Mercury, Zinc, Chromium, Nickel, Arsenic, Copper, and Cobalt. An appraisal of the results using World Health Organization (WHO's) and National Standards for Drinking water Quality proved among others, the presence of Mercury, Cadmium, Iron, Arsenic, and high level of Lead contamination. There were also exceeding values of Cadmium in most samples, except in a few others where it was totally absent. Mercury had exceeding values in few samples and absent in the rest of the samples. Heavy metals pollution has harmful effects on the Biological system, via bio-accumulation, and cannot undergo biodegradation. Therefore appropriate remedial treatment is required for the groundwater in the study area since most of the heavy metals in the samples are above the WHO's and National standards.
Keywords: Heavy Metals, Biodegradation, Pollutants, WHO
DOI: 10.7176/JEES/12-12-04
Publication date: December 31st 2022

1. INTRODUCTION

The usefulness of water to man cannot be over-emphasized, as it is needed for most of his activities (i.e. domestic, Agricultural, and industrial usages). Groundwater is the water beneath the subsurface, and it is unevenly distributed across the globe, and less susceptible to pollution. Due to several anthropogenic activities, occasioned by high-technological and industrial developments of the 21$^{st.}$ century, the environment had been polluted. The water resources were not spared, particularly the surface water and to a large extent the ground water. Ground water is usually recharged by surface water source through percolation and infiltration of storm water during precipitation. Water moves through pores within the ground into a convenient storage formation called aquifer.

In Nigeria and other developing countries of the world, wastes are mostly dumped on open grounds, unsanitary landfills, public drains, and in water bodies, which impacts negatively on the surface and ground water quality, and ambient air, thereby constituting serious environmental and health problems. Contamination from solid wastes begins with the release of leachates unto land surface, which will be washed into the surface water during precipitation, and will in turn recharge the groundwater source. Through percolations too, the leachates reach groundwater. As noted by Bayowa, *et al*., (2015), solid waste is a non-liquid and non-gaseous product of human activities, which could pose threat to both surface and groundwater systems.

Precipitation on refuse dumpsite will either infiltrate the refuse or run off as over flow (Ariyo and Enikanoselu, 2007). During the vertical percolation process, the water leaches both organic and inorganic constituents from refuse and becomes part of the groundwater flow system, when they reach the water table (Langer, 1998; Baba and Tokogoz, 1999; Christoph and Dermietzel, 2000; Rao, *et al*., 2001; Baba, 2003). The groundwater system suffers major negative impact of leachate through the introduction of heavy metals (Pb, Cd, Fe, Zn etc.), dissolved minerals (Na, Mg, K, salts), suspended particles (clay, silt, sand) and development of leachate plumes (Mepaiyeda et al., 2019). The physical, chemical and biological characteristics of water may also be influenced by human activities such as urbanization and industrialization and this may affect the quality of water (Akintola et al. 2021). It is therefore improper to dump wastes indiscriminately and also important to segregate and characterize wastes before their disposal for efficient management through Wastes-to-Wealth programmes.

This study was carried out to assess the risk level of leachates over time, and the groundwater quality system around the dumpsite in Osogbo, the Osun State capital in Southwestern Nigeria.

The global increase in population and urbanization had resulted in the increased production of Municipal Solid Wastes, (MSW), thus, became a critical issue, as a result of poor environmental management system. The target therefore, is to investigate the environmental impact of the Unsanitary Landfill site on ground water. In achieving a Sustainable Solid Wastes Management Strategies, (SSWMS), as wastes are being generated, solid wastes characterization, collection, transportation, and treatment are paramount. Also essential, is reliable data on wastes volumes, wastes streams, and sources, as regulatory requirements for effective wastes management.

This research therefore, is also an effort to sensitize the public and government on the intrinsic danger in unsustainable wastes management; and to provide guidance and awareness in proper wastes handling, using sound scientific approach to investigate physiochemical parameters, associated with unsanitary landfills. The exercise was aimed at galvanizing the senses of Environmental Health Workers, Environmental Consultants, Wastes Management Organisations, and Policy Makers in the developing nations, particularly Nigeria, to develop and adopt a suitable and sustainable roadmap in developing an efficient data bank on Solid Wastes Management, (SWM), in line with global best practice. Due to several anthropogenic actions, occasioned by High-technological and industrial developments of the 21st. century, and the consequent unsustainable wastes management practices, the environment had been heavily polluted. The water resources were not spared.

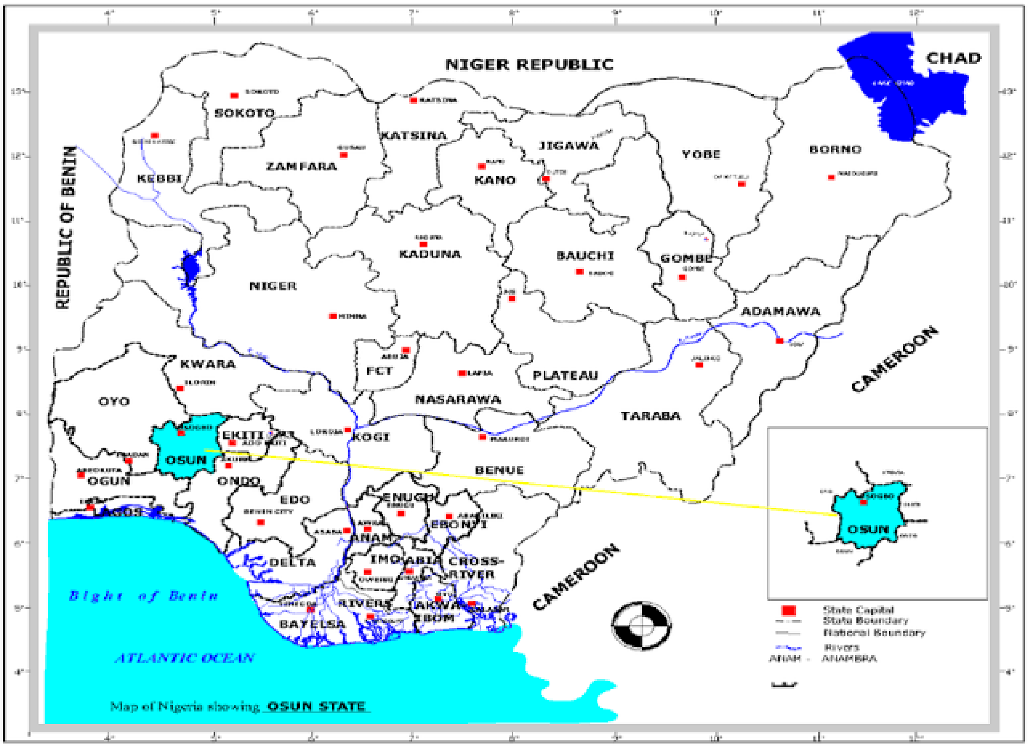

Figure 1: Map of Nigeria showing Osun State. (Osun State Ministry of Land and Physical Planning Osogbo, 2010).

A Rethink of solid wastes management, into a **Six (6) R in Wastes Management Practice, (SRWMP)**, would have turned **s**olid wastes into essential raw materials, by stimulating **Recovery, Re-using, Recycling, Repairing, Reducing and Re-invention** of wastes. Characterisation of solid wastes into **Biodegradables and Non-Biodegradables,** will ensure that little or no solid waste goes to dump sites. For instance, if plastic shopping bags could be **reused**, there will be wastes **reduction**; some essential components of end-of-life or near end-of-life equipment **recovered** (via Urban Mining), metallic and plastic material junks collected and **recycled,** some old electrical and electronic gadgets, (and other moribund devices) **repaired**, the domestic kitchen wastes **Reinvented** to composts, obviously nothing or little will go to the dumpsites. These will lead to the stimulation of **Circular Economic Strategy, (CES),** rather than the unsustainable **Linear Economic (LE) system.** Through these processes, soil, surface water and aquifer pollution will be abridged. Primary and ancillary jobs will be created, and there will be environmental and social security. For clarity, **Linear Economy** is an unsustainable traditional approach to production, consumption and wastes disposal, from Cradle to the Grave, while **Circular Economy** is a policy resource maximization model, economy of production, consumption and wastes management. It is a sustainable Cyclic Resource Management Initiative (CRMI), from Cradle to Cradle, through the implementation of Extended Producer Responsibility, (EPR), programme, and the six (6) R in wastes management.

2. LOCATION AND GEOLOGY OF THE STUDY AREA

Osun Central Dump site is in Onibu-Eja of Ido-Osun Area, at the outskirt of Osogbo, along Osogbo-Iwo road Osun State (figure1), Southwestern Nigeria, within Latitude 07°53'33.09"N and 07°53'34.14"N and Longitude 004°29'09.80"E and 004°29'48.83"E, (figures 1 & 2). The dumpsite used to be active and covered an area of 79 200m^2 and varies in elevation from 0.3m to 0.5m (Bayowa *et. al.,* 2015). The study area falls within the tropical rain forest region with humid climate and an average temperature of between 21.1^{o}C and 31.1^{o}C. It records an annual average rainfall of about 1000 mm with the rainy season covering eight months, beginning in April and ending in November (OSSADEP, 1997).

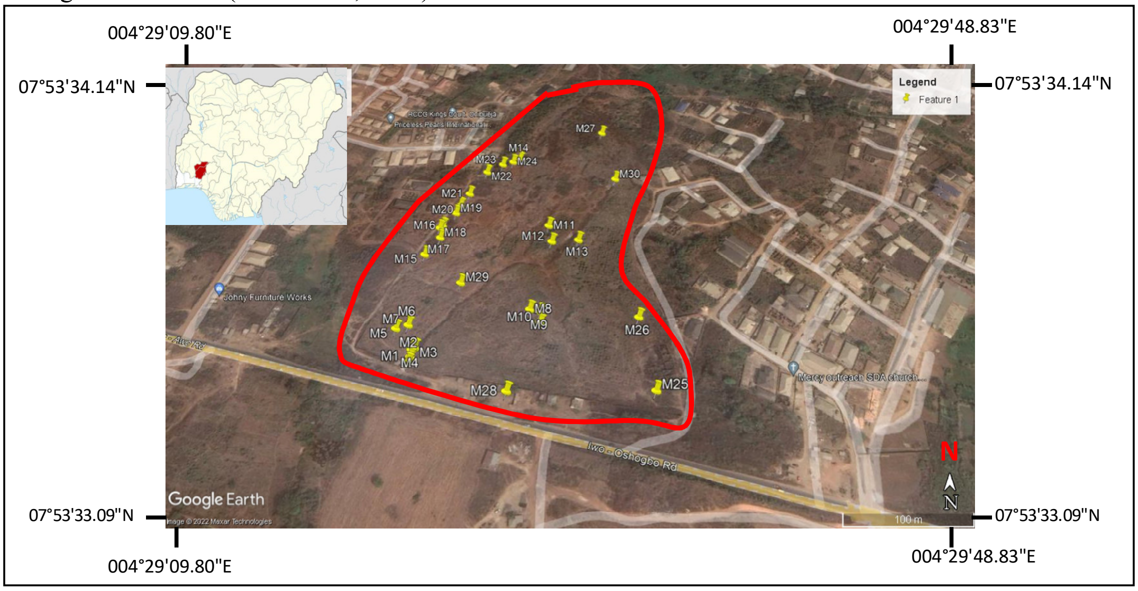

Figure 2: Map of the study area showing the abandoned dumpsite demarcated with red polygon line and water sample points in yellow button along Osogbo-Iwo road, Osogbo, Osun state. At the top left is the map of Nigeria, showing Osun State. (Modified after Goggle Earth, 2020).

The study area lies within the southwestern Basement Complex of Nigeria, which had been described in detail in various publications of the Geological Survey of Nigeria (GSN), and various authors, such as Oyawoye (1972), Rahaman, (1976) and Olarewaju (1988). The Ilesha Schist Belt, which covers the study area hosts these ore deposits: Gold, Iron Ore, Talc, among others (Rahaman, 1976; Ajeigbe,et al, 2014). The main rock types are granite gneiss, pegmatites, quartzites and quartzite schists (Figure. 3).

Basement complex rocks are competent rocks with low permeability and generally low water bearing zones. The hydrogeology of the study area was supported by the secondary porosity resulting from weathering of the parent rock and the tectonic activities. The presence of secondary porosity such as faults, fractures and weathered layers enhanced the groundwater potential of the study area. Storm water and Run-off, flow from Eastern higher gradient to the lower Western flank, which hosts a brook (Plates 1 and 2).

PLATE 1: Osun State Mobile waste receptacle, OWMA active dump site, Idu Osun, Osun State Capital Territory, (Phase II).

PLATE 2: Hills of wastes, OWMA active dump site, Idu Osun, Osun State Capital Territory, (Phase II).

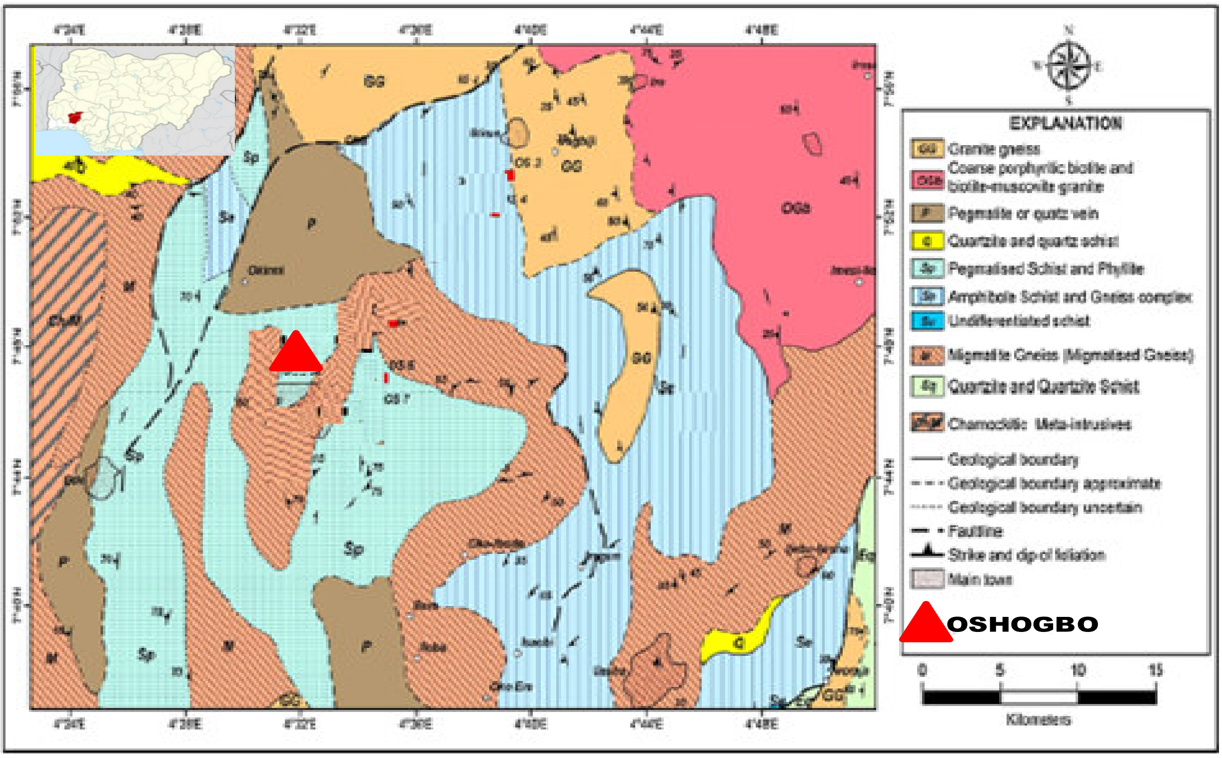

Figure 3: Geological Map of Osogbo and environs. Inset top left, is map of Nigeria showing Osun State (Modified after Oyelami and Van Roy, 2016).

It is pertinent to note that the contamination of the hydrogeological and hydro-chemical systems of groundwater regime in a developing area close to an abandoned dumpsite or in a dump site area, could pose a potential community health risk. It is therefore, expedient for relevant authorities to intervene to ensure the protection of the populace from the negative impacts of pollution; through the provision of potable water from a clean and safe location or designate the place as a disaster prone area, hence evacuate residents to a resettlement centre or create a new town for the residents.

3. METHODOLOGY

There was random collection of samples of leachates, well water, surface water and borehole water, using sterilized bottles. Preliminary tests were conducted on six (6) water samples to determine some parameters, such as pH, Oxidation-reduction potential, Conductivity, Total Dissolve Solids, (TDS), among others, (Table 1).

The collection and transportation to the laboratory was done on the same day. Each sample was carefully labeled at collection points and identified with coordinates to avoid mix up of the samples. The samples were collected and analyzed under strict scientific conditions and processes. At dried areas, soil samples were collected and distilled water was introduced to extract leachates. A total of thirty (30) samples were analyzed to detect the presence of pollutants in both surface and groundwater in and around the study area, (refer to tables 1 and 5). Twenty four samples were tested for heavy metal pollutants (tables 2 to 4). In tables 2 to 4 colour coding was adopted to effectively interpret the results. GREEN coloured values indicate values higher than WHO's (2004) standards, but equal or less than NIS (2017), while BROWN values indicated values that were higher than National Industrial Standard (NIS) limits, but equal or less than World Health Organization's (WHO's) standards. Red coloured values indicate that the results are higher than both standards, and un-highlighted figures represent compliant values.

4. RESULTS AND DISCUSSION

The results of the physico-chemical analyses of the groundwater samples from the study area were presented in Tables 1 and 5. The referenced physico-chemical parameters were compared with concentration levels in relation to the standards of World Health Organization (WHO), The Nigerian Industrial Standard (NIS), and Nigerian Standard for Drinking Water Quality's (NSDWQ) permissible levels.

The physico-chemical parameters that were indicative of groundwater pollution, such as turbidity, pH, and heavy metals' presence were the focus. The TDS conformed to Nigeria Standard of Drinking Water Quality (NSDWQ). Samples 3, 4, 5 agree with NSDWQ rating regarding Odour, while Samples 3, 5, 6 tasted okay. Samples 3, 5, 6 were Colourless. For Turbidity, only Samples 5 and 6 met the normal standard, (refer to table 1).

Table 1: Summary of Results of Physico-Chemical Analyses of Six Water Samples,
Obtained in the Study Area Compared to WHO and (NSDWQ). Note: >> indicates far greater than normal.

PARAMETERS	UNITS	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6	WHO STANDARD	(NSDWQ) STANDARD
Colour	NILL	Coloured	Coloured	Less	Coloured	Less	Less	15NTU	15NTU
Odour	NILL	Odoured	Odoured	Less	Less	Less	Odoured	Unobjectionable	Unobjectionable
Temperature	0° C	25	29.3	29	29.3	25.7	28.7	NA	NA
Turbidity	NTU	20.9	25.0	105	9.51	3.5	4.2	5NTU	5NTU
ORP	mV	166.3	171.9	181.7	162.1	205	154.6		
Conductivity	mS/l	3.10	3.16	312	336	238	259	1000	1000
PH	NILL	7.47	7.64	7.30	7.65	6.71	7.8	6.5-8.5	6.5-8.5
Total Dissolved Solids	mg/l	2.0693	2.133	210.6	226.8	160.6	174.8	500	500
Taste	NILL	Tasted	Tasted	Less	Tasted	Less	Less	Tasteless	Tasteless
Total Alkalinity	mg/l	290	298	72	72	52	26	100	
Total Hardness	mg/l	540	546	370	402	254	294	100	
Calcium Hardness	mg/l	NILL	NILL	292	338	196	280	75	
Mg Hardness	mg/l	NILL	NILL	78	64	58	14	30	
Flouride	mg/l	0.00	0.10	0.00	0.31	0.00	0.00		1.5
Free Chlorine	mg/l	1.02	1.32	0.31	0.51	0.05	0.00		
Nitrate	mg/l	>>	>>	0.54	>>	>>	0.885	10	50
Total Cl	mg/l	1.08	1.38	0.39	0.62	0.06	0.05		
Arsenic	μg/l	0.00	0.00	0.00	0.00	0.00	0.00		0.01
Iron	mg/l	0.40	0.41	0.20	0.12	0.00	0.00	0.3	0.3
Nitrite	mg/l	0.105	0.069	0.00	0.002	0.0	0.014		0.2
Phosphate	mg/l	0.85	1.06	0.00	0.20	0.00	0.00		
Chloride	mmol/L	∞	∞	35	37	44	56		
E. *Coli*	NILL	+ve	+ve	+ve	+ve	-ve	+ve		

Furthermore, results of a set of twenty-four (24) water or leachate samples (M1 to M24) proved heavy metals contamination, (see results in tables 2 to 5), especially westward of the study area. Most locations contain high levels of Arsenic, Lead, Cadmium, Mercury, and Iron, with Lead and Arsenic exceeding the NIS and WHO's Standards in all cases, (tables 2 to 4), (figs. 4 to 9). In all the samples, Lead (Pb) metal was higher than World Health Organization (WHO) and (NIS) standards, as can be observed, in the numerical value range of 6.7 mg/l in sample M3, to 5.35 mg/l in sample M4, (table 3).

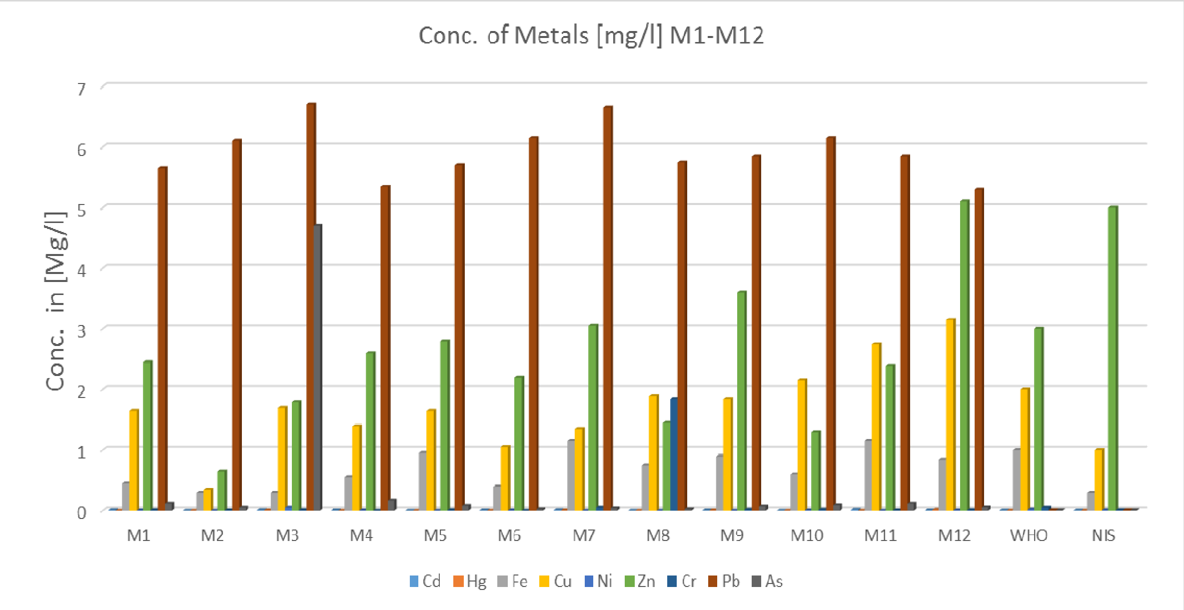

Figure 4: Bar chart of metal concentration in water sample 1 – 12.

For qualitative data interpretation, the data were first grouped into two different ranges. The first data group included Cd, Hg, Ni, Co, Cr. The second data group has Zn, Pb, Fe, Cu, As. From figure 5, the bar chart of five (5) metal (i.e. Cd, Hg, Ni, Co, Cr) concentrations in water samples, M1 - M12, Chromium level (shown in blue colour) in sample M8, at 1.85 mg/l was beyond [WHO] and [NIS] standards. The Arsenic level was higher than both standard values at 1.7 mg/l in sample M3.

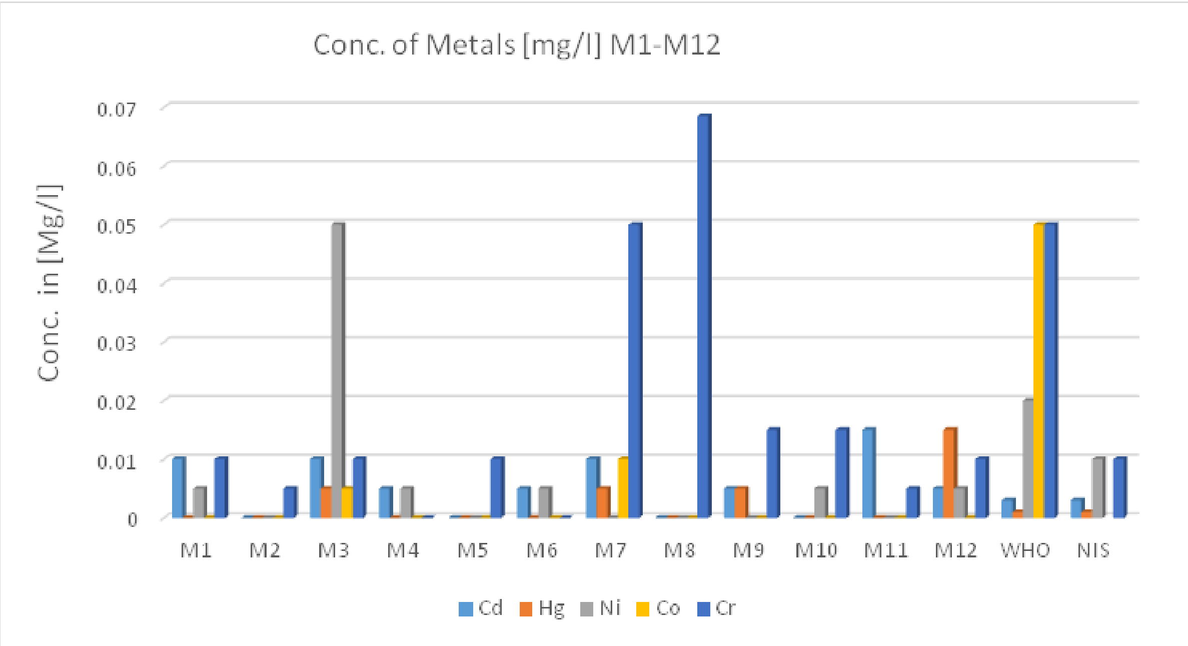

Figure 5*: Bar chart of [Cd, Hg, Ni, Co, Cr] metal concentration in water samples M1–M12.*

From the analysis in figure 4 above, the bar chart shows the risk level and metal concentration in water samples M1 - M12. In all the samples, Lead [Pb] was higher than

World Health Organization [WHO] and [NIS] standard as shown in the red bar, with values ranging from 6.7 mg/l in sample M3 to 5.35 mg/l in sample M4. Also the Chromium level in sample M8, which was 1.85 mg/l exceeded WHO and NIS standards as shown in blue colour, and Arsenic level was 4.7 mg/l in sample 3. However, the Zinc [Zn] level in all the samples M1-M11 (fig. 4) was within the accepted standard of NIS, only sample 12 has Zn level higher than NIS standard.

In Figure 5, the bar chart shows high concentration of Nickel in sample M3 and Chromium in Samples M7 and M8. Both metals are higher than NIS and WHO's standard.

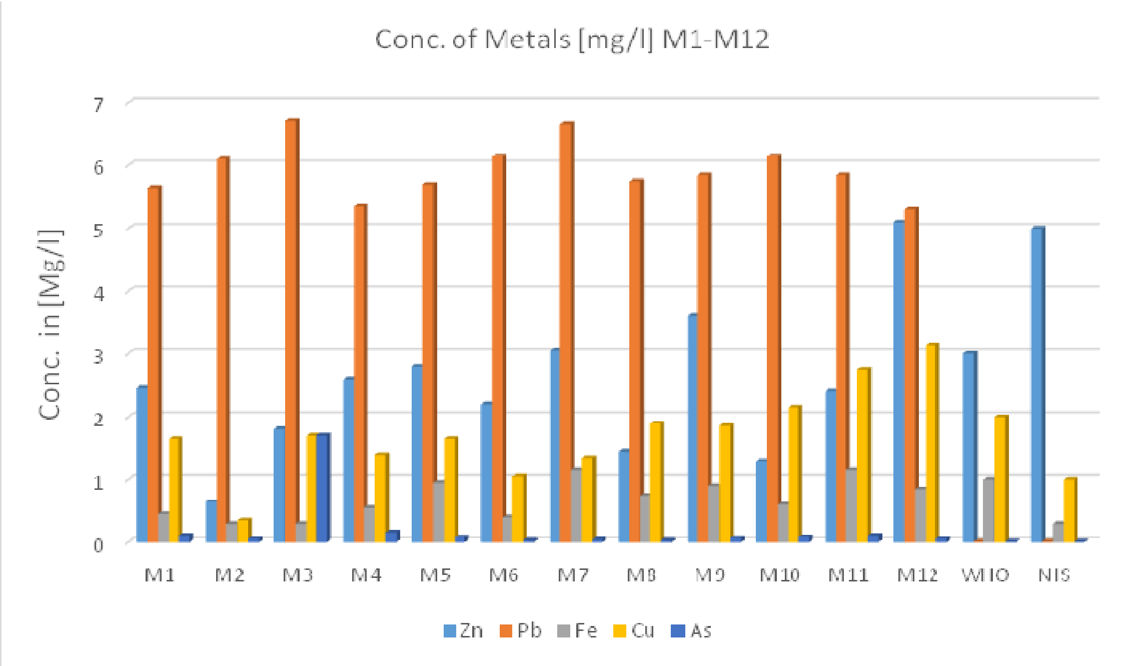

Figure 6: Bar chart of [Zn, Pb, Fe, Cu, As] metal concentration in water samples M1 – M12.

In Figure 6, Zinc in Sample M9 was higher than WHO's standard but lower than NIS, but the lead content in all the samples were exceedingly higher than both NIS and WHO limit. The Zinc (Zn) level however, in all the samples M1-M11 was within the accepted standard of (NIS), only sample M12 had Zn level higher than NIS standard, Zn at M7 and M9 were higher than WHO's limit, (Cf. tables 3 to 5).

Meanwhile, the bar chart of fig. 5 showed high concentration of Nickel, higher than both standards in sample M3, and Chromium was equal to WHO, but higher than NIS in Samples M7, and M8 was much higher than both.

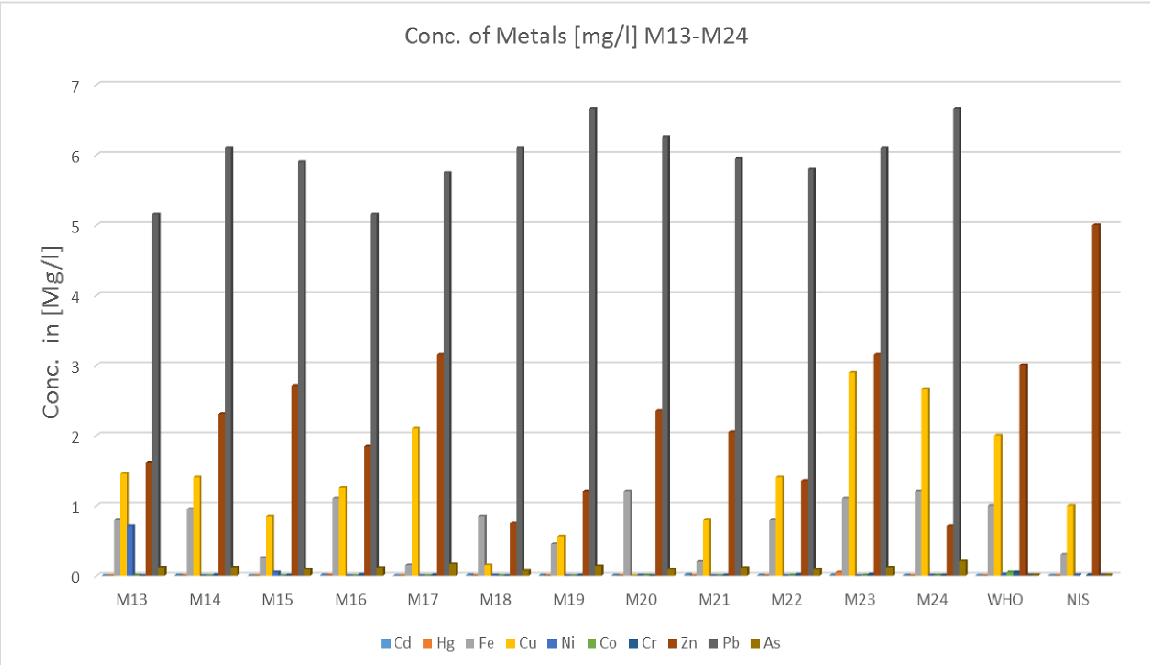

Figure 7: Bar chart of metal concentration in water samples M13 – M24

In water Samples from M13 – M24 (Figure 7) Lead [Pb] was observed to be extremely high. The data were grouped into two. The first data group is from 0.0 - 0.07 [mg/l], the metals that fell within this range are [Cd, Hg, Ni, Co, Cr], (fig. 8). The second data group has these metals [Zn, Pb, Fe, Cu, As] with data spanning between 0.0–7.0 [mg/l], (fig. 9).

Mercury (Hg) in dark green colour, in M16 and M23 were grossly high. Chromium in light blue colour, was also very high in most samples. Note that Cd was present in almost all samples, and higher than both WHO and

NIS standards, (Cf. tables 3 to 5).

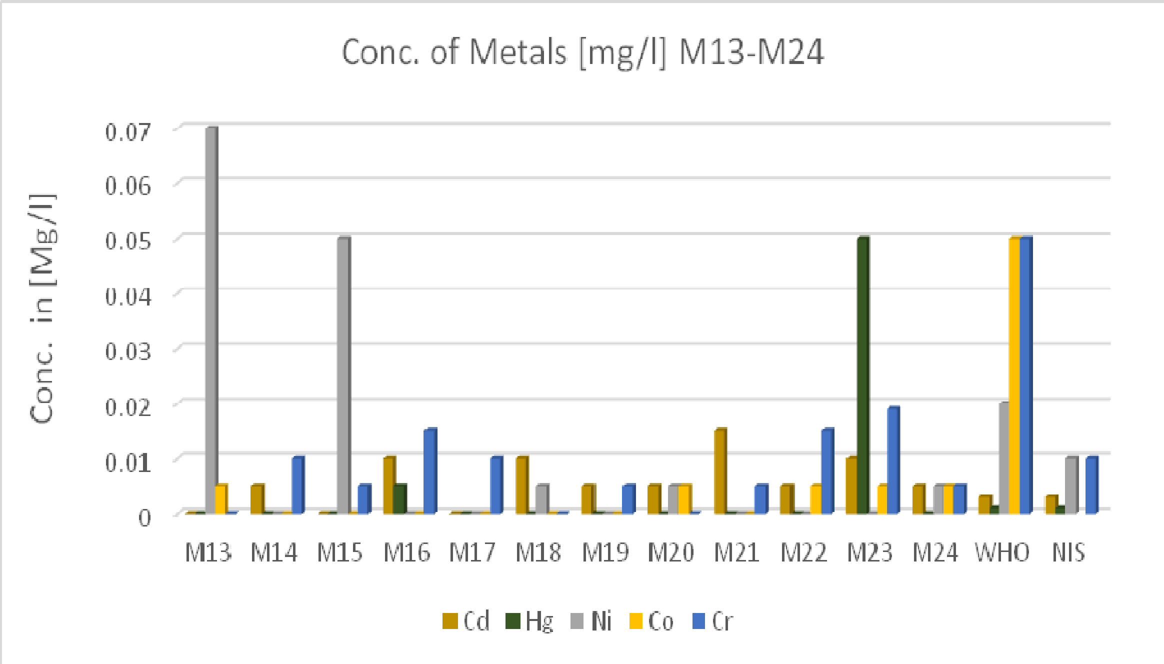

Figure 8: Bar Chart of Metal [Cd, Hg, Ni, Co, Cr] Concentration in Water Samples M13 – M24.

Fig. 9 is the second data group. The concentration of Lead in all the water samples was higher than NIS and WHO standards, as shown in the brown bar chart.

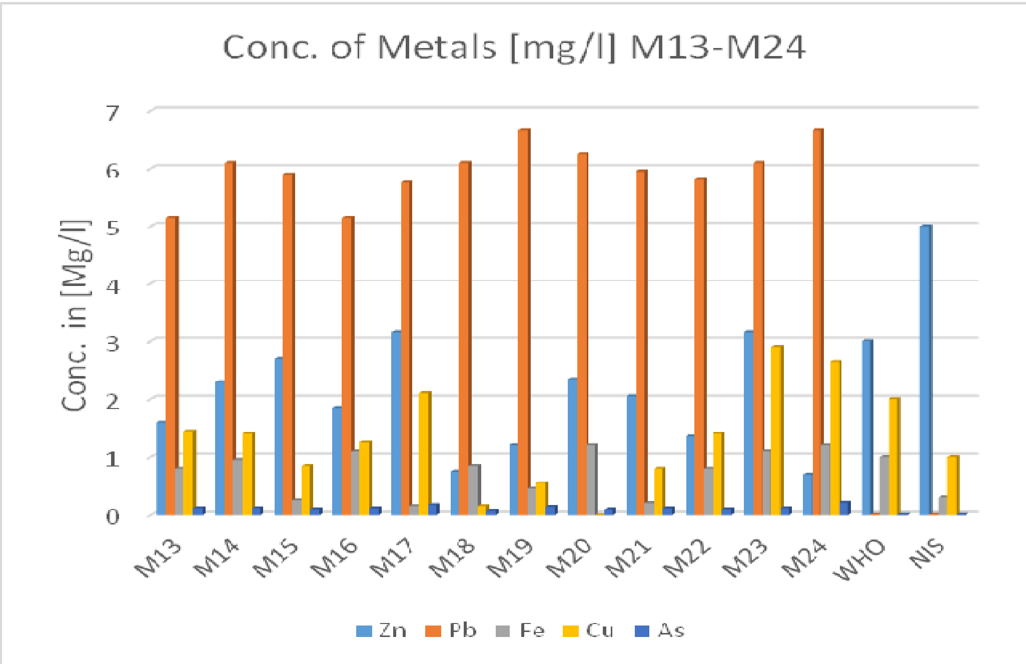

Figure 9*: Metals [Zn, Pb, Fe, Cu, As] Concentrations in Water Samples M13 – M24.*

Figure 9 shows that the concentration of Lead in all the water samples was higher than NIS and WHO standards, as shown in the red bar chart. Also, Copper [Cu] in samples M17, M23 and M24 was higher than NIS and WHO standards.

All the figures show that Lead (Pb) preponderates in all sample locations at a very dangerous risk level. It is generally known to be one of the lethal carcinogenic heavy metals, when assimilated through foods and water. Exposure to lead may cause System Weakness, kidney failure, brain damage, and Anaemia, while very high exposure can cause death. Among heavy metals, Lead, Cadmium, and Mercury do not have any biological benefit and are known to be hazardous. They are also capable of decreasing crop quality and production, due to the risk of bio-accumulation and bio-magnification in the food chain.

Also, Copper [Cu] in samples M17, M23 and M24 was higher than NIS and WHO standards, (Cf. tables 3 to 5). Note that the standard values for Zinc exceeded WHO's limit in M17 and M23, but within NIS standard in all the samples. Due to its importance in our dietary needs NIS allows it. So, all other samples were within NIS acceptable standards.

Table 2: The Analytical Results of Ten (10) Water Samples, (M1 To M10) From Former Osun Central Dump Site Onibu-Eja, (Concentration Of Heavy Metals).

HEAVY METALS	------------------------------------HEAVY METALS(mg/l)-------------------------------									STANDARDS	
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	WHO, (2004).	(NIS: 2017), TREATED DRINKING WATER.
Cd	0.01	0.00	0.01	0.005	0.00	0.005	0.01	0.00	0.005	0.00	0.003	0.003
Hg	0.00	0.00	0.005	0.00	0.00	0.00	0.005	0.00	0.005	0.00	0.001	0.001
Fe	0.45	0.80	0.30	0.55	0.95	0.40	1.15	0.75	0.90	0.60	0.30-1.00	0.30
Cu	1.65	0.35	1.10	1.40	1.65	1.05	1.55	1.90	1.85	2.15	2.00	1.00
Ni	0.005	0.00	0.05	0.005	0.00	0.005	0.00	0.00	0.00	0.005	0.02	0.01
Co	0.00	0.00	0.005	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.05	-----
Cr	0.01	0.005	0.015	0.00	0.01	0.00	0.05	1.85	0.015	0.015	0.05	0.01
Zn	2.45	0.65	1.80	2.60	2.80	2.20	3.05	1.45	3.60	1.30	3.00	5.00
Pb	5.65	6.10	6.70	5.35	5.70	6.15	6.65	5.75	5.85	6.15	0.01	0.01
As	0.115	0.05	4.70	0.165	0.08	0.025	0.04	0.025	0.07	0.09	0.01	0.01

KEY:

GREEN	**VALUES, HIGHER THAN WHO, (2004), BUT WITHIN 2017 NATIONAL STANDARD.**
RED	**VALUES, HIGHER THAN BOTH WHO, (2004), AND 2017 NATIONAL STANDARDS.**
BROWN	**VALUES, HIGHER THAN 2017 NATIONAL STANDARD, BUT WITHIN WHO, (2004).**
-----	**NATIONAL STANDARD NOT AVAILABLE.**
THE UNCOLOURED AND UNBOLDENED FIGURES REPRESENT COMPLIANT VALUES, TO BOTH WHO (2004), AND 2017 NATIONAL INDUSTRIAL STANDARD.	

Table 3: The Analytical Results of Ten (10) Water Samples, (M11 to M20) From Former Osun Central Dump Site Onibu-Eja, (Concentration of Heavy Metals).

HEAVY METALS	----------------------------------HEAVY METALS(mg/l)-----------------------------									STANDARDS	
	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	WHO, (2004).	(NIS 2017), TREATED DRINKING WATER.
Cd	0.015	0.005	0.00	0.005	0.00	0.01	0.00	0.01	0.005	0.005	0.003	0.003
Hg	0.00	0.005	0.00	0.00	0.00	0.005	0.00	0.00	0.00	0.00	0.001	0.001
Fe	1.15	0.85	0.40	0.95	0.25	1.10	0.15	0.85	0.45	1.20	0.30-1.00	0.30
Cu	2.75	3.15	1.45	1.40	0.85	1.25	2.10	1.15	0.55	1.65	2.00	1.00
Ni	0.00	0.005	0.70	0.00	0.05	0.00	0.00	0.005	0.00	0.005	0.02	0.01
Co	0.00	0.00	0.005	0.00	0.00	0.00	0.00	0.00	0.00	0.005	0.05	-----
Cr	0.005	0.01	0.00	0.01	0.005	0.015	0.01	0.00	0.005	0.00	0.05	0.01
Zn	2.40	5.15	1.60	2.30	2.70	1.85	3.15	0.75	1.20	2.35	3.00	5.00
Pb	5.85	5.30	5.15	6.10	5.90	5.15	5.75	6.10	6.65	6.25	0.01	0.01
As	0.115	0.055	0.115	0.115	0.09	0.11	0.165	0.07	0.135	0.09	0.01	0.01

KEY:

GREEN	**VALUES, HIGHER THAN WHO, (2004), BUT WITHIN 2017 NATIONAL STANDARD.**
RED	**VALUES, HIGHER THAN BOTH WHO, (2004), AND 2017 NATIONAL STANDARDS.**
BROWN	**VALUES, HIGHER THAN 2017 NATIONAL STANDARD, BUT WITHIN WHO, (2004).**
-----	**NATIONAL STANDARD NOT AVAILABLE.**
THE UNCOLOURED AND UNBOLDENED FIGURES REPRESENT COMPLIANT VALUES, TO BOTH WHO (2004), AND 2017 NATIONAL INDUSTRIAL STANDARDS.	

Table 4: The Analytical Results Of Ten (10) Water Samples, (M21 To M24), From Former Osun Central Dump Site Onibu-Eja, (Concentration Of Heavy Metals).

HEAVY METALS	--------HEAVY METALS(mg/l)--------				STANDARDS	
	M21	M22	M23	M24	WHO, (2004).	(NIS: 2017), TREATED DRINKING WATER.
Cd	**0.015**	**0.005**	**0.01**	**0.005**	**0.003**	**0.003**
Hg	0.000	0.000	**0.05**	0.000	**0.001**	**0.001**
Fe	0.200	**0.800**	**1.10**	**1.200**	**0.30-1.00**	**0.30**
Cu	0.800	**1.600**	**2.900**	**2.650**	**2.00**	**1.00**
Ni	0.000	0.000	0.000	0.005	**0.02**	**0.01**
Co	0.000	0.005	0.005	0.005	**0.05**	**-----**
Cr	0.005	**0.015**	**0.015**	0.005	**0.05**	**0.01**
Zn	2.050	1.350	**3.150**	0.70	**3.00**	**5.00**
Pb	**5.95**	**05.800**	**6.100**	**6.65**	**0.01**	**0.01**
As	**0.11**	**0.09**	**0.115**	**0.205**	**0.01**	**0.01**

KEY:

GREEN	**HIGHER THAN WHO, (2004), BUT WITHIN 2017 NATIONAL STANDARD.**
RED	**HIGHER THAN BOTH WHO, (2004), AND 2017 NATIONAL STANDARDS.**
BROWN	**HIGHER THAN 2017 NATIONAL STANDARD, BUT WITHIN WHO, (2004).**
-----	**NATIONAL STANDARD NOT AVAILABLE.**
THE UNCOLOURED AND UNBOLDENED FIGURES REPRESENT COMPLIANT VALUES, TO BOTH WHO (2004), AND 2017 NATIONAL INDUSTRIAL STANDARD.	

In all parameters that were analysed, from M1 to M24, the presence of Lead was very high, ranging from 37% to 82%, and exceeding both standards. The presence of Arsenic was also significant in all samples, refer to figure 10, and tables 2 to 5. Others that recorded high values in some cases included Mercury, Iron, Chromium, Nickel, Cadmium, Cobalt, Zinc, and Copper. Note that very few of the parameters were compliant with the standards. Note too that some parameters have insignificant values in few samples, so were not visible on the charts.

Using M2 as a model, Lead (a heavy metal), was leading with 82% occurrence, followed by 9% of Zinc, and 5% of Cupper, (fig. 10). Fe, (a trace element) recorded 4% occurrence. Others recorded very low percentage of less than 1% occurrence. Trace Metals (TMs) are minerals that are present in living tissues in small amounts, and are known to be nutritionally essential. Iron, as a constituent of haemoglobin and myoglobin, also plays a vital role in the transport of Oxygen, (Raja and Namburu, 2014). On the other hand, Heavy Metals are usually high dense materials with high atomic numbers and atomic weights, and are usually toxic at very low concentrations. Most of them have similar medical impacts on the living systems, (Dina M.S. and Andrew J. G., 2016).

TABLE 5: THE SUMMARY OF ANALYTICAL RESULTS OF TWENTY-FOUR (24) WATER SAMPLES WITH THEIR COORDINATES, AND RISK ASSESSMENT, FROM OWMA'S ABANDONED OSUN CENTRAL DUMP SITE, ONIBU-EJA, OSUN STATE.

LOCATION IDENTITY	GEO-REFERENCE	SOURCE	REMARK: CORRELATION WITH WHO (2004), and NIS 977: 2017. (N/A= NOT AVAILABLE, WHO= WORLD HEALTH ORGANISATION, NIS= NIGERIAN INDUSTRIAL STANDARD).
M1	**N** 07.79409, **E** 004.49021, **ALT:** 311m.	Brook channel (Surface water).	**Cd**>WHO/NIS; Hg (absent); **Fe** <WHO>NIS; **Cu**<WHO>NIS; **Ni**<WHO<NIS; **Co** (absent); **Cr** <WHO, =NIS; **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M2	**N** 07.79414, **E** 004.49022, **ALT:** 311m.	Brook channel (Surface water).	**Cd** (absent); **Hg** (absent); **Fe**<WHO>NIS; **Cu**<WHO/NIS; **Ni** (absent); **Co** (absent); **Cr**<WHO/NIS; **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.

M3	**N** 07.79423, **E** 004.49024, **ALT:** 311m.	Brook channel (Surface water).	**Cd**>WHO/NIS; **Hg**>WHO/NIS; **Fe**<WHO=NIS; **Cu**<WHO>NIS; **Ni>**WHO/NIS; **Co**<WHO, NIS (standard N/A); **Cr**<WHO>NIS; **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M4	**N** 7.79421, **E** 004.49022, **ALT:** 312m.	Brook channel (Surface water).	**Cd**>WHO/NIS; **Hg** (absent); **Fe**<WHO>NIS; **Cu**<WHO>NIS; **Ni**<WHO/NIS; **Co** (absent,); **Cr** (absent); **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M5	**N** 07.79442, **E** 004.49006, **ALT:** 310m.	Brook channel (Surface water).	**Cd** (absent); **Hg** (absent); **Fe**<WHO>NIS; **Cu**<WHO>NIS; **Ni** (absent); **Co** (absent); **Cr**<WHO, =NIS; **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M6	**N** 07.79445, **E** 004.49016, **ALT:** 312m	Brook channel (Surface water).	**Cd>**WHO/NIS; **Hg** (absent); **Fe**<WHO>NIS; **Cu**<WHO>NIS; **Ni**<WHO/NIS; **Co** (absent); **Cr** (absent); **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M7	**N** 07.79454, **E** 004.49018, **ALT:** 312m.	Brook channel (Surface water).	**Cd**>WHO/NIS; **Hg**>WHO/NIS; **Fe**>WHO/NIS; **Cu**<WHO>NIS; **Ni** (absent); **Co**<WHO, NIS (N/A); **Cr**<WHO/NIS; **Zn**>WHO<NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M8	**N** 07.79459, **E** 004.49115, **ALT:** 314m.	Surface leachate inside dumpsite	**Cd** (absent); **Hg** (absent); **Fe**<WHO>NIS; **Cu**<WHO>NIS; **Ni** (absent); **Co** (absent); **Cr**>WHO/NIS; **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M9	**N** 07.79456, **E** 004.49124, **ALT:** 314m.	Surface leachate inside dumpsite	**Cd**>WHO/NIS; **Hg**>WHO/NIS; **Fe**<WHO>NIS; **Cu**<WHO>NIS; **Ni** (absent); **Co** (absent); **Cr**<WHO>NIS; **Zn**>WHO<NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M10	**N** 07.79445, **E** 004.49134, **ALT:** 314m.	Surface leachate inside dumpsite	**Cd** (absent); **Hg** (absent); **Fe**<WHO>NIS; **Cu**>WHO/NIS; **Ni**<WHO/NIS; **Co** (absent); **Cr**<WHO>NIS; **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M11	**N** 07.79555, **E** 004.49129, **ALT:** 311m.	Brook channel (Surface water).	**Cd**>WHO/NIS; **Hg** (absent); **Fe**>WHO/NIS; **Cu**>WHO/NIS; **Ni** (absent); **Co** (absent); **Cr**<WHO/NIS; **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M12	**N** 07.79536, **E** 004.49132, **ALT:** 312m	Brook channel (Surface water).	**Cd**>WHO/NIS; **Hg**>WHO/NIS**;** **Fe**<WHO>NIS**;** **Cu**>WHO/NIS; **Ni**<WHO/NIS; **Co** (absent); **Cr**<WHO, =NIS; **Zn**>WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M13	**N** 07.79637, **E** 004.49156, **ALT:** 304m.	Ground water: Well 1	**Cd** (absent); **Hg** (absent); **Fe<**WHO>NIS; **Cu**<WHO>NIS; **Ni**>WHO/NIS; **Co**<WHO, NIS (N/A); **Cr** (absent); **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M14	N 07.79651, E 004.49098, Alt: 308m.	Ground water: Well 2	**Cd**>WHO/NIS; **Hg** (absent); **Fe**<WHO>NIS; **Cu**<WHO>NIS; **Ni** (absent); **Co** (absent); **Cr**<WHO, =NIS; **Zn**<WHO/NIS; **Pb>**WHO/NIS; **As**>WHO/NIS.
M15	N 07.79533, E 004.49012, ALT: 307m.	Brook channel (Surface water).	**Cd** (absent); **Hg** (absent); **Fe**<WHO/NIS; **Cu**<WHO/NIS; **Ni**>WHO/NIS; **Co** (absent); **Cr**<WHO/NIS; **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M16	N 07.79556, E 004.49004, ALT: 307m.	Brook channel (Surface water).	**Cd**>WHO/NIS; **Hg**>WHO/NIS; **Fe**>WHO/NIS; **Cu**<WHO>NIS; **Ni** (absent); **Co** (absent); **Cr**<WHO>NIS; **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M17	N 07.79546, E 004.49010, ALT: 308m.	Brook channel (Surface water).	**Cd** (absent); **Hg** (absent); **Fe**<WHO/NIS; **Cu**>WHO/NIS; **Ni** (absent); **Co** (absent); Cr<WHO, =NIS; **Zn**>WHO<NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.

M18	N 07.79556, E 004.49001, ALT: 308m.	Brook channel (Surface water).	**Cd**>WHO/NIS; **Hg** (absent); **Fe**<WHO>NIS; **Cu**<WHO>NIS; **Ni**<WHO/NIS; **Co** (absent); **Cr** (absent); **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M19	N 07.79563, E 004.49003, ALT: 308m.	Brook channel (Surface water), Wetland outside the dumpsite's fence.	**Cd**>WHO/NIS; **Hg** (absent); **Fe**<WHO>NIS; **Cu**<WHO/NIS; **Ni** (absent); **Co** (absent); **Cr**<WHO/NIS; **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M20	N 7.79589, E 004.49005, ALT: 308m.	Brook channel (Surface water).	**Cd**>WHO/NIS; **Hg** (absent); **Fe**>WHO/NIS; **Cu**<WHO>NIS; **Ni**<WHO/NIS; **Co**<WHO, NIS (N/A); **Cr** (absent); **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M21	N 07.79605, E 004.49009, ALT: 305m.	Brook channel (Surface water).	**Cd**>WHO/NIS; **Hg** (absent); **Fe** <WHO/NIS; **Cu**<WHO/NIS; **Ni** (absent); **Co** (absent); **Cr**<WHO/NIS; **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M22	N 07.79654, E 004.49032, ALT: 305m	Brook channel (Surface water).	**Cd**>WHO/NIS; **Hg** (absent); **Fe**<WHO>NIS; **Cu**<WHO>NIS; **Ni** (absent); **Co**<WHO, NIS (N/A); **Cr**<WHO>NIS; **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M23	N 07.79662, E 004.49032, ALT: 305m.	Brook channel (Surface water).	**Cd**>WHO/NIS; **Hg**>WHO/NIS; **Fe**>WHO/NIS; **Cu**>WHO/NIS; **Ni** (absent); **Co**<WHO, NIS (N/A); **Cr**<WHO>NIS; **Zn**>WHO<NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.
M24	N 07.79651, E 004.49060, ALT: 319m.	Brook channel (Surface water).	**Cd**>WHO/NIS; **Hg** (absent); **Fe**>WHO/NIS; **Cu**>WHO/NIS; **Ni**<WHO/NIS; **Co**<WHO, NIS (N/A); **Cr**<WHO/NIS; **Zn**<WHO/NIS; **Pb**>WHO/NIS; **As**>WHO/NIS.

M2, (fig. 10), had the highest value of Lead at alarming rate, (refer to tables 2 to 5). Lead (Pb) preponderates in all sample locations at a very dangerous percentage. It is generally known to be one of the lethal carcinogenic heavy metals, when assimilated through foods and water. Exposure to lead may cause System Weakness, kidney Failure, brain damage, and Anaemia, while very high exposure can cause death. Child exposure to Lead, can seriously harm a child's health, including damage to the brain and nervous system, diminutive growth and development. It can lead to hearing, speech, learning, and behavioural disorders.

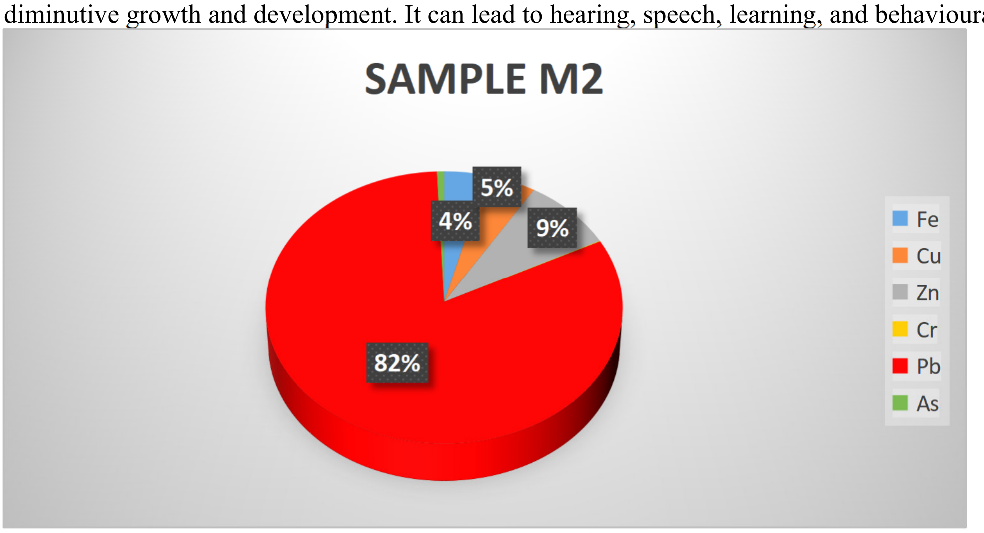

Fig 10: percentage occurrence of parameters in Sample M2.

Among 19 heavy metals, Lead, Cadmium, and Mercury do not have any biological benefit and are known to be extremely toxic. Industrial wastes contain large number of toxicants, such as salts of heavy metals, acids, organic matter, pesticides, and even Cyanides, which deteriorate the physico-chemical characteristics of water. These pollutants build up in the food chain and are responsible for adverse effects and even death of the organisms in the aquatic system. All wastes streams, ranging from end-of-life Electrical Electronics Equipment

(EEE), to municipal and industrial wastes, were dumped at the site, and were found to be the sources of the contaminants.

They are capable of decreasing crop quality and yield, due to the risk of bio-accumulation and bio-magnification in the food chain. The selection of Heavy Metals for analyses was based on their preponderance in other works on the area, their toxicity, and wastes streams. For zinc, only M12 value exceeded both NIS and WHO. Values of M7, M9, M17, and M23 were greater than WHO, but less than NIS. The rest of the samples were compliant to both standards. Lead and Arsenic exceeded both NIS and WHO standards in all the samples collected.

5. CONCLUSION

The collection of water samples for Heavy Metals analyses in the study area was based on their expected toxicity and wastes streams on the site. In all, thirty (30) water samples were analyzed to detect the presence of pollutants in the leachates in both surface and groundwater in and around the study area. An appraisal of the results showed high risk levels of contamination with Arsenic, Lead, Cadmium, Mercury, and Iron; with Lead and Arsenic exceeding the WHO's and National Standards limits in all cases.

Mercury, Lead, Chromium, Cadmium and Arsenic are the main heavy metals that induce human poisoning and bioaccumulation of these metals leads to toxic effects on various body tissues or organs. Therefore the Osun state government should designate the site area as hazardous and Non-Agricultural zone. Also groundwater development in the area should be deep and concentrated within the area of highly weathered basement for optimum and quality groundwater potential extraction, if it must to be done.

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