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Assessment of Drinking Water Samples Around Selected Oil Spillage and Metal Recycling Company in Lagos State, Nigeria

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Abstract

In recent times, anthropogenic source has been considered to be one of the major sources of environmental pollution. In this study, the levels of six heavy metals (Cadmium -Cd, Copper-Cu, Chromium-Cr, Iron-Fe, Mangenese- Mn and Lead-Pb) were assayed in water samples from well and borehole around Gemade oil spillage and Sun metal industry, Lagos, Nigeria using Flame Atomic Absorption Spectrometry (FAAS). The levels of these heavy metals were in the order Fe > Mn > Cu > Cd / Pb / Cr for the two sites and control, and within the range 0.001-10.162 mg/L. The results showed that significant difference exists between these levels and the controls ($t_v < 0.005$). In most cases, the levels of Fe and Mn from the sites were found above the WHO/FEPA limits. Significant differences exist between the levels of Cu and Mn in well and borehole water samples (t_v = 0.004 -0.005) but not Fe (t_v = 0.31 - 0.91). This indicated that the surrounding drinking water samples were polluted with some of these metals. The results obtained in this work also gave the baseline levels of these metals in the water samples at the selected sites.

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1. Introduction

Rapid acceleration of industrial growth throughout the world produces negative impacts on the environment. The discharge of contaminated effluents from industries with little or no attention to treatment or remediation is another matter of great concern. Wastewater from industries that are associated with manufacturing of automobile, purification of metals, electroplating, galvanizing, coating, paint, electronics, pharmaceutical, chemicals and battery manufacturing are the most common sources of heavy metal pollution. Arsenic, cadmium, copper, chromium, lead, mercury, nickel and zinc are commonly found in heavy metal contaminated wastewater [1]. These metals with toxic and persistent characteristics, can enter into the food chains and the ecosystem with serious adverse effects on the biotic and abiotic components of ecosystem. Water has also been identified as one of the major media of transport for pollutants with profound effects on both living organisms and the environment [2, 3]. Over the time, the pollutants can also bio-accumulate and bio-magnify through this aqueous medium, the moment they enter the biological system [4]. The toxicity or severity of the effects becomes much more significant in the trophic level once it reaches human as the final consumer in the food web and the health will be compromised. Several reports on these impeccable impacts on the environment and humans have been reported [5, 6]. For example, Lead (Pb) is not an essential trace element as far as nutrition in humans or animals is concerned. Its important properties like softness, malleability, ductility, poor conductibility and resistance to corrosion seem to make difficult to give up its use. It can affect organisms including human even at low concentration as it bio-accumulates and bio-magnifies in the food chain. Contaminated environmental media, food and consumer products result in the absorption of Pb into human body. The concentrations of Pb and exposure time are key factors in lead toxicity measurement. High Pb concentration could result into seizures, coma and death. Meanwhile, long time and low exposure of chronic poisoning is commonly found in case studies. Pb toxicity is an important environmental problem whose effects on the human body can be devastating. Other diseases associated with lead toxicity include anemia, neurotoxicity, hem toxicity, nephrotoxicity and toxic metabolic encephalopathy. It targets organs and tissues including the heart, bones, intestines, kidneys and the reproductive system and capable of disrupting metabolic processes thereby threatening lives [4, 5]. Its acute poisoning occurs when one is exposed to high concentration of Pb for a short period and the adverse effect is usually high and severe [7]

However, copper (Cu) is an element with atomic number 29. It is placed in Group 11 of the Periodic Table, commonly referred to as a "Transition Metal". It is a reddish-brown, malleable and ductile element with high/ excellent thermal and electrical conductivity. Cu is mainly used in the manufacturing of electric cables and equipment which are mostly utilized for plumbing, wood preservative, leather and fabrics, alloys, agricultural fungicides and pharmaceutical products. The common anthropogenic sources of Cu include copper wire mills, iron and steel producing industries, smelting companies, coal burning industries, metallurgical processes as well as mining activities. It was reported that a high concentration of Cu and other physico-chemical parameters had been reported in Malaysian rivers [8]. Cu is an important essential element when in a low concentration, particularly to higher plants and animals. In human, Cu is a component of metalloenzymes which can function as electron donor or acceptor. Cu is also present in normal human serum at concentration of 120 to 140 µg/g via binding to ceruloplasmin, albumin and other molecules. However, high levels of Cu results into health effects such as liver and kidney damage, gastrointestinal irritation and anemia. Furthermore, elevated level of Cu in the body is also associated indirectly with neurological disorders such as prion disease, Alzheimer and Wilson's diseases [9, 10]. It is also worthy to note that the bio-accumulation and bio-magnification of this metal could result into toxicity and therefore be detrimental to the health of the nearby living organisms and the environment at large. For instance, the dissolved Cu that is usually generated from a non-point source in ecosystem can progressively influence the water chemistry and bio-accumulate in fish which results in bio-magnification through food chain [11].

Nickel is classified as a hard, malleable and ductile transition metal that is widely used in various industries and consumer products including stainless steel, coins, rechargeable batteries, alloys and amour plates, burglarproof vaults, ceramics, magnets, domestic cleaning products, oil refining and fungicides. The major sources of contamination by nickel include mining, smelting, casting of alloys, refining and electroplating industries. Findings by the Department of Environment of Malaysia showed that Sungai Skudai in Johor river has concentration of Ni ranging from 0 to 10 mg/L while it was 16.42 to 31.83 mg/mL in Sungai Langat basin. This was an indication that the rivers were seriously contamination [12]. Despite these adverse effects, Ni has been found to be essential for the growth and as an important co-enzyme of some living microorganisms and plants. However, it can be mildly toxic if present in large amount and just like Cu, Ni can bio-accumulate and bio-magnify along food chains. Thus, posing serious problem to living organisms. Mansouri *et al*. [13] documented some evidences of Ni bio-accumulation and magnification in fish from embryos and non-feeding larvae phase to targeted organs such as gill, kidney, liver, brain and muscle. The short-term overexposure to the high concentration of Ni is not yet known to constitute any health problem to humans but long-term exposure could be detrimental to health. It predominantly affects the respiratory system, causes acute inflammatory on the nasal membrane, hypersension contact dermatitis and bronchial asthma [14]. Others include decrease in body weight, skin irritation, stimulation of neoplastic transformation, cardiovascular system poisoning, kidney and liver damage [15]. Other heavy metals of environmental concern are cadmium (Cd), chromium (Cr) and manganese (Mn) just to mention a few.

The objective of this study was to determine the levels of six heavy metals (Cd, Cu, Cr, Fe, Mn and Pb) in water samples from well and borehole around Gemade oil spillage and Sun metal industry. A comparative analysis was also made with the identical samples from the control and recommended limits.

2. Materials and Methods

2.1. Sampling

The Gemade oil spillage was caused by pipeline leakages. It is located in Idimu, Lagos State. Lagos state is within latitude 6.5244°N and longitude 3.3792°E. Lagos State is bounded on the north and east by Ogun State. Sun metal industry is a subsidiary of Ola' keen Holding Limited which started its operation in the year 1986 which has a coordinates of 7.9452 °N and 4.7888 °E. The operation being carried out involves manufacturing and mining. Four (each of) well water and borehole water samples were collected from the site considered. In this study, the depths of the water samples were not considered but the water samples were taken at different directions and distances from the source. Three identical samples each were also collected several miles where no anthropogenic activity took place. Samples were collected in good quality/new water bottles, each of 75 cl capacity, labelled properly and analysed in laboratory for trace metals using Flame Atomic Absorption Spectrometer (FAAS).

The bottles were rinsed properly with distilled water and samples were preserved in the refrigerator before being taken to the laboratory. Preservation and water analysis were based on standard method proposed by World Health Organization (WHO) and Federal Environmental Protection Agency (FEPA) and the six selected heavy metals (Mn, Fe, Cu, Pb, Cd, Cr) were analysed.

2.2. Sample Digestion and Procedure

Two hundred milliliter (200 mL) of each sample was measured into seperate 250 mL conical flask. Ten milliliter (10 mL) of HCL.HNO, (1:1) was added to each sample and heated on Foss Tecator digestor at a temperature of 105°C until the volume reduces to 50.0 m/s. It was allowed to cool and made up to the mark of 50 mL inside a standard volumetric flask. The resulting solution was analyzed using FAAS using the instrumental condition. The FAAS facility was properly calibrated for the observed heavy metals with high R^2 values (0.998-0.999) absorbance against concentration before use.

3. Results and Discussion

The levels of heavy metals in the water samples from the oil spillage site and the control were presented in Table 1. Table 2 shows the descriptive statistics of heavy metals in the samples from the site and the control while Table 3 shows the comparison of the observed levels with WHO and FEPA maximum permissible limits. The data obtained from the descriptive statistical analysis was further analysed using t–test to know if significant differences exist in the concentration of the observed heavy metals between the sites and the control (Table 4).

The results indicated that the concentrations of Fe, Mn, Cr, and Cu (mg/L) in well water were within the range of 6.378 – 8.885, 0.537 – 0.743, 0.388 – 0.665, 0.231 – 0.257, whereas, in borehole water within the range of 5.482 – 10.162, 0.205 – 0.210, 0.00 – 0.284, 0.057 – 0.134, respectively, while Cd and Pb were below the detection limits (ND). The concentration of the observed heavy metals were in the order of Fe > Mn > Cr > Cu > Cd/Pb. Out of the six heavy metals, the mean concentration of Mn, Fe and Cr were above their permissible limits. Table 2 implies that the water from the site at about 150 m away from the oil spillage source contained high level of these metals.

Table 1. Heavy metals content (mg/L) of water samples from metal recycling company and control.

Sample ID	Description	Mn (mg/L)	Fe (mg/L)	Cu (mg/L)	Cd (mg/L)	Pb (mg/L)	Cr (mg/L)	Approximate distance (m)
A	Well	0.537	6.378	0.231	ND	ND	0.390	150
		0.54	6.382	0.232	ND	ND	0.388	120
B	Well	0.743	8.883	0.257	ND	ND	0.665	100
		0.742	8.885	0.255	ND	ND	0.662	40
C	Borehole	0.205	10.152	0.057	ND	ND	0.002	150
		0.205	10.162	0.057	ND	ND	ND	100
D	Borehole	0.210	5.486	0.133	ND	ND	0.281	50
		0.209	5.482	0.134	ND	ND	0.284	25
E	Control (well) n=3	ND	ND	ND	ND	ND	ND	ND
F	Control (bore-hole) n=3	0.001	ND	ND	ND	ND	ND	ND

ND – Not detected (below the detection limit)

Table 2. Descriptive statistics of heavy metal (mg/L) of water samples from the oil spillage and the control.

		Heavy Metals											
Sample ID	Sample Description	Mn (mg/L)		Fe (mg/L)		Cu (mg/L)		Cd (mg/L)		Pb (mg/L)		Cr (mg/L)	
		Range	Mean ± SD	Range	Mean ± SD	range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
W1-W4	Well water	0.537-0.743	0.641± 0.118	6.378-8.885	7.632 ± 1.446	0.231-0.257	0.244 ± 0.014	ND	ND	ND	ND	0.388-0.665	0.527 ± 0.159
B1-B4	Borehole water	0.205-0.210	0.207 ± 0.003	5.482 - 10.162	7.821 ± 2.690	0.057-0.134	0.095 ± 0.04	ND	ND	ND	ND	0.00-0.284	0.142 ± 0.163
C1-C3	Control (well)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C4-C6	Control (bore-hole)	0.001	0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND – Not detected (below the detection limit)

The distance of either the well water or borehole samples from the anthropogenic source differs because the wells and boreholes were located haphazardly at the sites. The distance of sampling from the source could possibly assist in determining the extent of pollution and recommend a safe distance/water samples that are good for drinking (based on FEPA limits). In most cases, for the oil spillage site, the concentration of the observed heavy metals reduced with distance from the source and were greater than WHO/FEPA limits (except for Cu, while, Cd and Pb were below the detection limits). This is an indication of pollution arising from the source/activity (Table 3) and that the water samples within the distance covered in this study were not safe for consumption. Using t-test, the slight increase in the levels of Mn, Fe and Cu in well water samples between 150 m and 120 m was statistically insignificant (tv > 0.05) and

Table 3. Comparison of the levels of heavy metal (mg/L) in oil spillage area with WHO/FEPA limits.

Sample ID	Approximate distance (m)	Mn (mg/L)	Fe (mg/L)	Cu (mg/L)	Cd (mg/L)	Pb (mg/L)	Cr (mg/L)
A Well	150	0.537	6.378	0.231	ND	ND	0.390
	120	0.540	6.382	0.232	ND	ND	0.388
B	100	0.743	8.883	0.257	ND	ND	0.665
	40	0.742	8.885	0.255	ND	ND	0.662
C Borehole	150	0.205	10.152	0.057	ND	ND	0.002
	100	0.205	10.162	0.057	ND	ND	ND
D	50	0.210	5.486	0.133	ND	ND	0.281
	25	0.209	5.482	0.134	ND	ND	0.284
Control (n=3)	ND	ND	ND	ND	ND	ND	ND
WHO/FEPA limits		0 .05	1.0-3.0	1.300	0.005	0.01-0.48	0.100

ND – Not detected (below the detection limit)

Table 4. Heavy metal content (mg/L) of water samples around Sun metal company and control.

Sample ID	Description	Mn (mg/L)	Fe (mg/L)	Cu (mg/L)	Cd (mg/L)	Pb (mg/L)	Cr (mg/L)	Approximate240 distance (m)
A	Well	0.203	0.090	ND	ND	ND	ND	200
		0.202	0.095	ND	ND	ND	ND	
B		0.330	0.022	ND	ND	ND	ND	150
		0.332	0.020	ND	ND	ND	ND	
C	Borehole	0.010	0.040	ND	ND	ND	ND	50
		0.012	0.042	ND	ND	ND	ND	
D		0.001	0.030	ND	ND	ND	ND	70
		0.001	0.030	ND	ND	ND	ND	
E	Control240 (Well)	ND	ND	ND	ND	ND	ND	ND
F	Control (borehole)	ND	ND	ND	ND	ND	ND	ND
WHO/FEPA Limits		0.05	1.0-3.0	1.3	0.005	0.01-0.48	0.1	

ND – Not detected (below detection limit)

could be attributed to variation in soil composition or any other factors since no other anthropogenic activity occurred at the site during sampling.

The concentration of Cu in all the samples were below the WHO (2019) permissible limits. According to the United States National Research Council (2000), just a small fraction of the individual copper intake is obtained from drinking water which invariably makes drinking water not a potential source to meet the daily copper requirements. Low level of Cu can result in deficiency while high concentration poses a risk of toxicity [16].

However, it is essential to note that the continual exposure of drinking water to these heavy metals could result in bioaccumulation and later become toxic and not good for consumption. Generally, and also relative to the control, the results obtained from t-test indicated that significance difference exists ($t < 0.05$) in the concentrations of these heavy metals and the control. This was also an evidence of contamination as a result of the environmental exposure or spillage. The concentrations of these six heavy metals were also determined some meters (at different point) with respect to the distance (m) from the source. In most cases, the concentration of Fe reduces with respect to the distances from the source for both sites and also Cu or Mn in some cases (Tables 3 and 4).

For the Sun metal company, the concentration of Mn and Fe were in the range 0.001-0.332 and 0.020 - 0.095

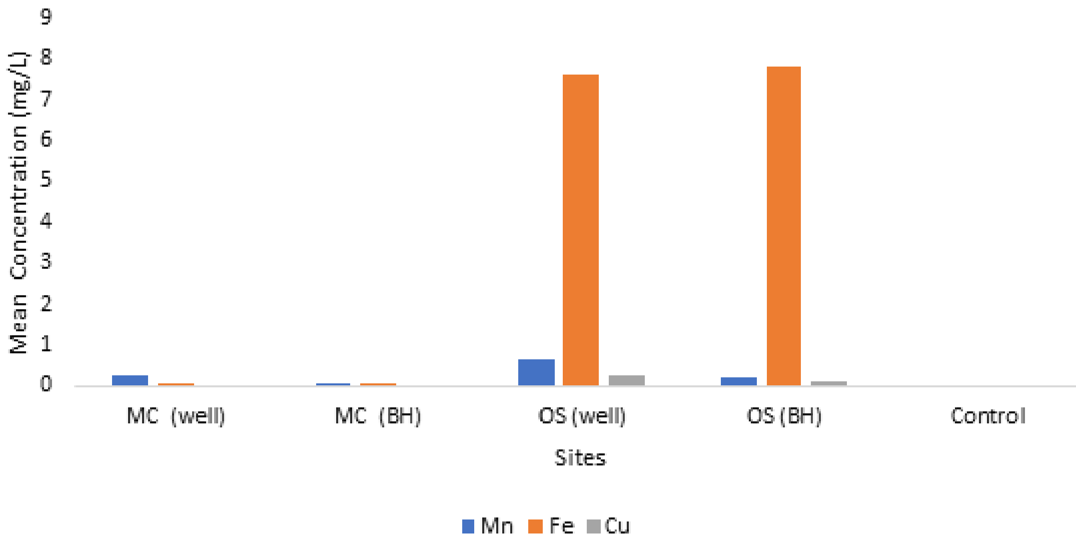

Figure 1. Levels of some heavy metals in water samples obtained around the sites; MC - Metal company, OS - Oil spillage area, BH = Borehole.

mg/L, respectively. For these two heavy metals, the levels reduced with distance from the source. Cu, Cd Cr and Pb were below the detection limits. Out of the six metals, only Mn had its concentrations above the WHO/FEPA recommended limits in drinking water. Generally, the levels of these six heavy metals in water samples from the site used for control were below the detection limits. Also, in this site, the result showed that well water samples within the perimeter (150-200 m) observed in this study were not safe for drinking as a result of the high Mn content. Well water samples located farther away from this perimeter may be safe at that moment.

Figure 1 depicts the comparison of the levels/mean concentration of Mn, Fe and Cu in water samples around Sun metal company and Oil spillage area.

The recorded high levels of Fe and Mn in samples from the oil spillage area may be an indication of pollution/contamination from the soil as reported by Ned & Frank [17] and possibly the composition of the pipes/crude oil [18]. According to Ravindra *et al.* [19], the undesirable presence of iron and manganese in drinking water may pose a toxicity threat to health. Although, both of them are required by the biological system as they play major roles in the hemoglobin synthesis and functioning of cells. The presence of these metals in water may cause staining of cotton clothes and give a rusty taste to drinking water. The major concerns focus on the dietary intake of iron because a higher dose may pose acute toxicity to newborn babies and young children. The gastrointestinal tract rapidly absorbs iron that may pose a toxicity risk to the cells and cytoplasm. The liver, kidneys and cardiovascular systems are the major toxicity targets of iron. Neurological disturbances and muscle function damage are the result of toxic effects of manganese in human bodies. However, the results obtained for Fe and Mn except Cu (in metal recycling company) in this study were higher compared with that of a similar study by Oketayo *et al.* [20]. It is worthy to note that continual drinking of this water could therefore result into bioaccumulation of heavy metals in the body which may eventually be detrimental to health considering the relatively high level of the heavy metals observed in this study.

4. Conclusion

The concentrations of heavy metals (Fe, Mn, Cr, Cu, Pb and Cd) in drinking water samples have been determined using FAAS. The results gave the baseline levels of these metals in water samples from both the oil spillage area and metal recycling company in Lagos State, Nigeria. Using t test, the concentration of these heavy metals was significantly higher than the control ($t < 0.5$). Fe, Mn and Cr in water samples from the site were above WHO maximum permissible limits while that of Cu was below the limit. The relatively higher levels obtained in this study compared with the control ($p < 0.005$, $t = 0.01$-0.04) and WHO/FEPA limits for some of the heavy metals (like

Fe and Mn as well as Cu in some cases) was an indication of contamination of the drinking water as a result of the selected oil spillage and metal recycling company. For metal recycling company, the levels of heavy metals in water samples were significantly higher than oil spillage. Using t-test, significant differences exist between the levels of Cu and Mn in well and borehole water samples (t_v = 0.004 -0.005) but not in Fe (t_v = 0.31 -0.91). The water samples were found to be slightly enriched in Mn (compared with control and WHO limits) which was an indication of pollution by nature as a result of these economically worthwhile anthropogenic activity and oil spill. However, various remediation technologies can be used for the removal of heavy metals from water/wastewater. These include precipitation and coagulation, ion exchange, membrane filtration, bioremediation, heterogeneous photocatalysis and adsorption. Hence, any of these methods could be adopted to mitigate the effects of the high levels reported in this study.

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