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Determination of some heavy metals in borehole and well water from selected industrial areas of Kaduna metropolis

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ABSTRACT

In this research work, the level of heavy metals was determined in boreholes and well water from Kakuri, Makera, and Kudenden industrial area of Kaduna metropolis. The water samples were digested using wet digestion technique and the heavy metal concentration were analysed using Atomic Absorption Spectrophotometry (AAS). The element analyzed are copper, zinc, lead, iron and nickel. The concentrations of heavy metals analyzed in this research work were all higher than those obtained in the control site (Mando). This is due to the industrial, human and domestic activities which are higher in the study sites than the control site. The concentrations of lead, nickel and iron in both well and bore hole water are statistically significant at ($p<0.05$) with exception of zinc and copper which were not statistically significant at ($p<0.05$) value. The results obtained in this study shows that, well water from Kakuri have the highest concentration of Iron (1.18mg/l), followed by Copper in well water from Kudenden area with 0.72mg/l, then Nickel in well water from Makera with 0.69mg/l and Lead in well water from Kakuri with 0.21mg/l, except for zinc which was between permissible limit. The concentrations determined were more than the maximum admissible and desirable limit when compared with the National and International organizations like, World Health Organisation, WHO (2008) and Nigerian Standard for Drinking Water Quality, NSDWQ (2007). The implications of these high levels of such metals in human health were highlighted.

Keywords: Well water, bore hole water, heavy metals, Atomic Absorption Spectrophotometer, Kaduna Metropolis, Nigeria.

1. INTRODUCTION

The availability of good quality water is an indispensable feature for preventing disease and improving quality of life (Oluduro and Anyakora, 2007). Water is an essential resource for living systems, industrial processes, agricultural production, and domestic use. Ninety seven percent of the world's water is found in oceans. Only 2.5% of the world's water is non-saline fresh water (Itodo *et al*, 2010). The use of water increases with growing population, putting increase strain on these water resources. An adequate supply of safe drinking water is one of the major pre-requisites for a healthy life. The importance of clean water and the link between contaminated or putrid water and illness was recognized in the distant past, even though the actual cause of disease was not properly understood until the latter half of the nineteenth century (WHO, 2006). Although water availability is not a problem on global scale, it may be a problem finding high quality fresh water at the required place, in the required quantity (Radojavic *et al*, 1992).

As a result of the increasing demand for water and shortage of supply, it is necessary to increase the rate of water development in the world and to ensure that the water is used more efficiently. Drinking water should be suitable for human consumption and for all usual domestic purposes (WHO, 2006). The importance of water in daily living makes it imperatives that thorough examinations be conducted on it before consumption (Ademoroti, 1996).

Heavy metals in water refers to the heavy, dense, metallic elements that occur in trace levels, but are very toxic and tend to accumulate, hence are commonly referred to as trace metals. The major anthropogenic sources of heavy metals are industrial waste from mining sites, manufacturing and metal finishing plants, domestic waste water, and acid rain runoff from roads. Many of these trace metals are highly toxic to humans, such as Lead (Pb), Mercury (Hg), chromium (Cr), Nickel(Ni), Cadmium (Cd), Arsenic (As) and Tin (Sn). Their presence in surface water and underground water at above background concentration undesirable (Radojavic *et al*, 1992).

Heavy metal is a generic term that describes the group of metals and metalloids with atomic density greater than 4 g/cm^3 or 5times or more, greater than water. Heavy metal according to Duruibe *et al*., (2007) has little to do with density but concerns chemical properties. However, lead, cadmium, mercury and arsenic are main threats to human health when exposed to them. Heavy metals have been excessively released into the environment due to rapid industrialization and have created a major global concern (Wan Ngah and Hanafiah, 2007).

Heavy metals (Nickel, Cadmium, Lead etc.) affect the nervous systems, damage the kidney, the liver and even skin and bones. Exposure to high levels of mercury and lead can cause various cancers and even death. It has also been associated with the development of auto-immune disease, in which the immune system starts to attack its own cells, mistaking them for foreign bodies (Yasar *et al*., 2010).

Lead absorbed in trace amounts over a long period of time and can accumulate in the body to a level which exceeds the threshold level thereby, produces a long delayed toxic symptom.

More so, children are known to be more susceptible to lead poisoning, suffering from mental retardation, disturbed behaviour and serious brain damage. In adult, high dose result in general metabolic discomfort, irritable anemia, convulsion and even death if not checked (Underwood and Pollack, 2009).

Zinc is an essential element for both animal and man, and it is important in the functioning of various enzymes system e.g alkaline phosphates. Acute Zn toxicity in human includes vomiting, dehydration, drowsiness, lethargy, electrolytic imbalance, abdominal pain, nausea, lack of muscular coordination, and renal failure. Chronic dose of Zn increases the risk of developing anemia, damage to the pancreas (Athar and Vohora*,* 1995).

Iron is essential compound in human and plays an important role in biology, forming complexes with molecular oxygen in haemoglobin and myoglobin; these two compounds are common oxygen transport protein in vertebrate. Iron is also the metal at the active site of many important redox enzymes dealing with cellular respiration, oxidation and reduction in plant and animal.

Copper is essential for the formation of enzyme in human beings. Intake of excessively large doses of Cu leads to severe mucosal irritation and corrosion, wide spread capillary damage, hepatic and renal damage and central nervous system irritation followed by depression. Copper toxicity includes blue green diarrhea stool and saliva and acute haemolysis and abnormalities of kidney functions. Wilson's disease is an inborn error of metabolism where the inherited defect lies in the incorporation of Cu^{2+} into apocerplasmin to form ceruloplasmin and also impaired ability of the liver to excrete Cu into the bile which leads to Cu accumulation in tissues of liver, brain, kidney and cornea resulting in organ damage (Scheiber and Julian, 2013).

Nickel is a chemical element and abundant on earth, most notably the planet's iron/nickel core. It is used in the manufacture of many alloys and products stainless steel, ceramic paint, jewelry, kitchen ware, batteries, textiles and coins. Nickel is released into the environment by power plant, metal factories and waste incinerators. It causes conjunctivitis, eocinophilic pheumonites, asthma and local or system reaction to Ni containing prostheses such as joint replacements, pins, cardiac valve replacements,

Wells can vary greatly in depth, water volume, and water quality. Well water typically contains more minerals in solution than surface water and may require treatment to soften the water by removing minerals such as iron, manganese and calcium (Britannica, 2011).

Borehole is the general term refers to any narrow shaft bored in the ground, either vertically or horizontally. Borehole water is gotten after the narrow shaft has been bored and a vertical pipe (casing) and well screen to completely installed to keep it from caving, this also prevent surface contaminations of the borehole and protects any installed pump from drawing sand and sediments.

Concentration of naturally occurring substances can have negative impacts on aquatic flora and fauna. Oxygen depleting substances may be natural material such as plant matter (leaves and grass) as well as man-made chemicals, many of the chemical substance are toxic, pathogen can produce water borne diseases in either human or animal (West and Carry, 2006).

The aim and objective of this research work is to determine some heavy metals (Cu, Zn, Ni, Fe and Pb) in borehole and well water samples from Selected Kaduna metropolis and to correlate the result obtained to standards prescribed by some regulatory agencies such as WHO and NSDWQ so as to ascertain the level of their contamination.

2. MATERIAL AND METHOD

Sampling procedure

Three set of water samples were collected from each sampling sites and analysed. The sampling sites were; Kakuri (KKR), Makera (MKR), and Kudenden (KDD) Industrial Area of Kaduna Metropolis. In each location the water samples were collected in triplicate from each source. These sources were; well water (WW) and borehole water (BHW). The sample bottles were washed properly and dried prior to the collections. Both well water and borehole water were also obtained from Mando (MND) to serve as control. This is because, in this control site (Mando) there is no industrial or less human activities taking place. The samples collected were labeled and then taken to the laboratory for analysis.

Digestion of the water samples

50ml of water was measured using measuring cylinder and poured into beaker and was heated to evaporation at 100^0c in fume cupboard, then removed from heating mantle and allowed to coo.10ml of aqua regia was also added to the beaker and its content and heated to dryness. The beaker was removed and cool and then 25ml of distilled was added to the beaker, stirred and filtered in 50ml volumetric flask and made to mark. The digested sample was transferred to the sample bottle and labeled. The heavy metals such as Cu, Ni, Fe, Zn and Pb were determined using Shimadzu AA-6800 model of Atomic Absorption Spectrophotometry (AAS).

3. RESULT AND DISCUSSION

Table 1 The Mean Concentration (mg/l) of Copper in well and borehole water in selected industrial Area

Sampling Sites	Water Samples Analyzed	
	WW	BHW
KDD	0.72 ± 0.02	0.71 ± 0.01
MKR	0.70 ± 0.03	0.71 ± 0.01
KKR	0.71 ± 0.01	0.71 ± 0.01
MND	0.50 ± 0.01	0.30 ± 0.01

KEY: KKD (Kudende), MKR (Makera), KKR (Kakuri) and MND (Mando) as control. WW (Well water) and BHW (Bore hole water).

Table 1 shows the mean concentrations of copper from the sampling sites (KDD, MKR and KKR) were found to be above the allowable limit. The mean concentrations for WW obtained were 0.72, 0.70 and 0.71 mg/l and BHW 0.71mg/l. These exceeds 0.05mg/l given by WHO (2008) and below 1mg/l given by NSDWQ (2007). The concentrations of copper in well and bore hole water were not statistically significant at ($p<0.05$) value. The result obtained for copper in the present study for both well water and bore water are above that obtained in the control site (MND) which are 0.50 and 0.30 mg/l respectively. This due to the less industrial activities taken place in the control site. The concentration of copper obtained is almost the same with that reported by Jatau *et al.*, (2008) in water analysis from Kaduna metropolis, which was in the range of 0.12-0.34mg/l. Also, Abdulrahman *et al.*, (2011) analysed for copper in ground water from Riyad and was found to be 0.02mg/l which is lower than that obtained in this research work, Ogbonna *et al.*, (2011) obtained 0.05mg/l in water samples from Kano metropolis, also lower than the concentration obtained in this research work. The high concentration in this study is as a result of industrial pollution in the sampling sites. At the same time, a common source of contaminating water is from the industrial effluent and natural deposits. Long term exposure may lead to liver or kidney damage (EPA, 2005).

Table 2 The Mean Concentration (mg/l) of Nickel in well and borehole water in selected industrial Area

Sampling Sites	Water Samples Analysed	
	WW	**BHW**
KDD	0.62 ± 0.08	0.67 ± 0.02
MKR	0.69 ± 0.02	0.69 ± 0.02
KKR	0.66 ± 0.01	0.67 ± 0.01
MND	0.47 ± 0.02	0.44 ± 0.01

Table 2 shows the concentration of Nickel in the water samples analysed, which was obtained from three sampling sites (KDD, MKR and KKR). The mean concentrations obtained from the analysis were; 0.62, 0.69 and 0.66mg/l for well water sample and 0.67, 0.69 and 0.67mg/l for borehole. These concentration exceeds 0.05mg/l given by WHO (2008) and 0.02mg/l given by NSDWQ (2007). The concentrations of Nickel in well and bore hole water are statistically significant at ($p<0.05$) value. The result obtained for nickel analysed in the present study for both well and bore hole water were higher than that obtained in the control site (MND) which are 0.47 and 0.44 mg/l respectively. This is because there is no much industrial as well as human activities in the control site when compared with the studied sites. In the present study, the concentration of nickel obtained is almost the same with that reported by Jatau *et al.*, (2008) in water analysis from Kaduna metropolis, which was 0.28mg/l. Also, Abdulrahman *et al.*, (2011) analysed for copper in ground water from Riyad and was found to be 0.07mg/l which is the same with that obtained in this research work, Ogbonna *et al.*, (2011) obtained 0.08mg/l in water sample from Kano metropolis. The high concentration of Nickel in this study is as a result of industrial effluent in the sampling sites and natural sources (acid rain and soil weathering). High concentration of nickel beyond allowable limit may cause dermatitis (insensitivity in people).

Table 3 The Mean Concentration (mg/l) of Iron in well and borehole water in selected industrial Area

Sampling Sites	Water Samples Analysed	
	WW	**BHW**
KDD	0.71 ± 0.021	0.36 ± 0.09
MKR	0.38 ± 0.16	0.35 ± 0.01
KKR	1.18 ± 0.81	0.33 ± 0.10
MND	0.25 ± 0.02	0.22 ± 0.03

Table 3 Shows the concentration of Iron in the water sample analyzed, the samples were obtained from three location (KKD, MKR and KKR), the result obtained were 0.71, 0.38 and 1.18mg/l for well water and 0.36, 0.35 and 0.33mg/l for borehole water, the result exceeds 0.3mg/l given by WHO (2008) and NSDWQ (2007). The concentrations of iron in well and bore hole water are statistically significant at ($p<0.05$). The concentrations of iron analysed in the present research work shows that both well and bore hole water were higher than that obtained in the control site (Mando) which are 0.25 and 0.22 mg/l respectively. This is as a result of industrial pollution is higher in the studied site more than that of the control site. In the present study, the concentration of iron obtained is

almost the same with that reported by Jatau *et al*., (2008) in water analysis from Kaduna metropolis, which was in the range of 0.32-0.67mg/l. Also, Abdulrahman *et al*., (2011) analysed for iron in ground water from Riyad and was found to be 0.09mg/l which is lower than that obtained in this research work. Ogbonna *et al*., (2011) obtained 0.04mg/l in water sample from Kano metropolis, also lower than the concentration obtained in this research. The high concentration of iron is due to anthropogenic activity and industrial waste in the sampling site. The body needs iron to fight bacterial infection, however excessive iron can damage the cells of the gastrointestinal tract and may also damage the cells in the heart and liver (Adriano, 2001).

Table 4 The Mean Concentration (mg/l) of Zinc in well and borehole water in selected industrial Area

Sampling Sites	Water Samples Analysed	
	WW	**BHW**
KDD	0.23 ± 0.03	0.28 ± 0.06
MKR	0.23 ± 0.10	0.26 ± 0.06
KKR	0.44 ± 0.06	0.29 ± 0.04
MND	0.18 ± 0.01	0.15 ± 0.02

Table 4 Shows the concentration of zinc in the water sample analysed, the samples were obtained from three locations (KDD, MKR and KKR). The mean concentrations for well water were 0.23, 0.23 and 0.44mg/l and 0.28, 0.26 and 0.29mg/l respectively for borehole water. These concentrations obtained were below 5mg/l given by WHO (2008) and below 3mg/l given by NSDWQ (2007). The concentrations of zinc in well and bore hole water are not statistically significant at ($p<0.05$) value. The result obtained for zinc in this research work for the well and bore hole water are above that of the control site (MND) which are 0.18 and 0.15mg/l respectively. This because of less industrial as well as human activities in the study areas which are more polluted than the control sites. In the present study the concentration of zinc obtained is almost the same with that reported by Jatau *et al*., (2008) in water analysis from Kaduna metropolis which was in the range of 0.12-0.16mg/l. Also, Abdulrahman *et al*., (2011) analysed for zinc in ground water from Riyad and was found to be 0.01mg/l which is lower than that obtained in this research work. Ogbonna *et al*., (2011) obtained 0.04-0.08mg/l in water sample from Kano metropolis also lower that obtained in this research work. However, signs of zinc deficiency include hair loss, wasting of body tissues and eventually death (EPA, 2005).

Table 5 The Mean Concentration (mg/l) of Lead in well and borehole water in selected industrial Area

Sampling Sites	Water Samples Analysed	
	WW	**BHW**
KDD	0.09 ± 0.05	0.17 ± 0.02
MKR	0.16 ± 0.08	0.15 ± 0.06
KKR	0.21 ± 0.08	0.19 ± 0.05
MND	0.05 ± 0.01	0.03 ± 0.01

Table 5 Shows the concentration of lead in the water samples analysed, the sample were obtained from three sampling sites (KKD, MKR and KKR).The concentrations of lead from well water were 0.09, 0.16 and 0.21mg/l and borehole water were 0.17, 0.15 and 0.19mg/l respectively. The mean concentrations exceeded 0.05mg/l given by WHO, (2008) and 0.01mg/l given by NSDWQ, (2007). The concentrations of lead in well and bore hole water are statistically significant at ($p<0.05$). The concentration of lead obtained in this research work for well and bore hole water were higher than the concentration obtained in the control site (MND) which are 0.02 and 0.01 mg/l respectively. This is due to the fact that the study areas were more polluted with these toxic elements as a result of industrial activities than the control sites. However, in the present study, the concentration obtained is almost the same with that reported by Jatau *et al*., (2008) in water analysis from Kaduna metropolis which was in the range of 0.06-0.29mg/l. Also, Abdulrahman *et al*., (2011) analysed for pb in ground water from Riyad and was found to be 0.07mg/l which is lower than that obtained in this research work. Ogbonna *et al.,* (2011) obtained 0.01-0.09mg/l in water sample from kano metropolis, also lower than the concentration obtained in this research work. The high concentration of lead in this study is as a result of industrial pollution in the sampling sites. Constant exposure to Pb may lead to delays in physical or mental development in infants and

children, while adults may have kidney problems and high blood pressure. Lead contaminate water due to corrosion of household plumbing systems, industrial waste, mining and erosion of natural deposits (EPA, 2005)

4. CONCLUSION

It was observed from the analysis carried out to ascertain the level of some heavy metals in water samples collected from selected industrial area of Kaduna metropolis, the research revealed that Cu, Pb, Ni and Fe levels in WW and BHW samples exceeds the permissible limits recommended by WHO and NSDWQ. The concentrations of heavy metals analyzed in this research work were all higher than those obtained in the control site (Mando). This is due to the industrial, human and domestic activities which are higher in the study sites than the control site. However, the concentration of Zn in the samples falls below the standard limits. Heavy metals pose a number of hazards to human health. Therefore their concentration in the environment and their effects on human health must be regularly monitored.

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