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Overview of Heavy Metal Concentrations in Public Pipe Borne Water and Its Safety Implications for the Communities in Abuja Metropolis North-Central Nigeria

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Abstract

Heavy Metals (HM) are relatively dense metal or metalloid noted for its potential toxicity in the environment and these metals appear in the World Health Organization List of Chemicals of public health concern. Long-term exposure to HMs have been linked to slowly progressing physical, muscular and neurological degenerative processes in human that mimic Alzheimer's disease, Parkinson's disease, muscular dystrophy, multiple sclerosis, liver and kidney failures as well as alterations in gene expressions. This study assessed the concentration of some HM in public water supply in Abuja Metropolis from 2015 to 2016 with the view to determining its overall percentage compliance with the WHO(2008) recommended limits for drinking water quality . The HMs selected were aluminum (Al), iron (Fe), copper (Cu), and zinc (Zn) and manganese (Mn). A representative water samples from the six locations within the study area were collected and analyzed according to the Standard Methods and Procedures. Sampling regime took place three (3) times in each sampling month from which the monthly and annual mean values were obtained and analyzed statistically. The result indicated the following mean concentrations Al (0.61±0.13mg/l), Fe (0.21±0.06mg/l), Pb (ND), Cr (ND), and Mn (0.03±0.03mg/l). The overall average percentage compliance WHO limits were Al (70.60%, Fe (85%), Pb (100%), Cr (100%) & Mn (91%) respectively. The results revealed that all the selected HMs concentration in the public drinking water within the period were within the WHO recommended aluminum concentration that was slightly above the recommended limit of 0.20mg/l. The study recommended for limit except a substitute of aluminum sulphate in public water treatment and also concluded that the selected HMs concentrations in the public water supply in Abuja Metropolis within the period were in compliance with the WHO quality for safe drinking water and therefore safe for human consumption. However, concern was raised for its aluminum level and possible health implications on long-term exposure particularly the aged population.

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Introduction

Water plays an indispensable role in the sustenance of life and is a key pillar of health determinants, about 80% of diseases in developing countries are associated with lack of good drinking water and poor sanitation [1, 2]. Diseases contacted through drinking water kill about five (5) million children annually and make 1/6th of the world population sick [3]. Adequate quantity and quality of drinking water supply is an essential service required by all strata of living organisms including man and his livestock. Water plays a critical role in disease incubation, transitions and outbreaks in the population. In most cities of the world, particularly developing countries, drinking water supply service is a major challenge to the government's efforts and therefore limited in scope and coverage with attendant negative impacts on the environment [4].

The most common wide spread health risk associated with drinking water is microbial contamination. Up to 80% of all sickness and diseases in the world are caused by the unavailability of enough safe drinking water and inadequate sanitation. Albera, et al., reported that approximately three out of the five persons in developing countries do not have access to safe drinking water and only about one in four has any optimal sanitary facilities [5].

Mebrahtu et al. in a study of concentration of HMs in Drinking Water from Urban Areas of the Tigray Region, Northern Ethiopia showed that, some of the physico-chemical parameters showed values higher than the WHO recommended maximum admissible limits [4, 6]. This is an indication of pollution hazards and poor drinking water treatment practices in the area which in turn have important human health implications and recommends that the government and other responsible authorities to take appropriate corrective measures.

Kaplan et al. in an assessment of some HMs in Drinking Water Samples of Tunceli in Turkey concluded that, the concentrations of the heavy metals (As, Cu, Cd, Cr, Pb, Ni and Hg) in the drinking water samples were found below the standards guidelines for drinking waters given by the WHO and the Water Pollution Control Regulation of Turkish Authorities and confirmed low HMs concentrations in the public water supplies [7].

Duan et al. in a health risk assessment of heavy metals in drinking water based on field measurement of exposure factors of Chinese people revealed that, the accuracy of health risk assessment could be improved a lot by the real measurements of exposure factors [8]. Attentions should be attached to exposure factor investigation to decrease uncertainty of health risk assessment.

Muhammad et al. in a study of health risk assessment of heavy metals and their source in drinking water of Kohistan region, northern Pakistan revealed that anthropogenic activities were major sources of water contamination in Kohistan region [9].

Njar et al. assessment of heavy metal status of boreholes in Calabar South Local Government Area, Cross River State, Nigeria observed absolutely low levels of heavy metal contents across the sampled boreholes which may indicate no pollution and as such suitable for human consumption [10]. The result therefore implies that the quality status of boreholes in the area is not in any way polluted, as the examined parameters are within WHO maximum permissible limits for drinking water.

Afolabi et al. reported in a comparative assessment of the portable quality of water from industrial, urban and rural parts of Lagos, Nigeria found that, Pb, Ni, Mg, and Fe concentrations exceeded permissible limits set by WHO, EU, and NIS for all samples ,with the Lagos Centre having the highest values [11]. However, Cu, Zn, Na, Ca concentrations were within the permissible limits, with Lagos Centre samples having the highest values. The work revealed the adverse effect of industrialization, high population density, and rapid urbanization on portable water sources in Lagos State, which could result to serious health hazards.

Mohod et al. in a review study of heavy metals in drinking water and their effect on human health noted that, the concentrations determined were more than the maximum admissible and desirable limit when compared with the National and International organizations like WHO [4, 12]. On account of the concentrations of heavy metals determined the authors detected possible adverse effects on human health. Priscilla et al. in a study of physio-chemical properties and heavy metals in drinking water from different sources in and around Ranchi, Jharkhand, India, found that, the concentrations of lead and cadmium were found more than the prescribed permissible limits of WHO [13].

Meghdad et al. reported in a measurement of heavy metals concentration in drinking water from source to consumption site in Kermanshah, Iran, that concentration of all measured metals except aluminum, iron and manganese in some water samples of source, distribution network and water reservoir were lower than the national standards and guidelines recommended by the World Health Organization [14]. The author recommended continuous monitoring of heavy metal concentrations in urban water system, from the source of production to consumption to identify the source of pollution.

Winifred et al. in an assessment of trace metals in drinking water and ground water sources in Otta southwest Nigeria found that, the mean metal levels in the sampled water sources followed a descending order: Fe>Cu>Zn>Ni>Pb>Mn. Fe (92%), Ni (53%) and Pb (25%) and concluded that the observed water sources exceeded the maximum permissible limits in drinking water as specified by WHO and SON standards [15]. Also, the pollution index result obtained confirmed significant pollution in lead, iron and nickel and therefore advised that the concern contaminated sources be subjected to further treatments that will reduce the concentration of these identified trace metals which are capable of posing adverse threat to health of consumers and the society.

Adamu et al. in a study of heavy metal contamination and health risk assessment associated with abandoned barite mines in Cross River State, southsouth Nigeria concluded that, average concentrations of Fe, Hg and Pb were above the required standards [16]. This indicates anthropogenic inputs from barite mining activities and the cancer risk of being exposed to arsenic by drinking water from these sources did not exceed the acceptable risk of 1:10,000 for regulatory purposes.

According to Federal Office of Statistics, Nigerian Poverty Profile 2004, only 44.98% of water in Federal Capital Territory (FCT) is sourced from improved sources against 55.02% from unimproved sources. The situation has serious health implication for the population of the Abuja Metropolis that is approximately 3.1million people.

Materials and Methods

Study Area

The Abuja Metropolis is one of the six (6) Area Councils that constitute the Federal Capital Territory of Nigeria that came into effect on 12 December 1991, replacing Lagos, though the latter remains the country's most populous city in Nigeria. The Abuja Metropolis is located within the Federal Capital Territory (FCT) of Nigeria with five major districts; Asokoro, Central Area, Garki, Maitama and Wuse District. It lies within the latitude of 7027'0"-7030' 0"E and longitude 901'30"-906'30"N and bounded in the north by Mpape, in the south, by Karo/Nyanya Communities, in the west by Kuje community and east by Kabayi settlements. The Lower Usuma Water Works is located along the geographical coordinates of 70 32' 10"E,90 8' 05" N at an elevation of 2000 meters above the sea level from where the piped water supply flows by gravity to Abuja Metropolis through a 10-meter diameter pipeline.

Weather and Climate

It experiences three weather conditions annually. This includes a warm, humid rainy season and a blistering dry season. In between the two, there is a brief interlude of harmattan occasioned by the northeast trade wind, with the main feature of dust haze, coldness and dryness. The rainy season begins from April and ends in October during which daytime temperatures reach 28 °C (82.4 °F) to 30 °C (86.0 °F) and night-time hovers around 22 °C (71.6 °F) to 23 °C (73.4 °F). In the dry season, daytime temperatures can soar as high as 40 °C (104.0 °F) and night-time temperatures can dip to 12 °C (53.6 °F). Even the chilliest nights can be followed by daytime temperatures well above 30 °C (86.0 °F).

The high altitudes and undulating terrain of Abuja act as a moderating influence on its weather conditions. Rainfall in Abuja Metropolis reflects the territory's location on the windward side of the Jos Plateau and the zone of rising air masses with the city receiving frequent rainfall from March to October while dry season starts from November to March. However, within these seasons is a brief harmattan season that is occasioned by the north east trade wind and the attendant dust haze, increased cold and dryness.

Vegetation

The Abuja Metropolis falls within the Guinean forest-Savana mosaic zone of the West African sub-region. Patches of rain forest, however, occur in the Gwagwa plains, especially in the rugged terrain to the south-eastern parts of Abuja where a landscape of gullies and rough terrain is found. These areas of the Federal Capital Territory (FCT) form one of the few surviving occurrences of the mature forest vegetation in Nigeria.

Population and Cultural Background

The Abuja Metropolis is the largest Area Council in the Federal Territory of Nigeria with a population of about 0.8

million in 2006. Because, it is the centre of Government, the influx of people is unprecedented in recent times. The urban growth and demand for water and energy are all very high. In 2016, the population was about two (2) million according to National Population Commission [17]. Government is making some efforts but private sector plays major role in the provision of houses for the civil servants. There are still some pockets of urban poor settlements within the high class districts.

In the Municipal Area Council, the indigenous groups are the Gbagyi, Gwandara, Gade, Bassa, Hausa and Fulani. Virtually all tribes use Hausa as official communication language. The cultures of the inhabitants are manifested in their ways of life, in terms of what they wear and their faith. Farming cuts across all the ethnic groups. The major farm crops are yam, maize, guinea corn, beans and millet. However, the ethnic groups have their respective specialty in divergent crafts; for example the Bassa people are good in farming and fishing while the Nupes and the Ganaganas are blacksmiths. Since the movement of Government seat to Abuja; the city has witnessed an unprecedented influx of people from all walks of life with its attendant environmental problems [18].

Description of Sampling Sites
Six sampling sites were chosen, these are;
Asokoro district

The district is in the southern part of the Abuja Metropolis and houses one of the withholding Tanks with a capacity of ---- from where; pipe water supply is distributed to some other areas such as Nyanya and Karu satellite towns within the Abuja Metropolis. Samples were collected from five (5) locations within the district at every sampling regime and mixed homogenized into one (1) sample to represent the district for analysis 2

Central Business District
This is the area with predominantly government offices, diplomatic missions and institutions and is sparsely populated. It houses the National Hospital-the only tertiary health institution in Abuja Metropolis. Water samples were collected from five (5) locations within the district during sampling regime and homogenized into one (1) sample to represent the district for analysis

Garki District
This is the foremost district in Abuja Metropolis. It came to being with the creation of the Federal Capital Territory (FCT) in 1986. It houses the first Federal Secretariat Complex in the Federal Republic of Nigeria with old house and dilapidated utilities. Water samples wer also collected as in other districts.

Maitama District

This is one of the exclusive districts for top Government and Diplomatic Officials. It is a modern district with all the social amenities including pipe water supply in adequate quantity and optimal regularity. It is exclusive as well as sparsely populated obviates the presence of the indigenous people. Water samples were collected from five (5) locations within the district during sampling regime and homogenized into one (1) sample to represent the district for analysis

Wuse district

This is one of the very old districts in Abuja Metropolis with predominantly civil servants and petty traders. Water samples were collected from five (5) locations within the district during sampling regime and homogenized into one (1) sample to represent the district for analysis. The study area and sampling sites' geographical coordinates and elevation are presented in figure 1 and table 1.

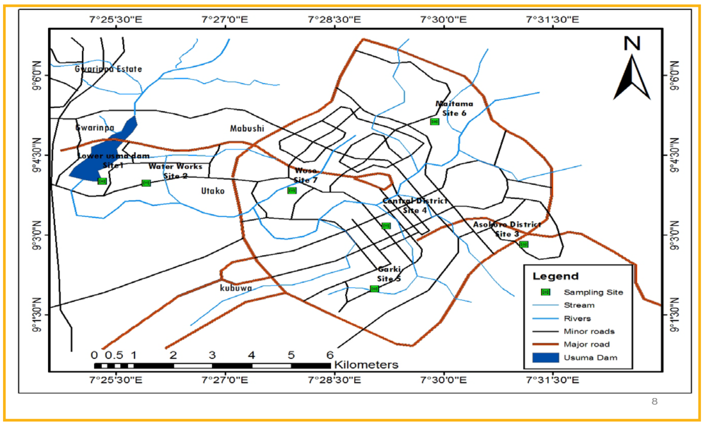

Figure 1: Map of the study Area –Abuja Metropolis. Source: Goggle Map, 2013.

Sample Sites	Geographical Coordinates	Elevation (M)
Lower Usuma Water Works(Tank-1)	7o 33' 00" E,9o 8' 30"N	2000
Asokoro District Households	7o 33' 00"E , 9o3' 05"N	1900
Maitama District Households	7o30'20"E,9o 6' 00"N	1600
Wuse District Households	7o 29' 50"E , 9o 5' 55"N	1500
Garki District Households	7o 31' 30"E , 9o 01' 30"N	1700
Central Area District Households(-CAD)	7o 30' 01"E , 9o 2' 05"N	1600

Table 1: Sampling Sites, Geographical Coordinates and Elevations.

Results and Discussions

The results of the assessment of some heavy metals in pipe borne water in Abuja Metropolis within the period is presented in Table 2. The result revealed that aluminium mean concentration within the district varied from a maximum of 0.73 ±0.13mg/l in Maitama District to a minimum of 0.64mg/l in Asokoro and Central Business district respectively within the period under review. The results also indicated that the aluminium concentrations in drinking water across the metropolis were above the WHO recommended limit of 0.2 mg/l for safe drinking water and the mean values were not significantly different at P<0.05. This result was in contrary to Adekunle et al. in a assessment study of the health and social economic implications of sachet water in Ibadan, Nigeria –a public health challenge, the aluminium level was around 0.06±0.04mg/l [19]. Daniel, et al. in a study of the relation between aluminium concentrations in drinking water and Alzheimer's disease: an 8-year follow-up study found that the hypothesis that aluminium in drinking water is a risk factor for AD [20]. Virginie in a similar study supported the hypothesis that a high concentration of aluminium in drinking water may be a risk factor for Alzheimer's disease. Use of aluminium salts as coagulants in water treatment may lead to increased concentrations of aluminium in finished water. Martyn, C.N.1. et al. in a study of aluminium concentration in drinking water and risk of Alzheimer's disease revealed that any risk of Alzheimer's disease from aluminium in drinking water at concentrations below 0.2 mg per liter is small, and they give no support for a protective role of silicon [21]. Concentrations of aluminium at which such problems may occur are highly dependent on a number of water quality parameters and operational factors at the water treatment plant.

The overall average percentage compliance of aluminium concentration with the WHO limit of 0.2mg/l was 70.06% which is significantly accepted with caution over long exposure particularly the aged. It was 29.04% deficient of the WHO recommendation of 100% (Table 3).

The mean result of iron concentrations in the pipe water supply in Abuja Metropolis within the period of study is presented in Table 2. The result vary, from a minimum value of 0.15±0.04mg/l in site E(Wuse District) to a maximum mean value of 0.33±0.04mg/l-1 in site A(Asokoro) within the period. All the values per site were significantly different at p<0.05 but slightly off the specification of WHO Guideline limit of 0.30 mg/l-1 for safe drinking water. The presence of iron may not be unconnected with the rusting metal pipe used in the water distribution and also the source water which come from the geological galena zone of the Nigerian igneous rock belt. The inefficient water treatment process may contribute its high iron concentration in the finished water. This result was in line with Adekunle, et al. recorded 0.43 ±0.35mg/l in satchet water in Ibadan, Nigeria [19]. The result is similar with the works of Afolabi et al, Meghdad et al, Odunola et al, Odafivwotu et al, and Winifred et al.[11,14, 15,22, 23,]

Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status, and iron bioavailability and range from about 10 to 50 mg/day. Although a low level of iron cannot do much harm, iron in water is considered as a contaminant because it also contains bacteria that feed off it. In addition to this, high iron content leads to an overload which can cause diabetes, hemochromatosis, stomach problems, nausea, and vomiting. It can also damage the liver, pancreas, and heart (Peninsula Water Conditioning Inc.),In drinking-water supplies, iron(II) salts are unstable and are precipitated as insoluble iron(III)hydroxide, which settles out as a rust-coloured silt . Iron also promotes undesirable bacterial growth ("iron bacteria") within a waterworks and distribution system, resulting in the deposition of a slimy coating on the piping [24]. Iron and manganese are primarily nuisance chemicals with characteristic staining properties, although high levels can impart a bittersweet or metallic taste to drinking water [25]. The overall average percentage compliance of iron concentration with the WHO limit of 0.3mg/l was 85% which is significantly caution. It was 15% deficient of the WHO recommendation of 100% (Table 3).

The result of the lead and chromium is presented in Table 2. The result revealed that both element were not detected in all the water samples from the Metropolis within the period. The reason may be attributed to the low resolution of the testing machine. Lead is a cumulative toxicant that affects multiple body systems and is particularly harmful to young children. Lead exposure can have serious consequences for the health of children. At high levels of exposure, lead attacks the brain and central nervous system to cause coma, convulsions and even death [26]. The study concluded that the overall percentage compliance with the WHO recommendation was 100% and therefore may not posed any ill-health related to lead and chromium (Table 3).

The mean manganese ion concentrations assessed during the period and the result is presented in Table 2. It revealed that manganese ions in the pipe water supply varied across the sites from a minimum mean value of 0.01±0.00 mg/l-1 in site D (Maitama District) to a maximum of 0.04±0.00 mg/l in sites A and B (Asokoro and Central Business District)). All values were found to be within the WHO recommended limit of 0.05mg/l for safe drinking water quality. However, the results per sites were significantly different at P<0.05. Buschmann et al. stated that, manganese is one the trace metals that are required by the body in small amounts for metabolic activities and at higher concentrations can cause adverse health effects or illness Manganese may hamper the intellectual development of the child [27]. Ikejimba et al. concluded that, trace metals are consistently of health concern due to their toxicity potentials at a very low concentrations and tendency to biaccumulate in tissues of living organisms over time [28]. The overall percentage compliance with WHO recommendation is presented in Table 3. It revealed that manganese had a compliance value of 91%, therefore fit for human consumption within the period. While a small amount of manganese is essential for human health, new Health Canada research has shown drinking water with too much manganese can be a risk to health. Manganese can also cause discolouration and an unpleasant taste in drinking water. It can also stain laundry.

WHO reviewed several investigations of adult diets and reported that the average daily consumption of manganese ranged from 2.0 to 8.8 mg/day [29]. Higher manganese intakes were associated with diets high in whole-grain cereals, nuts, green leafy vegetables and tea. From manganese balance studies, WHO concluded that 2–3 mg of manganese per day is adequate for adults and 8–9 mg/day is "perfectly safe [29]."

Districts	**PARAMETERS**				
	Al (mg/l)	**Fe (mg/l)**	**Pb(mg/l)**	**Cr(mg/l)**	**Mn (mg/l)**
A	0.64±0.13c	0.33±0.04a	00	00	0.04±0.00b
B	0.64±0.13c	0.17±0.04c	00	00	0.04±0.00bc
C	0.57±0.13c	0.29±0.04ab	00	00	0.02±0.00e
D	0.73±0.13c	0.16±0.04c	00	00	0.01±0.00e
E	0.67±0.13c	0.15±0.04c	00	00	0.03±0.00c
WHO limit	0.2	0.3	0.02	0.05	0.05

Keynotes: Sampling Sites:,A=Asokoro District, B=Central Business District, C=GarkiDistrict, D=Maitama District, E=Wuse District .WHO=World Health Organisation. Values are expressed as means ± Standard Deviation. Means having different superscripted alphabets along columns are significantly different at P < 0.05.Al-Aluminium,Cr-Chronium,Fe-Iron,Pb-Lead,Mn-Manganese.

Districts	**Overall Percentage Compliance (%)**					
	N	**Al (mg/l)**	**Fe (mg/l)**	**Pb(mg/l)**	**Cr(mg/l)**	**Mn (mg/l)**
A	36	68	94	100	100	89
B	36	70	94	100	100	92
C	36	82	82	00	100	84
D	36	68	77	100	100	96
E	36	65	78	100	100	94
Ave, Compl. (%)	36	70.6	85.0	100	100	91.0
WHO (100%)		100	100	100	100	100

Keynotes: N=Number of Samples, Sampling Sites: A=Asokoro District, B=Central Business District, C=Garki District, D=Maitama District, E=Wuse District .WHO (2008) =World Health Organisation. Values are expressed in %, HE-Heavy Metal. Al-Aluminium,Cr-Chronium,Fe-Iron,Pb-Lead,Mn-Manganese.

Recommendations

The study observed that the public water distribution infrastructure in Abuja Metropolis is old and obsolete coupled with the fact that most of them are of metal origin. However, it could be conclusive to say that water distribution facilities in the Metropolis may need urgent rehabilitation works geared towards improving the quality of the water delivery. The FCT Water Board is responsible for public water treatment and distribution in FCT and therefore should endeavor to conduct quality assessment quarterly and on annual basis undertake independent Total Quality (TQ) Assessment of public water supply including bacteriological load determination. This would enable the authority undertake programs and projects based on scientific evidence. It would also improve the public confidence in public water supply and the patronage.

Conclusion

The pipe borne water supply in Abuja Metropolis was safe for human consumption within the period based on the heavy metal concentration but care must be taken towards the dosage of aluminum sulphate as coagulant in the water and waste water treatment plants.

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