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Original Article

Estimation of potential chronic daily intake of heavy metal through consumption of potable water in South-south Nigeria

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Abstract

Industrialization and urbanization has increase the emission of pollutant into the environment; as such sensitive media subject to pollution (water, soil and air) has been infringed upon. Heavy metal is a potential pollutants found in Nigeria water sources. This study assessed the chronic daily intake (CDI) of heavy metal from potable water sources (surface and ground water) in the Niger Delta region of Nigeria. Secondary data (literatures) were used for the study. The study found the concentration of heavy metals under study to be above the permissible limit recommended by Standard Organization of Nigeria (SON), and the World Health Organization (WHO). The CDI of heavy metal for both children and adults were high ranging from 0.57 to 1436.33 µg/kg·day (iron), 0.00 to 323.33 µg/kg·day (zinc), 0.00 to 37.14 µg/kg·day (cadmium), 0.00 to 29.67 µg/kg·day (chromium), 0.00 to 116.67 µg/kg·day (lead), 0.00 to 123.33 µg/kg·day (copper), 0.00 to 21.33 µg/kg·day (nickel) and 0.00 to 78.0 µg/kg·day (manganese). The CDI value indicates that the consumption of these water sources without treatment could cause disease conditions. Hence, the water requires treatment prior consumption.

1. Introduction

Nigeria is blessed with several renewable and non-renewable resources including petroleum and natural gas, tin, iron ore, coal, lead, zinc limestone, niobium and arable land for agricultural purposes. The country is about 1 million square kilometer in size. Due to industrialization and urbanization, the country gross domestic products in the recent years have increased. The economic growth due to industrialization resulting from exploration activities of the resources has continued to cause environmental pollution in soil, air, water and sediment. These pollution often disrupts certain keystone biotic composition of the environment including humans. The pollution that occurs is often determined by certain activities in the region which could be biological, physical or chemical substances.

The Niger Delta is located in the coastal region of Nigeria, with high water table as compared to other non-coastal states. For instance, in some region of Bayelsa state, Delta and Rivers states, the ground water is very high and the region is frequently affected by flood. In the recent years, the rates of rainfall have deviated from the usual pattern. For instance, the pattern of rainfall used to be 4/5 months dry season (November to February/March), and 7/8 month wet season (March/April to October) [1 -3] with intermittent break in August. Beside crude oil and natural gas exploration in the Niger Delta states including Akwa Ibom, Abia, Rivers, Edo, Imo, Ondo, Bayelsa, Cross River and Delta, pollution have also occurred due to some inappropriate agricultural practices such as indiscriminate use of herbicides, pesticides, insecticides, fertilizer and other agrochemicals. Majority of the agricultural mechanization practices emits chemical compounds which could enter the environment leading to soil, water and air pollution. Surface water gets contaminated through soil erosion, while ground water is polluted through infiltration of toxic materials into the soil especially in soil with high level of porosity and permeability [4]. Also, the pollutant resulting from the combustion activities which often emits pollutants gases such as oxides of nitrogen, carbon and sulphur, volatile organic compounds, hydrogen sulphide, ammonia etc. These pollutants enter the atmosphere leading to acid rain. Other contaminants of the environment include wastes from several industries [5] such as pharmaceutical [6], oil and gas [7], agricultural, iron and steel based industries, markets wastes [2]. The availability of organic and synthetic pollutants which could contain oxides of heavy metal from elements such as zinc, iron, lead, nickel, manganese, copper, cadmium and chromium is also discharged into the environment.

Heavy metals are micronutrient that is required by biological system (plants and animals) in minute quantity and are referred to as essential elements [2]. This include zinc, iron, copper etc, however, some other heavy metals that are not required by living organisms often referred to as non-essential such as silver, mercury, arsenic, cadmium and lead [8]. Notwithstanding, high levels of some essential micronutrients could become toxic to some organisms. For instance, Ohimain and Angaye [9] reported the toxicity of groundwater containing high level of iron. Heavy metal concentration in potable water often exceeds their respective regulatory limit (World Health Organization and Standard Organization of Nigeria, also known as SON). SON is the regulatory body responsible for streamlining the water quality for consumption/drinking in Nigeria, just as WHO is in the global stage. Basically, Oyhakilome et al. [10] stated that water quality is an indication of the hydrology of the water with regard to its chemical, physical and biological conditions.

In Nigeria access to potable water to her increased populace (approximately 170 million) is grossly inadequate. Most citizens depend on rainwater, surface water (rivers, lake, stream) and ground water (hand dug well, borehole) for consumption. Vendors of sachet water abound in Nigeria which are either popularly known as “pure water” and table water (bottle water). The water sold by water factory is mostly from groundwater. In the recent times, water borne diseases such as diarrhea, typhoid, dysentery, cholera, hepatitis etc. has been attributed to some microorganisms that thrives in potable water in Nigeria.

However, Olaoye and Onilude [11] have reported *E.coli, Staphyloccocus aureus, Pseudomonas aeroginosa, Enterobacter aerogenes, Klebsilla* species, *Proteus vulgaris, Alcaligenes faecalis, Bacillus cereus, Streptococcus lactis, Aeromonas* species and *Micrococcus luteum* as the bacteria diversity found in potable water meant for drinking in western Nigeria. The disease conditions caused by microorganisms often lead to impairment vital body organ and tissues. Similarly heavy metals found in excess concentration in potable water sources could cause diseases conditions including destruction reproductive and nervous system and brain and kidney [6, 12 - 14], increased blood pressure, anemia, and weakness in fingers, wrists, or ankles [13] (lead), cancer, high breathing rate, nose and breathing problems and impairment of the kidney and liver [13] (chromium), liver and kidney impairment [13, 14] (cadmium), anemia, allergies, hair loss, arthritis, cancer, depression, diabetes, fatigue, fears, fractures of the bones, headaches, heart attacks, hyperactivity, hypertension, infections, inflammation, kidney and liver dysfunction, tooth decay [13], diarrhea [15] (zinc), lung disorder [14] (iron), poison and cancer [14], dermatitis, nausea, headache, vomiting and chest pain [16] (nickel) hypertension in patients older than 40 years [17] and neurological disorders [18, 19] (Manganese).Generally, Abata et al. [20] stated that exposure to excess heavy metals could lead to retardation in growth, kidney disorder, cancer, abortion, deficiency in intelligence quotient and behavior, and even death.

Chronic daily intake (CDI) is essential water pollution and effects index. CDI analysis has been widely employed in nations like Pakistan [21, 22]. Therefore, this study aimed at determining the CDI of heavy metal from the consumption of potable water in South-south Nigeria.

2. Methodology

Information for the study was obtained from secondary sources (i.e literature). An inventory of heavy metals that are frequently found in potable water sources i.e surface water (stream, river) and ground water (borehole, hand dug well) in south-south Nigeria is presented in Table 1.

Table 1: Concentration of some heavy metal found in drinking water sources in South-south Nigeria

Water source	State	Fe	Zn	Cd	Cr	Pb	Cu	Ni	Mn	References
Ground water	Akwa Ibom	1.8 – 8.3	1.3 – 2.9	0.00 – 0.50	0.0 – 0.25	0.01 – 0.54	-	-	0.0 – 1.4	[23]
Borehole	Akwa Ibom	0.03 – 0.05	0.00 – 0.160	-	-	-	0.020 – 0.180	-	-	[24]
Rivers	Akwa Ibom		0.21 – 0.37	-	-	-	0.03- 0.42	0.42 – 0.64	0.18-0.37	[25]
Groundwater	Edo	0.1 – 6.4	0.0 – 4.5	-	0.0 – 0.3	0.0 – 0.1	0.0 – 0.3	0.0 – 0.1	0.0 0.2	[26]
Surface water	Edo	0.3 – 0.37	0.07 – 0.27	0.04	-	0.08	0.04	0.05	0.03	[27]
Surface water	Cross River	12.4	9.7	1.3	1.8	6.3	3.7	-	-	[28]
Borehole	Cross Rivers	0.66 – 1.52	0.0 – 0.05	-	-	0.0 – 0.07	0.0-0.03	-	0.03 – 0.21	[29]
Rivers	Cross Rivers	0.95 – 5.11	0.04 – 2.97	0.0 - 0.0013			0.06 - 0.97	0.0 – 0.43	0.1 – 3.67	[8]
River	Delta	-	-	0.56 – 1.20	0.18 – 0.89	0.36 – 1.0	-	-	-	[30]
Shallow well		-	-	0.21 – 0.60	0.05 – 0.44	0.10 – 0.22	-	-	-	
Borehole		-	-	0.01 – 0.04	0.01 – 0.05	0.01 – 0.04	-	-	-	
Well	Delta	0.02 – 0.63	-	0.010 – 0.198	0.10 – 0.42	0.01 – 33.50	-	-	-	[31]
River	Delta	0.03 – 5.02	0.00 – 0.63	0.00 – 0.05	0.00 – 0.06	0.00	0.00 – 0.26	0.00 – 0.32	0.02 – 0.68	[2]
Borehole	Bayelsa	0.12 – 0.40	0.15 – 0.78	-	-	0.00 – 0.20	-	-	0.01 – 0.30	[32]
Borehole	Bayelsa	5.32 – 9.96	0.01 – 0.96	-	0.00	<0.01	<0.01			[33]
Ground water	Bayelsa	0.06 – 43.09	0.15 – 10.09	0.00 – 0.03	0.01 – 0.18	0.21 – 0.42	0.01 – 1.31	0.00 – 0.02	0.12 – 2.34	[3]
Ground water	Bayelsa state	0.40-1.40	-	0.00	0.00	-	0.00	-	-	[34]

The minimum and maximum range of each of the parameters per state was established according to the source of the water, thus surface (river and stream) and ground water (borehole, hand dug well). The resultant value was multiplied by 1000 to convert the values from mg/l to µg/l.

Heavy metals enter the human body through several pathways including food intake, dermal contact and inhalation[21]. In comparison to oral intake, however, all other pathways are considered negligible [21,22].

Chronic daily intakes **(**CDI) (µg/kg·day) of heavy metal through water ingestion were calculated:

$$CDI = \frac{Cm \times Iw}{Wb} \qquad [21, 22, 35]$$

Where, *C*m (µg/L) is the heavy metal concentration in water, *I*w (L/day) is the average daily intake of water. According to US EPA [36] stated that adult and children consumes average 2 and 1 liter (*s*) of water per day. Also Muhammad et al[22,37], Khan et al[38], Jan et al[39] stated that adults and children has average body weight of 72 kg and 32.7 kg respectively. Though, these studies were conducted in non-Nigeria environment. Hence, the quantity of water consumed by adults and children is 2 and 1 liter (s)/day respectively were used in this study. Also, average body weight of 70 kg and 30 kg were used for the study assuming adult and children age ranged between < 14 and >15.

3. Results and discussion

The concentration of heavy metal found in potable water sources in the South-south Nigeria is presented in Table 2. The concentration of heavy metals from ground water and surface water are respectively ranged from 20 to 8300 µg/L and 30 to 87000 µg/L (Fe), 0.00 to 10090 µg/L and 0.00 to 9700µg/L (Zn), 10 to 600 µg/L and 0.00 to 1300 µg/L (Cd), 0.00 to 440 µg/L and 0.00 to 1800µg/L (Cr), 0.00 to 33500 µg/L and 0.00 to 6300µg/L (Pb), 0.00 to 1310 µg/L and 0.00 to 3700 µg/L(Cu), 0.0 to 100 µg/L and 0.00 to 640 µg/L(Ni) and 0.0 to 2340 µg/L and 20 to3670 µg/L (Mn). Apart from lead the ground water, the concentration of the heavy metal under study is higher in surface water. Additionally, the concentration of these heavy metals was found to be higher than the permissible limit by WHO and SON.

Table 2: Estimated concentration of heavy metal found in Potable water sources in South-south Nigeria

Heavy metals	Delta		Edo		Bayelsa		Cross Rivers		Akwa Ibom	
	Ground	Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground	Surface
Fe	20 –630	30 – 5020	100– 6400	300–370	60 – 43090	NA	660– 1520	950 - 12400	30 - 8300	820-87000
Zn	NA	0.00 – 630	0.0– 4500	70 –270	10 – 10090	NA	0.0 – 50	40 - 9700	0.00– 2900	210 – 370
Cd	10 – 600	0.00 – 1200	NA	400	0.00 – 30	NA	NA	0.00– 1300	0.00 – 500	NA
Cr	10 – 440	0.00 – 890	0.0 – 300		0.00 – 180	NA	NA	1800	0.0 – 250	NA
Pb	10 – 33500	0.00 – 1000	0.0 – 100	80	10 – 420	NA	0.0 – 70	6300	10 – 540	NA
Cu	NA	0.00 – 260	0.0 – 300	400	0.00 – 1310	NA	0.0-30	60 -3700	20 – 180	30- 420
Ni	NA	0.00 – 320	0.0 – 100	500	0.00 – 20	NA	NA	0.0 – 430	NA	420 – 640
Mn	NA	20 – 680	0.0 -200	500	10 – 2340	NA	30– 210	100 – 3670	0.0 – 1400	180-370

The chronic daily intakes values of the selected heavy metals in the study states (Delta, Bayelsa, Cross Rivers, Akwa Ibom and Edo) is presented in Table 3. The CDI of heavy metals from ground water consumed by adult and children is respectively ranged from 0.57 to 123.14 µg/kg·day and 0.667 to 1436.33 µg/kg·day (Fe), 0.00 to 128.50 µg/kg·day and 0.00 to 150.0 µg/kg·day (Zn), 0.00 to 17.40µg/kg·day and 0.00 to 20.0 µg/kg·day (Cd), 0.00 to 12.57 µg/kg·day and 0.00 to 16.67 µg/kg·day (Cr), 0.00 to 957.14 µg/kg·day and 0.00 to 1116.67 µg/kg·day (Pb), 0.00 to 37.43 µg/kg·day and 0.00 to 43.67 µg/kg·day (Cu), 0.00 to 2.86 µg/kg·day and 0.00 to 3.33 µg/kg·day (Ni), 0.00 to 66.86 µg/kg·day and 0.00 to 78.0 µg/kg·day (Mn). Similarly the CDI of heavy metals resulting from the consumption of surface water for adults and children respectively ranged from 0.86 to 1242.86 µg/kg·day and 1.0 to 2900 µg/kg·day (Fe), 0.00 to 2771.0 µg/kg·day and 0.00 to 323.33 µg/kg·day (Zn), 0.00 to 37.14 µg/kg·day and 0.00 to 43.33 µg/kg·day (Cd), 0.00 to 25.43 µg/kg·day and 0.00 to 29.67 µg/kg·day (Cr), 0.00 to 180.0 µg/kg·day and 0.00 to 210.0 µg/kg·day (Pb), 0.00 to 105.70 µg/kg·day and 0.00 to 123.33 µg/kg·day (Cu), 0.00 to 18.29 µg/kg·day and 0.00 to 21.33 µg/kg·day (Ni), 0.57 to 104.86 µg/kg·day and 0.67 to 122.33 µg/kg·day (Mn). The CDIs of heavy metals were found in the order of Ni< Cr < Cd < Cu < Mn < Zn < Pb < Fe and Ni< Cr < Cd < Cu < Mn < Pb < Zn < Fe for ground and surface water. The result of this study is far from the CDI order heavy metal from potable water sources in Pakistan as Cr >Mn >Ni >Zn >Cd >Cu >Pb and Cr >Mn >Ni >Pb >Zn >Cd >Cu in surface and groundwater respectively reported by Khan et al. [21]. The difference could be attributed to the prevailing conditions and activities of such area. The high CDI reported in this study indicates that heavy metal related diseases could occur to individual that consumes or ingest this water over a long period of time. The potential sources of heavy metal contamination in potable water sources is from both natural and anthropogenic activities such as oil and gas exploration, emission of industrial wastes etc. However, iron was found to be the highest. Ohimain and Angaye [9] reported that iron content in the water reflects on the pH of water, hence water with high iron will have a corresponding increase in acidity (i.e low pH). Beside discharge of wastes into the environment, the geology of area significantly enhances the concentration of iron in the drinking water sources.

The CDI of water can be reduced through water treatment techniques. Some of the widely employed techniques for the removal of heavy metals in water include chemical precipitation, ion-exchange, bio-adsorption, membrane filtration, oxidation, reduction, reverse osmosis, coagulation-flocculation, flotation and electrochemical methods such as electrodialysis, and photocatalysis 14, 16, 40 – 43]. Treatment techniques such as chemical precipitation, ion exchange and bio-adsoption are formidable approach for removing several heavy metal pollutant from water due to their low cost of maintenance [14].

Table 3: Chronic daily intake of heavy metals in south-south Nigeria

	Delta				Edo				Bayelsa				Cross Rivers				Akwa Ibom			
	Ground		Surface		Ground		Surface		Ground		Surface		Ground		Surface		Ground		Surface	
	Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children
Fe	0.57 – 18.0	0.667 – 21	0.86 – 14.86	1-167.33	2.85-182.86	3.33 – 213.33	8.57 – 10.57	10 – 12.33	1.71-1231.14	2.0 – 1436.33	NA	NA	18.86 – 43.43	22.0 – 50.67	27.14 – 354.29	31.67-413.33	0.86 – 237.14	1.0 – 276.67	23.43-1242.86	27.33 – 2900
Zn	NA	NA	0.00 – 18.0	0.00 - 21	0.00 – 128.57	0.0 – 150	2.0 – 7.71	2.33 – 9.0	0.29-144.14	0.33 – 336.33	NA	NA	0.00 – 1.43	0.0 – 1.67	1.14 – 277.14	1.33 – 323.33	0.00 – 82.86	0.00 – 96.67	6.0 – 10.57	7.0 – 12.33
Cd	0.29-17.14	0.33 – 20	0.00 – 34.28	0.00 –40	NA	NA	11.43	13.33	0.00 – 0.86	0.00 – 1.00	NA	NA	NA	NA	0.00 – 37.14	0.00 – 43.33	0.00 – 14.29	0.00 – 16.67	NA	NA
Cr	0.29 – 12.57	0.33 – 14.67	0.00 – 25.43	0.00 – 29.67	0.00 – 8.57	0.0 – 10	NA	NA	0.00 – 5.14	0.00 – 6.00	NA	NA	NA	NA	51.43	60	0.00 – 7.14	0.0 – 16.67	NA	NA
Pb	0.29 – 957.14	0.33 – 1116.67	0.00 – 28.57	0.00 – 33.33	0.00 – 2.86	0.0 – 3.33	2.29	2.67	0.29 – 12.00	0.33 – 14.0	NA	NA	0.00 – 2.0	0.0 – 3.33	180	210	0.29 – 15.43	0.33 – 36.0	NA	NA
Cu	NA	NA	0.00 – 7.43	0.00 – 8.67	0.00 – 8.57	0.0 – 10	11.43	13.33	0.00-37.43	0.00 – 43.67	NA	NA	0.00 – 0.86	0.0-1.0	1.71-105.71	2.0 – 123.33	0.57 – 5.14	1.33 – 6.0	0.66-12.0	1.0 – 14.0
Ni	NA	NA	0.00 – 9.14	0.00 – 10.67	0.00 – 2.86	0.0 – 3.33	14.29	16.67	0.00 – 0.57	0.00 – 0.67	NA	NA	NA	NA	0.0 – 12.29	0.00 – 14.33	NA	NA	12.0 – 18.29	14.0 – 21.33
Mn	NA	NA	0.57 – 19.43	0.67 – 22.67	0.00 – 5.71	0.0-6.67	14.29	16.67	0.29 – 66.86	0.33 – 78.0	NA	NA	0.86 – 6.00	1.0 – 7.0	2.86 – 104.86	3.33 – 122.33	0.00 – 40.0	0.0 – 46.67	5.14-10.57	6.0 – 12.33

4. Conclusions

Potable water is an indispensable requirement required by all by biological system. Nearly all human consumes significant amount of water on daily basis. In the recent times, most diseases especially in the tropical region have been attributed to poor water quality. This study estimated the potential CDI of heavy metal from drinking water sources in South-south Nigeria. The results showed that CDI of the heavy metals i.e Ni, Cr, Cd, Cu, Mn, Zn, Pb and Fe were high in the potable water. Hence the consumption of this water could trigger disease conditions. Therefore, potable water in the study region should be treated before consumption to avert disease conditions associated with heavy metals presence in drinking water. Hence, the water requires treatment before consumption.

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