Available online at www.elixirpublishers.com (Elixir International Journal)

Bio Sciences

Elixir Bio Sci. 112 (2017) 49038-49041

ISSN: 2229-712X

Health Risk Assessment of Some Heavy Metals in Groundwater Resource in Warri Metropolis

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ARTICLE INFO

Article history:
Received: 20 September 2017;
Received in revised form: 11 November 2017;
Accepted: 22 November 2017;

Keywords
Heavy metals,
Health risk,
Assessment,
Groundwater,
Warri Metropolis.

ABSTRACT

Health risk assessment of three heavy metals (Pb, Cd and Cr) in groundwater resource in warri metropolis was confirmed by this research. Twenty (20) hand dug well water were analyzed using Atomic Absorption Spectrophotometer. Results showed that Lead ranged in concentration from 0-0.04mg/l. Cadmium ranged from 0-0.040 mg/l. Chromium concentrations ranged from 0-0.004mg/l. The combined hazard index (HI) values via ingestion of water were greater than unity and may poses health risk from oral exposure. Use of concrete ring to protect the dug wells are strongly recommended to avoid storm waters and other lecheates from dumpsites and other industrial waste.

Introduction

Water is one of the essentials that supports all forms of plant and animal life (1) and it is generally obtained from two principal natural sources; Surface water such as fresh water lakes, rivers, streams, etc. and Ground water such as borehole water and well water (2, 3). Water has unique chemical properties due to its polarity and hydrogen bonds which means it is able to dissolve, absorb, adsorb or suspend many different compounds (4), thus, in nature, water is not pure as it acquires contaminants from its surrounding and those arising from humans and animals as well as other biological activities (3).

One of the most important environmental issues today is ground water contamination (5) and between the wide diversity of contaminants affecting water resources, heavy metals receive particular concern considering their strong toxicity even at low concentrations (6).

Heavy metals are elements having atomic weights between 63.546 and 200.590 and a specific gravity greater than 4.0 i.e. at least 5 times that of water. They exist in water in colloidal, particulate and dissolved phases (7) with their occurrence in water bodies being either of natural origin (e.g. eroded minerals within sediments, leaching of ore deposits and volcanism extruded products) or of anthropogenic origin (i.e. solid waste disposal, industrial or domestic effluents, harbour channel dredging) (6).

Heavy metal can cause serious health effects with varied symptoms depending on the nature and quantity of the metal ingested (8). They produce their toxicity by forming complexes with proteins, in which carboxylic acid (–COOH), amine (–NH2), and thiol (–SH) groups are involved. These modified biological molecules lose their ability to function properly and result in the malfunction or death of the cells. When metals bind to these groups, they inactivate important enzyme systems or affect protein structure, which is linked to the catalytic properties of enzymes. This type of toxin may also cause the formation of radicals which are dangerous chemicals that cause the oxidation of biological molecules.

The most common heavy metals that humans are exposed to are Aluminium, Arsenic, Cadmium, Lead and Mercury. Aluminium has been associated with Alzheimer's and Parkinson's disease, senility and presenile dementia. Arsenic exposure can cause among other illness or symptoms cancer, abdominal pain and skin lesions. Cadmium exposure produces kidney damage and hypertension. Lead is a cumulative poison and a possible human carcinogen (9) while for Mercury, toxicity results in mental disturbance and impairment of speech, hearing, vision and movement (10). In addition, Lead and Mercury may cause the development of autoimmunity in which a person's immune system attacks its own cells. This can lead to joint diseases and ailment of the kidneys, circulatory system and neurons. At higher concentrations, Lead and Mercury can cause irreversible brain damage.

In Nigeria today, the use of ground water has become an agent of development because the government is unable to meet the ever increasing water demand. Thus, inhabitants have had to look for alternative ground water sources such as shallow wells and boreholes. The quality of these ground water sources are affected by the characteristics of the media through which the water passes on its way to the ground water zone of saturation (11), thus, the heavy metals discharged by industries, traffic, municipal wastes, hazardous waste sites as well as from fertilizers for agricultural purposes and accidental oil spillages from tankers can result in a steady rise in contamination of ground water (5, 12).

There is thus the need to assess the quality of groundwater sources. The World Health Organisation has specified Maximum Contaminant Level for the presence of heavy metals in water. The aim of this study is to assess the health risk of some heavy metals of ground water sources in Warri metropolis.

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With the aid of Atomic Absorption Spectrophotometer the presence and concentration of three heavy metals (Cadmium, Lead and Chromium) were determined and the results compared to the maximum contaminant level specified by the World Health Organisation.

Objectives of the Study

The objectives of this study were to determine the levels of three heavy metals in groundwater samples; compare the obtained values with the WHO acceptable limits for those metals in potable water and assess the health risks by ingestion of water by the determination of average daily dose (AAD), hazard quotient (HQ) and hazard index (HI) for adults.

Materials and Methods

Study Area

The study area includes the Warri metropolis and the rural fringes that lie roughly between latitude 5°30'N - 5°45'N and longitude 5°15'E - 5°50' E. The small and rural river port of Warri town with a population of a mere 20,000 people in 1933, has expanded to become the present day agglomeration of many towns and communities that include Effurun, Ekpan, Enerhen, Edjeba, Ogunu, Jakpa, Ovwian- Aladja.

Rainfall is between 3000 – 4500 mm. There is hardly any month without rain in the Niger Delta Coastline. Generally, in the southern part of the country, monthly averages are usually above 300 mm from June to October but less than 50 mm from December to March, during which time only about 4 % of the annual rain is recorded. The map of the sampling locations is shown in figure 1 while the sampling points and geographical coordinates are presented in table 1.

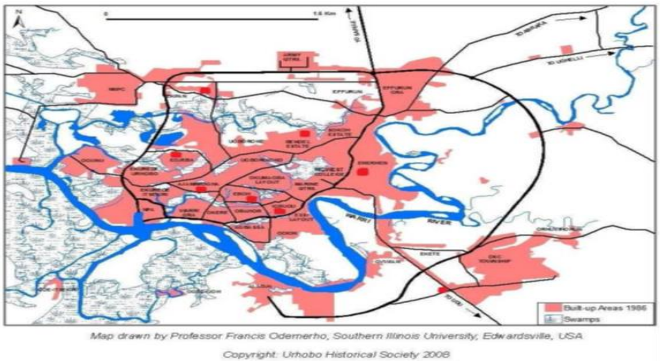

Figure 1. Map of Warri Metropolis showing sampling locations (red).

Table 1. Sampling points and geographical coordinates.

S/N	Latitude	Longitude	Sampling Location
HDW1	N05.57105	E005.704667	Ubeji
HDW2	N05.57061	E005.707861	Ubeji
HDW3	N05.57147	E005.692333	Ubeji
HDW4	N05.57305	E005.722167	Jeddo
HDW5	N05.57969	E005.826889	Okuokoko
HDW6	N05.50689	E005.789917	Orhuwhorun
HDW7	N05.50131	E005.795667	Orhuwhorun
HDW8	N05.49305	E005.782778	Ovwian
HDW9	N05.48042	E005.757222	Aladja
HDW10	N05.49514	E005.818028	DSC
HDW11	N05.56344	E005.789083	Effurun
HDW12	N05.57758	E005.768083	Army Barrack
HDW13	N05.53514	E005.778917	Effurun
HDW14	N05.52314	E005.731254	Ekurede Itsekiri
HDW15	N05.52597	E005.742472	Okere warri
HDW16	N05.54188	E005.750417	Ugboroke
HDW17	N05.47408	E005.748722	Aladja
HDW18	N05.56160	E005.751473	Jakpa
HDW19	N05.33534	E005.466154	Jakpa
HDW20	N05.33624	E005.451163	Ekpan

Methodology

Sample Collection and Analysis: Water samples were obtained in triplicates from twenty hand dug wells from different locations in Warri metropolis in Delta state.

An Ertec model GPS instrument was used to determine coordinates and to locate the well positions on the city map.
Samples were collected from the selected dug wells and screened for the selected heavy metals. Water samples were collected from each dug well into sterilized polyethylene bottles. Samples were immediately stabilized in situ with nitric acid, stored in ice boxes and sent to the laboratory within an hour of collection for analysis. At the laboratory, the Pye Unicam Atomic Absorption Spectrophotometer SP 2900 was employed in the determination of levels of lead, cadmium and chromium.

Human Health Risk Assessment

Human health risk assessment is considered as the characterization of the potential adverse health effects of humans as a result of exposures to environmental hazards (13). This process employs the tools of science, engineering, and statistics to identify and measure a hazard, determine possible routes of exposure, and finally use that information to calculate a numerical value to represent the potential risk (14). A human health risk assessment involves four steps which are: hazard identification, dose-response assessment, exposure assessment, and risk characterization. Health risk assessment classifies elements as, carcinogenic or non-carcinogenic. The classification determines the procedure to be followed when potential risks are calculated. Non-carcinogenic chemicals are assumed to have a threshold; a dose below which no adverse health effects will be observed where an essential part of the dose-response portion of a risk assessment includes the use of a reference dose (RfD). Also, carcinogens are assumed to have no effective threshold. This assumption implies that there is a risk of cancer developing with exposures at low doses and, therefore, there is no safe threshold for exposure to carcinogenic chemicals. Carcinogens are expressed by their Cancer Potency Factor (14).

Exposure Assessment

The daily environmental exposures to metals were assessed for carcinogenic and non-carcinogenic elements. There are two main exposure pathways: intake of the metals through water consumption, and by skin absorption through bathing. Calculations were done based on USEPA standards (The United States Environmental Protection Agency (15). Assessment of non-carcinogenic risks can be achieved by estimating the hazard quotient (HQ). It is calculated as the quotient between the environmental exposure and the reference dose (RfD).

RfD is an estimate of a daily oral exposure for the human population, which does not cause deleterious effects during a lifetime (16). HQ values were obtained for each element and exposure pathway. Subsequently, the hazard index (HI), which is defined as the total risk through heath exposure pathway, was obtained by summing the HQ of each element. Finally, the total HI was calculated by summing the HI through oral and dermal routes (HIing and HIderm, respectively) (17). Values of HI under the unity are considered as safe (17). The HQ is considered to be an estimate of the risk level (non-carcinogenic) due to pollutant exposure with respect to ADD (Average Daily Dose) which is calculated from the following equation:

Health Risk Assessment was calculated for Non cancer hazard and carcinogenic effects as follows (18)

(1.) Average Daily Dose (mg/L/day) = $C * \frac{IR * EF * ED}{BW * AT}$

C = Concentration of metals in water (mg/L)

IR = Ingestion Rate (2 L for adult, 1 L for a child and 0.75 L for an infant)

ED = Exposure duration (years)

30 * 365 days for non-carcinogenic adverse effects and 50 years for carcinogenic effects for adult while ED = 6 * 365 days for a child and 1 * 365 days for infant (19)

EF = Exposure frequency (day/year)

= 250 days/ year (20)

AT = Averaging time = life expectancy

AT = ED for non Carcinogenic effects

While AT = 54.5 * 365 days for Carcinogenic effects on adult (21) and 6 * 365 days for children and 1 * 365 days for infant (22)

BW = Body weight, 60 kg for adult. 10 kg for a child and 5 kg for an infant.

2.) Non cancer hazard index = $HI = \sum_{i=1}^{n} HQ$

i= 1….n

Hazard Quotient (HQ) = $\frac{ADD}{RfD}$

ADD = Average Daily Dose

RfD = Oral Reference Dose

A summation of the hazard quotients for all chemicals to which an individual is exposed was used to calculate the hazard index (23).

HI = HQA+ HQB+ ………… +HQn

Health risk assessment of toxicant was interpreted based on the values of HQ and HI. Values less than one (HQ or HI <1) means no risk and the greater the values above one, the greater is the level of risk of the toxicants manifesting long term health hazards effects increasing (24)

(3.) Cancer Risk = ADD * SF

SF = Slope Factor

Table 2. Levels of lead, cadmium and chromium at different parts of Warri metropolis.

Sample code	Cadmium(mg/L)	Lead(mg/L)	Chromium(mg/L)
HDW1	0.008±0.001	0.04±0.002	0.001±0.002
HDW2	0.003±0.001	0.002±0.001	ND
HDW3	0.005±0.002	0.002±0.001	<0.001
HDW4	0.007±0.001	0.003±0.002	<0.001
HDW5	0.006±0.002	0.00±0.001	<0.001
HDW6	0.001±0.002	0.001±0.002	<0.001
HDW7	0.002±0.001	0.002±0.003	<0.001
HDW8	0.001±0.002	0.001±0.002	<0.001
HDW9	0.005±0.003	0.001±0.001	0.001±0.002
HDW10	0.006±0.002	0.004±0.002	0.002±0.001
HDW11	0.005±0.001	0.003±0.001	<0.001
HDW12	ND	ND	<0.001
HDW13	0.009±0.002	0.001±0.002	<0.001
HDW14	0.04±0.03	0.006±0.002	<0.001
HDW15	0.003±0.001	0.019±0.003	<0.001
HDW16	0.009±0.003	0.001±0.001	<0.001
HDW17	ND	ND	ND
HDW18	0.008±0.002	0.005±0.002	0.004±0.001
HDW19	0.003±0.001	0.002±0.001	0.002±0.001
HDW20	0.004±0.002	0.003±0.001	<0.001

Source: Field work, 2016

Risk is therefore a unit less of chances of an individual developing cancer when exposed over a lifetime and SF is the carcinogenicity slope factor (per mg/kg/day) and ADD is the average daily dose. Risks values exceeding 1×10^{-4} are regarded as intolerable, risks less than 1×10^{-6} are not regarded to cause significant health effects, and risks lying between 1×10^{-4} and 1×10^{-6} are regarded generally as satisfactory range, but circumstances and condition of exposure determine the range of the value of the circumstance (25).

Table 3. Health risk assessment for cadmium, lead and chromium.

Sample code	HQ Cd	HQ Pb	HQ Cr	HI
HDW1	67	83.25	2.76	153.01
HDW2	25	4.25	ND	29.25
HDW3	42	4.25	2.76	49.01
HDW4	58	6.25	2.76	67.01
HDW5	49	2.075	2.76	53.83
HDW6	8.3	2.075	2.76	13.14
HDW7	17	4.25	2.76	24.01
HDW8	8.3	2.075	2.76	13.14
HDW9	42	2.075	2.76	46.84
HDW10	49	8.25	5.67	62.92
HDW11	42	6.25	2.76	51.01
HDW12	ND	ND	2.76	2.76
HDW13	75	4.25	2.76	82.01
HDW14	333	12.25	2.76	348.01
HDW15	25	39.5	2.76	67.26
HDW16	75	2.075	2.76	79.84
HDW17	ND	ND	ND	ND
HDW18	67	10.5	11	88.7
HDW19	25	2.075	5.67	32.75
HDW20	33	6.25	2.76	42.01

Results and Discussion

Lead was detected in more than eighty per cent of all samples collected and ranged in concentration from 0-0.04mg/l. The highest value for lead was obtained from HDW1 with a value of 0.04 mg/l followed by HDW15 with a mean value of 0.019 mg/l, which was more than the WHO maximum concentration limit of 0.01 mg/l

Cadmium ranged from 0-0.040 mg/l and the highest value was obtained from HDW14well.

Cadmium was predominantly above the WHO limit of 0.003mg/l everywhere in the metropolis except for HDW6, HDW7, HDW8, HDW12 and HDW17.

The highest concentrations of cadmium in groundwater were in the older and more densely populated areas of the metropolis.

Chromium concentrations were within WHO maximum limit of 0.002 mg/l except for HDW14 with an average concentration of 0.004mg/l.

Health risk assessment

The levels of hazard quotient (HQ) of selected trace metals in water from Warri metropolis are summarized in Table 3. HQ values are between 8.3 and 333 for Cd, 2.075 and 83.25 for Pb, 2.76 and 11 for Cr.

Hazard Index (HI) for all heavy metals range from 2.76 to 348.01 and therefore poses a risk for Non-carcinogenic effect for adult. This study corroborates the work of (26) which showed moderately risk Cadmium, Lead and Chromium in Groundwater.

Conclusions

Elevated levels of cadmium and lead in groundwater are above WHO maximum allowable limits in drinking water. Heavy metals under study are more widespread and evenly distributed in the area that are densely populated, and because of the prevalent long term use of open and unregulated dumpsites as well as the possible mixing of groundwater as suggested by existing gradients. The toxicity of these heavy metals requires that their presence in groundwater be constantly monitored.

Recommendations

1. The hand dug wells should be protected with a concrete ring to avoid storm waters and other lecheates from dumpsites and other industrial waste.
2. Groundwater sources of the community should be treated for Pb, Cd and Cr pollutants, using the extraction, treatment and re-injection (ETR) technology; recirculating well technology (RWT) and natural attenuation methods.

Acknowledgment

This research was undertaken with the assistance of College of Education, Warri Consult Laboratory staff for which the authors are grateful.

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