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ASSESSMENT OF HEAVY METALS IN SURFACE WATER OF THE IKPOBA RESERVOIR, BENIN CITY, NIGERIA

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Abstract

The present study was carried out to determine the impact of some heavy metals namely, Cd, Mn, Cu, Fe, Pb, Ni, Zn and Cr on the water quality of the Ikpoba reservoir Benin City, Nigeria, with a view to safeguard public health. Water samples were randomly collected from four stations within the Reservoir from August 2005 to December 2005 and were analyzed for heavy metal concentrations using Atomic Absorption Spectrometric technique. The mean concentration of these metals were, Cd, (0.02mg/l), Mn(0.026mg/l), Cu(0.24mg/l), Fe(5.60mg/l), Pb(0.07mg/l), Ni(0.03mg/l), Zn(116.59mg/l) and Cr(0.033mg/l). The mean concentrations of Cd, Fe, Pb, Ni and Zn, exceeded the World Health Organization (WHO) maximum permissible level for drinking water.

Keywords: water quality, heavy metals, Ikpoba reservoir

1. Introduction

Surface water degradation has become a matter of increasing national and global concern as the impact of organic and inorganic contaminants, continue to render vital water resources less suitable for their intended uses. The protection of the aquatic environment and its associated resources is one of the Programmes of Action enlisted in Agenda 21 of the United Nations, geared towards achieving sustainable development [1]. In many African countries, it has been reported that 80% of human illnesses are attributable to contaminated water supplies [2]. In natural aquatic ecosystems, heavy metals occur in low concentrations; usually at the nanogram to microgram per litre level. In recent times however, the occurrence of heavy metals in excess of natural loads has become a problem of increasing concern. This phenomenon is as a result of rapid population growth, increased urbanization, expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern agricultural practices as well as poor enforcement of environmental regulations [2]. On the global level, problems associated with heavy metal contamination, were first highlighted in industrially advanced countries because of the larger industrial discharges and such incidents of mercury and cadmium pollution in Japan and Sweden. The consumption of fish and shellfish contaminated with mercury caused an epidemic of paralysis amongst human populations in Minamata, Japan in 1956 [3]. Heavy metals are high priority pollutants because of their relatively high toxic and persistent nature in the environment. A knowledge of the changing concentration and distribution of heavy metals in various compartments of the environment is a priority for good environmental management programmes all over the world [4]. Heavy metals have been reported in various water bodies in Nigeria. These metals have in most cases been traced to effluent discharged to receiving water bodies [5, 6]. Heavy metal pollution in natural water bodies may increase as a result of human activities which often lead to a variety of negative impacts with consequent disruption of the natural equilibrium and restriction in the use of natural aquatic resources [7, 8, 9]. Aquatic environments are natural sinks to pollutants including heavy metals and such metals reaching aquatic bodies can have grave environmental implications which may manifest through bioaccumulation and biomagnifications up food chains [10]. Heavy metals enter aquatic organisms, through the body, respiratory surfaces and by the ingestion of food and water [11]. The effects of heavy metals may manifest in a variety of ways including impairment of metabolic functions with possible changes to the distribution and abundance of wildlife [12]. Heavy metal accumulation and toxicity to aquatic organisms and their consequent health risk to man are well known [13, 14]. The Ikpoba reservoir, receives both domestic and industrial effluents which contain a wide range of pollutants from the heavily populated City of Benin. This study was undertaken specifically to ascertain the concentrations of Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Zinc (Zn) and Nickel (Ni) in water from the Ikpoba reservoir in order to determine the magnitude of the impact of these metals on water quality. Comparisons have been made with the World Health Organization (WHO) and the Nigerian Industrial Standards for drinking water with a view to safeguard public health.

2. Materials and Methods

2.1. The study area

Benin City, the administrative capital of Edo State Nigeria, lies between Longitudes 5°30′ and 5°45′E and Lattitude 6°30′N. The river is dendrite in the upper reaches and its headwaters originate from the Ishan Plateau, northwest of Benin City . The river, receives domestic and agricultural wastes through run-off from the surrounding agricultural lands including the University of Benin, which is situated close to the bank of the River at Ugbowo. The University of Benin and its Teaching Hospital deposits solid wastes in a forest clearing near the bank of the River. During rainfall, part of the sewage enters the river through run-off and seepage [15]. The river was impounded by the Ikpoba weir to form the Ikpoba reservoir which separates the downstream from the upstream sections of the river. Construction of the reservoir started in March 1977 and was completed in 1982. The reservoir has a storage capacity of 1.5 million m^3 and has a surface area of 107.5 hectares (1.1 million m^2) [16].The Reservoir was constructed primarily for the supply of potable drinking water to inhabitants of Benin City. The climate of the study area is typically tropical with two recognizable annual seasons, the dry and wet seasons. The wet season falls within April and November while the dry season falls within December and March. The vegetation in the area includes the blue flower grass (*Commelina spp.*), elephant grass (*Penisetum purpureum*, water leaf (*Talinuum triangulare*) and morning glory (*Ipomea sp.*). The length of the Ikpoba river is flanked by thickets of Indian bamboo (*Bambusa sp.*), shrubs and grasses. Human activities in the area include farming, car washing, animal grazing, sand quarrying and fishing. There is a drainage channel at the Okhoro end of the reservoir that brings in run-off from the city. A lot of solid wastes are visible at the Okhoro section of the reservoir.

2.2. Sample collection and preparation

In order to get a fair and adequate representation of the Reservoir, four (4) sampling stations were established within the Reservoir for the study viz: Okhoro station, Midpoint station, Low-lift Pump station and Ekiuwa station. The other stations are approximately equidistant (0.075 km) from the midpoint station. Duplicate surface water samples were randomly collected between 7:00 am and 9:30 am fortnightly from the aforementioned stations from August to December 2005 while operating from a dug-out canoe. The samples were collected in 1 litre polythene bottles with screw caps at approximately 30cm below the water surface. The bottles were treated with 5% nitric acid and rinsed with distilled water before use. The samples were acidified with 5% nitric acid to minimize the adherence of heavy metals to the walls of the bottles. Water samples were transported to the laboratory in an ice chest within 24 hours and were stored at -5°C in a Haier Thermocool freezer prior to further analysis. Heavy metal analysis was carried out with a Buck Scientific VGP 210 Atomic Absorption Spectrometer using element specific hollow cathode lamps in default condition by flame absorption mode. Blank solutions were handled as detailed for the samples. All values were expressed in mg/l. Statistically, data were presented as means of duplicate determinations.

3. Results

The concentrations of the investigated heavy metals varied. The concentration profile in descending order was Zn > Fe > Cu > Pb > Cr > Ni > Mn > Cd. Tables 1 to 5 shows the mean heavy metal concentrations in water from August 2005 to December 2005 while Table 6 shows the mean heavy metal concentrations in water for the study period, in comparison with the WHO and NIS recommended standards for drinking water.The mean concentration of Cd ranged from 0.014mg/l to 0.031mg/l while the mean concentration of Mn ranged from 0.02mg/l to 0.032mg/l. The mean concentration of Cu ranged from 0.19mg/l to 0.32mg/l while the mean concentration of Fe ranged from 2.73mg/l to 9.96mg/l. The mean concentration of Pb ranged from 0.05mg/l to 0.08mg/l while the mean concentration of Ni ranged from 0.022 mg/l to 0.042mg/l. The mean concentration of Zn ranged from 98.70mg/l to 132.38mg/l while the mean concentration of Cr ranged from 0.02mg/l to 0.05mg/l.

4. Discussion

The aquatic environment receives copious amounts of heavy metals from naturally occurring deposits, natural processes and anthropogenic activities. Heavy metals are transported as dissolved species in water or as an integral part of suspended sediments. These potentially toxic pollutants can endanger public health by being incorporated in the food chain or

Table 1: Mean heavy metal concentrations in water for August, 2005.

S/N	HEAVY METAL	OKHORO STATION	MID POINT STATION	LOW LIFT PUMP STATION	EKIUWA STATION	RESERVOIR MEAN
1	Cd (mg/l)	0.02±0.005	0.01±0.001	0.02±0.005	0.02±0.001	0.0175±0.005
2	Mn (mg/l)	0.03±0.005	0.03±0.02	0.04±0.002	0.03±0.004	0.0043±0.005
3	Cu (mg/l)	0.05±0.24	0.02±0.001	0.45±0.01	0.32±0.01	0.21±0.02
4	Fe (mg/l)	0.93±0.02	0.56±0.001	10.25±0.01	9.86±0.02	5.4±5.37
5	Pb (mg/l)	0.08±0.003	0.07±0.001	0.10±0.006	0.06±0.004	0.077±0.01
6	Ni (mg/l)	0.04±0.005	0.03±0.002	0.05±0.007	0.02±0.005	0.035±0.012
7	Zn (mg/l)	140±0.58	118±0.12	135±1.15	120±0.13	128.25±10.9
8	Cr (mg/l)	0.04±0.01	0.02±0.02	0.06±0.004	0.01±0.001	0.03±0.01

Table 2: Mean heavy metal concentrations in water for September, 2005.

S/N	HEAVY METAL	OKHORO STATION	MID POINT STATION	LOW LIFT PUMP STATION	EKIUWA STATION	RESERVOIR MEAN
1	Cd (mg/l)	0.01±0.001	0.02±0.001	0.02±0.001	0.01±0.005	0.015±0.005
2	Mn (mg/l)	0.02±0.002	0.03±0.002	0.03±0.001	0.02±0.006	0.025±0.005
3	Cu (mg/l)	0.54±0.01	0.52±0.005	0.40±0.01	0.24±0.01	0.425±0.13
4	Fe (mg/l)	0.92±0.01	0.73±0.006	11.37±0.02	3.45±0.02	4.12±4.99
5	Pb (mg/l)	0.07±0.001	0.06±0.005	0.08±0.003	0.04±0.01	0.06±0.02
6	Ni (mg/l)	0.05±0.003	0.04±0.005	0.03±0.002	0.03±0.005	0.037±0.01
7	Zn (mg/l)	141.67±0.94	112±1.52	140.25±0.66	102±0.10	123.98±20.03
8	Cr (mg/l)	0.05±0.02	0.01±0.005	0.04±0.002	0.03±0.005	0.032±0.01

Table 3: Mean heavy metal concentrations in water for October, 2005.

S/N	HEAVY METAL	OKHORO STATION	MID POINT STATION	LOW LIFT PUMP STATION	EKIUWA STATION	RESERVOIR MEAN
1	Cd (mg/l)	0.02±0.006	0.01±0.005	0.01±0.001	0.02±0.005	0.015±0.005
2	Mn (mg/l)	0.03±0.006	0.02±0.006	0.04±0.002	0.03±0.001	0.03±0.008
3	Cu (mg/l)	0.45±0.01	0.26±0.015	0.50±0.01	0.22±0.005	0.357±0.13
4	Fe (mg/l)	5.26±0.01	4.34±0.07	10.42±0.04	6.21±0.01	6.55±2.68
5	Pb (mg/l)	0.06±0.003	0.05±0.005	0.08±0.005	0.04±0.002	0.057±0.02
6	Ni (mg/l)	0.04±0.003	0.03±0.005	0.05±0.001	0.02±0.005	0.035±0.01
7	Zn (mg/l)	139.53±0.12	125±1.52	135.50±1.70	109±0.57	127.25±13.62
8	Cr (mg/l)	0.04±0.002	0.02±0.005	0.06±0.006	0.04±0.01	0.04±0.02

Table 4: Mean heavy metal concentrations in water for November, 2005.

S/N	HEAVY METAL	OKHORO STATION	MID POINT STATION	LOW LIFT PUMP STATION	EKIUWA STATION	RESERVOIR MEAN
1	Cd (mg/l)	0.01±0.001	0.001±0.0	0.01±0.001	0.01±0.001	0.0075±0.005
2	Mn (mg/l)	0.03±0.001	0.02±0.005	0.02±0.001	0.01±0.001	0.02±0.008
3	Cu (mg/l)	0.035±0.01	0.02±0.005	0.24±0.006	0.15±0.004	0.11±0.10
4	Fe (mg/l)	6.75±0.01	5.36±0.03	9.43±0.02	8.25±0.02	7.44±1.77
5	Pb (mg/l)	0.10±0.01	0.06±0.001	0.07±0.01	0.05±0.001	0.07±0.02
6	Ni (mg/l)	0.04±0.002	0.03±0.001	0.04±0.01	0.02±0.005	0.0325±0.009
7	Zn (mg/l)	100.46±0.08	95.26±0.015	120.50±0.10	100±0.57	104.05±11.21
8	Cr (mg/l)	0.04±0.00	0.02±0.001	0.05±0.006	0.01±0.001	0.03±0.02

Table 5: Mean heavy metal concentrations in water for December, 2005.

S/N	HEAVY METAL	OKHORO STATION	MID POINT STATION	LOW LIFT PUMP STATION	EKIUWA STATION	RESERVOIR MEAN
1	Cd (mg/l)	0.01±0.001	0.02±0.005	0.01±0.001	0.01±0.001	0.0125±0.005
2	Mn (mg/l)	0.03±0.001	0.01±0.001	0.03±0.001	0.01±0.001	0.02±0.011
3	Cu (mg/l)	0.30±0.01	0.15±0.005	0.005±0.001	0.004±0.001	0.14±0.14
4	Fe (mg/l)	5.25±0.03	2.64±0.02	8.35±0.15	1.75±0.02	4.49±2.96
5	Pb (mg/l)	0.08±0.006	0.05±0.005	0.07±0.005	0.06±0.004	0.045±0.01
6	Ni (mg/l)	0.04±0.001	0.02±0.001	0.03±0.002	0.02±0.001	0.027±0.009
7	Zn (mg/l)	140.25±0.14	120.65±0.03	74.42±0.11	62.52±0.06	99.46±36.98
8	Cr (mg/l)	0.04±0.001	0.03±0.001	0.04±0.001	0.02±0.001	0.032±0.009

Table 6: Mean heavy metal concentrations (mg/l) in water for the study period.

HEAVY METAL	OKHORO STATION	MIDPOINT STATION	LOWLIFT PUMP STATION	EKIUWA STATION	RESERVOIR MEAN	WHO maximum permissible level [25]	NIS maximum permissible level [26]
Cd	0.014	0.0122	0.014	0.032	0.02	0.01	0.003
Mn	0.028	0.022	0.032	0.02	0.026	0.5	0.2
Cu	0.275	0.194	0.32	0.19	0.24	1.5	1.0
Fe	3.82	2.73	9.96	5.90	5.60	1.0	0.3
Pb	0.078	0.058	0.08	0.05	0.07	0.05	0.01
Ni	0.042	0.03	0.04	0.022	0.03	0.02	0.02
Zn	132.38	114.18	121.08	98.70	116.59	15.0	3.0
Cr	0.042	0.02	0.05	0.02	0.033	0.05	0.05

being released into overlying waters which serve as drinking water supplies [17]. Urban run-off has been reported to contain toxic chemicals and heavy metals that can pollute drinking water supplies and in the process become a health risk to man [18].The mean Cd concentration (0.02mg/l) in this study exceeded the WHO maximum permissible level for drinking water. A lower mean Cd concentration of 0.004mg/l was recorded for the Alaro River in Ibadan, Nigeria [5]. A mean Cd range of 1.50mg/l to 2.60mg/l was recorded for the Delimi River, Jos, Nigeria [19]. According to the Nigerian Industrial Standard (NIS) for drinking water, Cd concentrations in excess of permissible concentrations can lead to kidney damage in man. Some sources of Cd include batteries, fossil fuels, fertilizers, plastics, alloys and paints.

The mean concentration of Mn (0.026mg/l) in this study was within the WHO maximum permissible level for drinking water as well as the NIS standard. A mean range of 0.045mg/l to 0.052mg/l was recorded for Mn in water from the Ikpoba river [20]. Possible sources of Mn include fossil fuels, fertilizers, pesticides and paint. The mean Cu concentration (0.024mg/l) in this study did not exceed the WHO standard for drinking water. A lower mean value of 0.055mg/l was recorded for Cu in water from the Ogba river [21]. Some sources of Cu include paints, copper pipes, copper wires, fertilizers and pesticides.

The mean Fe concentration (5.60mg/l) in this study exceeded the WHO maximum permissible level for drinking water more than five times over. A mean range of 1.3025mg/l to 2.5584mg/l was recorded for Fe in water from two stations along the Warri River [17]. The high concentration of Fe recorded in this study, can be attributed to the high solubility of both the ferric and ferrous forms of Fe and to an increase in the influx of the metal into the reservoir especially via run-off. Fe is an essential metal which is required as an oxygen carrier in the form of haemoglobin within the circulatory system of man. It can however become a health risk when permissible levels are exceeded by causing hepatic problems. Some sources of Fe include iron pipes, fossil fuels, and effluents from textile and metallurgical industries.

The mean Pb concentration (0.07mg/l) recorded in this study, exceeded the WHO maximum permissible level for drinking water. A mean range of 0.090mg/l to 0.155mg/l was recorded for Pb in water from five stations of the Buguma creek in the Niger Delta [22]. According to the Nigerian Industrial Standard (NIS) for drinking water, the adverse health impacts of Pb includes interference with vitamin D metabolism, indenting the mental development of infants, carcinogenic activity and toxicity to the central and peripheral nervous systems. Some sources of Pb include batteries, alloys, solders, fossil fuels, plastics and pesticides.

The mean Ni concentration (0.003mg/l) recorded in this study, exceeded the WHO maximum permissible level for drinking water. A lower mean value for Ni (0.011mg/l), was recorded for the Alaro river, Ibadan [5]. Sources of Ni include batteries, fertilizers, fuel and alloys. According to NIS, carcinogenic activity in man has been linked to excess Ni concentrations in drinking water. The mean Zn concentration (116.59mg/l) in this study, far exceeded the WHO maximum permissible level for drinking water. Mean Zn values of 10.3mg/l and 42.9mg/l for the Calabar river and Warri river respectively[23]. Zn had the highest mean concentration in water compared to the other investigated metals in the reservoir, an indication that the effluents reaching the reservoir conceivably contained more of the metal. Possible sources of Zn are batteries, refuse, pesticides, alloys, dyes, fossil fuels, electroplating and metallurgical precesses.

Heavy metals such as Zn, Cu, Mn and Fe are essential for the growth and well being of living organisms including man. However, they can exhibit toxic effects when organisms are exposed to levels higher than normally required. The mean Cr concentration (0.0033mg/l) recorded in this study, was within the WHO maximum permissible level for drinking water. A mean range of 0.010 mg/l to 0.020mg/l was recorded for Cr in both the Ikpoba and Ogba Rivers in Benin City, Nigeria [20]. Some sources of Cr include paints, textiles, automobile parts, fertilizers and alloys.

5. Conclusion

The study revealed that the concentrations of the investigated heavy metals in surface water varied. The mean concentrations of Cd, Fe, Pb, Ni and Zn, exceeded the WHO maximum permissible level for drinking water. The direct implication of this finding, is that water from the reservoir is unsafe for human consumption due to heavy metal contamination. It has therefore become imperative for regulatory authorities to closely monitor the Ikpoba reservoir especially by means of an integrated approach that would take into consideration aquatic flora and fauna.

The level of monitoring is expected to generate relevant data that would be needed to implement better management strategies which would alleviate the present negative implications and safeguard public health and resources of the reservoir. It is suggested that further studies be carried out on the water quality of the reservoir particularly with regard to other ecological indices and microbial contaminants.

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