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Assessment of heavy metals concentration in the sewage treatment pond of the Ahmadu Bello University, Zaria, Nigeria

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Abstract

Heavy metal concentration of the water in the sewage treatment pond of the Ahmadu Bello University Zaria, Nigeria, was studied between April and September, 2007 using Energy Dispersive X-Ray Fluorescence (ED-XRF) Analysis. The Mean± S.E of ten (10) Heavy Metals observed during the study is as follows: Vanadium 0.75±0.07mg/L; Chromium 0.69±0.04mg/L; Manganese 0.61±0.06mg/L; Iron 0.40±0.03mg/L; Cobalt 0.31±0.02mg/L; Nickel 0.25±0.02mg/L; Copper 0.25±0.02mg/L; Zinc 0.31±0.08mg/L; Arsenic 0.24±0.02mg/L and Lead 0.31±0.08/L. Metal Index of between 67.32 - 93.72 was observed during the study period. Metals like Lead, Arsenic, Nickel, Iron, Manganese and Chromium showed concentrations above NIS and WHO Maximum Allowable Concentration for drinking water while metals like Zinc and Copper showed concentrations below the NIS and WHO Maximum Allowable Concentration for drinking water, Vanadium and Cobalt had no values for comparison.

Keywords

Heavy Metals, Maximum Allowable, Concentration, Drinking Water

1. Introduction

Water is crucial for all aspects of life, and it has become the defining feature of our planet. Access to safe water is a human right (UNDP, 2006). Globally, two million tons of sewage, industrial and agricultural waste is discharged into the world's waterways and at least 1.8 million children under five years-old die every year from water related disease, or one every 20 seconds (UN-HABITAT, 2009). In many developing countries more than 70 per cent of industrial wastes are dumped untreated into waters where they pollute the usable water supply (WWAP, 2009).

Heavy Metal is a general term which applies to the group of metals and metalloids with an atomic density greater than $4 g/cm^3$ (Ademoroti, 1996). This classification includes transition metals and higher atomic weight metals of groups III to V of the periodic table. In terms of human exposure and toxicological significance, it is anthropogenic activities that are most important because they increase the levels of metals at the site of human activities.

Pollution of the aquatic environment by inorganic chemicals has been considered a major threat to the aquatic organisms including fishes. The agricultural drainage water containing pesticides and fertilizers and effluents of industrial activities and runoffs in addition to sewage effluents supply the water bodies and sediment with quantities of inorganic anions and heavy metals (ECDG, 2002). The most anthropogenic sources of metals are industrial, petroleum contamination and sewage disposal (Santos et al., 2005).

Metal ions can be incorporated into food chain and concentrated in aquatic organisms to a level that affects their physiological state. Of the effective pollutants are the heavy metals which have drastic environmental impact on all organisms. Trace metals such as Zn, Cu and Fe play a biochemical role in the life processes of all aquatic plants and animals in trace amounts (Mason, 2002).

Their presence in the environment is a major concern because of their toxicity to plants and animals. In Nigeria we cannot negate industrial asctivities as a threat to our environment; therefore, its effects on soils and water are increasingly alarming thereby making our entire earth to become an oasis of chemical substances (Ademoroti, 1996). Domestic waste according to Adakole (1995) is discharged untreated into natural water bodies causing deterioration of water body's quality. According to Abdulla (1995), pollution from human and animal wastes is a major cause of deteriorating water quality and increased nutrient load in coastal and inland waterways.

The world is facing a global water quality crisis. Global population is increasing rapidly and will reach between nine and 11 billion in 2050, and as population increases so does the production of wastewater and the number of people vulnerable to the impacts of severe wastewater pollution. Almost 900 million people currently lack access to safe drinking water, and an estimated 2.6 billion people lack access to basic sanitation (WHO/UNICEF, 2010). Continuing population growth and urbanization, rapid industrializations, and expanding and intensifying food production are all putting pressure on water resources and increasing the unregulated or illegal discharge of contaminated water within and beyond national borders. This presents a global threat to human health and wellbeing, with both immediate and long term consequences for efforts to reduce poverty whilst sustaining the integrity of some of our most productive ecosystems. However, untreated wastewater may contain a range of pathogens including bacteria, parasites, viruses, toxic chemicals such as heavy metals and organic chemicals from agriculture, industry and domestic sources (Drechsel *et al*, 2010).

Ponds are very crucial for developmental activities; it provides employment in the areas like irrigation, farming, fisheries, balancing ponds and rural water supply (Odhiambo and Giduki, 2000 and Balarabe, 2001). All factors occurring in the pond whether physical, chemical or biological influence the pond ecosystem because it serves as a wildlife habitat for many plants and animals and some animals use the pond at one stage or the other of their life cycle. Examples include frogs and toads. Ponds also serve as a source of water for livestock.

The ABU sewage treatment pond receives sewage from the university community where it is partially treated by oxidation before it is released into the oxidation spill way to the Kubani River. Water in Kubani River is used by cattle and humans for drinking and irrigation which means that both man and animals are at the risk of heavy metal poisoning as a result of bioaccumulation along the food chain.

The objective of this study was to assess the concentration of some heavy metals in the sewage pond and compare them with those of water quality standard.

2. Materials and Methods

2.1. Study Area and Sampling Stations

The sewage pond is located in the south eastern part of Ahmadu Bello University Zaria, Nigeria. The sewage pond lies between Latitude 11˚8'N, 11˚10'N and Longitude 7˚41'E, 7˚42'E.

2.2. Sample Collection and Preparation

Sampling was done on a monthly base for a period of 6 months, between the month of April and September, 2007. Water samples for chemical analysis were collected at 30cm depth with a distance of 1m away from the shore (APHA, 1998) using glass jars (100ml). Water samples collected were preserved by adding 1.0M of conc. HNO_3, stored in a refrigerator in preparation for elemental analysis.

Heavy metal composition and concentration of the water samples collected from the ponds were determined using

2.3. Elemental Analysis

Energy Dispersive X-Ray Fluorescence (EDXRF) at the Centre for Energy Research and Technology (CERT), Ahmadu Bello University Zaria, Nigeria.

2.4. Water Sample Preparation for XRF Analysis

10% of APDC (Ammonium Pyrrolidine Dithiocarbamate, $C_6H_{12}N_2S_2$) was added to 100ml of acidified water sample and allowed for 15 to 20 minutes. The sample was then filtered using Millipore membrane filter in a filtration unit by the aid of a vacuum pump. The precipitate on filter was then measured.

Measurements were performed using an annular 25mCi Cd-109 as the excitation source, that emits Ag-K X-rays (22.1KeV) in which case all elements with characteristic excitation energies were accessible for detection in the samples. The system consists furthermore of a Si (Li) detector, with a resolution of 170eV for the 5.90KeV line, coupled to a computer controlled ADC-card.

Quantitative analysis of the samples was carried out using the Emission-Transmission (E-T) method for which a number of quantification methods have been developed and applied (LEROUX and MAHMOUD, 1966, GIAUQUE et al, 1979, MARKOWICZ, 1979, MARKOWICZ and VAN GRIEKEN, 1993, KUMP, 1996, BERNASCONI et al, 1996, TANG et al, 1986). These quantification methods provide different approaches to correct the matrix absorption as well as enhancement effects. In this work quantification was carried out using a modified version of E-T method (KUMP, 1996, ANGEYO et al, 1998, FUNTUA, 1999a, FUNTUA, 1999b) and it involves the use of pure target Material (Mo) to measure the absorption factors in the sample.

The Mo target serves as a source of monochromatic X-rays, which are excited through the sample by primary radiation and then penetrate the sample on the way to the detector. In this way, the absorption factor is experimentally determined which the program uses in the quantification of concentration of the elements.

Sensitivity calibration of the system was performed using pure metal foils (Ti, Fe, Co, Ni, Cu, Zr, Nb, Mo, Sn, Ta, Pb) and stable chemical compounds (K_2CO_3, $CaCO_3$, Ce_2O_3, WO_3, ThO_2, U_3O_8). The spectra for the samples were collected for 3000s with the Cd-109 source.

The concentrations are expressed as milligram per litre.

2.5. Statistical Analysis

Data obtained from the concentration of heavy metals from the sewage pond was subjected to Analysis of Variance (ANOVA) using the Genstat 4.2 (2006) Statistical Analysis Software and Duncan Multiple Range Test (DMRT) to test for the differences between monthly concentrations and to separate the means respectively. LSD (least significant difference) was set at 95% confidence limit (p=0.05). A probability at level of 0.05 or less was considered significant (Bailey, 1981). Standard errors were also estimated.

3. Results

The metal contents (Mg/L) obtained from various locations of the ponds using EDXRF are shown in Table 1 below. Vanadium increases in concentration from the beginning of the rains in April till the end in September. Fe, Co, Ni and Cu were the minor elements detected in the sewage pond.

From the table, the relative vanadium content in the water ranged from 0.52 to 0.88mg/l with a mean of 0.75mg/l for all the ponds within the study period, the minimum content of Vanadium was obtained in June and the maximum in July. The concentration of Chromium was high in the sewage pond as against the NIS, 2007 (Nigerian Industrial Standard) and WHO, 2007 (World Health Organization) with a minimum value of 0.60mg/l in April and the highest concentration of 0.86mg/l in August and a mean value of 0.69mg/l. Manganese had a range of between 0.42 and 0.80mg/l in June and July respectively, with a mean of 0.61mg/l indicating a higher value than the NIS and WHO standard of 0.05mg/l. Iron recorded minimum value of 0.28mg/l in June and highest of 0.47mg/l in April with a mean of 0.40mg/l which is above NIS and WHO standard of 0.50mg/l. Cobalt had a lowest value of 0.24mg/l in June and highest in August of 0.32mg/l with a mean of 0.31mg/l. Nickel had a minimum concentration of 0.19mg/l in June and maximum of 0.28mg/l in August with a mean value of 0.25mg/l. Copper had a concentration of 0.17mg/l as its minimum in June and maximum of 0.28mg/l September and a mean of 0.25mg/l. Zinc mean content was 0.31mg/l and its minimum concentration of 0.13mg/l was in June with the highest concentration of 0.60mg/l in April. Arsenic had a minimum concentration of 0.17mg/l in June and maximum of 0.29mg/l in April with a mean of 0.24mg/l. Lead had a minimum value of 0.24 mg/l in June and a maximum value of 0.36mg/l in May with a mean of 0.31mg/l.

Table 1. *Monthly mean heavy metals concentrations (Mg/l) of A.B.U. sewage ponds.*

Months	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc	Arsenic	Lead
April	0.62	0.60	0.56	0.47	0.31	0.26	0.27	0.60	0.29	0.28
May	0.68	0.63	0.51	0.35	0.30	0.22	0.25	0.54	0.25	0.36
June	0.52	0.62	0.42	0.28	0.24	0.19	0.17	0.13	0.17	0.24
July	0.88	0.80	0.80	0.39	0.27	0.25	0.24	0.15	0.20	0.26
Aug.	0.86	0.86	0.72	0.43	0.32	0.28	0.27	0.18	0.23	0.32
Sept.	0.87	0.78	0.65	0.42	0.31	0.27	0.28	0.20	0.21	0.31
N.I.S.	*	0.05	0.20	0.30	*	0.02	1.00	3.00	0.01	0.01
Mean	0.75±0.07	0.69±0.04	0.61±0.06	0.40±0.03	0.31±0.02	0.25±0.02	0.25±0.02	0.31±0.08	0.24±0.02	0.31±0.08

4. Discussion

Water is an essential substance for life. Freshwater comprises 3% of the total water on earth, but only a small percentage (0.01%) of this freshwater is available for human use (Hinrichsen and Tacio, 2002). Unfortunately, even this small proportion of freshwater is under immense stress due to rapid population growth, urbanization and unsustainable consumption of water in industry and agriculture (Azizullah et al., 2011). According to United Nations report, the world population is increasing exponentially while the availability of freshwater is declining. Many countries in Africa, Middle East and South Asia will have serious threat of water shortage in two decades, while in developing countries is further aggravated due to lack of proper management, unavailability of professionals and financial constraints (PCRWR, 2005).

Water pollution is most often due to human activities (Hammer, 1986). However, the sources of these contaminants are unclear and merit further investigation. The major ones are indiscriminate disposal of industrial, municipal and domestic wastes in water channels, rivers, streams and lakes (Kahlown and Majeed, 2003), for example an estimated 2 million tons of sewage and other effluents are discharged into the world – water every day (Azizullah et al., 2011).

Vanadium, Chromium, Manganese, Iron, Copper, Nickel, Cobalt, Zinc, Arsenic and Lead were some of the metals detected from the sewage pond. There were variations in the concentrations of these metals during the study period. The concentration of Fe, Co and Ni decreased gradually from

April to June and then increased thereby forming a plateau, this is in accordance with the work of Oniye *et al* (2002) in their work in Zaria dam, Nigeria,they reported higher concentration of Iron in the rainy season. So also is Mwamburi and Oloo (1997) in their investigation on the concentration of levels of trace metals in sediments of Lake Victoria, Kenya where they obtained higher concentrations of Fe and Mn during the rainy season. The mean monthly concentrations of Cr, Mn, Fe, Ni, As and Pb were higher than the maximum allowable limit of NIS and WHO, 2007. Cr is used in metal alloys and pigments for paints, cement and paper etc, through many human activities and this might have been washed into the sewage pond. The concentrations of Cu and Zn were within the recommended NIS and WHO standard of 2007 for drinking water quality. V and Co had no NIS values in the table of maximum allowable limit. The concentration of trace metals in water is highly influenced by the flow of water (Jain and Sharma, 2001).

However, less availability of some elements (Ni, Cu, Zn, and Pb) in water samples especially during wet season may suggest higher dilution due to added water volume or that some elements are easily carried away by the water. On the other hand, the high availability of some elements (Fe, Mn, Cu and Co) in water during the wet season may also depend on complexes with other compounds in the crust.

There are clear health advantages related to wastewater use in agriculture, stemming directly from the provision of food (mainly vegetables) to urban populations. It is estimated that 10 per cent of the world's population relies on food grown with contaminated wastewater (WHO-FAO, 2006). In Pakistan, about 26 per cent of national vegetable production originates from urban and peri-urban agriculture irrigated with wastewater (Ensink *et al*, 2004). In Hanoi peri-urban agriculture, using diluted wastewater provides 60–80 per cent of the perishable food for local markets (Lai, 2002, Van den Berg *et al*, 2003).

Whilst providing affordable food, the use of wastewater for food production without proper management can pose a serious risk. This risk can be to farmers and farm workers who come into direct contact with wastewater affected through faecal-oral transmission pathways or contact with disease vectors in the water, such as *Schistosomiasis*. Consumers and marginalized communities living around agricultural and aquaculture regions where untreated wastewater is used are also exposed to risks. The impact on health varies depending on location and types of contaminant; however, bacteria and intestinal worm infestations have been shown to pose the greatest risk (Drechsel *et al*, 2010).

In addition farmers often lack knowledge of water quality, including nutrient content, so they combine nutrient-rich irrigation water with chemical fertilizers. This makes agriculture a source of pollution rather than a step in environmental sanitation (Evers *et al*, 2008).

While some countries have national guidelines for the acceptable use of wastewater for irrigation, many do not. The Guidelines on the Safe Use of Wastewater, Excreta and Grey water in Agriculture and Aquaculture (WHO/FAO, 2006) provide a comprehensive framework for risk assessment and management that can be applied at different levels and in a range of socio-economic circumstances. The main characteristics of the approach proposed by the guidelines are: monitoring at all stages to ensure that all measures are effectively and correctly applied with a view to obtaining the desired impact on health. Both improvements in sanitation and wastewater use are mutually re-enforcing actions in support of optimizing wastewater management from the public health perspective (WHO/FAO, 2006).

A global effort to offering affordable and healthy drinking water must to be launched around the globe, while various laws and regulations to protect and improve the utilization of drinking water resources should be updated or created throughout the world, including the low income countries; otherwise the problem of heavy metals polluted drinking water will be growing because demand for drinking water is still growing such as this problem will become even more pressing in the future. Politic, industrial and public education programs are required on awareness of health risks associated with heavy metals polluted drinking water. Finally, the development of robust, cheap and sustainable technologies to improve the drinking water quality is necessary, especially for rural and low income households.

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