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DISTRIBUTION OF SOME TOXIC HEAVY METALS IN THE DIFFERENT LAYERS OF SAND IN THE FILTRATION CHAMBER OF DUTSIN-MA WATER TREATMENT PLANT

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ABSTRACT

The distribution of ten heavy metals in the three layers of sand in the sand filter bed of Dutsin-ma water treatment plant was investigated. Soil samples were collected from the filtration chamber of the treatment plant, divided into three layers, top, middle and bottom layers corresponding to sandy soil layer, coarse layer and gravels layer. The heavy metal levels were determined using high tech. AAS machine after

INTRODUCTION

In many developing countries especially in the African sub-region, treatment of water to enhance its quality and make it fit for human consumption is still a major problem and a source of concern to international community due to the importance of water for human life. Expensive and complex treatment plants have been built in many of such countries but a significant number of these plants do not function satisfactorily because of certain factors ranging from inappropriate design, irregular power supply, and lack of fuel, chemicals, replacement of damaged parts to inadequacy of trained manpower (Visscher, et.al., 1987). This therefore suggests the obvious need for more reliable and simpler water treatment systems which can withstand the taste of time and which can be maintained by local technicians without major contributions from external sources. Slow sand filtration has been identified as a method which can fulfill these requirements. However, the sand in the filter usually gets saturated with contaminants including toxic

HNO_3 / HCl digestion. Results obtained revealed the following heavy metal distributions among the layers: Top layer: Cd(0.010), Cr(0.002), Co(0.063), Cu(0.038), Fe(4.940), Pb(0.340), Mn(0.570), Hg(246.3), Ni(0.0340) and Zn(0.0992), Middle layer: Cd(0.007), Cr(0.049), Co(0.091), Cu(0.027), Fe(6.380), Pb(0.970), Mn(0.605), Hg(54.1), Ni(0.034) and Zn(0.0655 ppm) and the bottom layer: Cd(0.008), Cr(0.279), Co(0.003), Cu(0.009), Fe(14.622), Pb(0.760), Mn(0.744), Hg(217.3), Ni(0.028) and Zn(0.0416 ppm). The mean levels of the metals in the filter were: Cd(0.00833), Cr(0.110), Co(0.052), Cu(0.025), Fe(8.647), Pb(0.690), Mn(1.919), Hg(172.57), Ni(0.032) and Zn(0.069 ppm). Based on their levels, the metals exhibited the trends, top later: Hg > Fe > Mn > Pb > Zn > Co > Cu > Ni > Cd > Cr; Middle layer: : Hg > Fe > Pb > Mn > Co > Zn > Cr > Ni > Cu > Cd and bottom layer: Hg > Fe > Pb > Mn > Cr > Zn > Ni > Cu > Cd > Co in descending order while the trend in the mean levels of the metals in the filter was: Cd < Cu < Ni < Co < Zn < Cr < Pb < Mn < Fe < Hg in ascending order of magnitude. Some of the metal levels were observed to be excessively high, Cd was 1.78 times greater than its permissible level, Mn was 37.38 times greater, Pb was 68 times greater, Fe was 85.47 times greater while Hg, a highly toxic metal was 2,156.125 times greater than its permissible level. Based on these observations, it was concluded that the different soil layers in the sand filter bed were heavily polluted with most of the metals studied and that the pollution comes from two major sources namely, the soil itself (geologic) and the water coming into the filter from the dam. It was therefore recommended among others that the filter should be immediately evacuated and the soil layers be totally replaced with new good ones free of heavy metal contaminants and that the dam water be assessed for heavy metals and remediation measures be taken to reduce the heavy metal levels in the water and that should be monitored on continuous basis.

heavy metals. Environmental contamination with heavy metals attracts the attention of international community due to their detrimental health effects on living organisms. Heavy metals pollution is a menace to our environment as they are persistent and non-biodegradable in nature which makes it easier for them to accumulate in the environment. They are contaminating agents of our water and food supply, most especially vegetables (Ghaun and Chauham, 2014). Vegetables get contaminated with heavy metals by absorbing the metals from polluted air, soil, and water (Sharma, et.al., 2008; Singh, et.al., 2010). Heavy metals occur naturally in the soil originating from the pedogenetic processes of weathering of parent rocks at levels considered as trace (<1000 $mgkg^{-1}$) and seldom toxic (Kabata-Pendias & Pendias, 2001; Pierzynski et al., 2000).

Due to the disturbance and acceleration of nature's slowly occurring geochemical cycle of metals caused by man, most soils of rural and urban environments may contain accumulated amounts of one or more of the heavy metals at levels above some defined background values high enough to cause risks to human health, plants, animals, ecosystems, or other media (D'Amore et al., 2005). Similarly, among the heavy metals, arsenic, lead, cadmium and mercury have more serious health implications (Agency for Toxic Substances and Disease Registry, ATSDR, 2007; Csavina et al., 2012; Sharma et al., 2014; Gupta et al., 2015a). As, Cd, Hg, and Pb are patho-physiologically significant due to their ability to bio-accumulate in living systems and cause severe damages to vital body organs (Sharma et al., 2014; Gupta et al., 2015b). Heavy metals can damage and alter the functionality of important body organs such as the brain, kidney, lungs, liver, and blood. Although both plants and animals require certain heavy metals for proper growth and development, and for efficient functioning of body organs, excessive amounts of these metals can become toxic and inflict severe damages to the organism.

Examples of some direct toxic effects that can be caused by high metal concentration include inhibition of cytoplasmic enzymes and damage to cell structures as a result of oxidative stress (Duruibe et al., 2007; Young, 2005). Heavy metals pollution is a menace to the environment being the foremost contaminating agents of our food and water (Chauhan & Chauhan, 2014). The discharge of heavy metals into the soil and its subsequent absorption by plants from the soil depends on several factors, including application of agrochemicals, solubility of the heavy metals, soil pH, soil type, and plant species (Young, 2005; Gupta et al., 2013). Heavy metals are one of the most persistent and widespread contaminants in the environment. They cause environmental pollution from sources such as industrial effluents, mine tailings, application of fertilizers, atmospheric deposition and leaching of metal ions from the soil into lakes and rivers by acid rain (Chauhan & Chauhan, 2014; Sharma et al., 2008; Singh et al., 2010). Previous researches have revealed that the main sources of heavy metals in the environment include geogenic, industrial, agricultural, pharmaceutical, domestic effluents, and atmospheric (Goyer, 1997). Heavy metal pollution is very prominent in point source areas of soil like mining, foundries and smelters, aa well as other metal-based industrial operations (Goyer, 1997; Singh et al., 2010; Chauhan & Chauhan, 2014). The most prominent heavy metals found at contaminated sites, arranged in order of their abundance are Pb, Cr, As, Zn, Cd, Cu, and Hg (Gupta et al., 2013). The current advancement in the area of information technology has caused the release of large volumes of e-wastes globally (Wagner, 2009). But, e-wastes contains a large number of hazardous materials such as Be, Cr, Hg, Cd, Pb, As, polycyclic aromatic hydrocarbons (PAHs), chlorofluorocarbons, polybrominated diphenyls, ethers and dioxin-like compounds. They also contain non-hazardous metals like Zn, Cu, Se and precious metals like Ag, Au, Pt, among others. These materials causes significant harmful environmental impacts especially to the soil if not properly disposed-off (Lim, 2010; Tsydenova & Bengtsson, 2011). However, even the non-hazardous substances such as Zn, Cu and Se can be converted to hazardous ones in humans and ecosystems by dose, concentration and receptor organ (Musee, 2011; Tchounwou et al., 2012; Itai et al., 2014).

Heavy metals pollution of soil and water poses a lot of adverse effects and therefore is of great concern to public health, agricultural productivity, and environmental health as well (Goyer, 1997; Fergusson, 1990; Msaky & Calvet; Ma, et.al., 1994). The soil get polluted mainly due to disposal of industrial and urban wastes and excessive use of agrochemicals (Buchsuer, 1973; McBride, 2003; Demirezenand and Aksoy, 2006), while water is polluted primarily by the release of industrial wastes, sewage disposal, petroleum oil contamination, and agricultural run offs (Santos, et.al., 2005; Midrar-Ulhaq, et.al., 2005; Tariq, et.al., 2006). Many areas in the developing countries are faced with the problem of air-soil pollution resulting from the fact that heavy metals containing aerosols are normally deposited on soil surface which then get absorbed by vegetables or sometimes get deposited on plant leaves (Voutsa, et.al., 1995). Agricultural soils receive tremendous amounts of pollutants from various sources. Heavy metal contamination of agricultural soils may impart some disorders in soils, affect soil performance, retard plant growth and may even harm the health of humans through contamination of food chain. The heavy metals uptake by plants from the soil depends on many factors, including application of agrochemicals, solubility of the heavy metals, soil pH, soil type, and plant species (Tinker, 1981; Lubben & Sauerbeck, 1991). Leafy vegetables absorb and accumulate higher amounts of heavy metals in roots and leaves than stems and fruits vegetables (Sharma & Kansal, 1986; Singh & Kumar, 2006; Yargholi & Azimi, 2008). When the heavy metals accumulate to exceedingly higher concentrations than that required for physiological demand of the vegetables, they can cause lethal effect in them ant may affect human health as well (Goyer, 1997; Waseem, et.al., 2014). Above certain critical levels, heavy metals impart hazardous effects on human health by hindering with the normal functioning of the body systems. The agency for toxic substances and disease registry (ATSDR) has listed arsenic, lead, mercury and cadmium at first, second, third and seventh position in terms of their frequency, toxicity and potentiality for human exposure.

The assessment of Heavy metal pollution of soil and water is of great significance to control and mitigate the increasing severity of their impacts on soil. It is a solid foundation step that if taken will reduce the risk of heavy metal pollution and poisoning. The methods commonly used in assessing heavy metal pollution of soil both locally and internationally can be divided into two, the index methods and the model methods. While the index methods are concerned with the assessment of single pollution, pollution load, and cumulative indexes, etc., the model methods concerns the enrichment factor method and potential ecological hazard index method, etc. (Kong & Liu, 2014). However, there is presently no uniform standard for the evaluation of soil quality parameters (Xie, 2021). Moreover, the existing evaluation methods have their own merits and demerits (Wang, et.al., 2015; Luo, et.al., 2016). Again, most studies focus mainly on the key areas, such as sewage irrigation area, mine area (Zhao & Luo, 2015) and most studies only focus on one particular heavy metal, such as Hg, As and Cd (Su, 2016). Furthermore, the different stakeholders such as regulatory agencies, landowners, and academia may have divergent interests and views on the effectiveness of remediation techniques (Yoo, 2018). These limitations and others seriously affect our overall knowledge on heavy metal pollution level in our environments. Therefore, there is the need for a more scientific, more comprehensive, and more reliable macro-evaluation method. To fill this knowledge gap, this study determined the levels of ten toxic heavy metals in different soil layers of the gravity sand filter used for water treatment in Dutsin-ma water treatment plant. Soil pH and conductivity measurements were also carried all with a view to later suggest the most appropriate remediation technique that will ensure safe water supply to consumers in Dutsin-ma town.

Sources and Toxicities of Heavy Metals

Heavy metals are metallic elements with relatively higher density compared to water (Fergusson, 1990). Heavy metals such as Mercury (Hg), Lead (Pb), Nickel (Ni), Chromium (Cr), Cadmium (Cd), Thallium (Tl), Iron (Fe), Lead (Pb), Manganese (Mn) and Zinc (Zn) are potentially hazardous in their combined or elemental forms. They are highly soluble in water and therefore they can easily be absorbed by living organisms. Previous studies have revealed the presence of heavy metals in the gills, liver, and muscles tissues of various species of fish in contaminated marine ecosystems (Sobhanardakani, et.al., 2011). The metals find their ways into the food chain through food and water and therefore may end up accumulating in the human body (Barakat, 2011) (Ravindra, et.al., 2014). Since most heavy metals and their compounds are widely used in industrial processes, exposure and contamination of the workers and residents close such facilities is likely to occur. Heavy metal levels above the allowable limits will often lead to damaging effects in humans, other organisms and the environment at large (Mansourri & Madani, 2016). Allowable safe limits of heavy metal levels in foods are indicators of low health risks in humans (Sobhanardakani, 2017a & Sobhanardakani, 2018). The toxicity effect of heavy metals in humans depends on some factors such as their dosage, rate of emission and duration of exposure. Some of the heavy metals that have been of serious concern in the last decades are As, Hg, Cd, and Pb (Valavanidis & Vlachogianni, 2010).

The adverse health effects that are usually associated with Hg and mercuric compounds in humans includes possible carcinogenic effect; damage of the brain, lungs and kidneys; damage of developing fetuses; high blood pressure or high rate of heart beat; vomiting and diarrhea; skin rashes and eye irritation (Martin & Griswold, 2009). The United State Environmental Protection Agency's (US EPA's) regulatory limit of Hg in drinking water is 2 ppb (Martin & Griswold, 2009). However, the World Health Organization (WHO) recommended safe limits of Hg in wastewater and agricultural soils are 0.0019 and 0.05 ppm respectively (Worid Bank, 1998).

Cadmium is another risk factor, Routes of exposure of people to Cd includes, eating contaminated food, cigarettes smoking, working in cadmium-contaminated work places and in primary metal industries (Paschal, 2000). Chronic toxicity effects of Cd in children include damages to respiratory, renal, skeletal and cardiovascular systems. Cadmium toxicity can also result in the development of cancers of the lungs, kidneys, prostate and stomach (USEPA, 2010; WHO, 2011). In a study carried out in Iran on the levels of Cd in canned fish samples, it was reported that the levels were higher than the maximum permissible limit (MPL) of Cd in canned fish. This was believed to be due to the discharge of heavy metal rich wastes into the aquatic ecosystems (Sobhanardakani, 2017b). The US EPA set the regulatory limit of Cd in drinking water as 5 ppb or 0.005 ppm (Martin & Griwold, 2009). However, the WHO recommended safe limits of Cd in both wastewater and agricultural soils is 0.003 ppm (Chiroma, et.al., 2014; Aneyo, et.al., 2016).

Another economically important heavy metal is lead (Pb), Routes of exposure to Pb can are through inhalation of contaminated dust particles and aerosols or by ingestion of contaminated food and water. Lead toxicity in humans result in damages to the kidneys, liver, heart, brain, skeleton and the nervous system (Flora, et.al., 2006). Initial symptoms of lead poisoning may include headache, dullness, memory loss and being irritable (Centre for Disease Control and Prevention, CDCP, 2002). Lead poisoning may also hinder hemoglobin synthesis and lead to anemia (Jarup, 2003). In small children, chronic exposure to low levels of Lead decreases their intelligence quotient (IQ). The International Agency for Research on Cancer (IARC) asserts that Lead is a possible carcinogenic substance in humans (Jarup, 2003). US EPA approved 15 ppb as the regulatory limit of Pb in drinking water (Martin & Griswold, 2009) while the WHO recommended 0.01 and 0.1 ppm as the safe limits of Pb in wastewater and agricultural soils respectively (Chiroma, et.al., 2014; Ayeni, 2014).

Another toxicologically important element is Chromium (Cr). Chromium is widely used in the manufacture of paints, pigments, preservatives, pulp and papers. It is also used in metallurgy, electroplating, and stainless steel making among others (Jaishankar, et.al., 2014). Chromium is most frequently introduced into the environment through sewage and fertilizer application (Ghani, 2011). Compounds of hexavalent Chromium including the chromates of Ca, Zn, Sr, and Pb are highly soluble in water, they are generally toxic and carcinogenic (Jaishankar, et.al., 2014; Wolinska, et.al., 2013). Furthermore, Chromium compounds have been linked to slow healing ulcers and reports also indicated that Chromate compounds can destroy DNA in cells (O'Brien, et.al., 2001; Matsumoto, 2006). The WHO recommended safe limits for Cr (hexavalent) in wastewater and agricultural soils as 0.05 and 0.1 ppm respectively (Chiroma, et.al., 2014; Aneyo, et.al., 2016).

Thallium is another toxic metal. It is a soft, tasteless, odorless white blue metal in its pure form and it oxidizes to thallium oxide when exposed to air. Thallium is a highly toxic metal with a lethal dose of 6 to 40 mg/kg of body weight. Common symptoms of Thallium poisoning include emotional changes, autonomic dysfunction, cardio toxicity, anorexia, vomiting, gastrointestinal bleeding, abdominal pain, polyneuropathy, alopecia, renal failure, skin erythema, seizures and coma among others (WHO, 2011). Thallium is released into the environment through electronics, optical glasses, semi-conductors and mercury lamps among others. Humans become exposed to Tl through ingestion, inhalation and dermal contact. However, the WHO recommended safe limits for Tl in both wastewater and agricultural soils were not available in the literature accessed and reviewed.

Nickel (Ni) is also an important risk factor. It is a silver - colored metal used in the manufacture of stainless steel, electronics, and coins among other uses (Group, 2003). At global level, the release of Ni into the environment is estimated to vary and range from 150, 000 to 180, 000 metric tons per year (Kasprzak, et.al., 2003). Humans are exposed to Ni through food, air and water (Duda-Chadak & Blaszcyk, 2008). Researches conducted previously have revealed that ingestion of Ni contaminated dust was the major exposure pathway of the heavy metal by local residents when compared to inhalation and dermal pathways (Sobhanardakani, 2019). Once exposed to high levels of Nickel, an individual may begin to show increased levels of Ni in his or her tissues and urine. The toxic effects of nickel on human health may include dermatitis, allergy, organ diseases, and cancer of the respiratory system (Seilkop & Oller, 2003). The WHO recommended safe limits for Ni in wastewater and soils for agriculture are 0.02 and 0.05 ppm respectively (Chiroma, et.al., 2014; Aneyo, et.al., 2016).

Zinc (Zn), is considered as a trace element needed by humans for proper functioning of the body and is relatively non-toxic, especially when taken orally. However, excess amount of zinc in the body can cause system dysfunctions that may result in impairment of growth and reproduction processes. The clinical signs of zinc toxicity as reported by different people are liver failure, kidney failure anemia, vomiting, diarrhea, bloody urine and icterus (yellow mucus membrane) (Duruibe, et.al., 2007).

Copper (Cu), which is an essential element in mammalian nutrition function as a component of metalloenzymes where it serves as an electron donor or acceptor. Exposure to high levels of Cu can cause a number of adverse health effects. Human exposure to Cu occurs primarily through the consumption of copper contaminated food and drinking water. Some members of the population may be more prone to the adverse effects of high Cu intake due to occupational exposure, genetic predisposition or disease. However, acute Cu toxicity is generally linked to accidental ingestion; however (Stern, et.al., 2007). Excessive intake of Cu by humans may lead to severe hepatic and renal damage, central nervous system irritation followed by depression, mucosal irritation and corrosion and widespread capillary damage. Severe gastrointestinal irritation and possible necrotic changes in the liver and kidney may also occur.

Arsenic (As), is also an important metallic toxicant that exists in different chemical forms like mercury and lead. Arsenic toxicity symptoms thus, depend on the chemical form ingested. It can coagulate protein, can form complexes with coenzymes and can as well inhibit the production of adenosine triphosphate (ATP) during respiration. It is a possible carcinogenic in compounds of all its oxidation states. High level of exposure to arsenic can easily cause death. Arsenic toxicity also presents a certain disorder similar to, and often confused with Guillain-Barre syndr-ome, which is an anti-immune disorder that occurs when the body's immune system mistakenly attacks part of the PNS, resulting in nerve inflammation that causes weakness of the muscle (Duruibe, et.al., 2007). The presence of arsenic in groundwater which usually come from the weathering of rocks and sediments and drinking of water contaminated with arsenic causes poisoning to the blood, central nervous system, lung and skin cancer, breathing problems, vomiting and nausea (Ravindra, et.al., 2014). The presence of arsenic in Third World Nations is becoming more hazardous. Countries suffering with the problems of arsenic include India, Brazil, Chile, South Korea, Bangladesh, Taiwan, China, Thailand and Indonesia (Ravindra, et.al., 2014). The amount of arsenic released into the environment from geogenic sources is becoming a serious problem worldwide but anthropogenic sources, such as the processing of metals and manufacture of pesticides and their byproducts, also contribute equally to the levels of arsenic in the environment and therefore the global arsenic problem (Ravindra, et.al., 2014).

Iron (Fe), is another environmentally important metal. It occurs in drinking water is as Fe^{2+} or Fe^{3+} in suspended form. It gets into water from natural geological sources, industrial wastes, domestic discharge and from byproducts. Iron is an essential element needed by plants and animals bodies. However, Excess amount of iron in the body (more than 10 mg/kg) causes rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension and drowsiness. Iron is also associated with staining in clothes and imparting of a bitter taste. The WHO in its report sets the maximum allowable concentration of iron in drinking water as 1.0 mg/L (Gutam Patel, et. al., 2011).

Another metal of environmental interest is **Manganese (Mn)**. It is a pinkish-gray chemically active element which is hard and brittle. Manganese is present in most common salts and mineral complexes widely distributed in rocks, soils and on the beds of lakes and oceans. Manganese is most frequently present in the form of dioxide, carbonate or silicate. It exists in varied oxidation states ranging from -3 to +7. The manganous (Mn^{2+}) and mangatic (Mn^{4+}) oxidation states are most important for aquatic ecosystems. Manganese makes up about 0.1% of the earths' crust placing it the 12th position of most abundant elements. Sea water contains only 10 mg/l manganese and the atmospheric air contains 0.01 mg/m^3 (Mersey, 2001). The most important manganese ore is pyrusite (Dill, 2010). Other manganese ores are usually exists in small amounts in iron ores.

Manganese exists in two forms; organic and inorganic and occurs naturally in rivers, lakes and in some underground water. Manganese is introduced into the environment through anthropogenic sources, such the application of inorganic fertilizers for farming, industrial processes and burning of fossil fuels (Mohaihsh, et al., 2004). Manganese is essential in iron and steel production. Presently, steel making accounts for 85 to 90 % of the total manganese demands. It is a key component of lowcost stainless steel formulation and is widely used in aluminum alloys. Manganese oxide is used as a catalyst and $KMnO_4$ is used in making violet colored glass. Other manganese compounds such as MnO_2 and manganese carbonate are used in fertilizers and ceramics making (Emelina, 2011).

In the body, manganese plays active roles in the formation of connective tissues, bones, blood clotting, carbohydrate metabolism, and calcium absorption and sugar regulation. It is also essential in the normal brain and nerve formation (Jeffrey et al., 1992). Low level of Mn in the body may result in development of dermatitis and elevated concentration of serum calcium and phosphorous. The main routes of absorption of manganese are the respiratory and the gastrointestinal tracts. In its organic form, manganese may be absorbed through the skin (Frances, 2009). The human body contains about 10 mg of manganese, stored in the liver and the kidney. Manganese compounds are less toxic than those of other heavy metals such as nickel and copper (Heather, 2008). However, exposure to manganese dust and fumes to levels exceeding the ceiling value of 5 mg/m^3 even for a short period of time may lead to manganese toxicity (Baum et al., 2002; ATSDR, 2008). At elevated levels, Mn causes chronic liver diseases.

If it accumulates in individuals with cirrhosis or liver failure, Mn may contribute to neurological disorders leading to Parkinson's disease, lung embolism and bronchitis. Men exposed to manganese for a long period may become impotent. A syndrome caused by manganese overload is characterised by symptoms such as Schizophrenia, dullness, weakness of the muscles, headache and insomnia (Emelina, 2011).. The central nervous system is the chief site for Mn attack and damage, which may result in permanent disability symptoms, such as: languor; sleepiness; weakness; emotional disturbances; spastic gait; recurring leg champs; and paralysis (Emelina, 2011). In drinking water, the level of Mn above 0.15 mg/l stains plumbing fixtures and laundry and gives an undesirable taste in beverages and causes the accumulation of microbialss in distribution systems. Also, excess Manganese in the body interferes with dietary iron absorption and long term exposure to excess level may result to iron deficiency, anemia and impairment of the activity of copper metallo-enzyme. High level of manganese in drinking water lowers the IQ of children (Bouchard, 2010). Symptom of manganese toxicity includes: Psychiatric illnesses; mental confusion; memory impairments and loss of appetite (Blaurock-Busch, 2011).

Daily intake of manganese that can promote optimum health benefits is not yet known, however, the recommended intake is 2.3 mg/day for adult men and 1.8 mg/day for adult women. The WHO has set 0.5 mg/l as the maximum permissible level for manganese in domestic water while EPA recommends 0.05 mg/l as the maximum allowable manganese level in drinking water (Hanaa et al., 2000; Calkins, 2009). However, FDA has set the same level of Mn as EPA for drinking water. Australian drinking water guideline set 0.5 mg/l Mn for health and a maximum of 0.1 mg/l for aesthetic. In some African countries, manganese level in drinking water has been reported to be below the recommended limit by WHO. For instance, a study of surface and well waters in Delta state Nigeria, revealed that manganese levels ranged from 0.006- 0.008 mg/l and the levels in well water were less than that in surface water for the simple reason of soil layer filtration

(Akpoveta et al., 2011). However from other regions the pollution index ranged from 2.40-2.80.

Wastewaters from factories and homes as well as rain water that flow through rocky areas channeled into surface water bodies may contain heavy metals part of which with time accumulate in the soil deposits along the water channels as well as in organisms that inhabit such channels or consume the water. Exposure of humans to contaminated wastewater occurs s designed to determine the concentrations of Pb, Cd, Cr, Ni, Zn, Fe, Hg, As, Mn and Cu in principally in urban and highly populated areas or where the wastewater is being reused for agricultural activities. Reports of previous studies have however shown that effective reuse of wastewater is a very big challenge in many countries of the world. The current study wa samples of soil obtained from the gravity sand filter of Dutsin-ma water treatment plant in Dutsin-ma, Katsina State, Nigeria and to highlight the potential health risks that may ensue when humans, livestock and crops become directly or indirectly exposed to the heavy metals. It is envisaged that the results obtained from the study will inform and justify on the need to adopt good water management and water treatment processes.

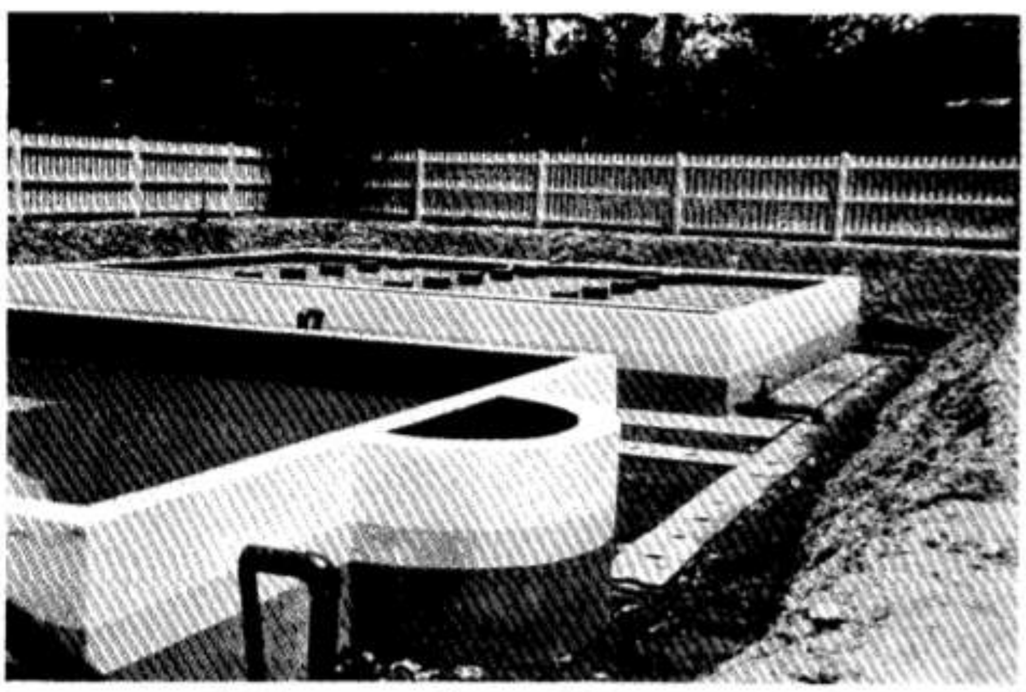

Figure 1: A Picture of conventional sand filter for water treatment

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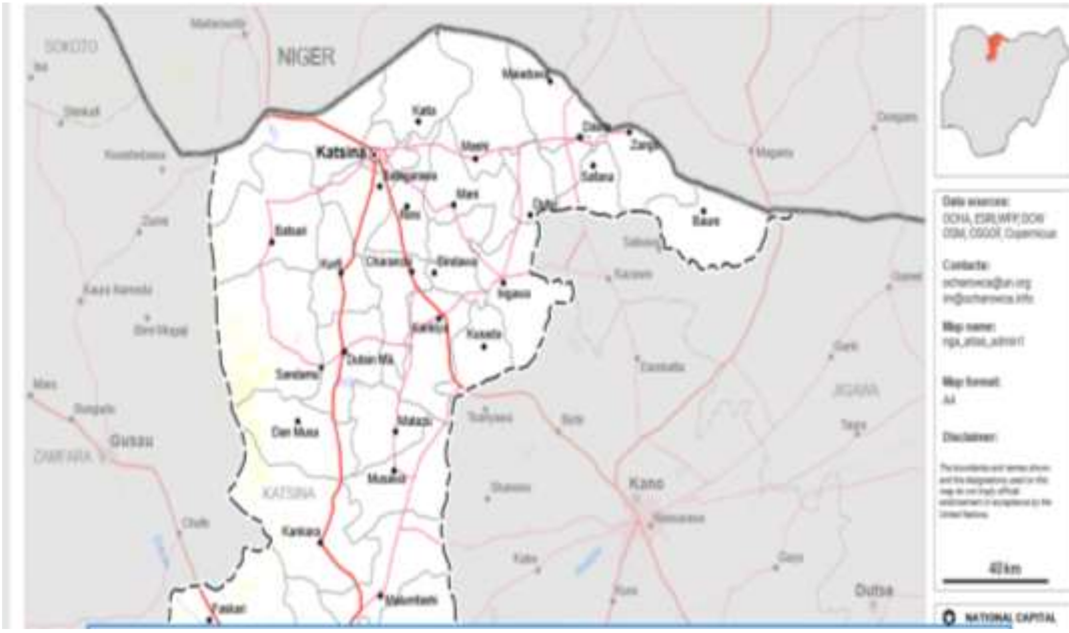

Figure1: Map of Katsina State Showing Dutsin-ma Local Government Area

Materials and Methods

The following methodologies were adopted in conducting the research:

Sample Collection and Treatment

The soil samples used were collected from the filtration unit of Dutsin-ma water treatment plant. Three soil samples A, B and C were collected from the plants' filter bed as follows:

Sample A: Sample collected from the top surface layer of the filter bed,
Sample B: Sample collected from the mid-point (middle) of the filter bed, and,
Sample C: Sample collected from the bottom of the filter bed.

The samples were placed in separate plastic containers already washed with de-ionised distilled water and rinsed with 10% Trioxonitrate(v) acid solution and then taken to chemistry laboratory where they were dried in an oven and kept in desiccators until needed.

Determination of pH

Soil sample (10g) each were weighed and transferred into a 250 cm^3 beaker. 30 cm^3 distilled water were added and stirred well with a glass rod. This was allowed to stand for 30 minutes with intermittent stirring. The electrode of the pH meter was then be immersed into the soil/water suspension in the beaker, and the pH value was determined from digital display of the pH meter and recorded.

Determination of Electrical Conductivity (EC)

The electrical conductivity (EC) was determined using the method of Sugumaran *et al.* (2012). In this metod, a 1% (w/w) solution of the soil in de-ionized water was prepared and stirred at room temperature for 20 min. The electrical conductivity was then be determined using a conductivity meter (Kent EIL 5013) and recorded.

Soil Digestion and Determination of Heavy metals

One gram (1.0g) of the soil sample was placed into a 250 cm^3 conical flask and 15 cm^3 of aqua-regia (HNO_3 : HCl mixture in the ratio 1:3 v/v) was added. The mixture was boiled on a hot plate at 90 °C for 2hrs with constant stirring using a magnetic stirrer. The digest was allowed to cool at room temperature and filtered through what man No40 filter paper in a 100 cm^3 volumetric flask. The filtrate was made up to mark with de-ionized distilled water (Olafisoye et al., 2013). The samples were then analyzed for Pb, Cd, Cr, Zn, Fe, Hg, As, Fe, Mn and Cu using Classical Atomic Absorption Spectrophotometer.

Results and Discussion

The results of the three parameters of soil (metal levels, pH and electrical conductivity of the soil samples from the sand filter bed are as presented in Table 1.

Table 1: Distributions in the sand filter bed

S/N	Name of Heavy Metal	Top Layer (ppm)	Middle Layer (ppm)	Bottom Layer (ppm)	Mean Level (ppm)	WHO MPL
1	Cadmium	0.010	0.007	0.008	0.00833	0.003
2	Chromium	0.002	0.049	0.279	0.110	0.10
3	Cobalt	0.063	0.091	0.003	0.052	0.01
4	Copper	0.038	0.027	0.009	0.025	1.20
5	Iron	4.940	6.380	14.622	8.647	0.10
6	Lead	0.340	0.970	0.760	0.690	0.01

7	Mn	0.570	0.605	0.744	1.919	0.05
8	Mercury	246.3	54.1	217.3	172.57	0.08
9	Nickel	0.034	0.034	0.028	0.032	0.05
10	Zinc	0.0992	0.0655	0.0416	0.069	0.80
11	pH	6.2	6.6	6.8	6.5	
12	Conductivity	2.0	3.0	3.0	2.7	

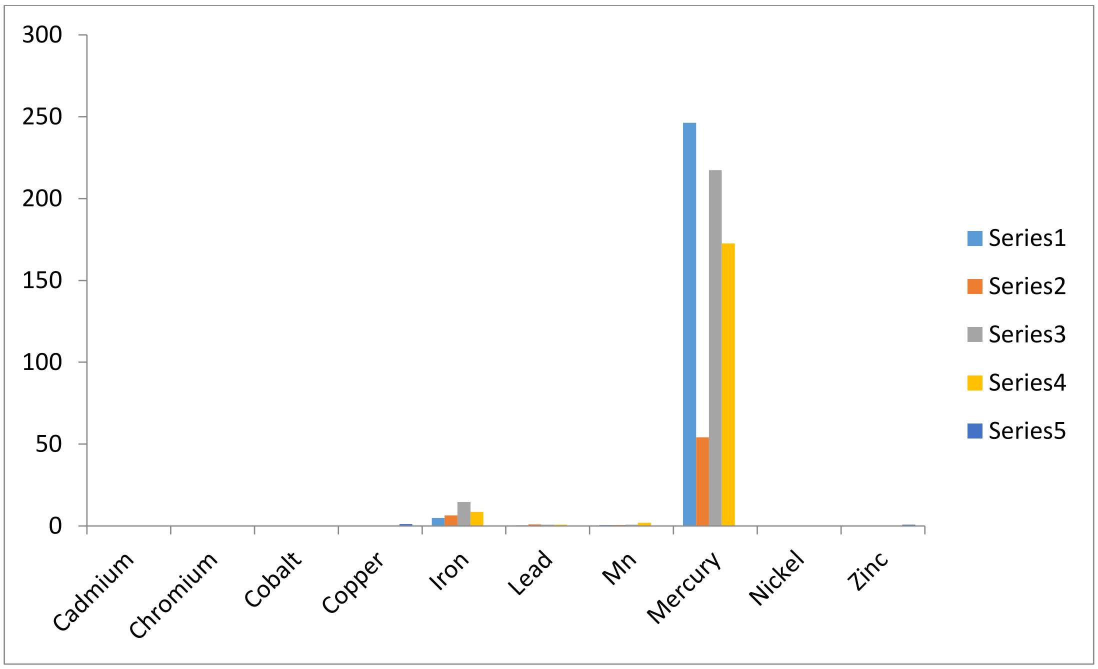

Figure 2: Histogram Showing the Distribution of Heavy Metals in the Filter bed

Results and Discussion

The distributions of ten heavy metals (Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Manganese, Mercury, Nickel and Zinc) in the different sand layers Top, Middle and Bottom layers) of the sand filter bed of Dutsin-ma water treatment plant and the control sand sample are presented in Table 1. From the results, the levels of these metals (in ppm) in the top layer were; Cd(0.010), Cr(0.002), Co(0.063), Cu(0.038), Fe(4.940), Pb(0.340), Mn(0.570), Hg(246.3), Ni(0.0340) and Zn(0.0992). These levels are generally high as they exceeded the maximum permissible levels (MPL) of the metals except for Co, Cu, Ni and Zn whose levels were below their MPLs. However, the metals showed varying levels in the range of 0.002 ppm (for Cr) to 246.3 ppm (for Hg), thus the metals form the trend in

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order or decreasing concentration in the top layer: Hg > Fe > Mn > Pb > Zn > Co > Cu > Ni > Cd > Cr. Mercury showed the highest concentration and chromium the least.

In the middle layer however, the results were; Cd(0.007), Cr(0.049), Co(0.091), Cu(0.027), Fe(6.380), Pb(0.970), Mn(0.605), Hg(54.1), Ni(0.034) and Zn(0.0655 ppm). Like the top layer, the levels of most of the heavy metals studied were observed to be above the WHO permissible levels only with the exception of Cr, Cu, Ni and Zn. Accordingly, the metals exhibited the following trend in order of decreasing concentration: Hg > Fe > Pb > Mn > Co > Zn > Cr > Ni > Cu > Cd. Here still, mercury had the highest concentration and cadmium had the least.

The concentrations of the metals (in ppm) in the bottom layer were Cd(0.008), Cr(0.279), Co(0.003), Cu(0.009), Fe(14.622), Pb(0.760), Mn(0.744), Hg(217.3), Ni(0.028) and Zn(0.0416 ppm). The pattern shown by the heavy metals in this layer was: Hg > Fe > Pb > Mn > Cr > Zn > Ni > Cu > Cd > Co. Here again, Hg had the highest level while Co had the lowest. The heavy metals exists in the layer with pattern almost similar to the one observed in the top layer.

However, considering the mean levels of each metal in the filter bed, the results (in ppm) were: Cd(0.00833), Cr(0.110), Co(0.052), Cu(0.025), Fe(8.647), Pb(0.690), Mn(1.919), Hg(172.57), Ni(0.032) and Zn(0.069 ppm). These mean values pose serious concern as they were above the WHO standards with the exception of Cu, Ni and Zn only. The trend of the heavy metal levels based on their mean was: Cd < Cu < Ni < Co < Zn < Cr < Pb < Mn < Fe < Hg. Cadmium had the least mean concentration while mercury had the least. These values are very alarming, Cd was 1.78 times greater than its permissible level, Mn was 37.38 times greater, Pb was 68 times, Fe was 85.47 times greater while Hg, a highly toxic metal was 2,156.125 times greater than its permissible level. These further confirm the high level of heavy metal pollution in the filter bed and around the water sources. The possibility of these metals causing toxic effects on the consumers of the water cannot be ruled out. They may be the reason behind occurrences of some unusual health disorders in the area. Recall the toxicities of these metals. For instance, Hg and mercuric compounds in humans can cause carcinogenic effect; damage of the brain, lungs and kidneys; damage of developing fetuses; high blood pressure or high rate of heart beat; vomiting and diarrhea; skin rashes and eye irritation (Martin & Griswold, 2009).

Lead toxicity in humans result in causes damages to the kidneys, liver, heart, brain, skeleton and the nervous system (Flora, et.al., 2006). Initial indicators are headache, dullness, memory loss and being irritable (Centre for Disease Control and Prevention, CDCP, 2002). It may also affect hemoglobin synthesis and lead to anemia (Jarup, 2003) and can lower the intelligence quotient (IQ) of small children.

Similarly, excessive levels of iron in the body causes rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension and drowsiness. It is also accused of causing stains on clothes and imparting of a bitter taste to water and food

The soil/water pH values were within normal range (near neutral) with only the top layer being slightly acidic. The conductivity levels confirm the presence of metals ions in the soil/water media.

These results therefore suggests the need effective measures to be taken in order to reduce the heavy metal burden on the soils of the filter and hence on the water being consumed by the people of Dutsin-ma and environs.

Conclusion and Recommendations

Based on the results obtained in this study, it was concluded that the different soil layers in the sand filter bed were heavily polluted with most of the metals studied and that the pollution comes from two major sources namely, the soil itself and the water coming into the filter from the dam. The following recommendations are therefore being forwarded to mitigate the possible effects of these heavy metal pollutants on the water and invariably on the consumers:

1. The filter should be immediately evacuated and the soil layers be totally replaced with new good ones free of heavy metal contaminants.
2. The dam water be assessed for heavy metals and remediation measures be taken to reduce the heavy metal levels in the water and should be monitored on continuous basis.
3. Soils for filling the sand filters should henceforth be screened for heavy metals to make sure that they do not contain metal levels that can contaminate the water being treated.
4. The sand filter should routinely be replenished on and approved regular basis to prevent accumulation of heavy metals and other pollutants to levels that are above their threshold.

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