



Review of Heavy Metals in Water Systems of Selected Locations in Nigeria

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Abstract

The use of contaminated water could be lethal to both human and aquatic lives. Toxic trace metal are continuously being released into the water bodies around Nigeria resulting from industrial and agricultural activities. Among the various toxic pollutants, heavy metals like lead (Pb), Mercury (Hg), Cadmium (Cd), Zinc (Zn), Cobalt (Co), Manganese (Mn), Arsenic (As) etc and several mixtures of heavy metals have severe action due to their tendency to accumulate in the fish tissue. This work reviews the heavy metals in Nigeria water system. Heavy metals are a problem of magnitude and ecological significance due to their high toxicity and ability to accumulate in living organisms. Many toxicologists have worked on the analysis and detection of heavy metals in the water bodies, soil, sediments, plankton, fish organs etc using Atomic Absorption Spectrometry. The results showed a high level of heavy metals above permissible limit except for river system around the central part of Delta State which has a tolerable level compared with WHO standard.

Introduction

Water is an elixir of life. It governs the evolution and function of the universe on the earth hence water could be referred to as the 'mother of all living things' [1]. Majority of water available on the earth is saline in nature, only a small quantity is fresh water. Freshwater has become a scare commodity due to over exploitation and pollution [2, 3, 4]

Pollution is caused when a change in the physical, chemical or biological condition in the environment harmfully affect quality of human life, animals' life and plants [5]. Effluents discharged into the water bodies with high concentration of nutrients, sediments and toxic substances e.g. heavy metals may have a serious negative impact on the quality and life of the receiving water body especially when the effluent discharged is untreated

or partially treated [6,7,8]. Generally, heavy metal contamination is worrisome because of their persistent nature as they are not easily degraded either through biological or chemical means unlike most organic pollutants.

Heavy metals are chemical elements with a specific gravity that is at least four to five times the specific gravity of water at the same temperature and pressure [9]. The term “heavy metals” can also be referred to as any metallic element that has a relatively high density and is toxic or poisonous even at low concentration [10]. Heavy metals include lead (Pb), cadmium (Cd), zinc (Zn), mercury (Hg), arsenic (As), silver (Ag), chromium (Cr), copper (Cu), iron (Fe), and the platinum group elements. We are constantly in contact with heavy metals while carrying out our daily activities, due to the necessity of some of them in our daily life as kitchen utensils, packaging materials, fuel components (Lead), and content of locomotives, such as Aluminum used in plane and boat constructions due to its strength to weight ratio.[11,12].

Sources of Heavy Metals

Massive amounts of domestic wastewater and industrial effluents are transported by rivers and discharged into the sea, contaminating rivers and coastal waters. Such anthropogenic pollutants are the main sources of heavy metal contaminants in the ocean [13]. Heavy metals carried down by effluents and have been the major threats for fish consumers and the effects on the contamination of fishing products becomes now a serious issue to be

addressed. The metal contaminants in aquatic systems usually remain either in soluble or suspension form and finally tend to settle down to the bottom or are taken up by the organisms [14]. Heavy metal contamination may have devastating effects on the ecological balance of the recipient environment and a diversity of aquatic organisms [15, 16].

Heavy metals can be emitted into the environment by both natural such as weathering of rocks and soil and volcanic eruption and anthropogenic sources such as mining operations etc [9]. Apart from mining operations, mercury is introduced into the environment through cosmetic products as well as manufacturing processes like making of sodium hydroxide. Heavy metals are emitted both in elemental and compound (organic and inorganic) forms [9].

Anthropogenic sources of emission are the various industrial point sources including former and present mining sites, foundries and smelters, combustion by-products and traffics [17]. Cadmium is released as a by-product of zinc (and occasionally lead) refining; lead is emitted during its mining and smelting activities, from automobile exhausts (by combustion of petroleum fuels treated with tetraethyl lead antiknock) and from old lead paints; mercury is emitted by the degassing of the earth’s crust. Generally, metals are emitted during their mining and processing activities [10].

Effects of Heavy Metals on Lives

Heavy metals have significant effects on both human and aquatic lives. Heavy metals are known to be carcinogenic and fatal, they are generally dangerous to living organism especially man because of their bioaccumulation nature, they accumulate in living tissues anytime they are taken up and stored faster than they are metabolized or excreted [18]. Butu, and Iguisi [19], noted that the major threats to human wellbeing are associated with heavy metals such as lead, arsenic, cadmium and mercury. Also Akoto [20] in the same manner observed that heavy metals such as Cd, Ni, As, Pb pose a number of hazards to humans; and are indeed cofactors as activator biochemical reactions and enzymatic for information of enzyme/substrate metal complex.

Additionally, these heavy metals gain entry into the human bodies via food, drinking water and air. Though, some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body, but, concentrations above the desirable level can lead to poisoning [18]. Some heavy metals that are especially toxic to aquatic organisms and humans are mercury, cadmium, chromium, and lead etc.

Mercury Toxicity

Mercury is very toxic metal when it forms methylmercury in form finds itself into the aquatic ecosystems when naturally occurring bacteria methylate inorganic mercury. The reaction takes

place at the water-sediment interface and is facilitated by low pH and high dissolved organic carbon. When methylmercury dissolves in water, it crosses biological membranes, and persists in fatty tissues of organisms. In addition to bioconcentration, methylmercury which undergoes biomagnification at each level of the food chain has higher tissue concentrations than its prey [21].

The Impact of Mercury on Human Health

The symptoms of Mercury poisoning are: impaired hand-eye coordination, memory and speech loss, blurred vision, blindness, muscle weakening and spasms, and in some cases death. If this enters into the water body, it can be acted upon by bacteria transforming it to methylmercury which undergoes bioconcentration and biomagnifications [22]. Mercury is now known to be a neurotoxin that causes structural damage to the brain and inhibits the activity of enzymes that are needed for normal neurotransmission. This impact occurs at lower concentrations than previously thought (10 ppm instead of 50 ppm) [22,23]. It decreases the DNA content of cells and adversely affecting cell division, mercury can cause cancer as well as birth defects such as twisted arms and legs. Kidney damage results from long-term exposure to mercury at higher concentrations [21].

Impacts of Mercury on Aquatic Ecosystem

The age, size, and species of exposed fish affect the bioconcentration and biomagnification of mercury. Older fishes have had more time in which to accumulate mercury in their tissues. Larger fish and predatory species eat further up on the food chain;

hence, more biomagnification takes place in their tissues. Walleyes contain about 0.2 to 1.0 ppm mercury concentrations which exceed the human health guideline of 0.5 ppm. Water temperature, pH, and softness, and presence of other metals affect mercury toxicity in fish, because the body temperature of a fish is the same as the water temperature, the metabolic rate will be higher when the water temperature increases. More mercury will accumulate in fish tissues in summer than in winter [21].

Impact of Cadmium on Human Health

Diseases which result from Cadmium exposure can cause outright death. Cadmium is toxic to humans when the daily intake is 250 to 300 micrograms [23]. Cadmium is highly persistent in humans, with a half-life of 20 to 30 years [23]. Exposed humans will never get rid of all of the cadmium in their bodies because it will take 20-30 years to get rid of 50% of the cadmium, 40-60 years to get rid of 75% of the cadmium, and 60-90 years to get rid of 87.5% of the cadmium [24]. Cadmium effects on human health include skeletal deformities and bone loss, kidney damage, and generalized pain. Vitamin D is essential for the deposition of calcium in bones; however, exposure to cadmium can inhibit Vitamin D synthesis, preventing bones from maintaining a normal level of calcium. The bones become soft or brittle.

Chronic cadmium exposure causes kidney damage by inhibiting enzymes responsible for resorption processes. Glucose, protein, and red blood cells are excreted in the urine rather than resorbed into the

bloodstream anaemia is an indicator of kidney damage. The International Agency for Research on Cancer has classified Cadmium as a Category I (human) carcinogen [22,23,21]

Impacts of Cadmium on Aquatic Ecosystem

Cadmium effects on aquatic organisms are analogous to those in humans, and include skeletal deformities and impaired functioning of kidneys in fish. Cadmium is more toxic in freshwater than in saltwater because cadmium combines with chlorides in saltwater to form a molecule that is less available from solution [22, 21].

The effects of cadmium on aquatic organisms can be directly or indirectly lethal and can impact populations and ecosystems as well as individuals. Skeletal deformities in fish can result in impaired ability of the fish to find food and to avoid predators; hence, this sublethal effect becomes a lethal effect. Cadmium impairs aquatic plant growth by disrupting its intake of other essential nutrients like Calcium, Magnesium, and Zinc etc. This affects the entire ecosystem because green plants are at the base of all food chains. When aquatic plants that are exposed to cadmium do not grow normally, leading to less food available for aquatic animals [22,23,21]. Cellular damage has been observed in the hepatopancreas of marine crustaceans that experience prolonged exposure to cadmium. The hepatopancreas is a combination of liver and pancreas and therefore has both digestive and metabolic functions. Reduced long-term survival and growth were observed in marine isopods (a group of marine invertebrates) when

sublethal cadmium exposure occurred during embryonic and larval development. Differential survival of cadmium-exposed isopods can result in long-term changes in population structure [22,23,21].

Chromium Toxicity

Chromium is an essential trace nutrient that is required in small amounts for carbohydrate metabolism, however, at higher concentration, it can become toxic leading to adverse health effects [25]. The most bioavailable and therefore most toxic form of chromium is the hexavalent ion.

Impacts of Chromium on Human Health

Effluent from the cooling towers discharged to unlined ponds, from where the hexavalent chromium can leach into groundwater that supplied drinking water and swimming pool water can lead to chromium poisoning. Although chromium does not undergo biomagnification, it does undergo bioconcentration. Affected person can develop mouth ulcers, nosebleeds, kidney disease, low white blood cell counts – hence depressed immune defense systems, miscarriages, and a variety of cancers. Babies were born with deformed spines [22,21].

Impacts of Chromium on Aquatic Ecosystem

Low concentrations of hexavalent chromium cause sublethal toxic effects in aquatic plants and animals. For example, 62 ppb inhibits growth in algae and 16 ppb inhibits growth in chinook salmon [26]. Chinook salmon are more sensitive than algae. This is consistent with the overall finding

that aquatic animals are more sensitive to metals than are aquatic plants [21]. Although reducing the growth of a plant or animal is not directly lethal, the smaller size increases the vulnerability of the organism to predators. What begins as a sub lethal effect of a metal may end up as a lethal effect.

Chromium toxicity to aquatic organisms

It increases as water temperature increases and as pH and salinity decrease. Additionally, chromium is more toxic in soft water than in hard water and there are species differences in sensitivity. For example, fathead minnows are more sensitive than goldfish. The concentration of chromium that caused death in 50% of the exposed population was 3 ppm in soft water and 72 ppm in hard water for fathead minnows and 18 ppm in soft water and 133 ppm in hard water for goldfish [26].

Lead Toxicity

The human use of lead goes back at least 5000 years. Because lead is resistant to corrosion and discoloration, its early uses included pipes for the collection, transport, and distribution of water and containers for the storage of food and beverages. Although the use of lead in drinking water pipes has been largely discontinued in developed countries

Impacts of Lead on Aquatic Ecosystem

Lead bio concentrates in the skin, bones, kidneys, and liver of fish rather than in muscle and does not bio magnify up the food chain. This makes lead less problematic via this route of exposure. However, people who eat the whole fish and other contaminated aquatic foods can potentially be

exposed to high concentrations of lead [21]. When lead concentrations in algae exceed 500 ppb, enzymes needed for photosynthesis are inhibited [26]. When less photosynthesis takes place, the algae will produce less food and therefore will not grow as much. Decreased algal growth means less food for animals; this has repercussions for the entire ecosystem. When lead concentrations exceed 100 ppb in the fish, the functions of the gills are affected. Embryos and fry are more sensitive to the

toxic effects of lead than are adults. Lead is more toxic at lower pH and in soft water [26, 21]. As is the case with other metals, the toxicity of lead to fish depends in part on the species. Goldfish are relatively resistant because they can excrete lead via their gills [23].



Fish affected by heavy metal pollution as a result of bioaccumulation.

Bioaccumulation and the Permissible Level of Heavy Metals

Several works have been done on the bioaccumulation of trace metals (Heavy metals) on the aquatic habitat. Obasohan and Eguavoen

[27], Investigated accumulation levels of Cu, Mn, Zn, Cd, Ni and Pb in a freshwater fish (*Erpetoichthys Calabaricus*) from Ogba River, Nigeria, during dry and rainy seasons. Findings showed that the accumulation levels in fish

exceeded the levels of the metals in water and indicated bioaccumulation in fish and no significant differences of metal levels between the dry and rainy season. Findings also showed that both dry and rainy season mean levels of Cu, Mn and Ni in fish exceeded WHO recommended limits in food, suggested that the fishes of the River are not suitable for human consumption. They recommended that a close monitoring of metal pollution of Ogba River is strongly advocated, in view of the possible risks to health of consumers of fish from the River. According to Obasohan and Eguavon [27], three samples; water, fish and sediments were collected from Ogba river at different seasons, analyzed and accumulation of heavy metals was observed in the order of Sediments > Fish > Water. In water, the order was found to be Mn > Fe > Zn > Cu > Ni > Cd > Co > Pb; Mn recorded a maximum of 506.9 μ .L-1 and Pb recorded a minimum of 0.006 μ .L-1 In sediments, the order was Mn > Fe > Cu > Zn > Pb \approx Co \approx Cd \approx Ni; Mn recorded a maximum of 851.1 μ g.g-1 and a minimum of below detectable levels were found in Pb, Co, Cd and Ni. In fish, the order was found to be Fe > Zn > Mn > Cu > Ni > Co \approx Pb \approx Cd; Fe recorded a maximum of 529.13 μ g.g-1 and a minimum of below detectable levels were found in Pb and Cd. Alinnor and Obiji [28], carried out a study to examine trace metal (Pb, Fe, Cd, Mn, Hg, Cu and Zn) composition in fish samples from Nworie River in Delta state Nigeria, and in frozen fish samples purchased from Ekeonunwa. Nworie River contaminated the biota in the aquatic system with these elements which its

toxicants will be transferred to man by consumption of fish obtained from the River. Also they found that frozen Tilapia fish samples purchased from Ekeonunwa market were contaminated with heavy metals which could be as a result of discharge of waste from nearby factories.

Shabanda and Itodo [29] used atomic absorption spectrophotometer for the detection of Cd, Cr, Pb, Mn and Al in water, sediments, gills and flesh of both *Synodontisorex* and *Bagrus filamentosus* from River Jega in Kebbi State, Nigeria. The pattern of distribution of the heavy metals showed a preponderance of Cr and Mn over other metals in the organs of the two fish species as well as in the water and sediment samples. Al was not detected in the organs of fish species, water and sediment. The concentration of Mn was found to be highest in the sediment and lowest in water.

The unexpectedly high concentration value obtained for Cr and Mn calls for medical alertness since it exceeded the WHO recommended acceptable limits for consumption. Cadmium (Ca) and lead (Pb) distribution in all the samples was lower than the WHO and USEPA recommended acceptable limits for consumption. According to the study conducted by Kaiser and Osakwe [30], result revealed through Atomic flame spectrophotometer that the heavy metal concentration in Tilapia zilli and water sediments along Kolo Creek in Ogbia Local Government Area, Bayelsa State. Tilapia fish and sediment

samples were collected from 5 stations, and analyzed for heavy metals following standard procedures four metals (Cu, Pb, Cd and Ni) were observed with increasing order of mean concentration as follows; Cu > Pb > Cd > Ni.

Copper was significantly more abundant in the sediments, gills and muscle tissues than other element with mean concentration of 10.73-16.61mg/kg, 3.32-5.20mg/kg and 2.48-4.89mg/kg respectively. Except for Ni, other metals were more abundant in the gills than in the muscle tissues. Positive correlation matrix of the elements highlights a common origin. The concentration of these metals exceeded the maximum internationally allowable tolerance limits in drinking water, suggesting that Kolo Creek water is polluted and calls for prompt interventions. To further prove that the level of heavy metal pollutant has gone beyond the acceptable standard in the Nigeria water system.

Maitera, et al [31] also carried out a research to determine the level of some heavy metals industrial effluents discharged into the water bodies within Kano metropolis, Nigeria, pose a serious threat to our agricultural products and aquatic lives. In view of this, Maitera, et al [31] assessed the level of these heavy metals, Zn, Pb, Cr, Cu, Ni, Co, Ag, Fe and Mn from water samples collected from two pollution prone areas around Kano (Sharada and Bompai industrial estates) and control site (Thomas Dam, Dambatta). The results obtained show that the mean values of all heavy

metals (with the exception of Zn) in water samples from the polluted areas studied were significantly higher than in the control site ($P < 0.05$). These mean values have also exceeded the acceptable limits, according to WHO 2017. However, the result of the physicochemical characteristics and heavy metal levels in water samples from five river systems in central part of Delta State, Nigeria were investigated by Kaiser and Osakwe [32] to access the quality status of the rivers. All the watershed selected for study were well distributed and possessed similar geology, climate, soil, and vegetation characteristics. Studies on the water samples collected from the rivers showed that the physicochemical characteristics of the river varied significantly.

The mean concentration of total solids within the rivers were 35.46mg/l, 31.57mg/l, 18.82mg/l and 45.53mg/l for Ase, Agbarho, Ethiope, Ekakpamre and Afiesere rivers respectively. Similarly, the mean concentration of heavy metal in the river system gave the following ranges zinc 0.93-2.96mg/l, copper 0.01-0.03mg/l, lead 0.003-0.08mg/l, cadmium 0.00-0.004mg/l, chromium 0.001-0.03mg/l, nickel 0.01-0.004mg/l, manganese 0.008-0.04mg/l, iron 0.03-0.08mg/l. A comparison of the heavy metal concentration in the respective samples and recommended international standard such as WHO 2017, showed that the rivers were not significantly contaminated and are therefore suitable for domestic and industrial purpose.

In the north Eastern Nigeria, Maitera *et al* [33] conducted a research on heavy metal concentrations of River Gongola in Adamawa State, Nigeria and discovered a high concentration of heavy metals in the sediment samples as compared to the water samples this is because sediments are the major depository of metals which in some cases can hold up to 99% of the total amount of metal present in the system. The concentrations of Mg in both water and sediment samples were higher than those of the other elements. While the concentrations of Mg, Zn, Pb, and Cr were high during dry season compared to those of Cu, Mn and Cd. Most of the values fall within the allowable limits of the WHO (As 0.01mg/l, Pb 0.01mg/l, Cu 2mg/l, Fe 2mg/l, Hg 0.001mg/l, Cr 0.05mg/l, Cd 0.003mg/l, Ni 0.02mg/l) except for those of Pb, Cd, and Cr. This was suggested be as a result of runoff from refuge dump around the area.

Conclusion

According to the literatures reviewed, the research conducted around the some states in the Northern part of the country such as Kano, Adamawa etc. The results show that the water system is highly polluted with heavy metals possibly because of the agrochemicals used in agricultural practices and industrial activities. Also, some parts of the south southern part of the country like Bayelsa State showed a high level of heavy metals pollution above permissible limit. However, one of reviewed paper showed that around the central part of Delta State, the level of pollution arising from

heavy metal is within the permissible level. More research should be carried out on regular basis to constantly ascertain the level of heavy water pollution not only for the sake of aquatic habitat but also for the safety of the humans who depend directly or indirectly on water for survival.

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