Water Quality Studies in parts of Eastern Niger Delta, Nigeria using Heavy Metal Pollution Indix

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Water Quality Studies in parts of Eastern Niger Delta, Nigeria using Heavy Metal Pollution Index

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Abstract

Eastern Niger Delta is the operational base of major oil producing and servicing companies in Nigeria. Petroleum exploration and exploitation have triggered adverse environmental impacts in the Delta area of Nigeria through incessant environmental, socio-economic and physical disasters that have accumulated over the years due to limited scrutiny and lack of assessment. Heavy metals are metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. They are not biodegradable rather the bioaccumulate and can enter our bodies through food, drinking water and air. Heavy metal enrichment index revealed the elements in the decreasing order of: Fe > Ni > Cu > Zn > Mn > Cd > Co > Pb > Cr > As > Hg. The study identified salt intrusion, oil spillage, gas flaring, use of agrochemicals and industrial effluents as well as poor sanitation as contributors to the groundwater deterioration in the area. Due to the monumental and devastating effects of hydrocarbon pollution in the area, the need to eradicate gas flaring and minimize oil spills in the area was advocated. Bioremediation and phytoremediation techniques were recommended to be applied in the clean-up of soils and water contaminated with hydrocarbon in the area.

Introduction

Since the discovery of oil in Nigeria, more than fifty years ago, there has been no concerted and effective effort on the part of the government, let alone the oil operators, to evaluate and control environmental and health problems associated with the industry while the host communities are on the receiving end. Niger Delta is an oil-rich region with high amount of gas reserves. It covers about 20,000 km² within wetlands of 70,000 km² formed primarily by sediment deposition (Akpokodje, 2001). It is home to over 20 million people and 40 different ethnic groups, this floodplain makes up 7.5% of Nigeria's total land mass (Nwankwoala, 2005). It is the largest wetland and maintains the third-largest drainage basin in Africa (Adelana et al., 2000; Adegoke, 2002). The region sustains a wide variety of crops, economic trees and a variety of fresh water fish than any ecosystem in West Africa. But this region, if care is not taken can lose most of its natural endowments due to uncontrolled gas flaring, oil spillage and poor sanitary situation in the area (Teme, 2002; World Bank, 2004). The Niger Delta is among the world's largest petroleum provinces and its importance lies on its hydrocarbon resources. It has been rated as the sixth largest oil producer and twelfth giant hydrocarbon province (Adegoke, 2002). The oil sector provides 20% of Nigerian's GDP and 95% of foreign exchange earnings as well as 75% of budgetary revenues (World Bank, 2004).

Land and water are precious natural resources on which rely the sustainability of agriculture, industrialization and the civilization of mankind. Unfortunately, they have been subjected to severe exploitation and contamination due to anthropogenic activities resulting from artisanal mining, industrial effluent, dumpsites, gas flaring, oil spillage and petroleum refining leading to the release of heavy metals into the environment (Bellos and Swaidis, 2005; Ahmad et al., 2010; Amadi et al., 2015). Industrialization and urbanization in the Nigerian oil-riched Niger Delta necessitated the choice of the study area, considering the impact of various anthropogenic activities on the soil and groundwater system. The aquifer system in the area is largely unconfined, highly porous and permeable and the tendency of contaminants infiltrating through the soil into the shallow water table is quite obvious, hence the need for this study.

The increase in groundwater demand for various human activities has placed great importance on water science and management practice world-wide (Nouri et al., 2006). Each source of contaminant has its own damaging effects to plants, animals and ultimately to human health, but those that add heavy metals to soils and waters are of serious concern due to their persistence in the environment and carcinogenicity to human beings. Unlike the organic pollutants which are biodegradable (Ammann et al., 2002; Adams et al., 2008), heavy metals are not biodegradable (Bird et al., 2003; Lee et al., 2007), thus making them a source of great concern. Through food chain, the heavy metals bioaccumulate in living organism and reach levels that cause toxicological effects (Kraft, et al., 2006; Aktar et al., 2010). Human health, agricultural development and the ecosystem are all at risk unless soil and water systems are effectively managed and protected from heavy metal contamination (Akoto et al., 2008). Close relationship exists between groundwater quality and land use as various land use activities can result in groundwater contamination (Amadi et al., 2014).

In Nigeria, immense tracts of mangrove forests have been destroyed as a result of petroleum exploration and exploitation in the mangroves and these have not only caused degradation to the environment and destroyed the traditional livelihood of the region but have caused environmental pollution (Plates 1 and 2) that has affected weather conditions, soil fertility, groundwater, surface water, rain water, aquatic and wildlife (Olujimi, 2010; Amadi, 2014). If this trend is allowed to continue unabated, it is most likely that the food web complexes in this wetland might be at a higher risk of induced heavy metal contamination. This unhealthy situation continues to attract the interest of environmental observers and calls for evaluation of the impact of oil and gas exploitation activities in the coastal areas of Nigeria and these was part of what this research investigated. The shallow depth and high permeability of the coastal plain-sand aquifer of Niger Delta has made the soil and groundwater system highly vulnerable to contamination (Amadi and Olasehinde, 2009). The strategic position of the Niger Delta in the socio-economic activities of Nigeria makes it imperative to have a good knowledge of the soil and groundwater quality status in the area.

Plate 1: Devastation of the vegetation in the area due to oil and gas exploitation and refining

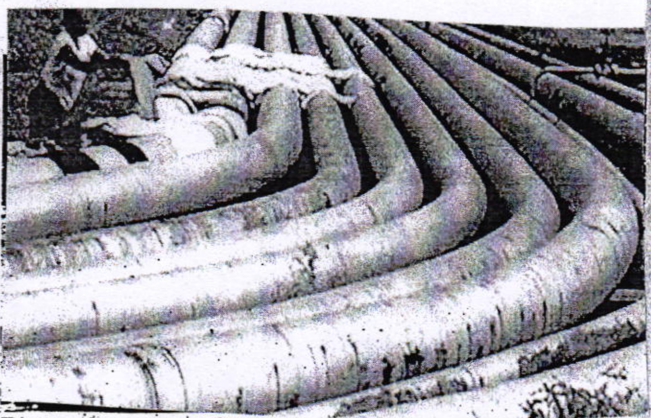

Plate 2: Land degradation caused by leakage from oil pipeline in the area

Materials and Methods

Study Area Description

The study area lies within the eastern Niger Delta region of Nigeria between latitude 440'N to 5°40'N and longitude 6°50'E to 7°50'E (Figure 1). It covers parts of Port-Harcourt, Aba and Owerri and a total area of approximately 12,056 km^2. The area is low lying with a good road network system. The topography is under the influence of tides which results in flooding especially during the rainy season (Nwankwoala and Mmom, 2007). The prevalent climatic condition in the area comprises of the rainy (March to October) and dry (November to February) seasons characterized by high temperatures, low pressure and high relative humidity throughout the year. A short spell of dry season referred to as the 'August break' is often felt in August and is caused by the deflection of the moisture-laden current. Due to vagaries of weather, the August break sometimes occurs in July or September.

Geology and Hydrogeology of the Area

The study area (Port-Harcourt, Aba, Owerri and environs) is underlain by Pliocene-Pleistocene Benin Formation (Figure 2) belonging to the Benin Formation. The type locality of the formation is in Port-Harcourt, Aba and Owerri where the formation overlies the older Ogwashi-Asaba Formation (Ezeigbo and Aneke, 1993). The formation outcrops sometimes in both surface (outcrop) and subsurface in mode of occurrence.

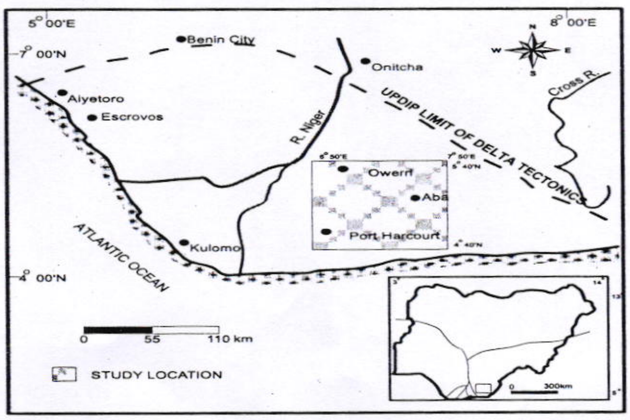

Figure 1: Map of Niger Delta showing the study area

Reyment (1965) described the formation as extensive reddish earth made up of loose, poorly sorted sands underlying recent Quaternary sedimentary deposits of southern Nigeria. It consists mainly of sands, sandstone and gravel with clays occurring in lenses (Onyeagocha, 1980). The sands and sandstones are fine to coarse grained, partly unconsolidated with varying thickness (Avbovbo, 1978). The formation has a thick sequence of sediments about 2100 m thick deposited in the continental phase of the Niger Delta (Weber and Daukoru, 1976). Within the study area the thickness of the formation is probably 900m and its maximum thickness near the sea is about 1,820 m. The Benin Formation is composed mostly of high resistant fresh water bearing continental sand and gravel with clay and shale intercalations (Ofoegbu, 1998). The sediments represent upper deltaic plain deposits (Peters, 1991). The formation comes in contact with the Ogwahi–Asaba Formation in the northern part and with Alluvium in the southern part and thickens southwards into the Atlantic Ocean (Figure 2). The sandy unit which constitutes about 95% of the rock in the area is composed of over 96% guartz (Onyeagocha, 1980).

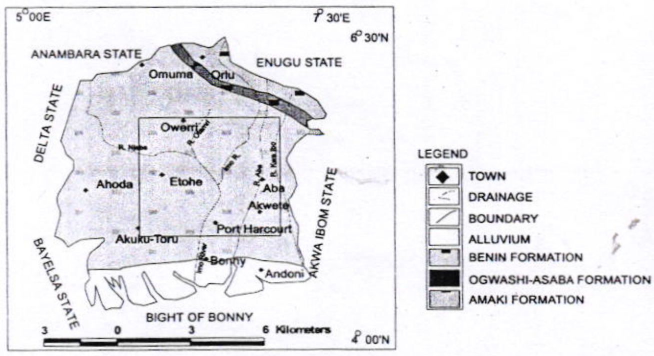

Figure 2: Geological Map of the Eastern Niger Delta showing the study area (Modified from Weber and Daukoru, 1976)

Sampling

A total of 125 water samples were collected between January, 2010 and November, 2011 using polyethylene bottles of one liter capacity for cation analysis. The water from boreholes were allowed to flow for about 2 minutes before the water is collected, and containers were thoroughly washed and rinsed with the water to be collected into them. Samples for the determination of cations were stabilized with a drop of dilute hydrochloric acid on collection. All the samples were preserved by refrigeration and analyzed within 24 hours of collection. The analyses were carried out in accordance with APHA standard.

Results and Discussion

Heavy Metals

Heavy metals are metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. It refers to chemical elements with a specific gravity that is at least 5 times the specific gravity of water. The specific gravity of water is 1 at 4°C (39°F). Specific gravity is a measure of density of a given amount of a solid substance when it is compared to an equal amount of water (Anderson et al., 1995). They cannot be degraded or destroyed and can enter our bodies through food, drinking water and air. Heavy metals are dangerous because they bioaccumulate. Bioaccumulation is an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Some of the heavy metals investigated in this study inclues: lead, cadmium, copper, nickel, zinc, chromium, cobalt, mercury, arsenic, manganese and iron.

Lead

Lead is defined by the United States Environmental Protection Agency (USEPA) as potentially hazardous to most forms of life, and is considered toxic and relatively accessible to aquatic organisms (USEPA, 1996). It is a gray-white, soft metal with a low melting point, a high resistance to corrosion, and poor electrical conducting capabilities. The lead concentration in the groundwater ranged between 0.02-1.09 mg/l with an average value of 0.08 mg/l. The values were far higher the maximum permissible limit of 0.01 mg/l (WHO, 2006; NSDWQ, 2007). High concentration of lead in the groundwater may be attributed to the various anthropogenic activities domiciled in the area. Studies had shown that lead is naturally available in all environmental media (atmosphere, biosphere and hydrosphere) varying concentrations. From the atmosphere, lead is transferred to soil, water and vegetation by dry and wet deposition. It is carcinogenic and affects several organs of the human body, including the nervous system, the blood system, the kidney, the cardiovascular system and the reproductive system.

The adverse effects of lead on the nervous system of young children includes: reducing intelligence and causing attention deficit, hyperactivity and behavioural abnormalities. These effects occur at relatively low blood lead levels without a known lower threshold (Schwartz, 1994; Ahmad *et al.*, 2010). Various studies have found a positive correlation between lead exposure and measured intelligence quotient (IQ) of school-age children (Bellinger, 1992; Bird *et al.*, 2003; Kraft *et al.*, 2006; Venugopal *et al.*, 2009). Reviews of studies concluded that a 10 µg/l increase in blood lead can be associated with a 2.5 point decrease in IQ (WHO, 2006; Lee *et al.*, 2007). The negative impact of lead exposure is generally stronger on verbal IQ than on performance IQ (WHO, 2006; Kar *et al.*, 2008). Prenatal exposure of lead was also demonstrated to produce toxic effects in the human fetus, including reduced birth weight, disturbed mental development, spontaneous abortion and premature birth. Such risks were significantly greater at blood lead level of 15µg/l and more (WHO, 2006).

Cadmium

The concentration of cadmium varied between 0.07-0.19 mg/l with a mean value of 0.14 mg/l as against the maximum allowable limit of 0.003 mg/l (NSDWQ, 2007). They observed high concentration of cadmium can be as a result of the heavy anthropogenic activities going-on in the area. Cadmium ingestion via food, especially plant-based foodstuff, is the major route by which cadmium enters the human body from the environment. The intake of cadmium dust through inhalation (absorbed by the lungs) is generally less than the intake via drinking water (Macklin *et al.*, 2003). The kidney, especially the renal tract, is the critical organ of intoxication after exposure to cadmium. Excretion is slow, and renal accumulation of cadmium may result in irreversible impairment in the reabsorption capacity of renal tubules (Adams *et al.*, 2008). Several renal dysfunction and damage to the bone structure, a syndrome known as itai-itai disease, have been associated with long-term exposure to cadmium in food (mainly rice) and water in Japan (USEPA, 1997; WHO, 2006).

Deficiencies of iron, zinc and calcium in the human body generally facilitate cadmium absorption. Most crops, with the exception of rice have been found to contain zinc that inhibits the uptake of cadmium by animals and humans (Chaney et al., 1995; Suthar and Singh, 2008). Acute and chronic exposure to cadmium dust and fumes as a result of working conditions or smoking can result in cadmium poisoning. Several studies have yielded sufficient evidence of cadmium carcinogenicity in animals (Hatje et al., 1998; Amman *et al.*, 2002; Kar *et al.*, 2008) while long term occupational exposure to cadmium causes prostate and lung cancer (Mohan *et al.*, 1996; WHO, 2006).

Copper

Copper is one of several heavy metals that are essential to life despite being as inherently toxic as non-essential heavy metals exemplified by Pb and Hg (Scheinberg, 1998). The concentration of Cu ranged between 0.03-1.15 mg/l with an average concentration of 0.08 mg/l. Some locations have concentrations above the maximum recommended value of 1.00 mg/l (NSDWQ, 2007). The higher value in parts of the area indicates an anthropogenic addition from industrial effluents and dumpsites. Gastrointestinal disorder in human can be due to elevated copper concentration in drinking water (USEPA, 1997; NSDWQ, 2007).

Nickel

Nickel values ranged between 0.01-0.04 mg/l with an average value of 0.28 mg/l. The mean concentration of nickel is greater the maximum acceptable limit of 0.02 mg/l recommended by (NSDWQ, 2007). Nickel is a very abundant element in the environment, and is found primarily combined with oxygen (oxides) or sulfur (sulfides). Small nickel particles in the air via tobacco smoke, auto exhaust and gas flaring settle to the ground or are taken out of the air in rain. Leachate from dumpsites and industrial effluents can also enrich nickel concentration in the groundwater. The most common adverse health effect of nickel in humans is an allergic reaction. People can become sensitive to nickel when things containing it are in direct contact with the skin, when they eat nickel in food, drink it in water, or breathe dust containing it (Aktar *et al.,* 2010). Once a person is sensitized to nickel, further contact with it will produce a reaction. The most common reaction is a skin rash at the site of contact. Less frequently, allergic people have asthma attacks following exposure to nickel. Lung effects, including chronic bronchitis and reduced lung function, have been observed in workers who breathed large amounts of nickel.

Acute toxic effects occur in two stages, *immediate* and *delayed*. Headache, dizziness, shortness of breath, vomiting, and nausea are the initial symptoms of overexposure to nickel; the delayed effects, consist of chest pain, coughing, shortness of breath, bluish discoloration of the skin, and in severe cases, delirium, convulsions, and death (Bird *et al.*, 2003; Kraft *et al.,* 2006). Recovery is protracted and characterized by fatigue on slight exertion. Repeated or prolonged exposure to nickel carbonyl has been associated with an increased incidence of cancer of the lungs and sinuses. Products of decomposition (nickel oxide and carbon monoxide) are less toxic that nickel carbonyl itself (USEPA, 1997; Lohani et al., 2008).

Zinc

The concentration of zinc varied from 0.03 mg/l to 10.09 mg/l and a mean value of 0.70 mg/l. This values falls below the permissible limit of 3.00 mg/l (NSDWQ, 2007). Zinc is one of the commonest elements in the earth's crust. It's found in air, soil, and water, and is present in all foods. Pure zinc is a bluish-white shiny metal and has many commercial uses such as coating to prevent rust, in dry cell batteries, and mixed with other metals to make alloys like brass and bronze. Zinc compounds are widely used in industry to make paint, rubber, dye, wood preservatives, ointments, household utensils, castings and printing plates. Some zinc is released into the environment by natural processes, but most comes from activities of people like mining, steel production, gas burning, and wastes dumps. Rain and snow remove zinc dust particles from the air and moves it into the groundwater and into lakes, streams, and rivers. The WHO recommended dietary allowance of zinc is 15 milligrams a day for men (15 mg/day); 12 mg/day for women; 10 mg/day for children; and 5 mg/day for infants (WHO, 2006).

Zinc is an essential element in our diet. Too little zinc can cause health problems, but too much zinc is also harmful. Acute toxicity may result in sweet taste, throat dryness, cough, weakness, generalized aching, chills, fever, nausea and vomiting. Zinc chloride fumes have caused injury to mucous membranes and pale gray cyanosis. Ingestion of soluble salts may cause nausea, vomiting and purging. Breathing large amounts of zinc (as dust or fumes) can cause a specific short-term disease called metal fume fever (Lee *et al.*, 2007). Chronic toxicity can cause stomach cramps, nausea, vomiting, anemia and pancreas damage (USEPA, 1997; Nouri et al., 2008).

Chromium

The concentration of chromium ranged from 0.02-0.11 mg/l with a mean value of 0.07 mg/l. The mean concentration is higher than the maximum permissible limit of 0.05 mg/l recommended by (WHO, 2006; NSDWQ, 2007). Chromium has three main forms chromium (0), chromium (III), and chromium (VI). Chromium (III) compounds are stable and occur naturally, in the environment. Chromium (0) does not occur naturally and chromium (VI) occurs only rarely. Chromium compounds have no taste or odor. Chromium (III) is an essential nutrient in our diet, but we need only a very small amount. Other forms of chromium are not needed by our bodies (Venugopal *et al.*, 2009).

Chromium is a naturally occurring element found in rocks, soil, plants, animals, and in volcanic dust and gases. In the beginning of life the mineral chromium is important from the very earliest stage of life. Conception of new life begins a process of rapid cell duplication by division (mitosis) over and over again. This requires lots of energy. Chromium is used in manufacturing chrome-steel or chrome-nickel-steel alloys (stainless steel) and other alloys, bricks in furnaces, and dyes and pigments, for greatly increasing resistance and durability of metals and chrome plating, leather tanning, and wood preserving. Chromium (III) helps insulin maintain normal glucose levels (Bellos and Swaidis, 2005).

All forms of chromium can be toxic at high levels, but chromium (VI) is more toxic than chromium (III). High chromium concentration can damage and irritate your nose, lungs, stomach, and intestines (USEPA, 1997). People who are allergic to chromium may also have asthma attacks after breathing high levels of either chromium (VI) or (III). Long term exposures to high or moderate levels of chromium (VI) cause damage to the nose (bleeding, itching, sores) and lungs, and can increase your risk of non-cancer lung diseases. Ingesting very large amounts of chromium can cause stomach upsets and ulcers, convulsions, kidney and liver damage, and even death. Skin contact with liquids or solids containing chromium (VI) may lead to skin ulcers. Some people have allergic reactions including severe redness and swelling (USEPA, 1997; Juang *et al.*, 2009).

Cobalt

Cobalt is a steel-gray, shiny and hard metal which can enter into humans through water, soil or food. The concentration of cobalt in the groundwater ranges from 0.00-0.08mg/l with an average value of 0.03 mg/l. Cobalt used in industry is imported or obtained by recycling scrap metal that contains cobalt. It is used to make alloys, paints, large appliances, and kitchen-wares. Cobalt has also been used as a treatment for anemia, as it causes red blood cell production (Mohanty et al., 2001). Acute toxicity of cobalt may be observed as effects on the lungs, including asthma, pneumonia, and wheezing. Animal studies have found problems with the development of the fetus in animals exposed to high concentrations of cobalt during pregnancy. The International Agency for Research on Cancer has determined that cobalt is a possible carcinogen to humans. Studies in animals have shown that cobalt causes cancer when placed directly into the muscle or under the skin and did not cause cancer in animals that were exposed to it in the air, in food, or in drinking water (Bellos and Swaidis, 2005).

Mercury

The value of mercury ranged from 0.001-0.004 mg/l and an average value of 0.003 mg/l. This concentration of mercury was found to be higher than maximum permissible limit of 0.001 mg/l (WHO, 2006; NSDWQ, 2007). The metallic mercury is a shiny, silver-white, odourless liquid, but when heated gives a colourless and odourless gas. Mercury also combines with carbon to form organic mercury compounds. The most common organic mercury compound is methyl mercury, which is produced mainly by small organisms in the water and soil. The more mercury becomes available in the environment the more methyl mercury is produced by these small organisms that make them. Metallic mercury is used to produce chlorine gas and caustic soda and also in thermometers, amalgams (dental fillings) and batteries (Singh et al., 2008). Mercury salts are used in skin-lightening creams and as antiseptic creams and ointments.

Mercury is used in scientific and electrical equipment, in the electrolytic production of chlorine and sodium hydroxide; and as a catalyst in polyurethane foam production. It enters the water or soil from natural deposits, disposal of wastes, and the use of mercury-containing fungicides (Mohanty *et al.*, 2001). The acute toxicity of mercury varies significantly with the route of exposure. Inhalation of high concentrations of mercury causes severe respiratory irritation, central nervous system, digestive disturbances, developing fetus, brain and kidney damage. The World Health Organization (WHO, 2006) reported no evidence that inorganic mercury is carcinogenic.

Arsenic

The concentration of arsenic ranged between 0.001-0.016 mg/l with a mean value of 0.007 mg/l. Most arsenic compounds have no smell or special taste. When arsenic enters the environment, it does not evaporate, instead it can be absorbed in the soil, dissolve in groundwater or release in the atmosphere via burning of arsenic compounds (Karbassi *et al.*, 2008). Arsenic is the most common cause of acute heavy metal poisoning in adults and is released into the environment by the smelting process of copper, zinc, and lead, as well as by the manufacturing of chemicals and glasses (Sekabira et al., 2010). Arsenic gas is a common by-product produced by the manufacturing of pesticides that contain arsenic. Arsenic may be also be found in water supplies worldwide, leading to exposure of shellfish, cod, and haddock. Other sources are paints, rat poisoning, fungicides, and wood preservatives. Target organs are the blood, kidneys, and central nervous, digestive, and skin systems (Khadse *et al.,* 2008).

Manganese

The concentration of Mn ranged from 0.01-0.78 mg/l with an average value of 0.29 mg/l. Some locations have values higher the WHO and NSDWQ acceptable limit of 0.2 mg/l. Decomposition and subsequent leaching industrial effluent are probable sources of groundwater enrichment in Mn. Manganese is essential for plants and animals, and are used in products such as batteries, glass and fireworks (Aboud and Nandini, 2009). Potassium permanganate is used as an oxidant for cleaning, bleaching and disinfection purposes. Other manganese compounds are used in fertilizer, fungicides and as livestock feeding supplements (Huang and Lin, 2003).

Iron

The concentration of iron ranged from 0.05-6.87 mg/l with a mean value of 1.62 mg/l as against the maximum recommended value of 0.30 mg/l by WHO, (2006) and NSDWQ, (2007). Iron is an essential nutrient that is vital to the processes by which cells generate energy. Iron can also be damaging when it accumulates in the body. The implication of the high iron content is that the water may have taste, colour and other aesthetic problems such as hemochromatosis. Because iron can exist in different ionic states, iron can serve as a cofactor to enzymes involved in oxidation-reduction reactions. In every cell, iron works with several of the electron-transport chain proteins that perform the final steps of the energy yielding pathways. There are so much of the body's iron is in the blood, as a result, iron losses are greatest whenever blood is lost. Bleeding from any site incurs iron losses. Active bleeding ulcers, menstruation, and injury result in iron losses. Women are especially prone to iron deficiency during their reproductive years because of repeated blood losses during menstruation (Shahtaheri et al., 2008). Pregnancy places iron demands on women as well since iron is needed to support the added blood volume, the growth of the fetus and blood loss during childbirth. Infants and young children receive little iron from their high milk diets, yet extra iron is needed to support their rapid growth. The rapid growth of adolescence, especially for males, and the menstrual losses of teen females demand extra iron that a typical teen diet may not provide. Organs that may be most affected by iron are the pancreas, liver, kidneys, brain, heart, arteries, and joints (Nouri *et al.,* 2006).

Metal Pollution Index

Metal pollution index (MPI) is a method of rating that shows the composite influence of individual parameters on the overall quality of water. The rating is a value between zero and one, reflecting the relative importance individual quality considerations. The higher the concentration of a metal compared to its maximum allowable concentration, the worse the quality of the water (Amadi, 2011). It is also a combined physio-chemical and microbial index which makes it possible to compare the water quality of various water bodies (Tamasi and Cini, 2004; Prasad and Kumari, 2008). It has wide application and it is used as the indicator of the quality of sea (Filatov. *et al.*, 2005) and river water (Amadi at al., 2012; Lylko *et al.*, 2001; Mohan *et al.,* 1996), as well as drinking water (Nikoladis *et al.,* 2008; Amadi *et al.,* 2010). The MPI represents the sum of the ratio between the analyzed parameters and their corresponding national standard values as shown in Table 1.

$$MPI = \sum_{i=1}^{n} \left[\frac{C_i}{(MAC_i)}\right]$$

where: C_i: mean concentration

MAC: maximum allowable concentration

Water quality and its suitability for drinking purpose can be examined by determining the metal pollution index.

Table 1: Calculated Metal Pollution Index for the Groundwater in the Area

Parameters (mg/l)	C_i	MAC_i	MPI Value	Rating
Arsenic	0.007	0.01	0.70	Lightly polluted
Cadmium	0.11	0.02	3.50	Moderately polluted
Cobalt	0.02	0.01	2.00	Moderately polluted
Chromium	0.07	0.05	1.40	Moderately polluted
Copper	0.8	1.00	1.90	Moderately polluted
Iron	0.62	0.30	2.10	Moderately polluted
Lead	0.08	0.01	2.50	Moderately polluted
Manganese	0.19	0.20	0.95	Lightly polluted
Mercury	0.003	0.001	3.00	Moderately polluted
Nickel	0.28	0.02	4.00	Moderately polluted
Zinc	0.17	3.00	1.57	Moderately polluted

< 0.01= Very lightly polluted; 0.01-1.0 = Lightly polluted; 1.0-5.0 = Moderately polluted;
5.0-10.0 = Highly polluted; > 10.0 = Very highly polluted

Conclusion

This study has clearly established that gas flaring, oil spills, agrochemicals, industrial effluents and indiscriminate dumping of wastes constitute a major source of water pollution in the oil producing region of Eastern Niger Delta, Nigeria. It is remarkable to note that concentration of these heavy metals consistently decreased away from the gas-flaring points, spill-point, effluent-point, flow-stations and dumpsites. It has also been confirmed that the concentration of heavy metals in groundwater and surface water in locations of these hot-spots exceeds their respected recommended maximum permissible limit. The metals decrease in the order of: Fe > Ni > Cu > Zn > Mn > Cd > Co > Pb > Cr > As > Hg. The study has revealed that the various anthropogenic activities domiciled in the area have constituted serious water quality problems which have resulted to classic environmental and health challenges in their host communities. It is recommended that the government should without any further delay, put an end to gas flaring and artisanal crude oil refining in the area in order to save the water system in the area from high class pollution via heavy metals.

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