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ORIGINAL PAPER

Pollution from non-oil sources in the river Nun downstream of Yenegoa Town, South-South Nigeria

Poluição de fontes não-petrolíferas no rio num, Yenegoa Town, Nigéria

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Abstract
Levels of heavy metals (mercury, chromium, lead, cadmium and iron) in the water snail (Pilaovata) in the river nun downstream of Yenegoa Town, south-south Nigeria and other parameters (temperature, ph,turbidity, Total Dissolved Solids TDS, oil and grease) in the water column was investigated in an attempt to understand the impact of urbanization and poor waste management practices on downstream communities in non-oil impacted communities in the Niger delta of Nigeria. While mercury was very minute, iron and chromium where within standards for food in the snail, lead (26-27.4 mg/l), cadmium (12.11--12.16 mg/l) and arsenic (6.92-8.41mg/l) concentrations where above the standards for food sources. Turbidity in the water column was above recommended levels for drinking water, aesthetics and aquatic health. The study concludes that the area may also have lost its capacity to support good fish production, and the water source has become a dangerous source of food and water to inhabitants due to hydrocarbon and heavy metal concentrations. Government intervention and environmental education is recommended.

***Keywords**: Heavy Metals. Ogbia River. Pila ovata. Pollution. Nigeria*

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Introduction

The Niger Delta of Nigeria is at the heart of an international environmental controversy caused by rising concern for environmental pollution caused by oil exploration and exploitation activities (Agbozu, 2001). This has led to several crises leading to tensions between oil operators, host communities and the Nigerian government. In spite of this, gas flaring which has been ongoing for over five decades and oil pollution from spills emanating from burst pipes, oil theft and drilling waste mismanagement has continued unabated leaving the Niger Delta environment perhaps to the path of total destruction.

A Wikipedia report (2013) from several sources (Nwilo & Badejo, 2001; Friends of the Earth, 2005; UNDP, 2006; Baird, 2010) states that Nigeria flares more natural gas associated with oil extraction than any other country in the world, with estimates suggesting that of the 3.5 billion cubic feet (100,000,000 m^3) of associated gas (AG) produced annually, 2.5 billion cubic feet (70,000,000 m^3), or about 70% is wasted via flaring. Also, oil spills are very common and the Department of Petroleum Resources (DPR), which regulates oil activities in the Nigeria's oil and gas industry confirmed recently that between 1976 and 1996, an approximately 1.89 million barrels of oil were spilled in about 4,647 incidents recorded in the Niger Delta region. A United Nations Development Programme (UNDP, 2006) report also revealed that a total of 6,817 oil spill incidents were recorded between 1976 and 2001, which accounted for three million barrels of oil.

These flared gases and spilled oil by means of wet deposition; seepage and run-off find their way into water bodies in the Niger delta posing grave dangers to environmental health. Pollution of the aquatic environment by inorganic and organic chemicals is a major factor posing serious threat to the survival of the aquatic organisms including fish (Samir & Shaker, 2008). Metal ions can also be incorporated into food chain and concentrated in aquatic organisms to a level that affect their physiological state and may have other drastic environmental impact on all organisms (Mason, 2002).

However, there are sections of the Niger Delta not directly impacted by oil production activities. These are areas that do not abut oil locations or oil drilling platforms or pipelines, as such are not directly impacted by oil production activities. It is a fact that most parts of the region may suffer wind assisted acid rain as polluted air mixed with precipitation may be redistributed from one part of the region to the other.

Also in most riverine communities in the Bayelsa area of the Niger Delta, there is a situation that may not be affecting just the physical, chemical and biological conditions of streams and rivers but their aesthetic value as solid waste is seen floating and hanging on to banks, roots, tree stumps and reeds along most creeks and rivers. This is a product of unwholesome waste management practices involving the dumping of both domestic and industrial waste upstream. Wastes from homes, markets, mechanic workshops and other industrial outfits are usually dumped directly into water bodies in most cities or channelled indirectly through urban storm water drainages. These wastes manifest downstream as non-biodegradable remains of polyethylene bags, empty drink cans, bottles, and logs of wood and oil films. It has been observed that, in developing countries, an estimated 90% of untreated waste water is discharged directly into river and streams polluting river and lakes to levels that make them unfit even for industrial uses (Asonye, Okoli, Okenwa, & Iwuanyanwu, 2007).

The effects of this contamination result in eutrophication and other related ecological problems. Important also is that most pollution in rivers that abut urban areas occur in the downstream segment of these population centres (Clabby, Lucey, & McGarrigle, 2006).

The left arm of the bifurcation of the River Nun south of the city of Yenegoa was considered for this study (Figures 1 and 2). This 10-30km stretch of fresh water flowing south of Yenegoa town delivers unwholesome water to communities downstream from Otuokpoti to Ewama 30km downstream. Interestingly, the study area does not have any direct water contact with adjacent oil fields in Oloibiri and the Kolo Creek, thereby making it a good case for our investigations as it rules out direct pollution from oil (exploration) sources. This 10-30 km stretch of fresh water suffers degradation from the effects of urbanization (upstream) in Yenegoa.

Metals and chemicals from polluted recharge and discharge when introduced into the aquatic environment do not remain in the water column. They may be concentrated in the surface film or become adsorbed onto suspended particulate matter so that they precipitate out on the bottom. Although sediments are sinks, trace metals may re-enter the water column by physical, chemical and biological processes. In this way, the sediment serves as a buffer and may be able to keep the metal concentrations in water and in bottom feeding biota above the background levels long after their input has been discontinued (Binning & Baird, 2001).

The accumulation of heavy metals in aquatic organisms has become an increasing concern in marine and coastal environments. In contrast to the non-essential trace elements, such as lead, cadmium, mercury, arsenic and others, the essential metals such as copper, zinc, iron and cobalt have important biochemical functions in organisms. However, if the heavy metal concentration at the source of supply (e.g. water, food) is too high, the essential metals may act in a toxic manner (Forstner & Wittmann, 1983). Thus, in the event of extended bioaccumulation of heavy metals, the organisms may be affected. Investigations on toxicity of metals to organisms in the aquatic environment reveal that physicochemical parameters have a considerable influence on the toxicity and accumulation of metals in organisms. The parameters such as oxygen content, temperature, pH value, hardness, salinity, organic metal ion interaction, heavy metal complexation, and the chemical characteristics of individual metal species in the aquatic environment are determining factors of the heavy metal effects on organisms (Forstner & Wittmann, 1983).

A number of communities and fishing hamlets are situated along this stretch of the Nun River including Otuokpoti, Otuedu and Ewama (Figure 2). These populace depend directly on the river for their livelihood including as a source of domestic water (usually used untreated), food (through fishing) and for sports (swimming and bathing).

A major fishing engagement down the Ogbia River as some people prefer to call it is water snail picking and diving. According to Aboho, Ahwange and Ber (2009), *Pila ovata* (Oliver, 1804), the most common species of water snail in the study area, is usually found in the bottom of streams, ponds, lakes, oceans, pet stones and people's aquaria. The shell is about 55-59 mm wide and 43-47 mm in height. It has a relatively high sphere and a round shell opening (aperture). It feeds on algae and decayed vegetation. It is believed to be a source of clearing agent for Aquariums, hence many people, who keep tropical fish also buy the snail as cleaners for their aquarium (Ajayi, Tewe, & Awesu, 1978).

These snails constitute an important source of diet for most villagers especially the rural dwellers, in Africa and elsewhere in the world. Apart from serving as a source of protein, they are used for medicinal purposes especially, their shell in many parts of the world (Aboho et al., 2009). The snail's habitat and feeding habits makes it vulnerable to the bioaccumulation of metals from algae, sediments and vegetal matter. According to Beady and Eaves (1983), snails can accumulate higher concentrations of metal ions than any other group of invertebrates especially in aquatic systems (Aboho et al., 2009).

The natural roles of *Pila ovata* as aquatic filterers position in the nutrition system of the population and their ability to bioaccummulate heavy metals therefore makes them very good indicators of environmental quality, while contamination by trace metals will eventually lead to some health problems among the vulnerable population (Aboho et al., 2009). The *Pila ovata* has also been used severally and successfully in environmental monitoring studies (Nuembang, 1984; Amusan, 2002; Ezemonye, Enobakhare, & Ilechie, 2006; Olomukoro & Azubuike, 2009). These necessitated the need to determine the levels of heavy metals in the water snail from the area and also in the water column in an attempt to understand the impact of urbanization and poor waste management practices on downstream communities in non-oil impacted communities in the Niger Delta of Nigeria.

Materials and methods

Study area

The River Nun marks the south-western end of Yenegoa city, 5 km downstream of a major bifurcation. It flows behind the city in a south westerly direction after receiving polluted recharge from the Epie Creek which runs through Yenegoa town. Apart from receiving polluted discharge from the Epie Creek which is a major sink for solid and liquid waste generated in the town (Ezekwe, Chima, & Ikogori, 2013), markets, homes, industries, plants are all situated on the banks of the River Nun in southern Yenegoa. Compounding these pollution sources is the direct channelling of untreated urban storm water and sewerage into the River Nun system.

Otuokpoti the first sampling station is located about 15km downstream of Yenegoa, while Ewama the last sampling station is about 10km downstream of Otuokpoti. The area is made up of fishing and farming communities and settlements that depend on nature directly for their livelihoods. They are located within the swampy aquatic environments of the rainforests in the humid tropical climate characterized by hot and wet conditions associated with the movement of the inter-tropical convergence zone (ITCZ) north and south of the Equator resulting in two major seasons, the dry and the wet seasons respectively. The study area also experiences high temperature regime of about 35^0C throughout the year and a heavy rainfall of up 1800mm marked by a double maxima peaking in June and October each year.

Sampling methods

Biota and area/depth integrated samples were collected at the sides and midstream of the river in three sites (Site 1[Otuokpoti ($4^0$49' 57.810"N, $6^0$16'09.270"E)], Site 2[Otuedo ($4^0$49'17.730"N, $6^0$15'49.780"E)], Site 3[Ewama ($4^0$48'18.780"N, $6^0$15'31.600"E)]. Water sampling, preservation and analysis followed standard procedures as outlined in Rainwater and Thatcher (1960), Brown, Skougslad and Fishman (1970); APHA-AWWA-WPCF (1994); Bartram and Balance (1996). Samples were collected with pre-rinsed 1 litre plastic containers for the analysis of physico-chemical parameters, while Samples for heavy metal analysis were collected with nitric acid pre-rinsed 1-litre containers and treated with 2ml nitric acid (assaying 100%, trace metal grade, fisher scientific) prior to storage. This was done to stabilize the oxidization states of the metals. The samples were placed in coolers before transferring them to the laboratories. Physico-chemical parameters of samples were determined using standard methods the stated standard methods.

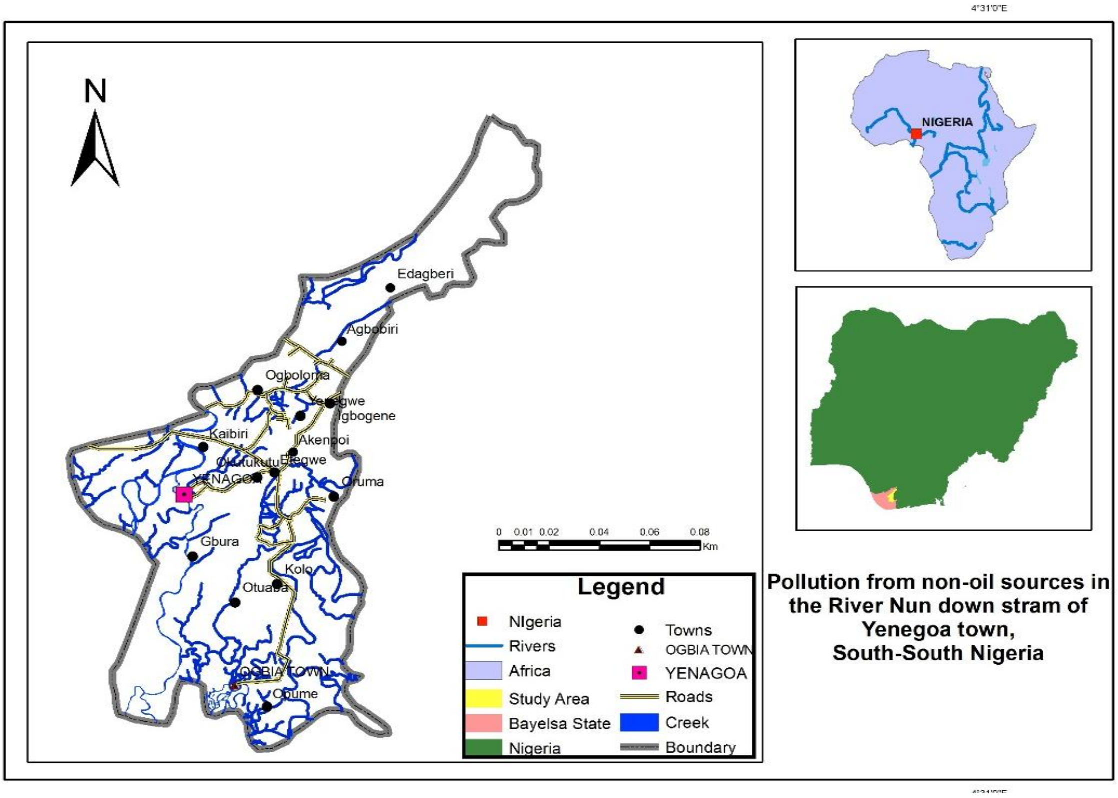

Figure 1. Location of the study area

Water quality analysis

Temperature and pH were measured in situ with a HM Digital Waterproof Ph/Temperature Meter ® while turbidity was measured with a WQ770 handheld Turbidity Meter. TDS was however determined by gravimetric methods.

For oil and grease analysis, water samples (350ml) plus carbon tetrachloride (35ml) were shaken in separating funnels; resulting in the formation of a distinct and lower organic phase. The lower organic phase was removed for absorbance determination at 410nm using a Hach DR/2010 Portable Datalogging Spectrophotometer. A standard curve of the absorbance of known concentrations of oil in the extractants was firstly obtained after taking readings from the spectrophotometer. The oil and grease content was subsequently determined with reference to the standard curve (APHA-AWWA-WPCF, 1994).

Also, samples of macerated water snail (*Pilaovata*) tissues were digested and extracts evaluated for selected heavy metal contents. Before analysis, two grams (2g) of ground oven dried total body weight were weighed using a high precision microscale and put in a digestion flask and digested with a mixture of 10ml of concentrated nitric acid and 2ml of concentrated perchloric acid. The contents of the flask was, for each case, digested gently and slowly, by heating in a water bath until the contents got to near dryness. It was then set aside to cool. The digest was filtered into a 50ml volumetric flask, made up to mark with distilled water and the concentrations of selected metals were determined by atomic absorption spectrophotometry using the Buck Scientific Model 200a Spectrophotometer, equipped with a high sensitivity nebulizer. Calibration of Buck Scientific Model 200a Spectrophotometer was performed before every run by successive dilution of a 100mg/l multi-element instrument calibration standard solution (Fisher Scientific) (Opuene & Agbozu, 2008).

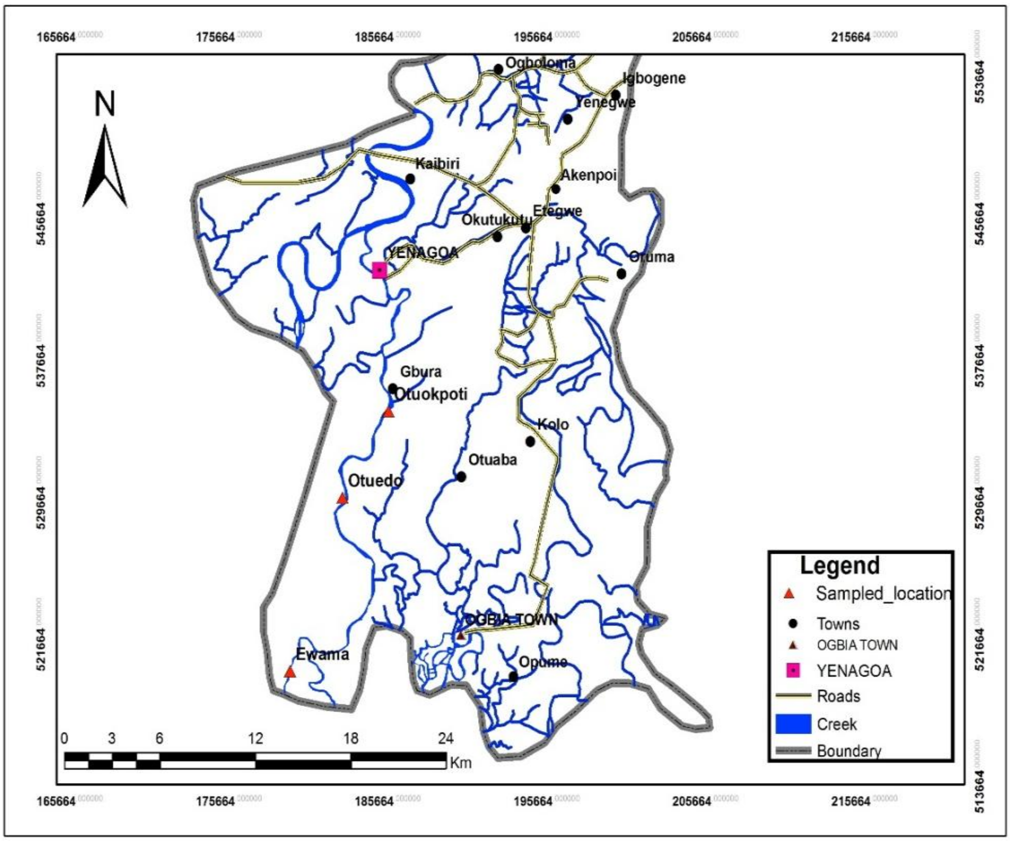

Figure 2. Sampling locations in the River Num.

Results

Water quality testing revealed a characteristic circum-neutral pH (6.3- 7.3), high levels of turbidity (65-66, FTU), low levels of dissolved materials (48-50 mg/l), and a high level (7mg/l) of oil and grease content. Also, heavy metal analysis revealed elevated levels of iron (>1915 mg/l), lead (>26 mg/l), cadmium (>12mg/l) and arsenic (>6 mg/l). Chromium levels were comparatively low while mercury was below detectable limits. Table 1 and 2 shows the results of parameters tested in the water column and in the biota (*P.ovata*). Low levels of dissolved constituents in water may be accounted for by the circum neutral nature of the river water which may have caused dissolved materials to precipitate out of solution (Offodile, 2002; Imes, 2003; Kaverina & Pogozheva, 2005; Chima *et al.*, 2010;).

Table 1. Tested water quality parameters in the water column

Parameters	SITE I	SITE II	SITE III
Temperature ^{O}C	26	27	27
pH	6.7	7.2	7.30
Turbidity, FTU	66.10	65.10	66.30
TDS, mg/l	50	48	50.10
Oil and Grease, mg/l	7	7	6.6

Table 2. Tested Heavy metals in water snail

Parameters ug/g	**SITE I**	**SITE II**	**SITE III**

Mercury (Hg)	BDL	BDL	BDL
Iron (Fe)	1916.7	1915	1915
Chromium (Cr)	0.039	0.0382	0.0692
Lead (Pb)	27.4	26.1	26.0
Cadmium	12.11	12.15	12.16
Arsenic	8.41	7.65	6.92

Discussion

While temperature, pH and TDS in the water column were within acceptable limits for domestic water use, turbidity and hydrocarbons are however above standards for drinking water and aquatic integrity. Turbidity is a measure of water clarity caused by suspended matter in water. It is an important indicator of suspended sediment and erosion levels. Turbidity increases sharply during and after a rainfall, which causes sediment to be carried into river systems. Elevated turbidity will also raise water temperature, lower dissolved oxygen, prevent light from reaching aquatic plants which reduces their ability to photosynthesize, and harm fish gills and eggs (Behar, 1997).

Turbidity levels must not increase beyond 5 NTU and 10 NTU units when background levels are equal to 50NTU units or above 50 NTU units respectively. Turbidity above 20 NTU (JTU equivalent) is above the Water Quality Standards for estuarine ecosystems for TropicalAustralia (Philminaq, 2008). For drinking water, turbidity standards for the United States of America range from 0.1 - 5 NTU units while Canadian standards specify , 1NTU units (drinking) to 5 NTU units (aesthetics) (Province of British Columbia, 1998; USEPA, 1986). Turbidity in the water column in the study area is therefore above recommended levels for drinking, aesthetics and aquatic health.

Whereas the World Health Organization – WHO (2005) recommendation for petroleum products in drinking water does not exceed 0.3mg/L in all circumstances, the oil and grease content of the water column in the Ogbia River was a minimum 7mg/L indicating a high level of pollution from industrial sources and a grave danger to human and aquatic health.

Also, The Thai Government (Thailand National Environment Board, 2000) on the other hand stipulates the following limits for petroleum hydrocarbons in marine waters; 0.5mg/L for natural resource preservation, coral reef conservation and aquaculture; <1mg/L for recreation and <5mg/L for residential district areas, while the Indian Government's standard for OilandGrease (including Petroleum Products) forsaltpans, shell fishing, mariculture and ecologically sensitive zones is 0.1mg/L. This recommendation derives from the fact that above this concentration levels, the survival of larvae and fish eggs is jeopardized (Maharashtra Pollution Control Board – MPCB, 2012).The study area may have lost its capacity to support good fish production, and the water source has become a dangerous source of food and water to inhabitants.

According to the US based Agency for Toxic Substances and Disease Registry- ATSDR (1999), hydrocarbons, especially petroleum hydrocarbons are released to the environment through accidents, industries, or as by-products from commercial or private uses. When spilled hydrocarbons enter the river system they may either float in water surface where they nay suffocate fish or sink to the bottom can accumulate in sediments where they become available to bottom feeders like the water snail. These compounds, particularly the smaller compounds such as benzene, toluene, and xylene can affect the human central nervous system or cause death if exposure is very high. Another compound (n-hexane) can affect the central nervous system in a different way, causing a nerve disorder called "peripheral neuropathy" while hydrocarbon compounds are known to affect the blood, immune system, liver, spleen, kidneys, developing foetus, and lungs. Certain petroleum compounds can be irritating to the skin and eyes. Other petroleum hydrocarbon compounds, such as (benzene) has been shown to cause cancer (leukaemia) in people. The International Agency for Research on Cancer (IARC) has determined that benzene is carcinogenic to humans (Group 1 classification) and benzo (a) pyrene and gasoline are considered to be probably and possibly carcinogenic to humans.

Table 3. Standard of heavy metals concentration in specified foods (WHO 2005)

Parameters	Description of food	Max. permitted conc. in parts per million
Mercury (Hg)	All food in solid form	0.5
	All food in liquid form	0.5
Iron (Fe)	All food in solid form	4500
	All food in liquid form	6500
	Fish, crab-meat, oyster,	2
Cadmium (Cd)	Prawns & shrimps.	0.2
	Meat of animal and poultry	6
	All food in solid form	1
	All food in liquid form	1
Lead (pd)	Fish, crab-meat, oysters, prawns.	1
	Meat of animal and poultry.	
Chromium (Cr)	Solids being shell fish & its products.	10
Arsenic (As_2O_3)	Solids being fish & fish products.	6

Iron, chromium mercury, lead, cadmium and arsenic were tested in the biota. While mercury was undetectable, iron and chromium where within standards (Federal Environmental Protection Agency – FEPA, 2003; Food and Agriculture Organization of United Nations – FAO, 1983; WHO, 1985), lead (26-27.4 mg/L), cadmium (12.11--12.16 mg/L) and arsenic (6.92-8.41mg/L) concentrations on the other hand where above the standards for food sources ranging from prawns and shrimps, meat, crab, fish and shell fish (Table 3). While arsenic and lead concentrations decreased downstream with increasing pH indicating increasing precipitation, cadmium tended to increase downstream.

Studies in and around the Niger Delta of Nigeria have reported similar levels of concentrations of heavy metals in aquatic species. For instance, Uhegbu, Chinyere, Ugbogu and Nwoku (2012) found arsenic and chromium concentrations ranging from 0.73 mg/L to 0.88mg/L (arsenic) and 0.075mg/L to 168mg/L (chromium) in biota from the Ethiope River around Warri town in the Niger Delta of Nigeria. Also Okafor and Opuene (2006) and Opuene and Agbozu (2008) found concentrations of up to 6.7 mg/l (cadmium), 24mg/l (chromium), 14.5mg/l (lead) and 2,000mg/l (iron) in *Bagrus bajad; and* 0.18mg/l (cadmium) and 0.358mg/l (lead) in the shrimp *Macrobrachium felicinum* in the Taylor Creek, about 30km north-west of the study area. Also Ezemonye et al. (2006) in a study Bioaccumulation of heavy metals (Cu, Zn, Fe) in freshwater snail (*Pila ovata*; Oliver 1804) from Ikpoba River in the Niger Delta found mean concentrations (μgg^{-1}) of Cu, Zn and Fe in the snail were as follow, 4.56 – 6.71, 35.35 – 77.09 and 1257.21 – 1762.59, respectively.

Exposure to inorganic arsenic can cause irritation of the stomach and intestines, decreased production of red and white blood cells, skin changes and lung irritation. It can also lead to development of skin, lung, liver and lymphatic cancer. Very high exposures can cause infertility and miscarriages in women and heart disruptions and brain damage in both men and women. Organic arsenic can cause neither cancer, nor DNA damage, but exposure to high doses may lead to nerve injury and stomach aches (Lenntech, 2013).

Lead is a heavy metal that is toxic at very low exposure levels and has acute and chronic effects on human health. It is a multi-organ system toxicant that can cause neurological, cardiovascular, renal, gastrointestinal, haematological and reproductive effects, while cadmium is a non-essential and toxic element for humans mainly affecting kidneys and the skeleton. It is also a carcinogen by inhalation. Cadmium is accumulated in bone and may serve as a source of exposure later in life (United Nations Environment Programme – UNEP, 2013).

It is important to note that while the Taylor Creek and Ethiope rivers are directly affected by oil production, the Ogbia River and the Ikpoba River are not directly affected by oil production. It therefore goes to show that oil spills alone cannot account for environmental pollution in rivers and creeks of the Niger Delta of Nigeria. Individual and corporate waste management habits and pollution from non-oil sources may be very important in the quality of rivers and streams.

Conclusion

In most riverine communities in the Bayelsa area of the Niger Delta, unwholesome waste management practices involving the dumping of both domestic and industrial wastes in streams or channelled indirectly through urban storm water drainages are carried out. These wastes manifest downstream as non-biodegradable remains of polyethylene bags, empty drink cans, bottles, and logs of wood and oil films. This is causing water quality problems in downstream areas as turbidity in the water column is above recommended levels for drinking water, aesthetics and aquatic health.

The study area may also have lost its capacity to support good fish production, and the water source has become a dangerous source of food and water to inhabitants due to hydrocarbon and heavy metal concentrations. Complete and comprehensive study and continues monitoring of river water for quality and impacts is expedient in the Niger Delta to forestall an impending '*ecological Hiroshima'*. A change of attitude in waste management is needed within government circles and among individuals and also the popular thinking of blaming the oil companies for every environmental damage need to be changed. Finally public enlightenment and education on the state of our waters and the health implications of their consumption including products from them is very important.

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