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Arsenic pollution of surface and subsurface water in Onitsha, Nigeria

A. C. C. Ezeabasili[1]*, O. L. Anike[2], B. U. Okoro[3] and C. M. U-Dominic[4]

[1]School of the Built Environment, Heriot-Watt University, UK.
[2]Department of Geological Sciences, Nnamdi Azikiwe University, Anambra state, Nigeria.
[3]Department of Civil Engineering, Nnamdi Azikiwe University, Anambra State, Nigeria.
[4]Department of Industrial Engineering, University of Ibadan, Nigeria.

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Study on arsenic pollution was conducted in Onitsha town in Anambra State, Nigeria to examine the pollution status of surface and subsurface water. Arsenic concentration in surface water within Onitsha metropolis ranged from 0.2001 mg/L (River Niger upstream) to 1.5883 mg/L (River Niger central drainage surface), while concentration in boreholes lies within the range of 0.0000 mg/L (22.2% of boreholes) and 1.2507 mg/L (creek road), respectively. Arsenic concentration in sampled water from river sources is above the WHO standard (0.01 mg/ L) while 87.8% of Arsenic concentration in boreholes adjacent and closest to these rivers and creek is also above the world Health Organization standard (WHO, 2011) of 0.01 mg/L. it is discovered that pollution of surface water is greater than that of the groundwater sources. Major sources of arsenic in Onitsha are refuse dumps, effluent from industries and sewage amongst other sources. Arsenic is known to be the most poisonous metal in existence on earth's surface, its production should be carefully monitored and effluents treated before discharge into the environment.

Key words: Arsenic, water, health.

INTRODUCTION

Water is one of the major means of transport of arsenic in the environment. Soil erosion and leaching have been reported to contribute to the quantity of arsenic in dissolved and suspend form. Soil erosion and agricultural runoff are large contributors to the arsenic concentration in sediments too. Arsenic in its various chemical forms and oxidation states is released into the aquatic environment by natural erosion processes, sewage, refuse and industrial discharges. On release to the aquatic environment, the arsenic species enter into a methylation/ demethylation cycle, while some are bound to the sediments or taken up by biota where they could undergo metabolic conversion to other organoarsenicals (Islam and Tanaka, 2004). A chemical factory manufacturing several chemicals including the insecticide Paris - green (acetocopper arsenite), was responsible for the contamination of wells in the southern part of Calcutta, India. Over seven thousand people consumed the arsenic-contaminated water for several years, but this fact remained unnoticed until September, 1989. A few died, and some of the victims were hospitalized, while symptoms of arsenic poisoning were evident in many families living in the area. Water samples analyzed for arsenic indicated extremely high levels of contamination,

*Corresponding author. E-mail: acczeabasili@yahoo.com or ezeabasilialoy@gmail.com

with total arsenic concentration ranging from as low as 0.002 to as high as 58 mg/L (Viaraghavan et al., 1999). According to Krishnamurthy (1992), about 1% of Americans consume drinking water that has arsenic levels of 25 ppb or more, and in Utah and California water supplies have been found to contain as much as 500 ppb; also an estimated one-in-a-thousand lifetime risk of dying from cancer induced by normal background levels of arsenic (this equals the risk estimate due to tobacco smoke and radon exposure) (Kosnett, 2005).

Inorganic arsenic is a potent human carcinogen and general toxicant. More than one hundred million people are exposed to elevated concentrations, mainly via drinking water, but also via industrial emissions (Vahter, 2008). Arsenic is metabolized via methylation and reduction reactions, methylarsonic acid and dimethylarsinic acid being the main metabolites excreted in urine. Both inorganic arsenic and its methylated metabolites easily pass the placenta and both experimental and human studies have shown increased risk of impaired foetal growth and increased foetal loss.

Recent studies indicate that prenatal arsenic exposure also increases the risk of adverse effects during early childhood. There is a growing body of evidence that the intrauterine or early childhood exposure to arsenic also induces changes that will become apparent much later in life. One epidemiological study indicated that exposure to arsenic in drinking water during early childhood or in utero was associated with an increased mortality in young adults from both malignant and non-malignant lung disease.

Furthermore, a series of experimental animal studies provide strong support for late effects of arsenic, including various forms of cancer, following intrauterine arsenic exposure. The involved modes of action include epigenetic effects, mainly via DNA hypomethylation, endocrine effects (most classes of steroid hormones), immune suppression, neurotoxicity, and interaction with enzymes critical for foetal development and programming (Vahter, 2008).

The mechanism of toxicity of arsenic is through induction of oxidative stress and impairment of the antioxidant defense mechanism, leading to apoptosis and cell death (Flora et al., 2008). Arsenicosis is the effect of arsenic poisoning, usually over a long period such as from 5 to 20 years.

Drinking arsenic-rich water over a long period results in various health effects including skin problems (such as colour changes on the skin, and hard patches on the palms and soles of the feet), skin cancer, cancers of the bladder, kidney and lung, and diseases of the blood vessels of the legs and feet, and possibly also diabetes, high blood pressure and reproductive disorders. Absorption of arsenic through the skin is minimal and thus hand-washing, bathing, laundry, etc. with water containing arsenic do not pose human health risks. In China (Province of Taiwan) exposure to arsenic via drinking-water has been shown to cause a severe disease of the blood vessels, which leads to gangrene, known as 'black foot disease'. This disease has not been observed in other parts of the world, and it is possible that malnutrition contributes to its development. However, studies in several countries have demonstrated that arsenic causes other, less severe forms of peripheral vascular disease (WHO fact sheet, 2001). Chronic arsenic toxicity occurred as a large epidemic in Bangladesh (Smith et al., 2000, WHO, 2011). Ogbuagu and Ajiwe (1998) found that Onitsha North and South have the greatest concentration of Industries in Anambra state, and stand a high risk of industrial pollution. He inferred that some of the industries in the state discharge their waste into the environment with little or no treatment.

This study investigates concentration of Arsenic in surface and subsurface water within Onitsha metropolis and possible impact on populace.

Study location

Onitsha is located in Anambra State in Eastern Nigeria and lies within latitudes 5°22[1] and 6°48[1] and longitudes 6°32[1] and 7°20[1]. Onitsha in Anambra State is located on the east bank of River Niger and covers an area of about 49,000 km^2. It is one of most important commercial centres in sub-Sahara African, as well as a transit city in Nigeria. It has an estimated population of about one million inhabitants (Figure 1).

The socioeconomic characteristics of Onitsha consist of about 75% labour force that is engaged in tertiary sector, such as, trading and services. The remaining 25% of labour force is engaged in manufacturing and industrial activities. However, Onitsha is a centre for the production of local goods and services, as well as, a market for the sale of foreign goods. The Onitsha main market, which is reputed as the largest market in sub-Saharan Africa, has increased the tempo of commercial activities in the city in recent times.

MATERIALS AND METHODS

Twenty seven (27) water samples (11 of which were from surface water sources and 16 from boreholes) were obtained from the Onitsha metropolitan city. Surface water sampling was conducted at constant depth of 0.5 - 1.0 m in areas where Onitsha main market/ auxiliary drains and industrial effluents enter the rivers. Borehole samples extracted were very close to the Niger river and in most cases less than 10 km away from the bank.

Research work was conducted for period of 2004-2008. Water samples were stored in sterilized 50cl PVC bottles; and acidulated prior to analysis.

Atomic Absorption Spectrometry method was used to determine concentrations of Arsenic in water samples from Onitsha. This method is based upon the absorption of radiant energy, usually in the ultra-violet and visible regions by neutral atoms in the gaseous state. Water sample were stored in 50 ml of PVC bottles, analysis was done using UNICAM 969 model Atomic Absorption

Table 1. Arsenic concentration in sampling points within Onitsha metropolis

Sampled area	Samples Identifier	Concentration (ppm)	pH
River Niger upstream surface	R. Niger Surf.	0.2001	6.1
River Niger upstream riverbed	R. Niger bed	0.9669	
Nwanaene Lake/ drain	Nwanaene	0.6058	5.4
River Niger/Otumoye surface	Otumoye surf.	1.4076	6.1
River Niger/Otumoye riverbed	Otumoye bed	1.0311	
River Niger/Creek road surface	Creek surf.	0.3203	6.1
River Niger/Creek road riverbed	Creek bed	0.6966	
River Niger Downstream surface	R. Niger Surf.	0.3409	6.1
River Niger Downstream riverbed	R. Niger bed	1.5779	
River Niger Central drainage surface	N. central surf.	1.5883	6.1
River Niger central drainage riverbed	N. central bed	0.3625	
Borehole at 20 Niger street, Onitsha	No 20 Niger	0.0188	6.1
Borehole at 2 Niger street, Onitsha	2nd Niger	0.0000	6.7
Borehole at 9 Abatete/Creek road, Fegge, Fegge	9 Abat.	1.2507	6.1
Borehole at Nigeria Mineral Water Industries, Onitsha	Nig. Min.	0.0026	6.6
Borehole at Royal Queen Table Water, Obosi	Royal Queen	0.0000	7.1
Borehole at Osemaco water, Onitsha	Osemaco	0.0000	7.1
Borehole at Oseokwodu market	Oseokwodu	0.0023	6.8
Borehole at Ivory metal industries, Onitsha	Ivory Metals	0.5140	6.8
Borehole at Akapaka forest avenue	Akapaka	0.0017	7.0
Borehole near Otumonye/ Relef market	Otumonye	0.3060	6.3
Borehole at Enda Table water, Onitsha	Enda	0.0000	6.4
Borehole at St. Joseph drinking water, Bridge Head, Onitsha	Onitsha	0.0000	6.4
Borehole at Banny table water, Nkisi layout, Onitsha	Banny	0.0000	6.8
Borehole at Onitsha South local government area	Onitsha south	0.0008	6.5
Borehole at 35a Ajasa street, Onitsha	35 Ajasa	0.0014	6.1
Borehole at Life Brewery company, Onitsha	Life brewery	0.0038	5.4

Spectrometry. Other chemical utilized were analytical grade chemicals (HNO_3, Sigma chemicals, Australia and standard heavy metal solutions). Samples for heavy metal analysis were digested using nitric acid (65% purity) as described in the APHA methods (APHA, 1999).

RESULTS AND DISCUSSION

Arsenic concentration in surface water within Onitsha metropolis range from 0.2001 mg/L (River Niger up-stream surface) to 1.5883 mg/L (River Niger central drainage surface), while concentration in boreholes falls within range of 0.0000 mg/L (22.2% of boreholes that is, 2nd Niger, Royal Queen, Osemaco, Enda, Onitsha, Banny) and 1.2507 mg/L (No. 9 Abbatete/creek road), respectively (Table 1, Figures 2 to 4). Arsenic pollution in these areas are traced to anthropogenic pollution especially industrial pollution, refuse dumps and oil/fuel dumps that get washed down to streams/rivers of these major cities on daily basis.

One hundred percent of arsenic concentration in river bodies is above the WHO standard while 87.8% of Arsenic concentration in boreholes adjacent and closest to these rivers and creek is over above the world Health Organization standard (WHO, 2011a) of 0.01 mg/L. It is inferred that river water intrusion into the adjacent soil formation is responsible for the high value of arsenic in the borehole beyond the World Health Organization standard (Al-Juboury, 2009; Igwe et al., 2007) especially as these soils have high permeability coefficients and the pH of these subsurface water are on the average below 7 making for the mobilization of metallic ion like arsenic.

In Nigeria, the World Health Organisation (WHO, 2011b) and the Nigeria Standard for Drinking Water Quality (NSDWQ, 2007) drinking water standard is 0.01 mg/L for Arsenic. Higher range of value is common both in the surface or bottom waters of heavily polluted rivers like River Niger at Onitsha, and their adjacent underground waters.

Degree of pollution of various water sources at Onitsha

In Onitsha, various kinds of pollutants are all over the places; they range from biological to chemical. The most polluted zones are the Nwangene Lake zone where all kinds of sewage and chemical effluent drain into. It is also in this place that the biggest refuse dumps are emptied. This has caused major pollution problems in the River

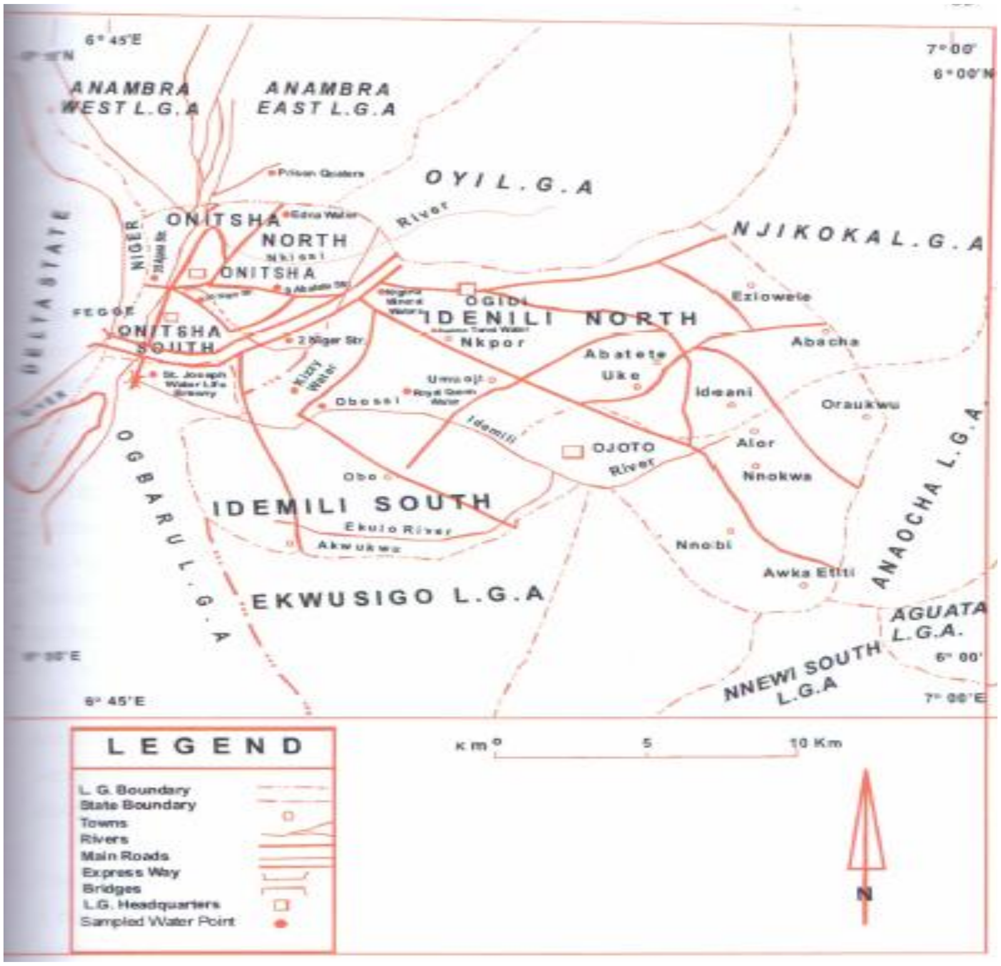
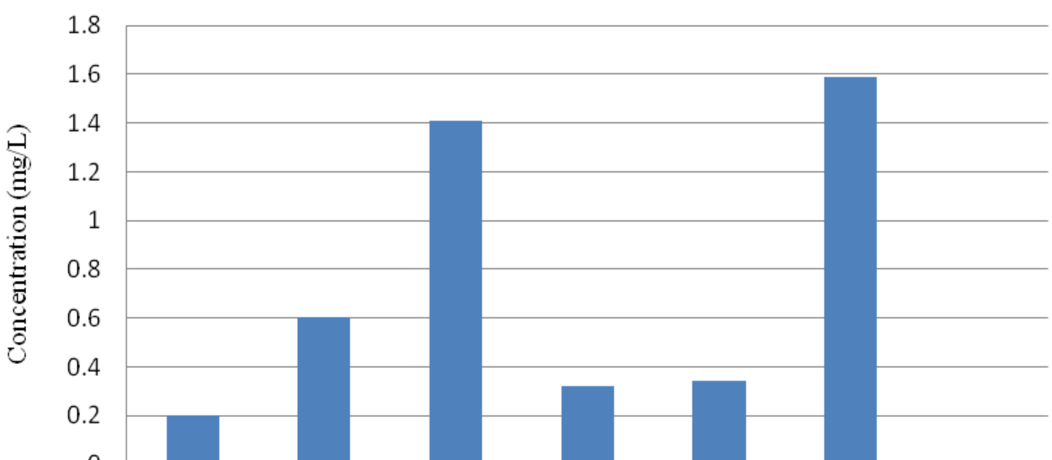


Figure 1. Map of Onitsha Metropolis showing some of the study locations (Source: Adapted from the Federal Survey, 1983).



	R. Niger Surf.	Nwanaene	Otumoye surf.	Creek surf.	R. Niger Surf.	N. central surf.	WHO (2011)
Series1	0.2001	0.6058	1.4076	0.3203	0.3409	1.5883	0.01

Figure 2. Arsenic concentration in surfaces of water bodies within Onitsha metropolis.

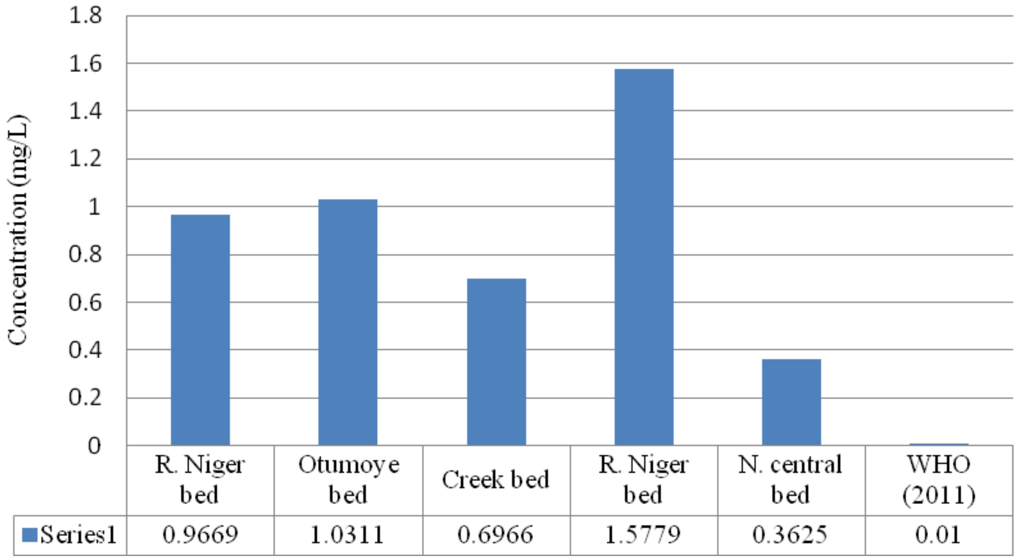


Figure 3. Arsenic concentration in river bed of surface water bodies within Onitsha metropolis.

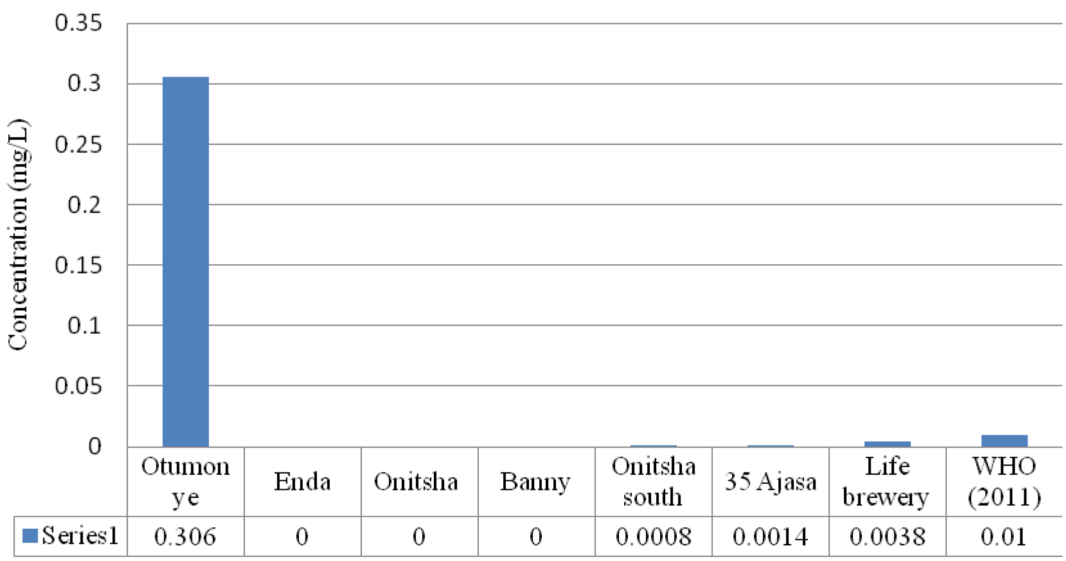


Figure 4a. Arsenic concentration in borehole water Otumoye, Enda, Onitsha, Banny, Onitsha south, 35 Ajasa and Lifebrewery.

Niger where it drains into at Otumoye major drain as can be seen from the results of the tests, but also have polluted boreholes along Creek road and Abatete streets as reported in Table 1 and Figure 4b; the pollution of water bodies in this area can be predicted by the extent of solid and liquid disposals in them. The intrusion of this polluted water is suspected to have stretched up to 100 m radius from the Nwangene Lake and River Niger. It is therefore a serious health hazard for hundreds of inhabitant in the area who use untreated borehole water. The concentration of the heavy metal is much higher than the WHO guidelines.

River Niger water is one of the major sources of water to the people of Onitsha city especially in times of scarcity. Currently all types of wastewater and refuse are disposed in the River Niger. The enormous growth of new industries and urbanization, results in pollution of the river water and the adjoining ground water. Urbanization and technological development results in generation of more and more waste effluents and is discharged into the water bodies resulting in pollution of the surface water. The water borne sewage, storm drainage from Onitsha city streets and effluents from smaller industries combined with flow from municipal outfalls in mounting

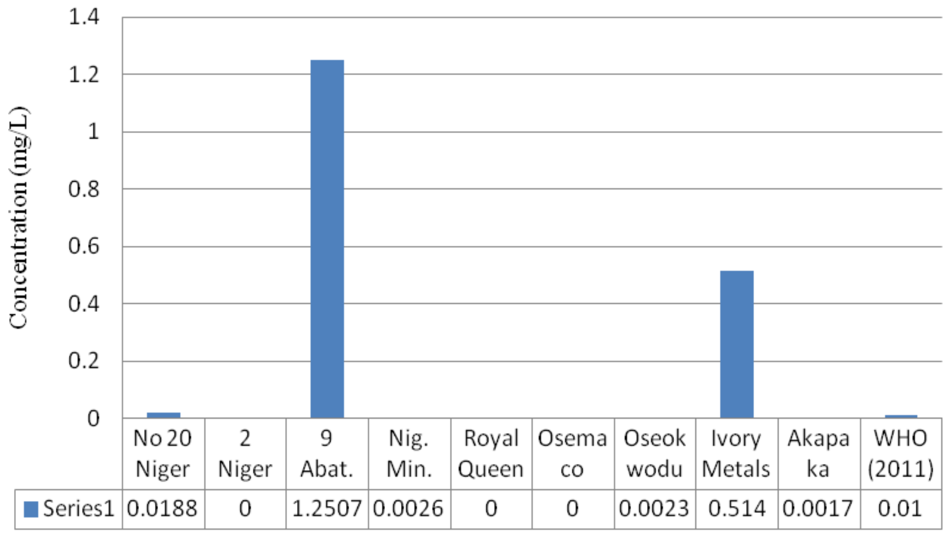


Figure 4b. Arsenic concentration in borehole water of No 20 Niger, 2 Niger, 9 Abat. Nig. Min., Royal Queen, Osemaco, Oseokwodu, Ivory Metals and Akapaka.

volumes along with agricultural runoff from the hinterland ultimately joins the surface water, which drains down the River Niger. Due to inadequacy of public water supply, usage of more ground water for domestic, industrial and agricultural purposes has become very important. Generally, the subsurface water is preferable because of its inherent advantages over surface water.

Major storm water drains in the Onitsha metropolis empties into the River Niger through the main market itself. This also impacts on the quality of water (Figure 2); most results also shows that the bed of the river where the velocity of water is near zero and where a lot of pollutants are supposed to settle are higher than the surface water, which expectedly has self cleansing effects. The general low values of arsenic in most subsurface waters is a thing of joy but it is noticed that consistent pollution activities could aggravate concentration of these dangerous metals with time especially with the rapid increase in urbanization.

Onitsha was a major battle field during the three (3) year Civil War in Nigeria. It is known that Onitsha was contaminated with a wide range of pollutants like hydrocarbons from fuel spillage and leaks, PAHs from fires, explosives, mines, bullets, smokes generating compounds which were not cleared up after the war, this adversely impacts on surface and sub-surface water quality of the environment.

Conclusions and recommendations

Reliable monitoring and surveillance methods are essential for keeping close watch on the health of the environment. Some unacceptable results were recorded for heavy metal loads in the surface and subsurface water in the area. It is obvious that if the rate of pollution is not abated, common health problems which are already found in at Onitsha would increase. The introduction of modern, sensitive and more reliable methods for testing drinking water for physical, chemical and biological parameters should be explored.

More intense training of health experts in the area in water pollution is a sine qua non. There are enough unpolluted ground water resources to satisfy the needs of the society and these could be exploited while effluents from various sources should be treated before discharge. The proper monitoring of industries through environmental impact assessment and environmental audit reports should be enforced by the Ministry of Environment in Anambra State. Information on increasing presence of heavy metals and their affect on health should be disseminated to various stakeholders, including researchers, policy makers, politicians, and donor agencies.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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