Effect of Industrial Effluents on Water and Soil Qualities in Nnewi, Nigeria

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Nnewi is the commercial nerve center and the most highly industrialized city east of the River Niger in Anambra State of Nigeria, West Africa. The industries specialize in manufacturing automobile batteries and accessories, electrical cables, agro-allied products and sundry items. One major problem in Nnewi is the lack or total absence of legal facilities authorized to dispose of industrial waste. We have investigated the impact of chemicals arising from industries on water and soil qualities in Nnewi. Higher levels of iron. copper, lead and manganese were found in the deep than in the top soil. Soil samples from battery manufacturing industries had the highest levels of manganese (3617 ppm) and 664 ppm of lead while soil samples from vegetable oil industry showed the highest level of lead (746 ppm). The pH of the soil ranged from 3.5—6.4. River Ele had a higher level of lead (192.5 ppm) at the source than in the middle and lower courses which had 25 ppm each. The total hardness, salinity and biological oxygen demand of River Ele ranged from 14—35 mg/l, 121.6—211.2 mg/l and 1.9—2.7 mg, respectively, from source to lower course. The highest level of volatile and non-volatile solids was 1.6 and 1.0 mg, respectively. There was an absence of live or dead macro-organisms along the course of the river. Since there were elevated soil lead levels from most of the industrial sites which could have a public health impact, we recommend a control measure to reduce lead exposure to adjoining communities.

Key words —— industrial effluents, lead, copper, biological integrity, total hardness, volatile and non-volatile solids

INTRODUCTION

Most developing countries face the enormous challenge of improving living standards against a backdrop of serious environmental and health problems, for instance because streams and rivers have been considered a convenient means of clearing and carrying wastes away from the discharge points, most rivers in urban areas are highly loaded with urban and industrial wastes.[1,2] According to the Pan American Health Organization (PAHO), less than 10% of the municipalities in developing countries treat sewage adequately before emptying it into natural water courses, and waste water treatment and sewers for industrial effluents are often not working or nonexistent.[3)]

Pollution prevention, recycling and chemical safety programs are also scarce or entirely lacking. As a result of these practices, poor education and apathy, most developing nations pollute more fresh water on a *per capita* basis than Europe.[3)] The untreated waste water dumped into the rivers in many cases becomes part of the water source downstream.

Nnewi, comprising the four villages of Otolo, Umudim, Uruagu, and Nnewichi, is the most highly industrialized city in eastern Nigeria and the commercial nerve center of Anambra State. The industries specialize in manufacturing automobile batteries, motor accessories, light reflectors, electrical cables, agro-allied products and other sundry items. Today between 80 and 90 percent of the Nnewi ultramodern "Nkwo" market is accounted for by auto spare parts dealers.[4)] Nnewi has a population of two hundred and one thousand, two hundred and sixty three (201263) (1991-population census) and about ten square

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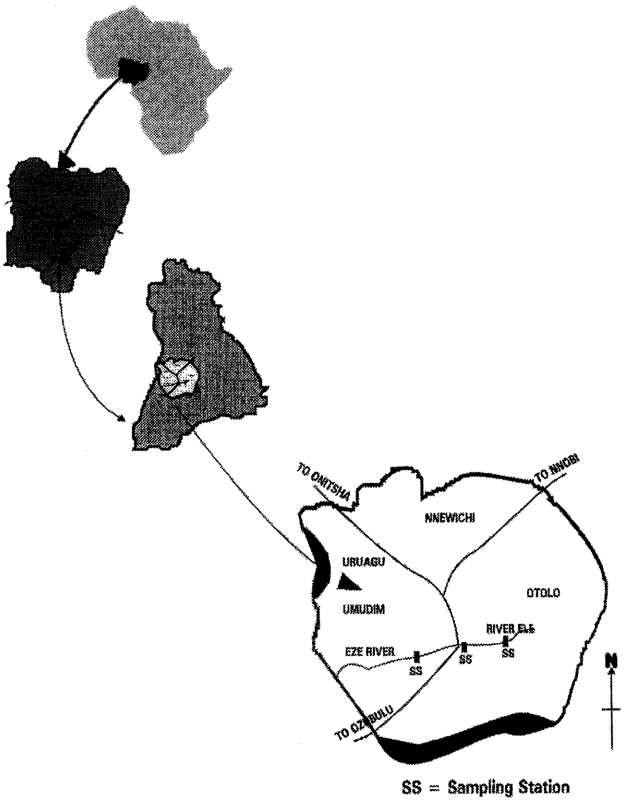

Fig. 1. Map of Nnewi Showing River Ele and Sampling Stations

kilometers in size.

The River Ele is located in the southern area of metropolitan Nnewi. It extends from Otolo to Umudim where it joins with Rivers Ohia and Eze before joining Atani River in Ogbaru Local Government Area of Anambra State. Since manufacturing outfits in Nnewi are randomly located, their effluents wash into River Ele, therefore the major cause of pollution is the high load of urban and industrial waste poured into the river. The river used to be dark in dry seasons and brownish colored in the rainy season. There is no comprehensive or documented evaluation available of the state of the environment in Nnewi, although the accompanying environmental problems characteristic of industrialized cities and the often undocumented cases of poor agricultural yield and gastroenteritis provide an idea of the extent of the environmental crisis. Water pollution and soil contamination particularly by hazardous substances could be an emerging problem in Nnewi with important implications for public health and agriculture. A major problem for Nnewi is the scarcity or total absence of legal facilities authorized to dispose of hazardous wastes.

The objectives of the present study include (a) to determine the soil contamination pattern in Nnewi, (b) to investigate the effect of industrial effluents on River Ele, (c) to determine the biological integrity of Nnewi soil and River Ele, and (d) to educate and recommend solutions to the possible enviromental crisis.

MATERIALS AND METHODS

We selected three sampling stations (source, middle and terminal courses) along the River Ele. All sampling stations were located far away from industrial discharge points. Surface water was collected from four spots at each site near the shore in July 1997. We used a manual pump to collect 10 liters of water at a depth of 0.5 m, transported the water to the laboratory and refrigerated it at 4℃ for processing. At each sampling station, the presence of macroorganisms was recorded by capturing them with a net (diameter of the mesh 0.2 mm) and by direct observation. Concentrations of lead, iron, copper and manganese were determined in each sample using atomic absorption spectroscopy. Complexiometric titration method was employed in the determination of total hardness of the water samples while a digital conductometer was used to measure electrical conductivity.

Water samples were filtered and standardized with 0.1 M KCl and the electrode of the pH meter was immersed into the sample in a flask. The manual was turned on and the pH was read directly. Water microbiology was determined using the method of Postgate.[5] Other pollutant parameters that were measured included salinity, volatile and non-volatile solids and biological oxygen demand (BOD).

Soil sampling was performed at six sites each of which was close (75—100 m) to one of the following industries: Jimex Industries Ltd. (aluminum products), RIMCO (vegetable oil), Cutix PLC (electrical cables), Ibeto Industries Ltd. (automobile batteries), A-Z Industries (lubricating oil) and the bank of River Ele. Two pairs of soil samples, each weighing 100 g, were obtained at four different spots within each sampling site: one sample from the surface soil and another from a 30-cm depth.

The soil samples were digested by adding 5 g of soil to 15 ml of conc. HNO_3 and $HClO_4$ at the ratio of 1 : 1 and allowed to stand for lh. This was then heated on a hot plate for 11/2 h until all acid turned from red to water color. The sample was filtered into a conical flask. The filtrate was made up to 100 ml in a clean labeled plastic container. This digested sample was then used for the determination of heavy metals composition[6] using an atomic absorption spectrophotometer. The biological integrity of the soil sample was determined by direct observation of live and dead macro organisms.[7] The pH, conductivity and soil microbiology were also determined.[5]

RESULTS

The constituents of the water and soil samples are expressed as milligram per milliliter (mg/ml) or milligram per cent (mg%) and parts per million (ppm), respectively. All duplicate experiments agreed very well. Water and soil microbiology data are presented as total counts per milliliter. Results were analyzed using Student t-test and Chi-square test analysis. The significance of data was put at 0.05.[8]

Figures 2A—F show the quantity (ppm) of copper, iron, lead and manganese detected in the top and deep soil from aluminum, battery, electrical cable, lubricating oil and vegetable oil industries and the bank of River Ele. Higher levels of

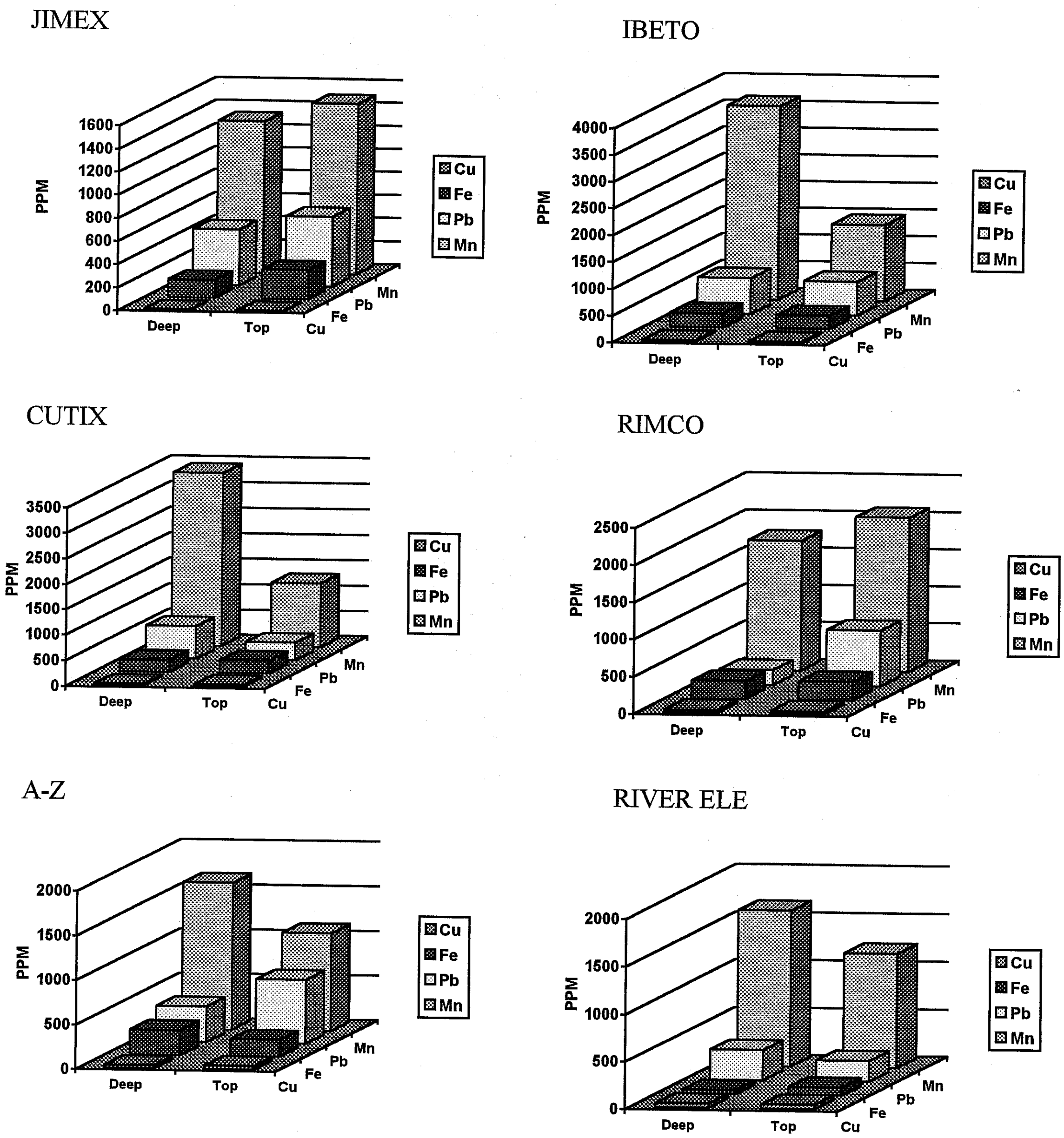

Fig. 2. Three Dimensional Bar Graph Based on Top and Deep Soil Quantities of Metallic Ions (Pb^{2+}, Fe^{2+}, Cu^{2+} and Mn^{2+}) from Different Industries: (A) Jimex, (B) Ibeto, (C) Cutix, (D) Rimco, (E) A-Z Oil, (F) River Ele Using Atomic Absorption Spectrophotometer

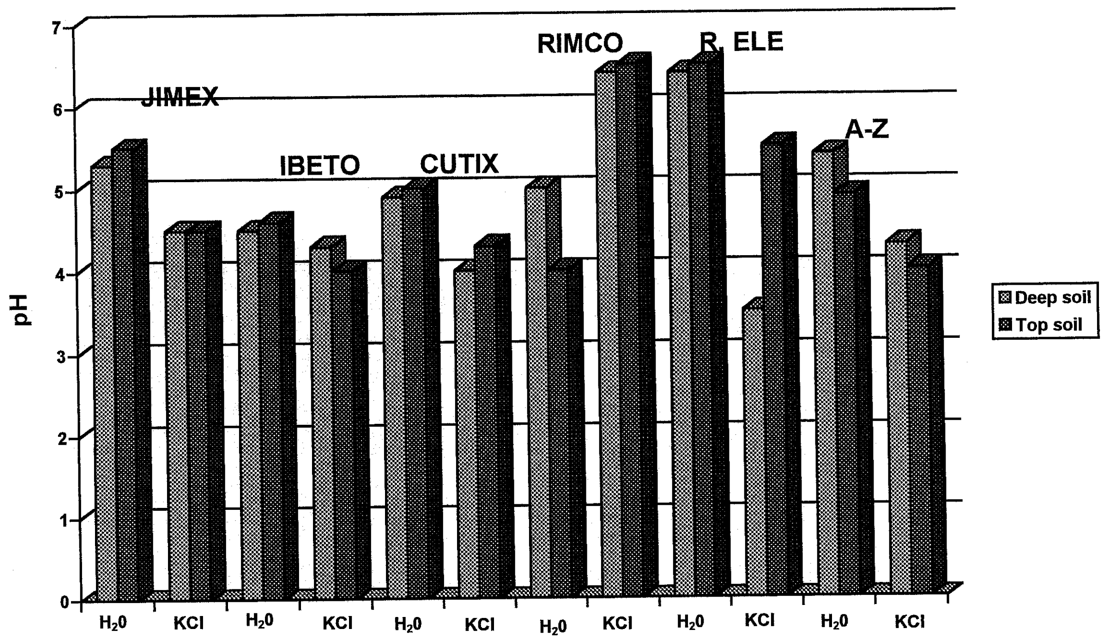

Fig. 3. Three Dimensional Bar Graph Based on pH of Top and Deep Soil of Some Industries in Nnewi, Nigeria

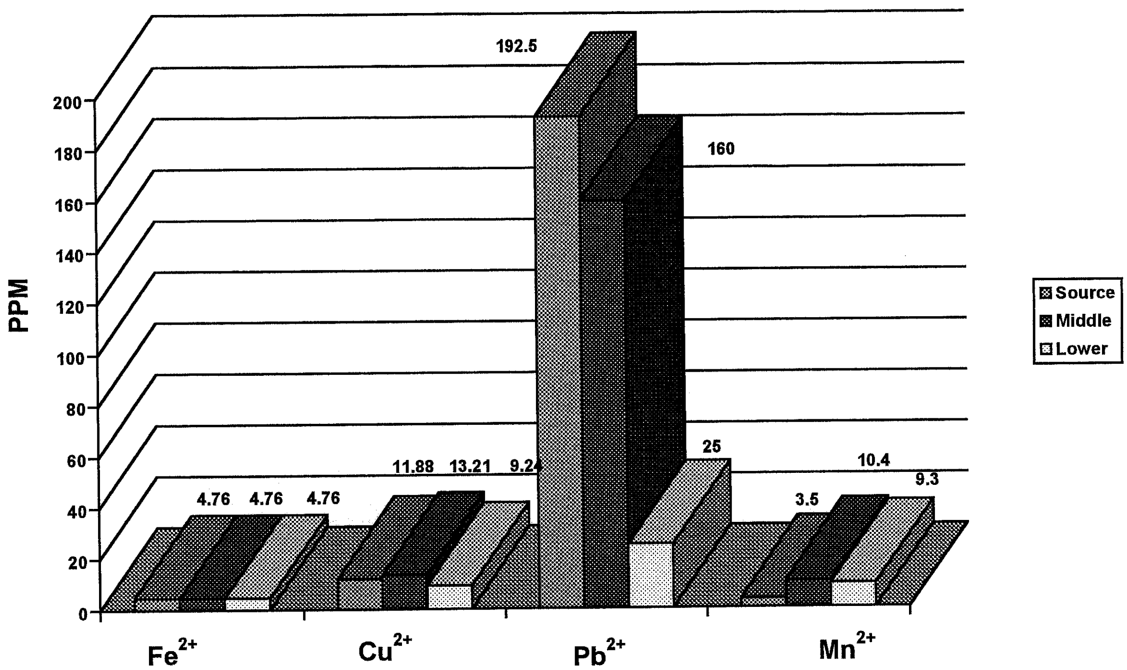

Fig. 4. Bar Chart Based on Metallic Ions (Pb^{2+}, Fe^{2+}, Cu^{2+} and Mn^{2+}) from Source, Middle and Lower Courses of River Ele

these metals were found in the deep than in the top soil. Soil from the battery industry had the highest level of manganese (3617 ppm) and 664 ppm of lead while soil from the vegetable oil industry showed the highest level of lead (746 ppm). In all, the soil samples showed lower levels of copper (range 5.28—47.54 ppm) than the other metals.

The pH of the top and deep soil samples from the industries and the bank of River Ele is shown in Fig. 3, and ranged from 3.5 to 6.4. Top and deep soil samples from all industries and the river bank had acidic pH.

Figure 4 shows the levels of iron, copper, lead and manganese at the different sampling stations (source, middle and lower) of the River Ele. The highest level of lead (192.5 ppm) was found at the source while 25 ppm was found at

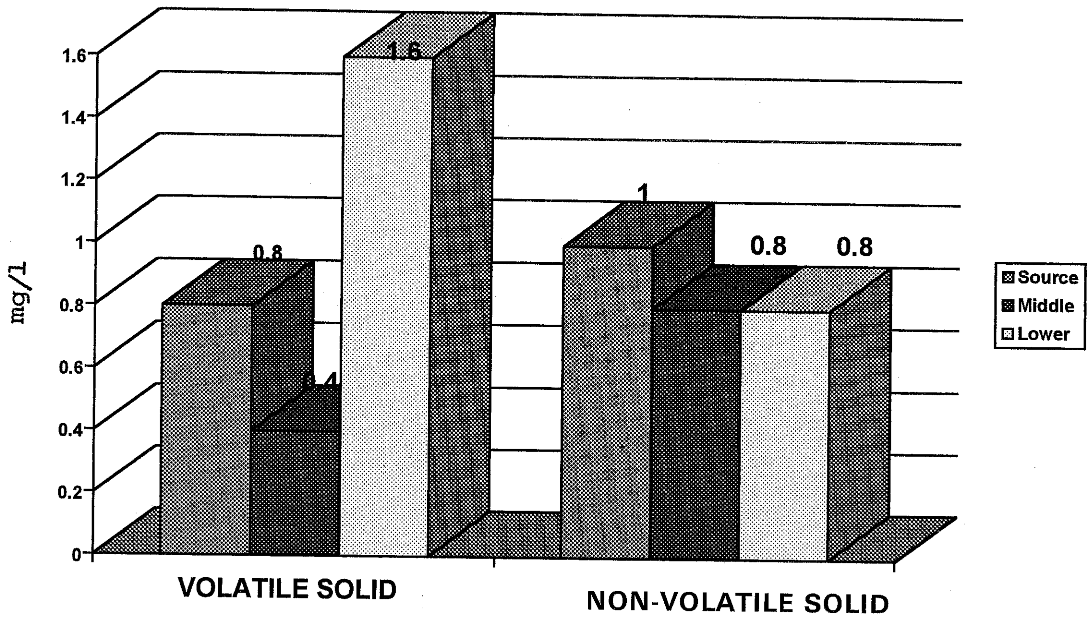

Fig. 5. Three Dimensional Bar Graph Based on Volatile and Non-volatile Solid from the Source, Middle and Lower Courses of River Ele

Table 1. Determination of the Electrical Conductivity (EC) and pH Value

Sample	EC	pH	
		H_2O	KCl
River Ele (Source)	0.19±0.03	5.9±0.01	5.9±0.01
River Ele (Middle)	0.33±0.06	6.1±0.01	6.1±0.01
River Ele (Lower)	0.22±0.01	6.0±0.01	6.0±0.01

Table 2. Determination of Total Hardness (TH), Salinity (SAL) and Biological Oxygen Demand (BOD)

SAMPLE	TH mg/l	SAL mg/l	BOD mg/l
River Ele (Source)	14±0.20	121.6±1.2	1.9±0.11
River Ele (Middle)	34±0.81	211.2±1.7	2.7±0.13
Riverl Ele (Lower)	35±0.11	140.8±1.9	2.7±0.13

Table 3. Bacterial and Fungal Colonies of Soil Samples from Different Sampling Sites

Sampling Site	Jimex		Ibeto		Cutix		RIMCO		River Ele		A-Z	
	Bacteria	Fungi	Bacteria	Fungi	Bacteria	Fungi	Bacteria	Fungi	Bacteria	Fungi	Bacteria	Fungi
Soil Sample												
Deep	120[a]	8	250	5	NA	NA	80	18	120	15	50	6
Top	130	12	400	30	NA	NA	300	5	500	20	30	50

a) Number of colonies of microorganisms. NA, not analyzed.

the lower course. This shows that the ionic movement is from the source to the lower course. The amount of volatile and non-volatile solids is shown in Fig. 5. The highest level of volatile solid (1.6 mg/l) was found at the lower course and the highest level of non-volatile solid (1.0 mg/l) at the source or upper course of the river.

Table 1 shows the electrical conductivity and pH values of water samples from the source, middle and lower courses of the River Ele, while the total hardness, salinity and BOD are shown in Table 2.

The bacterial and fungal colonies of deep and top soil samples from different industries and the river bank are shown in Table 3. In all, the top soil samples had higher populations of both bacterial and fungal colonies.

DISCUSSION

This study investigated the environmental impact of the chemicals resulting from industrialization with a view of compiling comprehensive ecotoxicological data of Nnewi soil and River Ele. The biological integrity of the Nnewi soil collected from the different industrial sampling sites was evaluated for the presence of macro-organisms (dead or alive). There was an absence of living macro-organisms at all the sites. At the source, middle and lower course of River Ele (reservoir of most industrial effluents), there were no living organisms. These observations indicate a high degradation of the water quality in this ecosystem, and is in agreement with studies documenting the poor chemical, physical and biological integrity of rivers in industrialized areas elsewhere.[7]

The pH value of soil may range from less than 4 to more than 8. The pH of soil samples from the different industrial sites ranged from 3.5 to 5.5. All the soil samples from the industries were acidic, a feature that might not be favorable for agriculture.

The River Ele is substantially anaerobic with a mean BOD of 2.43 mg/l and ranging from 1.9 mg/l at the source to 2.7 mg/l at the middle and the lower courses. Data on salinity, electrical conductivity and total hardness have also been presented here. Two theories have been offered concerning causative agent for the relationship between death from cardiovascular disease and water hardness. Soft water is more corrosive than hard water, and promotes the dissolution of cadmium, lead and other toxic substances from the plumbing system into the drinking water.[9,10] Another theory is the protective effect of magnesium from the water.[11,12] Regarding water hardness, there are no distinctly defined levels of what constitutes a hard or soft water supply. A generally accepted classification is that water with less than 75 mg/l of $CaCO_3$ is soft, 75—150 mg/l is moderately hard and above 150 mg/l of $CaCO_3$ is hard.[13] River Ele with a total hardness of 14—35 mg/l can be considered soft so that overall hardness of its drinking water cannot be seen as a main etiologic factor in cardiovascular disease in Nnewi, Nigeria.

The acceptable range for total dissolved solid in any water sample is 500—1500 mg/l. The observation that River Ele contains low dissolved solids in this study requires a reinvestigation, probably in the dry season. Our study revealed that the nitrate and ammonium levels from the river were in trace amounts. These can be attributed in part to the not-too-sensitive assay technique employed in this study and the few agro-based industries in Nnewi, since fertilizers and pesticides have been found to fix nitrogen to the environment.

A possible water problem in Nnewi, Nigeria may be bacteriological pollution associated with the lack of a city sewage system and the potential pollution of the water bed. Three key aspects in this problem are the lack of sewage lines, increase in domestic and industrial discharge beyond the capacity of the city and the physical expansion of the city faster than the expansion of the sewage system.

This study found very high levels of manganese and iron in soil samples from the battery manufacturing plant and the electrical cable industry. The soil samples from River Ele had highest level of copper. Considering the fast pace of industrialization in Nnewi and that the river flows into the River Eze, a source of potable water supply to inhabitants of the Umudim area of Nnewi, there is a danger of water pollution. Chronic copper toxicity, although rare, can result from contaminated water and lead to hepatolenticular degeneration or Wilson's disease.

Soil lead levels above 600 ppm were seen in the aluminum industry, the battery manufacturing plant, the electrical cable industry, the vegetable and soap industry and the lubricating factory which is barely one year old. In all, the top and deep soil samples had levels higher than 200 ppm. These values are higher than those obtained by Wohl and co-workers[14] in a battery recycling facility. In advanced countries like U.S.A., the EPA has issued cxdsew32 for clearing areas in residential soil with lead levels up to 400 ppm.

There was a high and uneven distribution of lead along River Ele ranging from 192.5 ppm at the source to 100 and 25 ppm at the middle and lower courses, respectively. The movement or distribution of lead can be said to be from source to the lower course since there was a gradual decline in the level along the river's course. The high lead level observed is probably due to the presence of several automobile and lead acid manufacturing plants in Nnewi, Nigeria. Despite its preventability, lead toxicity remains a common pediatric problem.[15,16] Not only can intoxicated children have impaired intelligence but they are also frequently overactive, aggressive, more distractible, disorganized and less able to follow directions.[17,18]

Since there were elevated soil lead levels from most of the industrial sites, we recommend a control measure to reduce lead exposure to the adjoining communities. A public awareness program has to be instituted to alert the workers in the plants and the communities of a possible environmental crisis. There is also a need for a follow-up study by research toxicologists of the blood lead levels of children and adults.

Nigeria as a Third World nation has difficulty enforcing waste laws, and years of neglect and accumulations pose problems that will be expensive to solve. With the down-turn in the economy, it is clear that expensive high-tech solutions for clean up are unrealistic. Therefore, it is important that relatively inexpensive ways be found to deal with old accumulations and that waste minimization strategies be developed to alleviate the problem of wastes generated in the future.

Evaluations of the environmental impact of human activities as well as strategies for river conservation should be considered a main priority for environmental and human health. The idea that rivers are convenient means of clearing and carrying pollution away from the discharge point should be urgently and properly reconsidered in order to protect water quality, the ecosystem and human health.

The control of illegal discharges into the municipal sewage system should be considered a high priority. Short-term structural actions to improve environmental enforcement must be taken by the Federal Environmental Protection Agency (FEPA). One of these actions could be to map and designate certain location(s) as industrial estate and to require such areas to collect and recycle waste from their plants. This would improve water management in the city and at the same time would reduce the number of potential illegal discharges into the municipal sewage system.

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