Pak J Sci Ind Res 2002 ***45** (1) 10-16*

ASSESSMENT OF THE PHYSICOCHEMICAL STATUS OF A TEXTILE INDUSTRY'S EFFLUENT AND ITS ENVIRONMENT

E I Adeyeye[a] and O O Ayejuyo[b]*

[a] *Chemistry Department, University of Ado-Ekiti, P M B 5363, Ado-Ekiti, Nigeria*

[b] *Chemistry Department, Lagos State Univeristy, Lagos, Nigeria*

(Received 15 January 2000; accepted 27 June 2001)

Physicochemical status of an industrial textile's effluent and its environment (soil and agricultural product-cassava tubers) at Ado-Ekiti, Nigeria was assessed. Results showed that great variation existed among the parameters (pH units, temperature, conductivity, total hardness, total alkalinity, bicarbonate and hydroxide hardness, calcium and magnesium hardness, chloride and metal elements) down the channel, significant difference ($P<0.05$) existed among the minerals in the effluent, soil sediments and cassava tubers in the three different zones. Fe, Mg, Ca, Na, K and Ni were found to be more concentrated in the effluent whereas Co, Zn, Cu, Pb, Cd and Mn were more concentrated in the soil sediments. However, Fe, Pb and Mn were more concentrated in the effluent than in cassava tubers. Mg, Ca, Zn, Cu, Cd, Na and K were more highly concentrated in cassava tubers showing evidence of bioaccumulation.

Key words: Physicochemical status, Textile effluent, Bioaccumulation, Cassava tubers.

Introduction

Like most other developing countries, Nigeria has for a long time embraced the concept of rapid industrial growth as the vehicle for overall economic development. Since the 1960's, the various National Development Plan (1962-1968, 1970-1974, 1975-1980 and 1981-1985) have consistently emphasized industrialization as the means of achieving rapid increase in the nation's productive capactiy as well as improving the standard of living of the people (Aina 1989). However, industries have been among the worst pollutants in Nigeria.

Heavy metals are taken up by both fauna and flora. This uptake could provoke an increase in the concentration of the metal in the organism; if the excretion phase is slow, this can lead to bioaccumulation phenomenon (FAO 1990). A few metals such as mercury have been shown to undergo biomagnification through the food chain. At low concentrations many heavy metals, including mercury, cadmium, lead, arsenic and copper inhibit photosynthesis and phytoplankton growth. The major routes of heavy metal uptake by man are food, water and air. Little or no money is spent on waste research and management in many parts of Nigeria and other countries. The uneducated rural people often use polluted waters discharged from mines. Many people from Abakaliki Mining district of Anambra State, Nigeria suffer from lead poisoning resulting from the contamination of their water sources by lead (Egboka *et al* 1989). Results from the Aba River, which drains the largely industrial city of Aba, showed abnormally high concentration of Co^{2+} and gave values for pH that varied between 4.0 and 6.5 (Nwankwor and Okpala 1986). Even though pollution is becoming widespread in developing countries, there is a paucity of data and records, poor documentation and information exchanges. There is thus a continuing need for assessment, surveillance, research and public information least these unknown dangers create irreparable environmental damages which in turn results in widespread human suffering in the future. The major aim of this work is therefore to report on the assessment of the physicochemical status of a textile industry effluent whose channel environment contained cassava plant meant purposely for human consumption.

Materials and Methods

1. Sampling. Effluent samples were taken from the Odua textile mills, Ado-Ekiti, Nigeria at three different zones along the effluent pathway. The effluent samples were collected into a clean 2-litre rubber container previously rinsed with the samples, it was tightly capped and labelled. The effluent samples were stored under deep freezing at 10°C. An auger was used to take soil sediment samples from the surface down to a depth of about 15cm at sites of effluent collections. These were stored in polythene bags and kept in the deep freezer pending analysis. Two pieces of cassava tuber (*Manihot esculenta*) were harvested along the effluent channel nearest to the three zones (Fig 1) at distances ranging from 1.52m to 20.32m. Each tuber was briefly washed with distilled water to remove any adhering contamination and then drained under folds of filter paper.

---

*Author for correspondence

2. Sample treatment. The effluent samples temperature was taken in situ, the pH and conductivity were measured on getting to the laboratory. The effluent samples were decolorized by filtering through activated charcoal after the pH and conductivity had been measured. The effluent samples were the stored in the deep freezer until analyses were carried out. Five ml of concentrated hydrochloric acid was added to 250ml of effluent sample and evaporated to 25ml. The concentrate was transfered to a 50ml flask diluted to the mark with distilled de-ionised water (Parker 1972).

After air-drying, the soil sediment samples were sieved using 200 mm mesh. 5g of the soil samples were put into 150ml conical flasks (two in number). 50ml of 0.1M HC1 was added and the flasks were agitated on an orbital shaker for 30 min at 200 rev min^{-1}. The contents were filtered into 50ml standard flasks and made to mark with 0.1M HC1 (Udo and Ogunwale 1978). These extractions were used to determine heavy metals. 5g of soil samples were put into another series of 150ml conical flasks. Three extractions using 30ml ammonium ethanoate solution (1 molar buffer) each were carried out. The contents were filtered into a 100ml standard flask and made up to the mark with the buffer solution. This was used to determine sodium, potassium and other macro minerals in the soil sediment sample (Udo and Ogunwale 1978).

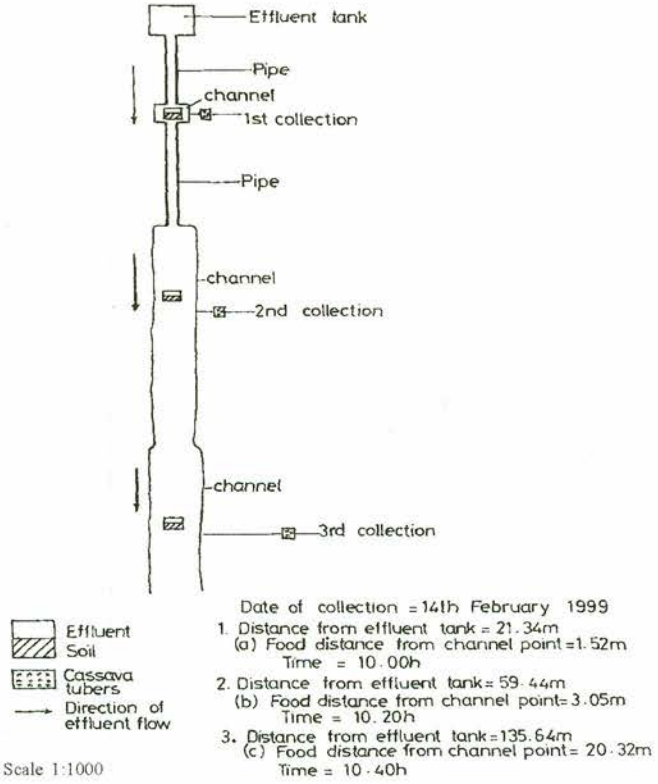

Fig 1. A sketch map of the location indicating the area where effluent soil and cassava tubers were sampled.

The peels of the cassava tubers were removed and chip were prepared from them, sun-dried and made into cassava flour using a kenwood major blender. Flour weights ranging from 0.35g to 0.41g were accurately taken for digestion. The weighed cassava tuber flours (in crucibles) were ashed at a temperature of 540°C in the furnance (NEY M-525) to constant weight. The ashed samples were transfered into a 50ml beaker, crucible washed with 25ml 20% (vv^{-1}) nitric acid into corresponding beakers, 2.0ml of 5% lanthanum chloride solution added and the beakers were heated to boiling to break the ash. The solutions were carefully filtered and transfered into 50ml standard volumetric flasks and made up to the mark with distilled de-ionised water (AOAC 1990).

3. Analyses. The pH of the effluent was measured with KENT EIL 7020 (Kent industrial measurement limited, Surrey, England) pH meter, temperature was measured with a simple thermometer calibrated in °C, electrical conductivity was measured with CDM83 conductivity meter (By Radiometer A/S Copenhagen, Denmark) after standardisation with KCl solution. Various standard methods (APHA 1969; Hutton and Ince 1984) were used for the determination of other parameters. Total alkalinity-acidimetry using bromocresol green-methyl red mixed indicator; chloride-Mohr's method; total hardness and calcium and magnesium hardness-EDTA titration using Erichrome Black T indicator.

Fe, Mg, Ca, Zn, Cu, Pb, Cd, Cr, Ni, Mn and Co were analysed in the three matrices using a Perking Elmer Model 306 Atomic Absorption Spectrophotometer. Sodium and potassium were determined using a flame photometer (Corning UK Model 405), using NaCl and KCl to prepare the standards. All data generated were analysed statistically (Steel and Torrie 1960).

Results and Discussion

Figure 1 shows a sketch map of the location indicating the areas where effluent, soil sediments and cassava tubers were sampled. Areas along the effluent path either have definite pipes or ordinary dug up channel. Areas where effluent, soil sediments and cassava tubers were collected the outside piped areas. Distances of sample collection from effluent receiving tank was between 21.34m and 135.64m (Table 1) while the

Table 1
Sample collection data

Parameter	Zone a		
	E_1	E_2	E_3
Time b	10.00 h	10.20 h	10.40 h
location	21.34 m	59.44 m	135.64 m
Date	14th Feb. 1999	14th Feb.1999	14th Feb. 1999

[a]E_1, effluent in zone one; E_2, effluent in zone two and E_3, effluent in zone three; [b]International time

Table 2
Some physicochemical parameters of the effluent

Parameter	E_1	E_2	E_3	Mean	SD	CV(%)
pH units	8.62	7.81	7.91	8.11	0.36	4.44
Temperature (°C)	36.00	35.00	31.50	34.17	2.25	658
Conductivity (μScm^{-3})	14.45	3.37	3.37	7.06	5.22	73.94
Total hardness (mg L^{-1}) as $CaCO_3$	106.00	120.00	160.00	128.67	22.88	17.78
Total alkalinity (mg L^{-1}) as $CaCO_3$	183.00	183.00	719.80	36193	253.05	69.92
Bicarbonate (mg L^{-1})	183.00	183.00	719.80	361.93	253.05	69.92
Hydroxide (mg L^{-1})	183.00	183.00	719.80	361.93	253.05	69.92
Calcium hardness (mg L^{-1})	BDL	BDL	BDL	------	------	------
Magnesium hardness (mg L^{-1})	25.76	29.16	38.88	31.27	5.56	17.78
Chloride (mg L^{-1})	625.25	2145.43	2453.14	1741.27	799.08	45.89

BDL, Below detection limit; SD, Standard deviation; CV, Coefficient of variation

Table 3
Changes in the mineral concentration (ppm) of effluent along the effluent channel

	Zone								Summary
Mineral	E_1	E_2	E_3	Mean	SD	CV(%)	Fc	Ft	Result
Fe	1304.00	1072.70	713.60	1030..10	242.90	23.58			
Mg	182.90	62.50	116.70	120.70	49.23	40.79			
Ca	713.00	169.60	7.19	296.60	301.81	101.76			
Zn	9.16	2.42	0.96	4.18	3.57	85.41			
Cu	5.24	1.45	1.44	2.71	1.79	66.05			
Pb	0.14	0.14	0.11	0.13	0.01	7.69			
Cd	0.003	0.003	0.003	0.003	0.00	0.00	12.76	2.15	*
Cr	N.D.	N.D.	N.D.	------	------	------			
Ni	0.76	0.21	0.13	0.37	0.28	75.68			
Mn	0.12	0.12	0.14	0.13	0.01	7.69			
Na	275.00	9.50	72.00	118.83	113.34	95.38			
K	80.00	38.50	19.00	45.83	25.44	55.51			
Co	0.20	0.09	0. 02	0.10	0.07	70.00F_c			

F_c,F calculated; F_t, F table; *significant at $P<0.05$; N.D, not detected.

cassava tubers distance from effluent channel point was between 1.52m and 20.32m while the time of sample collection was between 10.00h and 10.40h International time. The figure shows that the piped portions were narrower than the dug up channel. The channel portions continuously widen down the effluent path giving room for more contact between the soil environment and the effluent. The non-pipeline channel may likely encourage more environmental pollution.

Table 2 contains the physicochemical paramters of the effluent. The pH values were between 7.81 and 8.62 units with the coefficient of variation percent (CV%) of 4.44. The temperature decreased down the path with values of 36.0°C (E_1) and 31.0°C (E_3). The conductivity was low and decreased down the effluent path (14.45 down to 3.37 $\mu S\ cm^{-3}$). Both pH values and conductivity recorded here were lower than the values reported in literature (FEPA 1991) and they were below the maximum concentration allowed for discharge into inland waters (FEPA 1991). Both total hardness, total alkalinity, bicarbonate alkalinity and hydroxide alkalinity all increased down the path of the effluent. The values of total alkalinity, bicarbonate and hydroxide alkalinities were similar but greater than the value reported for total hardness. This observation agreed with literature reported (Adeyeye 1997). Calcium hardness was not detected; magnesium hardness was low but increased down the effluent path while chloride concentration was high and increased down the effluent path. Part of the problems encountered in textile mills are high pH, high suspended solids and color (FEPA 1991). Our results recorded pH values within the recommended values (6-9 units) (FEPA 1991) but our effluent samples have offensive odor and deep purple

Table 4

Changes in the mineral concentration (ppm of dry weight) in soil sediments along the effluent channel

Mineral	Zone^b			Mean	SD	CV$^{(\%)}$	Fc	Ft	Result
	S_1	S_2	S_3						
Fe	10.56	10.18	9.84	10.19	0.29	2.85			
Mg	9.83	9.36	8.10	9.10	0.73	8.02			
Ca	10.38	9.35	10.64	10.12	0.56	5.53			
Zn	8.87	6.12	4.44	6.48	1.83	28.24			
Cu	4.05	3.98	2.94	3.66	0.51	13.93			
Pb	0.34	0.05	0.04	0.14	0.14	100.00			
Cd	0.25	0.14	0.11	0.17	0.06	35.29	67.04	215	*
Cr	N.D.	N.D.	N.D.	------	------	------			
Ni	0.01	0.01	0.01	0.01	0.00	0.00			
Mn	5.90	3.20	1.92	3.67	1.66	45.23			
Na	10.14	10.43	9.90	10.16	0.22	2.17			
K	7.52	7.49	7.17	7.39	0.16	2.17			
Co	0.23	0.21	0.16	0.20	0.03	15.00			

b $_{S1}$, soil sediment in zone one; $_{S2}$, soil sediment in zone two; $_{S3}$, soil sediment in zone three.

color. The color could have been due to the dyes used (Tortora 1987). Chloride could range between less than 10ppm to greater than 25 000 ppm (in sea water) (Templeton 1981). The high values of chloride (625.25-2453.14ppm) in our effluent samples could have been due to the large quantity of industrial salt (particularly Na Cl) used in the Odua Textile Mill. Our chloride results were greater than literature values (222-312 ppm) (FEPA 1991).

Table 3 contains the values of the minerals in the effluents of the various zones (E_1-E_3). Among the macro minerals: Mg and Ca were highly concentrated while K was low but Na had high concentration in E_1. In the micro mineral concentrations: Cr recorded ND, Fe was high with values of 713.60 ppm (E_3) to 1304.0ppm (E_1). Zn and Cu recorded values greater then 1 ppm in most cases while Pb, Cd, Ni, Mn and Co had values less than 1 ppm in each case. Our value for Cu in E_1 (5.24 ppm) was greater than the value of 2.75 $\mu g\ ml^{-1}$ recorded in Ghana (Biney 1991) while the values in E_2 (1.45 ppm) and E_3 (1.44 ppm) were also greater than the value of 0.12 $\mu g\ ml^{-1}$ recorded for a Nigerian textile mill (Osibanjo 1994). Our Pb values were less than the literature value of 0.65 $\mu g\ ml^{-1}$ (Biney 1991) but close to the value of less than 0.10 $\mu g\ ml^{-1}$ of Osibanjo (1994). Other values in Table 3 which were greater than literature values were Co, Zn, Fe and Ni, Cd, Mn and Cr were less than literature values (Biney 1991; FEPA 1991; Osibanjo 1994). Statistical analysis showed that a significant difference existed in the mineral concentration of the effluents in the three zones since F_c(12.76) is greater than F_t(2.15) at $P<0.05$.

Quality requirement for textile industrial water at point of use (ppm) for Fe and Mn are 0.0-1.0 and 0.01 respectively (Gulp *et al* 1980). Only Mn was within this range in our results showing that the effluent was not polluted with Mn.

Table 4 shows the mineral concentration of soil sediments along the effluent channel. The following minerals showed downward reduction along the effluent path; Fe, Mg, Zn, Cu, Pb, Cd, Mn, K and Co. Cr recorded ND, the trend of consistency was zigzag in Ca and Na while the value of Ni was 0.01 ppm in S_1, S_2 and S_3 respectively. Comparison of Table 3 and 4 showed that K, Fe, Mg, Ca, Ni and Na were more concentrated in the effluent than in the soil samples while the reverse was the case in Zn, Cu, Pb, Cd, Mn and Co. The occurrence of some heavy metals in the sediments of Abu-Kir Bay of the Mediterranean Sea was studied by Saad *et al* (1981). The metals (Cu, Cd, Zn, Fe and Mn) showed a pattern of distribution similar to that of the mud and organic matter content of the sediments. This might likely be the case in our results as shown by the pattern of mineral distribution for Zn, Cu, Pb, Cd, Mn and Co. In the case of the Abu-Kir Bay sediments, the effects of industrial effluents were found to be restricted to sediments in the vicinity of their discharge. This observation would likely be the situation with our results but such effect would be mostly pronounced in S_1 where the highest concentration of the minerals (about 76.92%) were concentrated. Statistical analysis showed that a high significant difference existed among the minerals in the three soil sediment zones.

Table 5 depicts the mineral concetration of the cassava tubers in the various zones of C_1, C_2 and C_3. The tubers were high in Fe, Mg, Ca, Zn, Na, Cu and K while low values were recorded for Pb, Cd and Co but ND was recorded for both Cr and Ni. Low CV% were recorded in Ca (9.75), Zn (16.16),

Table 5

Changes in the mineral concentration (ppm of dry weight) in cassava tuber along the effluent channel

	Zone^c								
Mineral	S_1	S_2	S_3	Mean	SD	$CV^{(\%)}$	Fc	Ft	Result
Fe	182.96	140.48	72.16	131.87	45.64	34.61			
Mg	900.00	400.00	600.00	633.33	205.48	32.44			
Ca	2200.00	1800.00	1800.00	1933.33	188.56	9.75			
Zn	35.88	27.34	40.94	34.72	5.61	16.16			
Cu	117.73	4.78	9.90	44.14	52.08	117.99			
Pb	0.01	0.02	0.03	0.02	0.01	50.00			
Cd	1.19	1.50	2.56	1.75	0.59	33.71	0.34	215	NS
Cr	N.D.	N.D.	N.D.	------	------	------			
Ni	N.D.	N.D.	N.D.	------	------	------			
Mn^d	------	------	------	------	------	------			
Na	3003.74	2078.91	2078.17	2386.94	436.14	18.27			
K	14160.50	10602.44	10598.69	11787.21	1678.17	14.24			
Co	5.20	0.97	8.58	4.82	3.11	63.21C			

C_{C1}, cassava tuber in zone one; C_2, cassava tuber in zone two; C_3, cassava tuber in zone three; d, Not determined; NS, Not significant at $p<0.05$

Table 6

The mineral composition (ppm)in E_1,E_2,E_3,S_1,S_2,S_3 and C_1, C_2, C_3 compared

Sample	Fe	Co	Mg	Ca	Zn	Cu	Pb	Cd	Cr	Ni	Mn	Na	K
E_1	1304.00	0.20	182.90	713.00	9.16	5.24	0.14	0.0034	N.D.	0.76	0.12	275.00	80.00
E_2	1072.70	0.09	62.50	169.60	2.42	1.45	0.14	0.0031	N.D.	0.21	0.12	9.50	38.50
E_3	713.60	0.02	116.70	7.19	0.96	1.44	0.11	0.003	N.D.	0.13	0.14	72.00	19.00
S_1	10.56	0.23	9.83	10.38	8.87	4.05	0.34	0.25	N.D.	0.01	5.90	10.14	7.52
S_2	10.18	0.21	9.36	9.35	6.12	3.98	0.05	0.14	N.D.	0.01	3.20	10.43	7.49
S_3	9.84	0.16	8.00	10.64	4.44	2.94	0.04	0.11	N.D.	0.01	1.92	9.90	7.17
C_1	182.96	5.20	900.00	220.00	35.88	117.73	0.01	1.19	N.D.	N.D.	----	3003.74	14160.50
C_2	140.48	0.97	400.00	1800.00	27.34	4.78	0.02	1.50	N.D.	N.D.	----	2078.91	10602.44
C_3	72.16	8.58	600.00	1800.00	40.94	9.90	0.03	2.56	N.D.	37.50	----	2078.17	10598.69
Mean	390.72	1.74	254.38	746.68	15.13	16.83	0.10	0.64	----	4.29	1.90	683.70	3946.81
SD	476.69	2.88	297.93	871.76	14.45	35.75	0.10	0.86	----	11.74	2.13	1100.34	5628.07
CV%	122.01	165.52	117.12	116.75	95.15	212.42	100.00	134.38	----	273.66	112.11	160.94	142.60
F_c							1.45						
F_t							1.83						
Result							NS						

Na (18.27) and K (14.24) while others recorded CV% greater than 30.0 although the differences were not found to be significant (P<0.05). Literature values showed that cassava tubers have the following mineral values (mg $100g^{-1}$edible potrion): Fe (0.9), Ca (26), K (394) and Na (2) (FAO 1990) showing that our samples were much higher. It is gratifying to note that the highly concentrated minerals are the nutritionally valuable ones. However, the high values of the minerals in the cassava tubers might be an evidence of biological magnification (Adeyeye 1994).

Both lead and cadmium are not known to be useful biochemically. The only extent guidelines with respect to Cd concentrations in food concern rice in Japan. Limits of 1.0ppm in unpolished rice and 0.9 ppm in polished rice have been established for Cd, but the Japanese Ministry of Agriculture and Forestry "is not now distributing rice containing Cd over 0.4 ppm in consideration of the strong public feeling against eating Cd-containing foods" (OECD 1975). However, in Japan the mean concentration of Cd in polished rice is only 0.07 ppm (Yamagata and Shigematsu 1970) and most foods in the United States contain less than 0.1 ppm cadmium (OECD 1975); to this extent, we might say the cassava tubers were not fit for human consumption since the Cd values ranged from 1.19 ppm to 2.56 ppm. The major intake of Pb for adults through food items is 300 $\mu g day^{-1}$ on average (Varshney 1991); our cassava tubers under discussion might not be a major factor as a source of Pb in nutrition since the values only ranged between 0.01-0.03 ppm. Further critical evaluation of Tables 3,4 and 5 showed that we could further categorise the distribution of the thirteen minerals determined in the various matrices. The Tables showed that Fe was consistently highest in E_1,E_2 and E_3; the Fe was 7.69% of the minerals determined meaning that this percentage was distributed in the effluent samples. Since Fe was highest only in the effluent, it meant the mineral was existing in the effluent in its +2 oxidation state. This meant the pH units (7.81-8.62) did not affect the Fe solubility in the effluent negatively. If a solution contains both Fe^{2+} and Mn^{3+} then the following reaction is possible.

$$Fe^{2+}(aq) + Mn^{3+}(aq) \leftrightarrow Fe^{3+}(aq) + Mn^{2+}(aq)$$

and the values for E°suggest that it would indeed proceed to the right (Perrin 1979), this would further reduce the level of Fe in the effluent; this did not appear to have happened here since the soil sediments contained for less Fe than the effluent. The cassava tubers distributed as C_1, C_2 and C_3 consistently had highest concentrations of Mg, Ca, Zn, Cu, Cd, Ca, K and Co which collectively form 61.54% of the minerals determined. These observations agreed with earlier reports that living organisms were capable of biological magnification of mineral elements (Ipinmoroti and Oshodi 1993; Adeyeye 1996; Adeyeye *et al* 1996). Pb was found to be distributed in S_1, E_2 and E_3 where it was majorly concentrated. Pb was 7.69% of the total number of minerals determined while its distribution was 13.0% in soil (S_1) and 87.0% in effluent (E_2 E_3). The observation in Pb was also repeated in a different way in Ni,it was 7.69% of the mineral determined, existing in effluent (E_1 ,E_2) to the tune of 87.0% and cassava tuber (C_3) to the tune of 13.0%. Cr (7.69%) was ND. Mn (7.69%) existed in $S_2 > E_2$ (not determined in cassava tubers); this meant that Mn might be existing in the effluent as Mn^{3+} more than Mn^{2+}, probably because of high pH values.

Table 6 compares the mineral distributions in effluent (E_1,E_2,E_3), soil sediments (S_1,S_2,S_3) and cassava tubers (C_1, C_2, C_3). All the parameters investigated were highly varied among the samples as shown by the CV%, this did not however lead to a tangible difference statistically.

The Federal Republic of Nigeria has set up its own Federal Evironmental Protection Agency (FEPA) which has published an information booklet titled "Interim Guidelines and Standards for Environmental Pollution Control in Nigeria" (FEPA 1991). These are interim guidelines and standards which will be periodically reviewed and updated in the light of new knowledge. Egypt has established Environmental Pollution Control Laws and has been fairly successful in enforcing them and achieving beneficial results (Fano *et al* 1985). Strong emphasis should therefore be placed on public health and education programmes and enlightenment. the current report has tried to open a new field of investigation into textile effluent monitoring by investigating the mineral distribution along the effluent path in both effluent, soil sediments and the surrounding farm crops. Monitoring soil sediments pollution is important because of the possiblitiy of leaching of soil solutions (Ipinmoroti 1993). Planting of cassava or any other crops along the effluent path should be discouraged and completely avoided to escape consuming excessive mineral elements from such sources. It is hoped that this work will give a holistic approach that could influence future control strategies.

References

Adeyeye E I 1994 Determination of trace heavy metals in *Illisha africana* fish and in associated water and soil sediments from some fish ponds. *Intern J Environ Std* **45** 231-238.

Adeyeye E I 1996 Determination of major elements in *Illisha africana* fish, associated water and soil sediments from some fresh water ponds. *Bangladesh J Sci Res XXXI* (3) 171-184.

Adeyeye E I 1997 Water quality criteria and the relationship between the distribution and concentration of some mineral elements in soil sediments, ambient water and the body parts of *Clarias gariepinus* fish in a freshwater pond. *Ghana Journal of Chemistry* **3** (2) 42-50.

Adeyeye E I, Akinyugha N J, Fasobi M E, Tenabe V O 1996 Determination of some metals in *Clarias gariepinus Cyprinus carpio* and *Oreochromis niloticus* fishes in a polyculture freshwater pond and their environments. *Aquaculture* **147** 205-214.

Aina E O A 1989 Current trends in sustainable development and future of the Nigerian environment. *Environmental News* July-September 7-11.

American Public Health Association (APHA) American Water Works Association (AWWA) 1969 *Standard Methods For The Examination Of Water And Sewage Including Bottom Sediments And Sludges,* APHA Inc., New York, 12th ed., pp. 4652, 146-162.

Association of Official Analytical Chemists (AOAC) 1990 *Official Methods of Analysis,* Association of Analytical Chemists, Washington DC, 25th ed.

Biney C A 1991 A method for characterizing natural and waste waters using plant seeds. *Environ Monit Assess* **18** 13-128.

Egboka B C E, Nwankwor G I, Orajaka I P, Ejiofor A O 1989 Principles and problems of environmental pollution of groundwater resources with case examples from developing countries. *Environmental Health Perspectives* **83** 39-68.

Fano E, Brewster M, Thompson T 1985 Water quality management in developing countries, part I. *Proceedings of the 5th World Congress on Water Resources,* Brussels, pp 641-654.

Federal Environmental Protection Agency (FEPA) 1991 *Guide lines and Standards For Environmental Pollution control in Nigeria, FEPA,* Lagos, pp 13-194.

Food and Agriculture Organisation (FAO) 1990 *Roots, Tubers, Plantains and Bananas in Human Nutrition, FAO Food and Nutrition Series* No. 24, Rome, pp 1-118.

Gulp G, Wesner G, Williams R, Hughes Jr, M V 1980 Wastewater reuse and recycling technology, Noyes Data Corporation, New Jersey, pp 116-118.

Hutton L G, Ince M E 1984 Analytical methods manual, Loughborough University of Technology, Loughborough, pp 3-39.

Ipinmoroti K O 1993 Water quality of shallow wells located close to dump sites in Akure, Nigeria. *Pak J Sci Ind Res* **36** (4) 137-141.

Ipinmoroti K O, Oshodi A A 1993 Determination of trace metals in fish, associated water and soil sediments from fish ponds. *Discovery and Innovation* **5** (2) 135-138

Nwankwor G I, Okpala K O 1986 Assessment of the pollution risks in parts of Otamari and Aba river water works, Imo State, Nigeria. Technical report submitted to Imo state, Nigeria, Environmental Sanitation Authrity.

Organisation for Economic Cooperation and Development (OECD) 1975 *Cadmium and the Environment Toxicity, Economy, Control, OECD,* Paris, pp 1-88.

Osibanjo O 1994 Physico-chemical characteristics of effluents from selected Nigerian industries. In: *CIFA Technical paper* 25, FAO, Rome, pp 33-60.

Parker R C 1972 Water analysis by atomic absorption spectroscopy, *Varian techtron,* Switzerland, pp 20-30.

Perrin M B 1979 *An Introduction to the Chemistry of Rocks and Minerals: Studies in Chemistry Number 9,* Edward Arnold Ltd., London, pp 1-82.

Saad M A H, El-Rayis O A, El-Nady F 1981 Occurrence of some trace metals in bottom deposits from Abu-Kir Bay, Egypt. *J Etud Pollut CIEM* **5** 555-560

Steel R G D, Torrie J H 1960 *Principles of Procedures of Statistics.* McGraw-Hill, London, pp 1-481.

Templeton R G 1981 Freshwater fisheries management. Fishing news books Ltd., Farnham, Surrey.

Tortora P G 1987 *Understanding Textiles.* Macmillan Publishing Company, New York, 3rd ed, pp 27-446.

Udo E J, Ogunwale A J 1978 *Laboratory Manual For The Analysis of Soil Plant and Water Samples,* Department of Agronomy, University of Ibadan, pp. 70-76.

Varshney C K 1991 *Water Pollution and Management.* Wiley Eastern Ltd., New Delhi pp 74-93.

Yamagata N, Shigematsu I 1970 Cadmium pollution in perspective. *Bull Int Publ Health* **19** 1-27.