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Physico-chemical and Trace Metal Characterization of Battery Factory Wastewater

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Abstract: The physico-chemical and trace metal analyses of battery factory wastewater were carried out in this study. Samplings were done three times in a period of nine months at settling tank (i.e., before treatment) and at final discharge point (after treatment). High levels of pH, conductivity, Pb, Fe and Zn were observed, which may affect the health of the aquatic ecosystem of the receiving river. The high levels of conductivity, Pb, Fe and Zn may also adversely affect the health of the community that uses the receiving river directly for domestic use without treatment. The treatment technique employed by the factory is grossly ineffective for the removal of Pb, Fe and Zn but effective for removal of Cu and Cd.

Key words: Wastewater, battery, trace metals, physico-chemical

INTRODUCTION

A system and its surrounding are inseparable entities; both exert good and adverse effects on each other. Man as a system cannot be divorced from its surrounding (environment).

The quest of man to exploit his environment to his desired sophisticated standard of living has made him to continuously withdraw and add to his environment. This anthropogenic phenomenon has resulted in the environment deteriorating vastly everyday. The effect is hazardous to man's health and this is becoming a thing of a great concern for man.

The federal government of Nigeria through its agency made it mandatory that effluents be treated to acceptable standards and returned to the watercourse from where the water was originally obtained. Effluent discharge investigation is one of the water quality management tools adopted by Federal Environmental Protection Agency (FEPA) now Ministry of Environment for the management of point-source effluent.

Low pH could be expected from a battery factory wastewater since one of the major raw materials is tetraoxosulphate (IV) acid (H_2SO_4). Low pH values in a river adversely affect aquatic life and impair recreational uses of water (DWAF, 1996a). A change in pH from that normally encountered in unimpaired stream affects the biota (DWAF, 1996a). High pH values could also alter toxicity of water pollutants in the water body. A decrease in pH could also decrease the solubility of certain essential elements. Low pH also increases the solubility many other elements such as Al, B, Cu, Cd, Hg, Mn and Fe (DWAF, 1996a).

Conductivity of water is used as a measure of the total concentration of ionic species or salt content. Wastewater effluents often contain high amounts of dissolved salts. Sources of dissolved salts include windblown sea salt, municipal storm, water drainage and industrial effluent discharges (Morrison *et al*., 2001). Salts such as NaCl and K_2SO_4 pass through conventional water and wastewater treatment plants unaffected (Hammer, 1975). High salt concentrations in waste effluents can increase the salinity of the receiving water, which may result in adverse ecological effects on aquatic biota (Fried, 1991).

The advantage of the BOD parameter is that it is supposed to reflect the presence of materials, which will be oxidized biologically in the receiving water. BOD can be taken as a measure of the concentration of organic matter present in that kind of water (Ademoroti, 1986). The greater the decomposable matter present the greater the oxygen demand and the greater the BOD value. Continuous discharge of the effluent with high BOD into the river may have negative effects on the quality of the fresh water and can as well cause harm to the aquatic life especially fish down streams (Morrison *et al*., 2001).

The accumulation of metals in an aquatic environment has direct consequences to man and to the ecosystem. Some metals like Zn and Cu are needed for metabolism in organisms. Interest in such metals lies in the thin line between their toxicity and essentiality (Spear, 1981). Some metals (e.g., Al, Cd and Pd) are extremely toxic even at trace levels (Merian, 1991).

Cadmium has been found to be toxic to man, fish and other aquatic organisms (Woodworth and Pascoe, 1982). Cadmium has been reported to induce kidney damage in

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man (Herber *et al*., 1988). It is carcinogenic, mutagenic and causes pains in bones (Kjellstroem, 1986; Fischer, 1987; Kazantzis, 1987; Heinrich, 1988).

Copper has been reported to be toxic at very low concentration in water and induces brain damage in mammals (DWAF, 1996a).

Lead is a suspected pollutant in a battery factory effluent because is also a major raw material in the manufacture of lead acid accumulated batteries. Lead at very low concentrations is toxic and hazardous to most forms of life (USEPA, 1986). The chronic effect of Pb on man includes neurological disorders, especially in the foetus and in children. This can lead to behavioral changes and impaired performance in IQ tests (Lansdown, 1986; Needleman, 1987). Though Zinc has low toxicity to man, it has relatively high toxicity to fish (Alabaster and Lloyd, 1980).

The presence of Mn and Fe in water affects aesthetic value of such water because of the colour (Fatoki *et al*., 2002).

The objective of this study is to investigate possible impact of pollution from a battery factory wastewater on ambient environment using physico-chemical parameters-pH, temperature, conductivity, Biochemical Oxygen Demand (BOD) and trace elements as indicators of pollution.

MATERIALS AND METHODS

Wastewater samples were collected from a battery manufacturing factory in southwestern Nigeria. Samples were collected from two points; settling tank and final discharge point. Samples for BOD analysis were collected in BOD bottles and equivalent size white bottles. Wastewater samples for pH, conductivity were collected in 1-litre polyethylene plastic bottles. Samples for trace metal analysis were collected in 100 mL polyethylene plastic bottles. The samples were tightly sealed and kept in the refrigerator before analysis. Three samplings were done for a period of nine months at intervals of three months.

The temperature of wastewater was determined in situ using thermometer. The pH of wastewater was measured with a Griffin model 40 pH meter; the pH meter was standardized before use. BOD values were determined by titrimetric method using standard method. Initial 2% dilution of the wastewater was done prior to incubation. The period of incubation of the BOD tests was 5 days. A Hanna HI 8333 conductivity meter was used to measure the conductivity values of samples. The instrument was calibrated with 0.001 M KCl at 25°C. Trace metals analysis was done using atomic absorption spectrophotometer. The data of the analysis were retrieved from Gateway PC 2000 system using appropriate software.

RESULTS AND DISCUSSION

The results of the effluent analyses for first sampling (Table 1) showed that pH values range from 2.18 to 2.65 at the settling tank and 1.68 to 2.25 at the final discharge point. Temperature maintains a constant value of 26°C at the settling tank and 26.5°C at the final discharge point. Conductivity varies from 200 to 1200 $\mu S\ m^{-1}$ and 1020 to 4500 $\mu S\ m^{-1}$ at the settling tank and at the final discharge point, respectively. BOD value of 5.96 mg L^{-1} was obtained at the settling tank while 3.40 mg L^{-1} was obtained at the final discharge point. The values of Pb, Fe and Zn range from 2.17-5.32, 0.044-0.68 ppm and 0.18-7.27 ppm, respectively at the settling tank and 1.89-4.11, 0.028-11.52 and 0.12-4.85 ppm, respectively at the final discharge point. Concentrations of Mn, Cu and Cd were very low both the settling tank and the final discharge point.

The results of the effluent analyses for second sampling (Table 2) revealed that pH values vary from 3.15-3.75 and 2.20-2.65 at the settling tank and the final discharge point, respectively. Temperature values range from 25.8-26.5°C at the settling tank and 24.00-26.5°C at the final discharge point. Conductivity ranges from 230-448 $\mu S\ m^{-1}$, 1000-2900 $\mu S\ m^{-1}$ at the settling tank and the final discharge point, respectively. BOD values of 16.2 and 11.2 mg L^{-1} were obtained at the settling tank and the final discharge point, respectively. The values of Pb, Fe and Zn vary from 5.38-6.82, 0.36-2.17, 0.037-0.107 ppm, respectively at the settling tank and 1.72-2.52, 1.96-11.3, 0.083-0.138 ppm, respectively at the final discharge point. Concentrations of Mn, Cu and Cd were very low at both settling tank and final discharge point.

The results of effluent analyses for the third sampling (Table 3) showed that pH values range from 2.75-3.25, 2.62-2.86 at the settling tank and the final discharge point, respectively. Temperature values vary from 2.80-29.00°C, 26.00-28.8°C at the settling tank and the final discharge point, respectively. Conductivity values vary from 250-500 $\mu S\ m^{-1}$ at the settling tank and 1350-3500 $\mu S\ m^{-1}$ at the final discharge point. BOD values of 57.2 and 99.0 mg L^{-1} were obtained at the settling tank and the final discharge point. Pb, Fe, Zn and Mn concentrations range from 1.94-2.95, 0.20-1.73, 0.14-4.64, 0.13-0.402 ppm, respectively at the settling tank and 1.79-3.62, 2.72-3.15, 0.065-0.106, 0.55-0.111 ppm, respectively at the final discharge point. Concentrations of Cu and Cd were still very low.

Table 1: Effluent analyses for the first sampling data

	Settling tank			Final discharge point		
	ST(A)	ST(B)	ST(C)	AT(A)	AT(B)	AT(C)
pH	2.65	2.2	2.18	1.68	2	2.25
Temp. (°C)	26	26	26	26.5	26.5	26.5
Cond. (nS m^{-1})	200	1080	1200	4500	1200	1020
BOD (mg L^{-1})		5.96			3.4	
Pb (ppm)	5.32	2.17	2.46	1.89	2.47	4.11
Fe (ppm)	0.68	0.044	0.078	11.52	0.028	0.087
Zn (ppm)	0.18	5.076	7.27	0.12	3.64	4.85
Mn (ppm)	ND	ND	ND	ND	ND	ND
Cu (ppm)	0.032	ND	0.021	ND	ND	ND
Cd (ppm)	0.013	0.012	ND	ND	ND	ND

Table 2: Effluent analyses for the second sampling data

	Settling tank			Final discharge point		
	ST(A)	ST(B)	ST(C)	AT(A)	AT(B)	AT(C)
pH	3.25	3.75	3.15	2.65	2.45	2.2
Temp. (°C)	26.5	25.8	25.8	26.5	26	24
Cond. (nS m^{-1})	300	230	448	1050	1000	2900
BOD (mg L^{-1})		16.2			11.2	
Pb (ppm)	5.74	6.82	5.38	2.52	1.79	1.72
Fe (ppm)	0.36	2.17	ND	2.03	1.96	11.3
Zn (ppm)	0.037	0.037	0.107	0.111	0.138	0.083
Mn (ppm)	ND	ND	0.63	ND	ND	0.13
Cu (ppm)	ND	ND	ND	ND	ND	ND
Cd (ppm)	ND	ND	ND	ND	ND	ND

Table 3: Effluent analyses for the third sampling data

	Settling tank			Final discharge point		
	ST(A)	ST(B)	ST(C)	AT(A)	AT(B)	AT(C)
pH	2.8	3.25	2.75	2.62	2.86	2.65
Temp. (°C)	28	28	29	26	26.5	28.8
Cond. (nS m^{-1})	250	300	500	3500	1350	3200
BOD (mg L^{-1})		57.2			99	
Pb (ppm)	1.94	2.42	2.95	2.15	1.79	3.62
Fe (ppm)	0.803	1.73	0.2	3.15	3.15	2.72
Zn (ppm)	0.14	4.54	4.24	0.106	0.065	0.092
Mn (ppm)	0.402	0.13	0.16	0.095	0.111	0.55
Cu (ppm)	0.015	ND	ND	ND	ND	ND
Cd (ppm)	ND	ND	ND	ND	ND	ND

Table 4: Summary of the battery factory wastewater analyses

	Settling tank		Final effluent	
Parameter	Range	Mean	Range	Mean
pH	2.18-3.75	2.89±0.51	1.68-2.86	2.63±0.51
Temp. (°C)	25.8-29.0	26.8±1.21	24.0-28.8	26.4±1.22
Cond. (µS m^{-1})	200-1200	500±376.6	1000-4500	2191.1±1339.2
BOD (mg L^{-1})	5.96-57.2	26.5±27.1	3.4-99.0	37.82±53.1
Pb (ppm)	1.94-6.82	3.91±1.88	1.72-4.11	2.45±0.86
Fe (ppm)	ND-2.17	0.67±0.78	0.3-11.52	3.99±4.26
Zn (ppm)	0.04-7.27	2.40±2.85	0.07-4.85	1.02±1.85
Mn (ppm)	ND-0.63	0.147±0.23	ND	0.55±0.18
Cu (ppm)	ND-0.03	0.03	ND	ND
Cd (ppm)	ND-0.01	0.01	ND	ND

The averaged pH values at the settling tank and at the final discharge point (Table 4) indicate that the effluents are highly acidic, with their pH values being much below the FEPA limit of 6-9 for battery factory effluents. Since pH is a function of hydrogen ion concentration (i.e., pH = -log [H^+]). The high acidity was probably due to the high concentration of hydrogen ion [H^+] in the effluent, sourced mainly by Sulphuric acid-one of the major raw materials in lead acid battery manufacture. The aquatic life in the receiving stream will be adversely affected at low pH. Figure 1 is the histogram of parameters analyzed for in the first sampling. It revealed

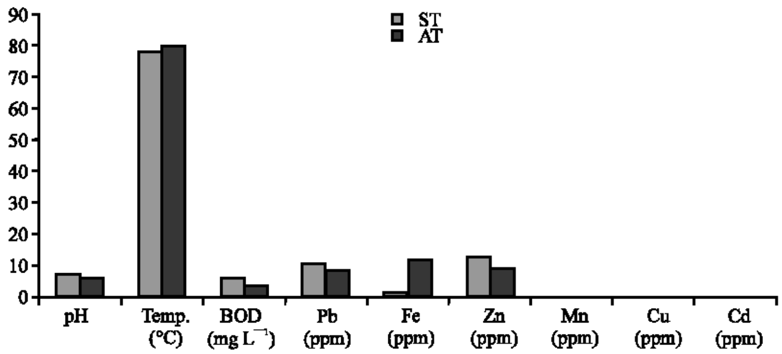

Fig. 1: Histogram representation of the analytes in first sampling

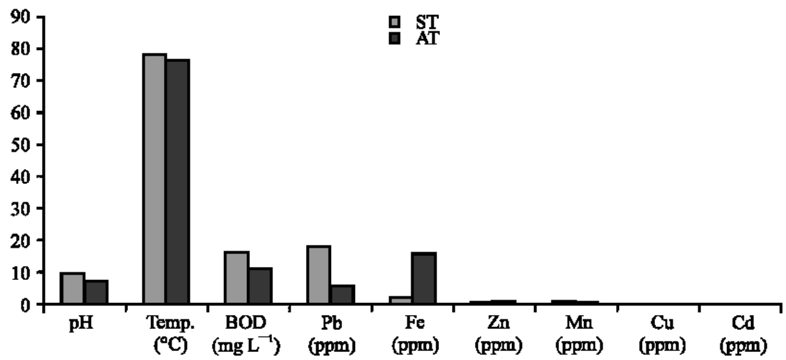

Fig. 2: Histogram representation of the analytes in second sampling

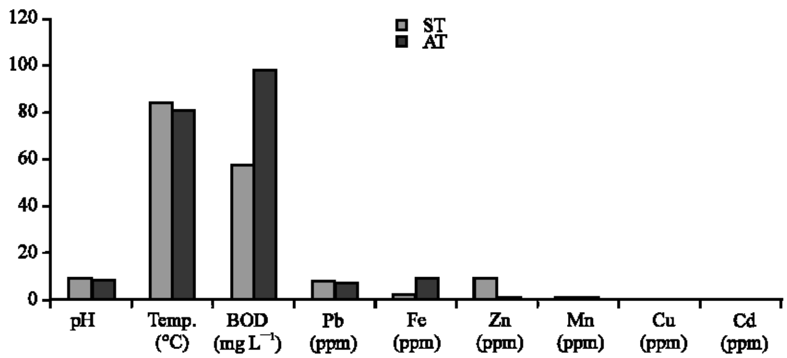

Fig. 3: Histogram representation of the analytes in third sampling

that averaged pH value at settling tank is higher than at final discharge point. The results of second and third samplings (Fig. 2 and 3) have the same trend. This suggests that the treatment plant is not effective for reduction of acidity of the effluent.

The averaged temperature values of the effluents at the settling tank and at the final discharge point (Table 4) are less than FEPA limit of 40°C.

The averaged conductivity values at the settling tank and at the final discharge point are high. Though, there is no FEPA specified guideline for conductivity value, the South African guideline for conductivity in effluent that will be discharged into the river is 250 μS m^{-1}. The effluent conductivity values are above this acceptable limit. Conductivity of water is an easy indicator of its salinity or total salt content (Morrison *et al*., 2001). The high conductivity values (i.e., high salt concentrations) in the effluents can increase the salinity of the receiving river, which may result in adverse ecological effects on the aquatic biota. Such high salt concentrations hold potential health hazard (WHO, 1979). There is a slight reduction of conductivity values (Fig. 4-9) at both settling

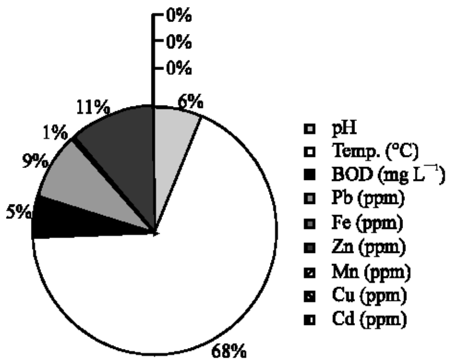

Fig. 4: Relative abundance of the analytes at settling tank in first sampling

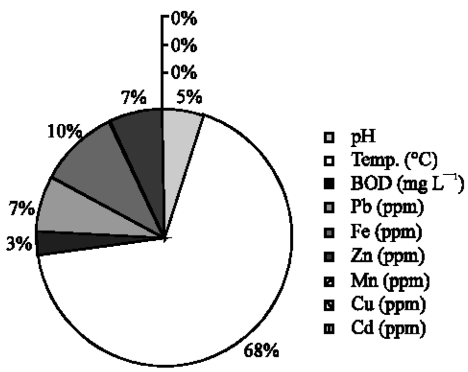

Fig. 5: Relative abundance of the analytes at final discharge point in first sampling

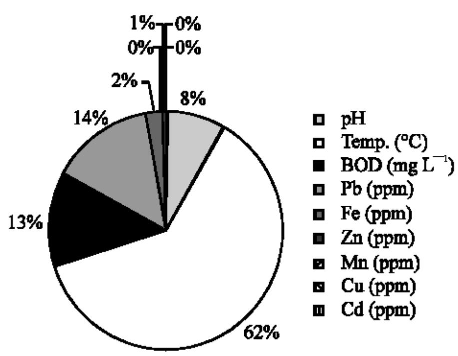

Fig. 6: Relative abundance of the analytes at settling tank in second sampling

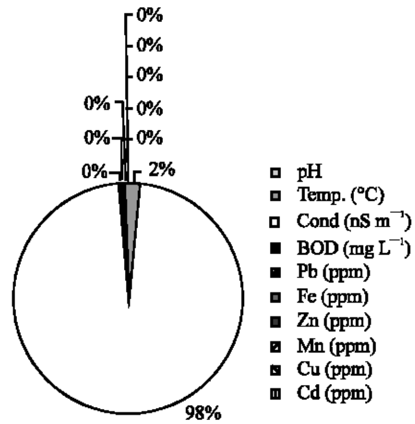

Fig. 7: Relative abundance of the analytes at final discharge point in second sampling

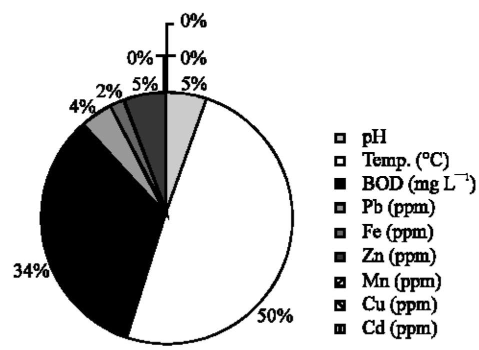

Fig. 8: Relative abundance of the analytes at settling tank in third sampling

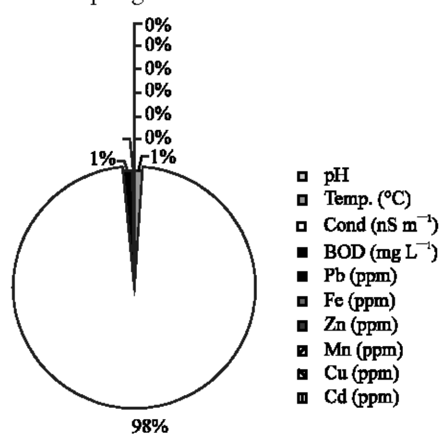

Fig. 9: Relative abundance of the analytes at final discharge point in third sampling

tank and final discharge point. This indicates that the treatment plant is not efficient for significant removal of total salt content.

There was a progressive increase in the BOD values (Table 1-3, Fig. 1-3) from first sampling through the third sampling. Though, the averaged values at the settling tank and at the final discharge point are below FEPA limit of 50 mg L^{-1} for industrial effluents, it is still considered high and hazardous for survival of the aquatic biota in the receiving stream (Alloway and Ayres, 1993). The BOD values at the third sampling were ten (10) times higher than the values in the first sampling. This indicates that biodegradable substances in the effluent have increased considerably. The histogram representations (Fig. 1-3) of the analytes in the wastewater samples indicate that there is a reduction of biodegradable substances from settling tank to final discharge point in the first and second samplings. It was vice versa in the third sampling. It is quite coincidental that the treatment plant became inefficient for the removal of biodegradable substances when the load of these substances suddenly increased astronomically.

The averaged lead levels in the effluent at the settling tank and at the final discharge point (Table 4) are above FEPA limit of 0.01 mg L^{-1}. At levels greater than 100 μg L^{-1}, possible neurological damage in foetus and young children may occur (DWAF, 1996b). These levels were exceeded in the effluent; direct use of water from the receiving river for domestic purposes without treatment could be detrimental to young children in the vicinity of the catchments. The receiving river also would not be suitable for maintenance of the aquatic ecosystem (Fatoki *et al*., 2002).

Concentrations of Fe at the settling tank and at the final discharge point exceeded FEPA limit for Fe of 0.02 mg L^{-1} in industrial effluent. This implies that the receiving river may have taste, colour and other aesthetic problems (DWAF, 1996a; Fatoki *et al*., 2002).

The averaged levels of Zn at the settling tank and at the final discharge point (Table 4) exceeded specified South African limit for Zn in water for aquatic ecosystem of 2 μg L^{-1}. Thus, the receiving river will not be suitable for the maintenance of the aquatic ecosystem.

There is no FEPA specified limit for Mn in industrial effluent. The averaged values of Mn at the settling tank and at the final discharge point exceeded the South Africa guideline for Mn 0.05 mg L^{-1} in water for domestic use (DWAF, 1996a).

The concentrations of Cu at the settling tank and at the final discharge point are low (Table 4). This shows that the treatment process is effective for the removal of Cu.

The levels of Cd at the settling tank and at the final discharge point are low (Table 4). The shows that the treatment plant is also effective for the removal of Cd.

The concentrations of the metals except Fe were more at settling tank than at final discharge point (Fig. 1-3) for the first and second samplings. This indicates that the treatment plant was slightly effective for the removal of these metals up to the time of the second sampling. At the third sampling the efficiency of the treatment plant for the removal of Pb, Fe and Mn has reduced to near zero, but was still efficient for the removal of Zn, Cu and Cu.

CONCLUSIONS

Temperature, Mn, Cu and Cd levels were below guideline values. However, high levels were observed for Pb, Fe and Zn, which may be hazardous to the health of the receiving aquatic ecosystem. The high levels of Pb and Zn may have adverse effects on the health of the community in the vicinity of the receiving river that uses the river water directly for domestic use without treatment. The treatment technique employed in the factory is not effective for pH, conductivity, Pb, Fe and Zn. The treatment plant needs to be overhauled and upgraded to improve its treatment performance.

Battery factory effluents pose environmental risk if not properly treated before discharge to the receiving stream.

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