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Evaluation of the Effects of Brewery Effluents Disposal on Public Water Bodies in Nigeria

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ABSTRACT

Investigation of the effect of brewery industries effluents disposal on their surrounding surface and ground waters were carried out. Four brewery industries at different locations in Benin, Ibadan and Lagos were selected for the study. The water samples were subjected to laboratory analysis to determine variation in physical, chemical and elemental components of the samples. The results of the groundwater parameters examined tended to fall within the Federal Ministry of Environment and Urban Development (FMEUD) and World Heath Organization (WHO) recommended standard values. The results of the surface waters when compared with National (FMEUD) and International (WHO) permissible limits for aquatic ecosystems indicated that the physicochemical condition of the streams located at Agidingbi, Alaka, Ona and Ossioma have been influenced by the various pollutants.

Keywords: brewery effluents, groundwaters, physicochemical, stream, surface waters

INTRODUCTION

Surface and ground waters are important sources of drinking water. Surface waters offer economic support for agricultural irrigation process and cooling waters for power plants, chemical, steel, breweries, mining and other industrial operation. Many people, particularly the rural population, get their household water supplies from underground sources. Groundwater is also used for a large proportion of industrial water needs. Both surface and ground waters are highly susceptible to contamination. Surface water has been the most convenient sewer for industries and municipalities. One of the pollutants in particular, oxygen-demanding wastes, has been such a pervasive surface water problem as they affect fish and other aquatic life (USEPA 1992). The pathogens, nutrients, heavy metals and volatile organic compounds adversely affect human and other living things. Unlike surface water, groundwater contamination is through percolation and migration of pollutants by way of soil into it; but usually undetected until when it is used.

Industries such as food and beverages, breweries, metal works, petroleum refinery, soap and detergents, textiles, paints, chemicals and plastics, etc. produce various effluents that are discharged into the environment. The pollutants from these effluents have been identified as being responsible for major health and environmental problems such as motor neurone disease (Iwani *et al.* 1994; Adenuga *et al.* 2006), reproduction disorders (Mantovani 1993) and cardiovascular diseases (Clayton 1976). In 1956, cases of minamata disease were reported in Japan (Ui Jun 1969, 1992). The disease affects the field of vision, hearing and speech. In extreme cases causing insanity, paralysis, coma and death (Ui Jun 1969) as a result of pollution of water by the release of methyl mercury in the industrial effluents from a chemical factory. In Nigeria there were cases of outbreak of mercury poisoning when a number of people ate bread made from wheat which had been treated with alkyl mercury as a fungicide (Ademoroti 1996).

Heavily populated cities like Lagos, Port Harcourt, Ibadan, Kaduna, Benin, Kano, etc. are mostly feeling the effect of pollution from industrial effluent discharged into the public water body. Although most of the multinational companies in Lagos and Port Harcourt have effluent pretreatment plants, they do not have primary, secondary and tertiary treatment facilities and most often the effluent discharged from these plants do not meet the Federal Ministry of Environment and Urban Development (FMEUD); or even the in-house effluent limits.

With the ever increasing pressure for both statutory and environmental source to reduce pollution to a minimum possible, it has become more necessary for effective treatment of various brewery effluents before discharge into any surrounding water body. In the light of this background the objective of this study was to evaluate the effects of brewery effluents disposal on the public water body by the three major brewery industries in Nigeria at their different locations.

MATERIALS AND METHODS

Study areas

The study areas cover the surrounding streams of four major brewery industries: Nigeria Brewery Plc located near Alaka stream in Ijora, Lagos and the Ibadan branch located near Ona stream, Alakia in the North east part of Ibadan, Guinness Nigeria Plc located near Agidingbi stream in Ikeja, Lagos and Benin branch located near Ossioma stream along Warri-Sapele road, Benin. The areas covered by these brewery industries are within different ecosystems.

Sample preservation and storage

Samples were collected at different locations along the course of the streams. The choice of locations was based on the ease of access to the streams. A total of six samples were collected at upstream, effluent stream intersection and downstream during dry and wet season over a period of two years. The sampling stations from each of the stream course are as indicated in the study area maps (**Fig. 1**). The samples were taken in acid washed 500 ml

Received: 3 August, 2008. Accepted: 9 October, 2008.

Original Research Paper

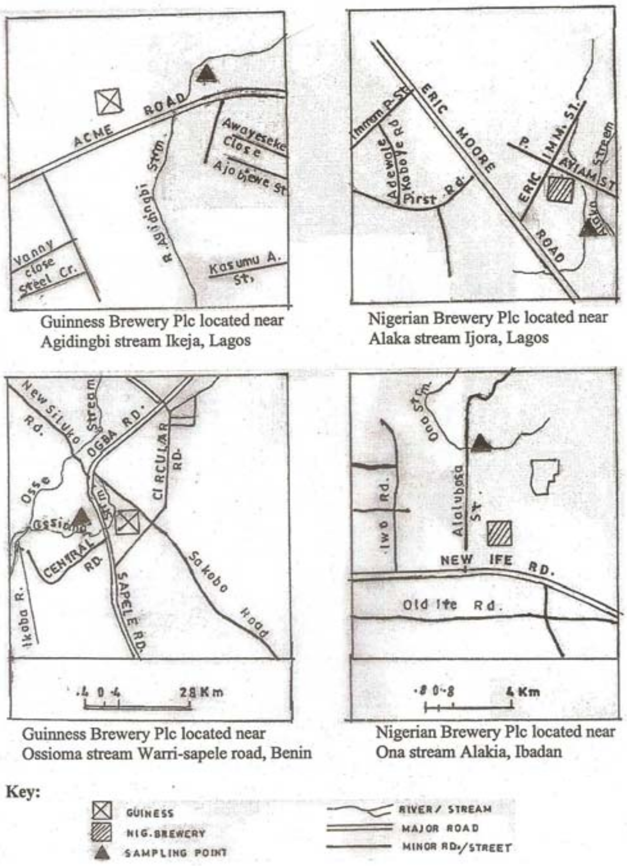

Fig. 1 Maps of the study area showing sampling sites around Guinness Brewery at Ikeja Lagos and Benin and around Nigerian Brewery at Ibadan and Ijora Lagos.

polythene kegs. Prior to collection, 2 ml of 40 mg/l mercuric chloride was added to each sample keg as a biocidal preservative. Samples collected were filled completely to eliminate air and hence inhibit aerobic biological action. At least two replicate samples were taken each time. For trace metal analyses, samples were collected in 50 cm^3 plastic bottles which has been previously soaked in 10% nitric acid for two days and thoroughly rinsed with distilled water. About two drops (3 ml analytical grade nitric acid per litre of sample) of nitric acid (pH < 2.0) were added to each sample, sealed in double polyethylene bags, kept in ice chests and taken to the laboratory where they were further preserved in a refrigerator before analysis. This was to ensure stability of the sample, maintain the oxidation state of the element and prevent metals from adhering to the walls of the container.

Water parameters (pH, conductivity, temperature and dissolved oxygen) were measured in situ. Samples for dissolved oxygen (DO) were collected in 300 Winkler bottles and preserved with 2 ml manganous sulphate and 2 ml of an alkali iodide azide of sodium solution. Samples for nutrients (nitrate and others) were stored frozen at 4°C. Samples for Biochemical Oxygen Demand (BOD) were collected in 250 ml brown BOD bottles and sealed to exclude air bubbles and then incubated in the laboratory for five days before analysis.

Method of analysis

The analyses were carried out using different standard methods to obtain parameters in **Tables 1** and **2**. For physico-chemical analysis of effluent; Temperature (thermometer); pH (WTW-pH 90 electronic meter, sensitivity ± 1.0%); Dissolved Oxygen (Winkler titration); Total Suspended Solids (TSS) Spectrophotometric determination according to HACH; Chemical Oxygen Demand (COD) Potassium dichromate oxidation and titmetry. Biochemical Oxygen Demand (BOD) was measured as the difference between initial oxygen concentration in sample and concentration after 5 days incubation in BO bottles at 20°C (APHA 1995). Zn, Mn, Fe, Cu, and Cr concentrations were determined using an Atomic Absorption Spectrophotometer, AAS model 2380.

All chemicals used were of analytical grade procured from BDH Chemicals Ltd., England and deionised water was used throughout the experimentation to ensure acceptable data quality. The methods of analysis are as specified in Standard Methods for Examination of Water and Wastewater (APHA 1995).

RESULTS AND DISCUSSION

The results of physico-chemical analysis of the surface and ground water samples are presented in **Tables 1** and **2**. These include the concentration levels of metals in the studied public water body. The tables show the mean, range and standard deviation of values of each parameter during the period of sampling compared with the Federal Ministry of Environments and Urban Development (FMEUD) and the World Health Organization (WHO) recommended standards.

The mean temperature value range from 26.4 to 27.2°C for surface waters while that of ground water ranged from 25.6 to 26.6°C. The observed lower temperatures at Ona stream, Ibadan and Ossioma stream, Benin could be partially related to the effect of shaded trees which preclude direct sun radiation along the stream course, this is a common phenomenon in tropical waters.

The results obtained for pH varied from 5.9 and 6.89. The mean pH value of Agidingbi stream, Lagos was 5.9 while pH value for Alaka stream, Lagos, Ona stream, Ibadan and Ossioma stream, Benin were 6.54, 6.37 and 6.89, respectively. However, the pH value in the study areas are within allowable limits for surface waters. The pH value of Agidingbi streams is the lowest and below the permissible limit which indicates it is acidic. This could be as a result of both industrial discharges and domestic waste disposal along the course of the stream.

The conductivity in the study ranged from 11.2 to 18.84 µs/cm for surface waters. The lowest value is that of Ona stream, Ibadan with 11.2 µs/cm while the highest is 18.84 µs/cm in Alaka stream, Lagos. The groundwater conductivity values ranged from 13.32 to 20.03 µs/cm. The conductivity values obtained in these study areas for both surface and groundwaters depict low corrosion potential and are within WHO acceptable limit. The low conductivity values suggest low total dissolved solids levels in boiling and cooling water of the demineralised section of the brewery industries.

The alkalinity of these study streams lie between 204.8 and 265.5 mg/l while that of groundwaters is 59.99 and 60.18 mg/l. The values obtained for both surface waters and groundwaters are within WHO permissible limit for alkalinity.

The results for total hardness show a variation of between 134.3 and 147.4 mg/l for surface waters 80.66 and 111.8 mg/l for groundwaters. Hardness is highest in Ossioma stream, Benin with a value of 147.4 mg/l, lowest in Alaka stream Lagos with a value of 134.3mg/l. It is highest in groundwater near Ona stream, Ibadan with a value of 111.8 mg/l and lowest in groundwater near Ossioma stream, Benin with a value of 80.66 mg/l. These values are below FMEUD and WHO permissible limit. However, the low hardness values are an indication that the groundwater in the study areas can be classified as soft being less than the regulated standard by WHO (**Table 1**).

Total suspended solids had a mean concentration ranged between 119.4 and 123.1 mg/l for surface waters. The observed high concentration of total suspended solids approaching permissible limits in surface waters at Ona and Ossioma stream are pointers to the fact that there are intense anthropogenic activities along the course of these streams.

The mean concentration of Chemical Oxygen Demand (COD) is 91.69 mg/l for Ossioma stream, Benin; 85.2 mg/l for Ona stream, Ibadan; 63.96 mg/l for Agidingbi stream, Lagos and 55.84 mg/l for Alaka stream, 67.11 mg/l Lagos.

Table 1 The mean values of physico-chemical and metals analysis of selected streams used as sewer by some breweries in Benin, Ibadan and Lagos.

	LOCATIONS							
	Ossioma Stream, Benin			**Ona Stream, Ibadan**				
Parameters	**Mean**	**St. Dev.**	**Range**	**Mean**	**St. Dev.**	**Range**	**FMEnv**	**WHO**
pH	6.887	0.656	1.31	6.27	0.057	0.1	6-9	6.5-8.5
Temperature (°C)	26.53	0.636	0.9	26.4	0.778	1.1	< 40	
Conductivity (us/cm)	13.17	0.417	0.59	11.2	0.431	0.9		400
Turbidity (FTU)	6.667	0.354	0.5	5.933	0.141	0.2		5
Acidity (mg/l)	3.55	0.173	0.3	3.867	0.636	1		
Alkalinity (mg/l)	260.8	0.799	5.39	265.5	7.566	10.7		500
Total hardness (mg/l) $CaCO_3$	147.4	1.237	10.9	140.3	6.329	10.16		500
Total Solids (mg/l)	502.2	7.757	11	492.2	5.551	106.92		1000
Total Suspended Solids (mg/l)	123.1	0.368	1.76	122.4	0.665	3.5		-
Total Dissolved Solids (mg/l)	562.2	2.341	5.8	567.2	8.351	17.56	2000	1500
Biochemical Oxygen Demand (mg/l)	51.55	0.431	1.57	51.27	1.909	2.7	50	< 40
Chemical Oxygen Demand (mg/l)	91.69	0.156	2.24	85.2	3.231	4.57	80.1	80
Dissolved Oxygen (mg/l)	1.36	0.552	1.41	1.23	0.177	1.19	7.5	7.5
Chloride (mg/l)	73.35	2.128	13.4	70.83	1.188	3.57	600	600
Nitrate (mg/l)	2.057	0.099	0.21	1.77	0.247	0.35	20	10
Sulphate (mg/l)	4.117	0.325	0.46	5.043	0.064	0.16	500	400
Metals								
Zinc (mg/l)	1.847	14.2	0.17	1.7	0.141	0.2		5
Manganese (mg/l)	BDL	BDL	BDL	0.047	0.014	0.03	5	0.5
Iron (mg/l)	1.383	0.092	0.42	1.153	0.035	0.11		0.3
Copper (mg/l)	0.176	0.008	0.1	0.121	0.016	0.022	<1.0	1.0
Chromium (mg/l)	0.027	0.007	0.01	0.027	0.007	0.01	<1.0	0.05
	LOCATIONS							
	Alaka Stream. Lagos			**Agidingbi Stream, Lagos**				
Parameters	**Mean**	**St. Dev.**	**Range**	**Mean**	**St. Dev.**	**Range**	**FMEnv**	**WHO**
pH	6.537	0.455	0.63	5.9	0.071	0.5	6-9	6.5-8.5
Temperature (°C)	26.97	0.778	1.1	27.167	0.707	1	< 40	
Conductivity (us/cm)	18.84	0.127	0.6	17.043	0.191	0.5		400
Turbidity (FTU)	5.333	1.414	2	6.8	0.424	0.6		5
Acidity (mg/l)	4.167	0.495	0.7	3.8167	0.035	0.6		
Alkalinity (mg/l)	204.8	5.091	98.1	205.91	4.914	97.92		500
Total hardness (mg/l) $CaCO_3$	134.3	1.471	2.08	137.64	1.294	11.81		500
Total Solids (mg/l)	450.9	9.369	85.15	55.79	48.63	97.07		1000
Total Suspended Solids (mg/l)	119.4	0.035	3.7	120.34	0.339	3.85		-
Total Dissolved Solids (mg/l)	566.1	14.56	35.19	518.57	39.23	85.21	2000	1500
Biochemical Oxygen Demand (mg/l)	43.08	2.029	5.38	41.82	0.266	0.53	50	< 40
Chemical Oxygen Demand (mg/l)	55.84	0.552	1.95	63.96	2.947	5.84	80.1	80
Dissolved Oxygen (mg/l)	1.25	0.608	1.24	1.2567	0.586	1.17	7.5	7.5
Chloride (mg/l)	70.09	4.087	9.13	75.077	8.887	13.24	600	600
Nitrate (mg/l)	2.777	0.184	0.39	2.6367	0.06	0.12	20	10
Sulphate (mg/l)	6.897	0.106	0.64	6.2333	0.322	0.63	500	400
Metals								
Zinc (mg/l)	1.25	0.745	1.16	0.95	0.269	0.48		5
Manganese (mg/l)	0.117	0.106	0.15	BDL	BDL	BDL	5	0.5
Iron (mg/l)	0.437	0.304	0.58	0.4333	0.459	0.84		0.3
Copper (mg/l)	0.457	0.304	0.49	0.6833	0.163	0.32	<1.0	1.0
Chromium (mg/l)	0.023	0.007	0.01	0.02	3E-10	0	<1.0	0.05

* BDL = Below Detection Level

The mean COD concentration at Ossioma and Ona stream indicated that the brewery effluents in these areas are highly polluted with both oxidizable organic and inorganic pollutants. Also the low Dissolved Oxygen (DO) concentration could be ascribed to waste discharges high in organic matter and nutrient along the course of the streams.

Biochemical Oxygen Demand (BOD) concentration ranged between 41.82 and 51.55 mg/l for surface waters. The lowest value is that of Agidingbi stream, Lagos with 41.82 mg/l while the highest is 51.55 mg/l for Ossioma stream, Benin. The mean high BOD concentrations in these public water bodies is an indication of high concentration of biodegradable organic substances. Also the increase in concentration of BOD within the study areas could be related to effluent high in degradable organic matter from brewery and unregulated domestic dumpsities along the course of the streams in Benin and Ibadan.

The locational variation in concentration of trace metals namely; iron, manganese, zinc, copper and chromium in the surface waters and groundwaters for the period of study are presented in **Tables 1** and **2**, respectively. Iron was dominant in all the water samples with Ossioma stream, Benin having the highest value of 1.383 mg/l and Agidingbi stream, Lagos having the least value of 0.433 mg/l. The values are well above the permissible level of 0.3 mg/l for Iron (Fe). The variations and high iron concentration across study areas could be as a result of anthropogenic inputs, as also demonstrated in the result of Valdes *et al.* (2005). Metals, namely Mn, Zn, Cu and Cr have values much lower than WHO and FMEUD permissible limits. In some study areas like Agidingbi river, Lagos and Ossioma stream, Benin manganese concentrations were either low or below detection limit of the instrument. However, because a metal concentration in the aquatic environment is low and considered to be naturally occurring does not mean that the concentration could not cause adverse ecological effects (USEPA 1992; Korfali and Davies 2004; Adenuga *et al*. 2007). The presence of one metal can significantly affect the impact that another metal may have on an organism. The effect can be synergistic or antagonistic (Eisler 1993).

Table 2 The mean values of physico-chemical and metals analysis of selected groundwater around brewery study areas in Benin, Ibadan and Lagos.

	LOCATIONS					
	Ground Water Sample, Benin			Ground Water Sample, Ibadan		
Parameters	**Means**	**St. Dev.**	**Range**	**Means**	**St. Dev.**	**Range**
pH	6.79	0.067	0.23	6.843	0.028	0.09
Temperature ^{0}C	26.6	0.115	0.4	26.33	0.088	0.3
Conductivity (us/cm)	16.9	0.09	0.31	13.32	0.211	0.73
Alkalinity (mg/l)	59.99	0.053	0.18	63.44	3.285	10.01
Total hardness (mg/l) $CaCO_3$	80.66	5.202	17.97	111.8	4.402	14.95
Total Solids (mg/l)	245.3	1.453	5	245	2.082	7
Total Dissolved Solids (mg/l)	325	2.309	8	351	0.882	3
Chemical Oxygen Demand (mg/l)	9.04	1.233	0.14	10.13	0.139	0.48
Chloride (mg/l)	4.74	0.057	0.19	3.773	0.103	0.35
Nitrate (mg/l)	0.047	0.002	0.007	0.065	0.002	0.006
Sulphate (mg/l)	3.503	3.503	0.03	3.117	0.061	0.21
Metals						
Zinc (mg/l)	0.173	0.012	0.04	0.33	0.012	0.04
Manganese (mg/l)	0.03	3E-10	0	0.038	0.001	0.005
Iron (mg/l)	0.377	0.009	0.03	0.177	0.003	0.01
Copper (mg/l)	0.46	0.006	0.02	0.603	0.003	0.01
Chromium (mg/l)	0.013	0.003	0.01	0.01	1E-10	0
	LOCATIONS					
	Ground Water Sample, (Alaka) (Lagos)			**Ground Water Sample (Agidingbi), Lagos**		
Parameters	**Means**	**St. Dev.**	**Range**	**Means**	**St. Dev.**	**Range**
pH	7.15	0.029	0.1	6.923	0.079	0.27
Temperature ^{0}C	25.83	0.296	1	25.6	0.153	0.5
Conductivity (us/cm)	18.97	0.176	0.6	20.03	0.176	0.6
Alkalinity (mg/l)	72.92	0.826	2.85	80.18	1.699	5.45
Total hardness (mg/l) $CaCO_3$	85.78	2.754	8.33	84.64	5.705	49.76
Total Solids (mg/l)	302.1	4.116	13.8	268.6	5.077	17
Total Dissolved Solids (mg/l)	252	3	9	243.3	4.485	15
Chemical Oxygen Demand (mg/l)	5.417	5.417	0.54	7.02	0.015	0.05
Chloride (mg/l)	8.29	0.195	0.6	9.09	0.111	0.36
Nitrate (mg/l)	0.756	0.017	0.06	0.724	0.023	0.07
Sulphate (mg/l)	2.82	0.335	1.02	2.403	0.003	0.01
Metals						
Zinc (mg/l)	0.22	0.006	0.02	0.24	0.006	0.02
Manganese (mg/l)	BDL	BDL	BDL	BDL	BDL	BDL
Iron (mg/l)	0.153	0.003	0.01	0.183	0.003	0.01
Copper (mg/l)	0.537	0.009	0.03	0.447	0.009	0.03
Chromium (mg/l)	0.02	2E-10	0	0.02	2E-10	0

* BDL = Below Detection Level

The chloride concentrations in the study areas ranged 70.09 to 75.08 mg/l with a mean value of 70.09 mg/l for Alaka stream, Lagos; a mean value of 70.83 mg/l for Ona stream, Ibadan. Chloride concentration in Ossioma stream, Benin is 73.35 mg/l while that of Agidingvi stream Lagos is 75.08 mg/l. These values are within the acceptable limit of 250 mg/l. The chloride content of groundwater may be due to the presence of salt water intrusion especially in Lagos.

Nitrate concentrations in the study areas ranged 1.77 to 2.78 mg/l for surface waters and 0.047 to 0.756 mg/l for groundwaters. The nitrate levels in both surface waters and groundwaters are within the acceptable limits of less than 10 mg/l. These findings are consistent with the established fact that nitrate levels in groundwater which exceed the WHO limits are not common (O'Neil *et al*. 1992; Smith and Sabone 1994; Stuart *et al*. 1995). High level of nitrate water may induce methaemoglobinaemia in infants less than six months old (Campbell and Forbes 1994).

All sulphate values of surface waters and groundwaters within the study areas are within the acceptable limit 250 mg/l. The sulphate concentration range 4.12 to 6.90 mg/l for surface water; and 2.40 to 3.50 mg/l for groundwater.

CONCLUSION

This study reveals that the parameter values in all the study areas for groundwaters are below FMEUD and WHO permissible limit and classify the water as unpolluted. The surface waters are generally characterized by pH in the range within FMEUD and WHO permissible limits. The values of total suspended solids (TSS), Chemical Oxygen Demand (COD) for Ona stream, Ibadan and Ossioma stream, Benin are above FMEUD and WHO permissible limits while the values for Alaka and Agidingbi streams in Lagos are low and within acceptable limits. The Biological Oxygen Demand (BOD) and trace metal Iron (Fe) levels in Ona stream, Ibadan, Ossioma stream, Benin, Alaka and Agidingbi streams, Lagos are above maximum permissible limits for aquatic ecosystem by FMEUD and WHO. This indicates that the physicochemical condition of the rivers have been influenced by the various pollutants. The consequence of the pollution in the study areas could lead to habitat destruction and alteration of species diversity. It is imperative therefore that breweries and other industries along the course of study streams, (Ona, Ossioma, Alaka and Agidingbi) in Ibadan, Benin and Lagos should set up effective measures using the best available technology to treat their effluents before discharge to the natural receptors.

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