Assessment of Toxicity of Effluents Discharged into Waterways by Some Industries in Nigeria: A Case Study of Ibadan.

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ABSTRACT

To assess the toxicity of certain discharged effluents and their potential impacts on the receiving water bodies in Nigeria, and in Ibadan as a case study, a whole effluent toxicity (WET) test was carried out on the effluents of five industries within Ibadan Metropolis. There has been a great concern about the level of safety of surface and underground waters, especially in developing countries where there is an exponential increase in water pollution and an inefficient system of waste management. Hence, there is the need for continual research on the impact of pollution on the aquatic ecosystem. In this investigation, juveniles of *Clarias gariepinus* (African catfish) were used as the experimental organisms. They were cultured in 100% of each effluent and subsequently in water dilution of 80%, 50%, 20% and 10% effluent concentrations for 96 hours. The mortality of the organisms were measured, and the lethal concentration fifty (LC_{50}) of each effluent was estimated by graphical method. Two of the effluents tested were found to be acutely toxic with LC_{50} of 12.5% and 15%, respectively. The other three effluent samples were found to be non-acutely toxic with LC_{50} greater than 100%.

(Keywords: whole effluent toxicity test, WET, *Clarias gariepinus*, African catfish, lethal concentration, LC_{50})

INTRODUCTION

As indicated in the latest issue of the *Directory of Industries* published in Nigeria by the Federal Ministry of Industry, there are over three thousand industrial establishments existing in the country, with various process technologies, scope, nature of products, and characteristics of the wastes discharged. At present, the major industrial categories with very obvious and considerable features include metals and mining; food, beverages and tobacco; breweries, distilleries and blending of spirits; textiles; tanneries; leather products; wood processing and manufacture; and chemical and allied industries. All these industries are associated with one type of effluent or the other.

Industrial effluent is a term used to describe liquid waste resulting from industrial activities. These effluents usually contain varying levels of organic and inorganic compounds, depending on their sources. The characteristics of industrial effluents vary widely across and within the same industry; the main determinants being the nature of raw materials used, physical and chemical processes employed, and various other factors. Most industries discharge their effluents into water bodies such as rivers, streams, lakes, etc. The major concern about these effluents is that if discharged untreated, they may exhibit acute or chronic toxic effects on organisms in the receiving water bodies and result in ecological damage. One of the major visible indicators of water pollution is fish kill, which could mean a massive death of fish and other aquatic organisms in a water body (Wittman, 1983).

To determine the actual impacts of effluents on organisms in the receiving water, a whole effluent toxicity test is required. Whole effluent toxicity test is defined as the aggregate toxic effect of an effluent measured directly by an aquatic toxicity test (US EPA, 1993). The test employs a suit of standardized fresh water, marine, and estuarine plants, invertebrates, and vertebrates to estimate acute and short-term chronic toxicity of effluents and receiving waters. Laboratory-reared aquatic organisms are exposed to various dilutions of

effluents for a specific time period, in order to predict at what levels the effluent may cause harm to the organisms. The fish (African catfish) *Clarias gariepinus* has been used as a test organism in many aquatic bioassays because of its hardiness, sensitivity to change in water quality and because it is present in most Nigerian fresh water and therefore it is representative of the indigenous population present in the possible area of impact of the effluent (Olaifa et al., 2003).

This work seeks to assess the acute toxicity of some industrial effluents discharged into the Ona River in Ibadan, predict the likely impacts of these effluents on organisms in the receiving waters, and recommended actions to be taken to reduce any present or potential impact.

MATERIALS AND METHODS

Sampling of the effluents was carried out at about 12 noon which was the peak production time for the industries observed. A grab sample of each effluent type was collected into plastic containers at the point of discharge. The effluent samples and type of industries from where they were obtained are given in Table 1.

Table 1: The Effluent Samples and Type of Industries.

Effluent Sample	Type of Industry
A	Plastic manufacturing
B	Confectioneries
C	Soft drink
D	Confectioneries
E	Brewery

The physico-chemical parameters of the effluents observed include pH, temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), lead, and cadmium concentrations. The temperature was measured with mercury-in-glass thermometer. The DO of the effluent was determined by the Winkler's method, while the pH was determined using universal indicator paper having a range of 1-14. Heavy metal – Pb and Cd concentrations were determined using an atomic absorption spectrophotometer; and the BOD was determined by the dilution method (APHA, 1992).

The experimental organism, *Clarias gariepinus,* juveniles were purchased from a reputable fish farm in Ibadan. The average weight and length of fish used for the experiment were 6g and 5cm, respectively. The fish were allowed to acclimatize for four weeks, and were inspected for general fitness. Water was changed every other day. The fish were fed with commercial fish pellets at 3-5% body weight. Feeding was discontinued during the 96-hour test period.

A 96-hour WET test (US EPA, 2002b) was carried out using the juveniles of *Clarias pariepinus* to assess at what levels the effluent may cause harm (death) to the organisms after an exposure period of 96 hours.

Six juveniles were randomly introduced into test bowls containing ten liters of undiluted effluent for each of the five effluent samples. There were two replicates for each of the effluent samples. A control in which the same number of test organism was introduced into a bowl containing dechlorinated water was set up. The treatment group and the control were allowed to stand for 96 hours and they were monitored every six hours. After 96 hours, the number of mortalities for each treatment group and control were noted. For effluent samples in which less than 50% mortality of test organism was observed, the test was discontinued and no further dilution of effluent was carried out; the LC_{50} was taken to be greater than 100%. For effluent samples in which test organism mortality was more than 50%, a dilution of the effluent with dechlorinated water to reduce the concentration to 80% was carried out, and the test was repeated. Further dilution of the effluent concentration to 50%, 20%, and 10% was done until an effluent concentration that produced less than 50% mortality in the population of the test organisms was reached. The LC_{50} of the effluents was determined by graphical method (US EPA, 2002b).

RESULTS AND DISCUSSION

Table 2 shows the results of WET test with the organisms for effluent A. Mortality was 0, and survival was 100%. For effluent B, as shown in Table 3, mortality ranged from 2 to 6 (that is, 33.3-100% mortality), and 0 (100% survival) for control. Similar to the observations for effluent A, Table 4 shows the results of observation of WET test for effluent C in which mortality was 0 (that is, 100% survival).

Table 2: Results of WET Test with *Clarias gariepinus* for Effluent A.

Effluent Concentration (%)	Mortality out of 6 Juveniles	Average Mortality	% Survival	% Mortality
100 (1)	0			
100 (2)	0	0	100.0	0.0
Control (1)	0			
Control (2)	0	0	100.0	0.0

Note: Number in parenthesis indicates replication.

Table 3: Results of WET Test with *Clarias gariepinus* for Effluent B.

Effluent Concentration (%)	Mortality out of 6 Juveniles	Average Mortality	% Survival	% Mortality
100 (1)	6			
100 (2)	6	6	0.0	100.0
80 (1)	6			
80 (2)	6	6	0.0	100.0
50 (1)	6			
50 (2)	6	6	0.0	100.0
20 (1)	6			
20 (2)	6	6	0.0	100.0
10 (1)	2			
10 (2)	2	2	66.7	33.3
Control (1)	0			
Control (2)	0	0	100.0	0.0

Note: Number in parenthesis indicates replication.

Table 4: Results of WET Test with *Clarias gariepinus* for Effluent C.

Effluent Concentration (%)	Mortality out of 6 Juveniles	Average Mortality	% Survival	% Mortality
100 (1)	0			
100 (2)	0	0	100.0	0.0
Control (1)	0			
Control (2)	0	0	100.0	0.0

Note: Number in parenthesis indicates replication.

Effluent D (Table 5) brought about 100% mortalities (0% survival). Figures 1 and 2 illustrate the %survival of the organisms against effluent B and D concentrations, respectively.

Table 6 shows the results of WET test with the organisms for effluent A. Mortality was 0, and survival was 100%.

The results of analysis of the physico-chemical parameters of the effluents are given in Table 7. The temperature ranged from 19 to 21^{o}C; pH, 7 to 10; DO, 1.40 to 2.30mg/l; BOD, 1.20 to 28.90 mg/l; Pb, 0.02 to 0.96 mg/l; and Cd, 0.001 to 0.014 mg/l. Table 8 shows the estimated toxicity endpoint of the effluent, ranging from 12.5% to >100%.

When the *Clarias gariepinus* juveniles were cultured in effluent A for 96 hours, no mortality was observed; the experimental organisms survived the test. According to the WET test guidance (US EPA, 2000), the test was discontinued since the LC_{50} was greater than 100%; that is, the raw effluent without dilution was not acutely toxic to the test organism.

Table 5: Results of WET Test with *Clarias gariepinus* for Effluent D.

Effluent Concentration (%)	Mortality out of 6 Juveniles	Average Mortality	% Survival	% Mortality
100 (1)	6			
100 (2)	6	6	0.0	100.0
80 (1)	6			
80 (2)	6	6	0.0	100.0
50 (1)	6			
50 (2)	6	6	0.0	100.0
20 (1)	6			
20 (2)	6	6	0.0	100.0
10 (1)	0			
10 (2)	0	0	100.0	0.0
Control (1)	0			
Control (2)	0	0	100.0	0.0

Note: Number in parenthesis indicates replication.

Table 6: Results of WET Test with *Clarias gariepinus* for Effluent E.

Effluent Concentration (%)	Mortality out of 6 Juveniles	Average Mortality	% Survival	% Mortality
100 (1)	0			
100 (2)	0	0	100.0	0.0
Control (1)	0			
Control (2)	0	0	100.0	0.0

Note: Number in parenthesis indicates replication.

Table 7: The Physico-Chemical Parameters of the Effluents and Control Water.

Sample	Temperature (^oC)	pH	DO (mg/l)	BOD (mg/l)	Pb (mg/l)	Cd (mg/l)
Control water	20	7	2.30	1.20	0.02	0.001
A	21	9	2.20	22.5	0.82	0.007
B	19	8	1.40	28.90	0.42	0.005
C	20	10	2.25	10.90	0.45	0.011
D	20	8	1.94	24.70	0.96	0.014
E	21	11	2.20	2.40	0.46	0.004

Table 8: Estimated Toxicity Endpoint of the Effluent.

Effluent	LC_{50}
A	>100%
B	12.5%
C	>100%
D	15%
E	>100%

When the organism was cultured in effluent B for 96 hours, all the six experimental organisms died within 10 minutes. The effluent was further diluted to 80%; this also resulted in the death of the six organisms within 20 minutes. A further dilution to 50% was done, and it as well resulted in the death of the six. The same thing was observed when diluted to 20%. Four of the organisms survived when diluted to 10%. The survival of the organisms increased with increasing dilution (Figure 1). The LC_{50} of the effluent obtained from the graph was 12.5%.

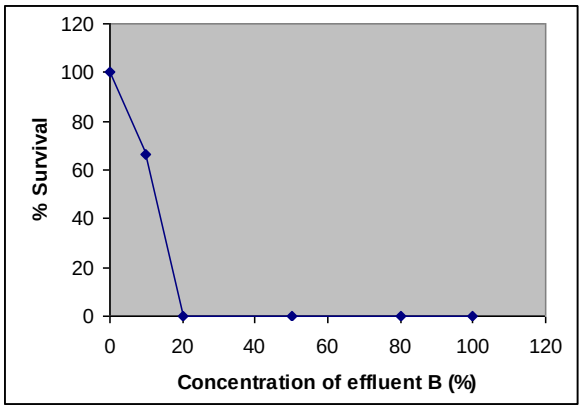

Figure 1: Percentage Survival of *Clarias gariepinus* against Effluent B Concentration (96 hours LC_{50} by Arithmetic Method: LC_{50} is 12.5%)

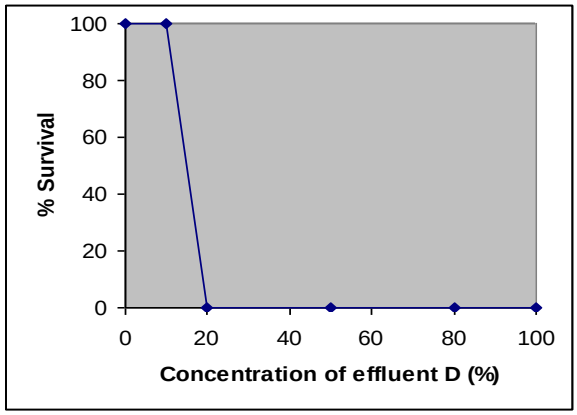

Figure 2: Percentage Survival of *Clarias gariepinus* against Effluent D Concentration (96 hours LC_{50} by Arithmetic Method: LC_{50} is 15%)

In effluent C, when the organisms were cultured for the same period of time, no mortality was observed; the experimental organism survived the test; the test was discontinued.

When cultured in effluent D, all the organisms died within 15 minutes. The effluent was further diluted to 80%; this as well resulted in the death of the six 20 minutes. Dilution to 50% resulted in the death of the six within 4 hours. 100% mortality was still observed on dilution to 20%; while 100% survival was observed when diluted to 10%. The survival increased with increasing dilution of the effluent (Figure 2). The LC_{50} obtained from the graph was 15%.

The clue to high mortality of the experimental organisms in effluents B and D could perhaps be drawn from the status of the physico-chemical parameters shown in Table 7. The two effluent types had similar pH (8), lowest DO (1.40 and 1.94 mg/l) and highest BOD (28.90 and 24.70 mg/l). However, further research is suggested to establish this.

CONCLUSION

Whole effluent toxicity tests were carried out to determine the actual impacts of effluents on organisms residing in receiving waters where the effluents were discharged. Three of the effluent samples (A, C, and E) were found to have a LC_{50} greater than 100%; which means at full strength, without dilution, these effluents are incapable of causing mortality of 50% or more in the population of the experimental organisms. However, two of the effluent samples (B and D) had LC_{50} of 12.5% and 15%, respectively, meaning that the two effluent samples exhibit a substantial acute toxic effect on the experimental organisms and may cause harm to organisms in the receiving water. It is recommended that a toxicity investigation evaluation (TIE) which will result in identification of the compounds responsible for toxicity be carried out.

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SUGGESTED CITATION

Adewuyi, G.O., J.O. Babayemi, and A.A. Olabanji. 2010. "Assessment of Toxicity of Effluents Discharged into Waterways by Some Industries in Nigeria: A Case Study of Ibadan". *Pacific Journal of Science and Technology*. 11(2):538-543.

Pacific Journal of Science and Technology