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Full Length Research Paper

Toxicity assessment of treated effluents from a textile industry in Lagos, Nigeria

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Water pollution caused by industrial effluent discharges has become a worrisome phenomenon due to its impact on environmental health and safety. Textile industries contribute immensely to surface water deterioration and are categorized among the most polluting in all industrial sectors. For this reason, the toxicity of treated textile effluent was assessed in *Celossia argentea* by exposing them to effluent-polluted surface water from Ibeshe River. In the present study, parameters investigated includes, growth, photosynthetic pigment content, lipid peroxidation, and metal accumulation. The results showed that treated textile effluent from Nichemtex Company, affected the growth, dry biomass, root development and photosynthetic pigment content of *C. argentea*. The treated effluent caused 41% growth inhibition while the total chlorophyll decreased by 59.87% in relation to the control plants. Furthermore, it also elevated the levels of lipid peroxidation and heavy metals in the plant. It was therefore implicated that treated textile effluent entering Ibeshe River could cause toxic effects on organisms. It was emphasized that using the water for irrigation and as portable water in its present state is unsafe.

Key words: Textile effluent, toxicity, surface waters, growth inhibition, *Celosia argentea.*

INTRODUCTION

Industrial effluents are undesirable by-products of economic development and technological advancement. When improperly disposed off, they imperil human health and the environment. Effluents from textile industries are complex mixtures of chemicals varying in quantity and quality. These industries can generate both inorganic and organic waste mixed with waste waters from the production processes, which leads to change in both biological and chemical parameters of the receiving water bodies (Gomez et al., 2008).

Conventional water quality parameters such as chemical oxygen demand and suspended solids may not detect toxic compounds present in a variety of industrial wastewaters and treated wastes, and chemical procedures alone cannot provide sufficient information on the potential harmful effects of chemicals on the environment (Sacan and Balcioglu, 2006). Sometimes, the treated effluent does not exceed the discharge limits but the results of toxicity tests show potential toxicity (Lin et al., 1994). It has been established that some chemicals are not totally removed because the conventional technology of treatment used in wastewater treatment plants seems to be insufficient for the complete removal of these compounds (Ternes, 1998). Thus, the toxic effects of substances in complex mixtures like textile effluents can be best evaluated through toxicity testing.

The key environmental issues associated with textile industry are water use, treatment and disposal of aqueous effluent. As in the case of Nichemtex Company in Ikorodu, the treated effluents are being discharged through drainage channels into the Ibeshe stream which subsequently affects the water quality of the stream. Depending on the dosage and exposure period, the effluents could be poisonous to plants, aquatic life and humans.

In many developed countries, toxicity tests on industrial effluents are required to ensure that such discharges will not have adverse effects on the environment (Whitehouse and Dijk, 1996). In Nigeria, environmental

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regulations on pollution control of industrial discharges and other pollutants are enforced by the Federal Environmental Protection Agency (FEPA) which relies on conventional physicochemical procedures.

Lagos is highly populated and there are quite a number of industries distributed across the city, a development that has put the city under serious pressure in terms of environmental safety. Consequently, the city and its environs have witnessed environmental degradation leading to decreased biodiversity and extinction of many sensitive organisms. Most of the industries in Lagos State do not control their wastewater effluents by processing, waste recycling or end-of-pipe treatment. Thus, effluents with some levels of toxic substances are being discharged into the environment.

Pollution of natural waters with waste effluents arising from various industries has become a serious problem in Lagos, as industrial growth and development have been on the increase. In Ikorodu axis of Lagos, textile mills represent an important economic sector. Nichemtex is a famous textile industry located in Ikorodu, Lagos and is well known for the production of textile materials in large quantities. Due to the nature of its operations which requires large volume of water, most of the wastewater generated ends up in the nearby Ibeshe stream thereby altering its natural state as regard quality.

The ecological and toxicological problems resulting from the discharge of wastewaters from this industry into drainage that ends up in Ibeshe stream has been the most important water pollution problems in this area. This problem is further aggravated because some residents in Ikorodu depends directly on this stream as source of water both for drinking and other domestic purposes. In addition, local farmers particularly, vegetable growers, use the water from this stream directly for irrigation purposes. Consequently, there is likelihood that toxicants from this wastewater may affect plants, enter the food chain and affect a larger human population. Thus, this work aims to evaluate the toxicity of treated effluent of textile industry using *Celosia argentea* as a model plant. The plant is a popular leafy vegetable consumed largely by the people in Lagos, Nigeria.

MATERIALS AND METHODS

Sample collection and treatment

Water samples were collected from two sites in Ibeshe stream, Ikorodu, Lagos into clean plastic containers. Site 1 was the point where the effluent flows into the stream while site 2 which served as the control was 100 m upstream from the discharge point. The water sample was immediately evaluated in its crude natural state for physicochemical variables.

Seeds of *C. argentea* were obtained from Institute of Agricultural Research and Training (IAR&T), Ibadan, Nigeria in a single batch and enough for the study. Seeds were planted on a sandy-loam nursery bed (1.5 m × 7 m) at the University of Lagos Botanic garden. The nursery bed was kept moist by adding water when necessary. Seedlings were allowed to grow on the nursery for 3 weeks after germination to enable them attain an appreciable height range of 6 to 8 cm. Seedlings of uniform height (7 cm) were selected and transplanted into plastic buckets containing sandy-loam soil. Four seedlings were planted in each bucket and each individual seedling was observed. The buckets containing the seedlings were then placed in a greenhouse and treated with 1 L effluent water sample every 3 days up to 3 weeks while the control plants received equal amount of water devoid of effluent. At the end of the treatment period, plants were harvested and various parameters were evaluated. All analyses were replicated 4 times unless otherwise stated.

Root growth measurement

Uprooted plants were thoroughly washed with clean water and the main root length was measured. Also, root architecture was visually examined.

Dry weight determination

Harvested plants were washed thoroughly in a running tap water to remove soil particles. After rinsing with distilled water, they were placed in labeled paper bags and oven dried at 80°C for 72 h. The dried samples were weighed using a digital top loading weighing balance (Mettler AE 100) to determine the dry weight.

Growth inhibition was then calculated in relation to the control mean:

$$\% \text{ inhibition} = 100 \times \left(1 - \frac{\lambda_{\text{treated}}}{\lambda_{\text{control}}}\right)$$

Determination of total chlorophyll

For the determination of pigment variation due to textile effluent treatment, only the leaves were used. Plant leaves (150 mg) were ground in 15 ml 80% acetone in the dark. After centrifugation at 4000 g for 5 min, the absorbance of the supernatant was read at 645 and 663 nm (Arnon, 1949). The total chlorophyll content was calculated using the formula given by Machlachlan and Zalik (1963).

Lipid peroxidation

Lipid peroxidation was measured by estimation of the malondialdehyde (MDA) content following a modified procedure of Wang and Jin (2005). Fresh leaves (300 mg) were homogenized in 3 ml 20% trichloroacetic acid (TCA). The homogenate was centrifuged at 10000 g for 5 min. The supernatant (1 ml) was mixed with equal volume of 0.6% (w/v) thiobarbituric acid solution comprising 10% TCA. The mixture was incubated for 30 min in a boiling water bath and cooled quickly on ice bath. The absorbance of the mixture was read at 450, 532 and 600 nm. The concentration of MDA was calculated as 6.45 (A_{532}-A_{600})-0.56 A_{450}.

Metal content in leaves

About 2 g of the dried samples were weighed individually into a porcelain dish and ashed in a furnace at 550°C. The ashed sample was transferred into quartz digestion vessel and 20 ml of conc. HNO_3 was added and heated to near dryness. It was refluxed with 15 ml of 20% HNO_3. After cooling, the digest was filtered through

Table 1. Characterization of the water sample from Ibeshe River polluted with treated effluent from a textile industry in Lagos compared with FEPA standards.

S/N	Parameters	Mean levels detected	FEPA standards
1	pH	8.46	6 - 9
2	Turbidity (FTU)	69.25	-
3	Conductivity (µs/cm)	1677.3	7000
4	TDS	821	2000
5	TSS	54.3	40
6	Cl^-	65.5	500
7	SO_4^{2-}	15.50	300
8	NO_3^-	21.27	20
9	NH_3^-	0.21	4.0
10	CN^-	5 .03	0.05
11	PO_4^{3-}	3.37	5.0
12	BOD_5	64.25	40
13	COD	138.75	200
14	Cu	17.73	0.2
15	Zn	54.71	2.0
16	Pb	0.08	0.1
17	Cr	3.04	0.1
18	Ni	0.24	0.2

All units are in mg/L, except for pH and where noted otherwise.

Whatman No. 1 filter paper into 25 ml volumetric flask and adjusted to volume with 2% HNO_3. Metal concentrations were determined using Atomic Absorption Spectrophotometer (AAS).

Statistical analysis

The experiment was set up with a randomized block design. The data were expressed as mean values with standard error (SE). One-way analysis of variance (ANOVA) was used to assess the significance of the effects of the treated effluent on the plant. Statistical analysis was performed with the SPSS 15.0 software package and *p* values < 0.05 were considered significant.

RESULTS

Physicochemical characteristics of the water sample

The results of physicochemical variables of the water sample are as shown in Table 1 together with the limit values accepted by the regulatory authority in Nigeria. The water sample's BOD_5, Cu and Zn levels were found to be higher than the reference standards, hence violating the discharge limits. The biochemical oxygen demand (BOD_5) was 64.25 mg/L; copper, 17.73 mg/L; and zinc, 54.71 mg/L.

Growth

The effects of the treated textile effluent on the root growth of *C. argentea* are shown in Figure 1 and Figure 2. The root growth of *C. argentea* was markedly affected by the textile treated effluent. At the end of the experiment period, the control plants exhibited a primary root length of 6.43 ± 0.46 cm while the treated plants had a mean value of 4.36 ± 0.25 cm, a difference that was significant at $p< 0.05$. In the same vein, there was a distinct difference in the root architecture between the control plants and those that received treated effluents. The roots of the control plants appeared thicker with more numerous lateral roots compared to the treated plants (Figure 2). The dry weight data clearly showed that treated effluent had significant inhibitory effects on *C. argentea* as the treated plants accumulated less biomass compared to the control plants (Figures 3 and 4). The treated effluent caused 41% growth inhibition in *C. argentea* relative to the control plants.

Effect on chlorophyll contents

Treated textile effluent showed a significant inhibitory effect on the total chlorophyll content in *C. argentea* (Figure 5). The total chlorophyll in the treated plants decreased by 59.87% in relation to the control plants.

Lipid peroxidation

To determine the membrane damage caused by the treated textile effluent, the MDA content was evaluated in leaves of *C. argentea*. At the end of the experiment, it

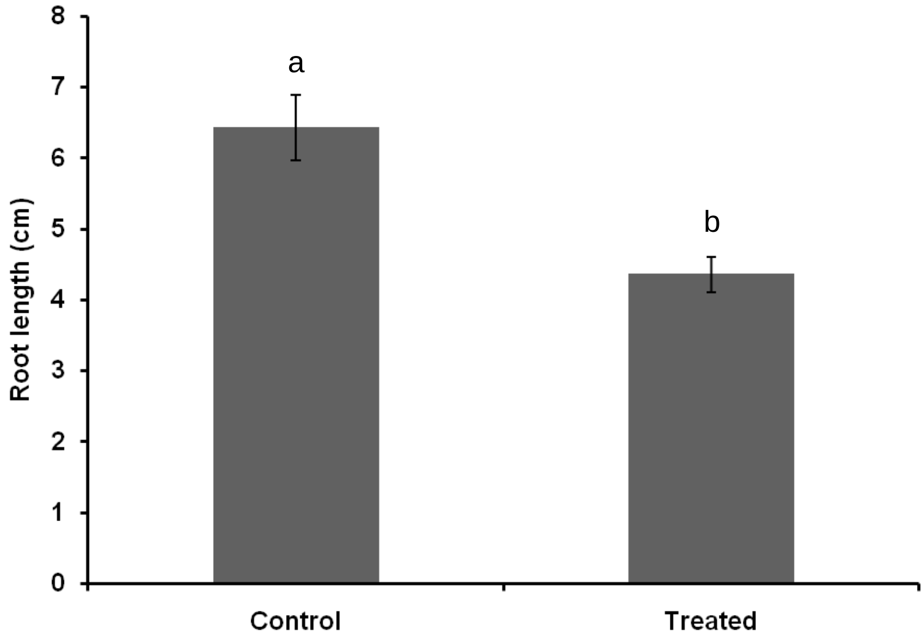

Figure 1. Effects of treated textile effluent on the root length of *Celosia argentea*. All the values are the mean of four replicates ± SE. ANOVA significant at $p < 0.05$. Columns with different letters are significantly different.

Figure 2. Differences in root architecture of *Celosia argentea* between the control (A) and the treated (B).

was observed that exposure treated textile effluent significantly affected the MDA content (Figure 6). It was determined that *C. argentea* exposed to treated textile effluent had higher MDA content, as compared to the control. A mean value of 9.63 ± 0.37 µmol g^{-1} f.wt was observed in plants that received the treated textile effluent, as compared to 5.86 ± 0.48 µmol g^{-1} f.wt observed in the control.

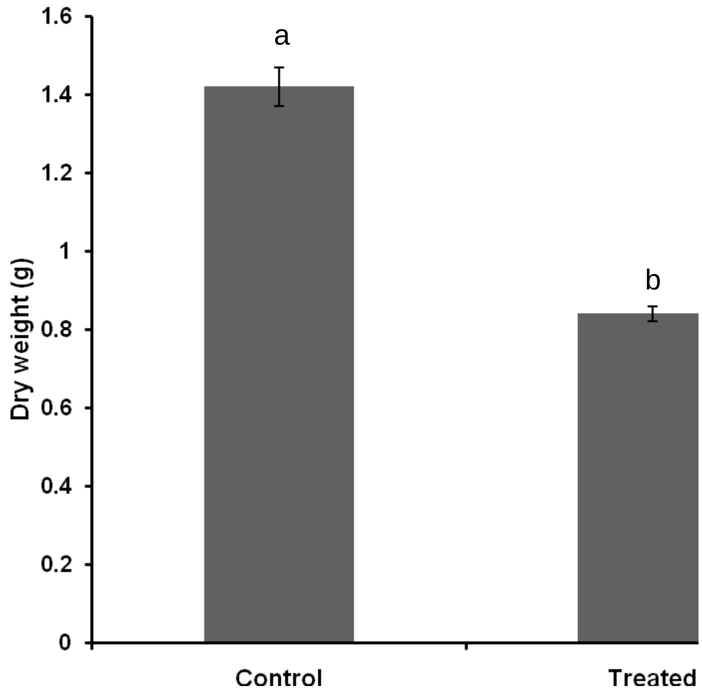

Figure 3. Effects of treated textile effluent on the dry weight of *Celosia argentea*. The values are the mean of four replicates ± SE. ANOVA significant at $p < 0.05$. Columns with different letters are significantly different.

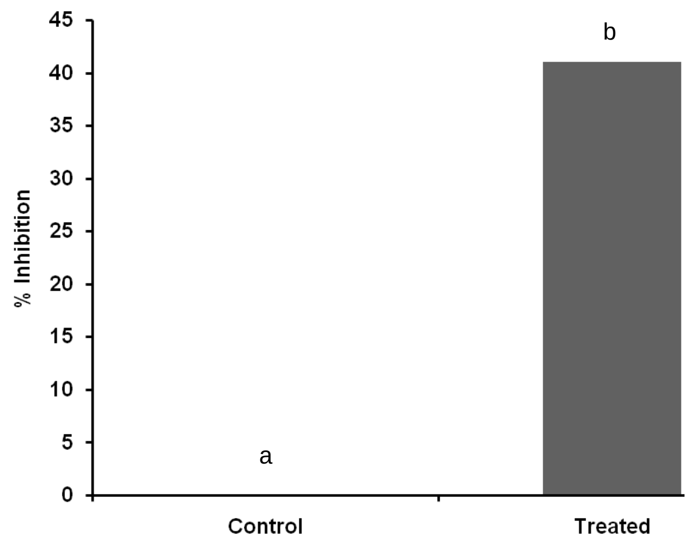

Figure 4. Growth inhibition (%) of *Celosia argentea* exposed to treated textile effluent. The values are the mean of four replicates ± SE. ANOVA significant at $p < 0.05$. Columns with different letters are significantly different.

Metal accumulation

The concentrations of Cu and Zn in plant tissues significantly increased following exposure to treated textile effluent. The treated plants showed elevated levels of Cu and Zn which were 0.198 ± 0.005 and 0.165 ± 0.002 µg g^{-1} d wt, respectively, compared to the control plants which respectively had 0.01 ± 0.002 and 0.006 ±

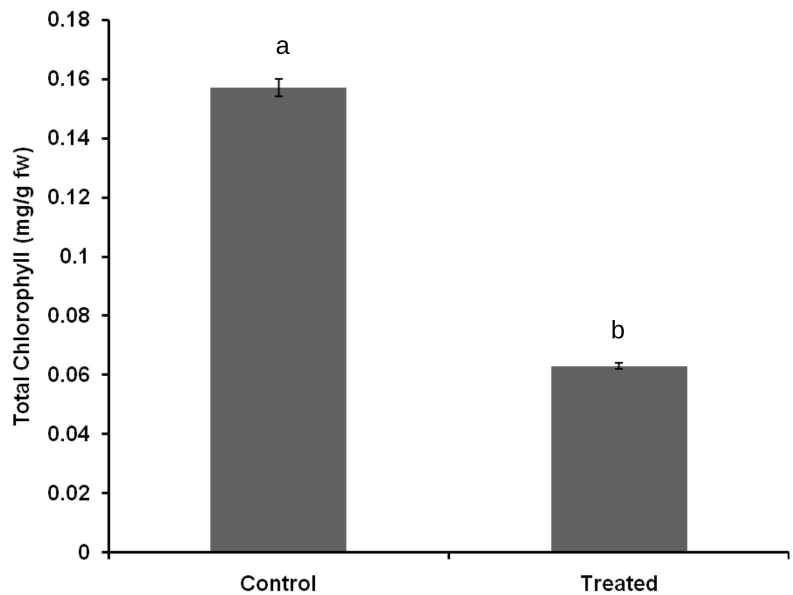

Figure 5. Effects of treated textile effluent on the total chlorophyll in the leaves of *Celosia argentea*. All the values are the mean of four replicates ± SE. ANOVA significant at $p < 0.05$. Columns with different letters are significantly different.

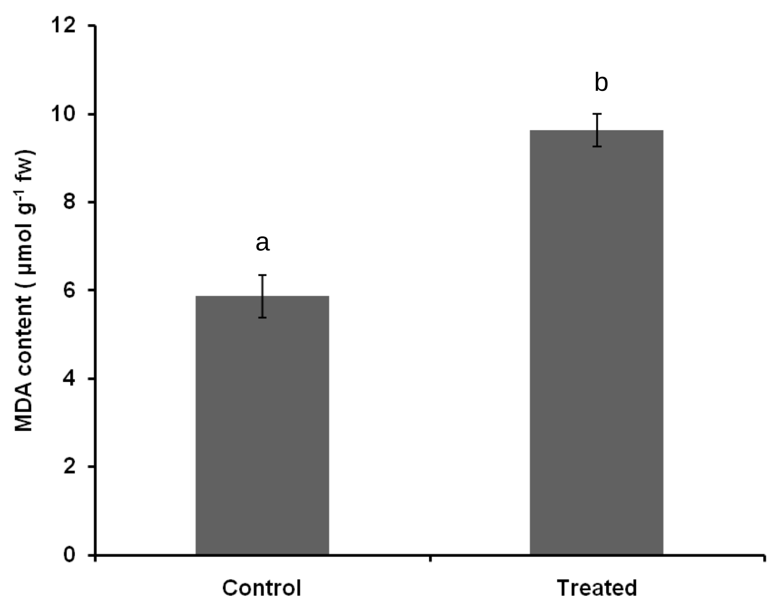

Figure 6. Malondialdehyde (MDA) content in leaves of *Celosia argentea* exposed to a treated textile effluent. The values are the mean of four replicates ± SE. ANOVA significant at $p < 0.05$. Columns with different letters are significantly different.

0.0005 µg g^{-1} d wt (Figure 7).

DISCUSSION

The present study demonstrates that treated textile effluent water sample affected growth, biomass, photosynthetic pigment, and membrane integrity of *C. argentea*. The results implied that treated textile effluent in Ibeshe River might cause bio-toxicity on organisms. Growth inhibitory and low chlorophyll content in plants has been reported in separate studies involving *Triticum*

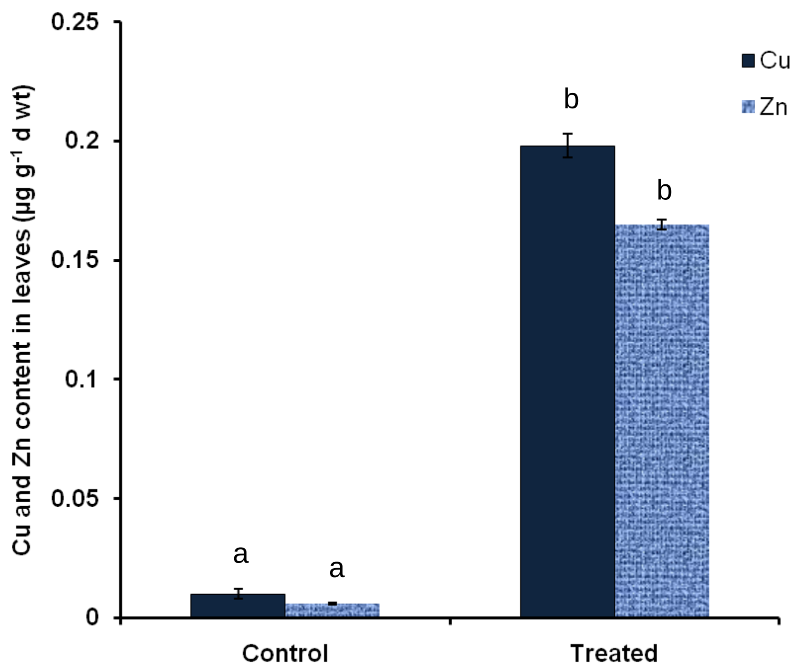

Figure 7. Copper and zinc content in leaves of *Celosia argentea* exposed to a treated textile effluent. The values are the mean of four replicates ± SE. ANOVA significant at $p < 0.05$. Columns with different letters are significantly different.

aestivum (Khan and Jain, 1995) and Zea *mays* (Pandey et al., 2008). These effects could be as a result of high salt content (Lauchli and Luttge, 2000) and presence of heavy metals in the treated textile effluent (Kabata-Pendias and Pendias, 1992). For clarity, we analyzed the properties of the treated effluent polluted river water. It was found that the water sample contained high concentrations of CN^-, Cu and Zn while the TSS and BOD_5 were far above the recommended standards. An important feature of metal-induced environmental stress is the activation of a common mechanism involving the production of Reactive Oxygen Species (ROS) in cells of the affected organism (Shi and Zhu, 2008; Mishra and Choudhuri, 1999; Wang et al., 2004). Since membrane lipid is one of the preferred targets of ROS in plant under environmental stress, it is considered to be a reliable indicator of controlled modulation of ROS levels and oxidative stress (Halliwell and Gutteridge, 1999). We investigated the levels of lipid peroxidation by measuring MDA in the leaves. *Celosia argentea* exposed to treated textile water sample showed significantly high level of MDA. This means that pollutants from the treated textile effluent was accumulated by the plants which induced the generation of excessive ROS, thus, the plant experienced substantial oxidative stress. These data are in agreement with the results from *Bruguiera gymnorrhiza* (Zhang et al., 2007) and *Oryza sativa* (Verma and Dubey, 2003).

Studies of surface water contamination are of immense importance because these waters are used for agricultural and domestic purposes. The present study has shown that surface waters, into which treated industrial effluents are directly discharged, are not safe for use in agriculture and other household domestic purposes.

Conclusion

The data obtained from this study indicated that the treated effluents from the textile industry that are directly discharged into the Ibeshe River contain toxic compounds. These compounds contaminate the surface water, thereby making it unfit for irrigation and drinking. Therefore, proper treatment of effluent water and enforcement of pollution control by the regulatory authority on the indiscriminate discharge of textile wastewater into water bodies should be carried out. Since farmers are using water from Ibeshe River for agricultural purposes and the residents of the town are using both the surface and underground waters from the same area as potable water, it is quite unsafe for this discharge into this water body to continue. The ecological and human health safety of continual discharge of this treated textile effluents into this river are undoubtedly under threat.

The present study also emphasized the importance of plants in toxicity assay. It can be used to complement other ecological, toxicological, and conventional chemical tests and for establishing priorities of pollution control. The authors therefore recommend proper treatment of waste waters before discharge into Ibeshe River, and also, occasional physicochemical analyses of the river water are necessary.

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