Toxicity Evaluation of Waste Treatment Plant of Textile Effluent Using Fish: Nile tilapia, Oreochromis niloticus
Kassaye Balkew Workagegn
Department of Biology, College of Natural and Computational Sciences, Hawassa University, P.O. Box 5, Hawassa, Ethiopia
Corresponding author email: kassayebalkew@gmail.com

Abstract
The experiment was conducted to evaluate the acute toxicity level of effluents from inlet and outlet of the biological lagoons of Hawassa Textile waste treatment plant using Nile tilapia, Oreochromis niloticus as test organism. Data for 24hrs, 48hr, 72hrs and 96hrs were recorded, and were analysed to determine the effects of toxicants of the effluent on behavioural responses and survival rate of Oreochromis niloticus. The results revealed that normal swimming behaviours were observed on the fish stocked at lower effluent concentration, while erratic swimming, gasping and frequent surfacing behavioural responses were observed on the fish stocked at higher effluent concentration. There was no fish mortality in control and 10% (v/v) outlet effluent concentration. The highest percentage mortality was observed at 100% (v/v) inlet effluent concentration followed by 100% (v/v) outlet and 40% (v/v) inlet effluent concentrations. The 96hrs fifty present lethal concentration (LC₅₀) and acute toxicity unit (ATU) values for inlet and outlet wastewater were 30.5% (v/v), 3.279, 71.5% (v/v) and 1.399, respectively. The safe effluent concentration for both inlet and outlet wastewater is set to be 3.05% and 7.15%, respectively. As a whole the present results revealed that the total efficiency level of the treatment plant to remove toxicants was 57.33% (v/v). However, efficiency of the treatment plant should be improved to use the water for irrigation and other domestic purposes; otherwise, the use of the wastewater at present condition is unsafe.

Keywords Oreochromis niloticus; Percentage mortality; Textile effluent; Toxicity test

Introduction
Aquatic ecosystems are exposed to a number of point and non-point sources of pollutants particularly form industries, swages treatment plants, drainage from urban and agricultural areas (Walker et al., 2006). Industries are among the most important point source of pollutants and discharge huge amount of waste substances into aquatic ecosystems. They can generate both organic and inorganic wastes, which could be alter all or parts of biological, physical and chemical characteristics of the receiving water bodies (Gomez et al., 2008). Depending on the dose and exposure time, some of these pollutants are toxic to living systems and cause a serious impairment to aquatic life (Walker et al., 2006; Gomez et al., 2008; Ogundriann et al., 2010). This is because, in the receiving water bodies, pollutants could accumulate in water, sediment and living systems. They also accumulate in food chain and thus cause adverse effects in aquatic systems (Walker et al., 2006).

Textile, tannery and flowering industries are currently some of the growing sectors in Ethiopia. As they are newly growing industries their treatment plants are inefficient to removal toxic substances, even some of them lack treatment plant. Instead, their waste substances directly or indirectly discharged to the surrounding water bodies and become potential source of pollutants. Among these, textile industry is one of the major sources of pollutants to the receiving water bodies due to the fact that it requires high volume of water that eventually results in high volume of wastewater (Yusuff and Sonibare, 2004; Roy et al., 2010). Depending on the types of raw materials and daily products, textile industry employs variety of chemicals such as detergents and dyes (Roy et al., 2010). The authors also stated that the quantities and characteristics of discharged textile effluent vary depending on the amount of water consumed, and types and amount of raw materials used.

Textile industry produces huge amount of wastewater particularly during wet processing such as sizing, fabric preparation, dyeing, printing and finishing
processes (Yusuff and Sonibare, 2004; Roy et al., 2010). Particularly dyeing process contributes high concentration of chromium, copper, mercury, and zinc, and could have high level of colour, toxicity and turbidity (Kabir et al., 2002; Zinabu and Zerihun, 2002; Moreira et al., 2004; Roy et al., 2010). As mentioned by Moreira et al., (2004), up to 50% of dyes are lost as waste substance in the effluents, and has serious negative impact on aquatic biota, and change the aesthetic value of the environment (Gomez et al., 2008; Aslam et al., 2004). Thus, the effects of waste substances from textile industries are therefore mainly depend on the amount of discharged effluents to the receiving water bodies.

Due to the fact that textile effluent has such characteristics, it should be discharged into a well-designed treatment plant before being released to the surrounding environment (Kabir et al., 2002; Movahedian et al., 2005). Physiochemical parameters are generally used to evaluate the quality of such types of textile effluent. However, it is not enough to determine the impact of pollution; thus, inclusion of toxicity evaluation is an important as toxicity evaluation provides a complete response of test organisms in a cumulative way (Tisler and Koncan, 1999; Ogugbue and Oranusi, 2005; Soni et al., 2006; Dahunsi and Oranusi, 2012). It is also useful to determine short term and long term impacts of wastewater to the receiving water bodies as well as the safe concentration of wastewater to be discharged.

Hawassa textile industry, established in 1989, is one of the oldest textile industry which discharges large amount of wastewater to the surrounding wetland and then into Lake Hawassa via Tikur Wuha River after treatment in its biological lagoons (treatment plant). Even though, the industry has biological lagoons (treatment ponds), nearly all its biological, chemical and physical characteristics of the surrounding water bodies are unchanged as compared with the treatment ponds (Zinabu and Zerihun, 2002; Birnesh et al., 2007). The objective of this study was therefore, to evaluate the efficiency of Hawassa Textile Effluent plant using Nile tilapia: *Oreochromis niloticus* as test organism.

1 Results

1.1 Physicochemical Parameters

The mean values of water quality parameters such as pH, conductivity, dissolved oxygen concentration and temperature are summarised in Table 1. Dissolved oxygen concentration was decreased as effluent concentration increased and had inverse relationship, while pH and conductivity were increased and thus exhibited a direct relationship with effluent concentration (Figure 1, Figure 2 and Figure 3). These imply that the recorded water quality parameters were affected by effluent concentration.

<table>
<thead>
<tr>
<th>Effluent concentration</th>
<th>Intel of biological lagoon</th>
<th>Outlet of biological lagoon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DO (mg/l)</td>
<td>pH</td>
</tr>
<tr>
<td>0%</td>
<td>7.3</td>
<td>8.8</td>
</tr>
<tr>
<td>10%</td>
<td>6.0</td>
<td>8.5</td>
</tr>
<tr>
<td>20%</td>
<td>4.7</td>
<td>8.4</td>
</tr>
<tr>
<td>30%</td>
<td>3.6</td>
<td>8.2</td>
</tr>
<tr>
<td>40%</td>
<td>3.3</td>
<td>7.7</td>
</tr>
<tr>
<td>100%</td>
<td>2.5</td>
<td>6.8</td>
</tr>
</tbody>
</table>

![Figure 1 Trend of DO concentration with respect to effluent concentration](image)
1.2 Behavioural Response
Based on visual observation during data recording, the fish were exhibited erratic swimming behavioural responses particularly when the concentration of textile effluent increased. As the experiment progressed the fish were become weakere and weaker with some color changes around the operculum and fins particularly doursal fins. However, normal behaviour were observed on the fish stocked in control and 10% (v/v) outlet effluent concentration, and had similar pattern.

1.3 Toxicity Evaluation
The effects of inlet and outlet textile effluent concentrations on percentage mortality of the fish for 96hrs exposure time is demonstrated by Figure 4. As indicated by this figure. mortality was not observed on the fish stocked in control and 10% (v/v) outlet effluent concentration. while maximum percentage mortality was observed on the fish stocked in higher effluent concentrations particularly for 100%. (v/v) inlet effluent concentration. The 96hrs LC50 was also extrapoloted to be 30.5% (v/v), and 3.279 as ATU for inlet. and 71.5% (v/v) and 1.399 as ATU for outlet from the quaratic graph of percentage mortality verves effluent concentration (Figure 5). The safe concentration of effluent for both inlet and outlet wastewater is set to be 3.05% (v/v) and 7.15% (v/v), respectively. Similarly, the efficiency of removal of toxicants was 57.33% (v/v) (Table 2).
Table 2 A Acute toxicity results obtained from both inlet and outlet effluent concentrations for *Oreochromis niloticus*

<table>
<thead>
<tr>
<th>Source of Effluent</th>
<th>96hrs LC$_{50}$ (%)</th>
<th>96hrs ATU</th>
<th>Efficiency (%)</th>
<th>Safe concentration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet</td>
<td>30.5</td>
<td>3.279</td>
<td></td>
<td>3.05</td>
</tr>
<tr>
<td>Outlet</td>
<td>71.5</td>
<td>1.399</td>
<td></td>
<td>7.15</td>
</tr>
<tr>
<td>Inlet/Outlet</td>
<td></td>
<td></td>
<td>57.33%</td>
<td></td>
</tr>
</tbody>
</table>

2 Discussion
The present findings confirmed that water quality parameters were affected by effluent concentration. As indicated by Figure 1, Figure 2 and Figure 3. The content of dissolved oxygen concentration was decreased. While pH values and conductivity were increased as the textile effluent concentration increased. This implies that the values of water quality parameters alter as effluent concentration changed. As a result of this. The behavioural responses of aquatic organisms were affected negatively and led to reduce fitness to the environment. And eventually death occurred. This is because water quality parameters such as pH, dissolved oxygen concentration, conductivity and water temperature are some of the most important limiting environmental factors that could affect the behavioural response. Growth rate and survival rate of aquatic organisms such as *Oreochromis niloticus* (Aslam et al., 2004; Noor et al., 2010; Kassaye, 2012). The present results confirmed that active behavioural responses of *Oreochromis niloticus* was observed at lower effluent concentration. While erratic swimming behaviour, gasping and frequent surfacing were observed on those fish stocked in higher effluent concentrations particularly the fish stocked in 30%, 40% and 100% (v/v) effluent concentrations. As the experiment progressed, the activity of those fish were decreased. Even they were collapsed to swim, particularly for the fish found in 40 and 100% (v/v) effluent concentrations. This result is in line with the works of Ogugbue and Oranusi (2005) and Dahunsi and Oranusi (2012) who reported that as effluent concentration increased, the activities of the fish are affected negatively. It was also noted that the fish stocked at higher effluent concentration had had three phases of behavioral responses. namely: active, fatigue and collapse. This result was in line with the findings of Adewoye et al. (2005) and Soni et al. (2006) who reported that erratic behavioural responses of the test organisms were resulted from high concentration of toxicants found in the industrial effluent. As the authors reported that as the experiment progressed, erratic behavioural response of the test organisms was reduced, and eventually they stopped swimming. This implies that the test organisms were not tolerated high effluent concentrations. Similar results were reported by Dahunsi and Oranusi (2012), Odjegba and Bambgbose (2012). And Roopadevi and Somashekar (2012). They stated that when test organisms stocked in higher effluent concentration for longer period. The homeostasis behaviour of the fish was disturbed, this eventually led to death, which is confirmed by the present results.

In the present experiment, mortality was occurred on a daily basis. In the first day of the experiment, the fish stocked in 30%, 40% and 100% (v/v) of the inlet effluent concentrations and 40% and 100% (v/v) of the outlet effluent concentrations were died. For lower concentration. 30% (v/v) of the outlet effluent concentration. Death was occurred from day two onward. In line with the present results. Movahedian et al. (2005) reported that immobility and mortality of the test organism (*Daphnia magna*) is increased as concentration increased on daily based. Similarly, 50% of the test organisms were died within 24hrs for 100% (v/v) inlet effluent concentration and 72hrs for 40% (v/v) inlet effluent concentration and 100% (v/v) outlet effluent concentration. These results clearly indicate that the treatment ponds are effective to remove some of the toxicants that are discharged for the textile industry. The present results also revealed that the 96hrs LC$_{50}$ values for both inlet and outlet were 30.5% (v/v) and 3.279 as ATU for inlet and 71.5% and 1.399 as ATU for outlet. This result implies that *Oreochromis niloticus* is susceptible to textile effluent or the effluent is very toxic even after treatment. The safe level for inlet and outlet effluent concentrations is set to be 3.05% (v/v) and 7.15% (v/v). This result is in line with the work of Dahunsi and Oranusi (2012). Who reported that the 96hrs LC$_{50}$ for *Clarias gariepinus* was found to be 35.518% and 2.5 as ATU of synthetic resin effluent. The present results are also in line with the work of Chude and Ekpo (2010) who reported that *Oreochromis niloticus* is more susceptible than *Clarias gariepinus*. 


As whole, the total efficiency of toxicity removal of the textile treatment plant of Hawassa textile industry achieved up to 57.33%. However, the treatment plant should be improved to use the water for irrigation and drinking purpose for domestic animals; otherwise, the use of the wastewater at present condition is unsafe.

3 Conclusions
The present results clearly demonstrated that the effluent treatment plant of the textile industry is effective to remove up to 57% of the toxicants. However, the discharged wastewater from its treatment plant (biological lagoons) contains toxic substances. Which could be potential source contaminate the receiving water bodies. Thereby it is unsafe to use for irrigation and drinking purpose for domestic animals unless the efficiency of the treatment plant is improved. Therefore, effective hazard analysis and critical control point monitoring should be advocated in order to maintain friendly environmental and usage of our water resources.

4 Materials and Methods
4.1 Sampling of Effluent
Effluent was collected from both inlet and outlet of the treatment plant (biological logon) of Hawassa Textile industry which is located at a distance of 2.5 km from the industry. The sample was transported to biology laboratory using plastic containers. The industry is found in South Nation Nationality and People Region. Hawassa. Located at a distance of 275 km from Addis Ababa. The capital city of Ethiopia, to south direction.

4.2 Sampling of Juvenile Oreochromis niloticus
Healthy juvenile Oreochromis niloticus of mixed-sex with an average body weight of 2.6 g/fish were collected from Lake Hawassa in May 2011. The fish were allowed to acclimatize for fifteen days until the fish become more active and stopped mass mortality. During the acclimatization period, the fish were fed with locally available fish diet. Dead and weakened fish were removed daily.

4.3 Experimental Design and Toxicity Test
The experiment was conducted in Biology laboratory. Hawassa University. In this experiment range finding test was carried out to determine the definitive concentrations to be used for acute evaluation test (Dahunsi and Oranusi, 2012). In this laboratory, 0%, 10%, 20%, 30%, 40%, and 100% (v/v) effluent concentration was prepared using tap water in triplicates with a total volume of 20L each. In each aquarium. 10 Nile tilapia. Oreochromis niloticus fingerlings were stocked for 96hrs.

4.4 Data Collection and Analysis
The experiment was monitored for 96hours and thus the behavioural responses of the fish were observed. Mortality was also registered at six hours interval and thus. Percentage of mortality at 96hours and LC50 were determined. LC50 values were determined from graph percentage mortality against effluent concentration using quadratic graphic method by modifying arithmetic graphic method used by Dahunsi and Oranusi (2012). Acute toxicity unit (ATU), total efficiency (E) of effluent treatment plant and safe concentration level (SCL) were also calculated using the follow formula described by US-EPA (2000):

\[ ATU = \frac{100}{LC50\% (v/v)} \]

\[ E = \frac{ATU_i - ATU_o}{ATU_i} \times 100 \]

\[ SCL = LC50\% (v/v) \times 0.1 \]

where ATU_i is acute toxicity unit for inlet. ATU_o is acute toxicity unit for outlet and 0.1 is application factors.

Acknowledgment
This research was financially supported by RDD. Hawassa University. The author would like to thank to Dr Tesfaye Abebe for his contribution to facilitating the financial aspect. The author also acknowledges to Dr Elias Dadebo for his professional advice in all aspects.

Reference


US-EPA, 2000, Understanding and accounting for method variability in whole effluent toxicity application under the national pollutant discharge elimination system, EPA-833-R-00-003

