Acute toxicity of copper sulphate to African catfish, (Clarias gariepinus)

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Abstract

In this study, 96 hrs LC<sub>50</sub> values of copper sulphate (CuSO<sub>4</sub>·5H<sub>2</sub>O), a highly toxicant heavy metal, on African catfish, Clarias gariepinus of average weight 98.43 ± 24.09 g and length 20.5 ± 2.5 cm was determined. The acute toxicity tests were performed according to the static non-renewable bioassay procedure. The experimental design consisted of a control and six concentrations (24, 31, 38, 44, 50 and 55 ppm) of copper sulphate, with two replicates per group and twenty fishes in each replicate. The 96 hour LC<sub>50</sub> value based on probit analysis was found to be 40.86 ppm; the lower and upper lethal confidence limit for copper sulphate indicated a wide range between 37.47 to 44.58 ppm. Susceptibility of catfish, Clarias gariepinus to lethal effect of copper sulphate was found to be duration and concentration dependent as mortality was increased with an increase in its concentration. Results indicated that copper sulphate is toxic to fish, to moderate extent even at lower concentrations. Therefore, the present investigation may provide useful guidance that can be exploited by the aquaculturists to formulate the safety levels of copper sulphate in water bodies.

Key words: Copper sulphate, Clarias gariepinus, 96 hrs LC<sub>50</sub>

Introduction

Metal concentrations in aquatic organisms appear to be of several magnitudes higher than concentrations present in the ecosystem (1). This is attributed to bioaccumulation, whereby metal ions are taken up from the environment by the organism and accumulated in various organs and tissues. Metals also become increasingly concentrated at higher trophic levels, possibly due to food-chain magnification.

Aquatic toxicity tests are used to detect and evaluate the potential toxicological effects of chemicals on aquatic organisms. Since these effects are not necessarily harmful, a principal function of these tests is to identify chemicals that can have adverse effects on aquatic organisms. These tests provide a database that can be used to assess the risk associated with a situation in which the chemical agent, the organism, and exposure conditions are defined. They can identify potential environmental problems before the health of a system is critically altered or compromised (2). Copper is a micronutrient essential for all living organisms required in small amounts, and important life functions cannot function properly in its absence (3). Copper ions are quite toxic to fishes and had already been reported by many...
Copper sulphate is often used as an algaecide in commercial and recreational fish ponds to control growth of phytoplankton and filamentous algae, and to control certain fish diseases (8). However, above a specific concentration, copper is toxic to fishes including such cultured species as salmonids, cyprinids and catfishes (9). Thus, treating plankton with copper compounds may lead to copper bioaccumulation reaching a toxic level in fish. The toxic effect of copper is related to its capacity for catalyzing oxidative reactions, leading to the production of reactive oxygen species (10).

Fishes are ideal organisms to monitor aquatic systems because they occupy positions towards the apex of food pyramids and may, therefore, reflect effect of heavy metals on other organisms including human beings as well as direct stresses on themselves (11). This study investigates the toxic effects of copper sulphate on the *Clarias gariepinus* by determination of 96-hour LC$_{50}$ value.

**Materials and Methods**

Alive, healthy and disease free specimens of catfish, *Clarias gariepinus* of either sex belonging to a single population were purchased on order from the local fish market of Sagar. Before introducing those in aquariums, fishes were treated with 0.01% KMnO$_4$ solution for 15 min to obviate any dermal infection. Fishes of average weight 98.43±24.09 g and length 20.5±2.5 cm were distributed in 120 L capacity aquariums and were unfed during the first 2 days to adapt to change in environment. Fishes were then kept for a period of fifteen days for acclimatization of laboratory conditions.

After acclimatization experimental fishes were selected at random and were kept in a static system of water. The feeding was stopped one day prior the exposure to CuSO$_4$ and fishes were not fed throughout the test. The acute toxicity tests were performed according to the static non-renewable bioassay procedure (12) as described in the previous study (13). The experimental design consisted of a control and six concentrations (24, 31, 38, 44, 50 and 55 ppm) of copper sulphate (CuSO$_4$·5H$_2$O), two replicates per group and with twenty fishes in each replicate. Fishes showing no respiratory movement and response to tactile stimuli were considered as dead and removed immediately. The 96 hrs LC$_{50}$ was computed with probit analysis using statistical SPSS 16 package (14). During the exposure in different concentrations of copper sulphate, the behavioural changes of the fishes were also recorded.

**Results and Discussion**

The 96 hrs LC$_{50}$ values provide a useful means of comparing the relative acute lethal toxicity of specific toxicants to organisms under specific conditions. Initially, copper sulphate exposure to fishes showed restlessness, rapid body movement, and difficulty in respiration displayed by fishes moving to the surface to gulp air, intense opercula movement, accumulation of mucus on body, loss of equilibrium by swimming sideways, finally fishes collapsed and died. From the results of mortality readings, the 96 hrs LC$_{50}$ value and 95% confidence limits for copper sulphate based on probit analysis was found to be 40.86 ppm (Table-1 and Fig.-1). The lower and upper lethal confidence limits indicated a range between 37.47 to 44.58 ppm (Table-2). Susceptibility of catfish, *Clarias gariepinus* to lethal effect of copper sulphate was duration and concentration dependent as mortality increased with an increase in its concentration.

![Probit vs. Log Concentration](image)

**Fig. 1: Showing the linear relationship between probit response and log sub-lethal concentration of copper sulphate on *Clarias gariepinus*.

In present study, we observed that, there was a corresponding increase in mortality response of the test fishes with increased time and exposure of copper sulphate. Forgoing results of Finney’s probit analysis revealed 40.86 ppm as LC$_{50}$ value of copper sulphate exposed to *Clarias gariepinus* for 96 hrs. The results of this investigation support the observations, in this regard, shown by Osman and co-workers.
Table 1: Showing the mortality of *Clarias gariepinus* at 96h after treatment of different copper sulphate concentrations.

<table>
<thead>
<tr>
<th>CuSO(_4) Conc. (ppm)</th>
<th>Log</th>
<th>Conc.</th>
<th>Mortality</th>
<th>No. of fish exposed</th>
<th>Expected Responses</th>
<th>Residual</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>1.38</td>
<td>01</td>
<td>20</td>
<td>0.994</td>
<td>0.006</td>
<td>0.04842</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>1.49</td>
<td>04</td>
<td>20</td>
<td>3.887</td>
<td>0.113</td>
<td>0.19433</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>1.58</td>
<td>07</td>
<td>20</td>
<td>8.205</td>
<td>-0.205</td>
<td>0.41025</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>1.64</td>
<td>11</td>
<td>20</td>
<td>11.822</td>
<td>-0.178</td>
<td>0.59111</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>1.70</td>
<td>15</td>
<td>20</td>
<td>14.708</td>
<td>-0.708</td>
<td>0.73538</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>1.74</td>
<td>19</td>
<td>20</td>
<td>16.458</td>
<td>-0.542</td>
<td>0.82291</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Confidence limits for effective concentration

<table>
<thead>
<tr>
<th>Probit</th>
<th>Concentration (ppm)</th>
<th>95% Confidence Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>0.10</td>
<td>27.09917</td>
<td>21.42389</td>
</tr>
<tr>
<td>0.15</td>
<td>29.31444</td>
<td>24.03412</td>
</tr>
<tr>
<td>0.20</td>
<td>31.20351</td>
<td>26.29886</td>
</tr>
<tr>
<td>0.40</td>
<td>37.67937</td>
<td>33.99955</td>
</tr>
<tr>
<td>0.50</td>
<td>40.86719</td>
<td>37.47484</td>
</tr>
<tr>
<td>0.60</td>
<td>44.32473</td>
<td>40.85207</td>
</tr>
<tr>
<td>0.70</td>
<td>48.34843</td>
<td>44.34777</td>
</tr>
<tr>
<td>0.80</td>
<td>53.52371</td>
<td>48.41539</td>
</tr>
<tr>
<td>0.90</td>
<td>61.63022</td>
<td>54.27602</td>
</tr>
<tr>
<td>0.99</td>
<td>86.14921</td>
<td>70.31773</td>
</tr>
</tbody>
</table>

The toxicity of copper sulphate is related to the levels of copper ions in the water. Copper toxicity studies in fish have demonstrated that toxicity of copper is dependent on the concentration of free Cu\(^{2+}\) (23).

Marine teleosts are more less sensitive to Cu, with reported 96 hrs LC\(_{50}\) values of 800-1000 µg/l range for spiny dog fish, *Squatius acanthis* (24), of 1140 µg/l for sheepshead (*Archosargus probatocephalus*), of 5660 µg/l for Atlantic croaker, *Micropogon undulatus* and of 2750 µg/l for pinfish, *Lagodon rhomboides* (25). Toadfish, *Opsanus beta* are even more resistant with the 96 hrs LC\(_{50}\) between 21,600 and 36,100 µg/l (26). The 48 hrs and 96 hrs LC\(_{50}\) for Cu on Mediterranean dogfish, *Scyliorhinus canicula*, was reported to be 4000µg/l and 2000 µg/l, respectively (27). The observed differences in the LC\(_{50}\) values of copper might be due to the physicochemical characteristics of the test medium, species and ages of fishes used and their susceptibility rates, which resulted in their subsequent different toxicity values. Differences in metabolic pathways among species may result in varied patterns of bio-transformation, leading to more or less toxic metabolites (28).

The lowest dose of copper sulphate that has been toxic when ingested by humans is 11 mg/kg (29). Long-term effects are more likely in individuals with Wilson’s disease, a condition which causes excessive absorption and storage of copper and manifests as neurological psychiatries symptoms and liver disease (30). Chronic exposure to low levels of copper in humans can lead to anaemia (31).

The impact of copper on the aquatic environment is complex and depends on the physicochemical characteristics of test medium (32). Therefore, the variations in the LC\(_{50}\) values for copper on fishes might be due to the variations in physicochemical characteristics of water used during

(15) who reported 72 hrs LC\(_{50}\) value of CuSO\(_4\) as 40.6 mg/l in *Oreochromis niloticus*. Tavares-Dias et al (16) evaluated 17.5 mg/l as the 96 hrs LC\(_{50}\) value of copper sulphate on juveniles of *Colossoma macropomum*. Ezeonyejiak and colleagues (17) reported that copper was significantly more toxic to *Oreochromis niloticus* than the catfish, the 96 hrs LC\(_{50}\) value of copper sulphate was 5.5 mg/l (1.75 mg/l Cu). This study revealed to be 58.837 and 70.135 mg/l, respectively. The 96 hrs LC\(_{50}\) value of copper was significantly more toxic to *Oreochromis niloticus* than *N. notopterus* as 30 mg/l (20). Darwish (21) reported that a 96 hrs median lethal concentration (LC\(_{50}\)) value for copper sulphate on *Ictalurus punctatus* was 6.89 mg/l (1.75 mg/l Cu) and on *Morone chrysops* was 3.35 mg/l (1.75 mg/l Cu). This study demonstrated that sunshine bass juveniles are less tolerant of CuSO\(_4\) than channel catfish fingerlings when exposed concurrently in waters from the same source. However, in contrast to our study, much lower LC\(_{50}\) values of copper were reported on *Poronotus triacanthus* as 502.95 µg/l (13) and *Danio rerio* as 73.83 µg/l (22), which suggests that these fishes are much less tolerant to toxic effect of copper. The physicochemical characteristics of water used during
experimentation. The incipient LC$_{50}$ of copper for juvenile rainbow trout (Salmo gairdneri) increased when hardness and alkalinity was increased (33). Also, Wurts and Perschbacher (09) observed the 48 hrs LC$_{50}$ of copper sulphate to channel catfish, Ictalurus punctatus as 48 mg/l, and found that mortality decreased as calcium hardness levels increased. Abdel-Tawwab and Mousa (34) reported that the LC$_{50}$ of Nile tilapia, O. niloticus not exposed to calcium and exposed to copper was 5.03 mg Cu/l, while as LC$_{50}$ value was increased with CaO (14.27 mg Cu/l). Merwe et al (35) reported that LC$_{50}$ values of copper on adult C. gariepinus ranged from 1.29 mg/l during summer to 1.38 mg/l in winter and suggested that water temperature may alter the lethality of copper to C. gariepinus.

Conclusion

From the results obtained, it can be concluded that the copper sulphate is quite toxic to C. gariepinus. The present investigation provides useful information that can be exploited by the aquaculturists to formulate the safety levels of copper in water bodies and to formulate safer and more effective application rates for copper sulphate when used for parasite control.

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References


