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Toxicity of Nickel and Nickel Electroplating Water to the Freshwater Cladoceran *Moina macrocopa*

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Production of electroplating wastewater and its discharge into aquatic ecosystems have increased greatly in recent years. The most important sources of electroplating wastewater pollution are dumping and spillage of rinse water and process solution. Electroplating wastewater contains high levels of heavy metals such as copper, chromium, nickel and zinc. The effects of heavy metals on aquatic environments have been extensively reviewed (Mance 1987). Wastewater discharged by electroplating factories in Hong Kong contains high concentrations of nickel. Toxicity of nickel to aquatic organisms such as bacteria (Giashuddin and Cornfield 1979; Babich and Stotzky 1983), algae (Spencer and Greene 1981; Spencer and Nichols 1983), invertebrates (Biesinger and Christensen 1972; Baudouin and Scoppa 1974; Bakoric-Popovic and Popovic 1977) and fish (Pickering 1974) is well-known. Among invertebrates, cladocerans are the most susceptible to nickel toxicity (Mance 1987). Cladocerans are exceedingly important components of many aquatic ecosystems. They are major consumers of algae, and they themselves are important food of aquatic invertebrates and fishes. Nickel is known to inhibit the growth of freshwater cladocerans (Biesinger and Christensen 1972; Khangarot and Ray 1987). However, there is no information on the toxicity of nickel electroplating water to freshwater cladocerans.

The present study investigates the effects of Ni^{2+} and other components of nickel electroplating water on the survival and reproductive capacity of the cladoceran Moina macrocopa, a common inhabitant of small ponds and rice paddies in Hong Kong and Southern China.

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MATERIALS AND METHODS

The chemical composition of electroplating wastewater depends on the type of electroplating process used. In this study, nickel electroplating water (EW) was prepared according to Wong (1984) by dissolving 300 g of nickel sulphate ($NiSO_4.6H_2O$), 45 g of nickel chloride ($NiCl_2.6H_2O$), 40 g of boric acid (H_3BO_3) and 7 mL of MIX, a commercial additive containing brightener and surfactant, in 1 L of distilled water. Stock solutions of Ni^{2+} (10,000 mg/L) were prepared by dissolving 4.47 g of $NiSO_4.6H_2O$ (NS) or 4.05 g of $NiCl_2.6H_2O$ (NC) in 100 mL of distilled water. All chemicals used in this study were reagent grade. Concentrations of N^{2+} in EW, NS and NC were determined by atomic absorption spectrophotometry with a Varian model AA 1475 atomic absorption spectrophotometer. A stock solution of boron ion (1,000 mg/L) was prepared by dissolving 0.57 g of H_3BO_3 (BA) in 100 mL of distilled water. A MIX solution (MIX) was prepared by adding 7 mL of MIX to 1 L of distilled water. All stock solutions were sterilized by autoclaving and stored in a refrigerator before use.

M. macrocopa came from a continuous laboratory culture raised from a single parthenogenetic female. Cohorts of newborn (< 24 h) individuals for toxicity tests were obtained by isolating egg-bearing females from stock cultures. Twenty newborn animals, 10 in each 150 mL beaker containing 100 mL of aged (> 1 week) tap water (pH 6.5-7.0), formed the two replicates used for each test condition. Test solutions were prepared by adding aliquots of EW, NS, NC, BA and MIX from stock solutions to each beaker. Toxicity of N^{2+} ion from EW, NS and NC was tested at concentrations of 0.25, 0.5, 1.0, 3.0, 5.0 and 7.0 mg/L. Toxicity of boron ion from BA was tested at 0.25, 0.5, 1.0, 5.0, 7.0 and 10.0 mg/L. Concentrations of MIX tested were 0.0035, 0.007, 0.014, 0.035 and 0.07 mL/L. Test solutions were changed every day. The number of surviving animals were counted during each change. Individuals without heartbeats were considered dead. Young produced during the previous 24 h were counted and discarded. Chlorella pyrenoidosa, at a concentration of 200,000 cells/mL, was added to the beakers to feed the animals after each water change. Surplus algae were usually still in suspension when the test solutions were changed. All beakers were kept at 25 $\pm$ 2°C under a 16L:8D light cycle in a test chamber. Each toxicity test lasted the entire life span of the cohort.

Results were evaluated statistically. Survivorship was recorded as day of death, while fecundity was

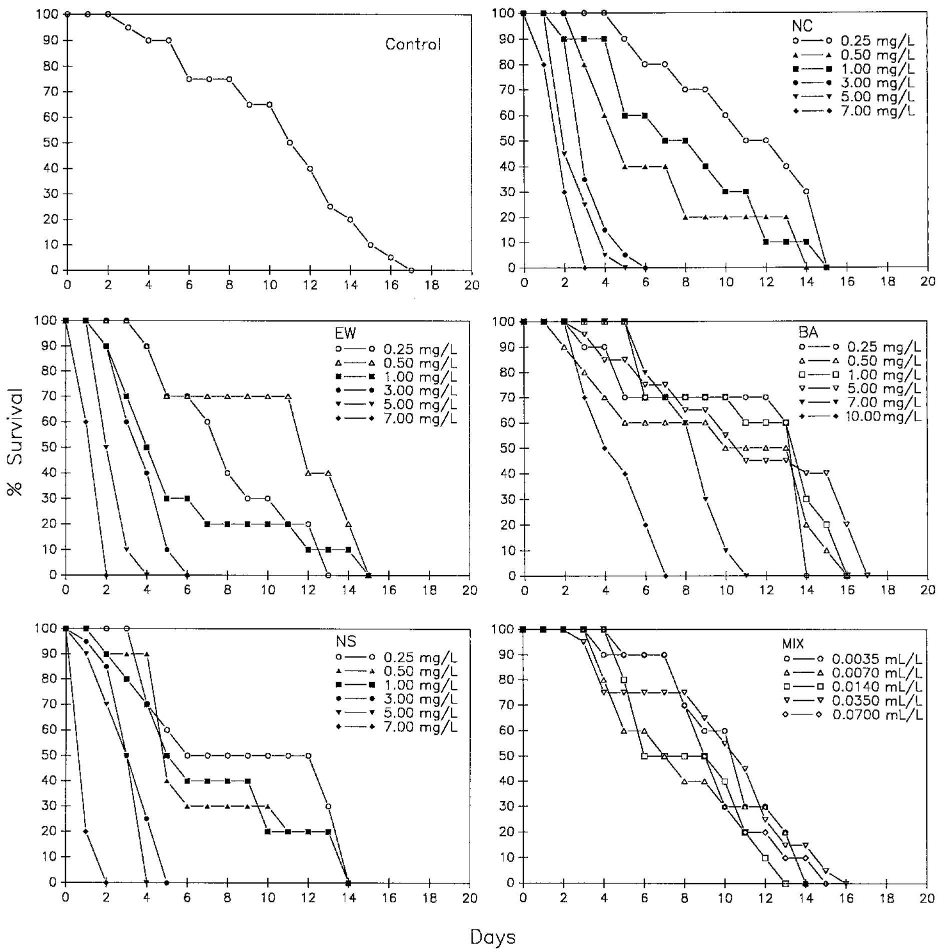

Figure 1. Survivorship curves of M. marocopa in control and various concentrations of nickel electroplating water (EW), nickel sulfate (NS), nickel chloride (NC), boron ion (BA) and MIX. Closed symbols represent treatments different from control ($P < 0.05$).

recorded as the average number of young per female per day. Difference among treatments was first compared using the single factor analysis of variance. The Dunnett's test (Zar 1984) was then used to compare the control mean to each other treatment mean. Significance level of 0.05 was adopted for all statistical analyses.

RESULTS AND DISCUSSION

In addition to nickel sulfate (NS) and nickel chloride (NC), nickel electroplating water (EW) contains boric acid (BA) and MIX (Wong 1984). Effect of N^{2+}, boron ion and MIX on the survivorship schedule of M. macrocopa populations is presented in Fig. 1. Toxicity of N^{2+} from EW, NS and NC increased with concentration. Maximum lifespan of M. macrocopa was reduced by more than 50% at 3.00 mg/L or higher concentrations of N^{2+}. In the case of N^{2+} from EW, longevity was significantly reduced at 1.00 mg/L or higher concentrations. In the case of N^{2+} from NS and NC, significant reduction in longevity was detected at 0.50 mg/L or higher concentrations.

Boron ion from BA appeared to be less toxic than N^{2+}. Survivorship at concentrations of 0.25, 0.50, 1.00 and 5.0 mg/L was not significantly different from survivorship of control (Fig. 1). Significant reduction in longevity was observed only at concentrations of 7.0 and 10.0 mg/L. Survivorship of M. macrocopa was also tested in the presence of different concentrations of MIX, ranging from 0.0035 mL/L to 0.07 mL/L. However, even at the highest concentration tested in this study, MIX did not affect the longevity of M. macrocopa. These results revealed that N^{2+} and boron ion were the major toxic components in nickel electroplating water.

Reproductive patterns of M. macrocopa exposed to different concentrations of N^{2+}, boron ion and MIX are presented in Fig. 2. Three separate bursts of reproduction, representing three successive broods, were observed in the reproductive pattern of the control population. In general, first reproduction occurred after 3 to 4 days. Animals exposed to N^{2+}, boron ion and MIX did not reproduce later than control animals. In the case of N^{2+} from EW, fecundity at concentrations of 0.25 and 0.50 mg/L was not significantly different from that of the control. Significant effect on fecundity was first detected at a concentration of 1.00 mg/L. No reproduction was recorded at concentrations higher than 1.00 mg/L. Results on the effect of N^{2+} from NS on the fecundity of M. macrocopa were somewhat spurious. Fecundity was significantly reduced at 0.25 and 3.00 mg/L, but not at 0.50 and 1.00 mg/L. In contrast, N^{2+} from NC caused no significant changes in fecundity at concentrations of 0.25, 0.50 and 1.00 mg/L. Animals exposed to 3.00 mg/L of N^{2+} from either NS or NC lived just long enough to produce one small brood. Animals exposed to 5.00 and 7.00 mg/L of N^{2+} from EW,

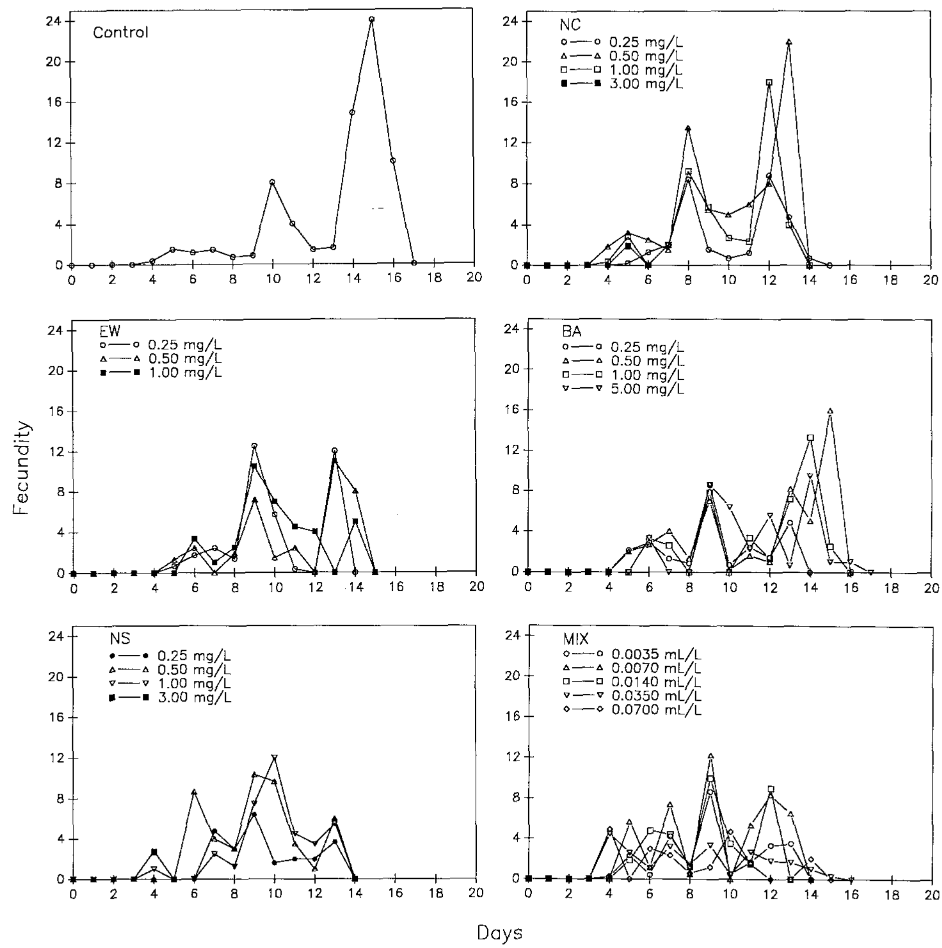

Figure 2. Fecundity curves showing the average number of young per female per day for M. marocopa in control and various concentrations of nickel electroplating water (EW), nickel sulfate (NS), nickel chloride (NC), boron ion (BA) and MIX. Closed symbols represent treatments different from control ($P < 0.05$).

NS and NC did not survive to the onset of reproduction..

At concentrations up to 5.00 mg/L, boron ion from BA had no significant effect on the fecundity of M. macrocopa. Reproduction appeared to stop rather abruptly at 7.00 and 10.00 mg/L. Since more than 60%

of the animals survived well beyond the day of first reproduction (3 to 4 days), the absence of reproduction at 7.00 mg/L was somewhat surprising. Similarly, while the maximum longevity at 10 mg/L was 7 days, no reproduction was observed. These results suggested that boron ion from BA was toxic to M. macrocopa. MIX, which had no lethal effect on M. macrocopa, also appeared to have no significant effect on fecundity.

Toxicity of nickel to freshwater cladocerans has been studied previously. Working with the freshwater cladoceran Daphnia magna, Biesinger and Christensen (1972) found that the N^{2+} concentration which caused 50% mortality of the population within 48 h (48-h LC_{50}) was between 0.5 and 1.1 mg/L. Reproduction was impaired at even lower concentrations. In contrast, Khangarot and Ray (1987) reported that the 48-h LC_{50} of N^{2+} for D. magna was 7.6 mg/L. Comparison between results is difficult because there was insufficient information to assess the effects of environmental variables such as water temperature, pH and water hardness. Information on other Daphnia species suggests that there may be interspecific differences in tolerance to N^{2+} toxicity. Baudouin and Scoppa (1974) found a 48-h LC_{50} of 1.9 mg/L for D. hyalina. Results of this study show that the 48-h LC_{50} of N^{2+} for M. macrocopa was around 7.0 mg/L. Comparison with information on other freshwater organisms (Mance 1987) confirms that cladocerans are very sensitive to nickel pollution.

Results of this study also indicate that other components in EW, such as boron ion, are toxic to freshwater cladocerans. Although N^{2+} is more toxic than boron ion and may account for much of the toxicity of electroplating water, boron ion is toxic at high concentrations and may enhance the toxicity of N^{2+}. MIX, which is a common ingradient of electroplating water, was found to have no significant effect on the longevity and fecundity of M. macrocopa. However, it must be noted that results of a previous study (Wong and Wong 1991) suggest that MIX may enhance the toxicity of N^{2+} to the green alga Chlorella pyrenoidosa. The composition of electroplating water depends on the type of electroplating process used. Electroplating wastewater collected from Hong Kong factories generally contains heavy metals and other pollutants such as cyanide and hexavalent chromium. The combined effects of these pollutants on aquatic organisms and the mechanisms of pollutant interaction are important aspects for future research.

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