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Effect of copper, cadmium and zinc on fish-food organisms, *Daphnia lumholtzi* and *Cypris subglobosa*†

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Abstract. The results of static and acute bioassay studies on *Daphnia lumholtzi* (Cladocera) and *Cypris subglobosa* (Ostracoda) to the varying dosages of Cu, Cd and Zn were presented. The 96 h, LC_{50} values for *Daphnia* were found to be 0·009, 0·083, 0·437 and for *Cypris* 0·25, 0·687, 8·3 mgl^{-1} for Cu, Cd and Zn respectively. This indicates that *Daphnia* is very sensitive while *Cypris* has a good amount of resistance. The rank order for toxicity of 3 metals is Cu > Cd > Zn. The study indicates that the waters getting polluted by heavy metals even at low concentration would remove the population of fish-food organisms without directly effecting fish fauna, thus making water body unfit for fishery use.

Keywords. Cu; Cd; Zn; bioassay; *Daphnia*; *Cypris*; $LC_{16-50-84}$.

1. Introduction

Metal concentrations have been on increase in rivers, lakes and ponds causing threats to aquatic environments. Though Cu and Zn are considered the essential trace elements of the human body, they become toxic at higher concentrations. Cd, however, is not known to be present in living organisms.

Copper sulphate a potent algicide is transiently toxic (Sawyer 1970) and gets transformed into organically bound undissolved sedimented Cu on lake bottom. This produces deoxygenation in epilimnion by decrease in algal photosynthesis and increase in oxygen demand due to decomposition of organisms killed by Cu (Spear and Pierce 1979). Cd is not known to have such effects but is said to be the most hazardous metallic pollutant causing impairments in liver, kidney and spleen function, spinal deformities, anemia and death in fishes (Holcombe *et al* 1976). Toxicity of heavy metals to zooplankton were studied by Biesinger and Christensen (1972) and Baudouin and Scoppa (1974). The importance of daphnids as experimental animals is reviewed by Anderson *et al* (1948) and Biesinger and Christensen (1972). The studies on Indian plankters are limited and hence an attempt has been made to study the effect of Cu, Cd and Zn on *Daphnia* and *Cypris*. Zooplankton are extremely sensitive to metals in comparison to fish. Zooplankton is the primary food source for several species of the fish and also forms a basic factor in aquatic food chain.

2. Materials and methods

Acute and static bioassays were followed (APHA 1980). Test solutions were renewed

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daily. Dechlorinated tap-water was used as diluent. The average physico-chemical factors of water were pH 7·9; alkalinity 180 mgl^{-1}, total hardness 200 mgl^{-1}, electrical conductivity 1200 μmhos cm^{-1}, dissolved oxygen 6·3 mgl^{-1}, dissolved carbon dioxide 2·4 mgl^{-1} and temperature 28·5°C. Salts of metals dissolved in acidic water (HCl) were added to the ambient medium. Organisms were cultured in cement cisterns with the addition of cow-dung. *Daphnia lumholtzi* and *Cypris subglobosa* were collected through small plankton hand net and individuals were sorted out with a wide bore pipette. Tests were performed in 100 ml glass beakers with 10 organisms in each. Two replicates were run simultaneously with a control. Percentage mortality were transformed to LC_{50} by the methods of Finney (1981) and relativity by Litchfield and Wilcoxon (1949).

3. Results

Tolerance levels in tables 1 and 2 show higher values in case of *Cypris* than in *Daphnia* indicating that the former is more resistant than the latter. The trend of toxicity in both the cases was Cd > Cu > Zn. The LC_{50} of Zn for *D. lumholtzi* ranged from 0·44–10·74 mgl^{-1}, within the exposure durations spanning from 12–96 h. However, values were as high as 8·35–47·78 mgl^{-1} in case of *C. subglobosa*. Similar was the trend for Cu (0·009–0·083 and 0·277–13·58) and Cd (0·083–2·325 and 0·69–12·66 mgl^{-1}). The $LC_{16} - LC_{84}$ is an approximation of rise in toxic levels between upper and lower asymptomate in toxicity curve on the concentration axis, above and below which sigmoid nature of curve gets disturbed. However, the range between this had regression equations as presented in tables 1 and 2 and the data were non-heterogenous. A few heterogenous data may be the result of eye traction errors in plotting straight line between concentration and probit mortality. Relativity was computed taking into consideration Cd as one unit in interaction with *Daphnia*. Relativity ranged from 1–46·53, highest being for *Daphnia* and Zn interaction. Toxicity patterns of various metals are also represented on concentration-time axes (figure 1).

4. Discussion

Cu is known to cause haemodilution, hyperglycemia, increase in haemopoiesis, decrease in plasma glutamic oxaloacetic transaminase activity, reduced antibody production leading to diseased fish followed by mortalities (Spear and Pierce 1979).

Tolerance of fresh water organisms may differ due to cationic actions on Ca^{+2} and Mg^{+2} levels. Suspended solids and colloids may form complexes with cupric ion and adsorption respectively thereby altering toxicities (Spear and Pierce 1979). In aqueous media, Cu ions co-ordinate with water molecules and form aqua-copper ions $(Cu, H_2O_6)^2$, in the absence of other interfering agents. The aqua ions of Cu get into animal tissues and bio-accumulates. However, the whole body concentrates of animals of higher trophic levels appear to have less metals. This may be because of higher metabolic efficiencies of these organisms. However, dynamics of any metal in a food-web is very little known. The earlier studies show that dissolved Cu converts itself into non-dissolved form within 5 days. Some of it get affected by water hardness, body tissue fluids leading to change in cell permeability (Lloyd 1962; Hoar 1969). Thus increase in fluid hardness decreases toxicity.

The toxicity values of the present study were found very similar to those stated in

Table 1. Tolerance levels of *D. lumholtzi* at various exposures with regressions, heterogeneity and relativity.

Test chemical	Exposure duration (h)	Tolerance levels in $mg l^{-1}$ (fiducial limits in parentheses) LC_{16}	LC_{50}	LC_{84}	Regression equation $Y = mx + c$	Heterogeneity d.f. $x^2 =$	Relativity
Cu	12	0·089 (0·048–0·099)	0·083 (0·078–0·088)	0·0996 (0·094–0·105)	$Y = 12·61x + 5·01$	1·08	—
	24	0·0502 (0·043–0·058)	0·0672 (0·062–0·0728)	0·09 (0·079–0·102)	$Y = 7·83x + 5·12$	0·78	—
	48	0·038 (0·038–0·042)	0·0546 (0·049–0·06)	0·07836 (0·07–0·87)	$Y = 6·33x + 5·11$	0·70	—
	96	0·0014 (0·0037–0·0074)	0·0094 (0·009–0·0178)	0·0623 (0·0261–0·150)	$Y = 1·21x + 5·37$	8·98*	1·0
Cd	12	0·9069 (0·362–1·379)	2·325 (1·625–3·327)	8·228 (3·80–18·81)	$Y = 1·87x + 4·9$	1·18	—
	24	0·7816 (0·60–1·01)	1·585 (1·31–1·91)	3·312 (2·43–4·25)	$Y = 3·24x + 4·93$	2·23	—
	48	0·3216 (0·25–0·42)	0·6186 (0·52–0·74)	1·19 (0·92–1·54)	$Y = 3·50x + 5·03$	9·04*	—
	96	0·034 (0·018–0·068)	0·083 (0·061–0·114)	0·206 (0·14–0·31)	$Y = 2·53x + 5·32$	3·22	8·83
Zn	12	5·776 (4·51–7·2)	10·74 (9·12–12·64)	19·95 (15·11–26·35)	$Y = 3·69x + 4·91$	2·38	—
	24	0·91 (0·23–3·67)	6·704 (2·96–15·16)	210·8 (14·0–3059·0)	$Y = 0·66x + 4·91$	—	—
	48	0·3134 (0·11–0·86)	2·29 (1·42–3·69)	16·62 (5·37–51·45)	$Y = 1·15x + 4·93$	4·51	—
	96	0·22 (0·13–0·37)	0·4375 (0·34–0·56)	0·87 (0·65–1·17)	$Y = 3·34x + 5·39$	0·30	46·53

*Data found to be heterogenous.

Table 2. Tolerance levels of *C. subglobosa* at different exposures with regressions, heterogeneity and relativity.

Test chemical	Exposure duration (h)	Tolerance levels in mgl^{-1} (fiducial limits in parentheses) LC_{16}	LC_{50}	LC_{84}	Regression equation $Y = mx + c$	Hetero-geneity d.f. $x^2 =$	Relativity
Cu	12	13·581 (13·12–13·38)	13·581 (13·46–13·72)	13·93 (12·70–5·29)	$Y = 91·24x + 4·92$	*	—
	24	9·187 (6·698–12·24)	12·20 (10·68–13·95)	16·21 (11·49–2·69)	$Y = 8·07x + 4·9$	0·006	—
	48	0·886 (0·42–1·83)	5·363 (3·52–8·18)	32·4 (9·99–15·2)	$Y = 1·27x + 4·63$	8·47	—
	96	0·0925 (0·0004–0·16)	0·2773 (0·21–0·35)	0·9356 (0·529–1·65)	$Y = 1·89x + 5·12$	0·65	1·0
Cd	12	4·62 (1·76–12·21)	12·66 (10·04–15·96)	34·67 (20·74–58·01)	$Y = 2·27x + 4·89$	0·10	—
	24	2·68 (1·76–4·06)	6·981 (3·48–13·98)	18·19 (12·68–26·08)	$Y = 2·39x + 5·12$	1·32	
	48	2·32 (2·10–2·56)	3·02 (2·76–3·31)	4·49 (4·11–4·99)	$Y = 6·93x + 5·33$	*	—
	96	0·3646 (0·25–0·52)	0·6874 (0·55–0·92)	1·296 (0·95–1·77)	$Y = 3·61x + 5·55$	−5·08	2·48
Zn	12	40·59 (35·31–46·66)	47·78 (43·95–51·95)	56·26 (53·15–59·55)	$Y = 14·02x + 5·93$	18·10	—
	24	39·77 (34·68–45·6)	50·62 (46·71–54·86)	64·4 (56·80–73·05)	$Y = 9·50x + 4·98$	0·56	—
	48	21·36 (16·86–27·06)	34·99 (30·76–39·77)	57·27 (21·33–153·7)	$Y = 4·64x + 4·98$	8·16	—
	96	3·312 (2·09–5·05)	8·352 (6·5–10·71)	21·06 (14·46–30·70)	$Y = 2·48x + 5·21$	2·07	30·12

*Data found to be heterogenous.

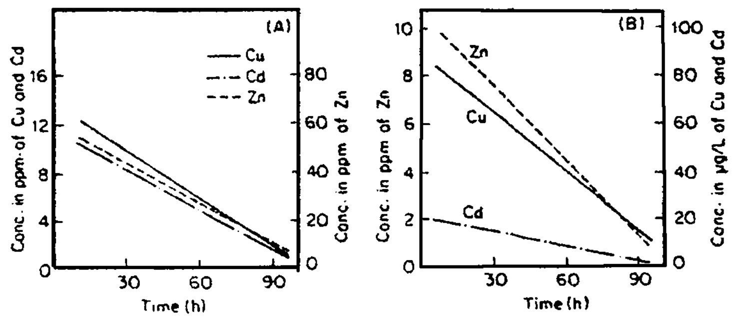

Figure 1. Toxicity relation of various metals to (A) *C. subglobosa* and (B) *D. lumholtzi* at LC_{50} levels.

the earlier works of Biesinger and Christensen (1972) and Winner *et al* (1977). Biesinger and Christensen (1972) studied 21 metals and concluded that Cu and Cd were the most toxic and Zn, median toxic to *Daphnia*. Effects of change in hardness and alkalinity seem nullified by effects of increased temperature (20–30°C).

Exposure of *Daphnia* to metallic toxicants reduces its own and progenial longevity significantly. It has also been observed that preadult invertebrates are generally less tolerant than adult (Spear and Pierce 1979). Stages, especially of ecdysis and pupa formation have been found more sensitive. Metals also promote ecdysis. These aberrations are related to enzyme inhibition by metals. Metals are also known to effect nervous system causing erratic swimming and loss of equilibrium in organisms residing in or exposed to polluted waters also observed in this study.

The present results have significance in manipulating the doses for algal eradication, detection of the pollution levels and hazard assessment in sub-temperate conditions of south-Rajasthan. Furthermore, results are significant in respect of the presence of zinc excavation and refining unit (Hindustan Zinc Ltd., Udaipur), nearby to the experimental site (10 km). This unit was established about a decade and a half ago and has by now almost destroyed the wild fauna and flora around its location and seriously threatened the nearby aquatic fauna by its fumes and acidic metal effluents. Recently, the company has undertaken antipollution measures like re-extraction of Zn from the wastes and liming the acidic effluents. However, the harm already done to the natural surroundings cannot be reversed.

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