Acute Toxicity of Cadmium to Six Intertidal Invertebrates

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Following a static bioassay techniques the acute toxicity of cadmium to six species of intertidal invertebrates was determined. The sensitivity of the animals to cadmium was of the following order. *Emerita* sp. (burrowing crustacean) *Donax spiculum* (burrowing bivalve) *Perna viridis* (sedentary bivalve) *Sabellaria clandestinus* (tube-dwelling polychaete) *Modiolus carvalhoi* and *Modiolus* sp. (sedentary bivalves). The above observation was based on the median lethal concentrations recorded for the different species, *Emerita* sp. 1.35 p.p.m., *Donax spiculum* 1.8 p.p.m., *Perna viridis* 2.5 p.p.m., *Sabellaria clandestinus* 2.8 p.p.m., *Modiolus carvalhoi* 5.6 p.p.m. and *Modiolus. sp.* 9.6 p.p.m. The findings throw insight into the toxicity of cadmium to the common intertidal animals which are either suspension or detritus feeders.

Cadmium is a non-essential heavy metal in the biological system. Acuteness of toxicity and its devastating effects on animals were amply proved by the itai-itai disease in human beings (Kobayashi, 1971). Several studies have revealed the extreme toxic nature of cadmium to aquatic organisms (Eisler, 1971; Voyer, Nimo *et al.*, 1977; Pesch & Stewart, 1980) and bioaccumulation in the food chain (Waldichuk, 1974; Bryan, 1976; Eisler *et al.*, 1972, O'Hara, 1973; Fowler & Benayoun, 1974). Experimental studies have proved that at very low levels in water, cadmium can cause deleterious physiological effects (Briggs, 1979; Pesch & Steward, 1980; Nelson *et al.*, 1976; Mac Innes & Thurberg, 1972; Gardner & Yevich, 1969; Eisler & Gardner, 1973; Newman & Maclean, 1974).

Representative species from the different taxa have been utilised to study the impact of aquatic pollution. Tarzwell (1971) has suggested that species of phytoplankton, zooplankton, worms, molluscs, arthropods and fishes should be employed for an effective deleniation of toxic effects due to marine pollutants. In the present investigation six intertidal sedentary species from three major taxa were selected for toxicological tests. It is evident that the results outlined in this paper would provide base-line data foı further investigation.

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Materials and Methods

The selection of the species was based on i) availability of organisms in the desired physiological state and successful survival under laboratory conditions. (ii) habitat and mode of feeding, the latter has been found instrumental for direct uptake of heavy metal (Amiard-Triquet & Amiard, 1975).

The species involved in the present study are *Perna viridis, Modiolus carvalhoi* and *Modiolus sp;* bivalve molluscs occurring on rocky shore. They are collected from the Someswar rocky shore (12° 47′ N; 74° 51′ E). *Donax spiculum,* a burrowing bivalve is collected from the sandy beach of Panambur (12° 57′N 74° 48′E). *Emerita* sp. is obtained from the sandy stretch of Someswar. *Sabellaria clandestinus,* a tube-dwelling polycheate is gathered from the rocky shore of Suratkal (13°00′ N; 74°46′ E). The naked worms removed from the arenaceous tubes were used for the experiment.

The collected animals were washed in fresh seawater, transported to laboratory and placed in aerated holding tanks at room temperature for 24 h prior to the experiments. The animals were not fed during the experiments. The seawater used for the present investigation was collected from the non-polluted areas of the Someshwar and Suratkal beach, the habitat of the test animals. Seawater was stabilised, sanitised and filtered before use. The physical properties of the seawater employed for the experiment were as follows: pH 8.15 to 8.30; dissolved oxygen ranged from 5 to 6 ml/1; salinity 34 to 35.5‰. All experiments were conducted at room temperature (30.0 ± 1°C).

The test solution prepared by appropriate dilution of stock solution (100 p.p.m. cadmium) of cadmium chloride was changed every 24 h.

Active and healthy animals were selected and then distributed at random in the experimental tanks containing test solutions. A batch of ten test individuals was used for exposure under each concentration.

Criterion for death of animals

In bivalve molluscs, inability to close the valves even under mechanical stimulation and valve gaping below 5 mm in *Perna viridis* and *Donax spiculum* and 2 mm in *Modiolus carvalhoi* and *Modiolus* sp. was taken as indices of death. Specimens of *Emerita* sp. emerged from the burrows and rested on the dorsal side when they became moribund before death. Cessation of the characteristic wriggling movement in the case of *Sabellaria clandestinus* was adopted as index of death in this species.

Mortality percentage was recorded every 12 h during the 96 h experimental duration. The concentration of cadmium tolerated by 50 per cent of the animals and the time taken to kill 50 per cent of the animals at different concentrations were determined by semilog-probit analysis.

Results

The LC_{50} and ET_{50} values worked out or documented in Tables 1 and 2 respectively for all the six invertebrates studied.

In the case of *P. viridis* upto 1.0 p.p.m. there was no mortality. Mortality commenced at 1. 5 p.p.m. but only 10 per cent of the animals died during 96 h. Forty and ninety percent of the test animals died at 2.0 and 4.0 p.p.m. respectively. Mortality started 48 h after exposure in all the higher concentration and increase in mortality was sharp once it commenced. The 96 h LC_{50} recorded was 2.5 p.p.m. and the ET_{50} was 48 h at 10.0 p.p.m., 76.7 h at 4 p.p.m. (Tables 1 and 2).

M. carvalhoi survived with minimal mortality upto 4.0 p.p.m. This species recorded LC_{50} values of 8.0 p.p.m. at 48 h and 5.6 p.p.m. at 96 h. The effective time (ET_{50}) ranged between 53 h and 18 h for the former at 8.0 p.p.m. and the latter at 12.0 p.p.m. (Tables 1 and 2).

Modiolus sp. could withstand very high cadmium concentrations. None of the test individuals collapsed within 96 h in any concentration below 5.0 p.p.m. The species recorded an LC_{50} value of 9.2 p.p.m. at 96 h.

Table 1. *The LC_{50} (p.p.m.) of Perna viridis, Modiolus carvalhoi, Modiolus sp. Donax spiculum, Emerita sp. and Sabellaria clandestinus as a function of time*

Species time (h)	*Perna viridis*	*Modiolus carvalhoi*	*Modiolus* sp.	*Donax spiculum*	*Emerita* sp.	*Sabellaria clandestinus*
48	—	8.0	—	—	—	—
60	7.0	7.2	16.0	2.7	3.0	4.0
72	5.0	6.4	12.5	2.3	2.0	3.1
84	3.1	5.8	10.0	2.1	1.5	3.0
96	2.5	5.6	9.2	1.8	1.35	2.8
	(2.4 to 2.55)	(5.4 to 5.7)	(8.9 to 9.5)	(1.76 to 1.9)	(1.2 to 1.5)	(2.7 to 2.9)

Figures in parenthesis show 95% confidence interval

Table 2. *The time taken for death of 50 per cent of the test population (ET_{50}) of Perna viridis, Modiolus, carvalhoi, Modiolus sp. Donax spiculum, Emerita sp. and Sabellaria clandestinus*

Concentration p.p.m.	*Perna viridis*	*Modiolus carvalhoi*	*Modiolus* sp.	*Donax spiculum*	*Emerita* sp.	*Sabellaria clandestinus*
2.0				76.66	74.16	
2.5				66.66		
3.0				55.0	58.33	85.00
3.5						68.33
4.0	76.66					
8.0	65.00	53.33				
10.0	48.33	23.33	86.66			
12.0		18.75	73.33			
15.0			61.66			

Donax spiculum proved to be a more sensitive bivalve. Concentrations ranging from 2.0 to 3.0 p.p.m. proved to be highly lethal to the species; resulting in 96 h LC_{50} value of 1.8 p.p.m. The ET_{50} values ranged between 77 h at 2.0 p.p.m. and 55 h at 3.0 p.p.m.

In the experiment with intertidal burrowing crustacean, *Emerita* sp. the LC_{50} values ranged between 3.0 p.p.m. and 1.35 p.p.m. the former for 60 h and the later for 96 h.

Tube-dwelling polychaete, *S. clandestinus* also could not tolerate high amounts of cadmium. Concentrations from 3.0 and 3.5 p.p.m. proved to be lethal for more than 50 per cent of the test animals. The 96 h-LC_{50} value was 2.8 p.p.m. (Tables 1 and 2).

Discussion

The results (Table 1) show that the LC_{50} values of cadmium for the different species studied ranged from 1.35 to 9.3 p.p.m. These results are comparable to a certain extent with the findings in invertebrate species from other localities (0.32 to 25.0 p.p.m.; Eisler, 1971; Table 3). It is apparent that the capacity to tolerate cadmium by the invertebrate takes definite species specific pattern. Eisler (1971) found crustacean to be most sensitive and teleosts to be least sensitive to cadmium stress. In the static bioassay carried out during the present study, the most sensitive species to cadmium stress was *Emerita* sp. and the toxicity decended in the following order: *Donax spiculum, Perna viridis, S. clandestinus, M. carvalhoi* and *Modiolus* sp.

The European flat fish *Fundulus heteroclitus* recorded a high 96 h-LC_{50} value of 114.0 p.p.m. of cadmium (Voyer, 1975) and the planktonic mysid, *Mysidopsis bahia* was so sensitive that 50 per cent of the test individuals died at a cadmium concentration as low as 0.0155 p.p.m. (*Nimmo et al.*, 1977) The inability of crustaceans to tolerate higher cadmium stress documented in earlier studies, is in conformity with the present study.

Majority of the species listed by Eisler (1971) are from the temperate or sub-tropical regions. These species depicted less sensitivity to cadmium when compared with that of the typical tropical species employed here. Species specificity in metal toxicity even within the same genus is clearly depicted in the findings obtained in *M. carvalhoi* and *Modiolus* sp. during the present investigation. Although these two species co-habit in the same locality under similar ecological conditions, there is a wide difference in their 96 h LC_{50} values (Table 1). Among the 4 bivalve mulluscs studied *D. spiculum* proved to be the most sensitive bivalve.

Ahsanulla (1976) found out that the 96 h-LC_{50} for *Mytilus edulis* was 3.6 p.p.m. under flow through bioassay studies and 1.62 p.p.m. under static conditions. Further, he reported

Table 3. *Literature 96h-LC_{50} (p.p.m.) values of cadmium for some invertebrates*

	Species	LC_{50}	References
Amphipod			
	1) *Austrochilotonia subtenuis*	0.04	Throp & Lake (1974)
Ostracod			
	1) *Daphnia magna*	0.05	Schneider (1971)
Decapoda			
	1) *Paratya tasmaniensis*	0.06	Throp & Lake (1974)
	2) *Crangon septemspinoss*	0.32	Eisler (1971)
	3) *Palaemonetes vulgaris*	0.42	Eisler (1971)
	4) *P. vulgaris*	0.76	Nimmo *et al.* (1977)
	5) *Crangon crangon*	0.60	Portmann & Wilson (1971)
	6) *Pagurus longicarpus*	0.32	Eisler (1971)
	7) *Carcinus maenas*	4.1	Eisler (1971)
	8) *Eurypanopeus depressus*	4.9	Collier *et. al.* (1973)
	9) *Mysidopsis bahia*	0.0155	Nimmo *et al.* (1977)
	10) *Emerita* sp.	1.35	(Present study)
Polychaeta			
	1) *Nereis virens*	11.0	Eisler (1971)
	2) *Neanthes arenceodenta*	12.0	Reish *et. al.* (1976)
	3) *Capitella capitella*	7.5	Reish *et. al.* (1976)
	4) *Sabellaria clandestinus*	2.8	(Present study)
Pelecypoda			
	1) *Mya arenaria*	2.2	Eisler (1971)
	2) *Mytilus edulis*	25.0	Eisler (1971)
		1.62	Ahanulla (1976)
	3) *Cardium edule*	2.0	Portmann & Wilson (1971)
	4) *Crassostrea virginica*	3.8	Calabrese *et al.* (1973)
	5) *Perna viridis*	2.5	(Present study)
	6) *Modiolus carvalhoi*	5.6	(,, ,,)
	7) Modiolus sp.	9.2	(,, ,,)
	8) *Donax spiculum*	1.8	(,, ,,)
Asterioidea			
	Asterias forbes	0.82	Eisler (1971)

that the trend shown in the nature of lethality indicate a cumulative effect in cadmium toxicity. Drastic increase in mortality in concentrations where no death occurred during the early phase of exposure obtained during the present study support the findings of Ahsanulla (1976). Curiously enough Eisler (1971) recorded a 96 h-LC_{50} value of 25.0 p.p.m. This value is surprisingly very high when compared to that recorded by Ahsanulla for the same species.

The 96 h-LC_{50} values reported for different polychaetes are given in Table 3. Cadmium was proved to be lethal to *Sabellaria clandestinus,* unlike the other three species tested elsewhere (Table 3).

Lack of uniformity in experimental techniques and selection of species from different geographical areas tend to result in drastic variation in the LC_{50} values recorded by various authors (Table 3). Since there is paucity of information on the toxicity of heavy metals on tropical invertebrates, comparisons are often drawn at from findings where temperate invertebrates are utilised for the toxicity studies.

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