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Effects of Aluminium and Nickel on Survival and Reproduction in Polychaetous Annelids

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The consequences of metal pollution in the sea as evidenced by Minimata disease (mercury) and Itai itai (cadmium) coupled with the potential for other metals to find their way into the human diet in toxic amounts have turned the attention of many scientists toward this problem (WALDICHUK 1974). This has resulted in an increasing number of studies dealing with the assessment of the effects of metals in marine and aquatic environments (EISLER 1973,EISLER & WAPNER 1975). Emphasis was placed on the traditional heavy metals: cadmium, copper, mercury, and zinc, and to a lesser extent chromium and lead. Aluminum and nickel are both abundant in the earth's crust and both possess qualities making them desirable for widespread use in industrialized societies. However, they are inefficiently removed from municipal effluents (BARTH et al. 1965), have long residence times in the ocean (BENDER & GAGNER 1976,YOKOYAMA et al. 1978) and, as a result, these metals may be potentially hazardous to marine life.

Specific studies on the effects of aluminum and nickel on polychaetes and other marine organisms are limited in number. The withdrawal activity of the polychaete *Myxicola infundibulum* was affected by aluminum as $Al_2(SO_4)_3$ at a concentration of 4.6×10^{-4} M [=0.084 mg-Al/L] (WARD 1977). The 96-h LC50 of $AlCl_3$ to the copepod *Nitocra spinipes* was 10 mg/L (BERGTSSON 1978). Crustaceans and polychaetes were the most sensitive animals to $NiCl_2$. The 96-h LC50 values were 6 mg/L for the copepod *N. spinipes* (BERGTSSON 1978); 25 mg.L to the polychaete *Nereis virens* (EISLER & HENNEKEY 1977); and 47 mg/L to the decapod *Pagurus longicarpus* (EISLER & HENNEKEY 1977). Mollusca, sea stars, and fish were more tolerant to nickel, with 96-h LC50 values ranging from 72 to 350 mg/L for these species (EISLER & HENNEKEY 1978).

The purpose of this investigation was to determine the acute effects of the chlorides of aluminum and nickel on the survival of three species of polychaetes and, in addition, to observe any effects on reproduction in one species having a short life history.

MATERIALS AND METHODS

Test Organisms. Laboratory bred strains of the polychaetes *Capitella capitata*, *Ctenodrilus serratus*, and *Neanthes arenaceodentata* were used. Laboratory colonies of these organisms were established from one or a few specimens collected from Los Angeles Harbor several years ago. These colonies have undergone 50 or more generations in the laboratory (REISH 1974). Selection of specimens for bioassay was dependent on the health and general condition of each animal. Sick and/or injured specimens were discarded. *C. serratus* was chosen to measure the effects of these metals on reproduction, since this

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species requires only about 21 days to complete its life cycle.

Test Solution. Hydrated chloride salts were dissolved in distilled-demineralized water to a concentration of 1000 mg/L for each metal. The pH was measured and adjusted to 7.6 to 8.0 with additions of 0.2 M NaOH. Test concentrations were made up by serial dilutions of the stock solution with natural seawater which had been passed through a 0.45 micron membrane filter. A white precipitate formed in $AlCl_3$ solutions greater than 5 mg/L when adjustment of the pH was attempted. No bioassays were conducted in solutions of aluminum greater than 2 mg/L.

Experimental Procedure. Acute bioassays were conducted using five test concentrations plus a control series. Each series consisted of 10 (20 for *Neanthes*) 60 x 20 mm polystyrene petri dishes. Five animals were placed in each container in experiments utilizing *Capitella* and *Ctenodrilus*. One specimen of *Neanthes* was placed in each dish because of its cannibalistic tendencies. At the end of the 96-h and 7-day experimental periods the number of living animals in each concentration was recorded and the LC50 determined (American Public Health Association 1977).

Chronic bioassays with *Ctenodrilus* through one reproductive period were conducted as described above except that the animals were fed dried, ground, green alga (0.5 g of *Enteromorpha crinita* in 50 mL seawater; 5-7 drops per dish) at the onset of the experiment and again at 14 days. At the end of the 28-day experimental period, the number of individuals per dish in each concentration were counted and compared to that of the control using the non-parametric Mann-Whitney Test (ZAR 1974).

RESULTS

The data for the 96-h and 7-day LC50 for these three species of polychaetes are summarized in Table 1. The data for the effects of $AlCl_3$ and $NiCl_2$ on reproduction in *Ctenodrilus* are given in Table 2. The 96-h LC50 values for nickel with *Capitella*, *Ctenodrilus*, and *Neanthes* were >50, 17, 49 mg/L, respectively. The 7-day LC50 values were >50 and 17 mg/L for *Capitella* and *Neanthes*, respectively.

Neither *Capitella* nor *Neanthes* were affected by a 7-day exposure to 2 mg/L concentration of $AlCl_3$, the maximum concentration which could be used without precipitation in seawater. On the other hand, the 96-h LC50 for *Ctenodrilus* to $AlCl_3$ was 0.48 mg/L. Only 7 of 50 specimens were present at 28 days in the dishes containing 0.5 mg/L $AlCl_3$. All *Ctenodrilus* were alive at 2.0 mg/L $NiCl_2$ but none had reproduced.

DISCUSSION

Capitella was the most tolerant of the three species and *Ctenodrilus* the most sensitive to these two metals. Survival of *Capitella* was 78% after 7 days at 50 mg/L $NiCl_2$; however, specimens

TABLE 1

The 96-Hour and 7-Day LC50 (mg/L) of $AlCl_3$ and $NiCl_2$ to three species of Polychaetous Annelids

	$AlCl_3$		$NiCl_2$	
Species	96-h LC50	7-Day LC50	96-h LC50	7-Day LC50
Neanthes*	> 2.0	> 2.0	49	17
Capitella**	2.0	> 2.0	> 50	> 50
Ctenodrilus**	0.48	---	17	---

* 20 Specimens/concentration ** 50 Specimens/concentration

Table 2

The Effect of $AlCl_3$ and $NiCl_2$ on Reproduction in *Ctenodrilus serratus* (28 days; 50 specimens/concentration)

Metal	1	0.1	0.5	1.0	1.5	2.0
$AlCl_3$	229	290	7*	0*	0*	---
$NiCl_2$	237	210	170*	127*	74*	50*

* 0.05 level of significance for reproductive suppression.

showed signs of stress in concentrations as low as 10 mg/L. Stressed *Neanthes* were also noted at 10 mg/L $NiCl_2$, but survival was less than 25% above this level for the same time period. They generally failed to construct mucoid tubes and *Capitella* frequently fragmented. In preliminary experiments with higher concentrations of $AlCl_3$, which precipitated, *Neanthes* generally fed upon the precipitate and passed the material through the gut without any apparent effect. OSHIDA *et al*. (1976) had observed the same species feeding upon the precipitate of trivalent chromium in an experiment of a similar nature. Lethargic behavior and inability to feed were noted in the higher sublethal concentrations of both metals.

Comparisons of the LC50 concentrations to that level at which reproduction suppression occurred in *Ctenodrilus* were different for these metals. Reproductive suppression and the LC50 value with $AlCl_3$ were essentially identical concentrations. The effect of aluminum may be similar to that of copper and mercury which also elicited an all-or-nothing reponse in this species REISH & CARR 1978). Conversely, suppression of reproduction with nickel was one to two orders of magnitude less than the 96-h LC50 value which is similar to that found with chromium and zinc (REISH & CARR 1978).

Comparable data from previous studies indicate that *Ctenodrilus*, with a 96-h LC50 value of 0.48 mg/L to $AlCl_3$, is more sensitive to aluminum than the copepod *Nitocra spinipes* with a 96-h LC50 of 10 mg/L to this metal (BERGTSSON 1978). The range of 96-h LC50 values of 17 to 50 mg/L to nickel are similar to the 6 to 47 mg/L measured for polychaetes and crustaceans but less for molluscs, sea stars, and fish (EISLER & HENNEKEY 1978).

The toxicity of aluminum and nickel to these three species as measured by the 96-h LC50 to six other metals (REISH 1978) indicate that mercury and copper are the most toxic, followed by aluminum, cadmium, and chromium, with zinc, lead, and nickel comprising the least toxic group.

Municipal wastewater effluents in southern California contain from 0.14 to 3.6 mg/L nickel (SCHAFER 1977) which is less than the 96-h LC50 values but coincides with the concentration of 0.5 mg/L at which suppression of reproduction occurred. Sediments from Los Angeles Harbor contain from 18 to 66 mg/kg nickel (MCCONAUGHA 1976) which is enough to be detrimental to these species. However, the manner in which the metal is bound to the sediment may prevent incorporation by the biota (PESCH & MORGAN 1978). Figures are not available for the concentration of aluminum in southern California wastewaters.

The natural influx of aluminum to the ocean is three orders of magnitude greater than that for nickel (BRULAND 1974) and yet the average concentration of these metals in seawater do not vary significantly from one another (RILEY & CHESTER 1971). Recent evidence suggests that marine diatoms play an important role in removing aluminum from ocean waters (MACKENZIE *et al*. 1978, STOFFYN 1979). Therefore, care should be exercised to avoid upsetting such biological control systems, especially when large quantities of materials traditionally thought to be biologically inert are added to wastewaters.

The results of these experiments indicate that aluminum is more toxic than nickel to these polychaetes, but the concentration at which reproductive suppression occurs in *Ctenodrilus* is similar with both metals. Since the amount of nickel in wastewaters exceeds, in some cases, the concentration which can suppress reproduction, this metal may already be at a critical level in nearshore waters adjacent to metropolitan areas.

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