Uptake and Accumulation of the Nickel Ion by *Mytilus edulis*

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Nickel, which is produced as a waste product of industry, passes through municipal wastewater plants in the soluble form (BARTH et al., 1965). Of the four heavy metals, zinc, copper, chromium, and nickel, nickel is removed least effectively.

Studies demonstrating the toxicity of nickel salts include the inhibition of embryonic development of the hard shell clam, Mercenaria mercenaria (CALABRESE and NELSON, 1974) and the sea urchin, Lytechinus pictus (TIMOURIAN and WATCHMAKER, 1972). The lethal concentration of nickel has also been reported for three freshwater zooplankton, (BAUDOUIN and SCOPPA, 1974), and for the brown shrimp, Crangon crangon, and the cockle, Cardium edule (PORTMANN, 1972).

Experiments with Mytilus edulis, a hardy, intertidal ciliary feeder, show an uptake and accumulation of heavy metals (PRINGLE et al., 1968; HOBDEN, 1969; SCHULZ-BALDES, 1974). Because M. edulis accumulates heavy metals and is common to the North Temperate region, M. edulis is a potentially useful indicator of heavy metal pollution.

The purpose of this research was to investigate the uptake and accumulation of nickel chloride by Mytilus edulis.

MATERIALS AND METHODS

M. edulis (mussels) were taken from a rock breakwater at the Berkeley Marina (Berkeley, California). The animals were always collected from the same intertidal level to eliminate any differences in metabolic rate (MOON and PRITCHARD, 1970). To further minimize any variation in metabolism, mussles from 30 to 33 mm were used for the four week experiment and mussles from 27 to 30 mm were used for the 96 hour experiment.

Following collection the shells of the test animals were immediately cleaned and washed of any extraneous materials. The mussels were then placed in "Instant Ocean" (Aquarium Systems, Inc.) which was prepared by the addition of "Instant Ocean" to deionized-distilled water. The "Instant Ocean", used throughout the experiment, had a nickel concentration of 0.0045 mg/l (as determined by an independent laboratory). Natural seawater was not used because of the possible variations in nickel concentration. Different results may have been

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obtained if natural seawater had been used due to the existence of organic ligands for the complexation of metals (CALABRESE and NELSON, 1974).

To minimize the problems of a static environment (losses due to uptake by organisms and aquaria) the artificial seawater was changed every three days. The mussels were fed 0.5 mg of Saccharomyces cerevisiae (in the form of Fleischmann's Dried Yeast) per individual per day.

The mussels for the four week experiment were left in holding tanks for 2 weeks in order to acclimatize them to the laboratory situation. Following this period, 110 animals were placed in five bio-assay tanks and the following concentrations of nickel (as reagent grade nickel chloride) were added to four of the aquaria: 0.013, 0.025, 0.051, and 0.102 mg/l. The fifth tank served as a control.

Five mussels were removed from each tank per week until the fourth week when all the remaining animals were removed. Upon removal, the animals were sealed in plastic bags and kept at 0°C.

The four week experiment consisted of two separate trials. During both trials the water temperature was an average of 12.8°C, the pH ranged from 7.8 to 8.0, and the salinity ranged from 30.8°/oo to 34.4°/oo with an average of 33.0°/oo.

The mussels for the 96 hour experiment were left in the holding tank for at least 8 days. Two separate trials with nickel concentrations of 20, 40, and 80 mg/l (including a control) were conducted. During the two separate trials the temperature ranged from 12.5°C to 13.0°C, the pH ranged from 7.9 to 8.4, and the salinity ranged from 32.0°/oo to 33.8°/oo. The mussels were not fed during the experiment. Upon completion of the experiment the animals were sealed in plastic bags and kept at 0°C.

An analysis of the soft parts of the frozen M. edulis for the presence of nickel consisted of wet digestion combined with flame atomic absorption spectrophotometry using a Perkin Elmer Model 303 spectrophotometer.

RESULTS AND DISCUSSION

The combined results of the four week experiments are summarized in Figures 1 and 2. At total concentrations of 0.018 and 0.03 mg Ni/l, the uptake and accumulation of nickel by Mytilus edulis is not significant over the four week period, while the uptake and accumulation of nickel by M. edulis is significant for total concentrations of 0.056 and 0.107 mg Ni/l.

Although some mussels died during the course of the four week experiment, there is no relationship between the number of deaths and the increasing concentrations of nickel.

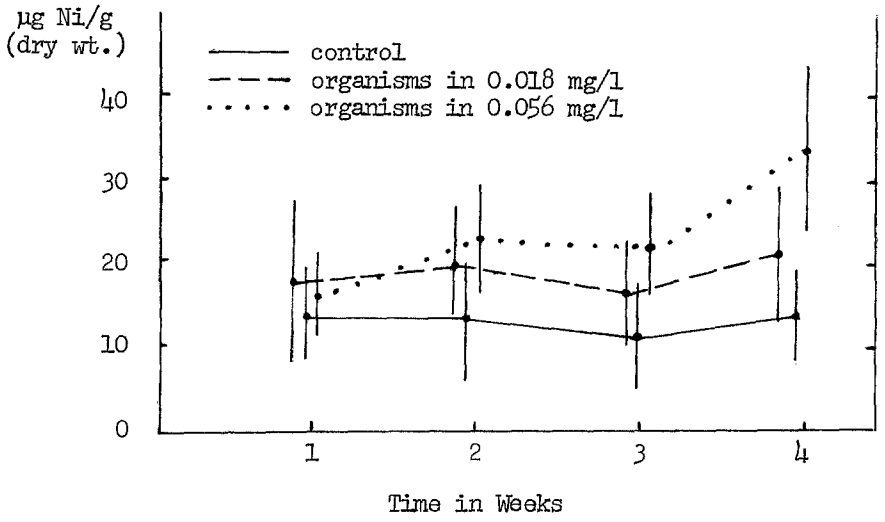

Figure 1. Nickel in the tissues of M. edulis after an exposure to a total of 0.018 and 0.056 mg Ni/l for a period of one to four weeks.

The analysis of the soft tissues of the 96 hour experiment are summarized in Figure 3. A significant uptake and accumulation is shown for mussels in 20, 40, and 80 mg Ni/l. No animals died during the experiment. Mussels secreted byssal threads in concentrations of 20 mg Ni/l, but not at 40 mg Ni/l and higher.

An increase in the uptake and accumulation of nickel by

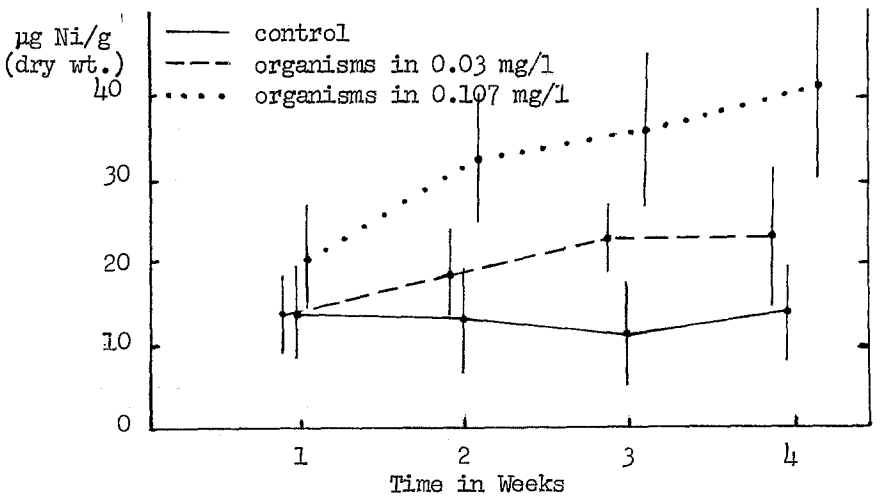

Figure 2. Nickel in the tissues of M. edulis after an exposure to a total of 0.03 and 0.107 mg Ni/l for a period of one to four weeks.

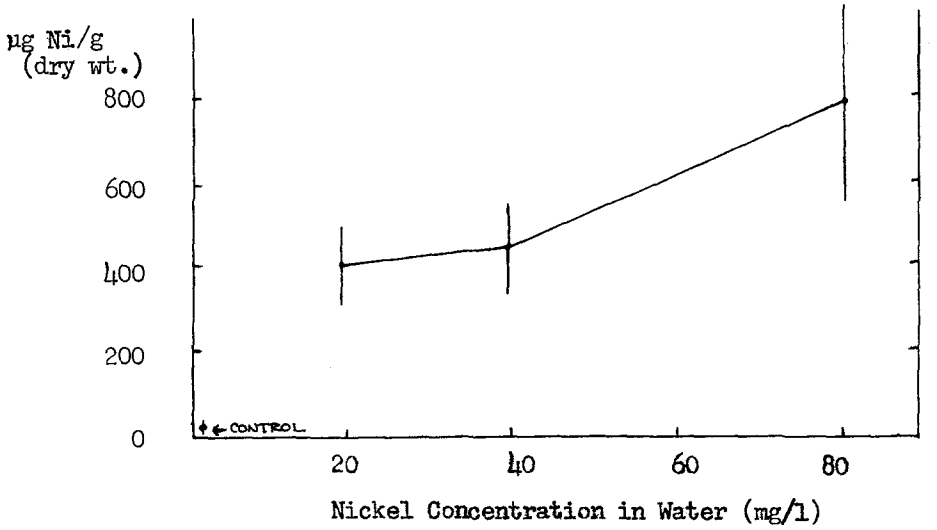

Figure 3. Nickel in the tissues of M. edulis after an exposure to 20, 40, and 80 mg Ni/l over a period of 96 hours.

M. edulis as the concentration of nickel in the seawater increases is shown by Figure 4. In a nickel concentration of 0.107 mg/l, uptake by M. edulis is rapid until saturation is reached during the third week, while the rate of uptake in a nickel concentration of 0.056 mg/l is slower. Uptake of nickel by mussels in 0.018 and 0.03 mg Ni/l is similar. Apparently 0.018 and 0.03 mg Ni/l are too close in concentration to give a significant difference in uptake.

Wide confidence intervals and negative deviations in mean up-

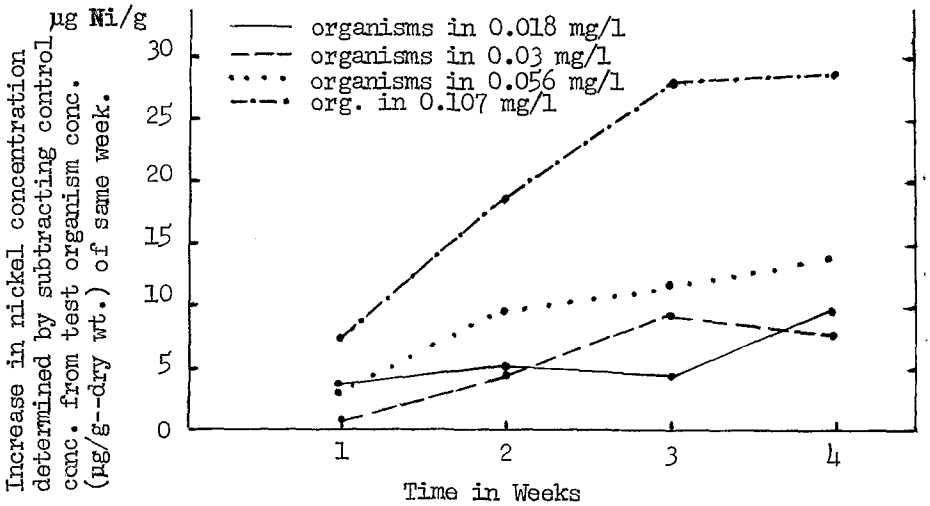

Figure 4. The increase in nickel concentration in the tissues of M. edulis after an exposure to a total of 0.018, 0.03, 0.056, and 0.107 mg Ni/l over a period of one to four weeks.

take from analysis to analysis have also been reported in experiments demonstrating lead uptake by M. edulis (SCHULZ-BALDES, 1974). The wide confidence intervals can be explained by variations in the metabolism and environment of the individual mussels.

As a protection from toxic environments, a bivalve can close its shell to exclude the medium (CALABRESE and NELSON, 1974). By closing the shell, M. edulis can exclude the toxic agent, i.e. nickel. However, in keeping the shell closed for long periods of time, byssal thread formation would be reduced. This could explain the lack of threads at and above 40 mg Ni/l.

The mechanics of heavy metal uptake and accumulation are not clearly understood, but the following theories can be postulated:

1) The ingestion of food elements (e.g. microflora) that have accumulated the heavy metal (BOWEN and SUTTON, 1951).

2) The uncontrolled absorption and inadequate excretion of heavy metals (CAVALLORO and MERLINI, 1967).

3) Absorption of heavy metals directly into blood stream across the gill or mantle epithelia (HOBDEN, 1969).

The accumulation of nickel by M. edulis may be due to an inadequate excretion of nickel. While uptake via food particles or other organisms is quite feasible, the 96 hour experiments point to a mucus sheet or transmembrane absorption, since the mussels were not fed for the duration of the 96 hour experiments.

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