ACCUMULATION AND TRANSFER OF ZINC AND COPPER IN A FOOD CHAIN FROM SEA WATER TO A TERRESTRIAL ANIMAL

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ABSTRACT

Bioaccumulation and transfer of copper and zinc from the primary producers to the higher trophic levels have been studied using molluscs exposed to short-term contamination. The bivalves Meretrix meretrix, were fed phytoplankton enriched with zinc and copper. Next these bivalves were eaten by carnivorous gastropod Chionea virginea. At the tertiary consumer level, four mice were fed with contaminated C. virginea for 21 days. The activity of the animals was monitored. The transfer of copper and zinc showed decreasing trend towards higher trophic levels. The retention time was 4 times higher with metals absorbed from food than from water. Mice fed C. virginea for 21 days did not accumulate zinc, but copper was found in kidney, brain, liver, heart, muscles and skin. The liver seemed to have absorbed copper more than other organs. Loss of weight and activity were observed in mice.

INTRODUCTION

Potentially hazardous metals find their way in ever increasing quantities into the marine environment from mining operation, metal processing facilities, chemical industries and numerous other sources. The intake of heavy metals by organisms and their passage through the food chain have been recognized as a major mechanism for their transfer to the different regions of the sea. Contaminants are often visualized as moving along a food chain from prey to predator with concentrations in the tissues of the organisms, either decreasing or increasing at each successive trophic level. Copper and zinc in trace quantities are essential for marine organisms within the biosphere. As they pass through higher trophic levels, the quantity of these metals is reduced. Reduction of their uptake occurs at two stages: at every point from one trophic level to the next, and at the point of their transfer from the chemical to the biological state. Many studies have been made on distribution of heavy metals in tissue (George and Coombs, 1975) and their seasonal variation in molluscs (Bryan, 1973). But knowledge of the mechanism of the intake of the metals and their subsequent transfer to higher trophic levels is scanty.

Few studies have been made on the actual or potential pathways of pollutant flow from one population of bivalves to or through the populations of the predatory gastropods. The present study is aimed at investigating the accumulation and transfer of zinc and copper from plankton to M. meretrix (bivalves) to C. virginea (murcid gastropod) to mice.

MATERIALS AND METHODS

A series of rectangular fiber glass tanks of 35 l capacity were used in the study. They were non-toxic with smooth interior surfaces. The animals selected for the study were groups of similar size. The bivalve Meretrix meretrix (1.3-2 cm size) and the murcid gastropod C. virginea (4-5 cm size) were used as the study. The molluscs were stocked in large aquarium tanks and acclimatized for 10 days in 34 ppt sea water, pH 8.0-8.2, and dissolved oxygen content of 5.4 mg/l. Controls were maintained for all the sets of experiments. Copper was given as cupric sulphate and zinc as zinc sulphate. The test concentration of copper and zinc was selected based on tolerance limits. Sublethal doses of copper and zinc were added for 7 days.
Experiment - I
The marine diatom *Pleurosigma elongatum* were collected from the Velas estuary by towing a plankton net and culturing them in the laboratory. The culture medium was the Guilford B/2 medium. Stocks of *P. elongatum* were cultured in 500 ml medium with a known amount of added pollutants. Seven cultures were stocked on subsequent days in order to feed *M. meretrix* with plankton exposed to the metals for exactly seven days.

Experiment - II
The second experiment was conducted to investigate the absorption of zinc and copper by the clam *M. meretrix* from water and phytoplankton respectively. Animals in seven tanks, 20 animals in each tank, were fed with 200 ml of plankton stock solution (10^3 cells/ml). Care was taken to feed the animals with exactly 7 days plankton culture. Another set of animals was exposed to 0.02 ppm copper and 3 ppm zinc concentration respectively in water in addition to zinc and copper enriched phytoplankton. After 7 days, five animals were sacrificed and the whole foot bodies of the animals oven-dried at 80°C. Another set of 10 animals was exposed to zinc and copper contaminated medium for 7 days.

Experiment - III
About 20 *C. virginica* tank, in 2 tanks, were fed with *M. meretrix* enriched with zinc and copper respectively at the rate of one bivalve per day. Care was taken to feed the snails with *M. meretrix* exposed to the pollutants for 7 days. Another set of 10 animals was exposed to medium containing 0.02 ppm copper and 5 ppm zinc in addition to food enriched with copper and zinc. After 7 days, 5 animals were sacrificed and various body parts like gill, mantle, gut, digestive gland and foot were dissected for metal analysis. About 5 animals were kept in natural sea water to study the retention time of these metals in *C. virginica*. Another set of about 10 *C. virginica* were exposed to sea water with 0.02 ppm copper and 3 ppm zinc for 7 days.

Experiment - IV
Four mice were fed with zinc and copper contaminated *C. virginica*. The contamination period lasted for 21 days.

Analyses of the samples
The tissues were acid digested following Topping (1973). Each specimen was dried, weighed and digested in a mixture of nitric acid and perchloric acid in the ratio 3:1. The digested samples were made up to 25 ml with double distilled water. Each digested sample was analysed for copper at 324 nm, and for zinc at 211 nm in a Varian Techtron AA 120 Atomic absorption Spectrophotometer. The metal concentration was expressed in μg/g of dried soft tissue.

RESULTS
The zinc and copper inputs into *M. meretrix* and *C. virginica* from sea water with known amounts of metal concentrations have been calculated from the accumulated concentration of zinc and copper in the body parts. The metal input which *M. meretrix* and *C. virginica* obtained from food have been calculated by dividing the value of the "Concentration of metals in tissue at that time" by the "mean value of metals in food".

The results are presented in Appendix 1 and 2. At the end of the feeding experiment, the amount of zinc and copper exchanged from phytoplankton to *M. meretrix* was 365 μg/g dry wt and 77 μg/g dry wt respectively. The rate of intake from *M. meretrix* to *C. virginica* was 116 μg/g dry wt for zinc and 16 μg/g dry weight for copper. In *M. meretrix* the input of zinc from food was 52.1 μg/g dry wt per day. In *C. virginica* the input of zinc from food was 16.5 μg/g dry wt per day. The input of copper in *M. meretrix* from food was 12.1 μg/g dry wt per day. In *C. virginica* the input of copper was calculated at 2.3 μg/g dry wt/day.

DISCUSSION
The gastropod molluscs accumulated more metals from feed than from water. Youtz (1975) showed that *Littorina obtusata* accumulated most of its iron and zinc from the brown seaweed *Fucus serratus*. The present study indicated that food chain transfer
of metal within the tissues of *M. meretrix* and *C. virginea* is more prominent than direct intake from water. Different parts of *C. virginea* exhibited different concentration, the digestive gland showed by far the highest rate of absorption regardless of the source. High concentration of zinc in the digestive gland may be due to the presence of zinc containing proteases in the digestive gland as reported by Ireland and Wootten (1977) for carnivorous species.

The gut seems to have accumulated more zinc when the animals were fed zinc enriched *M. meretrix*. Walker et al. (1975) reported the presence of granules containing zinc phosphate in parenchymal cells surrounding the mid gut of *R. halinodides* and this probably constitutes a site of high storage. The low rate of absorption from both water and food in foot and mantle indicated their insignificant role. The absorption of zinc and copper from the food into all organs is greater than that from the medium. Romeril (1971) proposed different mechanisms involved in the accumulation of heavy metals in marine animals. According to him, the metal may be absorbed by active or passive diffusion from the sea water across semipermeable membranes into the body. Another mechanism is the process of adsorption between water membrane interfaces. The third mechanism involves ingestion of ions with food or in combination with particulate matter or mucous and absorption through the gut wall. High concentrations of zinc and copper were recorded in digestive gland and the stomach of the animals fed with zinc and copper enriched *M. meretrix* and it is probable that the third mechanisms proposed by Romeril (1971) might have played a role. Gills were also found to have more accumulation. The differences in metal content at each trophic level may be due to excretion across the body, surface or gills, excretion via the gut and via the urine.

In the tertiary consumer level zinc accumulation was observed only in the skin. All the body parts showed copper accumulation within the short period of study. Liver has accumulated more copper than the other organs and loss of activity and weight in mice was noticeable at the end of the period of study.

Transfer of zinc from the primary producer level to the primary consumer level was 37.9% and 31.4% from primary consumer level to the secondary consumer level. The intake of copper from the primary produces level to the primary consumer level was 23.2% and 22.3% from the primary consumer level to the secondary consumer level. At the tertiary consumer level the rate of intake of copper was 7.5%, whereas for zinc it was 1.0%. Compared with the primary and secondary consumer levels copper was found to accumulate more in the tertiary consumer level than zinc.

REFERENCES


Appendix 1.
Zinc 3 ppm

<table>
<thead>
<tr>
<th>Sample</th>
<th>Control value</th>
<th>From water</th>
<th>Net uptake from water</th>
<th>From food and water</th>
<th>Net uptake from food &amp; water</th>
<th>From food alone</th>
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<tr>
<td>Plankton</td>
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<td>906</td>
<td>355</td>
<td>980</td>
<td>855</td>
<td>490</td>
<td>365</td>
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<tr>
<td>M. mercatoria</td>
<td>125</td>
<td>460</td>
<td>355</td>
<td>980</td>
<td>855</td>
<td>490</td>
<td>365</td>
</tr>
</tbody>
</table>

C. virgata
1) Mantle 100 180 80 300 200 206 106
2) Gill 160 260 100 415 255 320 150
3) Dig. gland 1080 1360 280 2160 1085 1859 779
4) Gut 220 240 280 420 200 395 175
5) Fox 80 140 60 230 150 166 80

Muss
1) Kidney 80 100 80 100
2) Brain 100 100 100
3) Gut 120 100 120
4) Heart 40 40 40
5) Skin 120 120 120 140 20

Appendix 2.
Copper 0.2 ppm

<table>
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<th>Net uptake from water</th>
<th>From food and water</th>
<th>Net uptake from food &amp; water</th>
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<th>Net uptake from food</th>
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<tbody>
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<td>Plankton</td>
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<td>27</td>
<td>176</td>
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<tr>
<td>M. mercatoria</td>
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<td>91</td>
<td>27</td>
<td>176</td>
<td>112</td>
<td>143</td>
<td>77</td>
</tr>
</tbody>
</table>

C. virgata
1) Mantle 90 98 12 112 48 112 26
2) Gill 96 108 12 130 48 112 26
3) Dig. gland 86 104 18 156 48 112 26
4) Gut 82 90 9 117 35 103 21
5) Fox 66 74 8 87 21 77 11

Muss
1) Kidney 42 100 100 54 12
2) Brain 50 60 60 10
3) Liver 58 72 72 14
4) Heart 50 80 80 10
5) Skin 42 56 56 14