Heavy Metals in Zooplankton from the Gulf of Aqaba, Red Sea

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Abstract

This study was carried out to determine the concentration level of selected heavy metals Mg, Cu, Fe, Zn, Ni, Pb, Zn and Cd in zooplankton. The result showed that trace metal in zooplankton did not vary significantly between different sites, this despite of the slightly higher values of Mg, Zn, Ni and Cd in the Marine Science Station, Fe in the Jordanian Fertilizer Industry and Pb in the Yacht Club. Temporal variations of trace metals in zooplankton were significant for Zn, Ni, and Cd with higher concentrations in autumn and Pb in spring. The other elements did not show any significant difference. The small size zooplankton (100-500 μm) appears to contain higher levels of heavy metals compared to the large size zooplankton (>500 μm).

Keywords: Zooplankton, Heavy metals, Gulf of Aqaba, Red Sea, Pollution.

Introduction

Marine zooplankton can be used for toxic trace metal biomonitors of their environment from which accumulate trace metals, and concentrate, and store them in their tissues. They can accumulate them from both dissolved phase and from ingested food. When other organisms such as fish consume zooplankton, the metals contained in the tissues can be accumulated and further concentrated by the predators, thereby transferring metals up the food web. This is why zooplankton is considered key link in the transfer of carbon and trace elements through marine food webs [14]. The concentrations of the metals in both microplankton and marcozooplankton were related to dietary transfer from the smaller to the larges size fraction [10]. Due to their central role in the food chain and the world wide distribution of zooplankton, they are considered as interesting candidates for bioaccumulation studies The spatial and temporal accumulations of metals from the environment into the zooplankton tissue and transferring to its predator have been studied by different scientists [27; 19; 9]. However, the interpretation of the data concerning metal pollution in zooplankton and other biological indicators is a complicated task unless enough information about the composition, size fraction and environmental conditions such as temperature and salinity are available. Zooplankton composition, mainly Crustatian copepods in the Gulf of
Aqaba have been studied in details by different Authors [24; 5; 12; 6; 7]. However, still there is no information on the levels of heavy metal pollution and bioaccumulation in zooplankton of the gulf of Aqaba as a whole and of the mostnorthern tip that subject to different human activities, development and uses and consequently to different environmental impacts. The aim of this study is to fill the gap in the information about the metal concentrations, provide unprecedented information on the concentration levels of Cd, Cu, Ni, Pb, Fe and Zn metals in zooplankton and the possibility of using them as bioindicator for metal pollution in the Gulf of Aqaba.

Materials and methods

Study area:

The Gulf of Aqaba is considered to be a partially enclosed water body that constitutes the eastern segment of the V-shaped northern extinction of the Red Sea (Figure 1). It is located in a sub tropical arid area between 28º-29°30’ north and 34°30’-35°east. The deep Gulf (>1800 m) is 180 km long and has a maximum width of 25 km, that decreases at the northern tip to about 5 km. It is connected to the Red Sea by the Strait of Tiran, which has a depth of about 252 m (18, 22, 20). The present study area lies within the Jordanian portion of the Gulf of Aqaba, which constitutes the most northern and northeastern side of the Gulf and extended for about 27 Km to the north of the border with Saudi Arabia.

Zooplankton collection and treatment

The zooplankton community > 150μm includes 73 species distributed in 45 genera within 10 taxa, namely; Tintinnidea, Foraminifera, Trachymedusea, Thecosomata, Cladocera, Ostracoda, Copepoda, Malacostraca, Chaetognatha and Urochordat was collected from five coastal sites (Hotels, Yacht Club Marina, Phosphate Loading Berth, Marine Science Station (MSS) and Industrial Complex/ Jordan Fertilizer Industry (JFI) sites and one offshore site off the Marine Science Station (Fig. 1). These sites embrace various habitats that usually occur along the coast of the Gulf of Aqaba such as fringing coral reef, seagrass beds and unconsolidated sandy bottom areas. In addition, the selected sites represent portions of the coastal zone where major development, and maritime, industry and tourism activities are taking place. A150-μm mesh plankton net was used for zooplankton sampling. At each station the plankton net was towed horizontally for 10 minutes, at 10 cm below the surface, by the use of a rope connected to the boat. After then, the net was pulled out of the water and washed with filtered seawater in order to remove all zooplankton from the net. Samples were transferred to a plastic container and immediately brought to the laboratory for further processing. Laboratory processing includes splitting the catch (sample) into two size fractions (>500 and 150-500 μm) by the use of a sieve column. Each of the separated fractions was put onto a pre-weighed and GF/C filter. The filter was subsequently dried at 80°C to constant weight for about 24 hrs, and then kept in desiccators to bring to room temperature. The samples were finally weighed on an analytical balance to obtain dry weight in milligrams.
Fig. 1: Study Area and Sampling Sites

**Trace metals digestion and measurements**

The zooplankton fractions were placed in pre-cleaned small capacity (100 ml) glass beakers, and oxidized by the addition of 8ml of 69.5% ultra-pure nitric acid at room temperature for 4 hrs. Beakers were put on a hot plate at 100°C for 6 hrs, and then allowed to cool to room temperature. The samples were heated again to near dryness for the removal of the nitric acid. The residue was then dissolved in 8ml of 1% nitric acid and kept on a hot plate for about 1 hr to enhance dissolution. The samples were allowed to cool to room temperature and then filtered on a Whatman filter paper number 43. Samples were finally diluted to 25ml with 1% nitric acid. Concentrations of Mg, Cd, Cu, Ni, Pb, Fe and Zn were measured by the use of Jena AA 300 atomic absorption spectrophotometer. Duplicate measurements were made for each sample, by direct aspiration into air-acetylene flame. The instrument was instructed to give the mean value and standard deviations of three readings as the final reading of each sample. The
precision of the whole procedure was assessed by 10 replicates for a sample and the results agreed to within 4%. Duplicate blanks were used for each batch of digested samples. The mean value of the blank if any was subtracted from the readings of the sample to give the final reading. In addition to the blank solution, three standard solutions were prepared to cover the expected range of the element concentrations in the samples and within the linearity of the procedure (within the linear portion of the calibration curve of the procedure).

**Results**

**Temporal variations in zooplankton metals**

Figure 2 shows the mean concentration and Standard Error (SE) of Cd, Pb, Cu, Fe, Zn, Ni and Mg concentrations in zooplankton from different sampling seasons. The statistical analysis of the results indicates significant differences between different seasons for Pb, Zn, Ni and Cd, but not for the rest of elements. Higher concentrations of almost all metals occurred during spring with mean concentrations of 8.63, 1.22 and 0.75 ppm for Zn, Pb and Ni, respectively. Meanwhile higher concentrations in autumn have been observed with mean concentrations of 16.84, 1.95 and 0.162 ppm for Zn, Ni and Cd, respectively.

**Spatial variations in zooplankton metals**

Figure 3 shows the mean concentration of metals in zooplankton that has been collected from different sites within the study area. Relatively high concentrations were found in the Marine Science Station for Zn, Ni, Cd and Mg with mean values of 0.04, 18.0, 1.6 and 10.7 ppm, respectively. The lower concentrations of the same elements were found in the Yacht Club Marina with mean values of 0.01, 1.6, 0.2 and 1.1 ppm, respectively. Relatively higher concentrations of Fe in the Jordan Fertilizer Industry zone with mean value of 6.0 ppm. However, statistical analysis does not show any significant differences in zooplankton metal contents between different sampling stations along the Jordanian coast.

**Metals in different zooplankton fractions**

Figure 4 shows the mean concentrations of Mg, Pb, Cu, Fe, Zn, Ni and Cd in the two size fractions of zooplankton. Significantly higher concentrations were found in the size fraction 150-500μm for Zn, Ni and Mg with mean values of 1.65, 12.53 and 6.45 ppm, respectively. The rest of the elements however, does not show any significant differences compared to those found in the >500μm fraction.
**Figure 2**: Mean concentrations ±SE of Mg, Pb, Cu, Fe, Zn, Ni, and Cd in Zooplankton from the Jordanian coast of the Gulf of Aqaba, Red Sea.
Figure 3: Mean concentrations ±SE of Mg, Pb, Cu, Fe, Zn, Ni, and Cd in Zooplankton from the Jordanian coast of the Gulf of Aqaba, Red Sea.

Mg:

\[\text{Season} = \text{Autumn, Spring, Summer, Winter}\]

Pb:

\[\text{Season} = \text{Autumn, Spring, Summer, Winter}\]

Cu:

\[\text{Season} = \text{Autumn, Spring, Summer, Winter}\]

Zn:

\[\text{Season} = \text{Autumn, Spring, Summer, Winter}\]

Fe:

\[\text{Season} = \text{Autumn, Spring, Summer, Winter}\]

Cd:

\[\text{Season} = \text{Autumn, Spring, Summer, Winter}\]

Ni:

\[\text{Season} = \text{Autumn, Spring, Summer, Winter}\]
Figure 4: Mean concentrations ±SE of Mg, Pb, Cu, Fe, Zn, Ni, and Cd in different zooplankton fractions from the Jordanian coast of the Gulf of Aqaba, Red Sea.

Mg:

Cu:

Fe:

Ni:

Pb:

Zn:

Cd:
Discussion

The data show that zooplankton from different sites along the Jordanian coast are able to accumulate varying amounts of heavy metals in their tissues. Levels of Zn, Ni and Mg are relatively high at the Marine Science Station (MSS). By comparison, the zooplankton samples from the Yacht Club Marina showed relatively high content of Cd, and Pb. Apparently, the samples from the Industrial Complex (JFI) area showed relatively high Fe content, but the statistical examination of the concentration did not show any significant differences between metal contents among the six different sampling sites. The higher concentrations of Zn and Ni in the Marine Science Station area are difficult to explain. However, a potential unknown source can be attributed to various anthropogenic activities at the nearby passenger port. The high concentration of Pb and Cd in Yacht Club Marina is mainly due to the relatively high activities of boats fueling, anchoring and maintenance which includes painting and cleaning that is taking place almost on daily basis in the marina. The high concentration of Fe in the Industrial complex area is attributed to corrosion of metal, cables and other parts and piping system by the effect of various industries in the area. The general trend in spatial variations of the metal contents in zooplankton are in general agreement with those of previous studies [2; 4] on the bioaccumulation of trace metals in the tissue of bivalves (Modiolus auriculatus) at different locations along the Jordanian coast. They reported high concentrations of trace metals (Pb and Cu) at the Marine Science Station and Cd and Ni at the Industrial complex area.

In a comprehensive study on the distribution of different trace metals in different sites along the coast of Kuwait, [9] reported a similar conclusion on the source of trace metals in zooplankton. They attributed the high concentration of some trace metals to the input of industry, associated with pollution caused by other human activities. The increase in metal concentration in zooplankton soft tissues was in the following order Zn> Mg> Fe> Ni> Pb> Cu> Cd, which indicates that Zn, Fe, and Mg are accumulated by planktons in preference to other metals, possibly because these elements are essential for cell growth, when they present in small amount [8]. In addition, they constitute integral part of respiratory protein [1], they are required for the activity of diverse enzymes [3; 25; 26] and for the healthy living of planktons [17]. At elevated concentrations, however, these metals become toxic to organisms [21].

In the present study seasonal variations of metals in zooplankton have been observed for Pb, Zn, Ni and Cd in which higher concentrations of the elements were detected during autumn and spring. However, the rest of the metals did not show significant seasonality. In general, the seasonal variations of metals in zooplankton could be related to the changes in the pollution load of the sites, changes in the accumulation strategy of zooplankton from regulation to net accumulation, or increase in feeding rate during autumn and spring [13].

Similar seasonality in mixed zooplankton samples has been reported by [13], who found highest concentrations for all elements in summer and autumn. He found also that the pattern of temporal variation in the heavy metals concentration of zooplankton was not statistically similar. In contrast, [9] found significant differences between seasons.
He found higher iron concentrations during winter season than all other metals against summer.

Significant difference in the concentrations of Mg, Fe, Zn, Ni and Cd was found in different size fractions of the zooplankton of the present study area. The small size fraction of zooplankton (100-500) showed higher concentration for most of the element studied compared to the large size fraction (>500). This could be explained in view that the metal uptake process may depend on the taxonomic differences and/or on surface area to volume ratio. The 100-500 μm zooplankton fraction absorb metals more efficiently than >500 μm fraction [15; 16; 11].

Acknowledgment

The Authors would like to thanks the efforts of the Marine Science Station team, especially Mr. Ehab Eid and Mr. Abdel Wahab Al Sheyab for their help in samples collections. The scientific and logistic cooperation with the Department of Earth and Environmental Sciences at Yarmouk University is highly appreciated. This work is part of the project of environmental assimilative capacity of coastal habitats and green mariculture of high revenue low environmental burden on the Jordanian sector of the Gulf of Aqaba, Red Sea funded by the Higher Council for Science and Technology, Amman, Jordan.

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