

Element concentrations in some species of seaweeds from La Paz Bay and La Paz Lagoon, south-western Baja California, Mexico

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Abstract

La Paz Bay and La Paz Lagoon are water bodies of the Gulf of California that are influenced by waste water discharges from the City of La Paz and from activities of the phosphorite mining company “Rofomex”. Because seaweeds concentrate elements from the water and are used as effective indicators of contamination by metals, we investigated their usefulness in this region. Concentrations of certain major elements (Ca, Fe, K and Na) and trace elements (As, Ba, Co, Cr, Cs, Hf, Rb, Sb, Sc, Se, Sr, Ta, Th, U, Zn and Zr) were determined in 12 species of seaweeds from La Paz Bay and La Paz Lagoon using instrumental neutron activation analysis. The contents of trace elements of environmental importance (As, Co, Cr, Fe, Sb, Se and Zn) in all studied samples are within the range of typical levels for a pristine environment not subjected to anthropogenic impact. Somewhat higher concentrations of Cr (81 mg kg⁻¹), Hf (4 mg kg⁻¹), Rb (48 mg kg⁻¹), Sc (6.3 mg kg⁻¹), Ta (0.95 mg kg⁻¹), Th (6.8 mg kg⁻¹), U (33 mg kg⁻¹) and Zn (90 mg kg⁻¹) were found in the green seaweed species *Ulva* (formerly *Enteromorpha*) *intestinalis*, whereas such elements as As (77 mg kg⁻¹), Sb (1.4 mg kg⁻¹) and Se (1.8 mg kg⁻¹) were mainly concentrated in the species *Sargassum sinicola*, *Codium cuneatum* and *Padina mexicana* respectively. Because of their higher abundance and heterogeneity in elemental composition the seaweeds species *Ulva intestinalis* and *Caulerpa sertularioides* seem to be more suitable for further biomonitoring of heavy metal pollution of the coastal waters in this zone.

Introduction

The development of marine ecosystems is strongly controlled by the biogeochemical cycles of chemical elements, which depend on their interactions with each other and the geological, climatic, physical, chemical and biological processes that occur in the water column and on the interfaces with sediments and the atmosphere (Chester, 2003; De La Lanza & Cáceres, 1994). In coastal marine areas, it is important to understand the biogeochemical cycles of both the major and trace elements because of the possibility of the changes which may occur in them as a result of either natural or man-made alterations to the environment.

Bays, being partly enclosed water bodies, often show strong variations in terms of sediments and chemical composition of the water column. In particular, coastal marine sediments are usually made up of both terrigenous and marine biogenic materials, and their composition can vary depending on hydrodynamic and climatic conditions, the type and strength of material inputs, distance from source and the extent of dilution of natural terrigenous or anthropogenic components, usually enriched in many elements, by silica and carbonates of marine biogenic origin (Chester, 2003).

Some elements are mainly present in the dissolved fraction (ions and molecules) in the sea water, whereas others are incorporated into either colloidal or

particulate matter. Particulate and/or dissolved material may interact with each other and alter the biogeochemical fate of the elements in the marine environment. During early diagenesis elements stored in the marine sediments because of the changes in the sediment's pH and redox potential Eh can be released into the interstitial and overlying sea water by dissolution, desorption or autolytic biological processes (Chester, 2003). Any disturbance caused by either physical factors (e.g. currents) or biological factors (e.g. movement of organisms) will stimulate exchanges between the elements in the sediments and those in the seawater.

A variety of organisms, such as seaweeds, can also transfer and accumulate trace elements in the sea (Kennish, 1997). Seaweeds take up metal elements from the aquatic environment, depending on species, exposure time, type of metal and its oxidation state, pH, salinity and presence of organic pollutants (Bernhard & Zattera, 1975; Hassett et al., 1980; Jensen et al., 1976; Mykkestad et al., 1978; Phillips, 1977). Contamination of the seaweed surface from simple contact with the elements dissolved in sea water has been observed in both unicellular and pluricellular algae, while metal ions, some of which are essential elements, are also taken up by algae through pores in their cell walls. Consequently, the cell components as well as the composition and structure of the cell walls are important factors in determining the ability of a seaweed species to absorb metals (Kuyucak & Volesky, 1990). For example, in brown seaweeds, the alginates of the cell walls and of the intracellular spaces regulate the exchange of ions, showing an affinity for metals in the following decreasing order: Pb > Cu > Cd > Ba > Sr > Ca > Co > Ni > Zn > Mn > Mg.

Many studies of contaminants and their effects on marine macroalgae have been published since the beginning of the 1960's (see Lobban & Harrison, 1994). Other data have shown that seaweeds can absorb metals such as Pb and Sr (Eide et al., 1980). For example, Ho (1990) found that the seaweed *Ulva lactuca* is an important bioindicator of Cu, Zn and Pb present in sea water. Similar studies were recently done for the coastal zone of Mexico. For example, Robledo & Freile Pelegrín (1997) reported the chemical composition of six species of edible macroalgae from the Yucatan region. Closer to La Paz Bay, Sánchez-Rodríguez et al. (2001) reported the concentrations of elements in various seaweeds from the almost pristine Bay of Loreto, in the central Baja California peninsula.

La Paz Bay and its smaller component, La Paz Lagoon, are particularly interesting for environmen-

tal studies because of their proximity to the City of La Paz, the oil reservoirs of Petroleos Mexicanos (PEMEX), the electrical plant owned by the Compañía Federal de Electricidad, and the activities of the mining company "Roca Fosfórica Mexicana, S.A. de C.V." ("ROFOMEX"), located near the San Juan de la Costa in the western coast of the La Paz Bay. Because of the dry and arid climate of the region, terrigenous material is carried into La Paz Bay and La Paz Lagoon mainly by wind or with episodic discharges of the ephemeral water streams ("arroyos") only after rare but heavy rains. The characteristics of these inputs into the coastal marine environment are largely determined by the different types of rocks (sedimentary rocks, igneous rocks and alluvium, a product of the weathering of the rocks of San Gregorio and San Isidro Formation, and the Comondú geological formation) in the surrounding areas (Figure 1, Hausback, 1984).

The high productivity of coastal waters of La Paz Bay and La Paz Lagoon makes it more interesting to determine the concentrations of elements in the seaweeds, because some of them are edible or could be used as food additives for domestic animals. It is also necessary to determine which seaweed species are most suitable for future biomonitoring of heavy metal pollution in these areas.

Taking all of this into consideration, as well as the need to increase the use of the region's natural resources in a controlled manner, the present study aimed to determine the concentrations of major and trace elements in some species of seaweeds that occur in La Paz Bay and La Paz Lagoon, and to select species suitable for further biomonitoring of heavy metal pollution of these areas.

Materials and methods

In August 1998, 35 samples of seaweeds were taken from a boat by scuba diving at 19 different locations in La Paz Bay, between Punta Tarabillas and the Espíritu Santo Island (Figure 1, Table 1). The seaweeds were collected by hand directly from the substrate and put into identified plastic bags for later analysis. In the laboratory, they were washed with tap water to get rid of any residues such as sand or shells, and then sorted according to sampling station and species. The seaweeds were identified using taxonomic keys (Abbott & Hollenberg, 1976; Norris, 1975; Silva et al., 1996; Taylor, 1945). They were then left to dry at room temperature, on absorbent paper. Once completely dried, each sample was crushed, sieved and