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Metals anomalies in foraminiferal shells as indicators for industrial pollution: a case study from the Mediterranean coast of Israel

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In recent years we have been witnessing a considerable growth of industrial facilities along coastal areas. Some of these have major economical and national importance yet their operation can introduce a wide range of chemicals that might contaminate the coastal area and impact local ecosystems and our health. Among some of these harmful chemicals are metals that are introduced to the coastal environment by some of these facilities. Here we present a novel approach for monitoring low-level industrial pollution in coastal environments based on anomalies in metal concentration within foraminiferal shells.

Living foraminifera are used as bio-indicators of the environmental status of any marine habitat. As unicellular organisms with short life and reproductive cycles, they are extremely sensitive to long and short-term changes. The majority of foraminifera precipitate $CaCO_3$ (low-Mg-calcite, high-Mg calcite or rarely aragonite tests). Their calcareous shells are precipitated by a mechanism that involves direct seawater vacuolization which reflects the chemical composition of the ambient water. For this reason the geochemical composition of their shells is particularly applicable as a tool for marine environmental monitoring.

Material for this study was obtained during the monthly campaigns of a biomonitoring project (2012-2015) of a heat polluted area and of a nearby natural clean station off the northern Mediterranean coast of Israel. Essentially, monitoring of water chemistry in both habitats showed no indications of presence of heavy metal contamination. Yet, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analyses of two common local foraminifera the hyaline species *Pararotalia calcariformata* and the miliolid species *Lachlanella* sp. 1 that were collected alive from both areas, recorded presence of various metals (Mn, Cu, Zn, Ba, Pb) within their shells. Metal concentrations within the miliolid species were significantly higher than those of the hyaline species despite of the fact that both species were collected from the same environment. For example, the concentration of Cu in the ambient water was lower than 1μg/L, whereas the values recorded in *P. calcariformata* ranged between 2-12 μg/L in and between 11-157 μg/L in *Lachlanella* sp. 1. These results highlight the efficiency of using miliolid species that are extremely common in shallow coastal areas as recorders of extremely low concentrations of metals, thus potentially detecting pollution before harming the ecosystem.