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Monitoring of trace metals in the marine environment: Looking Backward and Looking Forward

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Traditionally, monitoring of metals in the marine environment has involved quantification and comparison of metals in sea water and sediment. The main problem associated with monitoring metals in sea water is that concentrations are typically low, making analysis difficult and contamination problems significant. Furthermore, no time integration can be provided in discrete water sampling, and hence a large number of water samples must be taken and analysed to cover the considerable temporal variations of metals in the marine environment [1]. Monitoring metals in sediment poses another set of problems : effects of particle size, organic content and redox potential on metal levels are significant, and in addition, these factors are difficult to standardise and account for. Bioavailability of metals in sediment are also difficult to determine [2].

Due to problems and limitations associated with monitoring trace metals in water and sediment, biological indicators have been commonly used in the last two decades. In particular, mussels have been widely used to monitor and compare metals in coastal marine waters on a global scale [3]. The use of biological indicators has obvious advantages over the use of water and sediment in metal monitoring, since biological indicators can concentrate metals and provide a time-integrated estimate of metal concentrations in the monitoring environment, whilst only the bioavailable fractions of metals are accumulated. However, major shortcomings in the use of biological indicators include difficulties in standardising the sex, size, reproductive and nutritional stages of the species, which may have significant effects on metal accumulation. In addition, different species may have different strategies of metal accumulation. Difficulties also exist in ascertaining the well being and survival of the biological indicators species in polluted areas. Limits of natural distribution often prevent direct comparisons between different indicator species in different geographic areas and environmental conditions. Furthermore, environmental effects on the uptake and depuration of metals in the biological indicators are generally poorly understood.

Recently, we have successfully developed a novel chemical device for monitoring heavy metals in the aquatic environment. The device consists of a polymer ligand (e.g. Chelex-100) suspended in artificial sea water within a plastic tubing, which is sealed at both ends with permeable gels. Results of our laboratory experiments have shown that both uptake and release of Cu, Cd, Cr, Pb and Zn by the chemical device are directly related to metal concentrations in the ambient environment. Concentration factors for various metals within the chemical device are comparable to biological indicators, while the coefficient of variability is lower. Results of anodic strip voltammetry studies further demonstrate that the ligand predominantly takes up the ionic and labile metal species (the bio-available fractions) in sea water. Uptake and release of metals by the device are not significantly affected by fluctuations in environmental factors such as temperature and salinity, as well as short term fluctuations in ambient metal concentration.

Field experiments have been carried out in which the chemical devices were deployed side by side with the green mussel (*Perna virvidis*) at three locations with different levels of metal contamination. Levels of metals accumulated by the device were able to provide a time-integrated estimate of metal levels in the monitoring environment. The results further showed that both spatial and temporal variations of metals concentrations in the chemical devices closely resembled those in the mussels, indicating that the uptake and release of metals by the chemical device were similar to this commonly used biological indicator.

The performance of this chemical device has been evaluated against the selection criteria for biological indicators [4], and the chemical device meets all the selection criteria for an ideal metal biological indicator. In addition, the use of this chemical devices confers major advantages over existing monitoring techniques. Since the device can be deployed in different hydrographic conditions over a wide geographic area, it will be able to provide a direct comparison of metal monitoring results world-wide. The device can also be used to monitor metals in a highly polluted environment (e.g. in the vicinity of industrial and sewage outfalls), where survival and / or metal accumulation of biological indicators may be seriously affected.

References

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