Abstract

Seven seaweed species of Malaysia; *Chaetomorpha linum, Padina tetrastomatica, Sargassum baccularia, S. siliquosum, Gracilaria changii, G.edulis* and *G.salicornia*, were used in 24 h single metal exposure static studies to characterise the heavy metal (Cu, Zn, Mn and Cd) accumulation patterns in the seaweeds. This was done by incubating the seaweeds in a range of metal concentrations in sea water and by determining the metal content, at fixed time intervals, in the seaweeds and seawater over a 24 h exposure period. Five metal accumulation patterns were observed in this study; Pattern 1 : An initial rapid uptake, followed by a gradual accumulation till 24 h; Pattern 2 : A continuous gradual accumulation pattern for the entire 24 h; Pattern 3 : An initial rapid uptake, followed by a release-uptake pattern before a maintenance pattern or gradual accumulation continued till 24 h; Pattern 4 : An alternating uptake-release or vice-versa pattern throughout the 24 h; Pattern 5 : An initial net accumulative pattern, followed by a continuous regulatory discharge till 24 h.

Based on the three criteria; i) seaweed should possess net accumulation pattern; ii) seaweed should have strong positive correlation between metal accumulated in tissues and

time of exposure; iii) seaweed should have strong positive correlation between metal accumulated in tissues and available metal concentration in seawater; which characterise organisms as potential bioaccumulative indicators of selected heavy metals, the Phaeophytes were most suitable, followed by the Chlorophyte *C. linum* and then the Rhodophytes, the *Gracilaria* species.

Exposing three seaweed species, *C. linum*, *S. siliquosum* and *G. changii* to a single metal concentration of 1 mgL^{-1} (Cu, Zn, Mn and Cd) for 2 h, respectively at differing salinities of 20, 25, 30 and 35 ppt concentration, showed that decreasing salinity levels correlated ($p<0.05$) with increased accumulation of metals in seaweeds.

Exposure of the same three seaweed species to a single metal concentration of 1 mgL^{-1} at differing pH (4, 5, 6, 7 and 8) did not show any corresponding trend for the effect of pH on metal accumulation in seaweeds for the 2 h exposure. However, pH above 4 produced significantly ($p<0.05$) higher accumulation generally.

Toxicity studies showed that IC_{50} values using growth parameters (Chlorophyll-a content and dry weight) , can vary greatly, depending on the incubation time used. *G. changii* was the most sensitive species to Cd exposure. In the range

finding test, there was 50% inhibition in dry weight after 96 hours in *G. changii*. Toxicity results for Cd exposure in 96 h definitive test conducted on *G. changii* : IC_{50} = 31.071 $mgCdL^{-1}$, LOEC = 15 $mgCdL^{-1}$ and NOEC < 15 $mgCdL^{-1}$. In contrast, exposure of *C. linum* and *S. baccularia* to Cd in 96 h range finding test did not produce 50% inhibition in chlorophyll-a content and dry weight respectively. Further exposure to Cd for 7 and 10 days in the definitive tests showed that *G. changii* was still the most sensitive species. However, the inhibitory concentrations decreased with the incubation time used. The order of decreasing sensitivity to Cd exposure according to species is as follows : *G. changii* > *S. baccularia* > *C.linum*.