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# Uptake of Lead, Chromium, Cadmium and Cobalt by *Cladophora glomerata*

Jan Vymazal

Water Research Institute, Department 252, Podbabská 30, 160 62 Praha 6, Czechoslovakia

The kinetics of heavy metal uptake by algal cells involves two stages (Khummongkol et al. 1982; Starý et al. 1983). The first phase is very rapid, occurring immediately after initial contact with the cell and usually lasting for less than 30 minutes (Conway and Williams 1979; Sakaguchi et al. 1979; Gipps and Coller 1980; Geisweid and Urbach 1983). This initial phase is thought to be passive, involving physical sorption or ion exchange at cell surfaces. The second phase is slow and extended, and has been observed to continue for more than one month (Skipnes et al. 1975; Bryan 1969; McLean and Williamson 1977). It may be separated from the first phase by a lag period (Sakaguchi et al. 1979) and may be linear (McLean and Williamson 1977) or hyperbolic (Conway and Williams 1979) in nature. The slow phase appears to be active and related to metabolic activities of the cell. The relative importance of these two stages depends on the organism involved. More detailed information about the course of both phases are given by Trevors et al. (1986).

Previous studies dealing with uptake of heavy metals by freshwater algae (e.g. Gerhards and Weller 1977; Albergoni et al. 1980) have noted differences in accumulation rates of individual elements. The purpose of the present communication is to describe the time-course of uptake of lead, chromium, cadmium and cobalt by Cladophora glomerata (L.) Kütz., a common filamentous green alga in freshwaters.

## MATERIALS AND METHODS

Cladophora glomerata was collected from Šárecký Brook in Prague. Tests with the alga were made only after cultivation for 14 days in a dilute (1:5) modification of Gorham's medium (Fitzgerald 1968).

Send reprint requests to J.Vymazal at the above address.

The experiments were conducted in vessels (500 ml beakers) which were illuminated from above by TESLA Z-RZ fluorescent tubes. Incident radiation in the experiments was 170 $\mu Em^{-2}s^{-1}$. The temperature was 20 ± 1 °C. The cultivation flasks were bubbled with a mixture of $CO_2$ in air to maintain a constant pH (8.0) since, in the presence of algae, the pH gradually increases. Differences between the initial and final pH of the experiments did not exceed 0.05 units. The exposure period was 6 hr and within this period samples of water were taken after 0.25, 0.5, 1, 2, 4 and 6 hr.

The uptake experiments were conducted by placing the alga into 400 ml of the test medium. The metals were tested separately; for each of them 15 replicates with algal biomass approximately 1 g/L dry weight were done. As the algal biomass plays an important role in determining the specific uptake of the metal, only 10 replicates in the range of 1.00 ± 0.2 g/L dry weight were taken into account for the computation. The test solutions were added 24 hr previously so that chemical equilibria could be established. Reagent-grade salts added were $Pb(NO_3)_2$, $CrCl_3 \cdot 3H_2O$, $CdCl_2 \cdot 2H_2O$ and $CoSO_4 \cdot 7H_2O$. The nominal concentration of metal in each case was 200 µg/L. Actual concentrations were measured just before introducing the alga. The decline was negligible, but was taken into account when uptake rates were calculated (Pb 197 µg/L, Cr 198 µg/L, Cd 197 µg/L, Co 199 µg/L; average values from 10 replicates). One vessel, which did not receive the alga, served as a control to determine the decline in metal concentration during the exposure period (6 hr). There was no change during 6-hr exposure though. The uptake of metal was determined using changes in metal concentration in the test medium during the 6-hr exposure period. This was expressed as mean specific uptake in µg/g dry weight. Trace metals solution, EDTA, Fe-citrate and citric acid were not added to the experimental medium (Gorham's medium diluted 1:5) in order to minimize metal competition and chelation.

Samples of water were analyzed for trace metals with a ZEISS Jena atomic-spectrophotometer (model AAS-1). Measurements of Cladophora biomass dry weight were made after the experiments were completed by drying at 105 °C to constant weight. Statistical evaluations were done using two-tailed Student's t-test (Tuček and Holata 1978).

## RESULTS AND DISCUSSION

It can be seen from Table 1 that the short-term uptake

Table 1. Mean concentrations of Pb, Cr, Cd and Co in Cladophora glomerata (μg/g dry weight) after exposure to an initial concentration of 200 μg/L of the metal in solution. Standard deviations are given in parentheses; n = 10.

| Exposure time (hr) | Pb | Cr | Cd | Co |
|---|---|---|---|---|
| 0.25 | 60.5 (6.8) | 120.7 (11.8) | 16.8 (2.3) | 25.1 (3.4) |
| 0.5 | 93.1 (7.9)$^{++++}$ | 136.8 (20.9) | 35.1 (4.1)$^{++++}$ | 40.3 (3.9)$^{++++}$ |
| 1.0 | 125.6 (9.3)$^{++++}$ | 151.0 (14.6) | 63.8 (8.5)$^{++++}$ | 60.6 (7.5)$^{++++}$ |
| 2.0 | 145.4 (11.9)$^{+++}$ | 157.6 (19.5) | 94.2 (10.3)$^{+++}$ | 73.4 (10.1)$^{+}$ |
| 4.0 | 155.4 (13.5) | 162.6 (19.8) | 111.6 (11.0)$^{++}$ | 80.2 (7.4) |
| 6.0 | 159.1 (17.4) | 168.0 (15.6) | 119.1 (14.0) | 86.9 (12.2) |

$^{++++}p<0.001$, $^{+++}p<0.005$, $^{++}p<0.01$, $^{+}p<0.05$; concentrations are compared with values for the previous exposure time in tests of significant change.

of four trace metals by Cladophora glomerata differs not only in the rate of uptake but also in the maximum concentration attained.

The highest metal concentration in Cladophora after 6-hr exposure to an initial concentration of 200 µg/L was chromium (168 µg/g). The next highest concentration was lead (159.1 µg/g). There was no statistical difference between the Cr and Pb values. Comparable values for cadmium and cobalt were 119.1 µg/g and 86.9 µg/g, respectively. The concentrations of Cd and Co after 6-hr exposure were significantly ($p<0.001$) lower than the concentrations of Cr and Pb. The concentration of cadmium was also significantly higher ($p<0.001$) than that of cobalt.

The most rapid uptake appeared with chromium - 120.7 µg/g after 15 minutes of exposure (i.e. 71.8% of chromium available). Further increases in Cr concentrations of cells were only slight and were not statistically significant (see Table 1). These results are in agreement with those reported by Starý et al.(1982) for chromium(III) uptake by planktonic algae. The initial rate of lead uptake was also rapid (60.5 µg/g after 15 minutes of exposure), but substantial uptake continued to occur for 2 hr. The cell concentration of Pb after 2 hr was significantly higher than after 15 min of exposure.

The uptake rate of cadmium was initially slower than that of Cr or Pb (16.8 µg/g after 15 minutes of exposure), but cell concentrations continued to increase during the first 4 hr of exposure (see Table 1). Similar results were reported (Sakaguchi et al. 1979; Geisweid and Urbach 1983) for cadmium uptake by planktonic algae. Uptake of cobalt continued for 2 hr of exposure. Differences between the 2 hr and later cell concentrations were not significant. This result is in agreement with the findings of Vymazal (1984) on Co uptake by periphytic algae.

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