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Influence of Anionic Surface-active Agents on the Uptake of Heavy Metals by Water Hyacinth (*Eichhornia crassipes*)

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Many reports have published on the toxicity and uptake of mineral and nutrients (Ornes et al. 1975; Roger and Davis 1972; Sheffield 1967) by aquatic plants, especially water hyacinth (*Eichhornia crassipes* (Mart.) Solms) from polluted waste and heavy metals, such as copper (Sutton et al. 1971), mercury, lead, cobalt (Wolverton and Mcdonald 1975a), and nickel (Wolverton and Mcdonald 1975b). In the previous paper (Muramoto and Oki 1983a), the ability of water hyacinth to remove toxic heavy metals, cadmium, lead, and mercury, from the metal-containing solution was reported. However, information on the effects of surface-active agents on the metal uptake from waste water by water hyacinth is insufficient. Surface-active agents including anionic detergents have been found in lake, ponds, and rivers polluted by waste from industry and municipal sewage treatment plants (Muramoto and Aoyama 1982).

The present study was chosen for this investigation since there are common toxic metals found in refinery factory and in plating factory waste waters. Cadmium has not been shown to be essential to the growth of plants, and induced a vertebral deformed fish (Muramoto 1980, 1981). Nickel is essential trace metal for mammals (Nielsen 1971). The accumulation of Ni in fish is relatively lower than those in the fish exposed to another some heavy metals, such as Cd, Pb, Zn, Cr, and Al (Muramoto 1983b).

MATERIALS AND METHODS

Water hyacinth (*Eichhornia crassipes* (Mart.) Solms) were prepared on June in 1983, and were kept in plastic tanks containing tap water and added chemical fertilyzer for 10 days prior to the starting of experiments. The plants were prepared for two groups: (A) Old root groups; (B) New root groups, which were taken from the old roots. Individual plants were planted in 2.0-L in plastic pots in a phytotoron house and were maintained at 25 °C ± 2 °C. There were altogether 15 such groups; six kept in cadmium ($CdCl_2 \cdot 2.5H_2O$) or nickel ($NiCl_2$) alone at concentrations of 1.0, 4.0, 8.0 ppm of cadmium or nickel: six groups with each metal plus 25 ppm of sodium dedecyl sulfate ($C_{12}H_{25}SO_3Na$, SDS): one group containing metal mixed anionic detergents, Cd 1.0 ppm + Ni 1.0 ppm + SDS 25 ppm; one SDS 25 ppm alone group; and one control group. There are two replicates for analysis of the experiments. Water characteristics were (mg/L): Ca 12.2; Mg 1.9; Na 4.0; K 0.87; SO_4 5.4; Cl 4.2;

SiO_2 13.3; Alkalinity 38.5 as $CaCO_3$; Dissolved solid 65.4; Cd 0.001; Cu 0.01; Zn 0.07; Pb 0.07. pH was 6.9–7.3.

The plants were carefully washed with tap water, and were divided into two parts; tops (including rhizome) and roots. Each sample was dried at 60 °C for 48 hours in a hot-air drier, and ground with a mill. The ground sample was dissolved in HNO_3-$HClO_4$ (2:1) and made up a fixed volume by addition of 1N-HCl. This solution was used for determination of Cd and Ni using atomic absorption spectrophotometer after application of diethyldithiocarbamic acid methylisobutylketon extraction methods. Anionic surface-active agents, dodecyl sodium sulfate was determined by the methods with graphyte furnace after application of $CHCl_3$ extraction methods with ethylene diamine-copper ion (Michel J. Gagnon 1978).

RESULTS AND DISCUSSION

Relationship between the concentration of SDS in water and the growth of root length (old root) of water hyacinth at the 12th days from the beginning of the experiments were given in Fig. 1. No effects of SDS on the increasing ratio of root length were indicated within 25 ppm SDS in water, but significant decreases were observed for concentrations of SDS above 30 ppm in according to increase of SDS in water. At the 100 ppm SDS, the growth ratio of root length was decreased approximately to 60 percent compared with those of the control.

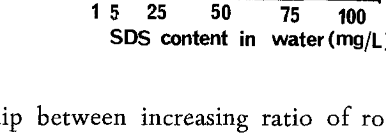


Fig. 1 Relationship between increasing ratio of root length and SDS concentration in water (*increasing ratio of root compared with the initial root length (= 1.00))

The photograph of the roots of water hyacinth exposed to SDS alone containing water for 12 days are shown in Figs. 2a–2b, and the controls are in Fig. 2c. The morphological changes on the epidermis or roots of plant were not observed within 25 ppm SDS alone group containing water. However, the phenomenon of the damage of new lateral roots induced by SDS toxicity (Figs. 2b, 2c).

Fig.2a Fig.2b Fig.2c

Figs. 2a–2c Magnified photographs of roots of water hyacinth exposed to (2a) 50 ppm dodecyl sodium sulfate (SDS), (2b) 75 ppm SDS, and (2c) photograph of normal (control) water hyacinth. Arrow indicates the part of damage of new rateral roots.

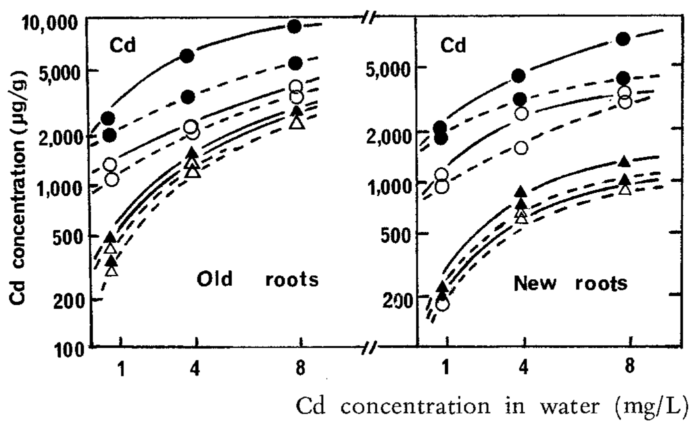
The growth of plants exposed to metal and metal plus 25 ppm SDS for 12 days after the beginning of the experiment are shown in Table 1. In both Cd and Ni metal alone groups, the weight of whole plants was obviously decreased with an increase in the concentration of metals in water compared with those at the beginning of the experiments. However, in the Cd plus SDS, and Ni plus SDS group, no particular effects on the plant growth was recognized. Therefore, the growth ratio of plants in 25 ppm SDS group was almost the same value as the control group.

Table 1. The growth of water hyacinth on a wet weight basis at 12 days after the beginning of the experiment.

treatment	growth ratio	
	metal alone	metal + SDS
Cd 1.0 ppm	1.23	1.35
4.0	0.83	1.06
8.0	0.82	0.84
Ni 1.0 ppm	0.87	1.10
4.0	0.70	0.73
8.0	0.71	0.70
Cd 1.0 ppm + Ni 1.0 ppm	0.74	0.78
SDS 25 ppm	1.71	
control	1.75	

Relationship on the metal concentration between in water and in tops and roots of water hyacinth at 12th days after the beginning of the experiments were shown in Figs. 4a and 4b.

The uptake of cadmium in plants was higher in root than those in metal plus SDS group. It was clear that the presence of SDS was decreased Cd concentration in plants at various concentration of cadmium.



Root	Top
●——● metal alone	▲——▲ metal alone
●----● metal + SDS	▲----▲ metal + SDS
○——○ metal mixture	△——△ metal mixture
○----○ metal mixture + SDS	△----△ metal mixture + SDS

Fig. 4a The concentration of metals (μg/g in dry matter) in water hyacinth treated with metal alone or mixed metal, and with anionic surface-active agents (SDS) at the 12th days after the beginning of the experiments.

The absorption of nickel by water hyacinth was slightly lower compared with that of cadmium. Addition of SDS to nickel containing water was not significantly higher than that of Ni alone group. Also it was indicated the translocation of nickel from the root tissue to the tops of plant was slower than those of cadmium.

The phenomenon of withering of roots and changes a black color of the surface of roots induced by nickel toxicity appeared on the 5th and 10th days after exposure to water containing 8.0 ppm Ni alone. The uptake of metal in plant was lower in addition of SDS to Cd plus Ni group than those in both Cd and Ni alone group.

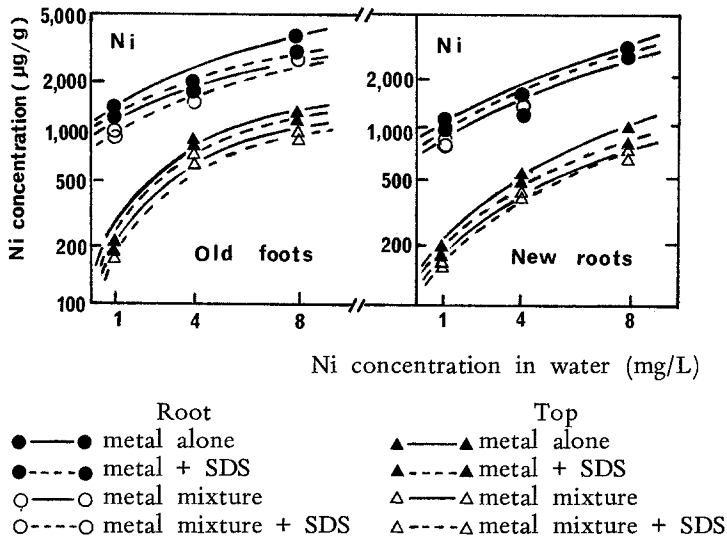


Fig. 4 The concentration of metals (μg/g in dry matter) in water hyacinth treated with metal alone or mixed metal, and with anionic surface-active agents (SDS) at the 12th days after the beginning of the experiments.

The concentration factors of water hyacinth with exposure for 12 days to metal containing water are shown in Table 2. The values for Cd and Ni are presented as dry matter of plants. The values of concentration factors of roots tended to decrease with increasing concentration of metals in water, and were higher than that in tops.

Table 2. Concentration factors for Cd and Ni by water hyacinth with exposure to metal-containing water.

treatment		metal alone		metal + SDS	
metal	root	top	root	top	root
Cd 1.0 ppm	old	4.360×10^2	2.500×10^3	3.270×10^2	2.360×10^3
	new	2.370×10^2	1.122×10^3	1.960×10^2	6.950×10^2
4.0	old	3.840×10^2	1.576×10^3	3.133×10^2	8.725×10^2
	new	1.758×10^2	4.315×10^2	1.203×10^2	2.515×10^2
8.0	old	5.765×10^2	1.453×10^3	4.951×10^2	7.175×10^2
	new	1.644×10^2	3.789×10^2	1.324×10^2	1.863×10^2
Ni 1.0 ppm	old	1.840×10^2	1.330×10^3	1.030×10^2	4.136×10^2
	new	1.644×10^2	3.789×10^2	1.324×10^2	1.863×10^2
4.0	old	4.930×10^2	6.038×10^2	4.110×10^2	2.613×10^2
	new	5.075×10	2.725×10^2	3.460×10	1.990×10^2
8.0	old	7.660×10^2	5.297×10^2	4.510×10^2	4.543×10^2
	new	3.863×10	1.413×10^2	2.578×10	1.110×10^2

The concentration factors of roots in 0.01 ppm Cd alone group were about 5.8 times and 4.7 times greater than those in the tops for old root group and new root group. These results were almost similar for cadmium as reported in previous paper (Muramoto and Oki 1983a). Also, the concentration factors under the presence of the anionic surface-active agents were decreased by 31–44 % and 4.5–51 % of those in the tops and roots in Ni alone group, respectively.

The amount of metals Cd and Ni by water hyacinth from the polluted water in natural field were estimated using of removal of metals were as follows: 526 kg/ha in 8.0 ppm Cd containing water, 95.4 kg/ha in Ni 8.0 ppm containing water. The mean value of cadmium uptake by water hyacinth were higher by 2.4–7.1 times compared with those of nickel.

Table 3. Calculated mean and maximum values for removal of heavy metals by water hyacinth those in natural fields.

metal concentrations	root	*metal uptake (kg/ha)			
		Mean		Max	
		metal alone	metal + SDS	metal alone	metal + SDS
Cd 1.0 ppm	A	20.7	14.6	93.2	65.7
	B	6.65	5.88	29.9	26.5
4.0	A	54.9	34.5	247	144
	B	36.1	13.4	162	60.3
8.0	A	117	68.9	526	310
	B	23.5	22.7	106	102
control	A	0.074	0.075	0.33	0.34
	B	0.009	0.006	0.04	0.03
Ni 1.0 ppm	A	6.74	6.98	30.3	31.4
	B	2.56	1.87	11.5	8.42
4.0	A	15.0	12.8	67.5	57.6
	B	5.06	4.18	22.8	18.8
8.0	A	21.2	11.2	95.4	50.4
	B	9.59	8.64	43.2	38.9
control	A	0.011	0.013	0.049	0.059
	B	0.002	0.001	0.009	0.005

* Mean values of standing crop 10 kg wet weight/m^2.
Maximum values of standing crop 45 kg wet weight/m^2.
A: Old roots (including new roots), B: New roots.

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