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Sorption of Cadmium and Effects on Growth, Protein Content, and Photosynthetic Pigment Composition of *Nasturtium officinale* R. Br. and *Mentha aquatica* L.

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Toxic metal pollution of waters is major environmental problem pollution of the biosphere with toxic metals, has accelerated dramatically since the beginning of the industrial revolution (Settle and Patterson 1980) The primary sources of this pollution are the mining and smelting of metalliferous ores, burning of the fossil fuels, municipal wastes, fertilizers, pesticides and sewage (Kanbata and Pendias 1989). Cadmium enters the aquatic environment through anthropogenic sources such as industry and agriculture. Cadmium is not known to be an essential element to plants. Although a limited transport of cadmium to shoots and binding to cell walls occur in the roots. (Balsberg 1989). In many ways living plants can be compared to solar driven pumps which can extract and concentrate certain elements from their environment (Raskin et al 1994). Aquatic plants and algae are known to accumulate metals and other toxic elements from contaminated water (Kaçar 1972). All plants have the ability to accumulate metals and other toxic elements from contaminated water. All plants have the ability to accumulate from soil and water, those heavy metals (Fe, Mn, Zn, Cu, Mg, Mo, and Ni) which are essential for their growth and development (Raskin et al. 1994). Certain plants also have the ability to accumulate heavy metals (Cd, Cr, Pb, Co, Ag, Se and Hg) which have no known biological function (Raskin et al. 1994: Baker and Brooks 1989). However excessive accumulation of these heavy metals can be toxic to most plants. The ability to both tolerate them to unusually high concentrations has evolved both independently and together in a number of different plant species (Banuelas et al. 1990). The aquatic plants are often the first link in relation to metal contents of aquatic environments (Baker et al. 1989) Some aquatic such as *Eichornia crassipes* (Dierberg at el.1987), *Azolla pinnata* (Jackson at al.1990), *Spirogyra fluviatilis* and *Veronica anagallis-aquatica* (Saygıdeger 1999) can take up Zn, Pb, Cu, Cd, Fe and Hg from contaminated solutions. They are known to be tolerant to these metals. This study was carried out to investigate the short-term uptake of Cd by *Nasturtium officinale* R. Br. and *Mentha aquatica* L.

MATERIALS AND METHODS

Two aquatic plants were used as test species (Davis PH 1965). The widespread and often prolific occurrence of *Nasturtium officinale* R. Br. and *Mentha aquatica* L. In Southeast Anatolia region freshwater has made it an ideal choice as test

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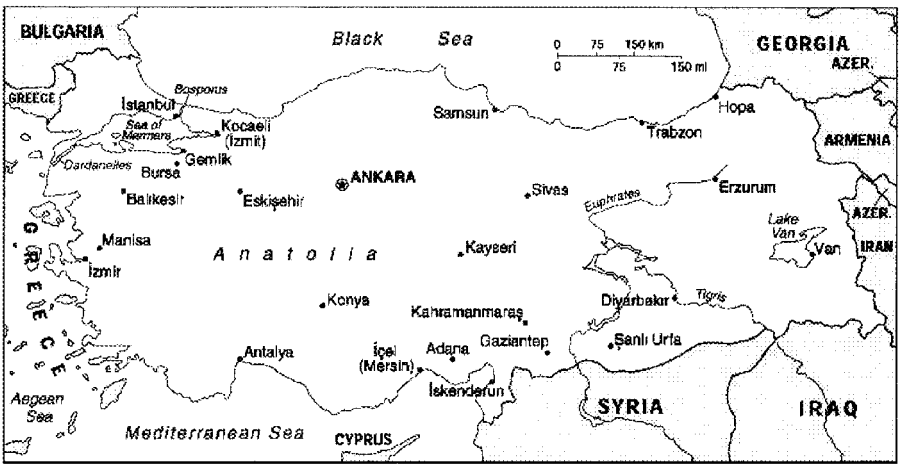

Figure 1. Euphrates River Şanlıurfa in Turkey

The strong affinity of cadmium ions for sulphydryl groups of several compounds and phosphate groups involved in plant metabolism might explain its toxicity.

Table 1. Cadmium concentration ($\mu g/g$ dry wt) in the organs of cd *Nasturtium officinale* R. Br. after treatment with Hoagland solution and clean water.

Treatment	N	Exposure peryot (day)	Root x ± sx	Leaf X ± sx	Stem X ± sx
Control	8	14	ND	ND	ND
0.5 ppm Cd	8	14	1.25 ± 0.79 a	1.12 ± 1.09 a	0.79 ± 21.0 a
Hoagland	2	7	0.93 ± 0.12 a	0.79 ± 0.59 a	0.60 ± 0.29 a
	2	14	0.73 ± 0.39 a	0.61 ± 0.70 a	0.47 ± 0.51 a
Clean Water	2	7	1.02 ± 0.59 a	0.92 ± 0.67 a	0.68 ± 0.45 a
	2	14	0.89 ± 0.37 a	0.80 ± 0.79 a	0.56 ± 0.52 a
0.1ppm Cd	8	14	6.03 ± 0.87 c	4.12 ± 0.80 c	2.28 ± 0.75 c
Hoagland	2	7	3.90 ± 1.04 b	2.07 ± 0.85 b	1.80 ± 0.79 b
	2	14	3.83 ± 0.80 b	1.80 ± 0.87 b	1.50 ± 0.55 b
Clean Water	2	7	4.22 ± 0.79 b	2.53 ± 0.91 b	1.97 ± 0.73 b
	2	14	3.90 ± 0.80 b	1.99 ± 0.89 b	1.89 ± 0.45 b
5.0 ppm Cd	2	14	11.50 ± 0.59 d	6.10 ± 0.63 d	3.54 ± 0.23 d
Hoagland	2	7	6.72 ± 0.76 c	3.44 ± 0.46 c	2.39 ± 0.27 c
	2	14	6.16 ± 0.12 c	3.08 ± 0.61 c	1.98 ± 0.31 c
Clean Water	2	7	9.18 ± 0.31 d	4.07 ± 0.49 d	2.66 ± 0.37 d
	2	14	7.49 ± 0.35 d	3.67 ± 0.96 d	2.59 ± 0.46 d

x ± sx: Mean ± Standard Error ND: Not Deductable N: Number of plant in each group SNK: a, b, c, d show the differences among control, cadmium and Hoagland data shown with different letters are significantly different at the $p < 0.01$ level.

When growing *Alnus rubra* seeding for 11 weeks in a nutrient solution, containing

3 to 122 μg Cd L^{-1} the growth of both leaves, stem and roots was stimulated slightly at the lower cadmium concentrations. A certain biomass decrease was noted at 0.60 μg Cd L^{-1} but leaf biomass was not significantly reduced below 122 μg Cd L^{-1} (Pahlsson). Photosynthesis and transpiration are inhibited by Cadmium (Pahission 1989). Measured as CO_2 uptake the photosynthetic rate in spruce (*picea abies*) was significantly decreased by 112 μg Cd L^{-1} in the growth medium. Cadmium is one of the most active metals on chromosome substances and in poisoning of the cell cytoplasma.

In *Acer sacharium* seeding grown in nutrient solution with 5 ppm cadmium leaf, stem and root dry weight decrease, height decrease and chlorophll content changes (Pahlsson 1989).

Elimination of cadmium in Honagland medium and clean water increased with increasing exposure period ($p<0.01$). The greatest cadmium elimination was in the *Nasturtium officinale* R. Br. in hoagland medium.

In all experimental conditions, the elimination of cadmium from *Mentha aquatica* L. and *Nasturtium officinale* R. Br. was greater in Hoagland solution than clean water. Hoagland solution significantly inhibited the effects of cadmium in test species Cd concentrations in the organs significantly decreased after 14 days of exposure to Hoagland solution.

Table 2. Cadmium concentration ($\mu g/g$ dry wt) in the organs of cd *Mentha aquatica* L. after treatment with Hoagland solution and clean water.

Treatment	N	Exposure peryot (day)	Root X ± sx	Leaf X ± sx	Stem X ± sx
Control	8	14	ND	ND	ND
0.5 ppm Cd	8	14	1.68 ± 0.69 a	1.33 ± 1.37 a	1.07 ± 0.09 a
Hoagland	2	7	1.49 ± 0.97 a	1.26 ± 0.46 a	0.77 ± 0.45 a
	2	14	1.29 ± 0.79 a	1.17 ± 0.26 a	0.66 ± 0.87 a
Clean Water	2	7	1.53 ± 0.49 a	0.85 ± 0.72 a	0.77 ± 0.45 a
	2	14	1.43 ± 1.11 a	0.97 ± 0.52 a	0.73 ± 0.69 a
0.1ppm Cd	8	14	7.21 ± 0.67 c	5.41 ± 0.90 c	2.89 ± 0.58 c
Hoagland	2	7	4.54 ± 0.76 b	1.93 ± 0.29 c	2.25 ± 0.51 c
	2	14	4.35 ± 0.97 b	1.81 ± 0.41 c	1. 33 ± 0.53 c
Clean Water	2	7	4.67 ± 1.09 b	1.87 ± 0.41 b	1.95 ± 0.74 b
	2	14	4.55 ± 1.21 b	1.91 ± 0.45 b	1.33 ± 0.56 b
5.0 ppm Cd	2	14	12.66 ± 0.42 d	6.96 ± 0.49 d	3.66 ± 0.59 d
Hoagland	2	7	7.47 ± 0.79 c	4.22 ± 0.65 c	2.57 ± 0.79 c
	2	14	7.19 ± 0.80 c	3.86 ± 1.12 c	2.48 ± 0.21 c
Clean Water	2	7	8.46 ± 0.79 c	3.79 ± 1.09 c	2.47 ± 0.29 c
	2	14	7.86 ± 0.57 c	3.87 ± 0.89 c	1.89 ± 0.37 c

x ± sx: Mean ± Standard Error ND: Not Deductable N: Number of plant in each group SNK: a, b, c, d show the differences among control, cadmium and Hoagland data shown with different letters are significantly different at the $p < 0.01$ level.

organism for pollution studies. Test species were collected from the River Euphrates (Şanlıurfa, Turkey Fig. 1) and kept under laboratory conditions at a temperature of 22±2 ^{0}C (day) and 18±2 ^{0}C (night), (p^H 7.5) and with a daily photoperiod of 16h of light (6000± 200 lux) and 8h darkness. *Nasturtium officinale* R. Br. and *Mentha aquatica* L. plants were cultured aseptically for 7, 14 and 28 days in eight beherglasses containing 500 ml solution in the absence (distiled water) or in the presence treated of 0.5, 1.0, 5.0 ppm Cd for each plant species. Four plants were than added into each beherglasses.

After exposure to either 0.0, 0.5, 1.0, 5.0 ppm *Nasturtium officinale* R. Br. and 0.0, 0.5, 1.0, 5.0 ppm *Mentha aquatica* L.This procedure was repeated twice. After 14 days two plants were removed from the each beherglasses to measure to levels of protein and chlorophyll and sorption of Cd. The remaining Cd contaminated (14 days) plants were than kept in clean water (Two plants for each concentrations) and modified Hoagland solution for (by diluting it tenfold with distilled water) 7 and 14 days. For each exposure period and concentrations, two plants were analyzed to determine Cadmium, Protein and chlorophyll concentrations and morphological observations for each plant species.The test media were changed every third day to replenish either the Cadmium or Hoagland medium (Kaçar 1972).

At the end of the experiments plants were washed thoroughly in distilled water, and each sample was dried at 80 ^{0}C for 24 h about 1 g each samples were separately digested in 14 M HNO_3 the acid evaporated and residues reddish solved in 1 M HCl Cadmium concentrations of the organs were measured using an Atomic Absorption spectrophotometer (AAS) Perkin Elmer Model 3100 Percent total Nitrogen analyzed by an ammonia distillation process using a micro Kjeldahl methods (Kaçar 1972) and protein account was multiplyed with 6.25 factor. Total chlorophyll was measured according to the method of Kirk (1968).

Student Newman Keul's Test (SNK) was used to determine the effects of clean water and Hoagland on the elimination cadmium from plants and changes biomass, protein and chlorophyll level (P=0.01) Balsberg (A.M. 1989).

RESULTS AND DISCUSSION

Mean Cadmium concentrations in the organs and their associated standard deviations in *Nasturtium officinale* R. Br. and *Mentha aquatica* L. after treatment with Hoagland medium and clean water are given in Table 1 and 2 respectively for each exposure concentration and period. Cadmium accumulation in tissues of plants increase with increasing expensure periods and concentration (Balsgerg 1989). *Nasturtium officinale* R. Br. and *Mentha aquatica* plants increased significantly after expensure to 1.0 and 5.0 ppm for 14 days cadmium uptake by the *Nasturtium officinale* R. Br. and *Mentha aquatica* L. result shpwed that cadmium concentrations were hinge in the *Mentha aquatica* L. than *Nasturtium officinale* R. Br. Other investigators have noted cadmium was rapidly adsorbed by *Asterionella* and *Fragilaria* in the first 5-10 min. (Conway and Williams 1979; Conway 1978).

In this study, Cd exposure of *Mentha aquatica* L. and *Nasturtium officinale* R. Br. caused decrease in total protein and chlorophyll concentration of the leaf (Table 3 and 4).

Protein and chlorophyll concentration in the *Nasturtium officinale* R. Br. and *Mentha aquatica* L. leaves decreased significantyl after exposure to 1.0 and 5.0 ppm Cd ($p<0.01$).the highest protein decrease occur in the *Mentha aquatica* L. Also the highest chlorophyll and biomass decreases occur in the *Mentha aquatica* L. after exposure to 1.0 and 5.0 ppm Cd ($p<0.01$). Protein and chlorophyll synthesis in the leaf due to 14 days of Cd exposure was normalized after Hoagland treatment in the *Nasturtium officinale* R. Br. and *Mentha aquatica* L.

In this study, plants treated with higher concentrations of Cd usual become stunted in growth the leaves are smaller, curled and chlorotic and leaf margins and veins snow a red-brown coloration.

Table 3. Protein (mg/g wet wt) and chlorophyll ($\mu g/L$) content and biomass(mg dry wt) in the leaf of Cd-accumulated *Nasturtium officinale* R. Br. after treatment with Hoagland solution and clean water.

Treatment	N	Exposure peryot (day)	Protein $X \pm sx$	Chlorophyll $x \pm sx$	Biomass $X \pm sx$
Control	8	14	18.68 ± 0.22 a	3.06 ± 1.22 a	32.70 ± 0.78 a
0.5 ppm Cd	8	14	15.50 ± 0.57 b	1.97 ± 0.39 b	27.37 ± 0.49
Hoagland	2	7	17.73 ± 0.78 a	1.36 ± 0.53 a	30.78 ± 0.29 a
	2	14	18.59 ± 0.48 a	2.88 ± 0.15 a	35.56 ± 0.53 a
Clean Water	2	7	17.23 ± 0.56 a	2.21 ± 0.15 a	29.69 ± 0.32 a
	2	14	17.82 ± 0.81 a	2.59 ± 0.99 a	30.60 ± 0.66 a
0.1ppm Cd	8	14	12.52 ± 0.89 c	1.72 ± 0.46 c	27.65 ± 0.98 b
Hoagland	2	7	15.65 ± 0.45 b	1.51 ± 0.66 b	27.87 ± 0.29 b
	2	14	17.13 ± 0.76 a	1.85 ± 1.21 b	28.09 ± 0.22 b
Clean Water	2	7	15.39 ± 0.45 b	1.81 ± 1.17 b	27.65 ± 0.29 b
	2	14	15.59 ± 0.28 b	1.85 ± 0.95 b	28.15 ± 0.21 b
5.0 ppm Cd	2	14	9.72 ± 0.34 d	1.62 ± 0.98 c	25.12 ± 0.42 c
Hoagland	2	7	10.87 ± 0.69 c	1.70 ± 0.84 c	25.96 ± 0.51 c
	2	14	11.58 ± 0.46 c	1.66 ± 0.89 c	25.99 ± 0.59 c
Clean Water	2	7	10.63 ± 0.78 c	1.70 ± 0.36 c	25.48 ± 0.67 c
	2	14	10.96 ± 0.78 c	1.69 ± 0.78 c	25.78 ± 0.85 c

$x \pm sx$: Mean $\pm$ Standard Error ND: Not Deductable N: Number of plant in each group SNK: a, b, c, d show the differences among control, cadmium and Hoagland data shown with different letters are significantly different at the $p < 0.01$ level.

The first signs of toxic effects were noted in both *Nasturtium officinale* R. Br. and *Mentha aquatica* L. exposed to 1.0 ppm Cd. The most conclusive evidence of damage was found for 5.0 ppm Cd solutions were *Nasturtium officinale* R. Br. and *Mentha aquatica* L. samples had predominant damaged at 14 days.

Results of this study showed that Hoagland solution increased elimination of cadmium from the organs of Cd-contaminated plant and also cadmium exposure of *Nasturtium officinale* R. Br. and *Mentha aquatica* L. caused decreased protein and chlorophyll concentrations of the leaves.

Uptake of cadmium was completely dependent upon physico-chemical adsorption on the cell surface (Sakaguchi et al.1979). The strong affinity of cadmium ions for sulphydryl groups of several compounds and phosphate group involved in plant metabolism might explain the great toxicity (Balsberg1989).

Table 4. Protein (mg/g wet wt) and Chlorophyll ($_{\mu g/L}$) content and biomass(mg dry wt) in the leaf of Cd-accumulated *Nasturtium officinale* R. Br. after treatment with Hoagland solution and clean water.

Treatment	N	Exposure peryot (day)	Protein X ± sx	Chlorophyll x ± sx	Biomass x ± sx
Control	8	14	10.47 ± 1.13 a	3.46 ± 1.17 a	18.91 ± 1.06 a
0.5 ppm Cd	8	14	9.93 ± 0.75 a	3.29 ± 0.52 a	17.60 ± 0.44 b
Hoagland	2	7	9.93 ± 0.75 a	3.29 ± 0.52 a	17.60 ± 0.44 a
	2	14	10.36 ± 0.37 a	3.49 ± 0.71 a	18. 20 ± 0.80
Clean Water	2	7	8.91 ± 0.52 a	3.32 ± 0.75 a	17.84 ± 0.45 a
	2	14	9.69 ± 0.65 a	3.36 ± 0.57 a	18.09 ± 0.18 a
0.1ppm Cd	8	14	8.89 ± 0.58 b	2.78 ± 0.73 c	16.45 ± 0.69 b
Hoagland	2	7	8.96 ± 0.68 b	2.99 ±0.92 b	16.87 ± 0.89 b
	2	14	8.69 ± 0.79 a	2.98 ± 0.84 b	16.66 ± 0.85 b
Clean Water	2	7	8.37 ± 0.63 b	2.97 ± 0.95 b	16.89 ± 0.78 b
	2	14	8.85 ± 0.78 b	2.96 ± 0.81 b	16.45 ± 0.98 b
5.0 ppm Cd	2	14	7.17 ± 0.97 c	2.45 ± 0.21 d	14.85 ± 0.72 d
Hoagland	2	7	7.65 ± 0.65 c	2.85 ± 0.32 b	15.18 ± 0.52 c
	2	14	7.98 ± 0.77 c	2.92 ± 0.38 b	15.72 ± 0.53 c
Clean Water	2	7	7.58 ± 0.91 c	2.66 ± 0.29 c	14.92 ± 0.65 d
	2	14	7.63 ± 0.78 c	2.71 ± 0.39 c	15.14 ± 0.65 c

x ± sx: Mean ± Standard Error ND: Not Deductable N: Number of plant in each group SNK: a, b, c, d show the differences among control, cadmium and Hoagland data shown with different letters are significantly different at the $p < 0.01$ level.

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