Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2018.23280

134 (2018) 305–309
December

Effect of anthropopressure on cadmium content in grasses – pot experiment

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Received 25 April 2018; Accepted 13 October 2018

ABSTRACT

One of the elements that pose a high risk to human health even in small doses is cadmium. The occurrence of cadmium and its bioaccumulation is a huge threat to the natural environment and to the proper functioning of the trophic chain. That is why it has been recognized by all international organizations, that is, WHO, FAO, UNEP as a priority threat on a global scale. In the trophic chain, the most exposed to elevated levels of heavy metals are plants, especially those that come from areas subject to heavy anthropogenic stress. Water is also threatened by the increase of pollution under the influence of anthropogenic pressure. Therefore, the content of cadmium in the leachates was determined during the experiment. The aim of the research was to determine the effect of anthropogenization of the natural environment on the content of cadmium in grasses and in leachates. The research included a pot experiment conducted in four groups of containers with an increasing degree of soil contamination with cadmium. The plant used for the tests was the quackgrass (*Elymus repens*). Three swaths were collected during the experiment. It can be noticed that the quackgrass which grew in the control group containers, took much lower amounts of cadmium compared with the other groups in which there were larger amounts of this element in the soil. The increase in the concentration of cadmium in leachates, which is progressing with the increase in the degree of soil contamination in cadmium, may also confirm the impact of anthropopression on the natural environment. The existence of a significant positive correlation between the increasing content of cadmium in the soil and the content of this element in above-ground parts of plants, regardless of the swath, suggests the impact of anthropopressure on the natural environment.

Keywords: Cadmium; Pot experiment; Anthropopressure; Grasses; Leachates

1. Introduction

Human's activity is the main source which brings heavy metals into soil. It is not possible to eliminate this source, therefore it should be aimed at limiting its impact on the environment. This is important especially because heavy metals, especially cadmium, have negative influence on health or life of both humans and animals [1,2].

Cadmium, applied to soil is kept in it or absorbed by plants' root system. The alkaline soil reaction, high organic matter content and high content of clay fraction in the granulometric composition of soil affect the increasing level of cadmium in soil. Thanks to such physico-chemical properties of the soil, cadmium uptake by plants is difficult, which decreases the risk of entering this element to the trophic chain and lowers the risk of human poisoning. Immobilization of cadmium by maintaining appropriate conditions in soils is also a way to reduce the leachability of this element to waters. This is important in reducing environmental exposure to cadmium poisoning [3–5].

The aim of the research was to determine the effect of anthropogenization of the natural environment on the content of cadmium in grasses and in leachates.

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Presented at the 13th Conference on Microcontaminants in Human Environment, 4–6 December 2017, Czestochowa, Poland.

1944-3994/1944-3986

2. Material and methods

Our research was carried out in the form of a pot experiment. For the experiment, loamy sand was used. Before starting the experiment, the basic soil properties were determined. The soil pH was 7.46. The organic matter content was 2.9%. The sorption capacity was 11.60 cmol(+)·kg^{-1}. Hydrolytic acidity 0.60 cmol(+)·kg^{-1}, while the sum of basic exchangeable cations 11.00 cmol(+)·kg^{-1}. These values indicate a significant advantage of basic exchange cations over acidic cations.

The cadmium content determined in the soil before the experiment was 0.02 mg Cd·kg^{-1} d.m.

The pot experiment was conducted in four groups of containers (40 kg of soil each) with an increasing degree of soil contamination with cadmium: control group without additional cadmium pollution, group I with additional contamination with 1 mg Cd·kg^{-1} d.m., group II with 3 mg Cd·kg^{-1} d.m., group III with additional contamination with 30 mg Cd·kg^{-1} d.m. Throughout the growing season, all containers were watered with the same dose of distilled water (0.5 dm^3 every other day).

The plant used for the tests was the quackgrass (*Elymus repens*). Quackgrass is a plant that occurs widely in lowland areas of Europe. It has the ability to collect significant amounts of heavy metals. Thanks to this, it can be used for phytoremediation of the environment contaminated with heavy metals.

For the purpose of the experiment, quackgrass rhizomes were used. In each container, six rhizomes were planted. During the experiment, the plants were mown three times, more or less every 90 d, however, each time before the stage of heading During 1st and 2nd cut, only above-ground parts of plants were taken for analysis. After harvesting the last cut (3), soil, above-ground parts of plants as well as leachate were collected for analysis. Each of the containers was provided with a tap that allowed the collection of leachate. The leachates were collected once after completion of the pot experiment.

In soil samples taken both before the experiment and from all containers after completion of the experiment, physicochemical properties were determined, such as pH was measured in a solution of 1 mol·L^{-1} KCl, hydrolytic acidity, sum of exchangeable cations, the cation exchange capacity and the organic matter content measured according to the methodology included in catalogue of methods [6].

Determination of cadmium content both in the soil before starting the experiment and in the samples taken from all containers after completion of the experiment was carried out using the atomic absorption spectrometry with the electrothermal atomization technique in a graphite furnace (GF-AAS). Prior to the determination, soil samples were extracted in a solution of 1 mol·L^{-1} HNO_3. This method was also used to determine the cadmium content in plant samples and leachates.

3. Results and discussion

After completion of the pot experiment, the selected soil properties were re-determined to observe any changes in value. The determination of cadmium content was also carried out (Table 1).

A slight reduction in soil pH and a simultaneous increase in hydrolytic acidity were observed irrespective of the research group. The CEC value calculated for individual groups of containers was lower than determined before the beginning of the experiment and decreased together with successive groups, taking the lowest value in group 3. Nevertheless, still basic exchangeable cations prevailed over acidic cations. The content of organic matter in all groups was determined at a slightly lower level than the initial level. These properties are favorable for cadmium retention in soils, which is confirmed by the results of studies [7,8], which indicate that a decrease in the pH value promotes an increase in the amount of Cd in plants.

The average content of the cadmium determined in the individual groups was significantly different from one

Table 1
Chosen physico-chemical properties of soil samples and Cd content after completion of the pot experiment

	pH	H	S	CEC=H+S	OM	Cd
	1 mol·L^{-1} KCl	cmol(+)·kg^{-1}			%	mg·kg^{-1}
Control group						
Range	7.29–7.39	0.25–0.31	8.86–10.12	9.04–10.31	2.4–2.7	0.012–0.022
Average	7.33	0.28	9.40	9.66	2.5	0.015
Group I						
Range	7.29–7.39	0.28–0.33	9.63–10.50	9.92–10.81	2.3–3.2	0.055–0.127
Average	7.35	0.30	10.11	10.41	2.7	0.089
Group II						
Range	7.38–7.41	0.25–0.28	8.55–10.88	8.80–11.16	2.5–2.7	0.193–0.241
Average	7.40	0.26	9.70	9.96	2.6	0.225
Group III						
Range	7.22–7.42	0.27–0.29	4.65–9.77	4.94–10.05	2.5–2.9	0.789–2.249
Average	7.36	0.28	7.50	7.68	2.7	1.215

H – hydrolytic acidity; S – sum of exchangeable cations; CEC – cation exchange capacity; OM – organic matter content.

another rising from 0.015 mg·kg^{-1} in the control group to 1.215 mg·kg^{-1} in group III.

In addition to determining the cadmium content in the soil after the experiment, an analysis was made whether there is a relationship between the examined properties of the soil and the cadmium content in soil. The calculations were made using the STATISTICA 6.0PL software [9]. Based on the calculations, a significant negative correlation was found between the S and CEC values and the Cd content in soils which is –0.83 (Fig. 1) and –0.82 (Fig. 2), respectively.

During the experiment plants were mown three times, each time before the stage of heading. Cadmium content in above-ground parts of plants collected during the pot experiment is summarized in Table 2. Table 2 also includes masses of above-ground parts of harvested plants. It cannot be clearly stated that the addition of cadmium to the soil affected the weakening of plant growing before the first cut. The decrease in the mass of plants with an increase in the amount of the element was observed only at the second and third cut.

Regardless of the swath, the above-ground parts of plants from control group contained the smallest amounts of cadmium, and the largest amounts of this element contained above-ground parts of plants from group III.

The cadmium content in the control group of plants after the first cut varied from 0.69 to 1.67 mg·kg^{-1}. It increased in plants harvested during the second cut and was from 1.18 to 1.37 mg·kg^{-1}. After the third cut, the cadmium content of the control group plants ranged from 0.41 to 2.30 mg·kg^{-1}.

The content of cadmium in plants of the first group determined after the harvest of the first cut ranged from 1.74 to 4.50 mg·kg^{-1}. It increased after the harvest of the second cut and was from 4.70 to 8.89 mg·kg^{-1}. After the third crop harvest, the cadmium content in the first group plants ranged from 2.43 to 4.03 mg·kg^{-1}.

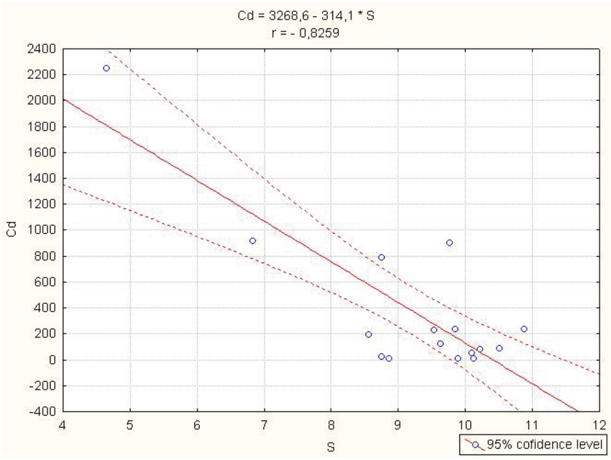

Fig. 1. Correlation between S value and Cd content in soil.

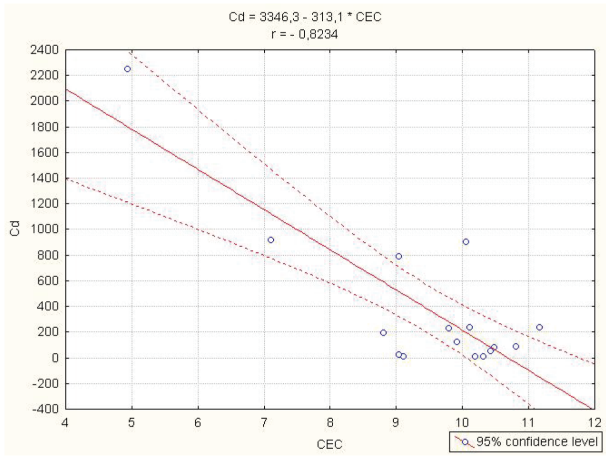

Fig. 2. Correlation between CEC value and Cd content in soil.

Table 2
Cadmium content in above-ground parts of plants collected during the pot experiment

Group of plants	Above-ground parts – range (g d.m.)	Above-ground parts – average (g d.m.)	Cd – range (mg·kg^{-1})	Cd – average (mg·kg^{-1})
1 cut				
Control	10.50–15.50	11.95	0.69–1.67	1.09
I	11.60–13.90	13.20	1.74–4.50	3.43
II	8.10–16.90	12.57	6.10–9.41	7.81
III	12.10–17.00	14.45	14.70–34.40	25.98
2 cut				
Control	5.9–12.2	10.10	1.18–1.37	1.27
I	7.7–13.6	9.67	4.70–8.89	6.49
II	6.8–9.5	8.07	6.49–18.50	10.55
III	4.9–10.2	7.80	73.50–159.00	110.88
3 cut				
Control	23.7–41.4	31.05	0.41–2.30	0.93
I	23.7–31.6	29.02	2.43–4.03	3.23
II	21.7–30.6	27.60	4.32–6.76	5.60
III	22.1–27.7	24.67	16.50–25.20	20.95

Table 3
Correlation coefficients between selected soil properties and cadmium content in above-ground parts of plants obtained in three cuts

Variables	Cd in above-ground parts of plants 1 cut	Cd in above-ground parts of plants 2 cut	Cd in above-ground parts of plants 3 cut
pH	–0.07	0.04	0.18
H	–0.17	–0.08	–0.21
S	–0.76[a]	–0.55[a]	–0.53[a]
CEC	–0.76[a]	–0.55[a]	–0.53[a]
OM	0.04	–0.04	0.10
Cd in soil	0.90[a]	0.79[a]	0.75[a]

[a]Significant correlation coefficients.

Table 4
Content of cadmium in the leachate from the containers after completion of the pot experiment

Group of containers	pH – range	pH – average	Cd – range (mg·kg^{-1})	Cd – average (mg·kg^{-1})
Control	7.47–7.74	7.63	0.0010–0.0013	0.0011
I	7.54–7.59	7.56	0.0021–0.0047	0.0028
II	7.11–7.34	7.22	0.0020–0.0045	0.0031
III	6.86–7.17	7.05	0.0029–0.0034	0.0033

Plants collected from the second group containers during the first cut contained from 6.10 to 9.4 mg·kg^{-1}. After harvesting the second crop, the cadmium content in the plants ranged from 6.49 to 18.50 mg·kg^{-1}. After the third crop harvest, the cadmium content for the second group ranged from 4.32 to 6.76 mg·kg^{-1}.

The cadmium content determined in plants from third group containers after the first cut was in the range between 14.70 and 34.40 mg·kg^{-1}. After marking the second cut, the content increased to 73.50 and 159.00 mg·kg^{-1}. After the third crop harvest, the cadmium content for plants from the third group ranged from 16.50 to 25.20 mg·kg^{-1}.

After determination of cadmium content in above-ground parts of plants, statistical analysis was performed to check if there is a correlation between soil properties and cadmium content in above-ground parts of plants. Based on the calculations, a significant negative correlation was found between the values of S, CEC and the Cd content in the above-ground parts of plants regardless of the swath (Table 3). A significant positive correlation was also found between the cadmium content in the soil and the content of this element in above-ground parts of plants regardless of the swath. The significance of the influence of cadmium content in soil on its content in plants is confirmed by a number of researchers [2,10,11].

Researchers investigating the possibility of toxic metals passing from the soil to the plant confirm that regardless of whether it is rice (*Oryza sativa*) or Indian mustard (*Brassica juncea*) or tobacco (*Nicotiana tabacum* L.), the increase in Cd content in plants is dependent on soil properties as well as the increase in the content of the element itself in the soil. They also draw attention to the affinity of plants for the metal, which if the crop species is not chosen properly for cultivation, may increase the risk of metal getting from the soil into the environment [12,13,14].

As mentioned earlier, water may be exposed to an increase in the concentration of elements under the influence of anthropopressure, therefore after completion of the pot experiment, samples of leachate were collected for testing. The pH value and concentration of cadmium were measured in the leachate from the containers. The results are summarized in Table 4.

A decrease in the pH value in the leachate from the containers is noticeable. It may be related to the increase of the hydrolytic acidity value in the studied soils from group III.

Comparing the content of cadmium in the leachate from the containers of individual research groups, it can be seen that the lowest content of this element occurs in the control group, while the highest cadmium content occurs in the group III. It can be concluded that this is related to the large amount of cadmium added to the soil of this group at the beginning of the experiment.

Similarly, changing the pH of leachate from alkaline toward neutral, may increase the cadmium content in the leachate of group III. This is confirmed by research published by researchers, indicating that the alkaline soil reaction favors the retention of this element in the soil, and limiting its leachability to waters [3,4,5].

4. Conclusions

Comparing the results of the control group with the results of the remaining groups of the experiment, it can be noticed that the quackgrass which grew in the control group containers, took much lower amounts of cadmium compared with the other groups in which there were larger amounts of this element in the soil.

The conducted experiment showed that the cadmium content in soils decreased with the increase of S and CEC values. This suggests that in order to limit the availability of cadmium to plants, it is necessary to maintain a high value of cation exchange capacity in the soil and a high content of basic ions.

The existence of a significant positive correlation between the increasing content of cadmium in the soil and the content of this element in above-ground parts of plants, regardless of the swath, suggests the impact of anthropopressure on the natural environment.

The increase in the concentration of cadmium in leachates, which is progressing with the increase in the degree of soil contamination in cadmium, may also confirm the impact of anthropopression on the natural environment.

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