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The impact of anthropopressure on lead content in grasses, soils and leachates from a pot experiment

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ABSTRACT

Lead belongs to trace elements strongly degrading the natural environment. One of the elements of the environment that can be polluted is water, which plays a special role in the movement of elements. Water quality is of great importance for the proper functioning of the environment, which is why water requires protection against pollution of elements. Taking appropriate actions to protect the aquatic environment requires the determination of the element's content in plants, soil as well as in waters so that it can be predicted to pass to other elements of the trophic chain. The aim of the research was to determine the impact of anthropogenization of the natural environment on the content of lead in grasses, soil and in leachates. The basis of the research was a pot experiment, which was carried out in four groups of vases containing soils with growing cadmium pollution. The plant used for the research was the quackgrass (*Elymus repens*). During the experiment, three swaths were collected in which the lead content was measured. The highest content of this element was determined in the vegetation samples from the control combination. The presence of trace elements in soils may affect their concentration in water, therefore, after the end of the pot experiment, samples of leachate were taken to investigate whether increasing amounts of cadmium in the soil can affect the content of lead in the effluents. It was noted that the leachate from the control group and group I, contaminated with cadmium to the smallest extent, was characterized by a higher concentration of lead than in other groups of the experiment.

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

1. Introduction

Water plays a special role in the circulation of trace elements between various elements of the environment. As a result of human activity, the most exposed to pollution are surface inland waters, marine coastal waters and soil waters. The source of water contamination can be, among others elements leached or rinsed from soils that contain fertilizers [1].

Fertilizers added to the soil can be a source of heavy metals, which pose a serious environmental problem and are considered a threat to humans and the ecosystem. Fertilizers can also affect soil properties such as soil pH, organic matter content and sorption capacity. Changing soil properties may contribute to changes in the mobility of elements and their availability to plants. They can also affect their leaching from soil to water [2–4].

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One of the elements that can be leached from the soil into water is lead. It is a toxic metal that can greatly degrade the biological environment. It is the contamination of the environment occurs through human activity such as zinc–lead ores mining, burning fossil fuels, fertilizers [5,6]. Lead is among the most widespread, persistent, and toxic soil contaminants. Short-term exposure to high levels of Pb can cause brain and kidney damage as well as gastrointestinal distress in humans, while long-term exposure can affect the central nervous system, blood, liver, and reproductive system. The maximum dose of lead absorbed by an adult during a week should not exceed 3 mg and the dose for children – 1 mg [7,8].

Reducing the environmental exposure, especially of the aquatic environment, to lead poisoning by determining the soil conditions that can reduce the leaching of lead to water is extremely important. Therefore, it is necessary to determine the content of this element in plants, soil as well as in waters, so that it can be predicted to pass to other elements of the trophic chain [9].

An important action in reducing human exposure to lead poisoning is the determination of the permissible levels of this element in soils intended for food crops, as well as the maximum concentration values of this element in water intended for human consumption. According to Polish law, the permissible lead content in soil is 250 mg kg^{-1} [10], while the permissible concentration of this element in drinking water is 0.01 mg kg^{-1} [11].

The research results available in the literature show the importance of grasses in the process of remediation of soils contaminated with elements such as lead. The results of the research on lead uptake and accumulation by the *Stipa hohenackeriana* trin and rupr. presented by Moameri et al. [12] are very interesting. The authors indicate that the studied species may be a suitable candidate for the accumulation of, among others, lead. They also suggest that the combined use of municipal waste compost (MSWC) and nano-silica powder may be an appropriate strategy to improve the phytoremediation capacity of *Stipa* in Pb contaminated soils. Similarly, research conducted with the use of *Secale montanum* [13] allowed to determine the possibility of increasing the usefulness of plants in remediation through the use of MSWC and nano-silica powder additives.

The grass species analyzed in the cited studies are native species to the areas where the research was conducted. This may be important in identifying plant species that can effectively reduce lead pollution to the environment, without affecting the botanical composition of the treated environment.

The aim of the research was to determine the impact of anthropogenization of the natural environment on the content of lead in grasses, soil and in leachates.

2. Material and methods

The concentration of trace elements in waters can be influenced by the content of these elements both in soil and in plants. Therefore, to be able to predict the transition of the element to the remaining elements of the trophic chain, our research was carried out in a form of a pot experiment. The conducted research was of a preliminary nature, which was to help determine the direction of further activities.

For the experiment, loamy sand with a pH of 7.46 and an organic matter content of 2.9% was used. The sandy soil commonly found in Poland was selected for research during the experiment. Detailed soil graining tests have shown that it is "loamy sand". The sorption capacity of the soil at the beginning of the test 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. while the lead content was determined at 1.16 mg Pb 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. The cadmium used in the experiment was supposed to imitate environmental pollution, which may come from, for example, fertilizers. Cadmium is an element that is easily absorbed by plants and is commonly found in living organisms. It has no regulatory role in living organisms, but may cause complications by disturbing metabolism. During the experiment, this element was used in the form of cadmium nitrate. 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. The first cut was made on day 89, the second cut on day 90 and the third cut on day 91, however, each time before the stage of heading. During the 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 the 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 the catalogue of methods [14].

Determination of lead 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 lead content in plant samples and leachates.

3. Results and discussion

Similar to the beginning of the experiment, also after its completion selected soil properties were determined to observe whether any changes in value occurred. The results are presented in Table 1, as well as the content of lead in the soil. The results presented in all tables are means of triplicates.

The values of the determined properties indicate the persisting advantage of basic exchange cations over-acidic cations, which, despite a slight decrease in pH, may favor the retention of lead in the soil. This is confirmed by the research results presented by researchers [3,15,16], which indicate the role of soil pH and other soil properties such as the organic matter content in the retention of lead in soil.

The average lead content determined in individual container groups slightly differed from each other, decreasing from 0.83 mg kg^{-1} in the control group to 0.77 mg kg^{-1} in group III.

The lead content determined in soils from individual containers does not exceed the permissible content for arable land (250 mg kg^{-1}), contained in the Regulation of the Minister of the Environment [10].

In addition to determining the lead content in the soil, after the end of the experiment, an analysis was made as to whether there is a relationship between the soil properties tested and the lead content in the soil. Calculations were made using STATISTICA 6.0PL software [17]. Based on the calculations, a significant positive correlation was found between H value and Pb content in soil, which is 0.63 (Fig. 1).

Lead 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 growth before the first cut. The decrease in the mass of plants with an increase in the amount of cadmium was observed only at the second and third cut.

Regardless of the swath, the above-ground parts of plants from the first group contained the smallest amount of lead. The highest amounts of this element in the first swath contained above-ground parts of plants from group III. In the remaining swaths, the largest amounts of lead were determined in the above-ground parts of the control group.

The lead content in the control group of plants after the first cut varied from 3.91 to 22.10 mg kg^{-1}. It decreased in plants harvested during the second cut and was from 7.46 to 16.40 mg kg^{-1}. After the third cut, the lead content of the control group plants ranged from 5.76 to 10.00 mg kg^{-1}.

The content of lead in plants of the first group determined after the harvest of the first cut ranged from 3.80 to 7.20 mg kg^{-1}. It increased after the harvest of the second cut and was from 3.71 to 9.13 mg kg^{-1}. After the third crop harvest, the lead content in the first group plants ranged from 2.25 to 4.41 mg kg^{-1}.

Plants collected from the second group containers during the first cut contained from 4.27 to 12.30 mg kg^{-1} of lead. After harvesting the second crop, the lead content in the plants ranged from 5.68 to 9.59 mg kg^{-1}. After the third crop harvest, the lead content for the second group ranged from 2.77 to 14.90 mg kg^{-1}.

The lead content determined in plants from third group containers after the first cut was in the range between 5.20 and 28.80 mg kg^{-1}. After marking the second cut, the content of this element decreased to 5.24 and 15.60 mg kg^{-1}. After the third crop harvest, the lead content for plants from the third group was the lowest and ranged from 3.23 to 14.70 mg kg^{-1}.

It is difficult to clearly answer why there was an increase in mass during the third cut. This is probably related to the uptake of some of the contamination by the plants, which could reduce the negative impact of cadmium contamination on plant growth and development.

When analyzing the obtained results, it should be emphasized that it is difficult to assess whether the lead content in the tested plants is too high or exceeds the

Table 1
Chosen physicochemical properties of soil samples and Pb content after completion of the pot experiment

	pH	H	S	CEC = H + S	OM	Pb
	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	0.77–0.91
Average	7.33	0.28	9.40	9.66	2.5	0.83
Group I						
Range	7.29–7.39	0.28–0.33	9.63–10.50	9.92–10.81	2.3–3.2	0.70–0.92
Average	7.35	0.30	10.11	10.41	2.7	0.85
Group II						
Range	7.38–7.41	0.25–0.28	8.55–10.88	8.80–11.16	2.5–2.7	0.71–0.78
Average	7.40	0.26	9.70	9.96	2.6	0.75
Group III						
Range	7.22–7.42	0.27–0.29	4.65–9.77	4.94–10.05	2.5–2.9	0.73–0.85
Average	7.36	0.28	7.50	7.68	2.7	0.77

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

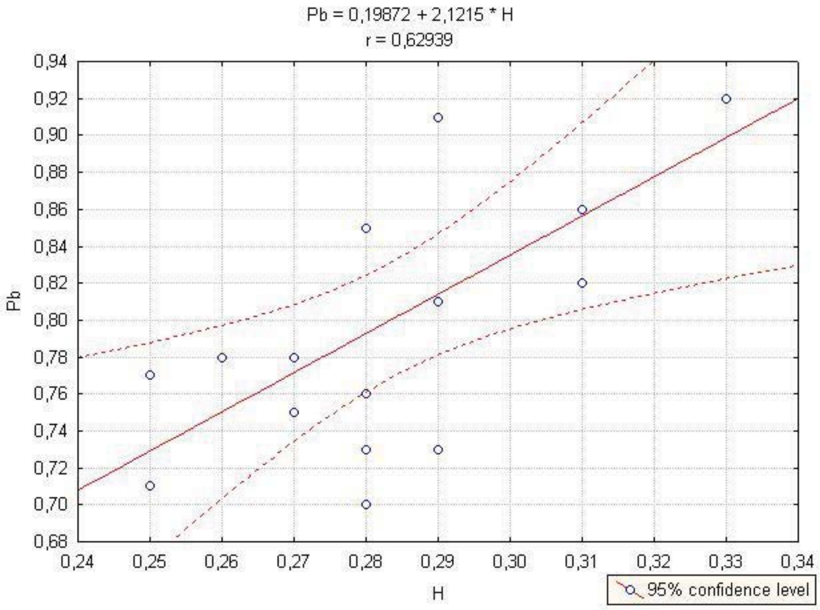

Fig. 1. Correlation between H value and Pb content in soil.

Table 2
Lead 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.)	Pb – range (mg kg^{-1})	Pb – average (mg kg^{-1})
1 cut				
Control	10.50–15.50	11.95	3.91–22.10	10.92
I	11.60–13.90	13.20	3.80–7.20	4.98
II	8.10–16.90	12.57	4.27–12.30	8.54
III	12.10–17.00	14.45	5.20–28.80	12.77
2 cut				
Control	5.9–12.2	10.10	7.46–16.40	11.30
I	7.7–13.6	9.67	3.71–9.13	6.27
II	6.8–9.5	8.07	5.68–9.59	7.38
III	4.9–10.2	7.80	5.24–15.60	10.44
3 cut				
Control	23.7–41.4	31.05	5.76–10.00	7.71
I	23.7–31.6	29.02	2.25–4.41	3.58
II	21.7–30.6	27.60	2.77–14.90	6.29
III	22.1–27.7	24.67	3.23–14.7	6.95

acceptable levels because there are no such regulations. The only regulations in Polish law apply to foodstuffs of plant origin such as dried herbs. The permissible lead content for dried herbs is 2 mg kg^{-1} and was exceeded in the tested plant samples [18].

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 lead were measured in the leachate from the containers. The results are summarized in Table 3.

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.

It was noted that the leachate from the control group and group I, contaminated with cadmium to the smallest extent, was characterized by a higher concentration of lead than in other groups of the experiment.

Comparing the content of lead in the leachate from the containers of individual research groups, it can be seen that the lowest content of this element occurs in the III group, while the highest lead content occurs in the first group. It

Table 3
Content of lead in the leachate from the containers after completion of the pot experiment

Group of containers	pH – range	pH – average	Pb – range (mg kg^{-1})	Pb – average (mg kg^{-1})
Control	7.47–7.74	7.63	0.0089–0.0289	0.0165
I	7.54–7.59	7.56	0.0067–0.5980	0.2890
II	7.11–7.34	7.22	0.0035–0.0143	0.0074
III	6.86–7.17	7.05	0.0030–0.0066	0.0048

can be concluded that the increasing amount of cadmium added to the soil at the beginning of the experiment may have reduced the leaching of lead from the soil to leachate.

Similarly, changing the pH of leachate from alkaline toward neutral, may increase the lead 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 [9,16].

Additionally, if the leachate from the experiment is considered as sewage, it can be concluded that the determined concentration of lead (0.0048–0.2890 mg kg^{-1}) does not exceed the limit values specified in accordance with the Regulation of the Minister of Construction [19] and amounting to 1 mg kg^{-1}.

4. Conclusions

Regardless of the swath, the above-ground parts of plants from the first group contained the smallest amount of lead. The highest amounts of this element in the first swath contained above-ground parts of plants from group III. In the remaining swaths, the largest amounts of lead were determined in the above-ground parts of the control group.

The presence of trace elements in soils may affect their concentration in water, therefore, after the end of the pot experiment, samples of leachate were taken to investigate whether increasing amounts of cadmium in the soil can affect the content of lead in the effluents. It was noted that the leachate from the control group and group I, contaminated with cadmium to the smallest extent, was characterized by a higher concentration of lead than in other groups of the experiment.

Comparing the content of lead in the leachate from the containers of individual research groups, it can be seen that the lowest content of this element occurs in the III group, while the highest lead content occurs in the first group contaminated with cadmium to the smallest extent. It can be concluded that the increasing amount of cadmium added to the soil at the beginning of the experiment may have reduced the leaching of lead from the soil to leachate.

References

[1] A. Kabata-Pendias, Trace Elements in Soils and Plants, CRC Press, Boca Raton, 2010, 548 pp.

[2] E. Ociepa, P. Pachura, A. Ociepa-Kubicka, Effect of Fertilization Unconventional Migration of Heavy Metals in the Soil-Plant System, Inżynieria i Ochrona Środowiska, 2014, t. 17, nr 2, s. 325–338 (in Polish).

[3] R. Attinti, K.R. Barrett, R. Datta, D. Sarkar, Ethylenediaminedisuccinic acid (EDDS) enhances phytoextraction of lead by vetiver grass from contaminated residential soils in a panel study in the field, Environ. Pollut., 225 (2017) 524–533.

[4] A. Kavehei, G.C. Hose, D.B. Gore, Effects of red earthworms (*Eisenia fetida*) on leachability of lead minerals in soil, Environ. Pollut., 237 (2018) 851–857.

[5] T. Chen, Q. Chang, J. Liu, J.G.P.W. Clevers, L. Kooistra, Identification of soil heavy metal sources and improvement in spatial mapping based on soil spectral information: a case study in northwest China, Sci. Total Environ., 565 (2016) 155–164.

[6] L. Zhang, Z. Mo, J. Qin, Q. Li, Y. Wei, S. Ma, Y. Xiong, G. Liang, L. Qing, Z. Chen, X. Yang, Z. Zhang, Y. Zou, Change of water sources reduces health risks from heavy metals via ingestion of water, soil, and rice in a riverine area, South China, Sci. Total Environ., 530 (2015) 163–170.

[7] H.W. Mielke, T.P. Covington, P.W. Mielke Jr., F.J. Wolman, E.T. Powell, C.R. Gonzales, Soil intervention as a strategy for lead exposure prevention: the New Orleans lead-safe childcare playground project, Environ. Pollut., 159 (2011) 2071–2077.

[8] EPA, Lead, 2019 (cited 8 November 2019). Available at: https://www.epa.gov/lead

[9] M. Ashrafi, S. Mohamad, I. Yusoff, F. Shahul Hamid, Immobilization of Pb, Cd, and Zn in a contaminated soil using eggshell and banana stem amendments: metal leachability and a sequential extraction study, Environ. Sci. Pollut. Res. Int., 22 (2015) 223–230.

[10] Journal of Laws of 2016 Item 1395, Regulation of the Minister of the Environment, (in Polish).

[11] Journal of Laws of 2017 Item 2294, Regulation of the Minister of Health, (in Polish).

[12] M. Moameri, M. Jafari, A. Tavili, B. Motasharezadeh, M.A. Zare Chahouki, F.M. Diaz, Investigating lead and zinc uptake and accumulation by *Stipa hohenackeriana* trin and rupr. in field and pot experiments, Biosci. J., 34 (2018) 138–150.

[13] M. Moameri, M.A. Khalaki, Capability of *Secale montanum* trusted for phytoremediation of lead and cadmium in soils amended with nano-silica and municipal solid waste compost, Environ. Sci. Pollut. Res., 26 (2019) 24315–24322.

[14] A. Ostrowska, S. Gawliński, Z. Szczubiałka, Methods of Analysis and Assessment of the Properties of Soils and Plants – Catalogue IEP, Warsaw, 1991 (in Polish).

[15] M.B. McBride, H.A. Shayler, H.M. Spliethoff, R.G. Mitchell, L.G. Marquez-Bravo, G.S. Ferenz, J.M. Russell-Anelli, L. Casey, S. Bachman, Concentrations of lead, cadmium and barium in urban garden-grown vegetables: the impact of soil variables, Environ. Pollut., 194 (2014) 254–261.

[16] T. Liu, F. Li, Z. Jin, Y. Yang, Acidic leaching of potentially toxic metals cadmium, cobalt, chromium, copper, nickel, lead, and zinc from two Zn smelting slag materials incubated in an acidic soil, Environ. Pollut., 238 (2018) 359–368.

[17] StatSoft, Inc. 2001 STATISTICA 6.0 PL – Data Analysis Software (in Polish).

[18] Journal of Laws of 2003 No. 37, Item 326, Regulation of the Minister of Health (in Polish).

[19] Journal of Laws of 2006 No. 136, Item 964, Regulation of the Minister of Construction (in Polish).