Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2015.1033135

57 (2016) 1034–1037
January

Taylor & Francis
Taylor & Francis Group

Evaluation of the soil quality from areas with varying degrees of pollution

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Received 2 September 2014; Accepted 26 February 2015

ABSTRACT

Petrochemical substances released into the environment contain, among others, some harmful trace elements, such as thallium that are harmful to human and animal health. Organisms that are poisoned with thallium are prone to some mental changes and are also susceptible to possible damage of the cardiovascular system. A characteristic symptom of thallium poisoning is alopecia. There is lack of limit values for this element in the legislation or recommendations for agriculture. Lack of limits, especially for elements such as thallium, poses a risk of uncontrolled accumulation in feed and food products. The aim of the study was to determine the mobility of thallium in an environment with varying degrees of pollution. The content of thallium in the extracted fractions detected in soil samples was below 1.0 $\mu g\, g^{-1}$, i.e. the level of quantification for atomic emission spectrometry with inductively coupled plasma. The results described in the literature referring to the content of this element in soils indicate that the content 1.0 $\mu g\, g^{-1}$ is specific to uncontaminated soils. At the same time, researchers suggest the presence of thallium in the upper layers of these soils at the level of 0.1–2.0 $\mu g\, g^{-1}$. Due to the high toxicity of even small amounts of thallium for humans and animals, we believe that it is necessary to intensify the pressure on the creation of legislation taking into account the limit values for thallium in soils, water, plants, foods, and animal feeds.

Keywords: Thallium; Anthropopressure; Environment

1. Introduction

Petrochemical substances released into the environment contain, among others, some harmful trace elements, such as thallium that are harmful to human and animal health.

Thallium is recognized as a toxic element which is particularly easily taken up by plants. The harmful effects of thallium on plants includ inhibition of root development, plant stunting, and chlorosis. The harmfulness of thallium also inhibited setting seed and decreased the germination capability. It is equally toxic when taken in with food, as well as a result of inhalation of dust or vapors, and absorption through the skin. A characteristic symptom of thallium poisoning is alopecia. In organisms poisoned by thallium, there are some changes in the nervous system and damage to the cardiovascular system [1–3].

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Presented at the 12th Scientific Conference on Microcontaminants in Human Environment 25–27 September 2014, Czestochowa, Poland

Thallium is adsorbed by clay minerals, Fe and Mn hydroxides, and organic matter, which indicates its potential ability to pass from the soil environment to the trophic chain. The possibility of the elements entering from the soil to the trophic chain in addition to the concentration of the element in the soil is affected by the physicochemical properties of the soils, such as the particle size distribution, organic matter content, sorption, as well as the pH [3].

The aim of the study was to determine the mobility of thallium in the environment with varying degrees of exposure to polluting substances.

2. Material and methods

In our research we have used samples of soil and plants collected from areas located at different distances from the emitter of petroleum substances (PKN "Orlen"—Płock, Poland) which means that the impact of these substances varied.

The areas selected for research in accordance with Kondracki [4] are located in the macroregion Chełmińsko-Dobrzyńskie Lakeland. The area around the PKN "Orlen" belongs to mezoregion Dobrzyńskie Lakeland, while Welski Landscape Park is located in the mezoregion "Garb Lubawski".

The area of Dobrzyńskie Lakeland is an agricultural land with soils that developed from glacial accumulation mainly glacial tills, loamy sands, or gravels. The area of Welski Landscape Park stands out as typically varied glacial land relief, with characteristic outwash plains, moraine uplands, and narrow and deep gutters of lakes and river valleys. Thanks to the limited interference of human, both the Wel River and her valley remained almost unchanged and the flora preserved some advantages of natural communities, which is a rarity in the scale of the country and Europe.

Samples of the soil were taken from topsoil layers (0.00–0.20 m) in the distance from 0.5 to 15 km radiantly from the borderline of PKN "Orlen"; however, in the area of Welski of the Landscape Park, samples of the soil were taken in the distance from 5 to 15 km from Lidzbark Welski. Sampling was performed in accordance with the guidelines included in the norm BN-78/9180-02 [5]. Twenty soil samples were collected from the area around the PKN "Orlen" and ten samples from the area Wel Landscape Park.

Altogether 30 tested samples were selected and physicochemical properties, such as particle size, were determined in accordance with the norm BN-78/9180-11 [6]; pH was measured in a solution of 1 mol L^{-1} KCl; and hydrolytic acidity, sum of exchangeable cations, the cation exchange capacity, and the organic matter content were measured according to the methodology included in the catalog of methods [7], and a sequential extraction was conducted according to the procedure given by Tessier et al. [8], distinguishing thallium in fractions: exchangeable, soluble in acids, reducible, oxidizable, and residual.

Determination of the content of thallium was performed using the ICP-AES method.

3. Results and discussion

The results of analyses of chosen physicochemical properties of the soils are summarized in Tables 1 and 2. Tested soil samples from both the vicinity of PKN "Orlen" and Lidzbark Welski were characterized by a predominance of sand fraction. The pH measured in the analyzed soils from the vicinity of Plock (3.66–7.00), similar to the soils from a landscaped park area, showed considerable variations and ranged from strongly acidic to neutral (3.67–6.66).

The soils from the area under the influence of the petrochemical plant with the exception of one sample (11.25 cmol (+) kg^{-1}) were characterized by lower values of hydrolytic acidity (1.14–4.50 cmol (+) kg^{-1}) than soils from the area of natural environmental values (1.83–7.68 cmol (+) kg^{-1}).

The sum of basic exchangeable cations in soils in the vicinity of PKN "Orlen" contained a wide range of values from 2.40 to 44.36 cmol (+) kg^{-1}, while in soils from the landscape park values ranged from 2.42 to 26.66 cmol (+) kg^{-1}.

Soil samples tested in both areas were characterized by the content of organic substances included in the range 2.25–10.95%.

The content of thallium in the extracted fractions detected in soil samples was below 1.0 $\mu g\, g^{-1}$, i.e. the level of quantification for atomic emission spectrometry with inductively coupled plasma (ICP-AES). Such a low content of the element in the extracted fractions was similar to the designated amount of thallium obtained by Martin and Kaplan [9] during examination of thallium movement through the soil profile. The soils studied by Martin and Kaplan were characterized by the acidic reaction, which is predominant of the sand fraction, the low value of the CEC, and the organic matter content at a level similar to that obtained in our study.

A higher content of thallium in soils (2.5–18.2 $\mu g\, g^{-1}$) was reported by Tremel et al. [10], but the soils they studied were characterized by a higher content of organic matter, a low content of sand fraction, a high clay content, and pH close to neutral.

Table 1
Chosen physicochemical properties of topsoil layers in the area of The Welski Landscape Park

Sample number	Percent of soil fractions (mm)			pH 1 mol L^{-1} KCl	H	S	CEC = H + S	OM
	1–0.1	0.1–0.02	<0.02		cmol (+) kg^{-1}			(%)
1	58	23	19	6.22	2.22	10.62	12.84	2.90
2	57	17	26	4.60	6.30	6.04	12.34	5.35
3	67	21	12	4.05	5.76	2.42	8.18	2.80
4	75	16	9	6.07	2.04	6.94	8.98	2.35
5	47	27	26	3.67	6.57	4.90	11.47	4.35
6	61	24	15	5.15	3.48	5.48	8.96	2.60
7	66	20	14	4.43	7.68	8.20	15.88	5.60
8	78	15	7	6.66	1.83	6.66	28.49	3.45
9	60	22	18	5.77	3.09	7.20	10.29	2.50
10	63	23	14	5.68	3.99	8.18	12.17	3.70

Notes: H—Hydrolytic acidity; S—Sum of exchangeable cations; CEC—Cation exchange capacity; and OM—Organic matter content.

Table 2
Chosen physicochemical properties of topsoil layers in the region near PKN "Orlen"

Sample number	Percent of soil fractions (mm)			pH 1 mol L^{-1} KCl	H	S	CEC = H + S	OM
	1–0.1	0.1–0.02	<0.02		cmol (+) kg^{-1}			(%)
1	47	26	27	6.62	1.74	24.30	26.04	4.55
2	62	23	15	6.80	1.83	44.36	46.19	4.85
3	74	13	13	7.00	1.56	17.42	18.98	2.35
4	57	27	16	4.05	4.29	2.80	7.09	2.50
5	53	30	17	6.18	2.34	12.04	14.38	4.30
6	34	32	34	6.74	1.44	38.10	39.54	8.35
7	42	32	26	4.10	4.32	3.74	8.06	3.05
8	42	33	25	4.87	3.12	7.96	11.08	3.80
9	42	23	35	5.13	3.63	9.30	12.93	4.85
10	62	24	14	6.50	2.10	25.40	27.50	6.15
11	53	32	15	6.25	2.13	13.22	15.35	3.85
12	67	21	12	3.66	1.14	2.40	3.54	3.50
13	36	37	27	5.04	3.81	9.02	12.83	4.15
14	40	33	27	5.41	2.13	6.68	8.81	2.25
15	40	38	22	6.20	2.37	9.48	11.85	3.45
16	53	29	18	6.66	2.28	14.20	16.48	4.80
17	53	24	23	6.86	1.47	18.96	20.43	3.20
18	38	41	21	5.56	2.97	6.78	9.75	3.80
19	43	23	34	4.22	11.25	20.06	31.31	10.95
20	83	5	12	4.70	4.50	4.74	9.24	3.20

Notes: H—Hydrolytic acidity; S—Sum of exchangeable cations; CEC—Cation exchange capacity; and OM—Organic matter content.

The results described in the literature regarding the content of thallium in soils indicate that the content 1.0 μg g^{-1} is specific to the uncontaminated soils. At the same time, researchers suggest the presence of thallium in the upper layers of these soils at the level of 0.1–2.0 μg g^{-1} [11–13].

4. Conclusions

The method used to determine the mobility of thallium has not been sufficient; however, on the basis of the results of our study and the results of the scientific literature, the studied areas can be considered to be uncontaminated by this element.

Taking into account the results of the research in the light of literature and the legislation in force, it was noticed that there was no limit values for this element in the legislation or recommendations for agriculture. Lack of limits, especially for elements such as thallium, poses a risk of uncontrolled accumulation in feed and food products. It is also impossible to determine whether the values identified during the research exceed or do not exceed the limit values.

Due to the high toxicity of even small amounts of thallium for humans and animals, we believe that further decisive measures should be taken in order to create the legislation which would take into account the limit values for thallium in soils, water, plants, foods, and animal feeds.

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