JEE Journal of Ecological Engineering
Volume 21, Issue 5, July 2020, pages 80–87
https://doi.org/10.12911/22998993/122186

Received: 2020.02.27
Revised: 2020.04.15
Accepted: 2020.05.06
Available online: 2020.05.25

The Influence of Urban Agglomeration on the Accumulation of Certain Heavy Metal Ions in Tansy (*Tanacetum vulgare L.*)

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ABSTRACT
Different compounds including toxic heavy metals ions have been used in various industrial branches for ages. Therefore, these compounds are nowadays often identified in the natural environment. Plants usually function like indirect transporters through which heavy metals, in the form of ions, infiltrate from the environment into the human and animals' food chains. The present paper studied the influence of urban agglomeration on the accumulation of certain heavy metals in tansy. The content of heavy metals ions (Cr, Ni, Cd and Pb) was marked in the tansy leaves. Depending on the location of sampling, large variations in the heavy metal content were observed in the plant material. The research results indicate that the heavy metal content of tansy is influenced by the close "neighborhood" of a well-developed urban agglomeration such as patrol stations and factories.

Keywords: *Tanacetum vulgare* L., heavy metals, anthropogenic areas, non-anthropogenic areas, environment.

INTRODUCTION

Plants function like indirect transporters through which heavy metals, in the form of ions, infiltrate from the environment into the human and animals' food chains. The study on the heavy metals influence on the crops quality is attracting more and more interest due to their meaningful increasing emission into the natural environment. Some heavy metal ions are essential micro and macro elements of plants (Morkunas et al. 2018), but both high and low concentrations of these ions can disturb the proper development of plants. (Madejon et al. 2006, Marques et al. 2009, White and Brown 2010).

Heavy metals compounds have been used in various industrial branches for ages. Even today, the mercury compounds are used in some regions of the worlds for the gold ore refinement process [Abbas et al. 2017, Hasriwiani et al. 2017, Esdaile and Chalker 2018]. In recent decades, scientists have been studying the possible effect of heavy metal ions on the environment and human health. The heavy metal ions are introduced to the natural environment as a result of rocks and soils weathering, so that their highest content appears in the areas rich in the mother lode [Anani and Olomukoro 2018]. The local concentration of heavy metals depends on many factors; that is why the study on the mineral content is becoming more and more important, especially when speaking in terms of growing dangerous compounds emission [Mandzhieva et al. 2014]. Plants are characterized with different resistance to the presence of heavy metals in soil, some of them also require increased concentration of heavy metal ions in the environment, the plants' growth stops in case of low or a total lack of concentration (Petr et al. 2011). Baker (1981) divided the plants, which tolerate heavy metals, into three categories: excluders, accumulators and indicators. Excluders are the plants which limit the transport only to shoots and keep relatively low concentration of heavy metals in the overground organs with concurrent high concentration of heavy metals in the soil. Accumulators possess the ability to translocate metals through roots to the ground-based organs parts. In turn, indicators show an indirect reaction to the concentration of metals in soil, and the presence of the metal ions in these plants reflects a certain measure of the bioavailable concentration of these elements in soil [Majid Ghaderian and Ghotbi Ravandi 2012].

The plants' fundamental defense mechanism against heavy metals is their accumulation in the soft tissue, both in the ground-based organs, as well as in the roots, owing to bonding metals with proteins (Morkunas et al. 2018, Kashin and Ubugunov 2012, Motuzova et al. 2014, Sajedi et al. 2010, Yuan et al. 2011). Apart from the internal accumulation of metals, plants are able to immobilize them on the surface of leaves through capturing in the wax produced by the surface hair of leaves. Bonding metals with the wax tarnish or with resin prevents their scouring [Chaplygin et al. 2018].

Nevertheless, in the case of majority of plants, the accumulation of metal ions over the defined level has a definitely negative effect on their physiological and morphological condition (Marques et al. 2009, Rodriguez-Serrano et al. 2009, Sajedi et al. 2010, Yuan et al. 2011). Only a certain content of microelements creates the optimal conditions for the right course of physiological processes (Yabe et al. 2010).

The plants' accumulation of metals is dependent on their accessibility in soil as well as on the roots' inception mechanisms (Shahid et al. 2017). Due to the root system barrier, the concentration of elements in many plants is usually lower in the ground-based organs than in roots (Carrier et al. 2003, Smolinska and Rowe 2015). Some plants, despite the presence of the root barrier, are able to accumulate large amounts of metals, exceeding even their maximum, permissible concentration. The property enables to employ plants to the phytoremediation process (Adams et al. 2013, Dmuchowski et al. 2014, Baltrėnaitė and Baltrėnas 2018). Despite the proper accumulation of metals, when certain concentration is reached, the physiological processes undergo irreversible changes. The plants that have been submitted to the process of phytoremediation are often incapacitated in the wrong way; therefore, the metal ions are released to the environment again. It happens quite often that even a significant growth of element concentration does not lead to any sudden phenotypical symptoms of poisoning that could be seriously dangerous for animals and people (Bennett et al. 2001, Jaishankar et al. 2014). That is why a long-standing monitoring should be performed when talking about metals in the farms located in the neighborhood of highways and various types of industry.

Tansy (*Tanacetum vulgare* L.) is a perennial aromatic plant belonging to the Asteraceae family. [Chaplygin et al. 2018, Jakobs and Müller 2018, Goudarzi et al. 2015, Vasilenko et al. 2016, Qi et al. 2018], which includes over 200 species [Özbilgin et al. 2018]. It is a species originating in Eurasia, currently occurring in the temperate climate of the Northern Hemisphere [Derda et al. 2012, Mitich 1992].

Tansy grows along roads, rail embankments, meadows and banks of ponds, rivers and lakes [Mehrparvar et al. 2018]. It has a highly branched root system that has a significant impact on the uptake of heavy metals from soil, as well as their accumulation [Devrnja et al. 2017, Mongkhonsin et al. 2011, Moradi et al. 2010].

The plants from the Asteraceae family are a precious source of substances that are biologically active and used in the traditional and contemporary herbal medicine. The tansy plants are rich in biologically active substances, contained in essential oils (EO) and are used in the traditional and contemporary herbal medicine (Kumar and Tyagi 2013). Both leaves and blooms of tansy also serve as convulsive, antiseptic as well as dermatological (Kumar and Tyagi 2013) and anti-inflammatory drugs [Sattarpour et al. 2018]. β-tujon included in an the essential oil shows antiparasitic effects. The level of the β-tujon content in tansy herbs is not constant, what was quite problematic in the traditional herbal medicine, for example because of the mistakes made while preparing an appropriate dose for making a particular extract. Consuming an excessive amount of β-tujon by people resulted in a wide range of afflictions in their case [Halicioglu et al. 2011].

Today, tansy is widely used in the cosmetics industry as an ingredient in lotions, creams and in the agricultural industry as the active substance of repellents and insecticides. Both leaves and blooms of tansy are used as convulsive, antiseptic as well as dermatological drugs [Kumar and Tyagi 2013]; however, they serve in the form of extracts, alcoholic essences and essential oils much more often. Their extracts are widely used as far as the treatment of rheumatism, stomach ulcers, fever and digestive disorders is concerned [Devrnja et al. 2017], the brew of *Tanacetum* *vulgare* L. blooms stimulate the process of healing up cuts, improve appetite and have an antalgic effect [Lahlou et al. 2008, Zaurov et al. 2013]. Most alcoholic essences from tansy also have biologic, including anti-inflammatory, antioxidant and antibacterial effects [Coté et al. 2017, Devrnja et al. 2017].

The aim of the study was to compare the accumulation of Cr, Ni, Cd and Pb in the Tansy leaves growing in the areas with different levels of urbanization in Poland.

THE MATERIAL AND METHODS

Plant material

The material of tansy in the form of leaves was collected during the full flowering period from June to September 2017 in 12 natural locations (Table 1). Four of the twelve locations were located in anthropogenic areas (A), in the areas with heavy traffic, or near gas stations and various types of factories. The remaining eight sampling sites were located in non-anthropogenic (N) areas, i.e. meadows more than 200 m from rural roads and on the banks of rivers and forests.

Preparatory procedures of the studied material and chemical analysis

The collected leaves were dried for five days at room temperature in the dark. Afterwards, the dry plant material was ground, and then a fraction smaller than 1 mm in diameter was separated from it. The obtained fraction was stored in the dark in hermetic containers until the chemical composition analysis. The metal content was determined by mass spectrometry with inductively stimulated plasma using an ICP-MS after microwaved wet mineralization with aqua regia in a Mars-X apparatus.

Statistical analysis

In order to assess the relationship between the concentrations of heavy metals in the *Tanacetum vulgare* leaves, a statistical analysis was performed by Pearson correlation analysis in the Statistica 13.1 software (Dell Software, Round Rock, USA).

RESULTS AND DISCUSSION

A relatively low chromium content was found in the tansy leaves, which oscillated from 1.529 to 1.947 mg·kg^{-1}d.m. (Fig. 1). In the other two locations, a significant rise of the chrome content was observed. Then, the content increased up to 3.740 mg·kg^{-1}d.m. in Starachowice; nevertheless, the highest content was noted in Stalowa Wola and grew by 257.3% in comparison to Starachowice.

The content of chrome in *Tanacetum vulgare* L. provided by Stević et al. [2011] was definitely lower than in the own research. It was 0.1 mg·kg^{-1}d.m. on the non-anthropogenic position; however, on the anthropogenic one – it increased up to 0.3 mg·kg^{-1}d.m. Different results were achieved by Adamcova [2017], who compared the content of metals in tansy on the positions around landfill sites, on the closed area of the site as well as in the soil that had a direct contact with wastes.

The results of the research presented by Adamcov indicate that both in the landfill and the surrounding area there is a multiple increase in the content of chromium in tansy leaves; and so the chromium concentration ranged from 13.38 mg·kg^{-1}d.m in the closed part of the landfill to 218.1 mg·kg^{-1}d.m. in the area surrounding the landfill.

In the case of the nickel ions in tansy, the results were similar to those of the chromium ions (Fig. 2). The lowest content of the nickel ions

Table 1. Locations of the tansy samples collection in Poland with the division into the anthropogenic (A) and non-anthropogenic (N) ones

Location	Geographical coordinates		Type of area	Location	Geographical coordinates		Type of area
	latitude (N)	longitude (E)			latitude (N)	longitude (E)	
Słubice	52.33226	14.62062	N	Pobiedziska	52.46613	17.28842	N
Szklarska Poręba	50.82014	15.43838	A	Łączki	50.23020	17.19177	N
Kraśnik Dolny	51.31680	15.59713	N	Stanowice	50.13162	18.68082	A
Międzychód	52.61319	15.90543	N	Białka Tatrzańska	49.23208	20.06148	N
Kudowa Zdrój	50.43530	16.22743	N	Starachowice	51.05880	21.06459	A
Żmigród	51.48086	16.91363	N	Stalowa Wola	50.54976	22.07053	A

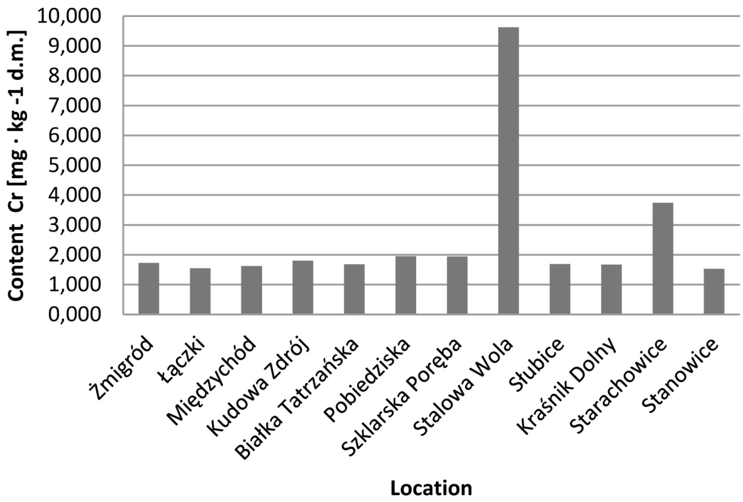

Figure 1. The content of Cr in the tansy leaves from different locations

was observed in Słubice – 1.62 mg·kg^{-1}d.m.; in the next nine locations, the value oscillated between 1.97 and 3.59 mg·kg^{-1}d.m. Finally the highest level of ions – 4.15 mg·kg^{-1}d.m. – was observed in Starachowice. What is more, in the research of Stević et al. [2011], the rise of the nickel concentration was observed too, from 0.05 mg·kg^{-1}d.m. on the non-anthropogenic area, to 1.1 [mg·kg^{-1}d.m.] on the anthropogenic one.

Higher concentration of the nickel ions in the own research might be caused by the neighborhood of petrol stations and holiday traffic. The results concerning the content of the nickel ions in *Tanacetum vulgare* L. were proven by the research carried out by Lorangera and Zayeda [1994]. The authors provided that the concentration of the nickel ions was higher in the industrial as well as residential areas, what may be the reason of using the same element in the oil-burning industry.

The total content of cadmium in ten locations was similar (Fig. 3), and oscillated within limits of 0.50 mg·kg^{-1}d.m.; only in Szklarska Poręba, the content reached 1.14 mg·kg^{-1}d.m. Out of the 12 studied locations, only in two of them the content of cadmium was diametrically different only in two of them, i.e. 178% higher in Stanowice than in Szklarska Poręba. Nevertheless, the rise of the cadmium ions content by 288% occurred in Starachowice.

The content of the cadmium ions in the *Tanacetum vulgare* L. leaves provided by Minkina et al. (2017) was similar to the results achieved in the own research and it has not exceeded 1 [mg/kg d.m.]. Similar contents were achieved

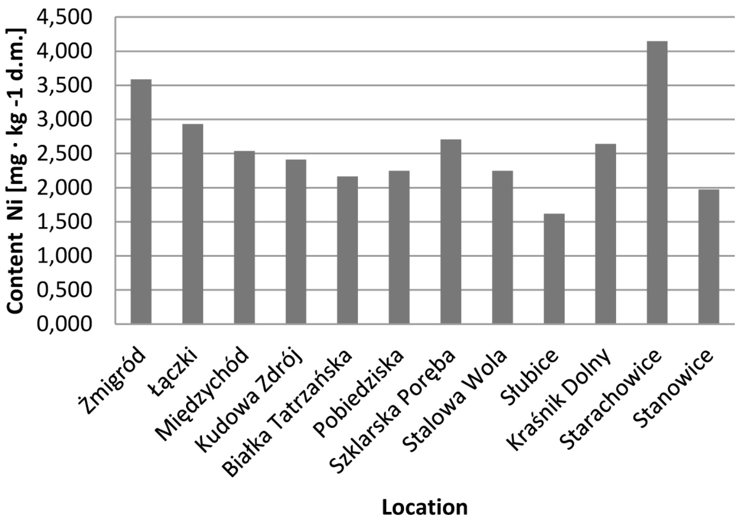

Figure 2. The content of Ni in the tansy leaves from different locations

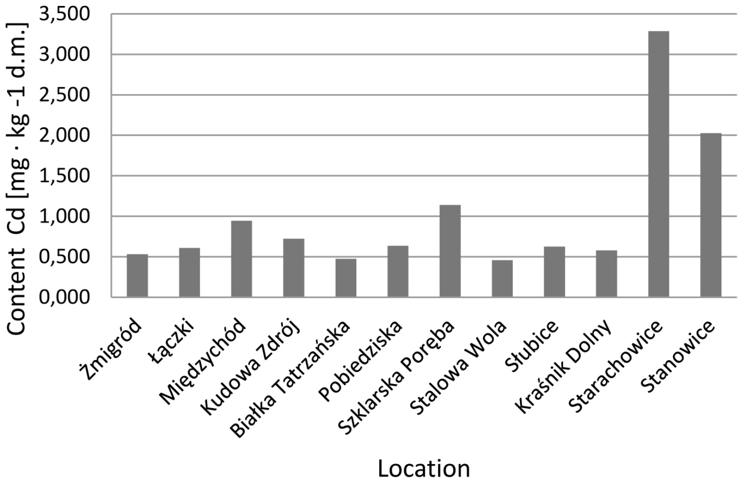

Figure 3. The content of Cd in the tansy leaves from different locations

by Adamcova et al. (2017) both on the area where soil had a direct contact with wastes, as well as on the closed part of landfill. However, on the area surrounding the landfill, a twofold rise of the cadmium ions content was observed. As the study results show, leaching of toxic metal ions from the landfill area causes their accumulation on the surrounding area.

The content of lead ions was similar to cadmium (Fig. 4), while in ten out of twelve studied locations, the total content of the lead ions in the tansy leaves was 0.63 – 1.18 $mg \cdot kg^{-1}$d.m. A significant growth of the lead ions appeared in the other two locations, it was 1.99 $mg \cdot kg^{-1}$d.m. in Starachowice and 3.50 $mg \cdot kg^{-1}$d.m. in Stalowa Wola. Such local growth of lead in the tansy leaves might be caused by soil contamination. In the research of Adamcova et al. (2017) the total content of tansy leaves on the whole researched area was not greater than 1.00 $mg \cdot kg^{-1}$d.m.; only in two places from which the research material was collected, both in the closed area of the landfill as well as on the one where soil had a direct contact with wastes the total content was 3.27 and 6.24 $mg \cdot kg^{-1}$d.m. The results presented prove the previous assumption.

Table 2 shows an important correlation between particular metal ions. Moreover, the data presented proves the significant relation between the total concentration of the content of the Pb and Cr ions. The correlation observed points at the fact that the concentration of the lead ions in the tansy leaves rises along the Cr concentration. This fact means that there is a high possibility that both of the elements are distributed in the environment.

Apart from incepting the toxic metal ions from soil, due to wide surface of tansy leaf, the

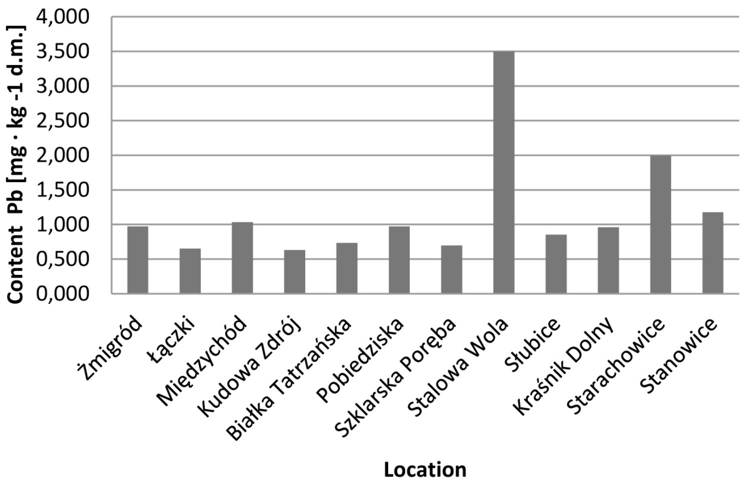

Figure 4. The content of Pb in the tansy leaves from different locations

Table 2. Correlation coefficients between heavy metal concentrations

Content of heavy metals	Content of heavy metals			
	Cd	Pb	Ni	Cr
Cd	1.00	0.20	0.51	0.01
Pb	0.20	1.00	0.11	0.96
Ni	0.51	0.11	1.00	0.02
Cr	0.01	0.96	0.02	1.00

plant absorbs large amounts of these ions by means of air and particulate matter. Therefore, even at low concentration of metals in soil, their concentration in plants may significantly exceed certain norms. The phenomenon shows that the accumulation of toxic metal ions depends both on the physiological, morphological as well as from the local contamination of ground. Thus, in order to assess the plants resistance to contamination, it is necessary to employ an integrated approach with regard to all plants' characteristics as well as the condition of the environment (Chaplygin et al. 2018).

CONCLUSIONS

The qualitative and quantitative analyses show a different content of such metals as: Cr, Ni, Cd and Pb in tansy leaves on the two types of area studied. High concentrations of Cr, Cd and Pb in the industrial zone were closely related to the pollution caused by an increased traffic and industrial activity. The material collected from all types of environments showed a similar concentration of the nickel ions, which confirms the lack of influence of local pollution of the area on the concentration of heavy metals in the plant material.

The acquired and presented results included in the present study point at the usefulness of tansy plants in monitoring the environment contamination with toxic metal ions. A multiple rise of the toxic elements concentration in the tansy tissues in Stalowa Wola was caused by the vicinity of ironworks as well as other industrial plants dealing with plastic processing of metals. Nevertheless, a range of statistic analyses showed strong influence of the lead content on the chrome concentration in the plants on a particular area. The results achieved might suggest that if the contamination by the lead ions appears on a particular area, the chrome ions will probably occur as well.

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