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Full Length Research Paper

Environmental study of heavy metals influence on soil and Tansy (*Tanacetum vulgare* L.)

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The aim of this work was to define the correlation between heavy metal (mercury, lead, cadmium, chrome and nickel) concentration changes (in soil, leaf, stem, root and essential oil in Tansy) and type and distance from source pollution. The concentration was monitored on different locations: 1) Chemical industry pančevo (with accident situation); 2) Pančevo industrial zone; 3) highway; 4) Ada Ciganlija recreation zone and 5) Topčider park. Mercury (Hg) concentration was analyzed as a function of time, starting from accident situation from 1999 to 2008. Hg had maximum concentration of 131 200 mg/kg at a soil depth of 0 - 15 cm. After three, six and nine years, linear accident Hg concentrations in soil decreased from 85 400 via 41 060 to 106.0 mg/kg. Mercury concentration which results in the location where accident occurred showed that 6 years was necessary for concentration to drop below the limits and for revitalization of standard industrial Tansy vegetation. Concentrations of Hg in the Tansy plants from contaminated site were 5, 10, 100 and 200 times greater than in industrial zone, highway, Ada Ciganlija and Topčider, respectively. The highest amount of lead (Pb) was in leaves (14.1 mg/kg) and in essential oil (0.7 mg/kg) of Tansy near the highway. However, Pb concentration in soil and plant was decreased with square of highway distance.

Key words: Environmental study, heavy metal concentration, mercury accident, correlation, *Tanacetum vulgare*.

INTRODUCTION

Heavy metals are defined as that group of elements that has specific weights higher than 5 g/cm^3 (Holleman and Wiberg, 1985). There are about 40 elements that fall into this category. As a result of the industrial revolution, there is enormous and increasing demand for heavy metals that leads to high anthropogenic emission of heavy metals into the biosphere (Ayres, 1992). Apart from the release of some emissions into the atmosphere in the form of dust particles or vapors, these heavy metals stay largely in the aquatic and soil phases of the planet. Plants are largely immobile organisms and in the metal-contaminated environment, it is usually the root of a plant that is the primary contact site with the metal ions. In order to survive, plants must have developed, on one side, efficient and specific mechanisms by which heavy metals are taken up and transformed into a physiologically tolerable form, providing the essential elements for the plants' metabolic function. On the other side, excess of these essential elements or those toxic heavy metal ions that do not play a role in metabolism, to which plants are exposed, has to be metabolically inactivated (Zeng, 1996).

Plant cells must have developed a mechanism by which the metal ion can enter the cytosol of the cell, thus preventing the metal from inactivating catalytically active or structural proteins to protect themselves from heavy metal poisoning (Zeng, 1996). Heavy metals interact with several functional groups of proteins, primarily SH-groups. As a result, protein conformation is changed, and many enzymes with SH-groups in their active centers lose their activities (Ivanov et al., 1998). This precludes, for instance, an inducible system. In the case of plants, one should expect a constitutive mechanism for the detoxification of heavy metal ions. Indeed, such a mechanism was found when we set forth to explore the fate of heavy metal metabolism in higher plants and their cell suspension cultures. Heavy metal content in medicinal

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plants is a subject of great interest, published in many papers (Blagojević et al., 2009; Stancheva et al., 2009).

Some essential aromatic and medicinal plants are capable of accumulating heavy metals from contaminated soils (Abu-Darwish and Abu-Dieyeh, 2009). All heavy metals, both essential (copper (Cu), zinc (Zn)) and non-essential (Cd, Pb) can cause toxic effects on plants and humans, if found in high concentrations (Alloway, 1990).

Mercury (Hg) and its compounds are hazardous to humans, plants and animals. Mercury metal, its vapor, and most of its organic and inorganic compounds are protoplasmic poisons. The tolerance limit of inorganic Hg in aqueous solution is 1 mg L^{-1}, while total mercury in soil is generally low. Mercury adsorbed onto soil is subjected to a wide array of chemical and biological transformation processes such as Hg (0) oxidation and Hg (II) reduction or methylation, depending on soil pH, temperature and soil organic matter content (Weber, 1993).

It is a well known fact that Hg^{2+} is strongly bound to the organic matter present in soil (Yin et al., 1997; Grigal, 2003). This indicates that under these circumstances the metal has low mobility, especially under low pH conditions (Yin et al., 1996).

Mercury is often found in soils as "hot spots" located close to industrial facilities that either use Hg in their fabrication processes (e.g., chlor-alkali plants) or produce Hg compounds (e.g., Hg-fulminate plants). This explains why the soils surrounding many of these old facilities contain high levels of Hg contamination.

Mercury is naturally present in soils at concentrations ranging between 0.003 and 4.6 mg/kg, in most cases below 0.5 mg/kg (Schlüter, 1993), whereas in contaminated sites, concentrations of up to 11 500 and 14 000 mg/kg have been reported (Gray et al, 2002; Neculita et al., 2005). In these contaminated areas, where Hg entrance to the system is mainly via surface spills, wastewater discharge, and/or by condensation of atmospheric Hg, the element tends to accumulate in the soil surface horizons, and is mainly retained by sorption onto organic compounds and, to a lesser extent, clays (Biester et al., 2002; Rule and Iwashchenko, 1998). Maximum absorption onto soil organic surfaces occurs in the range of pH 3 to 5 (Andersson, 1979), whereas as pH increases, sorption decreases, mainly because of the increase in dissolved organic matter complexed with Hg (Yin et al., 1996). Other factors affecting Hg retention in surface soils, in addition to organic matter, are chemical properties, such as soil pH and redox potential, which affects Hg speciation and solubility (Hogg et al., 1978) amount and type of mineral colloids (Cruz-Guzmána et al., 2003), presence of ligands (Yin et al., 1996; Miretzky et al., 2005) and soil temperature.

In higher plants, exposure to mercury reduced photosynthesis and transpiration, water uptake, and chlorophyll synthesis (Godbold and Huttermann, 1986). In spruce (*Picea abies*) seedlings exposed to mercury and methyl mercury, changes in photosynthesis and transpiration were attributed to mercury induced root damage rather than the direct action of metals in the needles. The authors of this study suggest that in seedlings exposed to mercury, the primary damage to roots affects nutrient and water supply to the needles. In the young root tips, the effect of mercury on mineral levels was more pronounced than in older root parts. Exposure to both organic and inorganic mercury resulted in a loss of potassium, magnesium, and accumulation of iron. A dramatic decrease in the level of potassium in the root tip nuclei of the mercury seedlings supports the idea that both inorganic and organic mercury may cause changes in root tip cell membrane integrity. However, there are differences in how these two forms of mercury carry out cell injury. While inorganic mercury ($HgCl_2$ in particular) affects the plasma membrane, methyl mercury may primarily affect organelle metabolism in the cytoplasm which subsequently affects membrane integrity. Mercury induced root damage may have serious consequences for nutrient and water supply above ground plant parts, and should be taken into account when assessing the effect of mercury on the physiology of leaves or needles (Godbold and Huttermann, 1986). In another study on mercury toxicity in spruce seedlings (Godbold, 1991), methyl mercury was found to significantly decrease root elongation, while mercury chloride had no impact on root length. The authors concluded that the greater toxicity of methyl mercury is due to a higher toxicity to root metabolism, rather than a greater root uptake.

It was also determined that several factors probably contributed to the seedling receiving a greater exposure to methyl mercury via soil acidification, decreases in soil pH, an increase in humus layer depth, and microbial activity.

Some researchers have implemented mercury biomonitoring, using grass cultures (Temmerman et al., 1986). Grass cultures can provide a reliable indication of the average concentrations found in leafy vegetables. However, for washed leafy vegetables, the concentrations are usually lower than those found in grasses. Mercury accumulation in herbs, especially in perennials, is far higher than that in grasses and leafy vegetables. A clear relationship exists between the mercury concentrations found in herbs, and those in grass cultures. Thus, no such relationship was found in roots, tuber, bulbs (10 times less accumulation than in grass cultures), fruits or leguminous vegetables (Temmerman et al., 1986).

In the present study Hg contaminated soils and Tansy plants were investigated. The goal of this work was to define the correlation between heavy metal (mercury, lead, cadmium, chrome and nickel) concentration changes (in soil, leaf, stem, root and essential oil in Tansy), type and distance from source of pollution.

MATERIALS AND METHODS

Study area

Soils and *Tanacetum* vulgare plants on five different localities

(Chemical Industry Pančevo with accident situation, Pančevo industrial zone, highway, Ada Ciganlija Recreation Zone and Topčider Park) were analyzed.

Sample collection

The soils were sampled at 0-15 and 15-30 cm depths, respectively, and then transferred into well labeled polyethylene bags for storage and laboratory analyses. Tansy plants found growing on the refuse dump soils were uprooted, labeled and taken to the laboratory for the analysis of their partitioned parts (leaf, stem and root). For the Hg analysis, plant samples were collected at Chemical Industry Pančevo (with Hg accident) and compared with Hg noncontaminated sites (Pančevo industrial zone, High way, Ada Ciganlija park and Topčider Park, and under similar climatic conditions).

Soil preparation and physicochemical analyses

In the laboratory, the soils were dried at ambient temperature (25℃), crushed in a porcelain mortar and sieved through a 2 mm (10 meshes) stainless sieve. Air dried < 2 mm samples were stored in polyethylene bags for subsequent analysis. The < 2 mm fraction was used for the determination of selected soil physicochemical properties. Soil pH was measured using a pH meter (Thermo Orion 250, Orion Research, Inc., Boston, MA, USA) and H_2O according to Folson et al. (1981). The soil/solution ratio was 1:2.

Determination of total heavy metals

1 g of the soil samples was introduced into digesting tubes following the addition of 10 ml concentrated HNO_3. The samples were placed in the digestor for 8 h at 96℃ with intermittent stirring. Upon complete digestion, the samples were filtered into 100 ml volumetric flasks using Whatman no. 42 filter paper. The samples were made up to the 100 ml mark in the volumetric flask using distilled-deionised water. The concentrations of Hg, Pb, cadmium (Cd), chromium (Cr) and nickel (Ni) in the supernatant solutions were determined using atomic absorption spectrophotometer (AAS), Perkin Elmer (USA) model 403 with deuterium background correction.

Determination of heavy metals in the plant tissues

The plant tissue samples were dried in a force-air oven at 60℃, ground to 20 mesh using a stainless steel Wiley mill, and digested using concentrated nitric and perchloric acids. The samples were diluted to 25 ml, filtered through Whatman no. 42 filter paper. The supernatants were made up to 50 ml mark in the volumetric flask and then analyzed for Pb, Cd, Cr and Ni using atomic absorption spectrophotometer Perkin Elmer (USA) model 403.

Plants to be analyzed for total Hg were prepared in the following manner: Shoots and roots were washed in tap water and placed in a drying oven at 70℃ until a constant weight was obtained. Sub-samples (0.1 g) were accurately weighed into 50 ml plastic pots and digested with 15 ml of HNO_3. The plant samples were left overnight, and the following day were heated in a water bath at 80℃ for 1 h. Subsequently, the plant digests were transferred to 10 ml polythene tubes and diluted with reverse osmosis water to make a final volume of 10 ml.

Preparation of plant material

Plant material was milled in a domestic blender (Zepter MixSy, type VG-022-K) and, after sieving (laboratory Erweka sieves) a sample with a mean particle diameter size of 0.7 mm was obtained. A prepared batch was kept in a hermetically sealed bag and stored at 8℃ for 2 days before use, in order to avoid loss of volatile compounds.

Essential oil preparation

Herb material (20 g) was submitted to hydrodistillation in a Clevenger-type apparatus for 2 h according to Yugoslav Pharmacopoeia IV. The obtained oil was dried over anhydrous sodium sulphate, measured, poured in hermetically sealed dark-glass containers and stored in a freezer at - 4℃ until analyzed by atomic absorption spectrophotometer. Obtained oil was acidified with 1% (v/v) HNO_3 for analysis by flame AAS, Perkin/Elmer 4000.

RESULTS

Mercury distribution in the soils of the study locations

Eight tons of Hg was spilled in the surrounding area during the accident in the Chemical Industry Pančevo (Stević, 2000). Extremely high Hg concentrations were detected in the moment of accident situation, in the year 1999. Mercury concentration in the first 0-15 cm soil depth was 131 200 mg/kg, while in soil depth, 15 - 30 cm was 74 000 mg/kg. After three, six and nine years, linear accident Hg concentrations decreased from 85 400, via 41 060 to 106.0 mg/kg in soil depth of 0 - 15 cm. Also, similar Hg trends were noticed in soil depth from 15 - 30 cm (Table 1).

Comparison was made of the concentrations of Hg within the 5 different localities at the same year, 2008. The results thus show a typical distribution mercury, with Hg levels decreasing with distance from the Chemical Industry Pančevo *via* Pančevo industrial zone, highway, Ada Ciganlija to Topčider park (Figure 1, Table 2). Mercury is generally of low mobility because of its high density, which explains the high concentrations in the soil samples.

Mercury accumulation in plants and essential oils

Tansy plant did not survive the accident in the Chemical Industry Pančevo. Three and six years after the accident, Tansy plants could not grow on contaminated soil. Mercury concentration which results in the location where accident occured showed that 6 years was necessary for concentration to drop below the limits, and for revitalization of standard industrial Tansy vegetation.

After 9 years, mercury concentrations were also high in the Tansy plant in Pančevo, with values above 9.7 mg/kg in roots, 5.1 mg/kg in stem and 2.4 mg/kg in leaves, covering an extension of ~0.5 ha, in contrast with the concentration of Hg detected in a noncontaminated Topčider plant materials in the soils close to the study area (0.04 mg/kg in root, 0.02 mg/kg in stem and 0.01 mg/kg in leaves) (Table 3). Thus, Hg concentrations in

Table 1. Mercury content in the soil (0-15 cm depth and 15-30 cm depth; in mg/kg) from Chemical Industry Pančevo with accident situation, from 1999 to 2008 year.

Hg (mg/kg) treatment		1999	2002	2005	2008
Soil depth	0-15	131 200	85 400	41 060	106.0
	15-30	74 000	53 700	24 600	66.1
Plant	Leaves	NS	NV	NV	2.4
	Stem	NS	NV	NV	5.1
	Root	NS	NV	NV	9.7
Essential oil		-	-	-	0.1

NS, Plant did not survive Hg accident; NV, no vegetation.

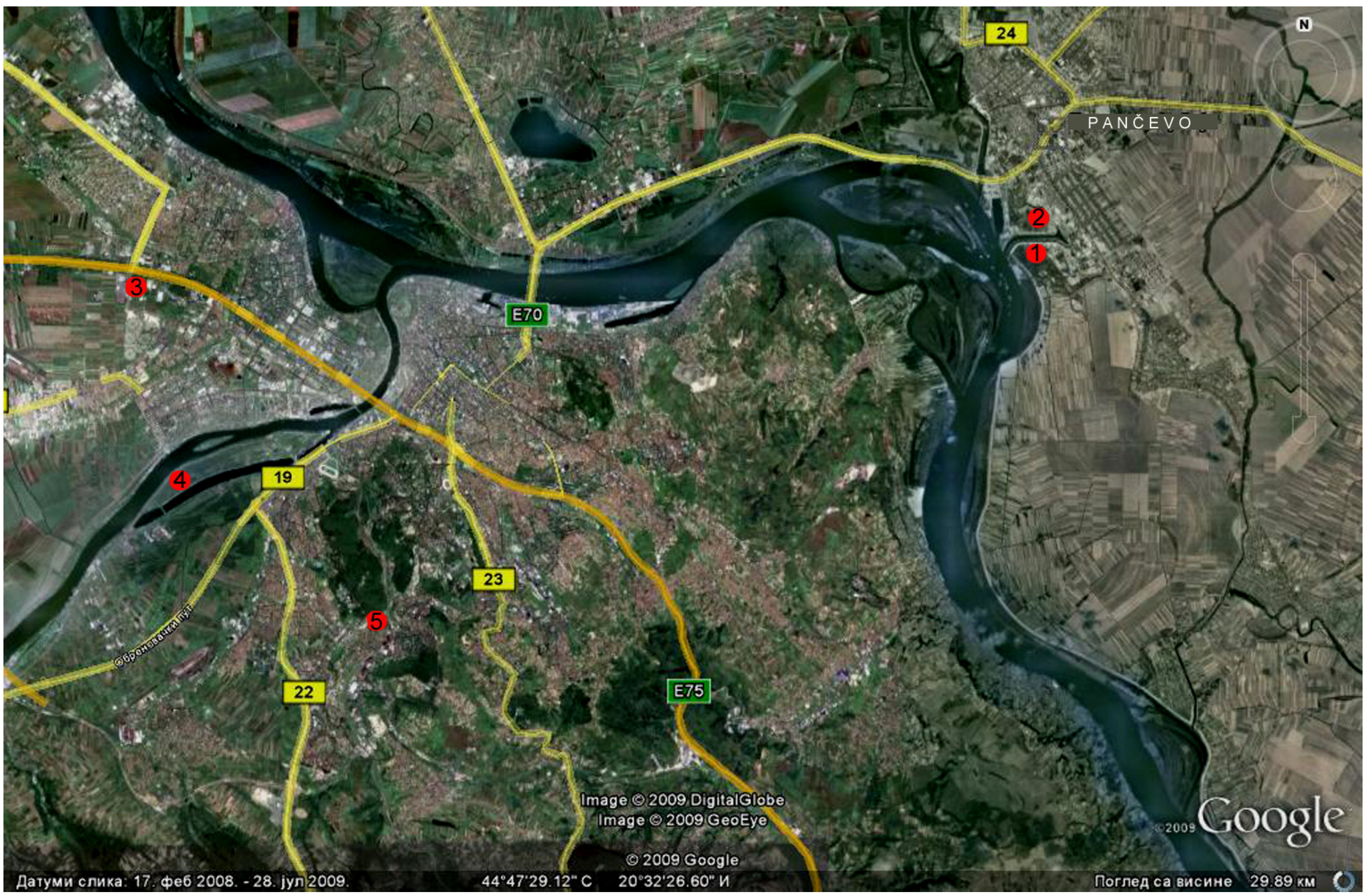

Figure 1. View of the study area (source: Google Earth). 1, Chemical Industry Pančevo (with accident situation); 2, Pančevo industrial zone; 3, highway; 4, Ada Ciganlija recreative zone; Topčider park.

plant tissue from contaminated site were 5, 10, 100 and 200 times greater than in the industrial zone, highway, Ada Ciganlija Recreative Zone and Topčider Park, respectively (Table 3).

On the other hand, the data obtained also indicated that the Hg concentration in Tansy roots, stems and leaves increased linearly as soil Hg concentration. Moreover, in each contaminated site, Hg concentration in roots, stems and leaves were consistently higher than those in the other plants studied, suggesting a higher capacity of the former species to accumulate Hg.

The results thus show a typical distribution and accumulation of Hg through plant vascular elements from roots to leaves. Essential oil concentrations of Hg was about 10 times higher in samples from Chemical Industry Pančevo (0.1 mg/kg) than in samples for Industrial Zone (0.01 mg/kg), while samples in other locations were not detected (Table 4).

Table 2. Heavy metals content in the soil samples (in mg/kg).

Heavy metal	Soil depth (cm)	Chemical Industry Pančevo	Pančevo industrial zone	Highway	Ada Cingalija Recreative Zone	Topčider Park
Hg	0-15	106.0	37.6	28.0	3.1	0.9
	15-30	66.1	21.1	17.0	2.0	0.7
Pb	0-15	19.0	14.0	125.0	9.0	6.0
	15-30	7.0	4.0	85.0	7.0	3.0
Cd	0-15	8.3	6.0	4.0	3.4	2.1
	15-30	4.6	3.0	1.5	1.2	0.5
Cr	0-15	15.4	13.0	11.0	7.0	4.6
	15-30	8.7	7.0	5.0	3.0	1.8
Ni	0-15	30.3	27.8	19.0	10.0	4.3
	15-30	16.0	15.0	9.4	5.5	2.0

Table 3. Heavy metals content (mg/kg) in different parts of Tansy plants.

Plant location	Tissue	Hg	Pb	Cd	Cr	Ni
Chemical Industry Pančevo	Leaf	2.4	3.3	1.3	0.8	1.9
	Stem	5.1	1.6	0.6	1.2	2.3
	Root	9.7	2.1	0.8	1.6	2.9
Pančevo industrial zone	Leaf	0.6	2.0	1.0	0.8	1.7
	Stem	1.1	0.6	0.5	1.1	2.1
	Root	1.8	1.1	0.7	1.4	2.6
Highway	Leaf	0.2	14.1	0.7	0.5	1.2
	Stem	0.5	8.3	0.2	0.8	1.5
	Root	1.0	9.5	0.4	1.0	1.8
Ada Cingalija recreative zone	Leaf	0.02	1.8	0.5	0.2	0.6
	Stem	0.5	0.6	0.1	0.4	0.9
	Root	1.0	1.0	0.3	0.6	1.1
Topčider Park	Leaf	0.01	0.7	0.3	0.1	0.05
	Stem	0.02	0.2	0.08	0.2	0.1
	Root	0.04	0.4	0.2	0.4	0.3

Lead distribution in the soils of the study locations

The concentration of Pb in surface soil samples decreased from 125 mg/kg (5 m distance of the High way), through 19 mg/kg (Chemical Industry Pančevo), 14 mg/kg (industrial zone), 9 mg/kg (Ada Ciganlija) to 6.0 mg/kg (Topčider) (Table 2). Also, Pb concentration in soil and plant was decreased with square of highway distance (5, 10, 20 and 25 m) (Figure 2). Regular Pb amount according to World Health Organisation (WHO) was on 20 m distance of the highway in soil depth of 0 - 15 cm (Figure 2). Lead concentration was the highest in the soil near the highway, due to a traffic density on the investigated road.

Lead accumulation in plants and essential oils

The highest Pb level was detected in plants harvested near the highway (14.1 mg/kg in leaves, 8.3 mg/kg in stems and 9.5 mg/kg in roots), while the lower concentrations were in plants from the Topčider park (0.7, 0.2 and 0.4 mg/kg) (Table 3).

Essential oil of the Tansy plants grown near the highway had the highest Pb level (0.7 mg/kg), while the oils orginating from the Ada Ciganlija and the Topčider plants consist of 0.01 mg/kg of Pb (Table 4).

The amounts of Pb determined in essential oils at the highway contamined site were 2 to 3 times more than the industrial zone and the Chemical Industry Pančevo. Also,

Table 4. Heavy metals solubility (%) in sage leaf essential oil.

Heavy metal	Essential oil				
	Chemical Industry Pančevo	Pančevo Industrial Zone	High Way	Ada Cingalija Recreative Zone	Topčider Park
Hg	0.1	0.01	ND	ND	ND
Pb	0.3	0.2	0.7	0.01	0.01
Cd	0.08	0.14	0.06	0.02	0.01
Cr	0.10	0.09	0.05	0.03	ND
Ni	0.70	0.60	0.30	0.1	ND

ND = Not detected.

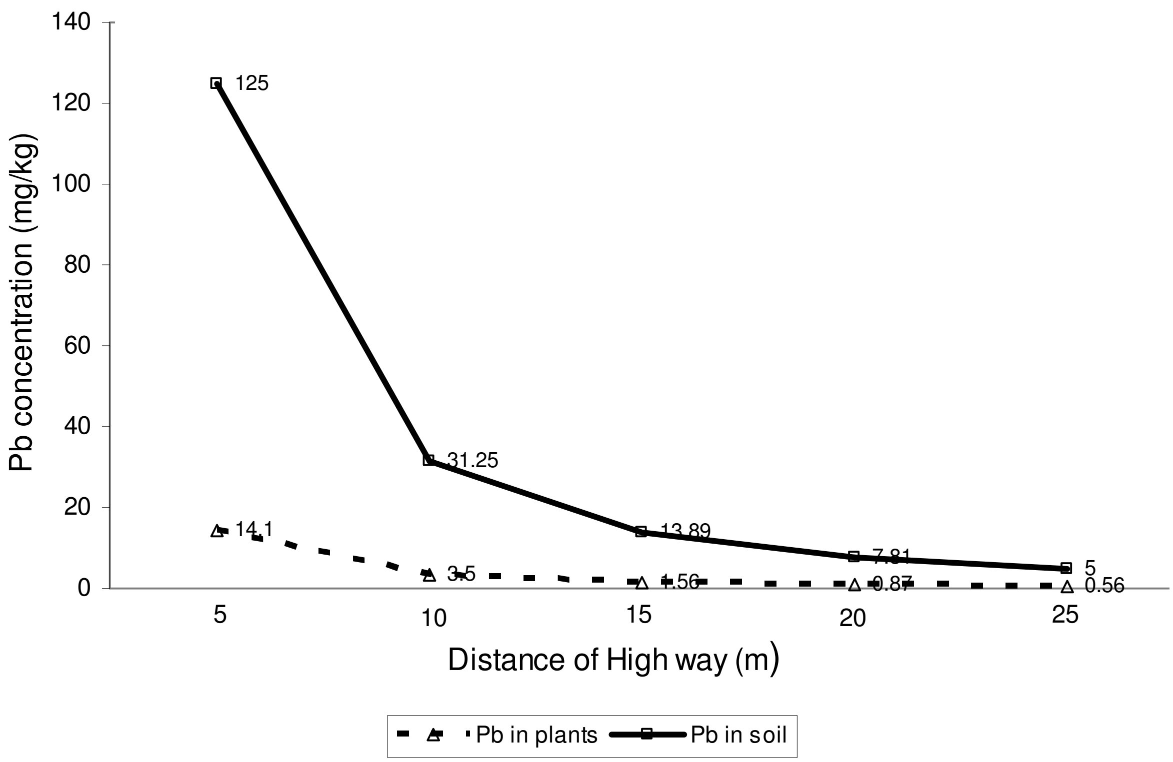

Figure 2. Concentration of Pb near the highway.

Pb level detected in essential oil from highway was 70 times higher than in oils from the Ada Ciganlija and the Topčider site locations (Table 4).

Cadmium distribution in the soils of the study locations

Cadmium was detected in soil, Tansy plant materials and essential oils of all investigated site locations. Soil samples from the Chemical Industry Pančevo (8.3 and 4.6 mg/kg) and Industrial Zone had the highest level of Cd (6.0 and 3.0 mg/kg) than the other localities. In contrast, the Topčider soil samples had the lowest Cd amount (2.1 and 0.5 mg/kg) (Table 2).

Cadmium accumulation in plants and essential oils

Analysed plants from the Chemical Industry Pančevo consist of the highest Cd concentration (1.3 mg/kg in leaves, 0.6 mg/kg in stems and 0.8 mg/kg in roots) (Table 3). Also, Cd amount in plants from the Chemical Industry Pančevo was a little higher than in plants from the Pančevo industrial zone (1.0 mg/kg in leaves, 0.5 mg/kg in stems and 0.7 mg/kg in roots), and about two times higher than in plants from the highway. Tansy plants from the Ada Ciganlija and the Topčider Park had 2 to 4 times lower Pb concentration than plants from the Chemical Industry Pančevo (Table 3).

Cadmium, as well as lead distribution in Tansy decreased in the order: leaves > roots > stems (Table 3). The same

Cd trends persisted in essential oils (Table 4). However, Cd and Pb were only found in essential oil from Topčider Park in low concentration of 0.01 mg/kg, while the other heavy metals were not detected.

Chrome distribution in the soils of the study locations

Chrome in soil samples from the Chemical Industry Pančevo and the Pančevo industrial zone showed similar values (15.4 and 13.0 mg/kg in soil dept of 0 - 15 cm, and 8.7 and 7.0 mg/kg in soil depth of 15 - 30 cm, respectively). Nevertheless, the amount of Cr in the soil samples from the Topčider park was signifficantly lower (4.6 and 1.8 mg/kg) (Table 2).

Chrome accumulation in plants and essential oils

Accumulated Cr in Tansy plants was the greatest in the samples orginating from both localities in the Pančevo, while the samples from the Topčider Park was the lowest (Table 3). Moreover, Cr amount in essential oils from the Chemical Industry Pančevo and Pančevo industrial zone was two times greater than samples from the highway, and three times more than Ada Ciganlija samples (Table 4). However, chrome in essential oils from the Topčider Park could not be detected (Table 4).

Nickel distribution in the soils of the study locations

Chemical Industry Pančevo and industrial zone soil samples had significant higher concentration of Ni (30.3, 16.0 and 27.8 and 15.0 mg/kg, respectively) than all other locations (Table 2). The amount of nickel in the soil from the Topčider Park was about 7 - 8 times lower than samples from the Chemical Industry Pančevo.

Nickel accumulation in plants and essential oils

Amount of nickel in plants (Table 3) and essential oils (Table 4) had similar trend as well as in soils samples (Table 2). Nickel concentration was similar in plant and essential oil samples from the Chemical Industry Pančevo and the Pančevo industrial zone (Tables 3 and 4). However, the essential oil of Tansy from Ada Ciganlija consists of Ni about 7 times lower than samples from the Chemical Industry Pančevo (Table 4).

Nickel as well as Hg, and Cr was not detected in the essential oil of Topčider Tansy plants (Table 4).

DISCUSSION

The concentration of heavy metals in soils, plants, as well as essential oils of the *T. vulgare* growth on 5 different localities was investigated in this paper. The heavy metal content depends mainly on type of plant, environment in which plant is grown, the level of industrial development of the region, air pollution, soil and climatic conditions, etc (Zenk, 1996). The results show that measured values on the locations like park and recreative zone are in the regular limits according to the criteria of WHO. Distribution of the heavy metals among plant organs was selective and dependent on the part of the plant, surface characteristics of the plant organ, and the element that was examined. Due to this, in this study, the root, stem and leaves were investigated.

From the results in Tables 2, 3 and 4, it can be concluded that the examined soil, Tansy plants and essential oils from different localities had different heavy metal concentrations.

Moreover, in Pančevo contaminated site, Hg concentrations in roots were consistently higher than those in the other part of the plants' localities, suggesting a higher capacity of the root to accumulate Hg. Thus, Hg concentration in the root, steam and leaves from the Pančevo contaminated site were up to 200 times more than those in plants at the Topčider uncontaminated site. Our results on Hg content are in agreement with that of Fernández-Martínez et al. (2005) Schlüter (1993), Andersson (1979) and Yin et al. (1996).

A high concentration of Pb (125 mg/kg) in the soil along the highway was much higher (about 20 times) than the Topčider Park (6 mg/kg). The results on high concentration of Pb in soil and plants are mainly attributed to motor-vehicle exhausts; this was also shown by Oviasogie et al. (2009).

The results show that Pb concentration in soil and plant samples was decreased with square of highway distance and this correlate with the results of Oviasogie et al. (2009). Also, similar result on higher concentration of Pb (196 mg kg^{-1}) along the roadside of Amman City (more than 19 mg kg^{-1}) recorded in the uncontaminated area was reported by Al-Alawi and Mandiwana (2007). Moreover, Al-Khlaifat and Al-Khashmanb (2007) reported that the Pb levels were the highest (177 mg kg^{-1}) at highway sites, which have higher traffic density than background site (41 mg kg^{-1}) of Aqaba City in Jordan. Also, Kabata-Pendias and Pendias (1989) found lead on the surface parts of the grass on unpolluted soil in concentrations of 0.19-9 mg/kg dry matter, while the content of lead in contaminated soil amounted to 63 - 232 mg/kg. The same authors have stated that the natural concentration of lead in plants ranges from 5 - 10 mg/kg. According to some researches, normal lead concentration in white clover (*Trifolium repens*), which was taken as the standard, is 0.15 ppm (Backet and Davis, 1988).

On the other hand, high levels of Pb in Tansy as well as in thyme (Macrae et al., 1993) and *Zea mays* (Oviasogie et al., 2009) could be hazardous to human health. Concentration of Pb in Tansy essential oil from Ada

Ciganlija (0.01 mg/kg) and Topčider Park (not detected) had normal values; in relation, the maximum permissible concentrations of Pb in the plant of essential oil are 0.10 mg/kg.

Results showed that Tansy roots consist of lower Cd amounts than in leaves. Also, according to Angelova et al. (2005) deposition of Cd in the leaf is higher than that in the root. Pb and Cd distribution in Tansy decreased in the order: leaves > roots > stems noticed in *Salvia officinalis* (Blagojević et al., 2009).

Only essential Tansy oils from Ada Ciganlija (0.02 mg/kg) and Topčider Park (0.01 mg/kg) showed permissible concentrations of Cd (maximum in the essential oil are 0.05 mg/kg, respectively).

Roots of Tansy plants from Topčider Park consist of similar values of Cr as well as *Zea mays* and *Sorgum vulgare* plants. These results are in agreement with results of Oviasogie et al. (2009).

Ni content in leaves and Tansy essential oils (except for Topčider park) was much higher than permissible concentrations. Also, levels of Ni in all specimens of thyme in Jordan (Abu-Darwish and Abu-Dieyeh, 2009) indicated higher concentrations than the average (0.1 – 0.5 mg kg^{-1}) as reported by Kastori et al. (1997) for the same plant. This higher concentration of Ni may be due to the vicinity of road and the intensity of plant, which is progressively increased with locations full of vehicles and industrial activities in Amman or neighboring southern locations with cement factories in their surroundings (Jaradat et al., 1999).

The present results on Ni and Pb contents in soil and plants are in correlation with result of Loranger and Zayed (1994). These authors reported that Ni is higher in industrial and residential areas, which may be due to their use as fuel additives, just like Pb.

The largest Hg level was in soil samples from the Chemical Industry Pančevo with accident situation, while the largest Pb level was in soil samples from highway (Table 2).

Also, concentration of Hg, Pb, Cd, Cr and Ni were higher in soil samples on 0 - 15 cm depth than on 15 - 30 cm, on all localities. These results are in agreement with results of Oviasogie et al. (2009).

Soil, plant and essential oil samples from the Topčider Park, as well as green area in Belgrade, consist of the lowest concentration of the investigated heavy metals. Cleansing the soil of heavy metals via conventional methodologies is expensive and in most cases not feasible

Conclusion

Heavy metals are present in the soil and Tansy medicinal plant at different concentrations, which, in some cases, exceed the permissible levels. This could be attributed to contamination from traffic and industrial activities.

Moreover, high concentration of heavy metals in Tansy in Serbia is caused by old technology equipment and bad quality of gasoline. *T. vulgare* grown in Serbia had high concentration of Pb element, which may have a great health hazard. In general, the concentration of heavy metals is closely related to the source and distance of pollutant.

The obtained results show that *T. vulgare* is subject to contamination of the environment by heavy metals, but not as expected (due to the vicinity of high way and trash dump) in the investigated area and declining consumption of Pb-based gasoline in this region.

Due to the lack of regulations on acceptable content of heavy metals in medicinal and aromatic herbs extracts, the maximum allowable and safe concentration of each metal is urgently needed. Further studies of heavy metals contents in medical and agricultural plants grown in Serbia environment are recommended.

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