The Eurasia Proceedings of Health, Environment and Life Sciences (EPHELS)
ISSN: 2791-8033

The Eurasia Proceedings of Health, Environment and Life Sciences (EPHELS), 2022

Volume 5, Pages 56-61

ICMeHeLS 2022: International Conference on Medical, Health and Life Sciences

Research of Transport Effects of Heavy Metals in Plants of *Opuntia Vulgaris* Mill and *Rosmarinus Officinalis* L., Grown in the Technogenic Contaminated Soils

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Abstract: In this work, it was carried out the study of transport effect of a number of heavy metals from technogenic contaminated soil to the plants of *Opuntia Vulgaris* Mill and *Rosmarinus officinalis* L. For the conducting research it was selected two sites for each plant from the technogenic contaminated zone in the village of Gala, Absheron Peninsula of Azerbaijan. It was used transportable roentgen-*fluorescence* XRF spectrometer X Omega Roentgen Pluorescence Spectrometer of Innov–X for the measurement of plants of heavy metals in contaminated soil and plants. Seedlings of these plants were moved from ecologically clean areas to contaminated areas. Before planting, the concentration of a number of heavy metals was measured in the soil at depths of (0-5); (10-15); (15-20) cm. Measurement of concentration of heavy metals in the samples were carried out after 6 month of planting. It was revealed that, there is "Transport effect" of a number of heavy metals from technogenic contaminated soil to the above-mentioned plants. The results of experiment are expressed in the following figures (the concentration of specified heavy metals in soil corresponds to the depth of (0-5) cm). For *Opuntia Vulgaris* Mill – Cd (2,27-1,86): Pb (9,58-5,59); Zn (60,28-46,40); Ni (31,76-22,32); Co (4,60-2,46); Mn (39,76-16,57). For *Rosmarinus officinalis* L. – CD (2,36-0,92); Pb (9,31-3,38); Zn (58,17-39,90); Ni (29,61-12,75); Co (4,71-1,64); Mn (37,15-16,57) (unit of measuring concentration - mg/kg; in the brackets, in the first place there is concentration in soil, in the second place there is transported concentration in plants taking into account background measurement before planting).

Keywords: *Opuntia Vulgaris* Mill, *Rosmarinus officinalis* L., Heavy metals, Transport effect

Introduction

Phytoremediation is a new technology that uses plants and their associated rhizosphere microorganisms to remove contaminants from technogenic contaminated soils. In recent years this technology has been recognized as a cheap, effective and economically clean technology. But here we must note that, the effectiveness of this technology depends on many factors, for example properties of different soils and plants, physical and chemical processes occurring in soil, microbial properties and bioavailability of metals, the ability of different plant adsorption, accumulate and neutralize metals in technogenic contaminated soils. Despite some advantages, phytoremediation has not yet become commercially available technology. Progress in this area is hampered by lack of understanding of complex interactions in the rhizosphere of plants and mechanism that enable translocation of metals and their accumulation in plants. For further increase of effectiveness of phytoremediation, there is a necessity to improve the knowledge about the processes, such as the presence of pollution, especially rhizosphere layer, absorption of contaminants, translocation, poisoning, degradation and evaporation (Vinita 2007; Pilon-Smits; 2005, & Elizabeth et al., 2006). On the other hand, many research shows that a number of plants have the genetic potential to remove many toxic metals from soil (Lasat, 2002). In (Sawatsky, 1997), it has been studied the movement of water that plays a main role in phytoremediation processes in petroleum contaminated soils. It has been clear from the research that, there is critical soil moisture

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

about 20%, but when this indicator is higher than this value sorption processes in oil-polluted soil approaches to similar processes in purified soil. It has been established by researches that there is a critical soil moisture around 20% s, under this value sorption processes in oil-polluted soil approaches to similar processes in the treated soil.

In Pena-Castro et al. (2006), it has been indicated that the presence of petroleum contaminants in soils is a disadvantage for the growth of plants. Here, the main thing is that in these conditions the plant is growing under the stress of inserted organic contaminants. However, there is not much information about the molecular mechanisms underlying at the basis of adaptation to this stress. In this paper we studied the plants, Cynodon Dactylon grown under oil stress. Here, toxic concentration of oil was (5,5 ± 1,1) %.

In Macek et al. (2000), it is discussed the possibility of injection of alien genes into plant genes that can increase the speed of the bioremediation process. Thus it has been studied various aspects of metabolism in plant cells, the role of enzymes involved in the process and interaction with rhizosphere microorganisms, accelerating recovery processes. In (Duruibe et al., 2007), it was studied emerging risks of heavy metals for human health within bio toxic effects. Caney et al. (2005) indicated that subsistence farmers eating rice grain grown on contaminated sites throughout their lifetime are at risk from dietary exposure to cadmium. With greater awareness by the governments and the public of the implications of degraded environment on human and animal health, there has been increasing interest amongst the scientific community in the development of technologies to remediate contaminated sites.

Maize is grown in all parts of the country, though it is grown slightly more in the savannah belt of the country. About 50 species exist and consist of different colors, textures and grain shapes and sizes. White, yellow and red are the most common types. Maize is capable of continuous phytoextraction of metals from contaminated soils by translocating them from roots to shoots (Nascimento et al., 2006). The maize plant has been even shown to accumulate certain heavy metals such as Cd (Kimenyu et al., 2009) and Pb (Pereira et al., 2007) above levels that define metal hyper accumulation. Based on its capability of heavy metal uptake and sensitivity to high metal pollution, Máthé-Gáspár and Anton (Mathe-Gaspar et al., 2005) have grouped maize as an accumulator and a metal tolerant plant especially for Cd and Zn.

On the other hand, in the frame of use in phytoremediation technology of cacti has been attracted much attention as a biological indicator of the environment. The most basic kind of family of cacti is Opuntia due to the fact that this plant has no system leaves, it evaporates very small amount of water and this ability allows it to survive in very rigorous environments. The unique properties of the plant of Opuntia are that it can collect in their internal organs of water from the environment and this property allows it to act as a biological indicator which determines the degree of deviation from the ecological balance of the environment. With this plant we can determine the degree of purification from contaminants of soil, water and air. At the same time the plant of Opuntia has the property of absorbing and neutralizing contaminants (Barrera et al., 2009; Milner, 2004).

There is also particular interest to the plant of *Rosmarinus officinalis* L. for using it in phytoremediation processes. This plant in the natural form is common in Mediterranean countries. There is a bushy evergreen plant with a typical height of 1.5-2 meters. Rosemary is very resistant to drought and salinization of soil. It doesn't withstand low temperatures and frost very much. It doesn't like strong moisture. When cutting branches it acquires the desired shape and retains this form for a long time. Rosemary is rich with essential oils and used in perfumery in producing bakery products. Simultaneously Rosemary is used for strengthening the soil surface and in greenery planting. It is widely used in parks and boulevards of the Absheron Peninsula. (*Rosemary* et al., 2014; *Oregano*, rosemary extracts promise omega-3 preservation, 2007; Barbut et al., 1985).

Method

For conducting study, it was selected technogenic contaminated zone in the village of Gala, Absheron Peninsula of Azerbaijan. For planting seedlings of *Rosmarinus officinalis* L in this area, it has been selected separate part in size of 10 m × 10 m; as well planting chilik. A separate section in the same size was also selected for *Opuntia Vulgaris* Mill (section №2). The distance between sites was equal to 25-30 meters. Certain parts of our view will allow investigating the effect of transport of heavy metals from technogenic contaminated soil to both plants in more optimal way. On the other hand, in comparison with the size of selected technogenic contaminated area, both sites were selected as close as possible to each other, in order both parts of the soil climatic conditions to be practically the same. It should be noted that, dry climate of moderately warm temperate semi-desert and dry steppe is characterized for the Absheron Peninsula. The total solar radiation is 130-135 kcal

/ cm2 per year. The main part of the total radiation (86-90 kcal / cm2) is applied during the warm half of the year. The average annual temperature is 13,5-13,7 ˚C.

A characteristic feature of the selected area (village Gala, Absheron Peninsula) is that, except technologically-anthropogenic effects on soil, there is contaminated sediments of oilfield wastewater and weak oil pollution. Some characteristics of the soil of the zone are shown in Table 1.

Table 1. Some indicators of contaminated soils

The depth taken from the soil sample (cm)	Hygroscopic moisture (%)	pH	CO_2 (%)
0-10	2,85	7,9	10,13
10-31	3,78	8,6	9,56
31-51	3,6	8,7	8,54
51-88	3,75	8,6	7,92
88-150	4,01	8,5	7,97

It was seen from table 1 that, the characteristic feature of oil-contaminated soils is also a high pH in the upper soil horizons 8,8-9,4). These high indicators of pH in contaminated sections are not reduced in entire soil profile. Such strong basic conditions are explained by the presence of oil and alkalinity of drilling water, impregnating the whole soil profile. Acidity of pure soil varies within 7,9-8,2.

It is pertinent to note that the mobility of heavy metals in soil and their flow into the plant is very variable and depends on many factors: the type of plant, soil and climatic conditions. The concentration of heavy metals in plants depends on the age of the plants and strongly varies in different organs.

Soil shows its buffering properties, by transferring the water-soluble metal compounds to sparingly soluble form and sparingly soluble to more mobile, e.i. traced convergence of included compounds of elements and their conversion to compounds, characteristic of soil of particular composition and properties. However, the buffering capacity of the soil is not unlimited, and the amount of those compounds in which they enter the soil and then into plants is gradually increased with increasing exogenous concentrations of metal.

In the specific soil and climatic conditions of the region and the presence of certain type of vegetation of availability of heavy metals is determined by the properties of soil, a change that can significantly affect the accumulation of heavy metals in plant products. Heavy metals are the most mobile in the humus-poor acid soils of light granulometric composition with a low capacity of cation exchange and low buffer.

For the measurement of concentration of heavy metals in soil of both sites, locations of two sections were randomly selected (four sections in total). Sections were made up to a depth of 20 cm. With the help of transportable roentgen-*fluorescence* XRF spectrometer the concentration of heavy metals was measured in the vertical direction of three points: at a depth of 0-5sm; 10-15 cm; 15-20cm. The results of measurement are shown in Table 2 (the data are averaged over two sections of each site).

Table 2. The concentration of heavy metals in soil

Sections / Heavy Metals	Concentration (mg/kg)					
	Section № 1 Depth (cm)			Section № 2 Depth (cm)		
	(0-5)	(10-15)	(15-20)	(0-5)	(10-15)	(15-20)
Cd	2,27	1,35	1,12	2,36	1,22	0,97
Pb	9,58	8,12	7,61	9,31	8,07	8,11
Zn	60,28	52,26	50,05	58,17	51,17	49,11
Ni	31,76	28,63	27,54	29,61	28,62	28,08
Co	4,60	5,42	5,53	4,71	5,46	5,62
Mn	39,76	43,65	45,84	37,15	42,37	46,57

* It should be noted that, Cd- includes in I risk group; Pb- includes in II risk group; Zn and Ni include in III risk group; Co and Mn include in the groups of less danger.

10 seeding of *Rosmarinus officinalis* L. and 10 Chilik of *Opuntia Vulgaris* Mill was transferred from ecologically clean areas to these contaminated sites and was planted. The concentration of heavy metals was measured with the help of roentgen-fluorescent spectrometer of XRF samples of plants (plantlets and chilik) before planting them in contaminated areas. Results of control measurements are given in Table 3. Observation

of the plants lasted for 6 months. During this period, the survival of plants was analyzed in technogenic contaminated sites. From planted Chilik of *Opuntia Vulgaris* Mill plant survived only 6 plants (60% survival), but from planted seedlings of the *Rosmarinus officinalis* L. plant survived only 4 (40% survival). This fact demonstrates the relative stability of the *Opuntia Vulgaris* Mill plant to technogenic contaminants in relation to *Rosmarinus officinalis* L. Exactly 6 months after planting, it was measured the concentration of heavy metals of surviving samples of these plants. For this purpose, three samples were taken from 6 surviving *Opuntia Vulgaris* Mill and 3 samples from 4 survivors *Rosmarinus officinalis* L. and the results of measurement of the concentrations of heavy metals were averaged over three samples for each plant. Technology of manufacturing plant samples was as follows: plants were separated neat way from soils with root systems, then the root systems of plants have been thoroughly washed and dried. Then the plants with their roots were grinded and transferred to a separate vessel until homogenous properties (see. Table 3).

Table 3. The concentration of heavy metals in plant samples (mg / kg)

Heavy Metals / Plants	The concentration of heavy metals in plant samples (mg / kg)													
	Cd		Pb			Zn			Ni		Co		Mn	
	1		1				2		2				1	2
Opuntia Vulgaris Mill	< LOD	,86	< LOD	,69	,21	0,61	5 ,37	8,69	2 ,28	,74	,33	9	7,65	2
Rosmarinus officinalis L.	< LOD	,92	< LOD	,38	,36	3,26	4 ,11	7,86	1 ,19	,83	,64	7	4,21	2

Note: 1- control measurement; 2-measurement in the samples, after 6 months

Results and Discussion

Observation of planted plants in the technogenic contaminated sites has shown that "survival effect" (resistance to technogenic contaminants in *Opuntia Vulgaris* Mill plants in relation to the *Rosmarinus officinalis* L. plant) is more than 1.5 times. This is explained by the fact that the plant has a catchment Opuntia property and very resistant to aridity, high temperature and salinity. This is explained by the fact that the plant of Opuntia has a catchment property and it is very resistant to aridity, high temperature and salinity.

The concentration and distribution of selected heavy metals at depth is almost the same for two contaminated sites. This fact is explained by that in order to achieve identity of external influencing factors, two contaminated sites were chosen optimally close to each other (the distance between the two sites is equal to 25-30 m). The optimal distance between two technologically contaminated sites is conditioned by the fact that it is possible to trace the effect of transport of heavy metals from contaminated soil to both plants independently.

As seen from Table 2 the concentration of Cd, Pb, Zn, Ni, Co changed in the direction of decreasing from top to bottom along the vertical direction. Only Mn concentration increased with the increase of depth. Comparative analysis of table 2 and 3 has showed that the effect of transport of Cd which includes in I risk group for *Opuntia Vulgaris* Mill plant was 81, 94%. The effect of transport of heavy metal to the plant is calculated by the following formula:

$$EFTR = \left[\frac{C_{cd}^{Op} - C_{cd}^{(Op)}}{C_{cd}^{(1)}} \right] * 100\% (1)$$

Where EF_{TR} - effect of transport of heavy metals from contaminated soil to the plant measured in percentages;

$C_{cd}^{(1)}$ - Cd concentration in the contaminated soil measured in units of mg / kg at depth of (0-5 cm).

$C_{cd}^{(op)}$- The concentration of Cd in samples of plants of *Opuntia Vulgaris* Mill after 6 months of planting;

$C_{o,cd}^{(op)}$ – The concentration of Cd in samples of plants of *Opuntia Vulgaris* Mill before planting the plants (control measurement)

"The effect of transport" for other heavy metals from contaminated soil to both plants has been calculated using the same formula (1). The results of calculations of «the effect of transport» of heavy metal are demonstrated in Table 4.

Table 4. The effect of transport of heavy metals from contaminated soil to plants calculated in percentages (%)

«Effect of transport» / Plant	"The effect of transport" of heavy metals from contaminated soil to plants calculated in percentages (%)					
	Cd	Pb	Zn	Ni	Co	Mn
Opuntia Vulgaris Mill	81,94	58,35	76,97	70,27	53,48	41,68
Rosmarinus officinalis L.	38,98	36,31	68,59	43,06	34,82	44,57

Conclusion

As it is shown in Table 4, "effect of transport" of these heavy metals from technogenic contaminated soil to the plants is expressed more clearly for *Opuntia Vulgaris* Mill than *Rosmarinus officinalis* L. If averaging “effect of transport” for these heavy metals in both plants, it will turn out that observed “effect” is stronger 1,44 times in the plants of *Opuntia Vulgaris* Mill than in the plants of *Rosmarinus officinalis* L. This fact is explained by the physiological characteristics of the plant of Opuntia. In this work it was studied the effect of a number of transport of heavy metals from technogenic contaminated soils to plants of *Opuntia Vulgaris* Mill and *Rosmarinus officinalis* L.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPHELS journal belongs to the author.

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Medical, Health and Life Sciences (www.icmehels.net) held in Baku/Azerbaijan on July 01-04, 2022.

* This work was supported by the Science Devolopment Foundation under the President of the Republic of Azerbaijan – Grant № EIF-2013-9(15)-46/33/3

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To cite this article:

Zamanova, A. (2022). Research of transport effects of heavy metals in plants of *opuntia vulgaris* mill and *rosmarinus officinalis* l., grown in the technogenic contaminated soils. *The Eurasia Proceedings of Health, Environment and Life Sciences (EPHELS), 5,* 56-61.