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ASSESSMENT USABILITY OF JERUSALEM ARTICHOKE (*Helianthus tuberosus* L.) FOR PHYTOREMEDIATION OF SOIL CONTAMINATED WITH PESTICIDES

OCENA PRZYDATNOŚCI TOPINAMBURU (*Helianthus tuberosus* L.) DO FITOREMEDIACJI GLEBY ZANIECZYSZCZONEJ PESTYCYDAMI

Abstract: The aim of present research was to assess the usefulness of Jerusalem artichoke (*Helianthus tuberosus* L.) to phytoremediation of sorption substrate contaminated with pesticides. Studies upon purification of sorption substrate consisting of a soil and dairy sewage sludge were conducted under pot experiment conditions. The study design included control pot along with 3 other ones polluted with pesticides. The vegetation season has lasted since spring till late autumn 2007. After plants acclimatization, the mixture of chloro- and phosphoorganic pesticides was added into 3 experimental pots in the continuous intervals. After harvest the samples of substrate and plant material, both tops and roots, were taken. It was found that pesticide contents in sorption subsoil (from 0.10313 to 0.38909 mg $\cdot$ kg^{-1} d.m.) were much higher than in control soil (from 0.01781 to 0.22702 mg $\cdot$ kg^{-1} d.m.). Achieved results allow initially certify that Jerusalem artichoke can be used for reclamation of soils contaminated with pesticides, particularly for vitality prolongation of sorption barrier around the graveyard area. In future, it would allow for applying the sorption screen around pesticide graveyard, which reduces pesticide migration into the environment, and grown energetic plants – through phytoremediation – would prolong the sorbent vitality and remove pesticides from aboveground parts by means of combustion.

Keywords: phytoremediation, Jerusalem artichoke (*Helianthus tuberosus* L.), sorption, pesticide, graveyard

Waste dumps with outdated and useless plant protection means are the most serious threat for natural environment, the use of agrichemicals could cause in Poland. In the case of corrosion and damage of pesticide graveyard site construction, a continuous supply of contaminants to open waters occurs and will occur for many years [1–3]. Therefore, there is a need to search for methods to reduce pesticide migration to the environment and incorporate new concepts. Thus it is purposeful to perform studies upon the application of sorption process on selected natural and waste materials as the

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shield for penetration of pesticides and metals (as pesticide constituents) into the environment, and to reduce their migration from other pesticide graveyard sites and stores [4, 5]. Phytoremediation on energetic plants was additional element that should limit the contaminants migration. The success of phytoremediation depends mainly on the properly selected plant species [6, 7]. Desirable features making possible to apply a given plant are: fast growth, producing large amounts of biomass in short time, developed root system, high tolerance to pollution, great ability to accumulate toxins in aboveground parts, resistance to diseases, pests, and weather conditions. All above requirements are met by energetic plants, the representative of which is Jerusalem artichoke (*Helianthus tuberosus* L.). This species does not require special soil conditions, thus its cultivation may be performed on chemically contaminated areas where production of consumption plants is not necessary. Jerusalem artichoke is utilized for energetic purposes as the fuel, for chipboards and compost production.

Present study was aimed at evaluating the usefulness of Jerusalem artichoke to phytoremediation of sorption subsoil (consisting of the soil and stabilized dairy sludge) contaminated with pesticides. In future, it would allow for applying the sorption screen around pesticide graveyard area, which reduces pesticide migration into the environment, and grown energetic plants – through phytoremediation – would prolong the sorbent vitality and remove pesticides accumulated in aboveground parts by means of combustion.

Material and methods

Investigations upon phytoremediation of sorption material were conducted under pot experiment conditions. The experimental design included 4 objects: control pot and 3 other pots containing soil amended with pesticides. The initial studies confirmed [4] the usefulness of soil mixture collected from pesticide graveyard area and stabilized dairy sewage sludge [8] to make a sorption shield around that site. Jerusalem artichoke was grown in 4 pots of 0.3 m^2 area and 90 dm^3 capacity filled with above mixtures (Fig. 1).

Fig. 1. Jerusalem artichoke (*Helianthus tuberosus* L.)

Sorption substrate consisting of a soil and dairy sewage sludge which characteristic is presented in Table 1.

Table 1

The characteristic of sewage sludge

Substance	$[g \cdot kg^{-1}$ d.m.]						
	[%]	Ca	Mg	total N		total P	
Manurial element		21.9	13.1	39.2		31.4	
Organic matter	66.5						
Heavy metal	$[mg \cdot kg^{-1}$ d.m.]						
	Pb	Cu	Cd	Cr	Ni	Zn	Hg
Content in sludge	3.3	24.3	0.15	10.9	3.8	137	0.12
Permisssible standard	500	800	10	500	100	2500	5

The vegetation period has lasted since spring till late autumn 2007. After acclimatization of plants, mixtures of chemically pure chloro- and phosphoorganic pesticides (aldrine, chloropropham, HCH, DDE, DDT, DDD, metoxychlor) were continuously added (which imitated surface supply) onto 3 experimental plots. During the whole experimental period, 5 mg of each active substance per pot was administered. After harvest, samples of soil, above- and underground parts of plants were collected. Pesticide concentrations were determined in collected samples in accordance to obligatory methodology using gas chromatograph coupled with mass spectrometer (GC/MS/MS 4000) as well as gas chromatograph AGILENT6890 equipped with ECD1 and NPD2 columns. Moreover, after sample digestion according to EPA 3015 procedure using microwave digester Mars 5, also metals concentrations (Cd, Cr, Cu, Ni, Pb and Zn) were determined by means of ICP-AES technique, and mercury content was determined by means of CV-AAS technique.

Results and discussion

Achieved results confirm observations made by Borkowska [9] and Styk [10], who found that Jerusalem artichoke, as perennial multipurpose species, is characterized by great yielding potential despite of poor soil and climatic requirements. Plants set in the first experimental year (set as several-year-old seedlings from a plantation) revealed high yields of aboveground parts. Opportunity to get high yields allows for proposing Jerusalem artichoke as one of the species useful for chemically degraded areas reclamation, particularly phytoremediation of pesticides from the sorption barrier.

Studies of Lunney et al [11] were to compare the ability of five plant varieties to mobilize and phytoremediation DDT and its metabolites. The potential and limitations of phytoremediation for removal of pesticides in the environment have been reviewed by Chaudhry et al [12].

Table 2

Mean concentration of pesticides and heavy metals in soil and Jerusalem artichoke

Pollutants	Limit detection	Control test			Test 1–3		
		Soil	Jerusalem artichoke		Soil	Jerusalem artichoke	
			stem	leaves		stem	leaves
Pesticides [mg · kg^{-1} d.m.]							
Aldrine	0.001	0.0097	—	—	0.1623	—	—
Chloroprophane	0.005	0.0178	—	—	0.1031	—	—
HCH	0.001	0.0669	0.0004	0.0008	0.1289	0.0021	0.0019
DDE	0.001	0.1599	0.0018	0.0011	0.3891	0.0101	0.0026
DDT	0.005	0.1909	0.0024	0.0011	0.3488	0.0073	0.0019
DDD	0.002	0.2270	0.0038	0.0007	0.3763	0.0180	0.0013
Metoxychlor	0.001	0.1120	0.0032	—	0.2647	0.0150	—
Metals [mg · kg^{-1} d.m.]							
Cd	0.06	0.079	—	0.143	< 0.06	0.070	0.111
Cr	0.3	7.721	—	0.667	7.714	0.481	0.623
Cu	8.0	55.638	—	11.898	10.147	5.311	8.321
Ni	1.2	5.021	—	0.957	3.212	0.609	1.725
Pb	1.0	71.426	—	0.439	7.347	0.591	0.845
Zn	6.0	65.055	—	23.337	21.123	20.161	28.032
Hg	0.001	0.056	—	0.016	0.048	0.018	0.021

Studies of Antoniewicz and Jasiewicz [13, 14] revealed high yielding potential of Jerusalem artichoke on the soil with varied heavy metals contamination, which proves its great resistance and fast adaptation to polluted soils. Own studies also confirmed results obtained by Borkowska [9], who observed more abundant yields of Jerusalem artichoke on substrate amended with sewage sludge than on mineral soil. It referred both to plant height and yield of biomass (Fig. 1). Besides high yield-forming potential, Jerusalem artichoke also shows a great ability to intake pesticides and heavy metals from the substrate. Much higher levels of absorbed pesticides were recorded in soil mixed with stabilized dairy sludge (0.10313–0.38909 mg · kg^{-1} d.m.) than in natural soil (0.01781–0.22702 mg · kg^{-1} d.m.). Similar dependence was observed in samples of Jerusalem artichoke above ground parts. Both leaves and stems of plant cultivated on sorption substrate accumulated more pesticides. Higher toxins concentrations were detected in stems (DDD 0.0180 mg · kg^{-1} d.m.) than in leaves (DDD 0.0013 mg · kg^{-1} d.m.), regardless the substrate Jerusalem artichoke was cultivated. Furthermore, metoxychlor was found in stems; it was not taken and accumulated by leaves both in “sorption” and control pots. It was symptomatic that Jerusalem artichoke takes only chloroorganic insecticides group from pots amended with pesticides, while aldrine, chloropropane, and pyrimicarb remained in the substrate.

Conclusions

Achieved results allow conclude that Jerusalem artichoke (*Helianthus tuberosus* L.) can be used for phytoremediation of soils contaminated with pesticides, and particularly to prolong vitality of sorption barrier around a pesticide graveyard area. More abundant yields of Jerusalem artichoke on the substrate amended with dairy sludge than mineral soil allows for predicting large amounts of a biomass for energetic purposes, thus removing accumulated pesticides by means of combustion.

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OCENA PRZYDATNOŚCI TOPINAMBURU (*Helianthus tuberosus* L.) DO FITOREMEDIACJI GLEBY ZANIECZYSZCZONEJ PESTYCYDAMI

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Abstrakt: Celem pracy była ocena przydatności topinamburu (*Helianthus tuberosus* L.) do fitoremediacji podłoża sorpcyjnego zanieczyszczonego pestycydami. Obiektem badań było podłoże sorpcyjne, będące mieszaniną gleby oraz ustabilizowanego osadu mleczarskiego, przeznaczone do wykonania ekranu sorpcyjnego wokół mogilnika. Doświadczenie obejmujące 4 obiekty: kontrolę oraz 3 pozostałe zanieczyszczone pestycydami, prowadzono w wazonach o powierzchni 0,3 m^2 wypełnionych ww. mieszaniną, do których nasadzono topinambur. W badaniach wstępnych potwierdzono jego przydatność. Sezon wegetacyjny trwał od wiosny do późnej jesieni 2007 roku. Po okresie aklimatyzacji roślin do wazonów wprowadzano w stałych odstępach czasowych mieszaninę pestycydów chloro- i fosforoorganicznych. Po zbiorze roślin pobrano próbki podłoża oraz części naziemnych i podziemnych rośliny. W próbkach określano stężenie pestycydów zgodnie z obowiązującą metodyką. Stwierdzono, że zawartości pestycydów w podłożu sorpcyjnym (od 0,10313 do 0,38909 mg · kg^{-1} s.m.) były dużo większe niż w glebie kontrolnej (od 0,01781 do 0,22702 mg · kg^{-1} s.m.). Uzyskane wyniki pozwalają wstępnie stwierdzić, że topinambur może być wykorzystany do rekultywacji gleb zanieczyszczonych pestycydami, zwłaszcza do przedłużenia żywotności bariery sorpcyjnej wokół mogilnika. W przyszłości pozwoli to na zastosowanie wokół mogilnika ekranu sorpcyjnego, który zredukuje migrację pestycydów do środowiska, a uprawa fitoremediacyjnych roślin energetycznych umożliwi przedłużenie żywotności sorbentu i usuwanie pestycydów z części nadziemnych przez spalanie.

Słowa kluczowe: fitoremediacja, topinambur (*Helianthus tuberosus* L.), sorpcja, pestycydy, mogilnik