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PHYTOREMEDIATION OF AGRICULTURAL LAND CONTAMINATED WITH PESTICIDES

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ABSTRACT

Pesticides are substances intended for preventing, destroying, suppressing or reducing pests. They are in use for more than 60 years and they are divided according to purpose, chemical composition and toxicity category. The use of pesticides in agriculture has positive and negative sides, both from an economic as well as a social and environmental point of view. It is known that pesticides through biogeochemical cycles mature to all environmental media, and even the food chain, which explicitly has an impact on human health. Phytoremediation is one of the natural methods used for solving the problem of the presence of pesticides in agricultural soils, using plant species that perform stabilization and degradation of pesticides. During the planning ecoremediation project of degraded agricultural land, selection of phytoremediation techniques depends on many factors, among other things, the types of contaminants and plant species that will be used.

After examining the results of some studies, reports, and regulations, this paper shows the importance of phytoremediation of degraded agricultural land in the light of affordable and green technology without negative effects and products on the environment and human health as well as appropriate techniques of modern man who seeks to sustainable development. It is necessary to take into consideration the use of biopesticides as alternatives to current trend of uncontrolled use of conventional pesticides.

Keywords: *pesticides, phytoremediation, sustainable development*

1. INTRODUCTION

Pesticides are defined as substances or mixtures of substances intended for controlling, preventing, destroying, repelling, or attracting any biological organism deemed to be a pest. There is a classification of pesticides based on the object of their action, according to the mode of entry into the organism, by the action in the organism, on the basis of toxicity and according to chemical composition. Based on the object of activity caused there are: insecticides, acaricides, bactericides, virocide, fungicides, herbicides and zoocides. According to the method of penetration and the effects of pesticides are classified as contact (destroying vermin touch), digestive (pass through the gastro-intestinal tract) and systemic (affecting or destroying vermin through one of its systems) [1].

Pesticide use raises a number of environmental concerns. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water and soil [2]. Bearing in mind that the effect of pesticides on the biocenosis and the environment in general is complex, this paper presents some aspects of phytoremediation of agricultural land contaminated with pesticides.

2. EFFECTS OF PESTICIDES ON THE ENVIRONMENT AND HUMAN HEALTH

After application of the preparation, the molecules of active ingredient for some time remain in place that were applied, and then under the influence of the movement of air or water can be transported in the atmosphere (water vapor) in the deeper soil layers (flushing) or lateral to the soil surface (runoff).

The fate of pesticides in the environment affects the processes that can be grouped into three categories:

1) adsorption (the binding of pesticides to mineral and organic matter, soil);
2) degradation (chemical, photochemical and microbiological);
3) transportation (movement of pesticides in environmental- evaporation, rinsing, washing and adoption of the plants).

Where the pesticide ends up depends on the cumulative effects of pesticide and soil properties, application methods and site conditions. With regard to the detoxification mechanisms, such as mobility, degradation (mainly microbiological) and phytoextraction refer only to the free (non absorbed) fraction of molecules of pesticides, we can say that adsorption is the most important process that determines the fate of pesticides in soil [3-5].

Persistent organic pollutants (POPs) are organic compounds that, to a varying degree, resist photolytic, biological and chemical degradation. POPs are often halogenated and characterised by low water solubility and high lipid solubility, leading to their bioaccumulation in fatty tissues. They are also semi-volatile, enabling them to move long distances in the atmosphere before deposition occurs. Some pesticides, including aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex and toxaphene, are considered POPs [6]. Table 1. show pesticide persistence in soils. Some POPs have the ability to volatilize and travel great distances through the atmosphere to become deposited in remote regions. Atmospheric transport and accumulation of POPs (PCBs, DDT, HCHs, and chlordanes) in the polar regions has been extensively documented. Accumulation in polar regions is partly the result of global distillation followed by cold condensation of compounds within the volatility range of PCBs and pesticides [6-8].

POPs can affect non-target organisms in the environment and increase risk to humans by disruption in theendocrine, reproductive, and immune systems. From the standpoint of protecting people, pesticides are classified as harmless, hazardous, very dangerous and dangerous. Four groups were established on the basis of the degree of pesticide toxicity, which are given in Table 2.

2.1. Regulatory issues

Because POPs can be found anywhere in the world, cleaning them up requires international solutions and cooperation. International treaties such as the Stockholm Convention have been developed to control and phase out the use of POPs. Over 180 countries have ratified the Stockholm Convention. Serbia (SCG) signed Convention on May 2, 2002 but not ratified. The United States has signed, but not ratified the Stockholm Convention which makes it difficult for new chemicals to be regulated. Continuous collection of data and research is required so that new POPs can be evaluated and information can be shared across the globe [7,9].

Table 1. Contaminant persistence in soil

Contaminant	Persistence (in half-lives)
Aldrin/Dieldrin	5 years
Chlordane	1-3 years
DDT	1-3 years
Endrin	12-15 years
Heptachlor	up to 2 years
HCB	2.7-22.9 years
Mirex	up to 10 years
Toxaphene	100 days- 12 years
PCBs .	1-7.25 years
Dioxins/Furans	over 20 years
Sources: WWF 2005, Ritter et al. 2005, ETOXNET 2001	

Table 2. Classification of pesticides according to the degree of toxicity [1]

The World Health organizations(WHO)	LD 50 (mg/kg)
harmless	>1000
hazardous	200–1000
very dangerous	50–200
dangerous	<50

In R. Serbia, the adoption of the Law on Environmental Protection in 2004 and the Waste Management Law in 2009 created the conditions for the development of remediation technologies. From November 2010 determination of contaminated sites is based on the Regulation on the program of systematic monitoring of soil quality indicators for assessing the risk of soil degradation and methodology for the development of remediation programs ("Off. Gazette of the RS", no. 88/10) which determines the impact to soil from chemical pollution. Setting priorities for rehabilitation and remediation is done on the basis of the adopted Regulation on the establishment of criteria for determining the status of particularly vulnerable environmental status of endangered environment and the setting of priorities for rehabilitation and remediation ("Official Gazette of RS", no. 22/10) [10-13].

In Table 3 are shown the limit values of concentration and remediation of hazardous and noxious substances and values that may indicate significant soil contamination according to Regulation on the program of systematic monitoring of soil quality indicators for assessing the risk of soil degradation and methodology for the development of remediation programs ("Off. Gazette of the RS", no. 88/10)

Table 3. The limit values of concentration and remediation of hazardous and noxious substances and values that may indicate significant soil contamination [12]

Dangerous and harmful substances	**Soil (mg / kg absolute dry matter)**	
Pesticides	**Limiting value**	**Values may indicate of the significant contamination**
DDT / DDD / DDE (total)	0,01	4
Drini	0,005	4
Aldrin	0,00006	-
Dieldrin	0,0005	-
Endrin	0,00004	-
HCH compounds	0,01	2
α - HCH	0,003	-
β - HCH	0,009	-
γ – HCH	0,00005	-
Atrazine	0,0002	6
Carbaryl	0,00003	5
Carbofuran	0,00002	2
Chlordane	0,00003	4
Endosulfan	0,00001	4
Heptachlor	0,0007	4
Heptachlor epoxide	0,0000002	4

3. PHYTOREMEDIATION TECHNOLOGY

Phytoremediation is one of the natural methods used for troubleshooting the presence of pesticides in agricultural soils, using plant species that perform stabilization or degradation of pesticides. During the planning ecoremediation project of degraded agricultural land, selection of phytoremediation techniques depends on many factors, among other things, the types of contaminants and plant species that will be used. Table 4. show phytoremediation processes, mechanisms and related pollutants/plant species. Use of a specific technique is dependent on site characteristics and contaminants being treated [14-16].

A significant amount of research is being conducted on the interaction between microorganisms and plants in the rhizosphere and the potential to use this for the remediation of pesticide contaminated media. According to preliminary studies, enhanced degradation of atrazine, metolachlor and trifluralin have been observed in contaminated soils where plants of the *Kochia scoparia* have been planted.

The increased degradation occurs in the rhizosphere of this herbicide tolerant plant, suggesting that rhizosphere interactions between the plant and microorganisms have led to the increased degradation of the pesticides present. Additional studies using the *Kochia scoparia* have been conducted by these researchers and also show promise for the phytoremediation of pesticide contaminated soils and groundwater [17].

Table 4. Phytoremediation processes, mechanisms, and related pollutants/plant species [14]

Phytotechnology	Mechanism	Pollutants	Plants
Phytoextraction	Hyperaccumulation in harvestable parts of plants	Inorganic: Co, Cr, Ni, Pb, Zn, Au, Hg, Mo, Ag, Cd Radionuclides: Sr, Cs,Pb, U	*Brassica juncea, Thalspi caerules-cens*, *Helianthus annus*
Rhizofilteration	Rhizosphere accumulation though sorption, concentration and precipitation	Organics/Inorganics:Metals like Cd, Cu, Ni, Zn, Cr Radionuclides	*Brassica juncea, Helianthus annus*, Tobacco, Rye, Spinach and Corn
Phytovolatilization	Volatilization by leaves through transpiration	Organics/Inorganics: Chlorinated solvents, inorganics (Se,Hg, As)	*Arabidopsis thaliana*, Poplars, Alfaalfa, Brassica juncea
Phytodegradation	Pollutant eradication	Organic compounds, Chlorinated solvents, Phenols, Herbicides, Munitions	Hybrid poplars, Stonewort, Black willow, Algae
Phytostabilization	Complexation, sorption and precipitation	Inorganics: As, Cd, Cu, Cr, Pb, Zn, Hs	*Brassica juncea*, Hybrid poplars, Grasses

Before starting the phytoremediation process it is necessary to assess the risk and impact on the environment, and how they will manage the process. It is necessary to characterize the place, including the type and volume of contaminated mediums to be treated. Define what is needed to degraded and to what concentrations, where and how to dispose of the end product of the process. It is important the full acceptance of legal regulations governing the grounds for the application process [18].

4. COSTS AND ECONOMIC IMPACTS

Research shows that the cost of phytoremediation ranging from $15,000 to $694,000 in full-scale applications. Costs differ with the site size and operation and maintenance requirements. Table 5. show estimated remediation costs according to the phytoremediation mechanism [19]. In order to enhance phytoremediation efficiency of soil organic contaminants, a biofuel crop-microbe combination system was developed. Instead of the special plants for phytoremediation, biofuel crops were suggested to use for remediation and utilization of contaminated agricultural soils. Biofuel crops are easy for management, produced large biomass and have comparable remediation rates to some special phytoremediation plants. Figure 1. show comparison of conventional phytoremediation and the profitable phytoremediation with biofuel crops [21].

Table 5. Estimated phytoremediation costs

Mechanism	Estimated Cost
Phytoextraction	$60,000-$100,000
Rhizofiltration	$2,000-$6,000/thousand gallons of water
Phytostabilization	$200-$10,000/hectare
Phytodegradation	$250,000
Sources: ITRC 2001, EPA 2000	

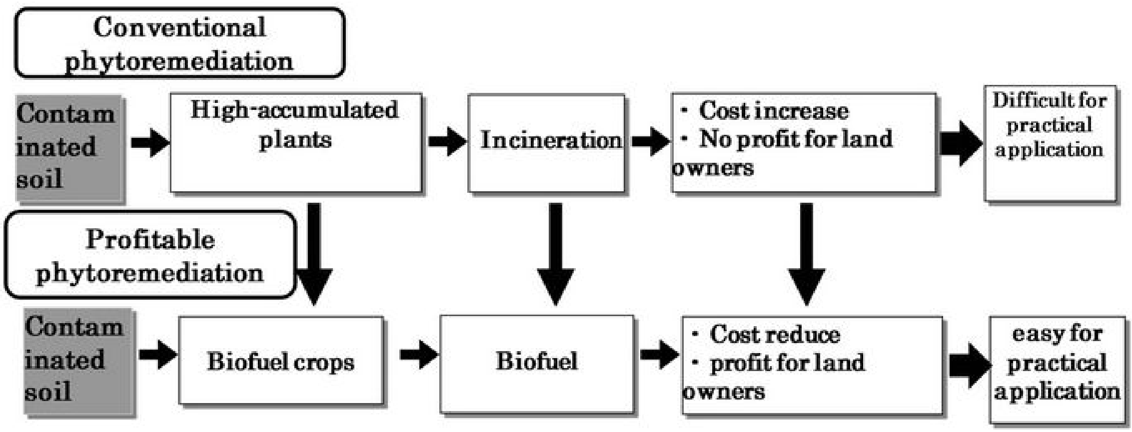

Figure 1. Comparison of conventional phytoremediation and the profitable phytoremediation with biofuel crops [21]

5. CONCLUSION

Contamination of agricultural soil has been a worldwide concern, and phytoremediation is a promising alternative to conventional soil clean-up technology as a low cost and environment-friendly technology.

Results indicate that phytoremediation using biofuel plants possibly works effectively for remediation of contaminated soils as well as provide economic benefits to the owners of contaminated sites. Therefore, biofuel crops would be a reasonable choice for phytoremediation of contaminated agricultural soils.

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