PHYTOREMEDIATION NEW TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

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Authors promote Phytoremedation as new technology for Sustainable Development.
Phytoremedation is the technology in wich we use green plants with an aim of polluting substances removal from humans environment and their transformation into harmless forms.
Phytoremediation of lead contaminated soil is experiments Authors. For Phytoremediation contaminated soil we used phytoaccumulator plant Brassica juncea.
Experiments have proved that usage of synthetic chelates in the phytoremediation process increased lead (heavy metals) uptake by plants.
Phytoremediation of innovative cleanup technology for Sustainable Development with clean contaminated soil using hyperaccumulator plants.

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INTRODUCTION

Concept of Sustainable Development presentis a social development of human race in accordance with economic development and environmental protection. The Rio Earth Summit in 1992 resulted in a global plan for action for sustainable development – Agenda 21; Recommendations have been set for developed and developing nations regarding to sustainable development strategies in various areas, such as clean air and water, water supply, energy, land use, housing, waste treatment, transportation, and health care.
Orientation for the concept of the Sustainable Development is participation the Republic of Serbia in process"Environment for Europe".
The future generations are dependent on nowadays.
Sustainable development in future means reduction of use of the fossile fuel, such as coal,oil and gas with necessarily effort for environmental protection.
On the global and local plan we need technologies for decreasing greenhouse gas emission and enviroment revitalization. We propose alteration for decrease environmental damage and exchange the fossile fuels with restorable energetically resources (wind or solar energy) in future and development our society in sustainable direction.

SUSTAINABLE DEVELOPMENT AND THE PHYTOREMEDIATION

Phytoremediation is new technology based on the use of higher plants for cleanup proceses of contaminated environment.Fundamental and applied researches have unequivocally demonstrated that selected plant species have potential to remove, degrade, metabolize, or immobilize a wide range of contaminants. Phytoremediation, as well as the Sustainable Development is based on the implementation of three fundamental components: environmental protection, economic growth and social equality.

Phytoremediation for Sustainable Development is based on the reduction of the contaminated terrains

Phytoremediation uses education from nature for environmental protection.

Phytoremediation is innovative cleanup technology for Sustainable Development for cleaningup the contaminated water, soil, ash and cinder**,** by using growing plants.

Phytoremediation is innovative, economical, and environmentally friendly approach for removing toxic metals from hazardous waste sites, and contaminants soil, using the Sun energy

Application of the phytoremedation, under our climate conditions, are positive and have scientific confirmation, in situ i ex situ projects.In situ application is more often.

Support to Sustainable Development in the reduction of the pollution, and cleaning-up places contaminated with waste materials is subject-matter of researches done by author of this work.

GOAL OF THE WORK

- Application of the Sustainable Development principles in global and local community
- Promotion of the economic growth and the environmental protection using Phytoremediation.
- Raising of public‘s ecological sense.

DESCRIPTION OF THE PROBLEM

Antropogenic activities-generate pollutations.
For many years, human activities connected to industry, energy production, mineral exploitation and distribution and traffic, etc caused, and still causing, production and storage of dangerous polluting substances. Pollutations come to air, water, soil. Pollutations from the air, gaseous or like aerosol, in time mostly come to soil and after that to underground and ground waters. Soil is being irreversibly lost and degraded as a result of increasing and often conflicting demands from nearly all economic sectors. The main problems are irreversible losses due to soil sealing and erosion, continuing contamination from local and diffuse sources, acidification, salinization, compaction and desertification. We support the use of market based and economic instruments, but promotion of economic growth and environmental protection through improving efficiency and sustainability in the use of resources and production processes.
Connected to human‘s and animal‘s health pollutations could be toxical, cancerogenic, teratogenic, allergogenic, mutatogenic, bio-accumulative. In time, depending to substratum, in wich pollutations are, polluting materials are degradated by different speed.

Soil pollutations, as researches on territory of the Republic of Serbia show, includes: heavy metals, pesticides, PCBs, PAHs, radio-nuclides, acid rains, wasted waters, particles of dust, coal, minerals, pathologenic organismus, etc. Under influence of pollutations, soil does self-purification, until it losses that ability, by destruction of the soil or furthermore to temporary or permanent expulsion from use. In that way comes up reduction of healthy drinking water, reduction of territory convenient for agricultural use, reduction of terrain convenient for production healthy and safe food.

If we don‘t pay attention on degradation of the soil, especially on contamination by heavy metals, pesticides, radio-nuclides, and other dangerous materials from different sources, it could be possible, very soon, to have ”chemical time bomb”, parraled with appearance of cancer metastasis in human organism. (P. Sekulić, Kastori R., 2003.)
Heavy metals like cadmium, mercury, nicle, lead, uranium, copper, iron, manganese, zinc, etc. are toxical substances wich include in food chain, and performe high risk for bio-diversity in long term period. Risk could be different: deteriorated human‘s, animal‘s and plant‘s health, object damage, or structures on the ground, contamination of underground and ground waters wich are connected with the soil.
Influence of toxic metals dependes on their conditions and shapes, wich causes theirs behaviour in soil. For example As and Se are more mobile in alcal pH while Hg, Pb, Cd and Zn are more mobile in acid pH of soil (Adriano, 1986; Alloway, 1990).
Influence of the soil pH on the radio-nuclides and organic compounds is relatively specific.
Ansewer of the scientists on problems connected to soil contamination and wasted waters are solutions for the decontamination. In that way, the natural processes connected to capability of higher plants, are used for remediation-cleaning up the soil and wasted waters.

Processes in the higher plants, caused by presence of pollutations, on the observed terrain, point to high potential for cleaning up through plants. These plants are named Phytoremediators. Thanks to the plants Phytoremediatiors, wich are able to accumulate metals and radio-nuclides in the above ground part of the plant, realizes the possibility for soil and technogenic pollutations decontamination. After the use of green plants to clean-up the terrain, decontaminated soil could be used in agriculture.

World-wide researches and application of the Phytoremediation show that Americans, Chinamen and Englishmen, in accordance with published works, are leaders on this field. Specially helpful were researches of these scientists: Salt, Baker, Lasat, Raskin, Chaney, Adriano R., Malik M., Yin L., Brown, Brewer, Krämer, Hung J.W., Cnningham S.D., on wich we are very grateful.

PHYTOREMEDIATION IN THE REPUBLIC OF SERBIA

Necessity for decontamination of the terrain-places contaminated by waste materials in R. of Serbia existes. Solution through use of the Phytoremediation is intruded, as the alternative to expensive and aggressive processes for environmental decontamination. Application of the Phytoremediation, we achieved:

- Reduction of the risks from heavy metals in the soil
- Reduction of risks for water resources
- Reduction of human‘s health risks

Occupation Battery Factory Sombor, soil contaminated by lead and heavy metals. Prof Bojka Blagojevic and colleagues, from the Nis University and Mara Vlajkovic from Institute for Public Health of Serbia, Belgrade, decided that contaminated soil, should be cleaned up. Fundamental and applied research have unequivocally demonstrated that selected plant species possess the genetic potential to remove, degrade, metabolize, or immobilize a wide range of contaminants including lead and others heavy metals. Plants from sp. Brassicacea as Brassica juncea, and Brassica napus are able to phytoaccumulate, degrade and phytostabilize toxic matters from soils and waters.

Cleaning up contaminated soil is an expencive and arduous work but a growing technique phytoremediation appeard perfect for the task.

Through the Phytoremediation, Djordjevic-Miloradovic J., Vlajkovic M., extracted arsenic, from ash deposit of Kostolac thermo electrical power plants, by using the fern, in 2002: ”Adoption of arsenic by plants grown on the Kostolac thermo electrical power plants ash.” We investigated quantity of arsenic in bottom coal ash from thermo electrical power plant Kostolac, and uptake of arsenic in plants (Calamagrostis epigeios), (Tusilago fanfara), (Sysibrium orintale), in coal ash area Kostolac. Although, the potential for metal extraction is of the primary importance, other criteria, such as ecosystem protection must be also considered when selecting remediating plants. As a general rule, native species are preferred to exotic plants which can be; invasive and endanger the harmony of the ecosystem.

To avoid propagation of weedy species, crops are in general preferred although some crops may be too palatable and pose a risk to grazing animals. Reduce the risks to human health through pollution prevention and control.

Vlajkovic M. inducted, by using plants phytoaccumulators and helath reagents, phytoaccumulations of toxic metals (Pb, Cu, Zn, Cr , Mn), from soil, 2000.- 2001. In that way, effects and possibility for decontamination by the Phytoremediation were strengthened. Used helath reagents: citric acid and EDTA increased lead accumulation by several tenth times.

Team Djordjevic-Miloradovic, Vlajkovic applied Phytoextraction for Cleaning-up Uranium-contaminated soil. Phytoextaction as their specially form, establishes on the

hyperaccumulative capability of plants. The oil rape (Brassica napus var Banacanka) demonstrated hyperaccumulative capablity.

We came to know that soil pH has large influence on accumulation and translocation of uranium from the soil. By reduction of pH on the amount of 5, uranium accumulation is intensived by 14 times. Helath factors as citric acid, acetiqum acid, EDTA i HEDTA increase uranium accumulation by several hundreds times.

Exploration the remediation of soil, contaminated by uranium in the mine Kalne surrounding, performed 1995, Sarić M., Stojanović M., Babić M. and co-operators: "Uranium in plant species grown on natural barren soil".

Petrović. N., Arsenijević-Maksimović. I., Kastori. used Phytoremediation in 2002.:" Heavy metals-uptake, tolerance mechanisams and phytoremediation in rhizosphere".

Sanitary Ecology Society of Belgrade, (2004/2005.) applied Phytoremediation for Cleaning of heavy metals from the soil on terrain around Livnica Rakovica, Belgrade Serbia and Montenegro. Part of the project is introduction of new ways of sustainable usage of the soil and water in the interaction of the plants.

MATERIALS AND METHODS

Phytoremediation is method wichs green plants for clean-up contaminated hazardous waste sites. Phytoremediation is applied ex situ and in situ,continually and inducted to clean-up contaminated terrains of toxical metals.

Researching contains a few different smaler researchings:

1. identification of the area
2. chemical analysis of the soil before application of the phytoremediation
3. sowing the plants phytoaccumulators
4. usage of agricultural and technical measures and inspection of vegetative development
5. picking up and drying the plants
6. chemical analysis of soil near the root after finished Phytoremediation
7. chemical analysis of green leaves of plants
8. determination of coefficient of concentracion CF of plants

Gathered material is dried in shadow and draft without sun light presence. After sample preparation content of heavy metals is determined by atomic absorption spectrophotometry.

Important factors as starting basis for successful application of the soil Phytoremediation:

- observation of the orographic and climate factors of the area
- correct plant selection
- chemical characteristics of the soil
- determination of pH value
- determination the humus content

RESULTS

Phytoaccumulation of lead from the soil - inducted phytoextraction

Inducted phytoextraction is understood as course of the Phytoremediation with induction (addition of helath factors). During 2000-2001., research of inducted or guided Phytoremediation ex situ on the soil from contaminated terrain,has been led by application of the plants from sp. Brassicaceaa- Brassica juncea.

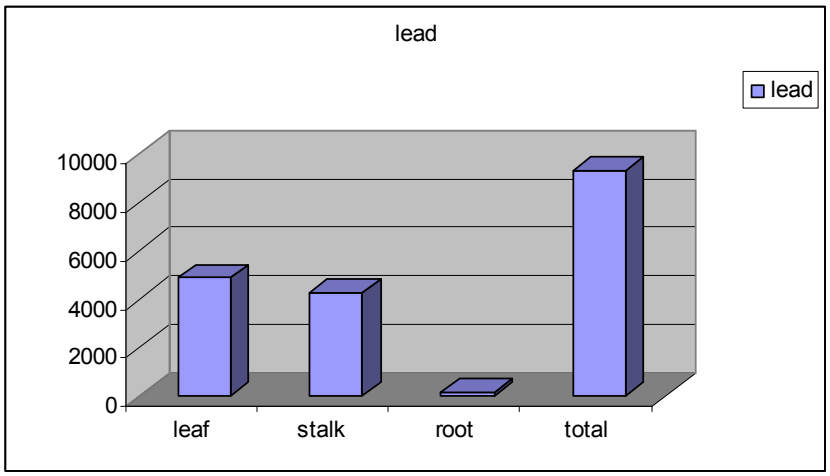
Lead adoption from the soil by plant Brassica juncea is expressioned in mg/kg of dry matter. Results are represented as the lead contents in the parts of examined plant Brassica juncea, after the Phytoremediation.

Table 1. The lead contents in the plant Brassica juncea (mg/kg)

Brassica juncea	lead	method
leaf	4888,72	AAS
stalk	4303,44	AAS
root	150,46	AAS
total	9342,62	

Lead adoption from the soil by tested plant Brassica juncea, expressioned in mg/kg, showes that Brassica juncea has accumulated lead in all its parts, totally 9342,62 (mg/kg).

Graph 1. Disposition of the adopted lead in the plant phytoaccumulator



The most of the lead Brassica juncea has accumulated and translocated in the green leaves, stalk and root.

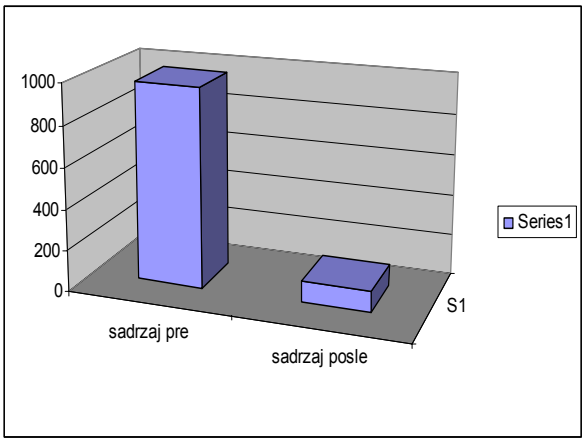
The lead content in the soil,after application of the Phytoremediation in one harvest season,is reducted, compared to content before the Phytoremediation.

Table 2. Parallel review for the lead in soil before and after ex situ applied of the Phytoremediation

The lead content in the soil before application of the Phytoremediation (mg/kg)	972,31
The lead content in the soil after application of the Phytoremediation (mg/kg)	105,52

The lead content in the soil is reducted for more than 9 times compared to content before application of the inducted Phytoremediation.

Graph 2. The lead content in the soil before and after application of the Phytoremediation



Obtained results representes that Phytoremediation is very well worked off.

Confirmation was got that high concentrations of accumulated lead in the plant had been achived by application the citric acid and EDTA.

Inducted Phytoremediation representes suggestion for application whenever is possible.

Estimate and modeling from experiment

Results obtained from researchings could be used for determination of the coefficient of concentracion by using equation:

$$CF = \frac{C_{L_{(Pb)}}}{C_{Z_{(Pb)}}}$$

CF -plant's concentracion factor

$C_{L_{(Pb)}}$ -lead concentracion in dry matter of biomass in plant remainders,at the and of the experiment = 9342,62 mg/kg

$C_{Z(Pb)}$ -initial concentracion of lead in soil before experiment = 972,31mg/kg
CF=9342,62 /972,31
CF = 9,61

According to data from literature (Salt et al., 1995), CF factor for lead for Brassica juncea is between one and ten.

Ex situ researchings about inducted Phytoremediation,for lead from the soil,tested plant Brassica juncea hs shown excellent results.

Phytoaccumulation of heavy metals from the soil -continual phytoextraction

Continual phytoextraction is understood as course of the Phytoremediation without using of induction(helath factors). In the work is described using of the Phytoremediation for lead adoption from the soil by plant Brassica juncea. Researchings were led on the contaminated soil in situ, during 2001.

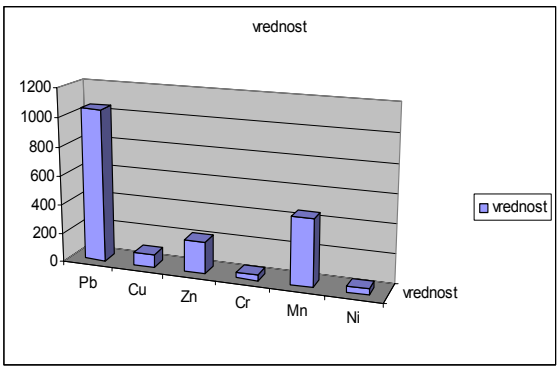
Table 3. The content of heavy metals,in soil expressioned in mg/kg

metal	Pb	Cu	Zn	Cr	Mn	Ni	Fe	method
amount	1051,46*	86,57	218,90	36,69	458,71	41,79	22477,06	AAS
MAC	100	100	300	100	-	50	-	

Total content of heavy metals, in soil is 24399,17 (mg/kg).

* concentracion found for lead (point T 13m), is 1051,46 mg/kg[1]

Graph 3. Heavy metals in the soil



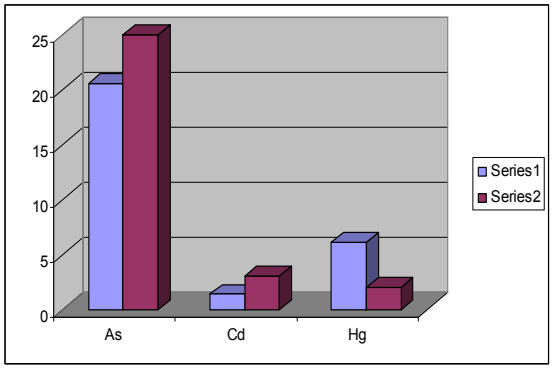
Contents for lead, copper, zinc, manganese, crome, nicle, etc. are determinated as total amount of heavy metals in the soil

[1] concentracion found for lead (point T 13m), is 1051,46 mg/kg[1]

Table 4. Contents of arsenic, cadmium and mercury, in soil expressioned in mg/kg

Metal, metaloid	As	Cd	Hg	Method
amount	20,55	1,38	6,06	AAS
MAC	25	3	2	

Graph 4. The contents of arsenic, cadmium and mercury, compared to MAC



Metals and methaloids in soil 2.

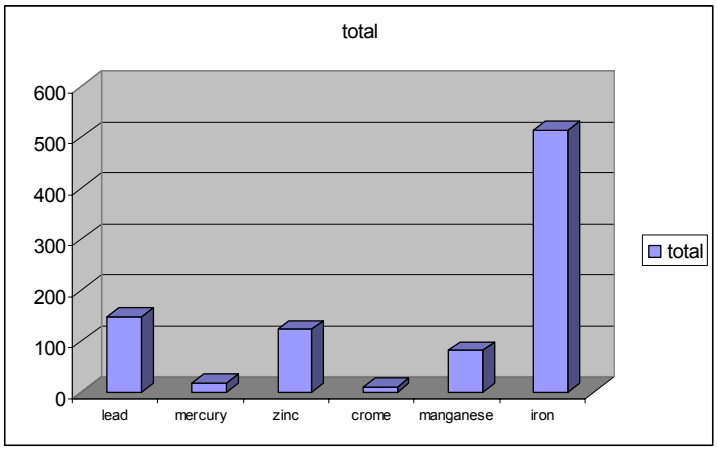
In this graph are shown contents of arsenic, cadmium and mercury, compared to MAC
Adoption of the metals, from the soil, by the plants expressioned in mg/kg of dry matter is shown in the table.

Table 5. The contents of total phytoaccumulation of metals, from the soil

Brassica juncea	lead	mercury	zinc	crome	manganese	iron	method
leaf	113,97	3,65	28,35	2,41	50,93	192,88	AAS
flower	26,19	7,35	44,35	2,21	18,61	127,29	AAS
root	7,16	3,54	25,55	0,99	6,29	134,31	AAS
stalk	7,37	4,02	25,22	5,77	6,43	60,09	AAS
total	147,53	18,56	123,47	11,38	82,26	514,57	

Total content of phytoaccomulated heavy metals, from the soil is 897,77 (mg/kg) by plants Brassica juncea - mostly translocated in the green leaves.

Graph 5. Heavy metals phytoaccumulated from the soil



Adoption of the metals, from the soil, showes that Brassica juncea has phytoaccomulated lead, mercury, zinc, crome, manganese, iron

CONCLUSIONS

Plants the Phytoremediators could be used on different environmental bases:for cleaning up the air, ground waters, waste waters, soil.For the decontamination was used plant sp. Brassica juncea. Also, researchings were performed with other plants the Phytoremediators (*Brassica napus, Helianthus annus, Clamagrostis epigeios, Tussilago farfara, Sysimbrium orientale*) on contaminated terrains.

According to the results of the researchings, application of the Phytoremediaton territory of R. of Serbia on areas new biotechnology could be recommended for further application in practice. Researchings led to knowledge that Brassica juncea possess ability for natural adaptation on the explored territory, in Vojvodina and widely parth of Serbia.

Solution through application of the Phytoremediaton is intruded as alternative to expensive and agresive well- known processes for cleaning up the environment.Advantage on the others cleanup technologies is that the Phytoremediation is less-expensive.This technology does not degradate ecosystems as the conventional engineering methods do. Phytoremediation bases on the implementation of three fundamental components of sustainable development : environmental protection, economic growth and social equity.
Authors promote Phytoremedation as new technology for Sustainable Development.

Phytoremedation is technology in wich we use green plants with an aim of polluting substances removal from humans environment and their transformation into harmless forms. Phytoremediation is relatively cheap technology compareing to physical and chemical clean-up techniques.
Cleaning up contaminated soil is a costly and arduous affair, but a growing technique phytoremediation appeared to be perfect for the task.
Brassica juncea, has been found to have a good ability to transport lead from the roots to the leaves, which is an important characteristic for the phytoextraction of lead .

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