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The biomonitoring and bioremediation of toxic water resulting from municipal waste storage of Somârd, Sibiu county

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Abstract. This paper presents information from the specialty literature and laboratory experimental results on biomonitoring, phytoextraction, biodegradation, and biotransformation of toxic water pollutants at the biotechnology laboratory of the Faculty of Environmental Science and Engineering. The study was conducted in laboratory micro tanks with contaminated water from the municipal landfill water storage pit with toxic bund of Somârd/Medias, Sibiu County, in order to research and develop a bioremediation technology using constructed wetlands. In this research of biomonitoring and bioremediation, *Lemna minor, Vallisneria spiralis* were used as biological indicators and as useful species in phytoextraction and biological depollution.
Key Words: constructed wetlands, bioremediation, phytoextraction, *Lemna minor, Vallisneria spiralis*.

Introduction. The purification of water is a natural process that occurs during its transit through the waters of rivers, lakes and wet areas. The concept of constructed wetland, modelled after the natural processes of remediation, is only a few decades old in the field of wastewater treatment. Constructed wetlands are used to recycle polluted water from various sources, including rainwater drainage from surface soil, domestic wastewater and wastewater from agriculture and water drainage (USEPA 1993). Constructed wetlands are also used to purify wastewater from oil refineries, compost, leachate from wastes landfills, discharges from fish hatcheries and industrial wastewater pretreated (Dyck et al 2009; Jing et al 2001; Juang et al 2007; Kuschk et al 2005; Masi et al 2002; Sim et al 2007; USEPA 1992).

Some constructed wetlands for wastewater treatment are applied as part of biological treatment processes (USEPA 1999). For wastewater treatment are built some complex technical integrated ecosystems, having water component, plants, microorganisms, and a build micro ecosystem. Because natural wetlands systems are reliable in terms of wastewater treatment, possessing self-regulation mechanisms is essential for the realization and operation of constructed wetlands to understand how they are structured and how these wetlands work (Kuschk et al 2005; Malschi 2009; Malschi et al 2012). In a constructed wetland some hydrological, geotechnical and biological constructive parameters which influence the processes can be controlled with treatment or artificially, therefore resulting controlled module from carrying out certain processes in nature (USEPA 1992, 1993).

All natural and constructed wetlands have a common feature: the presence of surface water or near the surface water at a regular period of time. For most wetlands, hydrological conditions are such that the substrate is saturated with water for a long period during the growing season, thus creating anoxic conditions and limiting vegetation to those species adapted to these environmental conditions. Wetlands hydrology is represented by streams of water flowing slowly and shallow waters, or saturated substrates. The slow flow of water and the shallow depth are allowing the sedimentation of the particles in time as the water passes over the surface of the wetland, allowing prolonged contact between water and surfaces in wetlands (Mincu & Tociu 2011).

Constructed wetlands accumulate a number of functions and meanings. Functions are inherent processes meet in this framework such as removable mechanisms, which are divided into two categories: biological and physic-chemical. Biological mechanisms include a lot of aerobic and anaerobic processes leading to biological degradation by microorganisms. Once pollutants are transformed and altered, biological process occurs following the absorption by plants. These plants feed on some of the decomposition processes result of microorganisms and have a great capacity to absorb pollutants that could not be decomposed Physico-chemical mechanisms include absorption and fixation of various minerals and metals in soil such as phosphorus, calcium, aluminium, iron, by means of specific plants. Sedimentation is also important because is a part of this process (Dyck et al 2009; Juang et al 2007). The types of plants found in constructed wetlands are of two categories: helophyte and hydrophilic. Helophyte are those perennial aquatic plants, rooted. Water hydrophytes are plants with roots below the surface of the thin layer of water (floating plants).

Advantages and limitations of constructed wetlands. The advantages are that the hydrophytes plants keep the wastewater with low oxygen and microorganisms can well developed their activity. It restricts the transfer of gas from water to air, and sunlight penetration is reduced. Various imbalances can occur. One of the constructed wetlands limiting problems is uncontrolled growth of algae and various microorganisms (Jing et al 2001).

Material and Method. In 2011-2012, at the Biotechnology laboratory of the Environmental Science and Engineering Faculty, Cluj-Napoca were performed research on biomonitoring and bioremediation of polluted waters. *Lemna minor* L. and *Vallisneria spiralis* L. species has been used to study the biomonitoring and phytoextraction of water pollutants, in micro containers tests.

The sample of water used for tests came from the bund of the municipal and industrial waste landfill Somârd-Mediaş, Sibiu county and from the Somârd river-downstream bund, which is loaded with various pollutants: heavy metals, oxides, phosphates, etc. and with a slightly acidic pH. (HG 349 2005) This bund polluted water was an important environmental problem, studied lately (Mihaiescu et al 2010; Modoi & Ozunu 2012; Muntean 2003; Oprea et al 2010; CCPAIM 2006a, 2006b).

For phytoextraction and phytotoxicity analyze has been used *L. minor* species. *V. spiralis* was used for phytoremediation and water decontamination study. The experiment lasted 2-3 weeks for each water plant species. There were placed three different types of water for each species: 1. = micro containers with plain water as blank, 2. = micro containers with water comes from the bund of Somârd waste landfills 3. = micro containers with water from Somârd river - downstream of the bund.

The water quality parameters of samples analyzes were performed using multiparameter WTWinolab 720. Were determined the physical parameters of water and then compared with standard drinking water in Romania and in European Union. With the device 10 Meck camera flex RQ has been determined the concentrations of ions calcium, magnesium, sodium, chloride and sulphate and various heavy metals.

Results and Discussion. Using constructed wetlands, composed of water plants, green algae, cyanobacteria and various species of water microbiota with high biological effect of pollutants bioaccumulation, can remove various heavy metals and other pollutants (Kuschk 2005; Malschi 2009 a, b, Malschi et al 2012; Oros & Draghici 2002; Rachel et al 2011).

The study on the species *V. spiralis* was remarkable since its introduction in the ecosystem bioremediation was particularly interesting because it has adapted very easily to the hostile environment created. It has been noticed the plant's influence in the balance of algae growth: green algae, red algae and cyanobacteria which had previously an uncontrolled grouth, but was stopped in newly constructed tanks (Sears & Kevin 1996).

After the individual study of *V. spiralis* plant by placing the plant in three plastic containers with different water content, it observed significant differences between samples using visual and olfactory senses.

The application of ecotoxicity and biomonitoring tests on contaminated water samples were made by the testing method with *L. minor* (Malschi 2009; Malschi et al 2012; Oros & Draghici 2002).

The results of the polluted water's parameters, obtained before applying the phytoremediation tests (Table 1) it revealed an extremely high level of heavy metal (Fe, Cd, Zn) pollution, in the water samples from Somârd-Mediaş municipal waste landfill, and from the Somârd river-downstream of the bund, in Sibiu county, mentioned in the previous studies (Mihaiescu et al 2010; Muntean 2003; Oprea et al 2010; UBB Cluj-CCPAIM 2006a, b).

The results obtained after applying the three weeks of lead, cadmium, zinc phytoextraction and bioremediation tests with *L. minor* and *V. spiralis* (Tables 2 and 3) proved the important role of this wastewater bioremediation treatment using *L. minor* and *V. spiralis* as main component of constructed wetlands in laboratory micro containers.

After the first week (Figure 1), the color of *L. minor* plant is changed, depending on the degree of water pollution. Where pollution is high (versions 2 and 3), the plant dies or, is getting darker compared to variant 1 of micro tank which is blank.

According to analyzes, we observed a high concentration of heavy metals. The tests of ecotoxicity and biomonitoring with *L. minor* applied to the water samples, it has revealed that the level of water pollution from landfills waste dump Somârd and from the stream Somârd (downstream of the bund) is higher compared with blank samples.

Figure 2 shows the affected plants and the fact that they have extracted some pollutants from the water. In micro tank no. 1 with blank sample is obviously that *L. minor plant* hasn't suffered changes of color. In micro tank no. 2 with polluted water from bund, you can see *L. minor* plant changed his color and the water after phytoextraction plan changed its transparency and color. The plant shows a change to dark green color indicating a degree of pollution. In micro tank of version no. 3 is seen a massive plant mortality who have changed color to brown by phytoaccumulation pollutants from water. This indicates a high pollution of the stream Somârd, near bund.

After only 2 weeks of bioremediation with *V. spiralis* plant it has been noted that the plant has a big capacity to phytoextraction of heavy metals.

In Figure 3 it can be noticed the bioremediation ability of *V. spiralis*, which biodegrades, biotransforms and bioaccumulate heavy metals and others polluants.

The plant biodegrades and transforms some pollutants that accumulate as a viscous oil-film on the surface. Biotransformation of toxic compounds and their extraction from the water in a film of oil on the water surface has been shown for the version with *V. spiralis*. These oil films can be collected and removed with absorbent material (bio-absorbers, such as *Sphagnum* peat moss).

Figure 4, version 3, highlights the oily material collected in Petri dishes, from water surface was subjected to bioremediation of *V. spiralis*. It was also noted that *V. spiralis* has a darker color after bioaccumulation of pollutants. After only 2 weeks of bioremediation process with *V. spiralis,* it can be seen in version 2 - sample of water from the bund as well as version no. 3 sample of the stream, the transparency of water, after being "purified" by *V. spiralis*, comparing with blank.

From present experimental results, it has been found that *V. spiralis* has a very important role in the bioremediation of wastewater pollution with various toxic compounds and heavy metals and is recommended for use in micro ecosystems of constructed wetlands, from Central European and Eastern areas. The species *V. spiralis* has a high capacity of adaptation to the polluted aquatic environments and it is recommended to be used for bioremediation and ecological reconstruction, especially for heavy metal phytoextraction plan (Figure 5). Yield of these species is influenced by temperature and varies from 100% to 60 % (Masi et al 2002) and 76% from an experimental study (Sim et al 2007).

Table 1

Heavy metals in polluted waters from waste landfill area in Somârd, on 05/11/2011

Parameters analysed	*Measure unit*	*Results from stream*	*Results from bund*	*Standard values Ord. 161/2006 Quality class 5*	*Used method standard*
pH	pH unit.	4.5	4.3	6,5-8,5	SR ISO 10523
Lead	µg L^{-1}	25	38	>25	STAS 8637-79
Cadmium	µg L^{-1}	11	9.4	>5	STAS 6953/81
Zinc	µg L^{-1}	425	472	>200	STAS 7852-80

Table 2

Heavy metals in water samples from creek downstream of waste landfill Somârd, after three weeks phytoextraction (04-26/05/2012) with *L. minor* and *V. spiralis*

Parameters analysed	*Measure unit*	*Results obained*			*Maximum values allowed by Ord. 161/2006*				
		Before phytoextraction	*After phytoextraction*						
			L. minor	*V. spiralis*	1*	2*	3*	4*	5*
Lead	µg L^{-1}	25	12	24	5	10	25	50	>50
Cadmium	µg L^{-1}	11	6.4	8.1	0.5	1	2	5	>5
Zinc	µg L^{-1}	425	278	402	100	200	500	1000	>1000
pH		4.3			6.5-8.5				

*Class of water quality

Table 3

Heavy metals in water samples from the bund of waste landfill Somârd after three weeks phytoextraction (on 04-26/05/2012) with *L. minor* and *V. spiralis*

Parameters analysed	*Measure unit*	*Results obained*			*Maximum values allowed by Ord. 161/2006*				
		Before phytoextraction	*After phytoextraction*						
			L. minor	*V. spiralis*	1*	2*	3*	4*	5*
Lead	µg L^{-1}	38	23	35	5	10	25	50	>50
Cadmium	µg L^{-1}	9.4	7.1	8.9	0.5	1	2	5	>5
Zinc	µg L^{-1}	472	310	421	100	200	500	1000	>1000
pH		4.3			6.5-8.5				

*Class of water quality

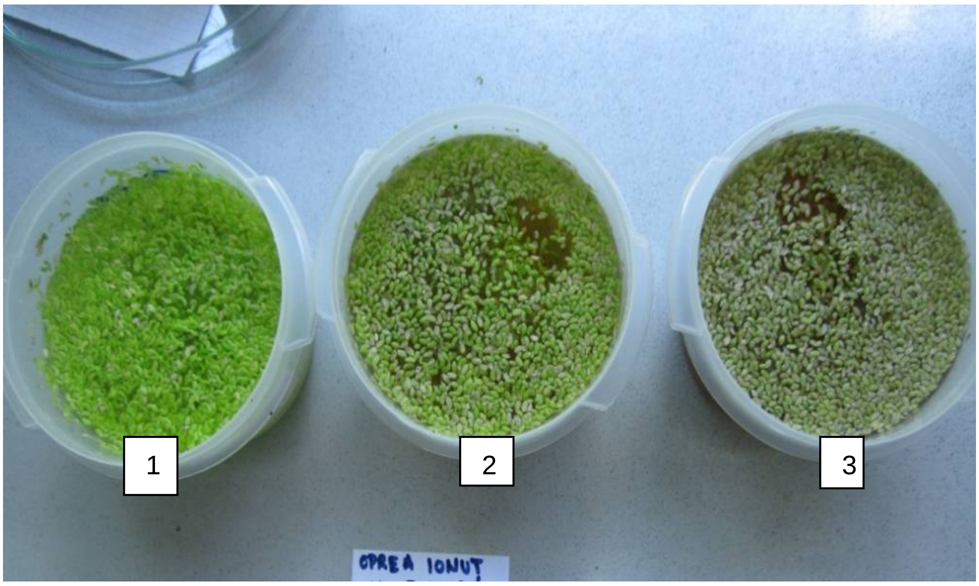

Figure 1. Biomonitoring with *L. minor*, in water from waste landfills Somârd Mediaş.
1 = blank, 2 = water from bund, 3 = water from stream, near the bund (05/04/2012).

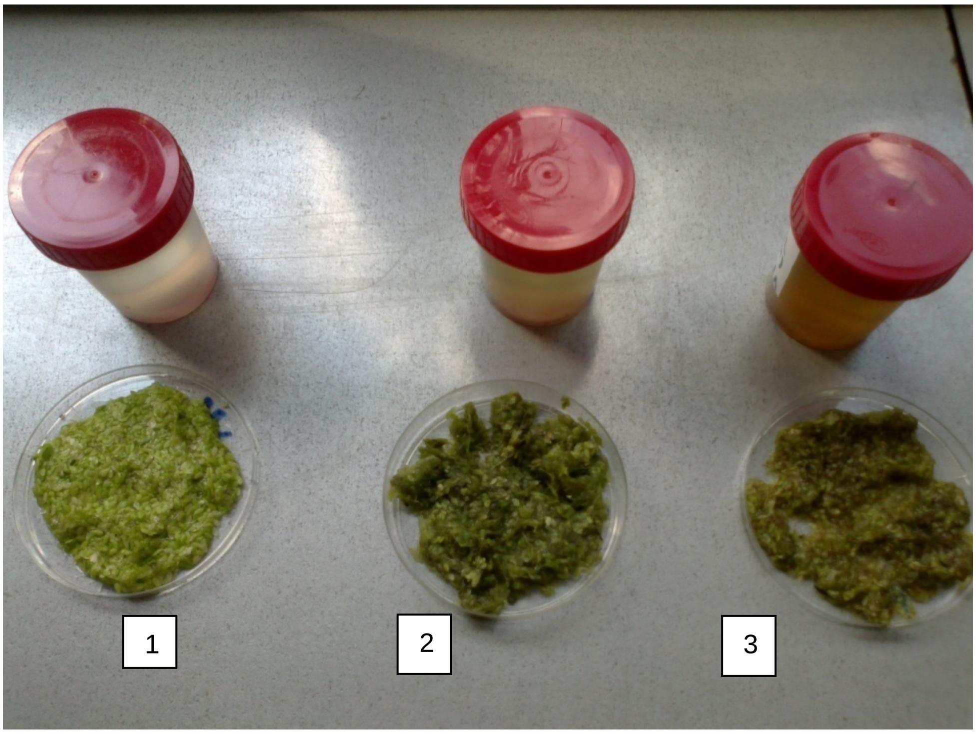

Figure 2. The highlighting effect of phytoextraction pollutants with *L. minor* from samples came of the waste dump from Mediaş Somârd. 1 = blank, 2 = water from bund, 3 = water from stream, near the bund (10/04/2012).

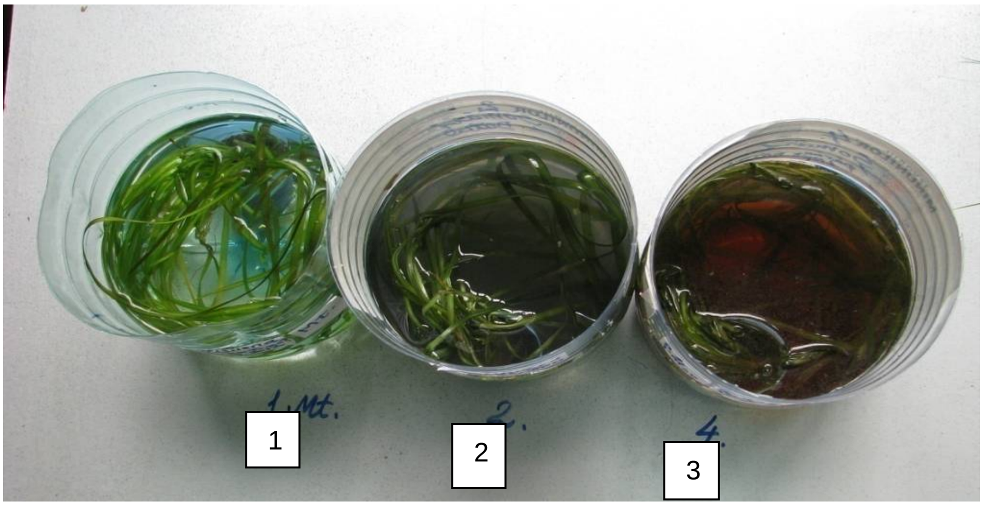

Figure 3. Bioremediation with *V. spiralis*, in polluted water from waste landfils Somârd, Mediaş (18/05/2012). 1 = blank, 2 = water from bund, 3 = water from stream.

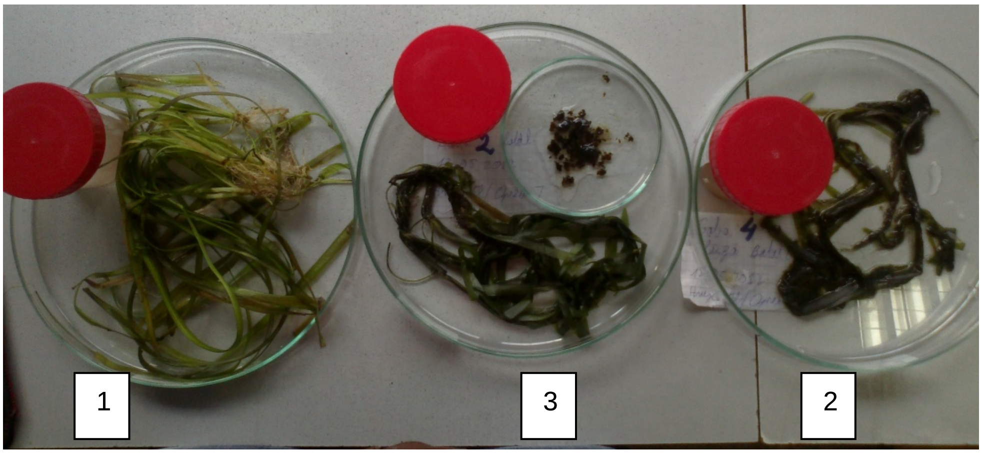

Figure 4. Bioremediation by phytoextraction and decontamination with *V. spiralis*, in polluted water from waste dump landfils Somârd Mediaş (18/05/2012). 1 = blank, 2 = water from bund, 3 = water from stream.

Figure 5. Bioremediation by phytoextraction plan and decontamination with *V. spiralis*, in polluted water from the waste dump landfils Somârd Mediaş (26/05/2012). 1 = blank, 2 = water from bund, 3 = water from stream.

Conclusions. The solution presented shows a biotechnology of waste water biological treatment from municipal landfills waste of hilly lands. The studies and laboratory experiments revealed that *L. m.* and *V. spiralis* are recommended for bioremediation as a decontamination method of the polluted area: municipal landfill waste Somârd platform-Mediaş, Sibiu county. After biomonitoring and the analysis (performed with laboratory equipment) was established that the river water is not more polluted than the bund of landfill waste. This means that infiltration occurs from landfills in the river near the ramp.

The biomonitoring was performed in the laboratory of biotechnology by *L. minor* which was clearly affected by toxic pollutants. Biotransformation of some toxic contaminants and their removal from the water in a film of oil on the water surface, has been shown for *V. spiralis* case. These oil-films can be collected and removed with absorbent material. This study states that *L. minor* and *V. spiralis* are important species for use in constructed wetland complex for bioremediation, biological treatment of polluted water and ecological reconstruction.

The research highlights the possibility of using *L. minor* and *V. spiralis* species successful in the treatment of type systems constructed wetlands from Central European and Eastern areas for improvement of wastewater treatment process.

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