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A constructed wetland

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I. Introduction

A constructed wetland is, in brief, a water treatment facility. Duplicating the processes occurring in natural wetlands, constructed wetlands are more complex, integrated systems in which water, plants, animals, microorganisms and the environment interact to improve water quality. In local water reservoirs, especially in the countryside, excessive pollution occurs frequently, in particular microbiologic pollution, which is most often a result of poorly safeguarded water protection areas. Agricultural activities can be the cause of increased content of nitrates, pesticide residue and microbiologic pollution. The existing technological solutions (e.g. membrane and absorption filters) are too expensive and difficult to manage in case of small water supply systems. Commonly used chlorination or ozonization do not remove harmful nitrates. Also, nitrates cannot be removed by adsorption agents (activated carbon, quartz sinter, diatomaceous earth, etc.), but they can be removed by reverse osmosis or chemically (ionic exchangers, etc.). Constructed wetlands (CW) are expected to provide a certain solution to all above-mentioned problems (Istenič and other, 2009).

Picture 1. Constructed wetland as a water treatment facility (Limnos arhiv, 2009).

II. Constructed wetland and ecoremediation

Ecoremediation methods include different bioremediation and phytoremediation methods. These are processes by which living organisms are used to degrade or transform hazardous organic contaminants and remediate contaminated soil, sediments, surface water or underground water.

All across Europe underground water sources, especially small supplies/wells, are contaminated with microorganisms, nitrogen, phosphorus, heavy metals, and pesticides. In the project the methods will be placed in all partners states having problems with drinking water. One of main reasons for pollution is still intensive agriculture activity. The main problem in newly independed states is microbiological contamination of drinking water due to decaying infrastructure e.g. water treatment systems that are no longer functioning properly and prohibitive cost of chlorination and other conventional drinking water treatment processes.

The problem with conventional drinking water treatment such as chlorination and ozonization is possibility to change chemical water structure. Chlorinating water loaded with organic matter causes carcinogenic AOX compounds. Also with ozonization could be formed organic chlorides and bromide ion is oxidized to bromatic ion. All these technologies are very complicated and expensive and for small communities with less than 500 residents, out of reach (Istenič, D., L. Oblak, 2009)..

With ecoremediation methods (ERM), which combine bioremediations, phytoremediations and mycoremediations is possible to remove most of pollutants in drinking water. ERM technologies are use of natural, co-natural and artificial ecosystems for protection of nature, space and environment. Those ecosystems have strong buffer, purification and biodiversity capacities, and they are able to assist by neutralisation, decomposition of wasted waters, lands and air form different pollution sources (agriculture, tourist facilities, industry, landfill sites, and settlements). With relatively low costs we can achieve relatively high efficiency in protecting environment, drinking water sources, underground water, streams, rivers, lakes and see. Technology is most appropriate in rural areas with spread settlements. One of very often used and efficiency ERM technology for cleaning waste waters from different sources are constructed wetlands (CW). CW imitates the self-cleaning ability of nature for the treatment of polluted waters. The system consists of several successive beds isolated with foil and filled with substrate. Advantage of using CW is their simple technology, reliability and low maintenance costs. World wide they are used mostly for cleaning sewage waste waters. Efficiencies of removing nitrogen in different forms (nitrites, nitrates, and ammonia), heavy metals, pathogens and also pesticides are very high. All this cleaning capabilities could be used for conditioning of drinking water or to reach underground water from freshwaters (lakes, rivers). While in nowadays exists a few systems of CW for reaching underground water, CW for conditioning drinking water are relatively scientific novelty.

With ERM methods we can revitalise and return multipurpose role to a regulated streams and ponds which have been regulated in the past with an aim to fulfil only one role like fast drainage and outflow of water from the surrounding area or only retention of water. The ERM possibilities are in (1) introduction of vegetative buffer zones and filter strips in streams and drainage ditches; (2) installation of grassed buffer strips, reed beds and constructed wetlands to prevent direct polluted outflow into the watercourse; (3) restoration of existing wetlands, etc. Additional measures are possible in (4) assurance of environmental flow in the rivers and (5) return of heterogeneous and dynamic water course with gravel deposits, barrages, pools, rapids, meanders, etc.

Selection of the particular measure depends on the objective to be attained which can be moderation of flow for water retention or flood prevention, purification with sedimentation or oxygenation, habitat creation, prevention of evaporation and warming, erosion prevention, etc. The advantage of ERM methods is in the possibility to offer complex solution, for example combining increasement of biodiversity, water purification and water retention in one system.

The most wide spread artificial wetlands are constructed wetlands for domestic water treatment. They are used all over the world. Their advantage is simple technology and the possibility of total nitrogen removal with simultaneous course of nitrification and denitrification (Vrhovešk, Vovk, 2009).

CW enable also the reduction of bacterial and viral pathogens, metals and pesticides. Istenič (2009) reported about successful reduction of viral concentration from municipal wastewater mention the reduction of coliform bacteria for two size classes in constructed wetlands as well as in sand filters. The efficiency of bacterial reduction depends on the presence of plants, filtering media and construction conditions. Adsorption, desorption and inactivation also play an important role in reduction of microbial population. They depend on specific characteristics of CW, substrates and local clime. Studies show that bacteria in wastewater can bind directly on the surface of plants' roots (Istenič and other, 2009).

III. Drinking water conditioning with ecoremediation (ERM)

Ecoremediation methods include different bioremediation and phytoremediation methods. These are processes by which living organisms are used to degrade or transform hazardous organic contaminants and remediate contaminated soil, sediments, surface water or underground water (Vrhovšek, Vovk Korže, 2009).

All across Europe underground water sources, especially small supplies/wells, are contaminated with microorganisms, nitrogen, phosphorus, heavy metals, and pesticides. Contaminated drinking water can be a consequence of agriculture, inappropriate deposition of waste, traffic, absent or leaking sewage system, etc. The most frequent contaminants of drinking water are coliform bacteria, nitrates, pesticides and their residues and heavy metals, all of which affect human health. In spite of reduced use of pesticides in agriculture their concentrations in drinking water will remain high for some time as majority of pesticides need long time to break down (Istenič and other 2009).

According to drinking water pollution in Slovenia the most problematic are small local water supply systems particularly in agricultural areas. Small water supply systems are defined as systems which supply between 50 and 1000 people. Water wells which supply less than 50 people are excluded. The most frequent pollutants are microbes from faecal origin, with which drinking water becomes polluted when in contact with human or animal faeces or domestic waste water. The most affected are small supply systems which supply between 50 and 500 inhabitants. In these systems according to national monitoring of drinking water every second sample is microbiologically polluted (Vovk Korže, Vrhovšek, 2010).

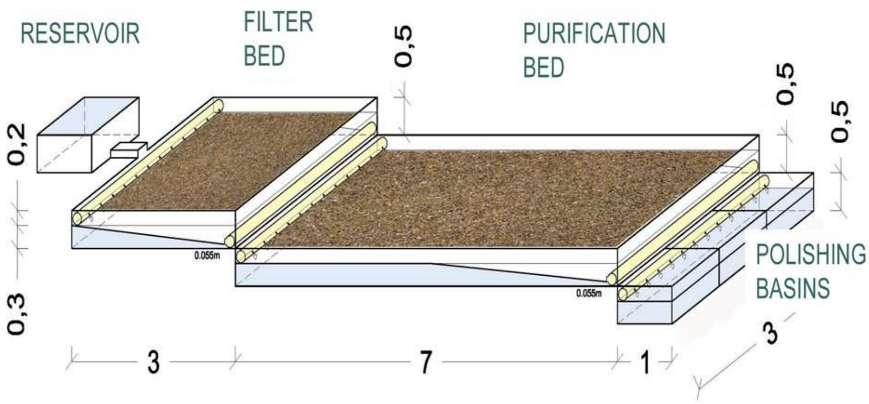
Conventional methods which enable effective elimination of all present pollutants are often too expensive form small water supply systems. In conventional methods for drinking water purification, bigger particles are removed through sand filters, small particles, microbes and pesticide residues through membrane and adsorption filters, and nitrates through reverse osmosis or chemically with ion exchange colons. The amount of microorganisms in water can be reduced also with chlorination and ozonization. Unpleasant side consequence of chlorination and ozonization is the formation of unwished chemical side products of disinfection (Istenič and other).

Picture 2. Phytoremediation as a process in CW (Limnos, arhiv, 2009).

The problem with conventional drinking water treatment such as chlorination and ozonization is possibility to change chemical water structure. Chlorinating water loaded with organic matter causes carcinogenic AOX compounds. Also with ozonization could be formed organic chlorides and bromide ion is oxidized to bromatic ion. All these technologies are very complicated and expensive and for small communities with less than 500 residents, out of reach (Poročilo, 2007).

With ecoremediation methods (ERM), which combine bioremediations, phytoremediations and mycoremediations is possible to remove most of pollutants in drinking water. ERM technologies are use of natural, co-natural and artificial ecosystems for protection of nature, space and environment. Those ecosystems have strong buffer, purification and biodiversity capacities, and they are able to assist by neutralisation, decomposition of wasted waters, lands and air form different pollution sources (agriculture, tourist facilities, industry, landfill sites, and settlements). With relatively low costs we can achieve relatively high efficiency in protecting environment, drinking water sources, underground water, streams, rivers, lakes and see. Technology is most appropriate in rural areas with spread settlements. One of very often used and efficiency ERM technology for cleaning waste waters from different sources are constructed wetlands (CW). CW imitates the self-cleaning ability of nature for the treatment of polluted waters. The system consists of several successive beds isolated with foil and filled with substrate. Advantage of using CW is their simple technology, reliability and low maintenance costs. World wide they are used mostly for cleaning sewage waste waters. Efficiencies of removing nitrogen in different forms (nitrites, nitrates, and ammonia), heavy metals, pathogens and also pesticides are very high. All this cleaning capabilities could be used for conditioning of drinking water or to reach underground water from freshwaters (lakes, rivers). While in nowadays exists a few systems of CW for reaching underground water, CW for conditioning drinking water are relatively scientific novelty.

Scheme of pilot constructed wetland *(Vrhovšek, Vovk Korže, 2009: Ecoremediation)*



<u>Basic morphological and anatomical structure of the plants</u>

Leaves
Stems
- Photosynthesis
- Oxygen production
- Accumulation of materials (nutrients, toxic matter)

Roots
- Aerenhim
- Gas transport
- Creation of O_2 area

<u>Plants in the ecosystem</u>

Plants have a strong influence on physical – chemical factors of water environment. Beside direct influence due to photosynthesis and cell respiration, they influence also indirectly because of temperature increasement.

- Light penetration
- Temperature, O_2
- Evapotranspiration
- CO_2, pH
- Conductivity – salinity – redox potential.

Influence on chemical parameters

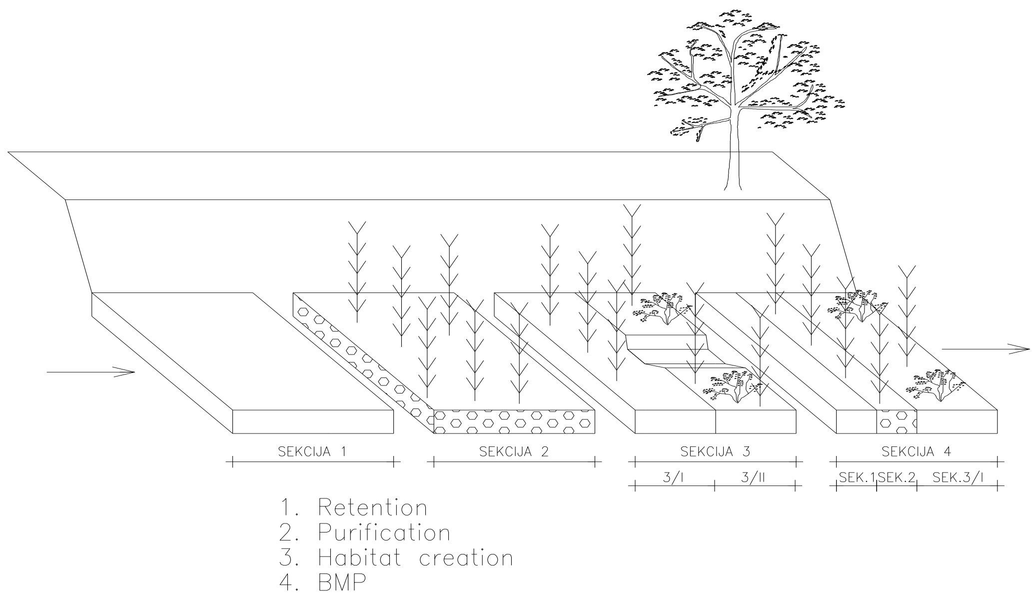
- Nutrient uptake and accumulation
- Toxic substances – pollutants uptake and accumulation
- Nitrification – denitrification.

Influence on the biology (other organisms)

- Phytoplankton, periphyton,
- Zooplankton, zoobentos,
- Other macrophytes
- Fishes
- Bacteria and their processes.

Landscape outlook

With the selection of the plants and the way of recultivation and revitalisation we can essentially influence on landscape outlook. However this should not be to the damage of the new ecosystem stability.



Picture 4. CW Shema (Vrhovšek, Vovk Korže, 2009)

The main problem in newly independed states is microbiological contamination of drinking water due to decaying infrastructure e.g. water treatment systems that are no longer functioning properly and prohibitive cost of chlorination and other conventional drinking water treatment processes.

IV. Constructed wetlands for communal sewage water

Constructed wetlands for communal sewage water are basically built of three or four beds. Constructed wetlands, especially those with vertical stream, are due to their big capacity to eliminate the excess of nutrients (phosphorus and nitrogen) and to eliminate pathogenic microorganisms (often as much as 99 %) have already been recognized as environmental technology with the function of tertial purifying. That is why they are suitable purifying technology for sensitive and water protective areas. Where another technology is being used that does not include tertial phase, it is sensible to put up a smaller constructed wetland, which will in this case do the function of tertial phase.

Picture 5. CW by private house (Limnos arhiv, 2009).

Tourist farms – functioning principle of constructed wetlands

Tourist farms are mostly situated outside of regulated communal infrastructures; therefore problems with purifying sewage water must be solved similar as with individual houses, at the location. Different to the sewage waters from individual houses at tourist farms is the seasonal dynamics; the usage of water in different periods (seasons, months, weeks) varies a lot. Due to the characteristics of retaining water through the whole system, constructed wetlands have proven to be one of the mot suitable systems for purifying sewage water.

Tourist settings (autocamps) – functioning principle of constructed wetlands

Where at tourist farms we mentioned dynamics of water usage and therefore the formation of sewage water, then dynamics of sewage water in auto camps is positively the largest. Here we deal with seasonal dynamics (most auto camps work only during the summer) as well as with daily (the largest water usage in the morning and in the evening). This oscillation need to be considered a lot when constructed wetlands are projected and formed, as only this way the water can be purified to the level, prescript by law.

Smaller settlements – functional principle of constructed wetlands

In Slovenia there are many cloddy, joint settlements, where cesspits are still being used. These are usually permeable and this way water can uncontrolled flow into surroundings. Communal sewage water is mostly loaded with organic substances, nitrogen compounds and phosphates as well as with faecal bacteria. Solving problems of purifying sewage communal water from smaller settlements is by using constructed wetlands even easier, as it enables solving of only a part of settlement, whereas the rest of the parts can join later, without any greater additional interventions. In case of expansure of settlements a part of the constructed wetland is simply added to the construction, whereas the original constructed wetland continues to perform its function undisturbed.

Picture 6. CW for a settlement (A. Brilej, 2011)

Constructed wetlands for purifying industrial water - functional principle of constructed wetlands

Due to large puffer, retaining and selfcleaning capacities, constructed wetlands are suitable as well for purifying sewage water from different industrial branches. With processes of mineralization, absorption and sedimentation constructed wetlands also successfully remove heavy metals, anionic elements, KPK, BPK_5 etc. At designing constructed wetlands it is necessary to consider specific polluters that are present in industrial sewage water in specific technological and production processes. Constructed wetlands are usually made of 3 to 4 beds with horizontal – vertical undersurface water stream, filled with gravel of different dimensions and planted with plants that like moisture.

Constructed wetlands for purifying strained water from deposits of communal waste – functional principles

Strained waters are due to their structure and toxicity considered as specific waste waters, and purifying them is difficult and therefore seriously endangers the quality of underground and surface waters. Problems considering strained waters can with widening of deposits get bigger

and bigger and can stay as well after the deposit is closed. Therefore the tendency in the world is to restrict widening of deposits or to sanitise active deposits as quickly as possible.
For purifying strained waters from dumping grounds constructed wetlands with 4 beds and horizontal - vertical undersurface water stream are being used.

Constructed wetland for treatment of landfill leachate from a dump at Ljutomer, Slovenia

Constructed wetlands for purifying strained water from highways – principles

Endangering water sources because of the traffic is very specific and can be divided into constant pollution as the result of constant traffic and to catastrophical pollution as the result of car accidents, overflow of harmful substances etc. Rainwater that is being rinsed from polluted roadways, most of the times flows off directly into nature and is dangerously loads its selfcleaning capacity.

Constructed wetlands for conditioning polluted water sources – functional principles

Constructed wetland for conditioning drinking water is a special type of constructed wetland, meant for reducing polluters from drinking water. Amongst polluters of drinking water in Slovenia is most frequently microbiologic pollution, but also its boundary value of pesticides and nitrates is exceeded. Using constructed wetlands for conditioning drinking water we want to improve the quality of drinking water and to reduce the costs of further purifying, where it should be needed.

Constructed wetland for tertial purifying - functional principles

Constructed wetlands, especially those with vertical stream, are due to their big capacity to eliminate the excess of nutrients (phosphorus and nitrogen) and to eliminate pathogenic microorganisms (often as much as 99 %) have already been recognized as environmental technology with the function of tertial purifying. That is why they are suitable purifying technology for sensitive and water protective areas. Where another technology is being used that does not include tertial phase, it is sensible to put up a smaller constructed wetland, which will in this case do the function of tertial phase.

MUNICIPAL WASTE WATER (SEWAGE)

No. of people connected to the system 250

Parameter		jul 2008	oct 2008	Limit value*
Suspended solids [mg/l]	Inflow	35	29	
	Outflow	10	10	
COD [mg/l]	Inflow	200	190	
	Outflow	30	30	150
BOD5 [mg/l]	Inflow	70	50	
	Outflow	3	3	30

Evidence No. 13/56-08/P

No. of people connected to the system 500

Parameter		sept 2008	oct 2008	Limit value*
COD [mg/l]	Inflow	143	448	
	Outflow	24	20	150
BOD5 [mg/l]	Inflow	----	----	
	Outflow	3,4	2	30

Evidence No. 13/56-08/P

V. Conclusion

Slovenia is bound to adapt its environmental status to the requirements of the European Union. On of Slovenia's environmental conservation goal is to preserve unique natural heritage and diversity of Slovenia's flora and fauna in the frame of Natura 2002 program. The objectives in the field of water are to increase the percentage of treated wastewaters. This includes point and non-point pollution sources. It is obvious that it would be difficult to ensure the setting up of expensive high technology solutions. Application of ERM methods offers the opportunity of fast adaptations to new legislative requirements. At the same time it represents an economically viable solution in less developed regions and for different pollution sources (agriculture, landfill leachate, motorway run-off) where treatment by devices that require complex operating processes and a constant source of energy is virtually impossible.

Taking into account the development of tourism, the size of communities, the present state of wastewater treatment systems, specific characteristics and economic situation of individual geographic areas and favourable climate conditions, the proposed technology could be applied in:

- areas of low population density where local communities do not have wastewater treatment systems;
- protected areas (natural parks, drinking water source areas);
- areas of diffuse pollution sources, such us landfills where leachate is not treated and its pollution potential is uncontrolled;
- Carst areas where underground water pollution represents a serious threat to the population due to poor self-cleaning capacity of underground water.

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