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THE PHYLOSOPHY AND APPLICABILITY OF ECOREMEDIATIONS FOR THE PROTECTION OF WATER ECOSYSTEMS

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Ecoremediation – following nature.

The phylosophy and applicability of ecoremediations for the protection of water ecosystems

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ABSTRACT: The problem of accelerated eutrophication of the water ecosystems has not been appreciated proportionally to the development of human society today. Accelerated or fast eutrophication is detected destiny in majority of ecosystems today, mainly due to adverse human impact. This paper aims to introduce ERM methods in treating the problems arising from increased total capacity and saprobity and also accelerated eutrophication. In this way the broadness and importance of ERM as an ecosystem service for the water protection should be emphasized. The basic characteristics of ERM are its high buffer and self-protective capacities, and preservation of natural habitats and biological diversity. ERM represents the 're-turning to nature' approach aiming to preserve or re-establish the natural balance of the ecosystems, but also a human endeavor that enables new jobs and by-side activities important for economic and social development of the human society.

KEY WORDS: ecoremediation, eutrophication, water quality, algal blooms, sustainable development

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1 Introduction

Humanity has emerged as a major force in the operation of the biosphere, with a significant imprint on the Earth System, challenging social–ecological resilience. This new situation calls for a fundamental shift in perspectives, world views, and institutions. Human development and progress must be reconnected to the capacity of the biosphere and essential ecosystem services to be sustained (Folke at al. 2011). The issue at stake is broader than climate change. It is about a whole spectrum of global environmental changes that interplay with interdependent and rapidly globalizing human societies. A key challenge for humanity in this new situation is to understand its role in the Earth System, start accounting for and governing natural capital and actively shape development in tune with the biosphere (Rockström et al. 2009). This is a new situation and it calls for new perspectives and paradigms on human development and progress-reconnecting to the biosphere and becoming active stewards of the Earth System as a whole.

Water ecosystems in this regard are particularly vulnerable. Immense pressures resulting from abstractions of surface and ground waters, input of numerous polluters in vast quantities and the global climate change processes have caused accelerated eutrophication and subsequent pollution of many ecosystems. It is therefore an urgent imperative to shift the historical view on waters as a resource towards their role as a life supporting systems, or the bloodstreams of the biosphere, with people as embedded part (Hoff 2009). Indeed, the new approaches linking water and ecosystem services, like adaptive water governance, are already emerging (Pahl-Wostl et al. 2011).

The knowledge on the use of ecoremediation (ERM) methods for wastewater treatment spread quite slowly during the 1970s and the early 1980s both in Europe and North America. The development of ecosystem methods has been taking place separately and inconsistently (Griesseler Bulc and Slak 2009). There are currently thousands of constructed wetlands throughout the world, but the use of these systems for treating wastewater is a relatively new technology in most countries (Vovk Korže and Vrhovšek 2006).

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Figure 1: A constructed wetland for a domestic waste water treatement, Slovenia.

Thirty years of the research on the use of constructed wetlands as the most common ERM method for various types of wastewater (Brix 1994; Scholz et al. 2007a) has proven that the great number of early worries and negative arguments has been successfully denied. For example, it has been shown that constructed wetlands may perform well under cold climatic conditions (Mander and Jenssen 2003). Also, constructed wetlands are commonly used in countries with high population densities, such as Denmark, Belgium or the Netherlands, while the U.S. government encourages the use of simple wetlands for economical treatment of sewage from small communities of less than 5000 people (Horne 2005). The use of constructed wetlands for various industrial effluents is also becoming quite common.

Ecoremediation method in broader sense is applied by Vrhovšek (Vovk Korže and Vrhovšek 2006) more than 20 years in the countries of ex Yugoslavia. The efficiency and genuinity of this idea has forced us in a more scientific, but also phylosophical approach which, we hope, will speed-up the practical implementation of ERM (Fig 1).

2 Ecoremediation – the philosophical approach

Ecoremediation as a system for protection, sanation and remediation of the environment can be appreciated from very different stand points. Globaly it can be said that ERM is a buffer system that enables the re-establishing of the disturbed ecological balance in its natural position. As an immune system of our planet, ERM is the preventive defence that protects against the system being in a not desirable modified stage. In general, ERM is consist of abiotic and biotic elements and processes that have a role in balancing the ecosystems.

Where is the recognition of ERM as a system for protection, sanation and remediation of the environment coming from? How was the ERM as a principle of human endevour recognised?

In millions of years, the nature and ecosystems evolved exceptional defensive and self-protective capacity to safeguard themselves against sudden and powerful impacts and to remove their harmful consequences.

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Figure 2: A natural wetland – reed belt along river and channels in Vojvodina, Serbia.

Through its history, the nature has experienced many catastrophes and survived them for this reason. Aquatic ecosystems and wetlands have a high retention capacity and could prevent flooding as well as severe and specific physical, chemical and toxic pollution. These ecosystems neutralize toxins and efficiently reduce various pathogenic organisms. Moreover, they increase biodiversity and contribute to many so far unknown or hardly known processes maintaining the equilibrium on our planet. Ecoremediation comprises systems and processes which function in natural and artificial ecosystems; it protects and restores the environment. It is comparatively inexpensive and highly efficient in protection of water resources, streams, rivers, lakes, groundwater and the sea. The basic characteristics of ERM, which can be utilized and improved, are its high buffer and self-protective capacities, and preservation of natural habitats and biological diversity (Vovk Korže and Vrhovšek 2006).

By observing the different ecosystem's ability for 'self reparation' after natural or anthropogenic impacts, the ERM system was recognized. Over the question *How has a certain ecosystem »learned« to survive and re-establish the functional relationships,* the basic ERM field is discovered. And, due to the complexity of ecosystems' properties, the term *ERM system* is used rather than *ERM methods.* ERM principles are the constitutional part of ecosystems' functioning since the begining of life on our planet. In the time scale of these global processes man is nothing but a tiny part. Nevertheless, on the scale of the impact on planet Earth, man is a very important and detrimental element (Rockström et al. 2009). Our attitude towards the planet has become a question of its survival. In this constalation, ERM becomes a survival phylosophy.

Natural selection of new solutions for ecosystem balance maintenance unequivocally leads us to ERM concept which incorporates: research, new technology development and education that together represent the new philosophical approach in line with the global paradigm of sustainable development.

3 The link between ecoremediation and eutrophication

The fact that biologists have often neglected the importance of abiotic factors has contributed to insufficient appreciation of the terms *oligotrophy* and *eutrophy* of the water systems. Dividing of water ecosystems to *oligo* and *eu* trophic ones is a separation to long and short living. Overall ecosystem elements that determine and define the organic matter quantity in the water are termed the *total capacity* of that water ecosystem. The total capacity is a whole chain of parameters whose combination (in a form of specific physic-chemical set-up) will guide the course of the eutrophication. Very specific elements which are part of, or influence the biomass synthesis in water ecosystems are essential for the primary production. Disproportion or lack of one element is therefore a relevant limiting factor.

One of the deadliest disturbances of water ecosystems is the accelerated production of biomass what leads to significant changes in natural balance and relations. These changes eventually lead to accelerated eutrophication which significantly shortens the life span of that particular water ecosystem. If there are no contra measures, or remediation measures, the consequences of increased saprobity get apparent and unpredictable. Due to constant increase of the total capacity via the increased saprobity, one of the most extreme consequences – the algal bloom is most probable, when the rapid multiplication of algae results in their visible apperance on the water surface (Bellinger and Sigee 2010). Blooming cyanobacteria might be very hazardous for whole ecosystem, but specially endangered are humans supplied with drinking water produced from blooming reservoirs and lakes (Svirčev et al. 2009; Svirčev et al. 2010; Dolinaj et al. 2011).

There are numerous missinterepretations of the stated definitions in the literature, what has lead to erroneous applications of the saprobic system in detection of the water quality (review on the matter can be found in Krstić et al. 2007). In order to establish the link between ecoremediation, total capacity, saprobity and eutrophication of the water ecosystems, we present the following comments.

In a case that the water ecosystem has such a primary organic production that corresponds in the intensity to the decomposition of the total biomass, the trophy (white circle T, Fig. 3) is about the same as saprobity (black circle S, Fig. 3 – the white and the black circle are same in size). The quantity of mineral matter in this system, which is utilized in the process of photosynthesis, is nearly equal to the quantity of mineral salts produced after the degradation of organic matter of the dead primary producers and food chain members. In those systems, there is no additional organic load and the aging process corresponds to the natural eutrophication.

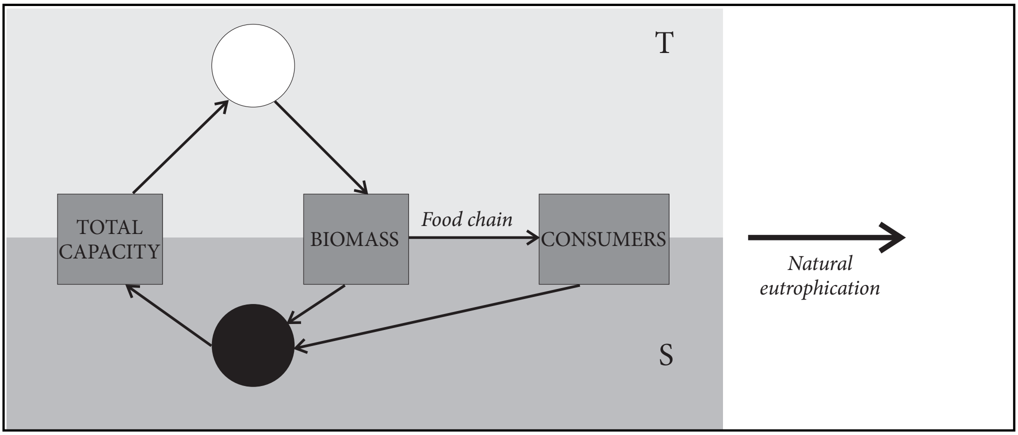

Figure 3: The elements and procceses of natural eutrophication (T – trophy; S – saprobity).

By entering of organic matter and mineral elements of whatever origin into the water ecosystem (human input or natural process), a certain amount of organic matter is decomposed, or the mineral salts are directly incorporated into the *total capacity* (Fig. 4 – the black circle is larger than the white circle). In both cases, there is an increase of the total capacity what results in increasing of the total organic production. The quantity of the newly generated biomass in the water ecosystem can no longer be attributed to the trophy, but more to the overall photosynthesis in the system, what increases the biomass of both primary producers and the food chain members (Fig. 4). Due to total biomass increase in the water body, similar amount of organic matter or equivalent amount of mineral matter enters the decomposition processes as in the case of immediate input of external matters into the system (Fig. 4). In fact, the self-purification process actually means that the water ecosystem successfully decomposes the organic matter. Nevertheless, a self-purification which will reverse the organic input on the quality and especially quantity level prior to organic load is impossible process. It is therefore recommendable to replace the term self-purification with more adequate expression,

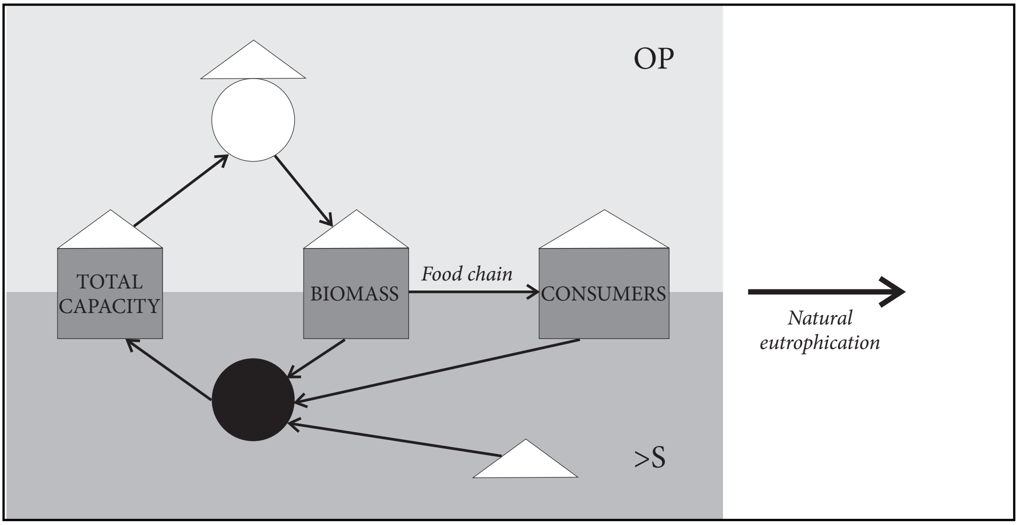

Figure 4: The elements and procceses of accelerated eutrophication (OP – organic production; S – saprobity)

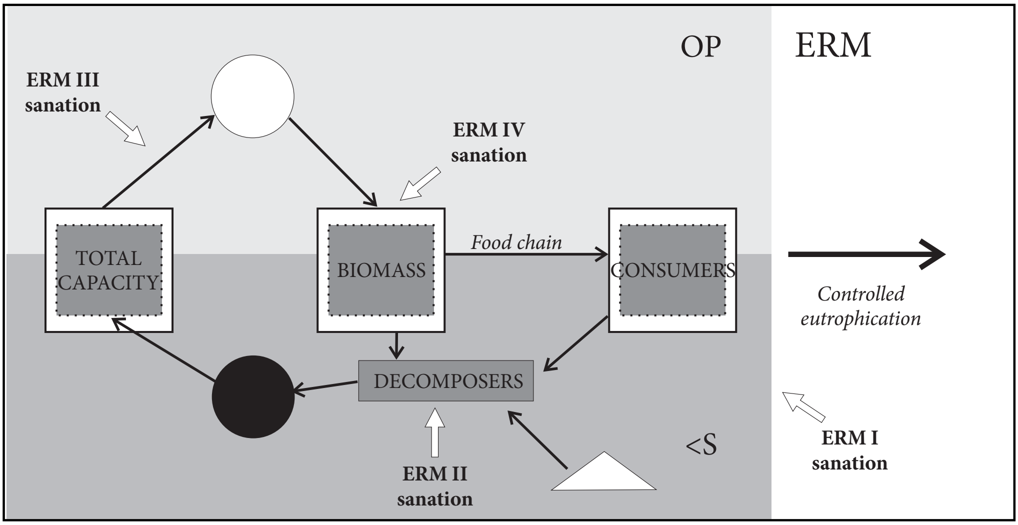

Figure 5: Ecoremediation as eutrophication menagement tecnique (OP – organic production; S – saprobity; ERM – ecoremediation).

such as 'auto-recovering'. In a case of saprobity increasing after a single or multiple incidents of organic and mineral input, there is an accelerated process of aging, or eutrophication. But, if the organic load is constantly present the water body can not be recovered and experiences rapid aging and intensive eutrophication.

Accelerated or fast eutrophication is detected reality in majority of ecosystems today, mainly due to adverse human impact. However, this process can be tackled by different activities, ERM having an especially important place. Eutrophication control can be achieved on four important levels in the functional dynamics of the ecosystems. Firstly, ERM is placed as key element in prevention, usually as channel constructed wetlands, in preventing the external influents in the ecosystem (Figure 5-I). In this case, the waterbody remains completely protected without the need of any additional purification system. But if there is an input of external compounds in the waterbody or nutrient liberation from the mud, ERM can be applied in the following three levels:

- Increasing of decomposition processes through different modes of aeration (rapids, waterfols …) in the ecosystem, completely stoping or significantly decrasing the mud formation in the same time (Figure 5-II);
- Decreasing of the total capacity of the ecosystem, usually via constructed wetlands for mud purification or re-direction (in lotic waters) and water course input (in lentic waters) via constructed wetlands aimed for purification of water's efluent (Figure 5-III);
- Planting and removing, or simply removing, of the riparian vegetation biomass only in cases when there is no disturbance in the ecosystems relations. In this way there is a decreasing in saprobity levels, but also in the total capacity of the ecosystem (Figure 5-IV).

It is important to stress that ecoremediation encompasses not only organic and mineral matter removal, but also the whole span of different pollutants. Ecoremediation methods eventually lead to overall decrease of the total ecosystem's capacity. Together with the bio-manipulation methods, ecoremediation represents a very effective system for purification of both water and soil ecosystems.

Certain processes that are functioning in the ecologically balanced systems, which might also be eutrophic ecosystems, belong to domain of 'technologies' which that system has 'implemented' in order to keep the current state. These technologies are usually seen in different aeration mehanisms, changes in system's configuration, effective biotransformation and biodegradation processes, as well as in specific microorganisms relations, vascular plants and predators. This technology of ecologically stable or 'successful' ecosystems might be called ***ecosystem technology***, while its recognition and transformation to a system of protection, revitalization and sanation of the environment are the basic elements of ERM system (Scholz et al. 2007b; Carty et al. 2008).

4 Ecoremediation – the applicative approach

ERM is used for multipurpose management of watercourses, lakes and wetlands, which enables integrated development of particular areas and contributes to the coexistence of man and nature. Therefore, the ecoremediation is among the most successful and sustainable methods of environmental protection, from the economic and ecological point of view (Vovk Korže and Vrhovšek 2006). Ecoremediation methods may reduce and avert the consequences of agricultural pollution, tourism, transport, industry, land fills and (over)population (Vovk Korže 2008; Griesseler-Bulc and Slak 2009).

Application of ecoremediation methods contributes to the quality of ecosystem resources such as food, drinking water, genetic resources, it has an effect on the regulation of climate, floods, disease and etc., and as a whole it contributes to the quality of life. Furthermore, it affects the reduction of costs for pretreatment processes (eg raw water in factories), improvement of the product quality in the field of fisheries, agriculture, and livestock, growing number of visitors in the recreational and tourist places. It also represents financially very cost effective and time-sustainable exploitation of resources, obtained from secondary ecological-remediation.

It is comparatively inexpensive and highly efficient in protection of water resources, streams, rivers, lakes, groundwater and the sea. The basic characteristics of ecoremediation, which can be utilized and improved, are its high buffer and self-protective capacities, and preservation of natural habitats and biological diversity (Vovk Korže 2008; Griesseler-Bulc and Slak 2009).

In its essence, ecoremediation represents the ‘returning to nature’ approach aiming to preserve or re-establish the natural balance of the ecosystems, but also a human endevour that enables new jobs and by-side activities important for economic and social (sustainable) development of the human society (Vovk Korže 2008; Griesseler-Bulc and Slak 2009). For example, decontamination of polluted media and the creation of a healthy environment also provide an opportunity for eco-tourism development in local communities, what contributes to their socio-economic prosperity. Successfully implemented ecoremediation system results in profit increase, which further leads to creation of new jobs and socio-economic development of the local communities.

In the last 30 years, several ecoremediation systems were installed in Slovenia: constructed wetlands, waste stabilization ponds (surface flow wetlands), vegetated drainage ditches, ecoremediation for restorations of landfill sites, and river revitalization. Constructed wetlands (CWs) were installed to treat sewage, industrial wastewater, landfill leachate, conditioning of drinking water, and for highway runoff treatment. Excavations were sealed with plastic membranes, clay, or with combination of both. The medium was mostly a mixture of different materials (peat, soil, sand, gravel), varying in grain size and proportion. Different wetland species were used such as *Phragmites australis*, *Carex gracilis*, *Typha latifolia*, *Schoenoplectus lacustris*, most often *Juncus effusus* and *Juncus inflexus*. The initial results showed similar values of average removal efficiency of chemical oxygen demand (COD), biological oxygen demand (BOD), ammonia, and total P (in sewage treatment: 86%, 89%, 85%, and 87% respectively) (Griesseler-Bulc and Slak 2009). Preliminary results of CWs that were used for water-conditioning at drinking water wells polluted with pesticides, herbicides, and pathogens, showed that removal efficiency of *Escherichia coli* was from 130–500 bacteria to 0–3 bacteria per 100 mL, while pesticide removal showed that bentazon was reduced from 1.8 mg/L to 0.06 mg/L, metholaclor from 0.73 to < 0.05 mg/L, and terbutylazine from 0.53 to < 0.03 mg/L (Griesseler-Bulc and Slak 2009). A pilot CW system that was set up for highway runoff in Slovenia showed that removal efficiency was 69% for suspended solids, 97% for settleable solids, 51% for COD, 11% for BOD_5, and 80% for Fe. Heavy metals such as Cu, Zn, Cd, Ni, and Pb were reduced in the system more than 90% (Griesseler-Bulc and Slak 2009).

For purifying raw water in a hypertrophic front of Lake Taihu, an aquatic vegetable bed (AVB) was implemented with local floating perennial aquatic plant *Ipomoea aquatica*. The results have shown that removal efficiency of *Mycrocystis* sp. in AVB averages 78%, while the removal rate of total microcystin-RR and microcystin-LR averages 63% and 66,7% respectively (Song et al. 2009). Very similar results were obtained by Li et al. (2010) after implementation of integrated ecological floating-bed. In all these cases the ERM approach and principles are very important which are fully natural and in coordinance with natural technologies. Defined as such, the ERM system means a constant search for the new forms of ecosystem technologies (Scholz et al. 2007b; Carty et al. 2008).

5 Conclusion

Humanity has emerged as a major force in the operation of the biosphere, with a significant imprint on the Earth System. This new situation calls for a fundamental shift in perspectives and world views, reconnecting human development and progress to the biosphere and becoming active stewards of our role in the Earth System. The current mental disconnect of human progress and economic growth from the fundamental interactions with the biosphere has altered the long-term capacity of natural resources to sustain human developments. Water ecosystems in this regard are particularly vulnerable.

Ecoremediations (ERM) is used for multipurpose management of watercourses, lakes and wetlands, which enables integrated development of particular areas and contributes to the coexistence of man and nature. Therefore, the ERM is among the most successful and sustainable methods of environmental protection, from the economic and ecological point of view. ERM as a system for protection, sanation and remediation of the environment can be appreciated from very different stand points. Globaly, ERM is a buffer system that enables the re-establishing of the disturbed ecological balance in its original position. As an »immune system« of our planet, ERM is the preventive defence that protects against the system being in not desirable modified stage. Using ERM methods, eutrophication control can be achieved on four important levels in the functional dynamics of the ecosystems. All of the methods are based on decreasing the total capacity and maintaining low saprobic level in water ecosystems.

Successfully implemented ERM system results in profit increase, which further leads to creation of new jobs and socio-economic development of the local communities.

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7 References

Bellinger, E. G. and Sigee, D. C. 2010: Freshwater algae – identification and use as bioindicators. Chichester.

Brix, H. 1994: Use of constructed wetlands in water pollution control: Historical development, present status, and future perspectives. Water science and technology 30-8. DOI: http://dx.doi.org/0273-1223(95)00002-X

Carty, A., Scholz, M., Heal, K,. Gouriveau, F., Mustafa, A. 2008: The universal design, operation and maintenance guidelines for farm constructed wetlands (FCW) in temperate climates. Bioresource technology 99-15. DOI: http://dx.doi.org/10.1016/j.biortech.2008.01.045

Dolinaj, D., Marković, S. B., Svirčev, Z., Jovanović, M., Savić, S., Lazić, L., Djordjević, J. 2011. Borkoviac reservoir. Acta Geographica Slovenica 51-1. DOI: http://dx.doi.org/10.3986/AGS51103

Folke, C., Jansson, A., Rockstrom, J. Olsson, P., Carpenter, S., Chapin, S., Crepin, A. S., Daily, G., Danell, K., Ebbesson, J., Elmqvist, T., Galaz, V., Moberg, F., Nilsson, M., Osterblom, H., Ostrom, E., Persson, A., Peterson, G., Polasky, S., Steffen, W., Walker, B., Westley, F. 2011: Reconnecting to the Biosphere. AMBIO 40. DOI: http://dx.doi.org/10.1007/s13280-011-0184-y

Griesseler-Bulc,T., Sajn-Slak, A. 2009: Ecoremediation – a new concept in multifunctional ecosystem tehnologies for environmental protection. Desalination 246/1-3. DOI: http://dx.doi.org/10.1016/j.desal.2008.03.039

Hoff, H. 2009: Global water resources and their management. Current opinion in environmental management 1. DOI: http://dx.doi.org/10.1016/j.cosust.2009.10.001

Horne, A., Fleming-Singer, M. 2005: Phytoremediation using constructed treatment wetlands: an overview. Bioremediation of aquatic and terrestrial ecosystem.

Krstić, S., Svirčev, Z., Levkov, Z., Nakov, T. 2007: Selecting appropriate bioindicator regarding the WFD guidelines for freshwaters – a Macedonian experience. International journal on algae 9-1. DOI: http://dx.doi.org/10.1615/InterJAlgae.v9.i1.30

Li, X. N., Song, H. L., Li, W., Lua, X. W., Nishimurab O. 2010: An integrated ecological floating-bed employing plant, freshwater clam and biofilm carrier for purification of eutrophic water. Ecological engineering 36. DOI: http://dx.doi.org/10.1016/j.ecoleng.2009.11.004

Mander, Ü., Jenssen, P. 2003: Constructed wetlands for wastewater treatment in cold climates. Southampton.

Pahl-Wostl, C., P. Jeffrey, N. Isendahl, M. Brugnach 2011: Maturing the new water management paradigm: Progressing from aspiration to practice. Water resources management 25. DOI: http://www.dx.doi.org/10.1007/s11269-010-9729-2

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, S. F. III, Lambin, E. F., Lenton, T. M., Scheffer, M. 2009: A safe operating space for humanity. Nature 461. DOI: http://dx.doi.org/10.1038/461472a

Scholz, M., Harrington, R., Carroll, P., Mustafa, A. 2007a: The integrated constructed wetlands (ICW) concept. Wetlands 27-2. DOI: http://dx.doi.org/10.1672/0277-5212(2007)27[337:TICWIC]2.0.CO;2

Scholz, M., Sadowski, A. J., Harrington, R., Carroll, P. 2007b: Integrated constructed wetlands assessment and design for phosphate removal. Biosystems Engineering 97-3. DOI: http://dx.doi.org/10.1016/j.biosystemseng.2007.03.021

Song, H. L., Li, X. N., Lu, X. W., Inamori, Y. 2009: Investigation of microcystin removal from eutrophic surface water by aquatic vegetable bed. Ecological engineering 35. DOI: http://dx.doi.org/10.1016/j.ecoleng.2008.04.005

Svirčev, Z., Krstić, S., Miladinov - Mikov, M., Baltić, V., Vidović, M. 2009: Freshwater cyanobacterial blooms and primary liver cancer epidemiological studies in Serbia (Review). Journal of environmental science and health – Environmental carcinogenesis and ecotoxicology reviews 27-1. DOI: http://dx.doi.org/10.1080/10590500802668016

Svirčev, Z., Baltić, V., Gantar, M., Juković, M., Stojanović, D., Baltić M. 2010: Molecular aspects of microcystin induced hepatotoxicity and hepatocarcinogenesis. Journal of environmental science and health –Environmental carcinogenesis and ecotoxicology reviews 28-1. DOI: http://dx.doi.org/10.1080/10590500903585382

Vovk Korže, A., Vrhovšek, D. 2006: Ekoremedijacije za učinkovito varovanje okolja. Institut za varstvo okolja, Maribor.

Vovk Korže, A. 2008: Sustainable development with ecoremediations. In: Ecoremediations – a means to achieve Environmental Goals and Sustainable Development in Slovenia. Ljubljana.