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Wastewater Treatment and Reuse for Metropolitan Regions and Small Cities in Developing Countries

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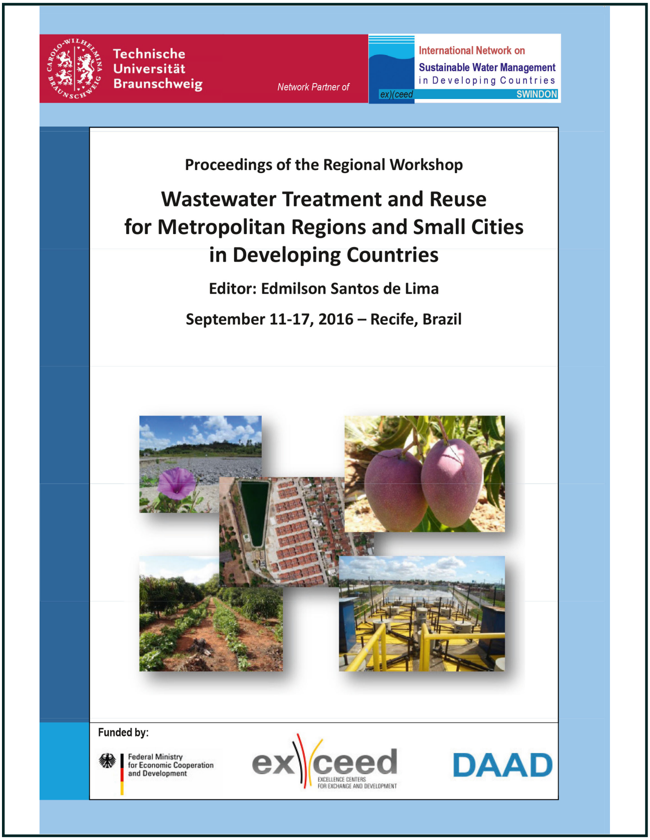

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NATURAL WASTEWATER TREATMENT AND WATER QUALITY MONITORING SYSTEM FOR EFFECTIVE REUSE

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Abstract

There is a large quantity of wastewater in Argentina, of which only about 10% is treated to reuse. The rest is sent directly to the rivers without any treatment, which increase their pollution. It is estimated that 73% of water in rural areas of Argentina is used for agriculture and livestock. An investigation concluded that there are few efficient methods in rural areas of Argentina to mitigate this problem. The solutions that have been proposed are too expensive to be applied in these areas. For this reason, the works are not completed because of high cost of investment and maintenance. From these findings, an easy handling and low cost investment tool of wastewater treatment as well as a system designed with "free software" tools to control and to monitor its quality was developed as a solution of this problem and to extend it elsewhere in the world with similar needs. First, the characteristics of design and implementation of wastewater treatment plant in rural areas through wetlands using native plants are presented in this study, and the details of this technique are explained. Then a solution to monitor and to optimize the water quality through software for their effective reuse is presented. Finally, the application of the two techniques and the performance, when both methods are applied, are presented in a scenario. This study has shown that by applying these techniques the treatment area will gain benefits from using low cost implementation tools, easy handling techniques and optimization of processes.

1 Introduction

There is a large quantity of wastewater in Argentina and only about 10% of this amount is treated to reuse. The rest is sent directly to the rivers without any treatment that increase their pollution. The Matanza-Riachuelo River (MR), a tributary of the Río de la Plata (La Plata River), is the most contaminated river basin in Argentina and is considered one of the most polluted water bodies in the world [1]. Pollution levels in Buenos Aires' rivers are so high that they have been considered "open sewers", making pollution the greatest environmental risk for the metropolitan area. Pollution levels have increased steadily as urbanization and industrial growth have continuously increased as well in the metropolitan and rural areas of Buenos Aires. It is estimated that more than 4,000 industrial facilities are located in the lower and middle sections of the basin. Almost all of these industries discharge untreated effluents into the drainage system or directly into the river. In addition to high levels of organic pollution, these discharges contain toxic contaminants such as heavy metals from petrochemical industries, tanneries, and meat processing facilities [2]. More specifically, the Riachuelo River has levels of lead, zinc and chromium 50 times higher than the legal limits in Argentina; 25% is from industrial sewage and waste, while the remaining 75% originates from domestic sources [3].

The sudden onset of environmental and social degradation of the basin has resulted from limited investment in public infrastructure, poor environmental management, lack of adequate urban and industrial planning, and limited public infrastructure investment. Also, in areas of intensive farming, uncontrolled use of agrochemicals contributes to pollution of water resources [4].It is estimated that 73% of water in Argentina is used for agriculture and livestock [5]

About 65% of the population has access to sewer system, but in rural areas only 1% of the population has the same. In rural areas, wastewater that comes from human use, industries, agriculture and livestock is not treated properly. In these areas, it is necessary to apply a low-cost method for the treatment of wastewater taking into account the low implementation costs, easy handling and low cost maintenance.

2 Material and Methods

2.1 Design and implementation of wastewater treatment plant through wetlands

Wetlands are one of natural systems that can be used for wastewater treatment and pollution control [6].

2.1.1 Type of wetland system used - Subsurface Flow (SSF)

In subsurface-flow systems, the effluent may move either horizontally, parallel to the surface, or vertically from the planted layer down through the substrate and out. This system has several advantages but also some disadvantages, as shown below:

Advantages of this technique are

- Operational simplicity, limited to the removal of waste pre-treatment, and cutting and removal of vegetation, when it is dried,
- Flexible system and low sensitivity to changes in flow and load,
- The vegetal biomass of the sediment acts as insulation, ensuring microbial activity throughout the year,
- Seamless integration into rural areas; no environmental impacts sound, no odor generated,
- Potential use of plant biomass produced,

- Subsurface horizontal-flow wetlands are less hospitable to mosquitoes, as there is no water exposed to the surface, whose populations can be a problem in surface-flow constructed wetlands, and
- Subsurface-flow systems require less land area for water treatment.

Disadvantages of this technique are

- Larger land area is required for implementation than conventional technologies of treatment, and
- In the wetlands of free flow, as water flows over the substrate surface, it can cause the proliferation of mosquitoes.

Characteristics of Subsurface Flow (SSF) wetlands are (i) one or more cells (usually two in number), (ii) ground limited by partitions (landfills), (iii) waterproofed with polyethylene film, (iv) filled with porous material (gravel, stone, sand or soil), (v) planted with emergent aquatic plants, (vi) bed depth of 0.7 - 1.2 m and water depth 0.6 - 0.7 m, (vii) their fund is constructed with slope of 1-2%, (viii) perforated pipe entrance used surface perpendicular to the flow, (ix) output per pipe drilled perpendicular to the flow line, (x) hydraulic loadings applied between 2 and 20 cm/d, and (xi) land areas between 0.5 and 5 ha per 1000 m^3/d) are required.

2.1.2 Phytoremediation

For this system, the technique of phytoremediation is used [7]. It is a cost-effective plant-based approach of remediation that takes advantage of the ability of plants to concentrate elements and chemical compounds from the environment and to metabolize various molecules in their tissues. It refers to the natural ability of certain plants called hyperaccumulators to bioaccumulate, to degrade, or to render harmless contaminants in soils, water, or air. Toxic heavy metals and organic pollutants are the major targets for phytoremediation. The figure 1 describes the phytoremediation process [8]. The most important characteristics of this method are the following:

Phytoextraction – uptake and concentration of substances from the environment into the plant biomass,

Phytostabilization – reducing the mobility of substances in the environment, for example, by limiting the leaching of substances from the soil,

Phytotransformation – chemical modification of pollutants as a direct result of plant metabolism, often resulting in their inactivation, degradation (phytodegradation), or immobilization (phytostabilization),

- *Phytostimulation* – enhancement of soil microbial activity for the degradation of pollutants, typically by rhizosphere organisms that associate with roots; this process is also known as rhizosphere degradation. Phytostimulation can also involve aquatic plants supporting active populations of microbial degraders, as in the stimulation of atrazine degradation by hornwort.

- *Phytovolatilization* – removal of substances from soil or water with release into the air, sometimes as a result of phytotransformation to more volatile and/or less polluting substances, and
- *Biological hydraulic containment* – some plants, like poplars, draw water upwards through the soil into the roots and the plant biomass. This decreases the transport of soluble pollutants downwards, deeper into the soil and the groundwater.

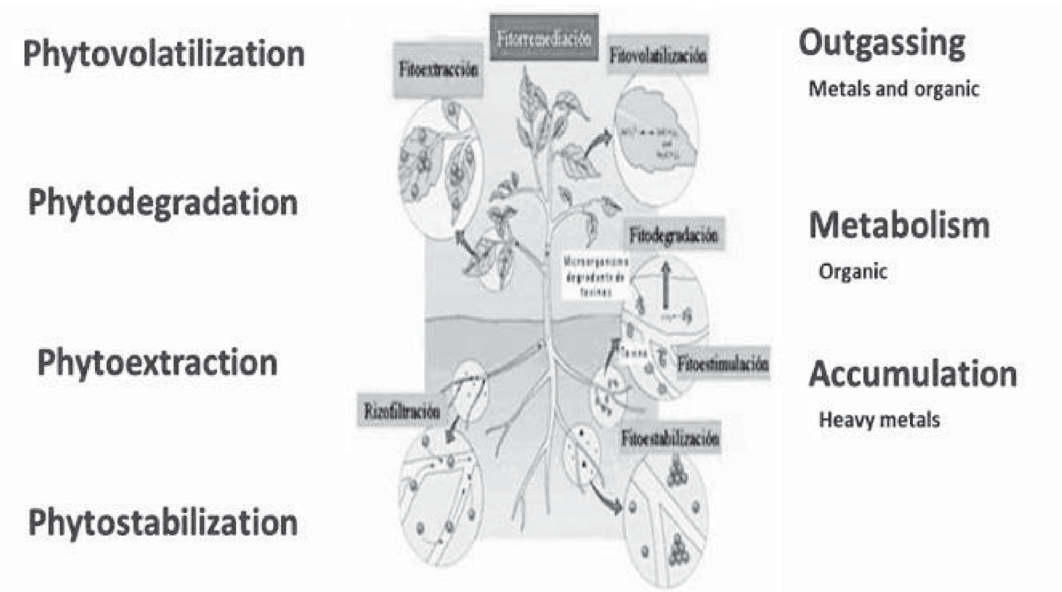

Figure 1: Phytoremediation process

2.2 Monitoring and optimization of water quality through software for their effective reuse

The software will act as decision making tool. Using specific informatics tools to import data from different sources and importing manual data on it, one can obtain important information to define the destination of water. Once the user inserts the data into the software, the informatics tool will show the results processing the inputs. It is a very useful tool to decide the correct destination of the treated water. This software was developed using open source tools [9-11].

2.2.1 Sample information

To evaluate the water quality in each water income, the software makes use of sample information to decide on outgoing water. The method taking samples is divided in this project in two levels:

Sampling Level 1 - Minimal equipment inversion and quick evaluation kits; this method can be learned with basic training.

Sampling Level 2 - Inversion in precision machines, more training, low number of participants

2.2.2 Web-based system software for information management

The web-based system software was developed using free license technologies to web developing: PHP 5, Apache web server, MySQL databases [10-12]. The information and services must be accessible to all and able to be used with all navigation devices. Furthermore, it must have clear and simple contents as well as simple navigation mechanisms. For information safety, backups, passwords, digital certificates, cryptography and remote backup systems are very important aspects of data security. It is very important to have concurrent access to the system from all navigation devices at the same time at different geographic points.

2.2.3 Development software advantages

It is very important to use easy handling techniques and friendly screens. Quick access to information through listings and graphs is required. Implementation costs are low compared with sophisticated systems. It is free license software.

2.2.4 Key Features

About the data obtained, decisions can be taken regarding the destination of treated water in terms of

- Access to information from any geographical point (working area, university),
- Evolution of different parameters,
- Analysis of requirements to avoid exceeding the allowable limits of pollutants,
- Analysis of indicators, and
- Information for decision-making (water recirculation, use for irrigation).

3 Results and Discussion

3.1 System scheme

This application is an alternative for wastewater treatment. It is developed to use in rural areas of Argentina, where shortage of water for irrigation and livestock causes a problem, and the wastewater is currently discharged untreated into rivers. The overall process scheme is shown in figure 2.

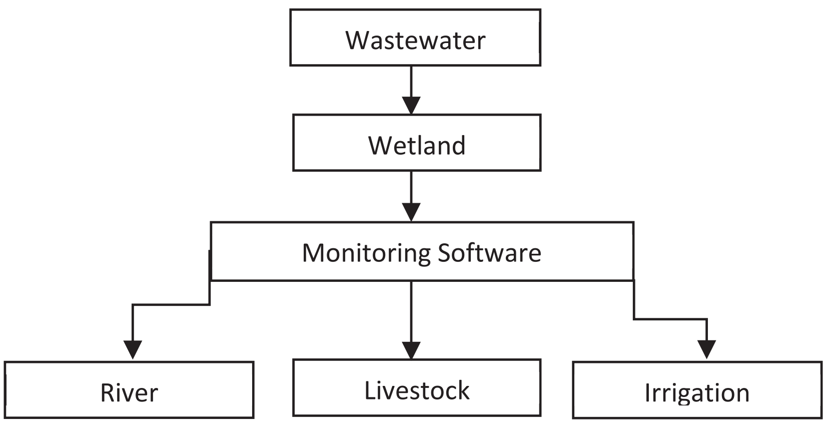

Figure 2: Scheme of full system steps