

Treatment for small polluted rivers: Design and performance of an experimental structure

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Abstract

In view of the economic reality of developing countries, it will not be possible to build all the necessary wastewater treatment plants (WWTP) needed to control the pollution of their rivers in the next 20 years. Therefore, low-cost alternative technologies must be developed to restore the water quality of polluted rivers. It is well-known that the self-purification cycle in nature uses several biotic and abiotic processes to restore polluted water to its former pristine quality. This cycle has been surpassed in many rivers due to continuous discharges of wastewater into them. A low-cost structure that will enhance the water quality in small polluted rivers is proposed and can be constructed *in situ*, based on three conditions: Disruption of plug flow, flow velocity and support material for bacterial growth. The design of the experimental stage of this structure can control slope, water flow, length, support material and the number of locks. Two 175m-long experimental models were constructed; both models were filled with crushed, washed and screened 10 to 12 mm diameter river stone. A mixture of primary and secondary effluents from a WWTP was used to test the models, with a chemical oxygen demand of COD ≈ 50 and $100 \text{ mg}\cdot\text{L}^{-1}$ respectively. For a uniform 0.5% slope, the maximum flows achieved were 27 and $30 \text{ L}\cdot\text{min}^{-1}$ with and without locks. The system worked efficiently breaking the plug flow, mixing the water flow and allowing stable aerobic microbial communities of 5.58 and $8.86 \log \text{ UFC}\cdot\text{g}^{-1}$, and COD reductions ranging from 90.27 to $555.2 \text{ mg}\cdot\text{min}^{-1}$ depending on the pollutant concentration.

Keywords: freshwater contaminants, self-purification, alternative technology, microbial communities

Introduction

The natural process of self-purification of rivers has allowed the transport and transformation of most of the anthropogenic wastes discharged into them. Nevertheless, the self-purification capacity of many rivers has been exceeded by far, and they now serve as wastewater collectors in many cities of the world. Even though with available technology for wastewater treatment water quality can be restored totally before it is discharged into rivers or creeks, this technology is not generally employed in most of the so-called "developing countries" and the "less developed countries". This will last for at least 10 or 20 more years due to the economic, political and social conditions of these countries (Palupi et al., 1995; Australia and World Affairs 1995; WHO-UNICEF, 2000; Josephson, 2001). In Mexico alone, ranked in the top 20 world economies, 82.26% ($196.6 \text{ m}^3\cdot\text{s}^{-1}$) of domestic raw sewage produced is discharged into rivers, creeks and agricultural fields (Semarnat/CNA, 1999). In addition, $159 \text{ m}^3\cdot\text{s}^{-1}$ of industrial wastewater are produced and only 15% undergo biological treatment (Sanchez-Santillan et al., 2002).

Agricultural practices in many countries still use flood irrigation and an uncontrolled use of pesticides and fertilisers. This combination leads to the production of non-point source discharges that

increase the concentration of these compounds in rivers. All the conditions mentioned above imply problems for large- (Dynesius and Nilsson 1994; Gore and Shields 1995) or medium-sized rivers, but are especially critical for small rivers.

The so-called small-sized rivers (5 to 12 m wide), low depth (0.3 to 0.7 m) and wide river beds (8 to 20 m) have slow and structured plug flows. These characteristics result in a slow oxygen transfer from the upper layer to the middle and to the one in contact with bottom sediments. Nutrients from the river basin, from river edges or from rain runoff are introduced into the rivers as part of the natural cycle. These nutrients allow the survival of bacteria and algae that will transform the organic matter into inorganic compounds, integrating them into the trophic cycle. Rivers under the conditions stated above are in equilibrium (Ostroumov, 1999). Anthropogenic activities disturb this equilibrium by continuously discharging wastes into rivers, like domestic and industrial raw wastewater or agricultural non-point sources, producing a decomposition zone, followed by a septic zone, a recovery zone and finally a clean zone. The length of each of these zones depends on the water flow rate, quantity and kind of bacteria (free or attached), nutrient transport and transformation, temperature, oxygen uptake and quality and quantity of anthropogenic contaminants (Barillier and Garnier, 1993; Stoodley et al., 1997; Crump et al., 1999; Burns and Ryder, 2001). Degradation of contaminants is especially slow in small-sized rivers due to low-flow velocity and few free bacteria in the water column. Therefore, the different zones are longer than those in the bigger-sized rivers (Edeline and Lambert 1979; Gantzer et al., 1988).

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