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Preliminary Study of a Low-Cost, Easily-Implementable Alternative for Waterbody Restoration

Bertho, G.G.[1]

[1]International Institute of Ecology and Environmental Management – IIEGA, Rua Bento Carlos, 750, Centro, CEP 13560-660, São Carlos, SP, Brazil

*Correspoding author: gabsbertho@hotmail.com

Abstract

As the population increasingly grows, the impacts of climate change rise and the lack of clean water start to surround us, the need for the restoration of waterbodies increase. Thus, new technologies have to be developed aiming to improve the water quality of rivers and boost its natural recovery. The objective of this preliminary study was to develop a cheap and accessible alternativeto improve the water quality of rivers and lakes by using low-cost waste materials. Experiments were conducted to observe the decrease of organic matter of biofilms supported in coconut fibers and in P.U spongesthrough time. Both biofilms presented high degradation efficiencies and at low contact times.The biofilm in coconut fiber showed a higher average organic matter degradation rate, but the biofilm in P.U sponges showed a higher decrease of coloration and odor. A structure was created to simulate the condition of a river and both materials were placed into it in order to analyze their efficiency. The results showed considerable decrease in nutrients, organic matter, suspended solids, turbidity and coloration. Considering the system had a relatively high flow rate, thus not allowing the water to have contact with the structure for a long time, these results establish that the structure could be applied in a real effluent to improve the water quality. However, further research is needed to analyze the effects of more variables and establish some strategies of how this should be applied in a real waterbody.

Keywords: waterbody, restoration, low-cost, biofilm, coconut, polyurethane.

Introduction

Considering the increasing impacts of climate change, the population growth and the quantity of rivers and lakes that currently are eutrophic, the efforts concerning river restoration have to be one of the main focuses of environmental engineers.

Government agencies and stakeholders recognize the importance of river restoration for the conservation of the environment. However, even with legal mandates, massive expenses, and the emerging industry of riparian restoration, aquatic ecosystems continue to deteriorate due to human influences (KARR, CHU, 1999).

According to the latest survey of Fundação SOS Mata Atlântica, of the water analyzed in 184 rivers, streams and lakes of 11 Brazilian States and the Federal District,27.5% showed poor quality, 70% showed regular quality and only 2.5% showed good quality (FUNDAÇÃO SOS MATA ATLÂNTICA, 2017).

When a river or stream is degraded, we lose many of the ecosystem services that are essential to society (BARON et al. 2002). River restoration aims to recoup some of these losses and to do it in more public acceptable ways and at lower costs than through technological fixes such as waste treatment plants (PALMER et al. 2004).

During the last decades, the use of aquatic macrophytes to improve the quality of water bodies has been very successful. These aquatic plants and the microorganisms associated to its roots can effectively decrease the quantity of nutrients, organic matter, heavy metals and turbidity of the water (SRIVASTAVA, CHANDRA, 2008). By improving the water quality, the aquatic environment can effectively start to recover itself. Thus, the use of macrophytes can offer a good alternative for effluent restoration, however the implantation and the accessibility of this technology is not flashy in some regions. Additionally, the macrophytes when saturated need to be replaced by new ones and they can become hazardous boosters for eutrophication if not controlled properly.

In order to conserve the environment and ensure the availability of water resources to any being in the future, new technologies have to be developed to improve the water quality of the aquatic ecosystems. These technologies can either be an alternative for the use of macrophytes or be used along with these plants. Any proper effort in the restoration of water bodies is valuable to augment the already strained water resource portfolios and preserve the diversity of not only the rivers, streams and lakes, but also the wetlands, forests and swamps interconnected to them.

Objective

Aiming to restore the water quality of rivers, prevent eutrophication and thus help ensure the availability of water resources to any living being in the future, this preliminary work has the object of developing a low-cost alternative method to reduce the concentration of organic matter, turbidity, coloration, suspended solids and nutrients of river waters using waste materials that are in abundance in Brazil.

Methodology

Sampling

Samples were collected from three main sources. The first source was the Gregorio River in which the sampling point was near a settlement called SESC, in the center of São Carlos, SP, Brazil. The second source was the Mojolinho River in which the sampling point was in a course near a lake located inside the Federal University of São Carlos. The third source was the sewage from São Carlos's neighborhood Santa Felicia which was provided by the Department of Environmental Engineering of the University of São Paulo. The samples were collected with buckets and stored in sterilized flasks.

Effect of time on organic matter degradation of biofilms supported in coconut fibers and polyurethane sponges

A study in laboratory scale was made to evaluate the degradation of organic matter of biofilms supported in coconut fibers and polyurethane (P.U) spongesthroughtime.

Twenty liters of water from the Gregorio River collected as described in this methodology before were flowed in an inert water tank, and then 200 grams of coconut fiber were added to the tank. Analysis of Biochemical Oxygen Demand (BOD) was made in the raw sample of the river water and then the same analysis was made in the water sample after 30 minutes, 1, 2, 3 and 5 hours of contact with the coconut fiber. The figure below portrays the water tank with the coconut fibers inside.

Figure 1 – Water tank with coconut fibers.

To compare the efficiency of organic matter degradation of the biofilms, twenty liters of the same water from the Gregorio River were flowed in a second inert water tank, and then 150 grams of P.U sponges were added to the tank. The sponges were cut into small pieces to allow water flow and the pieces were wrapped with a nylon cloth to prevent the water from floating the sponges up. BOD analysis was made in the raw sample of the river water and then the same analysis was made in the water sample after 30 minutes, 1, 2, 3 and 5 hours of contact with the P.U sponges. The figure below portrays the water tank with the sponges inside.

Figure 2 – Water tank with P.U sponges.

Development of a biofilm cell

In order to create a "biofilm cell" which would be applied directly in the effluent to enhance its quality, the following materials were used: coconut fibers, polyurethane sponges, nylon cloth and PVC tubes. The coconut fibers and the P.U sponges were previously left for 7 days in contact with organic matter and microorganism from a São Carlos water river sample (Monjolinho River); afterward, both materials were wrapped in a nylon cloth in order for them not to disperse in the water. In each biofilm cell, 100 grams of coconut fiber and 50 grams of P.U sponges were used. The sponges were disposed more at the top and the bottom of the cell; the coconut fibers were disposed at the center. It was made because biofilms created in coconut fibers are more efficient in the degradation of organic matter and the biofilms in the P.U sponges are more efficient in the reduction of coloration and turbidity as detected before in this study. This arrangement allows the water to have a greater contact with the coconut fiber while its suspended solids are retained by the P.U sponges. The PVC tube would be the support for the cell, and would be attached to the nylon cloth. The figure below outlines the biofilm cell.

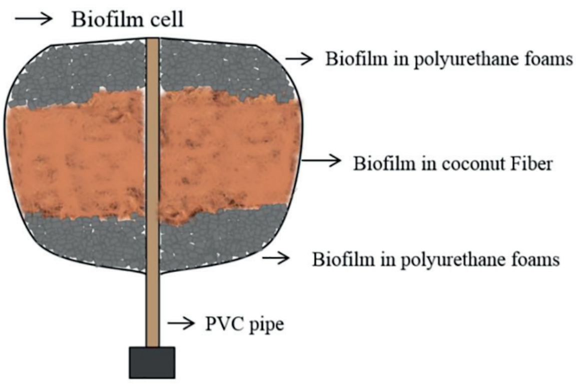

Figure 3 – Biofilm cell.

River condition simulation for efficiency analysis of the biofilm cells

Aiming to evaluate and establish the efficiency of the biofilm cells in the improvement of river's water, a structure was developed to simulate the condition of an effluent. The following materials were used: three wooden planks (Dimensions of 30 × 70 cm), impermeable plastic canvas, 50-liter water tank and wooden supports. The planks were nailed together to form a rectangle without its top face and the plastic canvas was used to clothe the wood and prevent water absorption by it. The water tank was attached to one side of the structure and an opening was made on the other side. The biofilm cells would be placed in the middle of the system, the contaminated water would be dispensed from the tank and the treated water collected at the other side as illustrated in the figure below.

For an initial efficiency test, 5 biofilm cells were placed in the center of the simulator structure. Sewage collected in the University of São Paulo as described before was taken to analysis in triplicate of biological oxygen demand (BOD), electrical conductivity, total suspended solids, turbidity, coloration, phosphorus, and nitrate. Afterwards, the sewage was poured with constant flow in the simulation system and the treated water was taken to the same analyses of the raw sample. The inlet flow rate was approximately 20 ml/s and the samples analyzed were only collected when 5 liters of water had already left the system in order to ensure that the system was already stabilized. A total of 3 treated water samples were collected.

Laboratory analysis

The laboratory analyses were all conducted in the International Institute of Ecology. Analysis for biochemical oxygen demand (BOD) began within 24 h of sample collection using the 5-day BOD test (APHA, 1998). Electrical Conductivity was measured using a Digimed EC meter. Turbidity was measured with a Hach 2100P Turbidimeter using nephelometric methods. Coloration was measured with a calibrated Hach DR3900 spectrophotometer. The Total Suspended Solids (TSS) was analyzed using the Standard method 2540D. Finally, for analysis of nutrients, 30 ml aliquots were used and analyzed by the method of digestion with Potassium Persulfate (VALDERRAMA, 1994), followed by colorimetric reading in the form of nitrate or phosphate as described in Strickland and Parsons (1972).

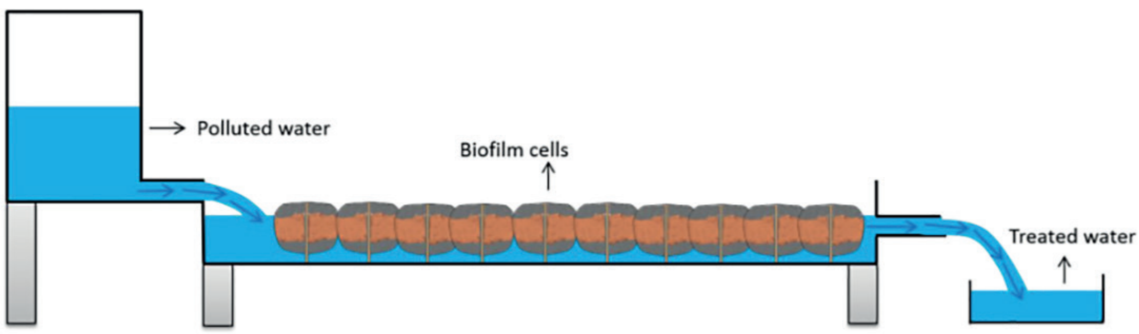

Figure 4 – Structure to simulate a river condition.

Results and Discussion

Effect of time on organic matter degradation of biofilms supported in coconut fibers and polyurethane sponges

The following graph deploys the results of the BOD analysis made to evaluate the effect of time in the organic matter degradation of the biofilms as described in the methodology and a line of best fit.

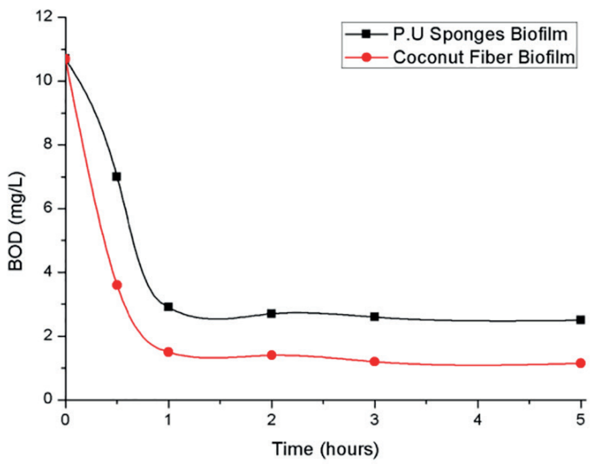

Figure 5 – Graph of BOD throughtime ofwater samples in contact with coconut fiber and P.U sponges biofilms.

As shown in the graph, the organic matter concentration decays exponentially in the first hour and then remains almost static in the next hours.An explanation for this may be that the remaining organic matter after the first hour werePersistent organic pollutants (POPs), therefore the biofilms were not able to degrade it rapidly. The biofilm supported in coconut fiber had an average organic matter degradation rate greater than the biofilm supported in the P.U Sponges. The pores of the coconut fibers are smaller than the ones of the P.U sponges, this makes the fibers more suitable for microorganisms and explains why the coconut fibers had a greater total efficiency for BOD reduction. However, the coloration and the odor of the water were observed todecrease faster in the biofilm supported in P.U sponges, establishing that it contains microorganisms of different functions compared to the ones in the coconut fiber.

These results demonstrate that the biofilms can have potential uses in river restoration once the degradation time was relatively slow for high efficiencies, what is an essential feature for their appliance in water bodies.

Efficiency analysis

The following table displays the results of the laboratory analyses of biochemical oxygen demand (BOD), electrical conductivity (EC), turbidity, coloration, total suspended solids (TSS), total phosphorus and nitrate in the samples collected to evaluate the efficiency of the biofilms cells as described in the methodology. The results shown are the arithmetic mean of the results of all analyzed samples.

Table 1 – Laboratory analysis results of samples in the efficiency analysis.

	Raw Sample	After treatment
BOD (mg/L)	34,82 ±1.21	23.42 ± 2.40
EC (µS/cm)	260.2 ±0.74	218.1 ±7.24
Turbidity (NTU)	50.2 ±0.08	28.6 ±2.08
Coloration (Pt/Co)	80.2 ±0.14	54.9 ± 0.78
TSS (mg/L)	30.00 ±1.75	10.67 ±1.24
Total Phosphorus (µg/L)	840.2 ±32.60	730.1 ± 37.10
Nitrate (mg/L)	5.04 ± 0.29	4.12 ± 0.23

As shown in the table, the biofilm cells are efficient at improving the water quality, having an efficiency of 32.73% in the reduction of BOD, 16% in the reduction of electrical conductivity, 43% in the reduction of turbidity, 31.5% in the reduction of coloration, 64.4% in the reduction of suspended solids, 13.1% in the reduction of phosphorus and 23.6% in the reduction of nitrate.

The decrease in BOD reveals that the microorganism established in the biofilm cells can effectively and rapidly degrade organic matter. The reduction of nutrients in the water is reflected in the fact thatthe coconut fiber can act as a natural biosorbent of nutrients due to its physical and chemical properties (LO MONACO, MATOS, SARMENTO, LOPES JÚNIOR, LIMA, 2009). Considering the simulation system was with a relatively high flow rate, hence not allowing the water to have contact with the coconut fibers and the P.U sponges for a long time, the reduction of organic matter, nutrients, and suspended solids show the potential of the biofilm cells of reducing these parameters in a real river condition, where the contact time will be even lower. The more biofilms cells in the system, the more it is expected to have higher efficiencies once there will be more microorganisms and more absorbent materials available. Therefore, these results show that the biofilm cells can be applied to improve the water quality of effluents.

Conclusion

Biofilms supported in coconut fibers and polyurethane sponges are efficient in the degradation of organic matter and the contact time needed to achieve great decrease percentages is relatively low. The biofilm supported in coconut fibers is more efficient at the decrease of BOD, but the biofilm supported in the P.U sponges is more efficient in the decrease of coloration and odor. By gathering both materials and applying them in a river simulating condition, it was possible to detect their efficiency in the reduction of organic matter, suspended solids, turbidity, coloration, and nutrients. The results gathered showed relatively great efficiencies to all parameters studiedand the contact time of the water with the materials was very low, what reveals the potential use of these materials to improve the water quality of waterbodies and thus boost its restoration.

The structures developed and studied in this preliminary work could either be applied directly in a river or applied along with floating macrophytes in order to achieve greater efficiencies. Thestructures are easy to implement, have a low-cost, and should be placed in several parts of a river or lake, tothereby gradually improve their water quality. However, further research is needed to establish the relationship between the number of biofilm cells and the system efficiency, the influence of the water flow rate, the influence of pH and temperature, the potential decrease of heavy metals and the maximum usage time of the biofilm cells.

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