# PILOT SCALE WASTE STABILIZATION PONDS ASSOCIATED WITH BIOFILMS FOR ORGANIC MATTER AND NUTRIENTS REMOVAL

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**ABSTRACT**

This study investigated the performance of facultative and maturation ponds associated with biofilms developed upon inert support material placed uniformly into the experimental modules. Two different operational regimes were carried out with the aim to identify the effect of biofilm removal on the overall process, mainly in terms of organic mater, solids, nutrients and pathogenic organism removal. The efficiency obtained when the biofilm was periodically removed was similar to values commonly obtained by energy consuming processes such as the activated sludge system.

Key words: Ponds, domestic wastewater, biofilms, organic mater removal, nutrients removal.

## INTRODUCTION

The protection of water bodies requires the efficient treatment of wastewaters giving emphasis to the removal of organic matter, pathogenic organisms and nutrients.

The control of eutrophication, directly related to the excess of nitrogen and phosphorus present in water bodies, is a matter of prime importance due to the changes in the balance of microorganisms that occur naturally in the aquatic environment.

Such events change the water quality, with damage to aquatic life, such as death of fish, reduction of dissolved oxygen, loss of scenic qualities and increasing costs in public water supply.

While in developing countries the main goal of wastewater treatment is the removal of pathogens for the control of endemic diseases, in developed countries the cases of endemic diseases are exceptional and the main concern is the removal of toxic pollutants and the reduction of nutrients (LEON & MOSCOSSO, 1999).

The growing demand of water for public supply, especially for small and medium cities requires more effective treatment of wastewaters at affordable costs.

The stabilization ponds are a competitive technology for pathogens removal in regions with mild climate and land availability. They are recognized by the simple operation which is closely related to the natural environment.

In Brazil, the lagoons have been introduced in 1960, with the construction of a facultative pond located in São Jose dos Campos, Sao Paulo (KELLNER & PIRES, 1998).

Despite the high efficiency in terms of pathogens removal, the effluent generally contains suspended solids, BOD and nutrients above the limiting standards required by the environmental agencies.

According KIM & KIM, (2000), the removal of algae biomass is essential to produce effluent with lower $BOD_5$, nutrients and solids.

This work presents the results obtained by the cultivation of attached photosynthetic organisms (periphyton) which are well known by the important role in metabolic conversion and removal of biodegradable material into bodies of water.

The development of biofilm (periphyton) is a strategy already recognized for the removal of nutrients (JÖBGEN et al., 2004). TOET, 2001 studying biofilms, showed that the use of artificial substrates placed in ponds is very efficient for the removal of nutrients, particularly phosphorous and nitrogen.

## OBJECTIVES

The main purpose of this study was to evaluate the performance of biofilms in facultative and maturation ponds for the removal of organic matter and nutrients from domestic wastewater pretreated by an anaerobic lagoon. The removal of suspended solids and pathogens were also investigated along the study aiming to identify the potential of the biofilm to improve the quality of the final effluent.

## MATERIALS AND METHODS

The experimental work was carried out in a pilot plant located at Lami Wastewater Treatment Plant, treating domestic wastewater from a resort located in the south of Porto Alegre/RS, Brazil.

The pilot plant consisted of four experimental systems operated in parallel, each one comprising three rectangular modules in series with length/width ratio of 3:1. The systems were fed continuously with the effluent from an anaerobic pond.

The influent flow was adjusted in each system to obtain a total HRT= 11 days.

The individual dimensions of each module were: length = 4.56 m, width = 1.44 m; useful height = 0.8 m. The surface area of each module was 6.57 m2.

The support material for the development of the biofilm consisted of plastic brushes with surface area of 2,210.56 $cm^2$/brush.

Figure 01- View of an individual module and support brushes


Figure 02- General view of the experimental system

The total area of the support material in each module is presented in Table 1.

Table 1. Values of the surface support placed on the experimental modules.

| | System | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Surface support material (m2) | 7,96 | 5,31 | 2,65 | zero |

The experimental work comprised two phases:

- Phase 1: characterized by not removing the biofilm attached to the support material. This phase lasted 25 weeks.

- Phase 2: the biofilm was removed every 45 days (modules A, B and C) and lasted 21 weeks.

Alkalinity, pH, temperature, $COD_T$, $BOD_5$, $NH_4$-N, $PO_4$, TS, TVS, TDS, total coliforms and thermotolerant organisms were monitored weekly according to APHA, 2005.

## RESULTS

Phase 1:
The main objective was to evaluate the effect of the biofilm on the performance of the ponds and the risk of detachment of the biofilm impairing the efficiency of the ponds. Previous studies demonstrated that biofilm reaches full development in a period of 45 days, from which may detach and be washed to the effluent.

The recolonization of the support material occur in a natural way up to the full development of a new layer of biofilm.

Table 1 presents the values of $BOD_5$, $COD_T$, VS concentration and the respective average efficiency removal.

Table 1: Results of $BOD_5$, $COD_T$, Volatile Solids and efficiency removal during phase 1.

| | $BOD_5$ | | | | | | $COD_T$ | | | | | | Volatile Solids | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Inf.** | **A3** | **B3** | **C3** | **D3** | | **Inf.** | **A3** | **B3** | **C3** | **D3** | | **AFL** | **A3** | **B3** | **C3** | **D3** |
| **Average** | 90,5 | 39,8 | 45,0 | 48,0 | 59,7 | | 159,5 | 74,6 | 85,1 | 96,0 | 151,6 | | 189,3 | 187,6 | 171,8 | 190,8 | 205,4 |
| **Deviation** | 248,5 | 156,2 | 185,1 | 189,1 | 232,3 | | 687,7 | 298,2 | 302,3 | 367,1 | 681,4 | | 702,0 | 519,6 | 546,6 | 542,5 | 484,8 |
| **CV** | 2,74 | 3,93 | 4,12 | 3,94 | 3,89 | | 4,31 | 4,00 | 3,55 | 3,82 | 4,49 | | 3,71 | 2,77 | 3,18 | 2,84 | 2,36 |
| **Max** | 130,0 | 170,0 | 189,1 | 160,0 | 145,0 | | 603,0 | 199,3 | 298,2 | 367,1 | 717,4 | | 664,2 | 500,0 | 503,0 | 453,0 | 429,0 |
| **Mín** | 1,0 | 6,0 | 0,0 | 30,0 | 2,0 | | 16,7 | 3,1 | 9,4 | 3,8 | 35,2 | | 54,0 | 74,0 | 59,0 | 55,0 | 52,0 |
| **Efficiency (%)** | | 56,1 | 50,3 | 46,9 | 34,1 | | | 53,2 | 46,6 | 39,8 | 5,0 | | | 0,9 | 9,2 | -0,7 | -8,5 |

The improvement in $BOD_5$ and COD removal was significantly affected by the presence of the biofilm in system A (greater surface support) with average removal of 56.1% and 53.2% respectively, compared with system D (reference), were the organic matter removal was insignificant.

The Volatile Solids removal was not significant at system B, averaging 9.2%. However, the efficiency at system D (reference) was negative (-8.5%), indicating high presence of algae at the final effluent.
The removal of total phosphorous (TP) and TKN (Table 2) was also influenced by the amount of the support material installed at systems A, B and C.

However, the ammonia nitrogen removal was not significantly influenced, indicating that other mechanisms, such as ammonia volatilization could be the main removal mechanism in this case.

Table 2: Results of TP, TKN, and $NH_3$-N and efficiency removal during phase 1.

| | $P_T$ | | | | | TKN | | | | | $NH_3$-N | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inf. | A3 | B3 | C3 | D3 | Inf. | A3 | B3 | C3 | D3 | Inf. | A3 | B3 | C3 | D3 |
| **Average** | 0,37 | 0,19 | 0,20 | 0,21 | 0,23 | 29,1 | 9,4 | 10,9 | 11,0 | 10,6 | 24,5 | 6,4 | 7,4 | 7,7 | 6,1 |
| **Deviation** | 0,29 | 0,28 | 0,37 | 0,34 | 0,43 | 121,6 | 34,6 | 37,0 | 43,2 | 42,1 | 102,8 | 31,8 | 32,4 | 36,3 | 39,5 |
| **CV** | 0,77 | 1,47 | 1,87 | 1,63 | 1,89 | 4,18 | 3,68 | 3,38 | 3,94 | 3,96 | 4,20 | 4,99 | 4,38 | 4,73 | 6,43 |
| **Max** | 0,56 | 0,47 | 0,54 | 0,58 | 0,52 | 122,1 | 33,8 | 29,2 | 36,8 | 32,5 | 101,3 | 27,7 | 24,4 | 26,3 | 27,1 |
| **Min** | 0,14 | 0,06 | 0,08 | 0,10 | 0,09 | 3,0 | 1,3 | 1,8 | 1,3 | 1,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| **Efficiency** | | 56,1 | 50,3 | 46,9 | 34,1 | | 53,2 | 46,6 | 39,8 | 5,0 | | 44,1 | 35,1 | 32,7 | 46,1 |

Phase 2:
The main objective was to evaluate the effect of the periodic removal of the biofilm on the performance of the ponds.

At this phase, one third of the biofilm was removed every two weeks, comprising its full removal every 45 days.

Table 3: Results of $BOD_5$, $COD_T$, Volatile Solids and efficiency removal during phase 2.

| | $BOD_5$ | | | | | $COD_T$ | | | | | Volatile Solids | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inf. | A3 | B3 | C3 | D3 | Inf. | A3 | B3 | C3 | D3 | Inf. | A3 | B3 | C3 | D3 |
| **Average** | 66,4 | 12,8 | 16,9 | 21,5 | 44,1 | 90,5 | 33,7 | 51,9 | 73,0 | 107,5 | 572,7 | 110,7 | 386,6 | 364,5 | 813,9 |
| **Deviation** | 164,4 | 50,3 | 74,3 | 60,1 | 75,6 | 173,6 | 115,6 | 198,6 | 191,2 | 184,7 | 6492,7 | 200,7 | 3106,5 | 3835,1 | 8957,4 |
| **CV** | 2,48 | 3,94 | 4,39 | 2,79 | 1,71 | 1,92 | 3,43 | 3,83 | 2,62 | 1,72 | 11,34 | 1,81 | 8,04 | 10,52 | 11,01 |
| **Max.** | 145,0 | 42,0 | 60,0 | 52,0 | 74,0 | 185,1 | 93,3 | 212,7 | 161,8 | 182,2 | 6539,0 | 204,0 | 2420,0 | 3991,0 | 7417,0 |
| **Mín.** | 15,0 | 1,0 | 2,0 | 6,0 | 24,0 | 27,9 | 3,1 | 3,1 | 9,3 | 15,0 | 60,0 | 53,0 | 58,0 | 54,0 | 14,6 |
| **Efficiency** | | 80,8 | 74,5 | 67,6 | 33,6 | | 62,7 | 42,7 | 19,4 | -18,7 | | 80,7 | 32,5 | 36,3 | -42,1 |

The periodic removal of the biofilm contributed significantly to improve the removal of organic matter, providing very low effluent $BOD_5$ and $COD_T$ concentrations.

The efficiency of volatile solids removal significantly increased during phase 2, corroborating the positive effect of biofilm removal upon the performance of the experimental ponds.

**Table 4:** Results of TP , $NH_3$-N, TKN and efficiency removal during phase 2.

| | PT | | | | | $NH_3$-N | | | | | TKN | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inf. | A3 | B3 | C3 | D3 | Inf. | A3 | B3 | C3 | D3 | Inf. | A3 | B3 | C3 | D3 |
| **Average** | 0,29 | 0,17 | 0,16 | 0,27 | 0,26 | 8,05 | 1,22 | 1,09 | 1,24 | 1,35 | 11,40 | 2,79 | 3,36 | 3,74 | 5,98 |
| **Deviation** | 0,46 | 0,21 | 0,27 | 0,36 | 0,40 | 17,65 | 2,86 | 3,52 | 3,85 | 4,18 | 20,65 | 6,32 | 10,51 | 6,30 | 10,02 |