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A simple, economic and efficient treatment solution for small communities in the State of Bahia

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Abstract
An experimental study was performed on a full-scale treatment plant consisting of screening and primary sedimentation followed by two-stages constructed wetlands. The aim of the study was to assess its suitability for the treatment of the domestic sewage from the small communities (up to 1000 population equivalent, PE) located in the State of Bahia (Brazil). The proposed depuration plant showed a very high removal efficiency of COD, BOD_5, suspended and settleable solids as well as of the microbiological load. The favourable weather conditions promoted high vegetation and degradation rates in the basins, and therefore it was possible to rise the influent load. The sale of the tropical flowers produced by wetlands provided the people with a good income, whereas the effluent was reused in agriculture for watering the communities' vegetable gardens.

Keywords
reuse; domestic sewage; small community; constructed wetland

INTRODUCTION

Brazil is the country with the highest biodiversity in the world. Its macrofauna includes about 525 species of mammals, 1622 birds, 468 reptiles and 517 species of amphibians, of which 788 being endemic. Brazil is the first country in the world for the number of plants and mammals, and the second for amphibians.

In the last years, many States of Brazil, among which the State of Bahia, have experienced a wide economic development which have carried also a rapid urbanization. However, the uncontrolled land exploitation by the new cities and settlements have led to a high pressure on the environment. The urbanization has often lacked of specific investments in the basic services, such as wastewater collection and treatment, electricity, drinking water supply. For instance, in many cities of the State of Bahia the wastewater are still discharged into the environment without any treatment, whereas the solid waste are disposed of through uncontrolled landfills, often closed to the rivers.

Although the general improvement of the economic level, however more than half of population, about 7 millions of people, are still living below the poverty threshold (Brazilian Institute of Geography and Statistics, IBGE, 2000).

The present project was designed within this framework with the aim to provide the small size low-income communities of the State of Bahia with a solution to reduce the environmental problems and control the infectious risks, with costs being sustainable for the local economic conditions. The proposed solution should be considered a prototype to be applied also to other similar areas of the Brazilian State.

Through a full-scale experimental program, it was evaluated the suitability of a selected plant lay-out for the domestic wastewater treatment to produce a final effluent suitable to be reused. The constructed wetland (Kadlec and Knight, 1996) was selected as the treatment technology, due to its

low investment and operation and maintenance costs requirements. Furthermore, the energy consumption is limited due to the minimal need of mechanical equipment, and the effluent might be reused for irrigation.
A thorough economic, social, topographic and environmental analysis was carried out to select the most suitable location where to install the treatment plant.

METHODS

The location of the treatment plant was selected due to its favorable weather conditions: (1) average temperature of 24-26°C, with a minimum of 18°C and a maximum of 33°C; (2) insolation for 2500 h/year; (3) relative humidity in the range of 80-85%.
The main input parameters used to design the plant were as follows: 400 population equivalents (PE) as the lower treatment capacity; 200 L/PE×d as the daily water supply per capita; 1.6 as the hourly peak flow rate; 54 g BOD_5/PE×d as the influent per capita BOD load.
The plant lay-out consisted of three stages: (1) pre-treatment through screening and primary sedimentation, (2) horizontal sub-surface flow wetland and (3) surface flow wetland. A final UV-disinfection was also designed but never installed. The latter two stages were carried through two in-parallel lines as shown in Figure 1 and were expected to accomplish the higher removal rate. A pumping station was used to transfer the influent from the pre-treatment stage to a small tank; the influent was then equally distributed into the two treatment lines by means of two Thomson weirs.
Design of the plant was carried out based on the peak flow rate, that was 128 m^3/d, and followed the criteria outlined by Kadlec and Knight (1996).
Each basin of stage (2) had the following dimensions: 18 mx20 m as a surface area; 0.8 m at the entrance section and 1 m at the outlet as height; bottom and banks slope of 1/100 and 1/1, respectively. Both bottom and banks were covered by a compacted clay layer. Small size gravel was used to fill the beds of the wetland basin. At the outlet, a well was installed to control the hydraulic level, equipped with a butterfly valve for the rapid discharge in the case of need of maintenance and washing activities. A by-pass was also installed on the outlet to allow the effluent from stage (2) to be directly delivered to the UV disinfection system.

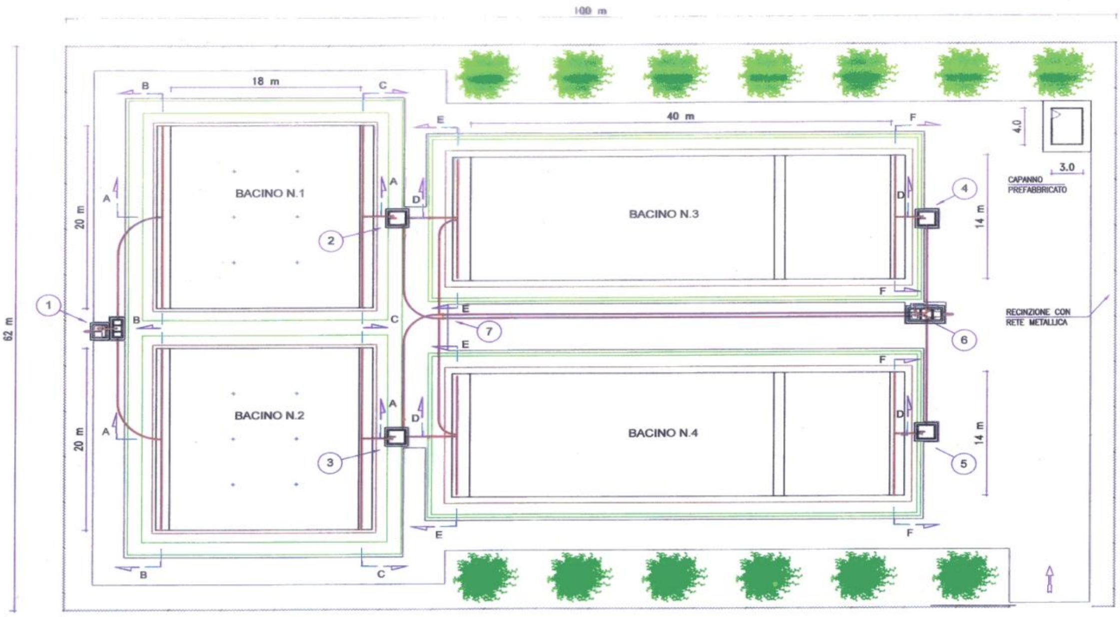


Figure 1. The plan of the plant.

In stage (3), one basin was vegetated with common reeds (*Phragmites australis*) whereas the other one with duckweeds (*Lemnaceae*), to compare their patterns in terms of solid production, microbial reduction, maintenance requirements and insect control. For instance, *Lemnaceae* were selected since produce a thick barrier capable of preventing mosquitos and other insects to deposit their larvae. Basins of stage (3) had the following dimensions: 1120 m^2 as the total surface area (14x40 m for each one at the surface); 0.5 m as a hydraulic level; bank slope of 1/2. Both bottom and banks were covered with a compacted clay layer. In order to reduce the solid content in the effluent, the terminal part (about 1/3 of the length) was separated from the previous part through gabions filled by pebbles and operated as a horizontal sub-surface flow.

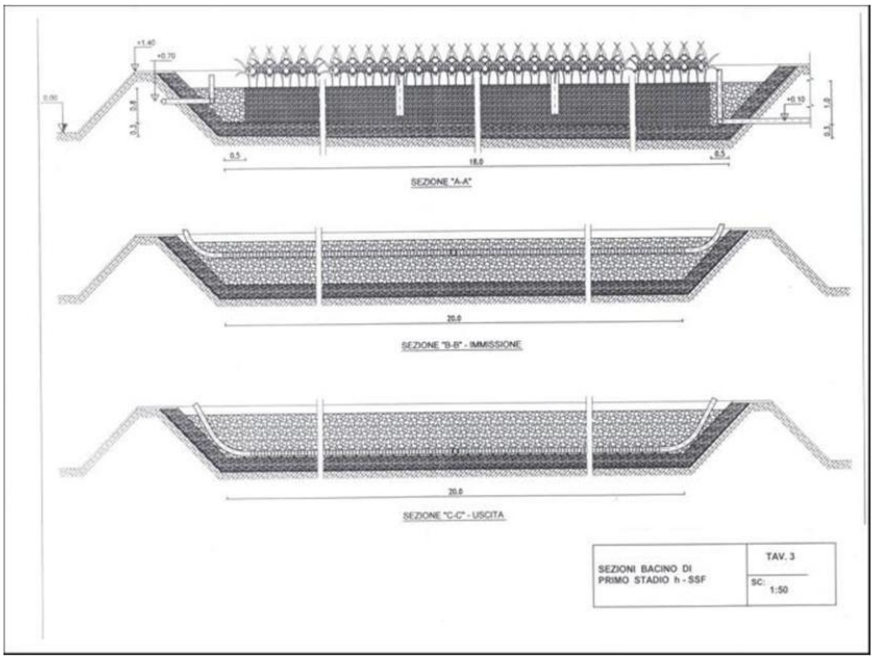


Figure 2. Sections of stage (2).

Figure 3. A view of the plant at the end of the construction phase.

Performance of the plant was determined based on carbon, nitrogen, phosphorous, solids and the microbiological content reduction (APHA, AWWA, WEF 2005; Metcalf & Eddy Inc. 2003).
Based on literature data, the horizontal sub-surface flow wetland was expected to provide the following removal efficiency: (1) 90% of the biodegradable organic load of about, (2) 20-25% of

nitrogen and phosphorus, (3) 90% of total suspended solids (TSS), and (4) about 95-99% of the microbial content. The following stage made by the surface flow wetland was considered as a tertiary treatment needed to further reduce the microbial content.

RESULTS AND DISCUSSION

The favourable weather conditions of the area promoted a high vegetation development and degradation rates in the wetland basins (Figure 4).

Figures 5, 6 and 7 show Total Suspended Solids (TSS), COD and BOD_5 removal efficiency, respectively, measured in the years 2004 and 2005 in the two lines of the plant (red and blue bars, respectively).

The results of an almost 2-years experimental study highlighted high performances of the treatment plant in both lines. The removal efficiency were always above 90% for both COD and BOD_5, and in most cases above 95%. The bacteriological load was also significantly reduced, as shown in Figure 8, as well as the solid content.

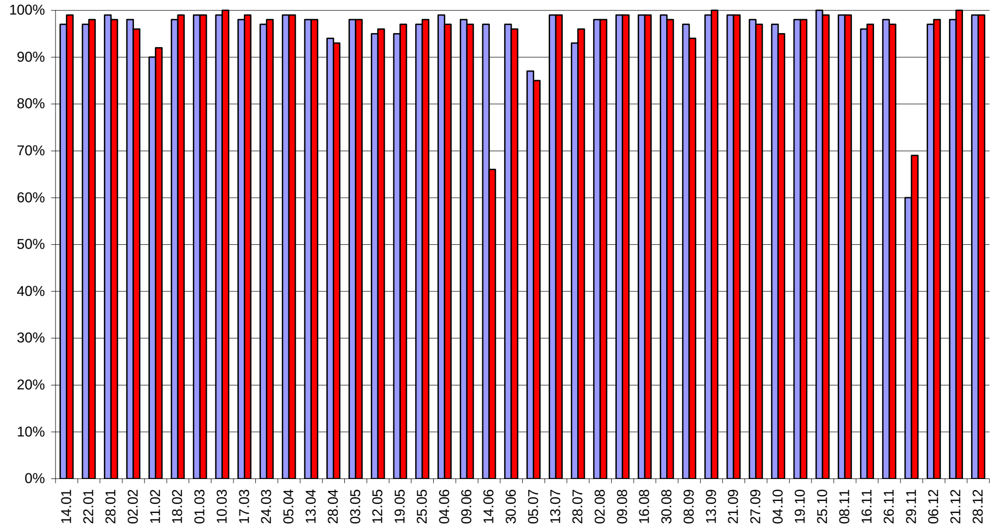
It is worth noting that, although the design treatment capacity was posed equal to 400 PE, however due to the good performances observed and also the urgent need to provide more people with a wastewater treatment, the influent load to the plant was increased up to 1200 PE during the last part of the experimental activity. Despite the higher load, the treatment efficiency remained still high, demonstrating the wide capacity of the plant to couple with variations and increase in the influent load. Performances of the two lines were always comparable, as highlighted by the following Figures. However, after three months of operation, the second line of the plant was converted into a sub-surface flow system due to the proliferation of mosquitos' larvae which are widely diffused in Brazil.

The tropical flowers showed a high rate of growth in the wetlands, and the community was able to sell them obtaining a good income (about 1 Euro per flower sold); similarly, for papyrus and sugar cane (Figure 9).

The State of Bahia also decided to grow vegetable gardens closed to the treatment plant for the communities in the surroundings and to water it with the effluent from the plant.

Figure 4. Vegetation developed in the first basin.

(a)



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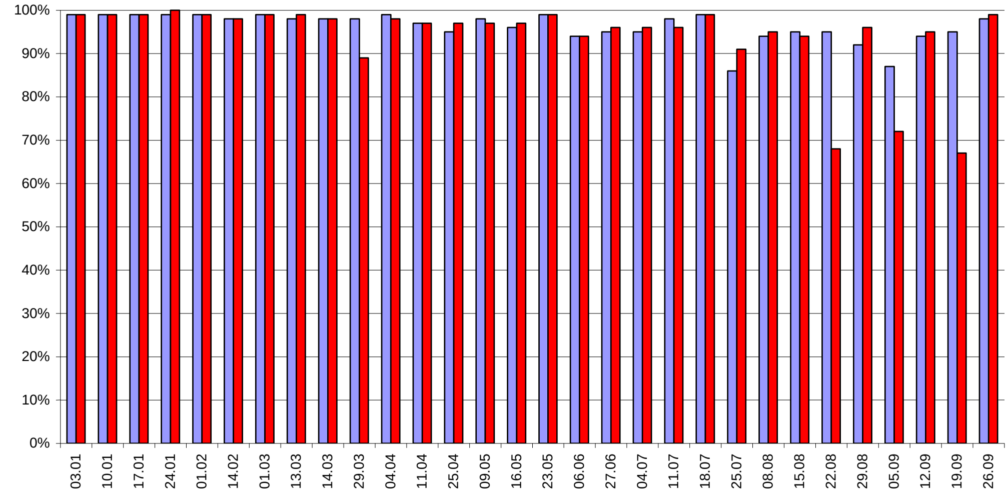
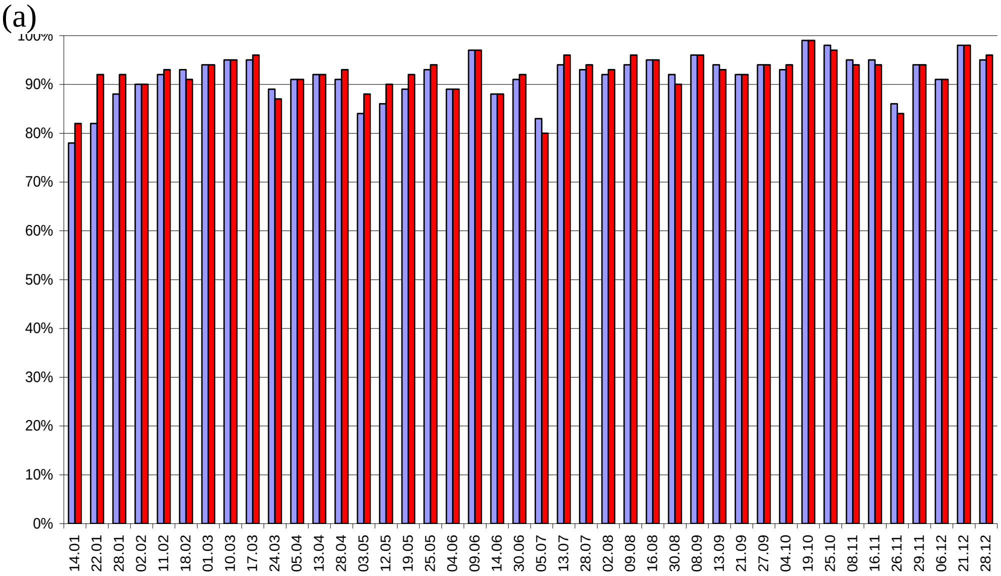


Figure 5. TSS removal efficiency with time in (a) 2004 and (b) 2005.

(a)



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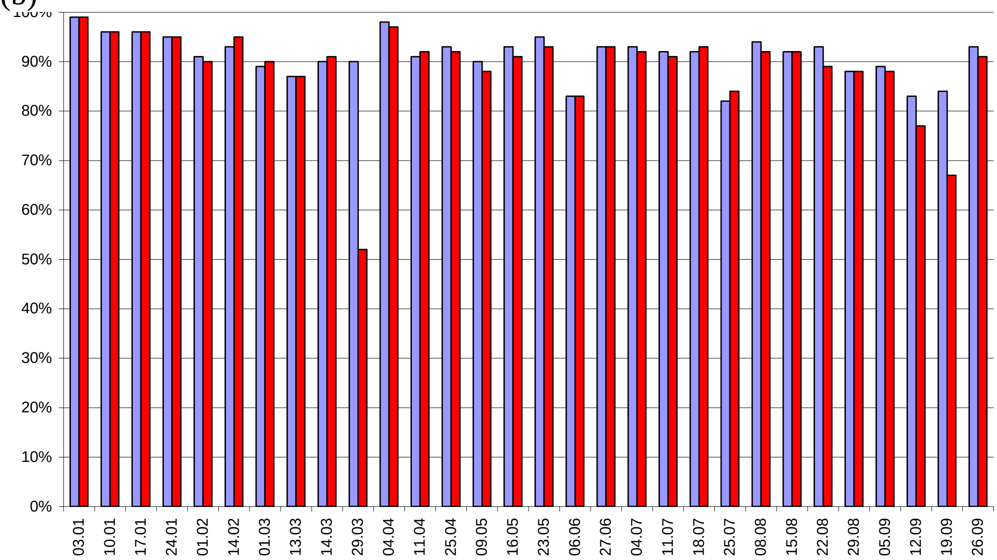
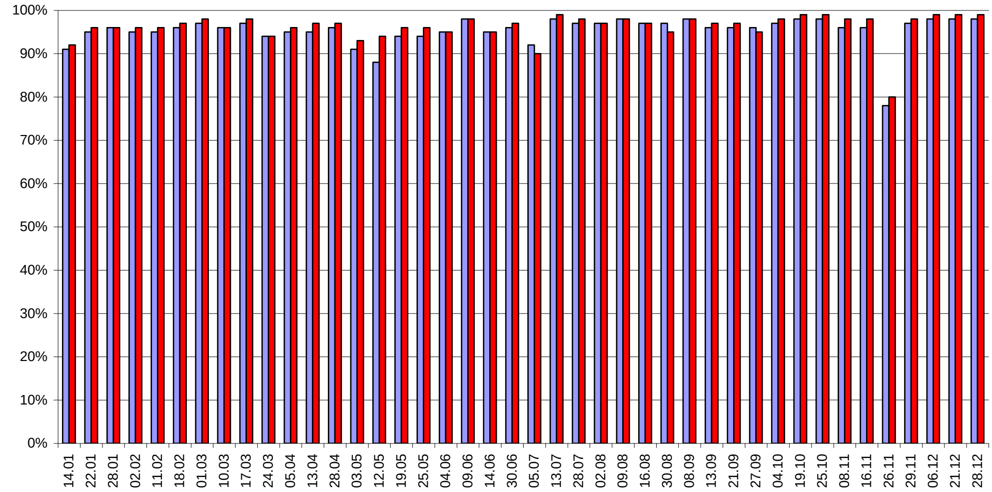


Figure 6. COD removal efficiency with time in (a) 2004 and (b) 2005.

(a)



(b)

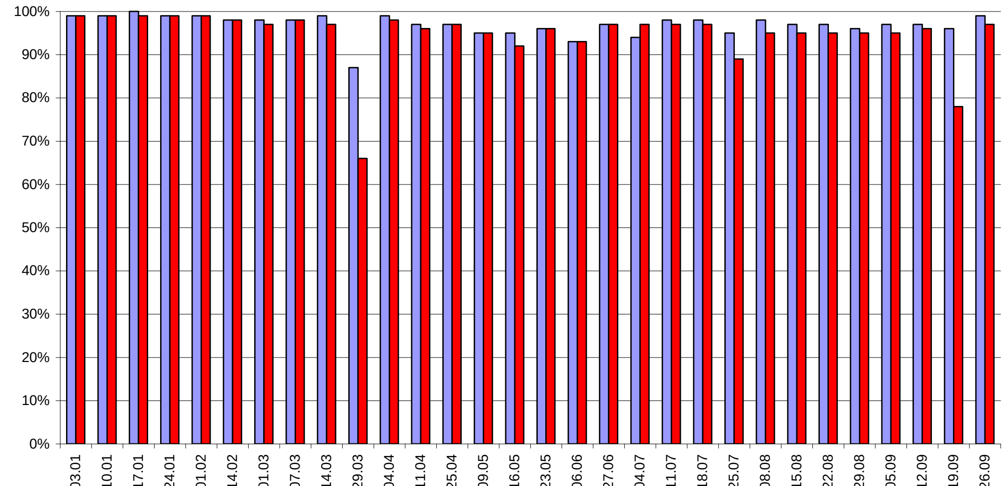
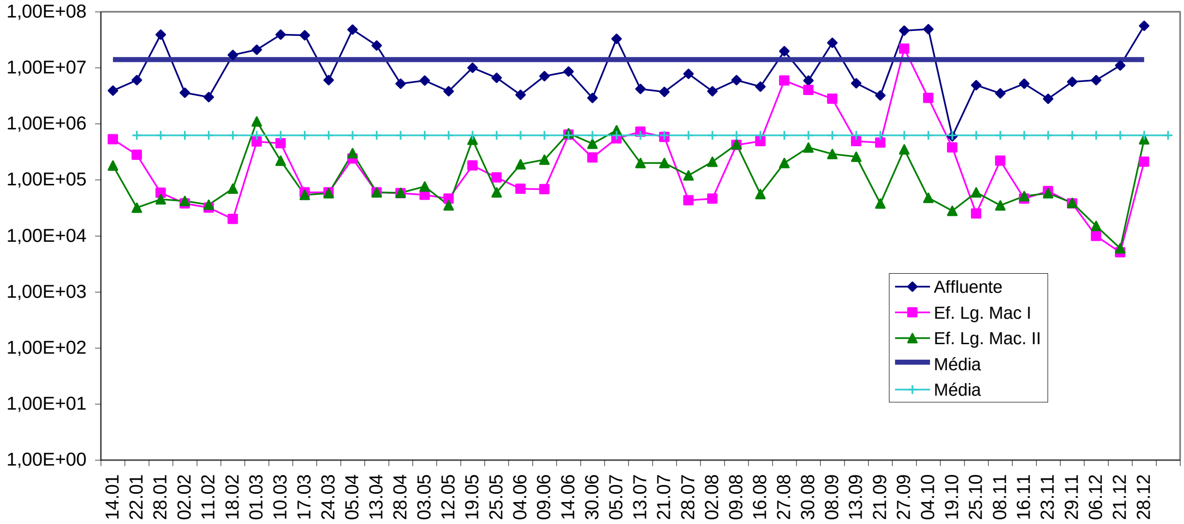


Figure 7. BOD_5 removal efficiency with time in (a) 2004 and (b) 2005.

(a)



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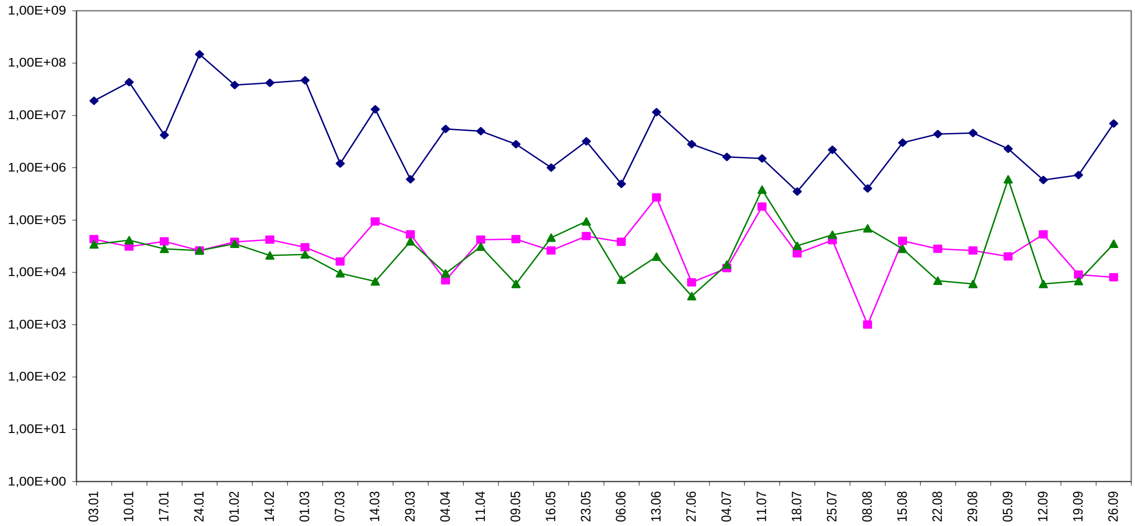

Figure 8. Time variation of thermotolerant *E. Coli* (CFU/100 mL) in (a) 2004 and (b) 2005.

Figure 9. Pictures of papyrus and flower produced in the wetland basins.

CONCLUSIONS

The experimental study demonstrated that the proposed treatment lay-out is capable to obtain: (1) a high and constant depuration efficiency even at the higher influent load; (2) a very low energy demand; (3) a final effluent with a high quality.

Therefore, the objectives posed by the project were fulfilled. For instance, people served by the treatment plant had the possibility to enhance the life conditions, also by the income arising from plants selling; collection and treatment of sewage will reduce the infectious risks and improve the environmental quality state. Furthermore, people had the opportunity to use the effluent to grow their vegetable gardens so as to obtain products to satisfy their personal needs.

The proposed treatment plant can be considered as a prototype which can be exported and applied to other small size and low income communities located in different areas of the State of Bahia.

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