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Water Resources Saving: A Possibly Contribution from a Greywater Collection, Treatment and Reuse

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Introduction

Greywater is the wastewater produced by showers, bath, basins, kitchen sink and laundry and it comprises the 50-80% total domestic wastewater (NOLDE, 2005). Greywater composition varies depending on many factors, such as: residents behavior and activities, income, age products used, infrastructure, and others. Greywater generally contain high turbidity, phosphorus, low Total Solid Suspended content, oils and grease and high surfactants content.

Greywater reuse is an important practice because contributes to reduce the wastewater production and the demand for potable water for purposes that do not require high quality water. Consequently, through the low wastewater generation, contributes to improve the environmental health, with the reduction of environmental impacts, such as: energy consumption, water and land pollution; to improve the public health through the reduction of occurrence of water related diseases; and reduction of required infrastructure of wastewater plant and sewage pipes. Moreover the water reuse can promote an increase of public awareness about water conservation and concerns of wastewater management. A Brazilian study estimated that greywater reuse may generate an economy of 25-30% of potable water consumption in a household (FERREIRA and GHISI, 2007). The treated greywater can be used for non potable purposes, such as: toilet flushing, vehicle washing, laundry, irrigation, industrial use and others.

Some chemical, physical and biological treatment processes have been evaluated for treating greywater, such as: adsorption on activated carbon, sand filtration, membrane bioreactor. However the physical processes have the limitation of non removal of dissolved compounds in high concentrations and requires pretreatment (LI et al., 2009). The chemical processes have low efficiency for COD, BOD and turbidity removal, and thus are applied in specific conditions, when there are less stringent standards for reuse (LIN et al., 2005). Therefore currently there is a trend to incorporate biological processes to greywater treatment.

There are few scientific studies which had evaluated the performance of biological treatment for greywater in Brazil and internationally. The main objective of this study was to evaluate the technical feasibility of a greywater collection and treatment system in order to locally reuse for non-potable purposes. The specific objectives were: to characterize in terms of quality and quantity the greywater from each source, to monitor a pilot system for synthetic greywater treatment and to analyze the quality of the effluent after treatment, to compare the pilot system with other greywater treatment processes, and to indicate potential non-potable uses for treated water.

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Material and Methods

To characterize qualitatively (physicochemical and biological) real greywater samples from different fractions were collected. The greywater sources were: 4 showers, 2 washbasins and 1 washing machine situated on two changing rooms used by employees of School of Arts, Sciences and Humanities, USP. To a better evaluation regarding the greywater generation in this building, interviews were done with the frequent users of the building. And to obtain more accurate measures water flow meters were installed in water inlet of each greywater source. On the outside of the building was built the pilot greywater treatment unit, which includes: 3 plastic collection tanks; equalization basin; pumping devices; aerobic moving bed biofilm reactor; and settling tank. The surplus of greywater collected was by passed to the sewer network. The MBBR (Moving Bed Biofilm Reactor) reactor comprised: carrier elements and aerators. The main operational conditions of MBBR are described on Table 1.

Table 1: Operational conditions of MBBR reactor.

Parameter	MBBR reactor	Unit
Daily flow rate	302	$L.d^{-1}$
Hydraulic Retention Time	4	h
Volume of reactor	83,3	L
Filling ratio	14	%
Biofilm surface area	490	m^2/m^3

During 6 months it was monitored a lab scale experiment with 2 plastic tanks of 20L to produce biofilm. Each tank was filled with 1.5L of seeding (activated sludge), 4L of carriers and 10.5L of raw greywater. The tanks were fed with raw greywater twice a week. After the ending of this experiment the sludge, carriers and greywater were put into MBBR reactor. The carrier ´´biomídia PZE®`` (Brazil) was used in the pilot plant reactor.

Due to an unforeseen event (no greywater generation in the studied building) we could not evaluate the experimental system with real greywater. So, synthetic greywater was prepared according to the formulation of NSF/ANSI 350 (2011), but the secondary effluent was not added. It was produced 800 L of synthetic greywater twice a week feeding the reactor at this frequency. The MBBR was in continuous operation for three months. During this period, samples were collected from the following points: equalization basin effluent (raw), inside MBBR reactor, after settling tank (treated). Determined parameters included: Turbidity, Total Suspended Solids (TSS), pH, Dissolved Oxygen, conductivity, alkalinity, oils and grease, residual chlorine, anionic surfactants, Total Nitrogen, Total Phosphorus, organic matter (COD and BOD), sulfate. These analyses were performed in accordance with Standard Methods for the Examination of Water and Wastewater 20th edition (APHA, 1998). The indication of potential applications for treated water was done through comparison between obtained values after treatment and effluent compliance values for non-potable applications according to some national and international water reuse regulation.

Results and Discussion

The biomass developed on the carriers in the laboratory and pilot experiments and could be visually verified, especially in the internal surface of the carriers but there was slow and low biofilm growth attached and suspended. The limited nutrient content and low organic matter content in raw synthetic greywater might have caused it. In addition the high anionic surfactant concentration could have affected the biofilm growth. Some microorganisms attached to the carrier were observed in microscopy. We identified protozoa (*Difflugia bacillifera*, *Cochlippodium bilimbosum*) and bacteria flocs, which are organisms generally found in sludge active treatment.

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The results of greywater generation indicated that the higher volume of greywater was produced by washing machine use (145.3 L/day), followed by showers (63.6 L/day) and washing basins (39.2 L/day). These results were similar to obtained by GONÇALVES et al. (2009) in a building with 3 persons. But it was different of the results reported by other authors, because the greywater generation is very variable and depends on the household occupancy, gender, age, water availability, country, and other factors. The characterization of real greywater showed COD:N:P of 100:6.42:0.95. In comparison with other studies (JABORNIG and FAVERO, 2013) this do not indicate nutrient deficiency in greywater. The Total Phosphorus content was low in greywater from washing machine because of the laundry products composition. BOD, TSS and turbidity were higher in greywater from shower than in the other sources. The COD/BOD ratio was 2.05 (similar to the value found by PIDOU *et al.*, 2008). The greywater from showers had the highest *E. coli* count ($5.06x10^4$cfu.$100mL^{-1}$). For most parameters the results of greywater characterization were in the range reported in the literature.
During the treatment of synthetic greywater the Dissolved Oxygen was high inside the MBBR reactor about 7 mg/L. The slowly/non-biodegradable organic matter fraction was higher in synthetic greywater than in real greywater. The Table 2 describes the mean results for each parameter in raw and treated water and the removal efficiency.

Table 2: Results of the monitoring of pilot treatment for synthetic greywater.

Parameter		**Raw**	**Treated**	**Removal Efficiency (%)**
Turbidity	n	11	11	
	Mean	40.23	13.67	66
	S.D.	21.27	7.79	
	n	10	11	
TSS	Mean	87.3	11.28	87.07
	S.D.	117.81	9.34	
	n	8	8	
Total N Kjeldahl	Mean	2.81	4.17	_
	S.D.	1.92	2.09	
	n	10	10	
Total P	Mean	6.59	5.8	12
	S.D.	5.62	5.31	
	n	8	10	
BOD	Mean	44.37	18.2	59
	S.D.	7.76	7.58	
	n	11	11	
COD	Mean	246.63	73.86	70
	S.D.	204.39	30.87	
	n	6	6	
Sulfate	Mean	90.1	71.39	21
	S.D.	37.96	7.82	
	N	6	6	
Anionic Surfactants	Mean	18.65	13.01	30
	S.D.	3.4	4.47	

S.D. = standard deviation.

In comparison with other studies that evaluated biological processes (e.g.membrane bioreactor, rotating biological contactor) in greywater treatment (JABORNIG and FAVERO, 2013) the removal efficiencies of Total Phosphorus, BOD and turbidity (Table 2) were lower than the

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results of these authors. If we compare our results with studies which evaluated the MBBR in domestic wastewater treatment (KIM et al., 2011) the removal efficiencies of Total P, Turbidity, BOD, COD and Total N are also lower. But it is important to note that the operational conditions vary from a study to other (HRT, carrier, influent characteristics) which affect the performance of the treatment. In spite of the low removal efficiencies for most parameters, depending on the required water quality and the purpose, this treatment can be enough and viable to be applied in household or commercial buildings. In comparison with the legislations from Queensland, Portugal and USA the water treated by this experiment do not comply the requirements for the application on flushing toilet and indoor uses, mainly due to the high turbidity in the treated water.

Conclusions and Outlook

The highest volume of greywater was generated in washing machine use, and in this building the mean greywater production was 248 L/day. The design and sizing of greywater treatment systems should be based on qualitative and quantitative parameters of greywater and should not be based on domestic wastewater (non segregated) parameters. The synthetic greywater had low Total Nitrogen content, which could have limited the biological treatment.

The treatment of synthetic greywater resulted in low removal efficiencies, which indicates that the pilot treatment may be enhanced with the addition of a treatment stage after the settling tank to increase the turbidity removal or through the evaluation of the influence of the operational conditions in the performance of the treatment.

Finally, the water reuse is a viable option to reduce significantly of the potable water consumption. And the treatment must ensure the safe reuse and the appropriate operation and monitoring of the treatment system.

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