Introduction

More than 2.6 billion people suffer from lack of access to basic sanitation according to WHO (2006). While in rich countries coverage and technology for treatment of sewage is growing and developing, in the less developed countries if water access is still a problem much less attention is fixed on sanitation. Water scarcity, poor water quality and health issues are among the main concerns about water according to UNESCO (2003). Millenium Development Goals by UN stated that, by year 2015, the people without basic sanitation should be reduced to half of that in year 2000.

Improving water quality, as well as mitigation of water scarcity, is very closely related to management of domestic wastewater. Currently, the interest in water reclamation and reuse is a hot topic for arid and semi-arid areas, leaving the countries with abundant water in risk of underestimation of the possible consequences of direct discharge of wastewater to water bodies. It must be not forgotten that sanitation is a key issue for the sustainable development of communities.

Traditional centralized methods have accomplished some success in urban and suburban areas, however, when considering rural area, where an important percentage of population is living and where such an key economical activity as agriculture is developed, the feasibility of traditional methods vanishes due to economical and material challenges. New holistic approaches, able to evaluate each case’s different conditions should be considered, among which onsite sanitation remains as the only appropriate alternative.

Literature Review

Onsite Wastewater Differentiable Treatment System

The Onsite Wastewater Differentiable Treatment System (Lopez Zavala, 2002) focuses on separating domestic wastewater into three types: Black water (from toilet), Lower Load Greywater (LLGW, from shower, bath, wash basin) and the Higher Load Greywater (HLGW, from kitchen, washing machine) (Funamizu, 2002). Together with implementing biotoilet for recovering feces as compost and urine as fertilizer, an adaptation of this system is thought as a viable alternative to provide or improve sanitation in houses located in rural communities of Central America.

OWDTS proposes the treatment of HLGW prior to discharge to soil infiltration, and no treatment of LLGW before its discharge. However, a review of many cases of greywater treatment examples around the world stated that no greywater of any kind should be directly discharged to soils in any case (EAWAG, 2006), due to the deleterious effects on environment. Therefore, the following greywater treatment scheme (Figure 1) is proposed:

Fig 1. Scheme for Greywater Management

Geotextiles use in wastewater treatment

The purpose of this research is to evaluate the performance of geotextile removing SS from domestic LLGW. Some researchers (Korkut, 2003 and Kotha, 2004) previously experimented about usage of geotextiles for treatment of urban runoff and municipal wastewater.

A geotextile is a synthetic fabric made of different polymer compounds. The geotextile has a porous or a permeable character and capable of retaining SS when wastewater is passed through it. The previous investigations emphasized the filtration principle, geotextile material properties and physical properties of SS in wastewater.

Shallow ISFs

Darby (1996) reviewed the technology of ISFs, arguing that whereas it was an old technology, through simple improvements it was possible to renew the interest in...
using them, especially because of their strong merits, as good quality of effluent and low skill requirements for maintenance. An experiment with 16 shallow (38 cm depth) ISFs was performed for 80 days and proved that through low HLR and multiple dosings it was possible to obtain very good effluent. Reaction rate within the ISFs was not obtained, but concluded the feasibility of shallow ISFs.

**Linear Alkylbenzene Sulfonates (LAS)**

LAS is an anionic surfactant used in detergents. Production of it surpasses the 2.8 million tons in the world. It is estimated that usage in some areas (Eastern Europe) is about 3.5 g/person/day, which means a concentration in graywater of around 30 mg/L. It is possible to say that LAS is one of the representative biodegradable surfactants in the world, but this biodegradation might be inhibited if larger than certain concentrations (20-50 mg/L). LAS contained in commercial detergents are compound in alkyl group, C10 to C14.

**Objectives**

**General Objective**

• Assess the feasibility of an integrated management system for reclamation and reuse in agriculture of source-separated gray water at domestic level in rural communities.

**Specific Objectives**

• Determine possible filters for removing coarse material in LLGW prior to treatment by Intermittent Sand Filter.
• Evaluate and compare performance of ISF with and without pretreatment.
• Optimize the lifetime of ISF and determine approach for design.

**Methodology**

For the evaluation of geotextiles, a series of batch tests were performed on 6 types of geotextiles selected according to literature on usage of this material as filter for suspended solids. Lower load greywater was used as influent and evaluated the effects of geotextile and the changes within them.

For evaluation of geotextile and ISFs, two experimental runs with 4 ISFs each were performed to discuss effects of geotextile on performance, as well as effects of media size and hydraulic loading rate when treating source separated lower load greywater. Quality of effluent was measured at different depths of ISF to determine the reaction rate and make an approach to design the depth and area required for onsite application. This experiment ran for 60 days, after which columns were dismantled and the layers of sand collected and analyzed to determine the biomass distribution and the effects on treatment.

**Sand Effective Size**

Media Effective Size for Intermittent Sand Filter is recommended to be fine to medium sand, between 0.40 and 1.50 mm diameter, according to USEPA. For this experiment, two media sizes were prepared, one fine: 0.30 mm and one medium: 0.60 mm. Sand was sieved to obtain the a uniformity coefficient of 1.4 and 1.66 respectively. In this experiment single layer of sand was used to determine the specific performance of each size.

**Hydraulic Loading Rate**

Darby (1996) experimented with several HLR and determined that for municipal wastewater, optimum limit would be between 16 to 32 ml/cm²/day.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Operation (days)</th>
<th>Column</th>
<th>Geotextile</th>
<th>HLR (ml/cm²/day)</th>
<th>Effective Media Size (mm)</th>
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<tr>
<td>1</td>
<td>60</td>
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<td>H</td>
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<td>48</td>
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</table>

**Dosing**

The daily hydraulic loading rate was split into 3 equal discharges during daytime (9:00, 12:00 and 18:00), each one corresponding to: morning, noon and evening time, respectively.

Table 1. Experimental Conditions
Results and Discussion

Performance of Geotextiles

Fig 3 shows the results of average batch tests performed on 3 samples of each material. Y axis represents the percentage to the initial measured permittivity and X axis is the loaded volume (in intervals of 50 ml/cm²) of LLGW.

AMANCO NT3000 was considered the most efficient material because of the amount of particles removed and longer lifetime than the only other comparable material (NT2000), therefore it was chosen for experiment with ISFs.

Fig 3. Lifetime of geotextile filters

![Graph showing lifetime of geotextile filters](image)

Fig 4 shows the removal of TSS when filtering 3 influents with different particle size distribution. Left Y axis is the concentration of TSS and right Y axis is the percentage removed. X axis is divided in the 3 cases, including the characteristics of raw LLGW and 3 measurements of effluent, after loading 50, 100 and 150 ml/cm² respectively.

Results shown in Figure 4 show that removal of small particles is related to the amount of large particles present in influent. Accumulation of the large particles rapidly reduces the theoretical "pore size" of the textile, therefore retaining more particles.

![Graph showing TSS removal by AMANCO NT3000](image)

Experiment 1 ran for 60 days. During the first 7 weeks Column A, B and C had a sustained increase of the infiltration time. After 27 days Column A was completely clogged and operation was stopped. Apparently pretreatment didn’t inhibit the accumulation of material in the surface of Column B, just delayed the clogging time.

Both Columns B and C showed some type of decrease in the rate of infiltration time after 6 weeks. Perhaps some point of stability could be achieved, but a longer operation is needed to determine that consistently.

Column D showed a slight increase in infiltration time after 5 weeks, but didn’t show more increase after that, showing a clear effect of geotextile on its performance.

An evaluation of the weight loss by ignition in sand was made and it showed the amount of solids that cause clogging in the surface of the filter media (1.5 cm depth).

Column A, B and C showed larger amount of Volatile Solids in surface layer than Column D. This is directly related with the infiltration time of influent shown in Figure 4.3. Less accumulation of solids in the upper layer means less decrease of infiltration time.

Reaction Rate of COD and LAS and Retention Time

COD in effluent had quite a stable value after two weeks of starting the experiment. Slightly lower values for columns with fine media was observed, but no huge difference. No TSS were observed at all at depth 100 cm.

![Graph showing reaction rate of COD in Experiment 1](image)
Column A was clogged before any analysis could be performed at different depths, so the data of Experiment 1 includes only Columns B, C and D. Figure 6 and 7 shows results of COD in Experiment 1 and Experiment 2 in logarithmic scale. It was expected to have a First Order Reaction, but the reaction was much more pronounced in the first 20 centimeters. Reaction K1 at 0 to 20 cm depth is different in the 3 cases B, C and D to the K2 from 20 to 100. As the target is to look for shallow ISFs, K1 was used for comparisons. Results indicate the importance of the 20 cm depth layer.

Reaction of LAS, similarly to COD reaction, in Experiment 1 columns, a different reaction coefficient K was observed for the 20 cm depth. However, for Experiment 2, K appears to have a single value for the whole column. Concentration was below 10 mg/L after at 20 cm depth.

The value of reaction rate K, was found to have a relationship with the retention time inside column. Larger volumes reduce the retention time in surface, making less effective the 20 cm layer as well as the overall performance. By increasing number of doses or the discharge time, retention time would increase and have a more efficient behavior. Figure 8 shows the value of K depending on the average retention time inside the sand filter column. Retention time is drastically reduced when loaded volume increases to double and triple of initial one, corresponding to the trend shown by the arrow.

Conclusions

- Polypropylene nonwoven needlepunched geotextiles showed a good capacity to remove suspended solids from lower load greywater. TSS could be reduced in a range of 50 to 95%. Removal of TSS increased progressively as the loaded influent accumulated.

- Geotextiles showed capability to extend lifetime of ISFs by inhibiting the accumulation of material in the surface of it. Intermittent Sand Filters with medium size media and a moderate HLR of 16 ml/cm2/day plus a geotextile filter pretreatment are very effective for treating LLGW. Shallow design is possible, as it was seen that the 20 cm depth achieves a quite large removal of COD and none or little TSS is observed in effluent at that depth. Reaction of removal of LAS is also happening at shallow depth.

- Retention time in the sand media was the factor that determined the quality of effluent rather than HLR itself. However, increase of HLR (in order to reduce area required) in ISF under the discharge conditions of experiment (one single sudden discharge), appears to reduce dramatically the retention time inside the filter, reducing the efficiency of treatment at shallow depths.

References


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