PHYSICOCHEMICAL TREATMENT OF GREYWATER

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ABSTRACT

Household wastewater consists of greywater and blackwater. Greywater is the wastewater produced in bathtubs, showers, hand basins, kitchen sinks, dishwashers and laundry machines and blackwater is the wastewater which comes from toilets, although wastewater originated from kitchen sinks is very often regarded as blackwater. Segregation of greywater from blackwater and on site greywater treatment for toilet flushing and/or garden irrigation is an interesting option especially in areas facing water shortage problems. Several studies have shown that greywater accounts for around 70% of the total household wastewater production, while at the same time it concentrates a rather limited portion of the total pollutional load of wastewater. It has also been demonstrated that the quality characteristics of the several greywater fractions (from bathroom, laundry, kitchen) vary significantly depending on resindents' habbits. In view of the above the aim of this study was to evaluate the effectiveness of a rather simple physicochemical treatment system to treat greywater originating from different sources.

Greywater samples were collected twice a week from bathtub, handbasin and laundry of a four residents household and based on the contribution of each fraction a greywater mixture was produced. Subsequently greywater was processed in an experimental system consisted of a sedimentation tank, followed by a sand filter and a granular activated carbon (GAC) filter. Samples were collected twice a week from the outlet of each treatment unit and subsequently being analyzed for turbidity, TSS, VSS, COD_t, COD_s and LAS.

Based on the results turbidity decreased significantly throughout the experimental system from 71 NTU to 43.5 NTU in the effluent of sand filter and finally to 10.5 NTU in the effluent of the GAC filter. Similarly, a TSS removal from an average initial concentration to the order of 74 mg/L to 12.5 mg/L in the final effluent was also recorded. The contribution of the three treatment units in the total TSS and VSS removal was equal to 35%, 17% and 48% for the sedimentation, the sand filter and the activated carbon filter respectively. Furthermore the role of sand filter on the removal of COD and surfactants was rather limited and activated carbon filtration was the primary removal mechanism for both pollutants (account for the 63-72% of the total COD and LAS removal). Based on the above a coagulation unit was added in the experimental system prior to sedimentation. For the evaluation of the optimum coagulant dose ($AL_2(SO_4)_3$ x14H_2O) a series of jar tests were performed. According to the experimental results the treatment capacity of the experimental system was significantly improved. More specifically effluent turbidity was as low as 1 NTU whereas average TSS, total COD and LAS concentrations in the effluent were equal to 2 mg/L, less than 10 mg/L and 1 mg/L respectively. Therefore it is anticipated that a system consisting of coagulation, sedimentation, sand and activated carbon filtration supplemented by a disinfection unit for pathogen reduction can provide for greywater reuse for both unrestricted irrigation and toilet flushing.

Keywords: Greywater; physicochemical treatment; reuse; sand filtration

1. Introduction

Household wastewater consists of greywater and blackwater. Greywater is the wastewater produced in bathtubs, showers, hand basins, kitchen sinks, dishwashers and laundry machines and blackwater is the wastewater which comes from toilets (Eriksson *et al*., 2002), although wastewater originated from kitchen sinks is very often regarded as blackwater. Segregation of greywater from blackwater and on site greywater treatment for toilet flushing and/or garden irrigation is an interesting option especially in areas facing water shortage problems. Several studies have shown that greywater accounts for around 70% of the total household wastewater production, while at the same time it concentrates a rather limited portion of the total pollutional load of wastewater (Friedler *et al*., 2004; Jefferson *et al*., 2004; Li *et al*., 2009; Donner *et al*., 2010; Antonopoulou *et al*., 2013). It has also been demonstrated that the quality characteristics of the several greywater fractions (from bathroom, laundry, kitchen) vary significantly depending on resindents' habbits (Cristova-Boal *et al*., 1996; Almeida *et al*., 1999; Nolde 1999; Palmquist and Hanaeus 2005; Eriksson *et al*., 2009; Hernandez Leal *et al*., 2007). In view of the above the aim of this study was to evaluate the effectiveness of a rather simple physicochemical treatment system to treat greywater originating from different sources.

Several greywater treatment systems have been tested in a great number of studies including physical, chemical and biological systems (Prathapar *et al*., 2006; Pidou *et al*., 2008). Based on their results it is anticipated that besides their favorable performance, biological greywater treatment systems are in some cases related with operating difficulties on a household basis due to nutrients deficiency of greywater and the need for sewage sludge handling.
In view of the above the aim of this study was to evaluate the effectiveness of a rather simple physicochemical treatment system to treat greywater originating from different sources.

2. Materials and methods

2.1. Greywater treatment experiments

Greywater samples from the bathtub, the handbasin and laundry were collected every two days and being processed in two experimental units. System A consisted of a 10 L sedimentation tank, followed by a sand filter and a GAC filter. System B is a modification of System A with the incorporation of a coagulation unit ahead of the sedimentation tank and the two filtering units (sand filter and GAC filter). The contribution of each greywater fraction was equal to 16%, 56% and 28% for bathtub, handbasin and laundry respectively. Greywater retention time in sedimentation tank of both experimental systems was equal to 20 h. The supernatant of sedimentation tank was fed initially to sand filter (5 cm plexiglass column) and eventually passed through the GAC filter at a flowrate of 2.8 L/h and a filtering velocity of 1.4 m/h. For the evaluation of the optimum coagulant dose ($AL_2(SO_4)_3$ x14H_2O) a series of jar tests were performed. Samples from the untreated greywater, the supernatant of the sedimentation tank and the effluent of the sand filter and the GAC unit were collected twice a week and subsequently being analyzed for turbidity, TSS, VSS, COD_t, COD_s and LAS.

2.2 Analytical methods

Greywater samples were analyzed for pH, conductivity, TS, TSS, VSS, total and soluble COD and LAS. All analyses were performed according to Standard Methods (APHA, 2005).

3. Results and discussion

The results from the operation of the experimental systems are presented in Tables 1-2 and Figures 1-2. More specifically Tables 1-2 present the average values of turbidity, TSS, total and dissolved COD and linear alkylbenzene sulfonates (LAS) at the effluent of each treatment unit for Systems A and B respectively, whereas the contribution of each treatment unit to the overall removal of each pollutant is illustrated in Figure 1. The results of the jar tests are presented in Figure 2.

Based on the results turbidity decreased significantly throughout the experimental System A from 71 NTU to 43.5 NTU in the effluent of sand filter and finally to 10.5 NTU in the effluent of the GAC filter. Similarly, a TSS removal from an average initial concentration to the order of 74 mg/L to 12.4 mg/L in the final effluent was also recorded.

Table 1: Results from the operation of experimental System A

System A (sedimentation-sand filtration-gac filtration)					
	Turbidity (NTU)	TSS (mg/L)	COD_t (mg/L)	COD_s (mg/L)	LAS (mg/L)
Influent	71.2	74.1	347	192	75
Sedimentation tank effluent	53.7	52.9	315	153	58
Sand filter effluent	43.5	42.2	261	143	48
GAC effluent	10.4	12.4	29.7	12.5	1.9

Table 2: Results from the operation of experimental System B

System B (coagulation-sedimentation-sand filtration-gac filtration)					
	Turbidity (NTU)	TSS (mg/L)	COD_t (mg/L)	COD_s (mg/L)	LAS (mg/L)
Influent	70.5	72.8	372	170	82
Sedimentation tank effluent	17.7	32.0	144	98.2	29
Sand filter effluent	4.86	7.69	113	92.3	20
GAC effluent	1.37	2.35	8.14	7.50	0.97

The contribution of the three treatment units to the total TSS and VSS removal was equal to 35%, 17% and 48% for the sedimentation, the sand filter and the activated carbon filter respectively. Furthermore the role of sand filter on the removal of COD and surfactants was rather limited and activated carbon filtration was the primary removal mechanism for both pollutants (account for the 63-72% of the total COD and LAS removal).

Based on the above a coagulation unit was added in the experimental system prior to sedimentation (System B). For the evaluation of the optimum coagulant dose (AL2(SO4)3 x14H2O) a series of jar tests were performed (Figure 2). According to the experimental results the treatment capacity of the experimental system was significantly improved. More specifically effluent turbidity was as low as 1 NTU whereas average TSS, total COD and LAS concentrations in the effluent were equal to 2 mg/L, less than 10 mg/L and 1 mg/L respectively. As illustrated in Figure 1, due to coagulation, the contribution of sedimentation to the total turbidity, TSS, total COD and LAS removal increased to 76%, 58%, 63% and 66% respectively, whereas activated carbon adsorption was the dominant mechanism for the removal of soluble COD. As a result the cleaning frequency of the sand filter was reduced from 9 d for the case of System A to 6 d for System B.

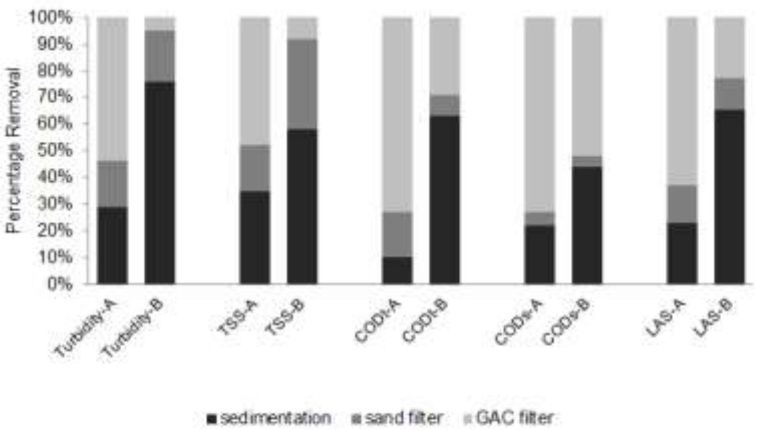

Figure 1: Contribution of each treatment unit to the removal of pollutants from greywater

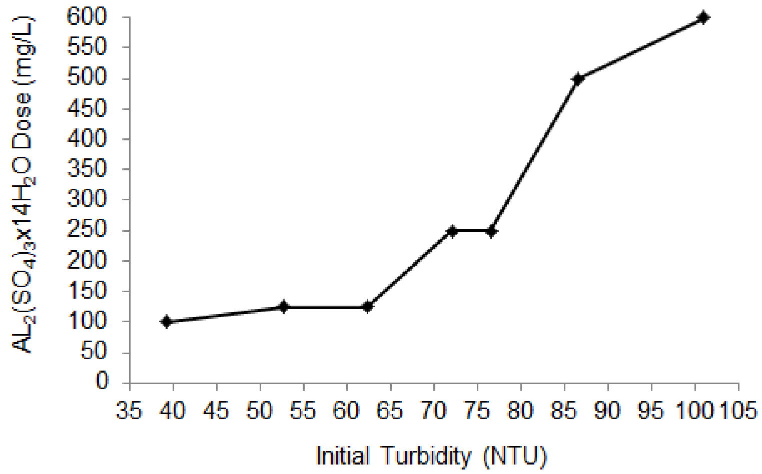

Figure 2: Optimal coagulant dose for variable initial turbidity values

By comparing the results from the operation of the two experimental systems TSS concentration for the 80% of the samples was equal to 14 mg/L and 2.6 mg/L for Systems A and B, whereas turbidity values for the 50% of the samples were equal to 11 NTU and less than 1 NTU for Systems A and B respectively. Therefore, by taking into account the national limit values for wastewater reuse (Joint Ministerial Degree 145116/8-3-2011) it is anticipated that a system consisting of coagulation, sedimentation, sand and activated carbon filtration supplemented by a disinfection unit can provide for greywater reuse for both unrestricted irrigation and toilet flushing.

4. Conclusions

The objective of this study was to assess the effectiveness of a rather simple physicochemical system to treat greywater originating from different sources. The experimental system consisted of a sedimentation tank, followed by a sand filter and a granular activated carbon (GAC) filter. According to the results the operation of such a system can provide for greywater reuse for restricted irrigation. In order to improve its operation and to achieve a treated greywater quality proper for unrestricted irrigation and toilet flushing a coagulation unit is required to be incorporated ahead of the sedimentation tank.

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