GREY WATER TREATMENT BY COMBINED RBC and TWO STAGE FILTRATION SYSTEM FOR REUSE

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ABSTRACT

The approach of household wastewater segregation to components and treatment separately for reuse is considered as a sustainable way to achieve resource management. Grey water (GW) comprises domestic wastewater which excludes toilet flushes and sometimes kitchen discharges. GW is recognized as more simple to be treated and more safe for non-potable recycling. Nevertheless, there is still need for technology assessment for the points of characterization, performance evaluation, reliability and adaptation for practical implementation purposes under local conditions.

In this study, GW produced from lodging buildings located in TUBITAK MRC including showers, washing basins, washing machines and kitchen discharges was utilized. The GW treatment experiments conducted with a pilot system incorporated, mash screens, rotating biological contactor (RBC), two-layer-filtration (anthracite-sand), disinfection by UV and chlorination. The system was operated for about 1.5 years and pollutant parameters relevant to reuse were monitored at monthly intervals. The system was operated using two different flow rates (580 and 720 Ld^{-1}) with an average COD loading rate of 9.7 g/m^2-d for RBC.

The average effluent BOD_5 concentration was determined to be 5-8 mgL^{-1} which designates BOD_5 removal efficiency of 91-94%. Whereas, overall 89-92% COD, 92-94% TSS, 98-99% turbidity and 80-85% TKN removal efficiencies were attained. Besides, THM, turbidity, colour, TN, TP, detergents oil and grease, microbiological parameters (total, faecal, E coli and enterococci) were monitored. Kinetic assessment of the biological processes was accomplished by using variable order model approach. It was proved that treated GW effluent satisfied criteria for non-restricted reuse. Energy requirement of the entire system was also determined. The system performance was evaluated in comparison with other GW treatment methods and reuse requirements. The results revealed that combined RBC and two stage filtration system, used in this study, may present a reliable method. Filtration was supportive for high organic loading rates to ensure reuse criteria constantly. The entire system can be placed in basements of buildings. It is beneficial in terms of installation and operation cost and maintenance need. The system may be manufactured using local materials and equipment. However, the major drawbacks are; prolonged biofilm growth time, back-wash requirements for filtration and continuous energy requirement. Moreover, GW reuse may considerably reduce potable water consumption and heat recovery from GW may also be accomplished, which constitutes an advantage for sustainability and mitigation of carbon foot print. The study was conducted within the context of PREPARED-FP7 project.

Keywords: grey water, characterization, treatment, reuse, RBC, process kinetics, energy assessment.

1. Introduction

Greywater (GW) is household wastewater produced from baths, showers, clothes washers, and lavatories. Kitchen wastewater is sometimes categorized as also GW. The characterization of GW, the required treated water quality and the type of reuse application plays important role for the selection of the technology to be implemented for GW treatment and reuse. GW can be treated using a vast range of technologies for reuse purposes including membrane bioreactors (Kraume *et al.*, 2010; Hocaoglu *et al.*, 2013; Atasoy *et al.*, 2007), rotating biological contactors, RBC (Baban *et al.*, 2010; Friedler *et al.*, 2005), anaerobic treatment (Leal *et al.*, 2011), combined physical and biological treatment systems (Kadewa *et al.*, 2010) and advanced oxidation systems. Although, various technologies implemented and tested depending on the local conditions, system performance and complexity, sufficient consent has not yet been established on the most appropriate technology option for viable and practical decentralized applications in individual buildings.

In this manner, in order to overcome operational difficulties and performance failures a combined biological and physical GW treatment system which, may be installed in the basements of buildings was proposed. The system was constructed and run for a period of 1.5 years. The elements of the treatment systems include mash screens, rotating biological contactor (RBC), two-layer-filtration (anthracite-sand), UV disinfection and a chlorination unit. In this study, GW produced from TUBITAK MRC lodging buildings was used. The study mainly focused on GW characterization including conventional parameters, microbiological parameters and micro-pollutants, assessment and comparison of the performances of different units, determination of the reliability of the proposed alternative, as well as the biological treatment process kinetics for organic matter removal and nitrification. The filtration unit was intended to polish biologically treated GW as well as to minimize the deteriorations in effluent quality due to biological processes failures.

2. Materials and methods

GW was collected from lodging buildings of TUBITAK–MRC. GW comprised of showers, washing basins, washing machines and kitchen discharges. Two coarse screens (6 and 3 mm) were used to remove large particles. GW was then fed to the RBC by a peristaltic pump (0-50 L h^{-1}). The RBC had 36 PVC discs with 16.0 m^2 total surface area, mounted in a steel structure. The system was operated with flow rates of 580 and 720 L d^{-1}. The RBC tank had a volume of 0.135 m^3. The hydraulic retention time (HRT) for RBC reactor was 5.6 h and 4.5 h for the applied flow rates respectively. The rotation speed was adjusted to 2-3 rpm. The sedimentation tank was made of PlexiGlass, having a volume of 60 L and HRT of 2.0-2.5 h. The bottom of the tank had a conical shape to enhance sedimentation of detached particles from biofilm. Further suspended material removal and polishing of RBC effluent was achieved by an anthracite-sand filter made of PlexiGlass with a diameter of 25 cm. The media include 0.45-0.65 mm quartz sand and 0.8-1.5 mm anthracite in diameter. The filter was fed by a peristaltic pump operated by a floating start-stop switch. The feeding pump rate was adjusted to 41Lh^{-1}. Surface loading rate for the filter was 0.8 $m^3m^{-2}h^{-1}$. The filter was equipped with back washing facility using treated effluent. Disinfection was accomplished by an UV lamp (300Jm^{-2},35 W) and a chlorination dosing system (20-30 mLh^{-1}, with 3% NaClO solution). The RBC was initially run by feeding with domestic wastewater treatment plant activated sludge to ensure rapid biofilm growth.

The biological process kinetics assessment for mineralization and nitrification was carried out by utilizing variable order removal approach (Al-Haddad *et al.,* 1996, Baban and Talinli, 2009). Chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total suspended solids (TSS), total kjeldahl nitrogen (TKN), phosphorus, detergents, oil and grease, turbidity, colour and microbiological parameters (total, faecal, E coli and enterococci) were monitored for a period of about 1.5 years with monthly sampling and analysis. The analysis for conventional pollutants were conducted according to the Standard Methods (APHA, AWWA, WPCP, 2005), trihalomethane (THM) concentration was measured using the method given in ISO 15680.

3. Results and discussions

3.1. Pollutant removal

The applied COD_T loading and corresponding removal rates for the RBC reactor are given in Figure 1. Under these conditions, some of the characteristics of influent GW, RBC and effluent samples are shown in Table 1. The average COD_T removal efficiencies were 89 and 92%.

Whereas, 92 and 94% TSS, 80 and 86% TKN removal obtained. Regarding the other monitored parameters about 80% oil and grease, 90 and 98% detergent, 76 and 90% phosphorus, 53 and 56% colour and 100% coliform group of bacteria (after chlorination) removal acquired for the applied flow rates.

In accordance with the EPA (2012) suggested reuse guidelines for unrestricted urban reuse, BOD_5 should not exceed 10 mg L^{-1}, turbidity should be less than 2 NTU, faecal coliforms should not be detected in 100 mL sample and pH should be in the range of 6–9. The results specified that for both cases suggested conditions were fulfilled. The positive effect of two-layer filtration units followed by RBC was more evident specifically for high loading rates (i.e. Q=720 Ld^{-1}). In this case, about 35% COD_T, 45% BOD_5 and 40% TSS additional removal efficiencies were achieved following to RBC on the average. The filter had also contributed additional removal of THM. The results indicated that in terms of COD_T, BOD_5 and TSS concentrations obtained in this study were slightly higher than GW treatment by membrane bioreactor (MBR) treatment effluent (Atasoy *et al.*, 2007).

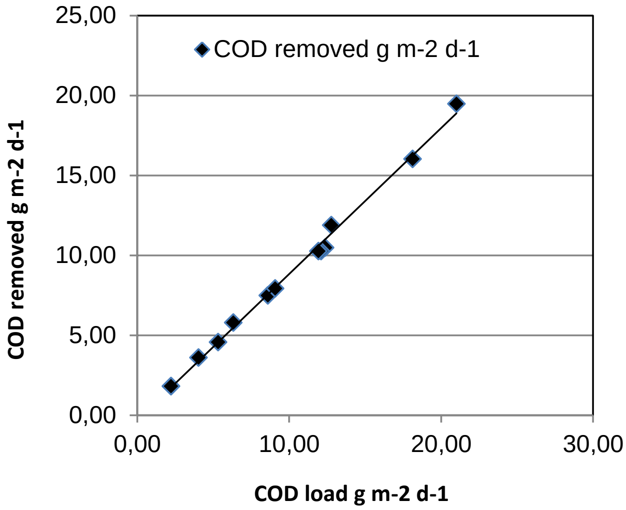

Figure 1: COD_T loading and removal rate relations for RBC

Table 1: Characteristics of some the GW operational parameters

parameters	GW inlet	Q=580 Ld^{-1}		Q=720 Ld^{-1}	
		RBC (sed. Tank.)	filter+UV outlet	RBC (sed. Tank)	filter+UV outlet
COD_T, mg L^{-1}	224 (124)	18.3 (7.6)	17.0 (8.9)	37.7 (6.6)	24.3 (15.2)
BOD_5, mg L^{-1}	86 (43)	4.7 (3.8)	4.5 (2.6)	14.3 (5.6)	7.5 (5.3)
TSS, mg L^{-1}	38 (51)	3.2 (1.7)	2.2 (0.9)	5.2 (3.0)	3.1 (1.8)
TKN, mg L^{-1}	7.2 (1.9)	1.4 (0.45)	0.9 (0.5)	2.2 (0.9)	1.4 (0.9)
TN, mg L^{-1}	9.1 (4.1)	3.1 (0.2)	3.1 (0.3)	2.5 (0.9)	2.6 (1.0)
TP, mg L^{-1}	5.8 (4.5)	0.5 (0.5)	0.5 (1.1)	3.6 (1.1)	1.4 (1.6)
Turbidity NTU	84.6 (95)	1.34 (0.6)	1.09 (1.2)	3.11 (2.3)	1.31 (1.3)
Colour	33.8 (13.8)	15.0 (5.8)	15.8 (4.9)	17.5 (3.5)	14.5 (4.5)
THM (ppb)	18 (7.0)	13 (4)	10 (0)	10 (0)	10 (0)
pH	7.4 (0.3)	7.9 (0.12)	7.9 (0.15)	7.6 (0.15)	7.9 (0.15)

*T= 20±2 °C for experimental runs, **values in parenthesis are std. dev.

3.2. Kinetic considerations

Depending on the bulk substrate concentrations half order and zero order removal kinetics were prevailing for organic matter removal. The removal rate and substrate concentration relation is shown in Figure 2. The removal rate equations derived from experimental results are illustrated in Table 2. Characteristic half order removal was observed for COD_T concentration up to 25 mg

L^{-1}. Whereas, zero order removal kinetic was perceived for higher concentrations. In the same manner, nitrification process also revealed occurrence of half order removal behaviour. In general, as compared to domestic wastewater treatment with biofilm reactor, the kinetic constants both for mineralization and nitrification obtained for this study showed low trends (Metcalf & Eddy, 2003). The zero order COD_T removal rate constant obtained in this study was higher as compared to GW treatability study by RBC (Baban et al., 2010) which was considered due to the higher organic loading rates applied.

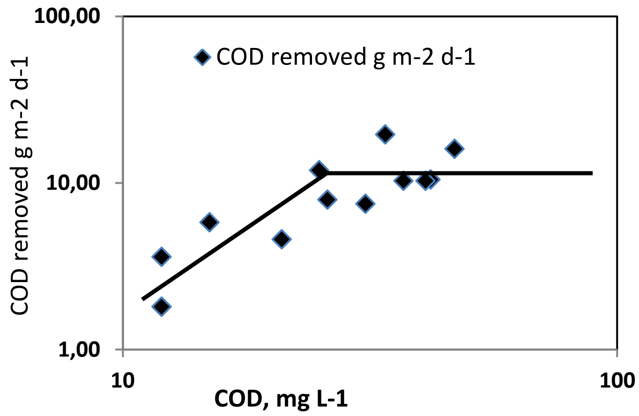

Figure 2: COD removal rates as a function of bulk COD concentration for determination of variable order model kinetic constants

3.3. Energy requirement

The energy requirement of the system, including feeding, RBC, pumps for transfer and filter back-washing operations and UV disinfection was calculated to be 1.87 kWh m^{-3}. This value is about 35% higher than operating the system without filtration facilities and very closed to GW treatment by MBR (Baban *et al.* 2010; Atasoy *et al.* 2007).

Table 2: Kinetic relations for the RBC reactor operating with GW

process	kinetic relations	definitions/units
mineralization half order reaction	$r_{a1/2} = Q(S_o - S_i)/A = k_{1/2a}S_i^{0.5} = 2.2\ S_i^{0.5}$	A= biofilm area, L^2 k_{ao}, $k_{1/2a}$, $k_{1/2an}$= reaction rate constants for mineralization and nitrification- zero and half order, Q = flow rate, $L^3\ T^{-1}$ $r_{a1/2}$, r_{ao}, $r_{an1/2}$ =half and zero order reaction rates- mineralization and nitrification, M $L^2\ T^{-1}$ S_o, S_i, S_{on}, S_{in} = substrate concentrations, influent and effluent, based COD_T, TKN, M L^{-3}
zero order reaction	$r_{ao} = k_{ao}$ =11.1 g m^{-2} d^{-1}	
nitrification	$r_{an1/2} = Q(S_{on} - S_{in})/A = k_{1/2an}S_i^{0.5} = 0.3\ S_i^{0.5}$	

4. Conclusions

GW treatment for reuse by using a combined RBC - anthracite-sand filtration and disinfection system offered robust and operationally simple features and provision of re-useable water which uninterruptedly fulfil urban non potable reuse recommended criteria. The combination of a two layer filter with RBC was found to be effective for high loads and fluctuations in GW characteristics. Filter back washing requirements, continuous supply of electricity, prolonged time period for biofilm growth are considered to be the major drawbacks of the proposed system. However, if appropriately designed and operated, GW reuse strategies may considerably contribute to reduction of potable water consumption. The concept may be considered as a partial adaptation strategy for climate change impacts. Moreover, heat recovery from GW may also constitute a beneficial option for sustainability and carbon foot print reduction.

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