Desalination and Water Treatment
www.deswater.com

23 (2010) 89–94
November

1944-3994/1944-3986 © 2010 Desalination Publications. All rights reserved
doi: 10/5004/dwt.2010.1955

Grey water treatment and reuse by using RBC: A kinetic approach

Ahmet Baban[a,*], Selda Murat Hocaoglu[a], Elif A. Atasoy[a], Kemal Gunes[a], Selma Ayaz[a], Martin Regelsberger[b]

[a]*TUBITAK—Marmara Research Center (MRC), Environment Institute 41470 Gebze, Kocaeli, Turkey*
Tel. +90 262 677 29 04; email: ahmet.baban@mam.gov.tr
[b]*AEE INTEC, Feldgasse 19, 8200 Gleisdorf, Austria*

Received 20 November 2009; Accepted 4 April 2010

ABSTRACT

Grey water treatment with rotating biological contactor (RBC) was investigated to assess water reuse potential. The study involves influent characterization, setting-up and operation of two RBCs, conformity assessment of the effluent for reuse and determination of the biofilm kinetics. Monod and variable order models were applied. Biofilm characteristics, such as weight per unit area and thickness were measured. Nitrification and mineralization processes took place in the biofilm matrix simultaneously. About 85% COD_T and 75% TKN removal efficiencies were achieved. The average effluent BOD_5 concentration was 7 mg L^{-1}. The reaction showed typical zero-order, 0° kinetic relation. The 0° rate constant was determined as 5.7 ± 1.5. UV light was used for disinfection of treated grey water. Efficiency, operational ease, reliability, and personnel requirements were compared with the other grey water treatment processes. It is concluded that RBC may be effectively used for grey water treatment and the effluent can be reused for toilet flush purposes after disinfection. However, it is recommended that detached particles from biofilm should be further removed by filtration.

Keywords: Grey Water; Treatment; Reuse/recycle; Biofilm kinetics; RBC

1. Introduction

The negative impacts of climate change are globally linked to the potential increase in water stress especially in Mediterranean countries. Hence, a new approach for water management is necessary to minimize the adverse impacts and sustainable methods are needed to substitute current water management practices. Wastewater reuse implementations are currently carried out in controlled and uncontrolled manner in arid areas, especially in Mediterranean countries [1]. The sustainable approach or ecological sanitation (ECOSAN) way of thinking implies that the best quality potable water is to be saved or utilized for drinking purposes. Whereas, alternative low quality water sources such as reclaimed water can be used preferably for toilet flushing or irrigation purposes provided that hygienic requirements are fully complied.

Conventional centralized water management approach is becoming less suitable due to high investment cost of long sewerage lines, which are sometimes even higher than the cost of treatment facilities, high operation and maintenance costs, high amount of good quality water needed for transportation of wastes to long distances and high risks involved. On the other hand, on-site segregation—collection—treatment—reuse of grey water for residential areas is receiving increasing attention as an element of decentralized approach [2]. Grey water is defined as low-polluted household streams from showers, bathtubs, washing basins and washing machines. Kitchen wastewater is not usually included in grey water [3]. Properly treated grey water

---

*Corresponding author.

can be used potentially for irrigation, toilet flushing and various type of cleaning purposes. Grey water constitutes about 70% of household water consumption, has lower concentration of organic compounds and fewer pathogens as compared to domestic wastewater [4]. Therefore, grey water is thought to be treated and reused much easier than overall composite domestic wastewater for the point of applied treatment technologies and relevant costs. Grey water treatment and reuse studies and implementation practices were started about a decade ago; several systems were constructed and operated. Some of these studies were proved to be successful; however, one forth of the systems was assessed to be unsatisfactory in Germany [5–7].

A broad spectrum of technologies, ranging from very simple to highly sophisticated systems, can be utilized for grey water treatment and reuse [8]. A number of treatment options including, natural systems, filtration, sequencing bath reactors (SBR), and membrane bioreactors (MBR) have been practiced. UV or chlorination processes are extensively used for disinfection purposes in grey water treatment and reuse systems [9–11].

Rotating biological contactor (RBC) has been used for municipal wastewater treatment since, attached growth systems have several advantages over suspended growth type biological systems. They typically exhibit more resistance to pollutant load fluctuations, can tolerate high organic loading rates, have high biomass content, and are advantageous for the point of simultaneous removal of organic matter and nutrients. Depending on the loading rates, up to 90% of COD, 90% of NO_3–N (under anoxic operation conditions), and 60% of TN removal efficiencies were reported for RBC implementations running with domestic wastewater [12–15]. Cortez et al. stated that C/N ratio of 1.5 is advantageous for denitrification [15]. RBC systems were successfully used following to the pre-treatment with upflow anoxic submerged biofilter (UASB) for domestic wastewater [16–17]. RBC may also be utilized for grey water treatment and reuse for especially toilet flushing purposes [18–21]. The treatment scheme generally includes a secondary sedimentation basin, sometimes followed by a filtration unit and always ended up with disinfection processes. Although, great variations observed in grey water characterization, sufficient biofilm growth and viable results were achieved for treatment of grey water by RBC. The results verified that, turbidity of 1.5 NTU, COD of 47 mg L^{-1}, and BOD_5 of 4 mg L^{-1} could be attained [19].

Grey water includes low organic matter, low nutrient content, and imbalance ratios for C:N:P, which may indicate insufficiency for effective biodegradation [8]. The average COD/BOD5 ratio for raw grey water was measured to be in the range of 1.6–3.4 [18–19]. It should also be noted that, most of the COD was in dissolved form as opposed to domestic sewage [19]. Hence, the process design and kinetic parameters for attached growth type biological systems operating with grey water may diverge from composite domestic wastewater. These parameters are needed to be assessed in order to achieve reliable design methodology and operational ease of the attached growth systems running with grey water. However, grey water studies by using RBC, typically focused on treatment by several technologies to comply with various aspects of reuse/recycle criteria as well as the optimization of treatment efficiency in the literature. Studies, in general, aimed to map and increase pollutant removal efficiencies rather than the determination and assessment of biofilm kinetics for the processes. Along these lines, the objectives of the present study are; determination of biofilm characteristics, process design parameters, biofilm reaction kinetics and evaluation of pollutant removal efficiencies for grey water treatment by RBC for reuse.

The treated grey water was mainly intended to be reused for toilet flush purposes. Kinetic variables were determined by using both Monod and variable order model biofilm kinetics. RBC performance and suitability for grey water treatment were assessed by taking into consideration of the advantages and disadvantages over other possible grey water treatment options.

2. Methods

2.1. Grey water treatment system

In this study, grey water was collected from the two lodging buildings of TUBITAK–MRC. The plumbing system was modified to allow segregation of black water and grey water streams in the buildings. Kitchen wastewater was also included in the grey water stream. Grey water stream passed through a coarse screen (6 mm pore opening) first, then 3 mm mash size screen, which was placed in an equalization-storage basin. Grey water was then pumped into two separate RBC units operating in parallel. The RBC1 and RBC2 had 36 and 20 discs with 16.0 m^2 (RBC1) and 2.8 m^2 (RBC2) total disc areas. The RBCs were continuously operated for a period of 10 and five months respectively. Peristaltic pumps, which allowed adjustment of the flow, were utilized to pump the screened grey water to the inlet box of RBCs. The flow rates of 400 and 150 L d^{-1} were applied for the RBC1, whereas, 86 and 43 L d^{-1} for the RBC2. The treated effluent from the RBC1 was further subjected to UV disinfection process. The schematic illustration of the experimental system is given in Fig. 1. Activated sludge taken from an MBR operated with grey water, was added to the reactors to acclimatize and accelerate biofilm growth on the discs at the initial stage of the operation.

2.2. Kinetic studies

Kinetic assessment for the biofilm was commenced approximately after two months of operation of the RBCs.

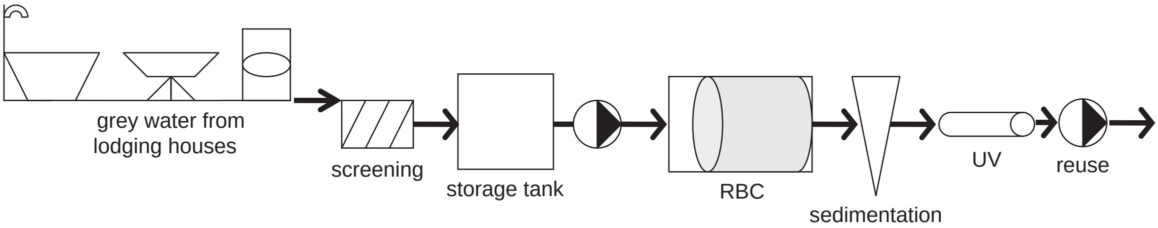

Fig. 1. The schematic illustration of the experimental system.

At this stage, the development of biofilm growth and relatively stable effluent water quality were attained. Biofilm growth characteristics, such as biofilm weight per unit area and biofilm thickness were determined. Due to the non-uniform structure of the biofilm grown on the RBC discs an indirect method was used [22]. The procedure involves carefully removing the biofilm layer and measuring the volume and the weight (incubated at 105 and 550 °C) per unit area and calculation of the thickness accordingly. Biofilm samples were taken from the RBC discs at three different places (front, mid and end) in the direction of flow. The averages of the measured three values for the thickness and weight were taken into account in order to represent the biofilm characteristics of the relevant RBC. Variable order removal rate and Monod kinetic models were applied to assess the kinetic relations and parameters. The variable order model predicts that the substrate removal rate can be expressed as a function of substrate concentration. On the other hand, substrate removal rate depends on a function, taking into account the substrate concentration and the amount of attached biomass for the Monod approach [23].

2.3. Treated wastewater reuse criteria

EPA (2004) suggested guidelines states that, the BOD_5 concentration should not exceed 10 mg L^{-1}, for TSS 5 mg L^{-1}, fecal coliforms should not be detected in 100 mL sample and pH should be in the range of 6–9 for all kinds of irrigation and toilet flushing [24]. Moreover, EPA (1992) water reuse guidelines refer that total coliform should not be detectable in 100 ml sample [25]. The other guidelines, such as WHO guidelines for grey water reuse [26], National standards for unrestricted irrigation [27] and EU bathing waters standards [28] have less stringent limits for the relevant parameters. Therefore, EPA, suggested guidelines were basically taken into account for the assessment of treated grey water for suitability to reuse.

2.4. Sampling and analytical measurements

The performance of the RBC, associated with hygienic and aesthetic aspects, were monitored by COD (total and soluble), BOD_5, TSS, total coliform and turbidity analysis. In addition to that, TKN, NH_4^+–N, NO_3–N, T.P were monitored for process control purposes. The samples were collected on weekly basis to appraise the reusability of the effluent. Total and fecal coliform were measured for the disinfected effluent during the first month of the operation of the RBCs, afterwards only total coliform measurements were conducted. The analysis, were carried out in accordance with the Standard Methods for the monitored parameters [29].

3. Results and discussion

3.1. Determination and assessment of biofilm kinetic parameters for grey water

Biofilm thickness and weight were measured as 5.4 and 3.5 mm, 34.2 and 18.4 g m^{-2} for the RBC1 and RBC2 respectively. It was observed that, the thickness of biofilim decreased slightly from the wastewater inlet ports to the exit ports of the RBCs through the reactor's longitudinal axis. The volatile fraction of the biofilm was measured as approximately 70% for the samples taken. As the variable order reaction model was applied, in terms of bulk COD_T concentrations, basically the reaction rate showed zero order kinetic relationship (Fig. 2). A typical zero order removal kinetics was prevailing for

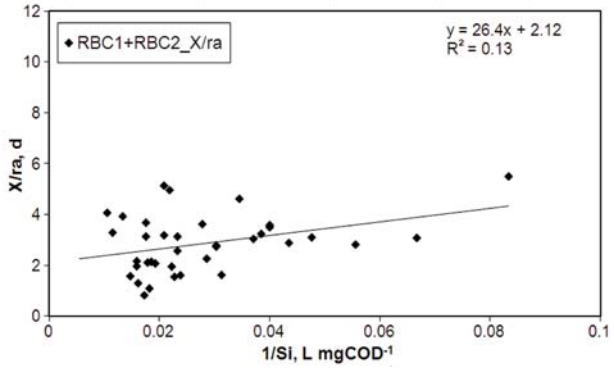

Fig. 2. Variable order model kinetic approach—prediction of kinetic constants.

COD_T concentrations higher than about 15 $mg L^{-1}$. However, it is not likely to encounter lower than 15 $mg L^{-1}$ COD_T concentration for practical implementation cases. The kinetic assessment implied that a portion of the substrate penetrated into the biofilm was consumed throughout the process and this portion was not dependent on the bulk COD_T concentration. Thus, the zero order removal rate expression, on the basis of COD_T can be derived as follows:

$$r_{ao} = k_{oa} = (5.7 \pm 1.5)\ gm^{-2}\ d^{-1} \quad (1)$$

where, $r_a = Q\ (S_o - S_i)/A$, r_{ao} is 0° substrate removal rate, k_{oa} = reaction rate constant for organic matter removal (0°), S_o and S_i = substrate concentrations based on COD_T ($mg L^{-1}$) at $t = 0$ and $t = t_i$, A = biofilm area, m^2 and Q = flow rate ($m^3\ d^{-1}$). The attained removal rates and the rate constants for grey water were lower than corresponding values for composite domestic wastewater treated by RBC reported in the literature [30–31].

As the Monod model applied to the results, the removal rate expression for COD_T can be obtained as follows (Fig. 3):

$$r_a = k_o \frac{XS_i}{K_s + S_i} = 0.47 \frac{XS_i}{12.4 + S_i} \quad (2)$$

where, X = attached biomass (volatile fraction), g m^{-2}, k_o = maximum substrate utilization rate constant, d^{-1}, K_s = half velocity coefficient in Monod model, mg L^{-1}.

The Monod model organic matter removal kinetic parameters were scattered in a wide range in the literature. The determined values for the relevant parameters in this study are in agreement with the low values previously reported [32]. Although, Monod model considers the unit weight and thickness of biofilm, variable order removal rate model exhibits slightly better performance than Monod model. The dispersed character of the data points in the Figures, may be attributed to the considerable fluctuations in the grey water characteristics encountered through the experimental study to some extent. However, the results are still important for the point of providing constants for the design equations of the attached growth systems operating with grey water. As the characteristics of the grey water to be treated is known or presumed in advance, it is likely to determine the biofilm area requirement for attached growth systems using the constants and the rate equations derived.

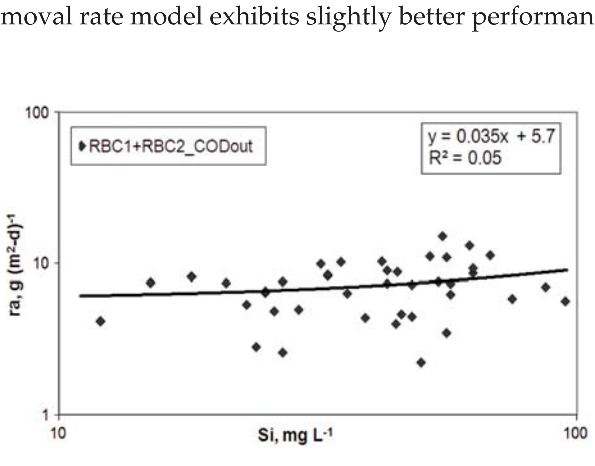

Fig. 3. Monod model kinetic approach—prediction of kinetic constants.

3.2. *Assessment of grey water treatment performance of the RBC reactors*

The characteristics of influent raw grey water and the treated effluent obtained throughout the experimental study are illustrated in Table 1. The raw grey water had COD_T:TKN:P ratios of 100:2.3:2.8. Consequently, as compared to the relevant ratios for domestic wastewater (100:5:1), grey water has imbalanced nutrient content. Furthermore, the observed COD_T :BOD_5 ratio of 3.4, for grey water, also implies a high value with reference to domestic wastewater.

The inlet COD_T loading rates, on the average, were measured to be 8.6 and 3.5 g $m^{-2}d^{-1}$ for RBC1 for the flow rates of 400 L d^{-1} and 150 L d^{-1} respectively. The corresponding values for the RBC2 were determined to be 12.2 and 5.6 $gm^{-2}\ d^{-1}$ for the flow rates of 86 and 43 L d^{-1}. The soluble fraction of COD_T was measured to be about 58% of the pretreated raw grey water. Especially, for RBC1 soluble fraction of grey water increased after the biological treatment on the average. This situation was attributed to the adsorption of particulate matter by the biofilm throughout the process along with the biological oxidation. The average effluent COD_T concentrations for high flow rates were slightly lower for RBC1, which was due to the relatively low average COD_T loading rates applied. As a result, removal efficiencies of 84–89 % for COD_T and, 85–91% for COD_{sol} were achieved.

The average effluent BOD_5 concentration was measured as 6.5 mg L^{-1}, which corresponds to the BOD_5 removal efficiency of 94%. Similarly, 83% TSS, 90% turbidity and 75% TKN removal efficiencies were obtained on the average. Additionally, up to 2 log reduction for total coliform was also observed throughout the biological process, In addition to total coliform analysis, fecal coliform measurements were also carried out during the first month of the RBC operation period for UV disinfected effluent. The results indicated that fecal coliform was not also detectable after the UV disinfection process. Although, grey water is considered as nitrogen limited for biomass growth, effective mineralization and even nitrification processes occurred, without encountering

Table 1
Average influent and effluent grey water characteristics treated by RBCs

Parameter	Influent Avg. (min-max)	Outlet – RBC1 Avg. (min–max) flow rate		Outlet – RBC2 Avg. (min–max) flow rate	
		Q = 400 L d^{-1}	Q = 150 L d^{-1}	Q = 86 L d^{-1}	Q = 43 L d^{-1}
pH	7.1 (6.9–7.4)	7.9	8.1	7.7	7.8
T, °C	22	22	22	22	22
COD$_T$, mg L^{-1}	347 (179–525)	42 (21–52)	41 (24–56)	55 (32–68)	35.5 (23–54)
COD$_{sol}$, mg L^{-1}	214 (89–286)	33 (18–60)	30 (20–40)	31 (26–37)	18 (11–24)
BOD$_5$, mg L^{-1}	119 (72–182)	6.3 (5–8)	6.8 (5–8)	NA	NA
T Coliform/100 mL	>10^6	5.6 × 10^4 0*	2.8 × 10^4 0*	6.3 × 10^4 NA	1.5 × 10^5 NA
Turbidity, NTU	103 (39–254)	6.0 (1–10.5)	13 (8–17.6)	17.1 (7.3–31.4)	4.4 (2.0–11.1)
TSS, mg L^{-1}	79 (28–146)	11 (2–35)	14 (8–19)	21 (6–47)	10 (6–18)
TKN, mg L^{-1}	8 (2–13)	2.3 (0.3–5.6)	1.5 (0.4–3.2)	3.5 (1.7–8.8)	2.6 (1.1–5.2)
NH_4^+–N, mg L^{-1}	2.2 (0.6–5.5)	0.7 (0.1–1.7)	0.1	1.4 (0.3–6.1)	0.5 (0.1–1.6)
NO_3–N, mg L^{-1}	NA	0.9 (0.1–2.7)	1.1 (0.7–1.3)	2.8 (0.2–6.8)	2.5 (1.5–3.8)
TP, mg L^{-1}	9.8 (3.7–14.6)	NA	NA	NA	NA

*Following to the UV disinfection process, NA: not available.

any problem, due to the fact that biofilm processes have low biomass yield and very high sludge ages. The ammonia nitrogen loading rate was about 0.06 and 0.021 g m^{-2} d^{-1} for RBC1 for the flow rates of 400 and 150 L d^{-1}.RBC2 had also low ammonia nitrogen loading rates as 0.07 and 0.03 g m^{-2} d^{-1} for the flows of 86 and 43 L d^{-1}. The nitrification rate was calculated as 0.04 and 0.02 g m^{-2} d^{-1} for both RBCs. These figures imply lower nitrification rates obtained throughout the study as compared to the values given in the literature [32]. This condition was caused due to the very low ammonia nitrogen concentration of the raw grey water. TKN loading rates ranged 0.14 and 0.06 g m^{-2} d^{-1} for the RBCs at the stated operational conditions.

The treated effluent quality mostly complied with the reuse criteria of EPA suggested guidelines for urban reuse including toilet flushing [24,25]. However, the criteria were violated occasionally for TSS and turbidity due to the influence of the detached particles from the biofilm although, sedimentation was provided. For this purpose, use of a simple sand filtration unit prior to the disinfection is virtually recommended to comply with the reuse criteria continuously, which also helps to guarantee the efficiency of the disinfection process.

The results were also assessed with respect to other grey water treatment technology options such as MBR, which was tested within the context of the Zero-m project in TUBITAK MRC premises [1]. It should be emphasized that the pollutant removal efficiency attained by MBR by using the same grey water during the same period resulted in 50–100% higher than RBC in terms of COD, BOD$_5$ and suspended solid concentrations [9]. However, RBC may comprise a promising method for grey water treatment for reuse, considering operational ease, low cost of operation and maintenance, less technical personnel requirement and provision of sufficient effluent quality. On the other hand, the time period needed for biomass growth during acclimatization, continuous electricity supply requirement and filtration process requirement due to the further removal of detached particles should be considered in design and operation to achieve efficient removal performance.

3.3. Energy requirement and cost assessment

The energy requirement of the operated RBCs was calculated as 1.2 kWh m^{-3} grey water treated and 5.7 kWh kg^{-1} COD$_T$ removed on the average. Whereas, the corresponding energy requirement for grey water treatment by MBR was calculated as 1.7 kWh m^{-3} [9]. Therefore, the energy requirement of grey water treatment by RBC is much lower than the case of treatment by MBR. Energy cost for treatment of grey water by RBC was estimated as 0.1 US \$ m^{-3}.

4. Conclusions

The biofilm kinetic relations for mineralization of organic matter were determined for real grey water, which may be utilized for design purposes of attached growth type biological systems. The results of RBC operation indicate that grey water, may be properly treated by RBC and reused especially for toilet flushing purposes after being disinfected by UV or other methods.

Due to the detached biofilm particles, a simple sand filtration is highly recommended to ensure to comply with the reuse criteria continuously. The proposed flow scheme includes screening, biological treatment, sedimentation, sand filtration and UV disinfection. Consequently, grey water treatment for reuse by using RBC may constitute an effective and sustainable approach. Use of RBC has several advantages, in terms of operational cost and simplicity, and low technical personnel requirements, over other more sophisticated grey water management technologies.

Acknowledgements

This study was conducted as a part of Zero-m project financed by the European MEDA WATER program (ME8/AIDCO/2001/0515/59768). The authors thank all partners of Zero-m project.

This paper was presented at the 11th International Conference on Environmental Science and Technology, CEST 2009, Chania, Crete, Greece, 3–5 September 2009.

Symbols

A — biofilm area, m^2
COD$_T$ — chemical oxygen demand, total, mg L^{-1},
COD$_{sol}$ — chemical oxygen demand, soluble, mg L^{-1}
K_s — half velocity coefficient in Monod model, mg L^{-1},
k_o — rate constant for maximum substrate utilization, d^{-1},
k_{oa} — reaction rate constant for organic matter removal, 0°
Q — flow rate, m^3 d^{-1},
r_{ao} — substrate removal rate, 0°
$r_{a1/2}$ — substrate removal rate, 1/2°
S_i — substrate concentration as COD at t=t_i, mg L^{-1}
S_o — substrate concentration as COD at t=0, mg L^{-1}
TSS — total suspended solids, mg L^{-1},
TKN — total kjeldahl nitrogen, mg L^{-1},
X — attached biomass (volatile fraction), gm^{-2}

References

[1] M. Regelsberger, A. Baban, L.Bouselmi, H. Abdel Shafy and B. El Hamouri, Desalination, 215 (2007) 64–72.
[2] R. Otterpohl, A. Albold and M. Oldenburg, Water Sci. Technol., 39(5) (1999) 153–160.
[3] E. Nolde, Urban Water, 1 (1999) 275–284.
[4] M. Henze, Water Sci. Technol., 35(9) (1997) 113–120.
[5] M. Maeda, K. Nakada, , K. Kawamoto and M. Ikeda, Area wide Use of Reclaimed Water in Tokyo -Japan, In A. Angelakis, T. Asano, E. Diamadopoulos, and G. schobanoglous (Eds.), Proceedings of the Second International Symposium on Wastewater Reclamation and Reuse, 55–62. October 17–20 (1995), Iraklion, Crete, Greece (Symposium Reprint Book 1).
[6] A. Huelgas, M. Nakajima, H. Nagata and N. Funamizu, Env. Techn., 30(1) (2009) 111–117.
[7] E. Nolde, Wat. Sci. Tech., 51(10) (2005) 203–210.
[8] B. Jefferson, A. Laine, S. Parsons, T. Stephenson and S. Judd, Urban Water, 1 (1999) 285–292.
[9] E. Atasoy., S. Murat, A. Baban and M. Tiris, Clean, 35(5) (2007) 465–472.
[10] F. Masi, B. El Hamouri, H. Abdel Shafi, A. Baban, A. Ghrabi and M. Regelsberger, Water Sci. Technol., 61(1), (2010).
[11] C. Merz, R. Scheumann, B. El Hamouri and M. Kraume, Desalination, 215 (2007) 37–43.
[12] Z. Chen, Q. Wen, J. Wang and F. Li, Process Biochemistry, 41 (2006) 2468–2472.
[13] A.H. Cabije, R.C. Agapay, and M.V. Tampus, Asia-Pac. J. Chem. Eng., 4 (2009) 735–743.
[14] M.S. Fountoulakis , S. Terzakis, A. Chatzinotas, H. Brix , N. Kalogerakis and T. Manios, Sci. Total Environ., 407 (2009) 2996–3003.
[15] S. Cortez, P. Teixeira, R. Oliveira and M. Mota, Environ. Technol., 30,13 (2009).
[16] A. Tawfik, G. Zeeman, A. Klapwijk, W. Sanders, F. El-Gohary and G. Lettinga, Water Sci. Technol., 48(1) (2003) 131–138.
[17] A. Tawfik, A. Klapwijk , F. El-Gohary and G. Lettinga, Biochem. Eng. J., 25 (2005) 89–98.
[18] E. Eriksson, H.R. Andersen, T.S. Madsen, A. Ledin, Ecol. Eng., 35 (2009) 661–669.
[19] Y. Gilboa, E. Friedler, Water Res., 42 (2008) 1043–1050.
[20] E. Friedler, R. Kovalio and Galil NI, Water Sci. Technol., 51(10) (2005) 187–94.
[21] E. Friedler and Y. Gilboa, Sci. Total Environ., 408 (2010) 2109–2117.
[22] S. Karnchanawong and C. Polprasert, Water Sci. Tech., 22(3&4) (1990) 179–186.
[23] A.A. Al-Haddad, H.M. Ettouney and T.M. Abu-Irhayem, Env. Technol., 17 (1996) 113–124.
[24] EPA, Guidelines for Water Reuse, U.S. Environmental Protection Agency/U.S Agency for International Development, Washington D.C, USEPA/625/R-04/108 (2004).
[25] EPA. Guidelines for Water reuse. US Environmental Protection Agency, EPA/625/R-92/004. US Agency for International Development, Washington, DC (1992).
[26] WHO, Guidelines for Safe Use of Wastewater, Excreta and Grey Water, Vol.4, (2006).
[27] WPCR, Water Pollution Control Regulation of Turkey–Technical Procedure Notification, (1991).
[28] Council Directive; 76/160/ECC Concerning the Quality of Bathing Water, 8 Dec. (1975).
[29] APHA, AWWA, WPCP Standard Methods for the Examination of Water and Wastewater, 21st ed. APHA (2005), Washington, D.C.
[30] E. Arvin and P. Harremoes, Wat. Sci. Tech., 22(1&2) (1990), 171–192.
[31] Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, 4th ed. McGrawHill, (2003).
[32] R.F. Cecen and I.E. Gonenc, Water Environ. Res., 67(2) (1995) 132–142.