Preliminary Study of Greywater Treatment through Rotating Biological Contactor

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RECIVED ON 02.05.2011 ACCEPTED ON 07.06.2011

ABSTRACT

The characteristics of the greywater vary from country to country and it depends upon the cultural and social behavior of the respective country. There was a considerable need to characterize and recycle the greywater. In this regard greywater was separated from the black water and analyzed for various physiochemical parameters. Among various greywater recycling treatment technologies, RBC (Rotating Biological Contactor) is more effective treatment technique in reducing COD (Chemical Oxygen Demand) and organic matters from the greywater. But this technology was not applied and tested in Pakistan. There was extensive need to investigate the RBC technology for greywater recycling at small scale before applying at mass scale. To treat the greywater, a single-stage RBC simulator was designed and developed at laboratory scale. An electric motor equipped with gear box to control the rotations of the disks was mounted on the tank. The simulator was run at the rate of 1.7 rpm. The disc area of the RBC was immersed about 40% in the greywater. Water samples were collected at each HRT (Hydraulic Retention Time) and analyzed for the parameters such as pH, conductivity, TDS (Total Dissolved Solids), salinity, BOD_5 (Biochemical Oxygen Demand), COD and suspended solids by using standard methods. The results are encouraging with percentage removal of BOD_5 and COD being 53 and 60% respectively.

Key Words: **Greywater, Recycling, Treatment, Rotating Biological Contactor, Hydraulic Retention Time.**

1. INTRODUCTION

Pakistan is an agricultural country and it is believed that agriculture is the backbone of this country. But the ever increasing population growth and rapid urbanization have threatened significantly the resources of fresh water which are depleting day by day [1]. The availability of fresh water resources is limited and depleting due to climatic change. In Pakistan, water availability has decreased from 5600-1200 m^3/capita per year by the end of year 2005 [2]. Recycling greywater is one of the possible options to meet the urban water demands and the irrigation needs [3]. This may contribute significantly to the water demand and reduce stress on fresh water resources. Greywater is wastewater being discharged from baths, washing machines and sinks. About 60% domestic outflow is greywater. It contains little pathogens and 90% less nitrogen than toilet water, so does not require much treatment [4]. Greywater is less polluted stream of wastewater generated from hand

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washbasins, baths and showers [5]. It will therefore be a potential approach for saving the valuable fresh water in areas where water scarcity is very high.

It is stated that the viability of internal recycling is to some extent dependent upon the water quality and quantities demanded for different operations [6]. Since domestic greywater production is greater than its consumption it is therefore preferable to reuse only "light" greywater (i.e. the less polluted greywater streams originating from baths, showers and washbasins only) and thus reduces treatment costs and possible adverse effects [7]. However, greywater recycling practice is not so common in Pakistan. The quality and nature of greywater is different from other developed countries, moreover the greywater quality characteristics have not been investigated as yet. There is an extensive need to quantify and characterize the greywater. Also there is a need to determine the suitable greywater treatment technology. The treatment system should be hygienically safe, aesthetic, environmentally tolerant, and technically and economically feasible [8]. Greywater can be recycled through many ways but the most technical problems are encountered when it is not sufficiently treated. If wastewater is merely aerated and built for single family, its maintenance cost becomes very high. Again if advanced physical methods are used, such as ultra-filtration and reverse osmosis, then they will require very high energy. The membrane filtration requires a reduced amount of energy and efficient in eliminating microorganisms but very less effective in reducing BOD [8]. Physical, chemical and biological schemes of greywater recycling are found in various parts of the world. Poorer countries favour the low cost and easy to maintain technologies for treatment of greywater [9]. To achieve high degree of treatment, wastewater is treated by aerobic biological treatment processes. Among various biological treatment technologies, RBC is more effective treatment technique. It requires low energy, short hydraulic retention time and low operating cost. It has excellent process control and is capable of handling a wide range of flows [10]. The combined RBC, sand filtration and chlorination process produces effluent which meets the non-restricted non potable water reuse standard [7]. HRT is also an important parameter in biological treatment process. This parameter has been investigated by Aizenchtadt, E., et. al. [11]. They studied the effect of HRT on the removal pollutants using three different technologies including RBC. It is therefore, necessary to investigate RBC for greywater recycling at small scale before applying at mass scale. The objective of the present study is to characterize light greywater under local climate conditions and develop a laboratory scale greywater treatment plant using RBC technology.

2. METHODOLOGY

2.1 Separation of Greywater and Sample Collection

Four bathrooms in a boy's hostel of NCEAC (National Centre of Excellence in Analytical Chemistry), University of Sindh, Jamshoro, Pakistan were selected and necessary plumbing work was carried out to separate the greywater from domestic wastewater. A tank was constructed just outside the hostel to collect the greywater. The samples were collected from the collection tank and transported to the NCEAC laboratory, where stored in the refrigerator at 4^{o}C temperature.

2.2 Analysis of Samples

In order to characterize the greywater, physiochemical parameters such as pH, TDS, TSS (Total Suspended Solids), BOD_5 and COD were determined. pH value was determined by pH meter (pH-meter 315i/SET) whereas, TDS was determined by using conductivity meter (Conductivity-meter, WTW LF330). These meters were calibrated prior to analysis. BOD and total suspended solids tests were carried out by standard method [12]. COD was determined by using potassium dichromate oxidation ($K_2Cr_2O_7$) standard method [12]. The results are presented in Table 1.

2.3 Design and Setup of RBC Simulator

A single stage RBC simulator was designed and developed at laboratory scale. The simulator tank of 54 liters capacity was fabricated from plastic sheets. The discs were also made from textured plastic and having the surface area of 9.7785 m^2.The ratio of greywater holding tank to the disc area was 0.0055 m^3/m^2. The simulator was a kind of batch reactor and greywater was kept in the system for specified time and the rotating discs were submerged up to 40% in the greywater. An electric motor equipped with gear box to control the rotations of the disks at the rate of 1.7 rpm was mounted on the shaft as shown in Fig. 1. In this system, large surface area of rotating disks provides accommodation and encourages growth of bacteria. As the discs rotate, the media come in contact alternatively with the greywater and air and produce an aerobic thin biofilm or biomass of micro organisms. The film contains different types of microorganisms, initially its color is brown and considered as healthy biomass whereas white and grey biofilms are regarded as unhealthy ones. It grows by time and oxidizes the pollutants present in waste water. In doing this, it removes BOD, COD and improves the efficiency of treatment process [13-14].

2.4 Operating Parameters of RBC

In present work, the RBC was run only on three different HRT i.e. ½ hour, 1 hour and 1 ½ hours. Whereas the discs surface area and rotational speed of the discs per minute were kept fixed.

TABLE 1. CHARACTERISTICS OF GREYWATER

No.	Parameter	Average Result
1.	Biochemical Oxygen Demand	55.61±17.28 mg/l
2.	Chemical Oxygen Demand	146.05±49.08 mg/l
3.	Total Suspended Solids	154.63±45.25 mg/l
4.	Total Dissolved Solids	101.50±20.98 mg/l
5.	pH	6.23±0.05

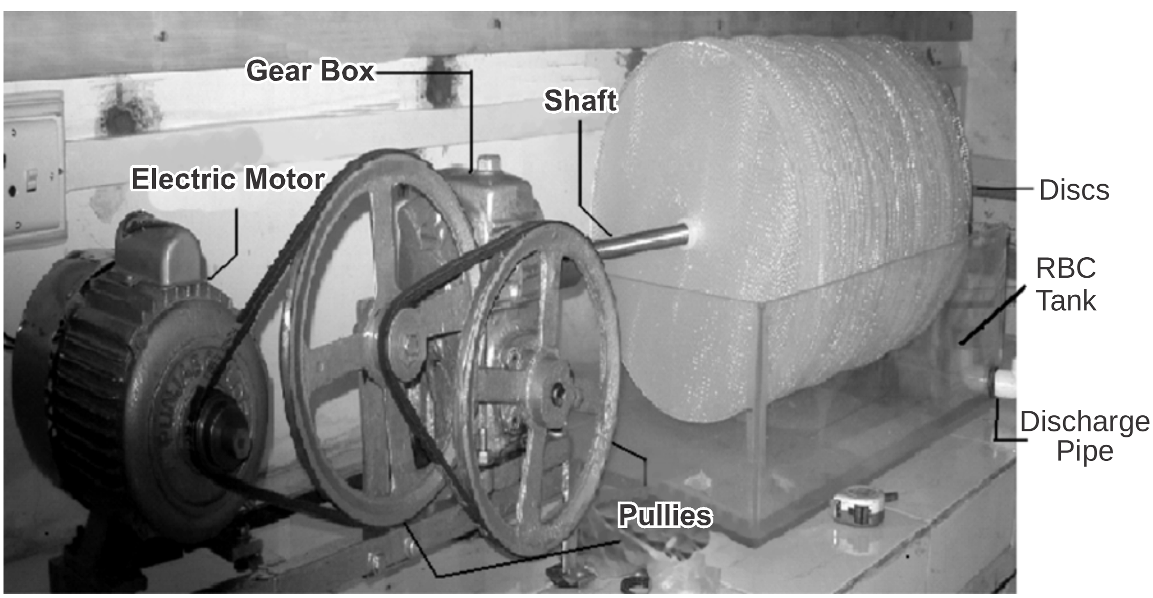

FIG. 1. SETUP OF ROTATING BIOLOGICAL CONTACTOR SIMULATOR

2.5 Sample Collection of Treated Greywater

To determine the performance of simulator, greywater samples were collected from the RBC simulator run at different HRTs i.e. ½ hour, 1 hour and 1½ hours and analyzed for aforesaid parameters.

2.6 Analysis of Samples

The samples collected before and after treatment were analyzed for pH, TDS, TSS, BOD_5 and COD by using standards methods as stated in Section 2.2. The results are given in Table 2.

3. RESULTS AND DISCUSSION

3.1 Characteristics of the Greywater

The sources of greywater for the present study were washbasin and showers. Greywater generated from laundry and kitchen was not connected with greywater collection tank. Thus physiochemical analysis of the greywater generated from the above mentioned source was carried out. The pH value of the greywater was witnessed in the acidic range and was observed between 6 and 6.5. It depends upon the consumption of type of toothpastes, soaps and shampoos as well as on the cleansing chemicals used to wash washbasins and bathrooms which greatly influence the pH value of greywater generated. It is reported that greywater characteristics are highly variable depending upon living styles, products used by the people, the type of distribution system and source of water supply [1,15]. The TDS of the greywater generated from NCEAC hostel varied between 74 and 123 mg/l. This variation depends upon the chemical used during the washing by users. Sometimes this variation is found to be significant which is due to variation in source of water supply, i.e. the river water. In the dry period flow in the river is less and basin flow is additionally supplied with surface water which includes salts and causes the increase in TDS. Similarly variation in TSS, BOD_5 and COD were also observed from 101-202, 36-77 and 79-195 mg/l respectively. The variation of TSS depends upon the sedimentation of the suspended materials in the greywater tank and the time of sampling after greywater generation. The variation of BOD_5 in the effluent depends upon the type of contamination added during washing, sedimentation and oxidation of organic matters. The variation of COD indicates variation in consumption of chemical during washing and this may be due to settlement or biodegradation in the storage tank [16].

3.2 Treatment of Greywater

The RBC simulator was operated at 1.7 rpm at various HRTs. Water samples were collected from the raw greywater, after ½ hour, 1 hour and 1½ hours HRTs and analyzed for physiochemical parameters. The pH value was observed of the untreated greywater and treated at ½ hour, 1 hour and 1½ hours HTRs in the range of 6.23±0.05, 6.48±0.08, 6.65±0.15 and 6.75±0.16 mg/l. The pH value is increasing with the increase of HRTs as shown in Table 2. The increase of pH value with increase of HRTs indicates that volatile fatty acids oxidized due to increase of aerobic condition in the tank.

TABLE 2. COMPARISON OF UNTREATED AND TREATED GREYWATER AT VARIOUS HYDRAULIC RETENTION TIMES

No.	Parameter	Untreated Greywater	Treated Greywater at Various Hydraulic Retention Times		
			½ Hour	1Hour	1½ Hours
1.	Biochemical Oxygen Demand	55.61±17.28 mg/l	40.43±13.36 mg/l	32.59±13.98 mg/l	26.46±12.96 mg/l
2.	Chemical Oxygen Demand	146.05±49.08 mg/l	114.68±8.94 mg/l	73.13±38.04 mg/l	57.90±26.03 mg/l
3.	Total Suspended Solids	154.63±45.25 mg/l	140.75±48.48 mg/l	136.75±41.64 mg/l	137.50±30.56 mg/l
4.	Total Dissolved Solids	101.50±20.98 mg/l	102.50±21.61 mg/l	102.25±23.13 mg/l	103.00±24.32 mg/l
5.	pH	6.23±0.05	6.48±0.08	6.65±0.15	6.75±0.16

No significant change in the values of TDS was observed during the treatment. The TDS content of the untreated and treated greywater at ½ hour, 1 hour and 1½ hours HTRs were found in the range of 101.50±21, 102.50±21.61, 102±23 and 103±24 mg/l respectively as mentioned in Table 2.

The BOD_5 in the greywater was due to the presence of biodegradable organic matters. The BOD_5 was observed of the untreated and treated greywater at ½ hour, 1 hour and 1½ hours HTRs in the range of 55.61±17.28, 40.43±13.36, 32.59±13.98 and 26.46±12.96 mg/l respectively as shown in Table 2. As depicted in Fig. 2, BOD_5 was significantly reduced due to the increase of HRTs. This indicates that further increase of HRTs would reduce more biodegradable organic matters and resultantly removal percentage of BOD_5 will be more. However, for the present study no further treatment was carried out as the results of BOD_5 were found to be within the range of American standards of 30 mg/l for restricted reuse only [17].

The COD in the greywater is due to the presence of biodegradable and non biodegradable organic matters. The COD was observed in the untreated and treated greywater at ½ hour, 1 hour and 1½ hours HRTs in the range of 146.05±49.08, 114±8.94, 73.13±38.04 and 57.90±26.03 mg/l as mentioned in Table 2. Fig. 3 shows the removal percentage of COD is increased or in other words the biodegradable organic matters being reduced, with the increase of HRTs.

Fig. 4 shows the percentage removal of TSS with the increase of HRTs. Only little change in the TSS was observed with the increase in HRTs due the growth of biomass during the aerobic treatment.

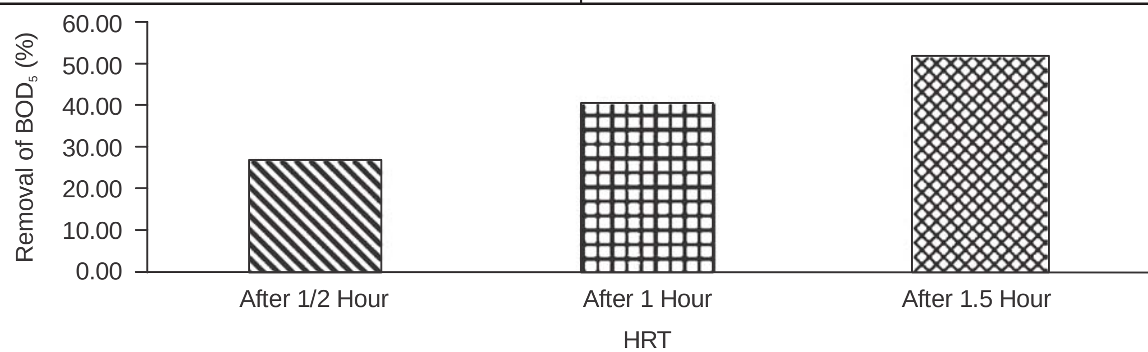

FIG. 2. BIOCHEMICAL OXYGEN DEMAND REMOVAL TREND WITH INCREASE OF HYDRAULIC RETENTION TIMES

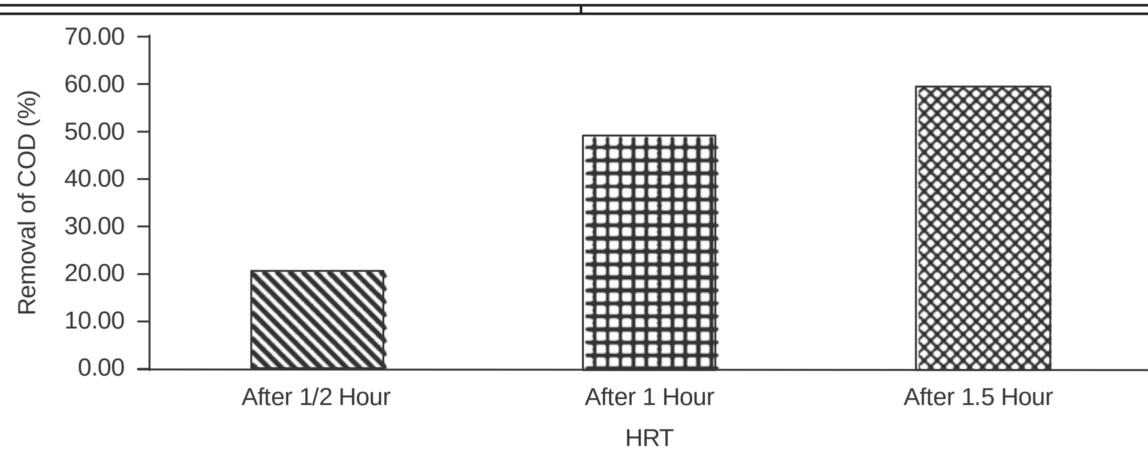

FIG. 3. COMPARISON OF CHEMICAL OXYGEN DEMAND REMOVAL AT DIFFERENT HYDRAULIC RETENTION TIMES

Based on the studies conducted by [8,18-20] a non-potable grey water reuse guidelines are proposed for both unrestricted and restricted reuses. It is obvious that restricted non-potable reuses have lower water quality requirements as compared to the unrestricted non-potable reuses [17]. The RBC simulator result of BOD_5 was compared with the greywater guideline values set by China, USA, and Japan [17]. It shows that BOD_5 observed at 1.5 HRTs is 26 mg/l which is less than USA guide lines (30 mg/l) and bit higher than the china and Japan standards (20 mg/l). However, this study is ongoing which would bring suitable standard values by optimizing the various parameters.

In literature effect of HRT on treatment is rarely focused by researchers. However, [10] have discussed different technologies for greywater treatment. In their study RBC was operated for 2 hours and got removal efficiency of BOD and COD as 61 and 97% respectively. Whereas the removal percentage of BOD and COD in present study with maximum 1½ h HRT is 53 and 60% respectively. The difference in removal efficiency may be due to the fact that in their study [10] the greywater has been treated in double basin RBC, given sedimentation period and operated on relatively more HRT.

3.3 Economic Feasibility of RBC

In this study economic feasibility of the RBC technology is considered. The investment costs of RBC-based system consist of less than 0.5% of the price of an apartment (five storey buildings). While conducting economic feasibility of any onsite greywater treatment system, two separate objectives should be considered which are costs and benefits [21]. Basically these objectives are availed by two characters i.e. individual consumer and general public. The individual consumer (flat owner, a family living in a flat, a group of occupants living in the same multi-flat building, etc.) can save money by using recycled greywater for non potable use like toilet flushing and gardening. On one hand the consumer saves extra charges in lieu of potable water and sewage bills but on other hand the customer takes load of paying the capital, operation and maintenance costs of the treatment and reuse system. The general public (the stakeholder likewise public water service, private water company, central government, etc.) does not pay for the on-site greywater treatment and reuse systems, but it gets benefit from the reuse practice of individual consumers in terms of low discharge of waste water. The reduced quantity of waste water means relatively less expenditure on sewage collection and energy required for its treatment [21].

Water is the basic need of human being. In the past 100 years, the world population tripled but water consumption for daily life multiplied six folds [22]. Report states that average utilization of domestic water in developing countries is 157 l/c/d. Hence a household of 6-8 persons will require more than 1000 litres or 1 m^3/day [23]. In Pakistan the average tariff of 1m3 of potable water is US$ 0.15 but most of the urban communities do not depend on government owned water connection because the water supply network is often ineffective due to

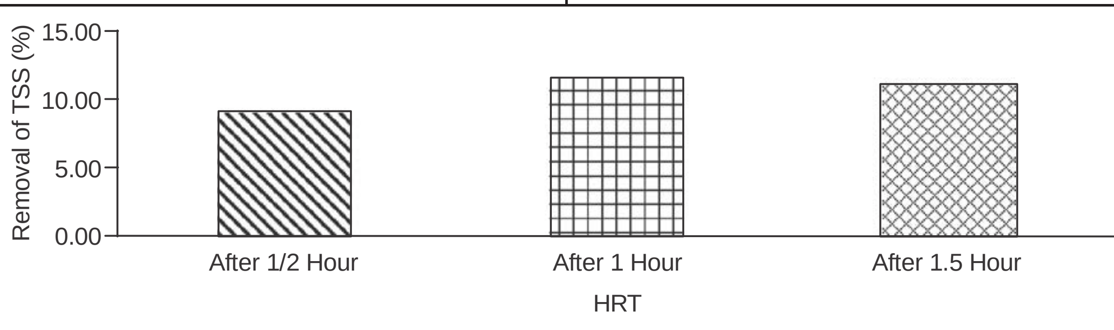

FIG. 4. TOTAL SUSPENDED SOLIDS REMOVAL TREND WITH INCREASE OF HYDRAULIC RETENTION TIMES

intermittent supply and break down of electricity that is why people are compelled to purchase potable water from water vendors which charge at the rate of US$ 1.14/m^3 (Rs: 100/m^3) or US$ 34.2/month [23]. It is about 8 times more than the average tariff of water.

In Pakistan, people use same quality of water for toilet flushing and gardening purposes which they receive from public or private water companies. The average requirement of water for aforesaid purposes is about 54% of the total household water consumption [24]. This need can be fulfilled by using treated greywater. Besides saving monthly charges in terms of utility bills, the use of treated greywater would minimize the load on sewage treatment plant and also protect the environment. The water carrying vehicles or trucks which are supplying water to the consumers, produce emissions of green house gases, create noise pollution and erode existing road ways. The use of treated greywater can save the potable water and its transportation and production charges. Whereas the cost of energy utilized for running the RBC system can be saved from the reduction (saving) of water and sewage bills. In this way the RBC system for treatment of greywater and reuse is feasible for centralized apartments.

4. CONCLUSIONS

The greywater generated in the NCEAC hostel was characterized and it was observed that greywater generated from the washbasins and showers is less polluted. BOD_5 and COD of the greywater were observed in the range of 36-77 and 79-195 mg/l respectively. RBC simulator was designed and developed at laboratory scale and operated at 1.7 rpm with various HRTs. The significant amount of BOD_5 and COD were removed about 53 and 60% respectively at 1.5 HRTs. The RBC simulator result of BOD_5 was compared with the greywater guidelines values set by China, USA, Australia and Japan. It shows that BOD_5 observed at 1.5 HRTs is less than USA guide lines and little higher than the china and Japan standards.

ACKNOWLEDGEMENT

Authors are greatly acknowledging this work to DFID for providing funding in DelPHE-II Project through British Council, Karachi, Pakistan.

REFERENCES

[1] Nghiem, D., Oschmann, N., and Schafer, I., "Fouling in Greywater Recycling by Direct Ultrafiltration", Desalination, Volume 187, pp. 283-290, 2006.

[2] Sheikh, B.A., Sheikh, S.A., and Soomro, G.H., "Pakistan Agriculture in Global perspective", Pakistan Journal of Agriculture, Agricultural Engineering, Vetterinary Sciences, Sindh Agriculture University, Volume 21, No. 2, pp. 53-59, Tando Jam, Pakistan, 2005.

[3] Halalsheh, M., Dalahmeh, S., Sayed, M., and Suleiman, W., "Greywater Characteristics and Treatment Options for Rural Areas in Jordan", Bio-Resource Technology, Volume 99, pp. 6635-6641, 2008.

[4] Madungwe, E., and Sakuringwa, S., "A Strategy for Water Demand Management in Harare", Physics and Chemistry of the Earth, Parts A/B/C, Volume 32, Nos. 15-18, pp. 1231-1236, 2007.

[5] Memon, F.A., and Butler, D., "Greywater Reuse in Households", Lehr, J., Keeley, J., Lehr, III Jak, T.B., (Editors), Encyclopaedia of Water, John Wiley & Sons, 2005.

[6] Sayers, D., "A Study of Domestic Greywater Recycling", Interim Report, National Water Demand Management Centre, Environment Agency, Worthing, UK, 1998.

[7] Friedler, E., Kovalio, R., and Galil, N.I., "On-Site Greywater Treatment and Reuse in Multi-Storey Buildings", Water Science Technology, Volume 51, No. 10, pp. 187-94, 2005.

[8] Nolde, E., "Greywater Reuse Systems for Toilet Flushing in Multi-Storey Buildings - Over Ten Years Experience in Berlin", Urban Water, Volume 1-4, pp. 275-284, 2000.

[9] Pidou, M., Memon, F.A., Stephenson, T., Jefforson, B., and Jeffrey, P., "Greywater Recycling: Treatment Options and Applications", Engineering Sustainability, Volume 60, pp. 119-131, 2007.

[10] Chan, Y.J., Chong, M.F., Law, C.L., and Hassell D.G., "A Review on Anaerobic-Aerobic Treatment of Industrial and Municipal Wastewater", Chemical Engineering Journal, Volume 155, pp. 1-18, 2009.

[11] Aizenchtadt, E., Ingmana, D., and Friedler, E., "Analysis of the Long-Term Performance of An On-Site Greywater Treatment Plant Using Novel Statistical Approaches", Urban Water Journal Volume 6, pp. 341-354, 2009.

[12] “Standard Methods for Examination of Water and Wastewater”, 19th Edition, American Public Health Association, Washington DC, USA, 1995.

[13] http://www.keeprocess.com (Dated: 25.03.2010).

[14] Zickefoose, and Charled, S., "Rotating Biological Contactor (RBC's)", Student Manual, Biological Treatment Process Control, EPA, Washington, DC, 1984.

[15] Eriksson, E., "Potential and Problems Related to Reuse of Water in Households", Ph.D. Thesis, Environment and Resources DTU, Technical University of Denmark, 2002.

[16] Birks, R., and Hills, S., "Characterisation of Indicator Organism and Pathogens in Domestic Greywater for Recycling", Environmental Monitoring Assessment, Volume 129, pp. 61-69, 2007.

[17] Li, F., Wichmann, K., and Otterpohl, R., "Review of the Technological Approaches for Greywater Treatment and Reuses", Science of the Total Environment, Volume 407, pp. 3439-3449, 2009.

[18] Maeda, M., Nakada, K., Kawamoto, K., and Ikeda, M., "Area-Wide Use of Reclaimed Water in Tokyo, Japan", Water Science and Technology, Volume 33, Nos. 10-11, pp. 51-57, 1996.

[19] Ernst, M., Sperlich, A., Zheng, X., Gan, Y., Hu, J., Zhao, X., Wang, J., and Jekel, M., "An Integrated Wastewater Treatment and Reuse Concept for the Olympic Park 2008, Beijing", Desalination, Volume 1, No. 3, pp. 293-301, 2006.

[20] Asano, T., "Milestones in the Reuse of Municipal Wastewater", Proceedings of Water Supply and Sanitation for All, pp. 295-306, Berching, German, 2007.

[21] Friedler, E., and Hadari, M., "Economic Feasibility of On-Site Greywater Reuse in Multi Storey Buildings", Desalination, Volume 190, pp. 221-234, 2006.

[22] Frank, R., Rijserman, and William, J.C., "Making Water Every Body Business", World Water Council, 2000.

[23] Second Water Utilities Data Book for the Asian and Pacific Region, Asian Development Bank, 1997.

[24] Boal, D.C., Eden, R.E., and Farlane, S., "An Investigation into Greywater Reuse for Urban Residential Properties", Desalination, Volume 106, pp. 391-397, 1996.