Study on reuse of grey water – A Review

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Abstract. Water scarcity is a huge problem and is been consistently increasing every year. Many of the water systems that keep ecosystems flourishing and feed a growing human population became stressed. Ocean, river, lake, streams are too much polluted. A lot of technologies are available on water recycling. Greywater is around 50% of household water usage but unfailing information relating to both the characteristics of greywater and the variety of recycling technologies are not available. In this review paper we have discussed the relative merits of different options available in greywater recycling and viability of onsite recycling systems.

Keywords: Greywater, recycling

Introduction

Water is an inevitable crucial need for our day to day activities like bathing, washing, drinking, cleaning, etc. Pressing need for water in many parts of the world had led to over-exploitation of renewable water resources. In order to solve the water related problems, greywater recycling is found to be a useful option. Reclaimed greywater can be used either for potable or non-potable use based on the requirements. Recycled water of lower quality can be used for non-contact purposes. This accounts around 50% of domestic and industrial water demand [1]. Greywater quality, quantity and recycling standards differ across the world. A major barrier for execution of greywater reuse is public opinion that the recycled water is hazardous or unhealthy. These recycling technologies are at its incipient stage due to its technical feasibility and public perception of water reuse. The paper aims to present a detailed study on various technologies in greywater recycling for sustainable management.

Greywater characteristics:

Greywater is a type of wastewater that is generated from domestic activities such as cloth washing, vessel washing, bathing and hand wash but eliminates streams from toilets because toilet water are considered as black water [2-5]. Some authors do not consider kitchen waste water as a source of greywater [6-8]. Greywater has less suspended solids and turbidity. In comparison with sewage water, greywater has high COD:BOD but low macronutrients such as phosphorous and nitrogen. COD:NH₃:P of sewage water is 100:5:1 whereas greywater is 1030:2.7:1 [9].

Factors affecting greywater

Greywater is mainly composed of soap or soap products such as bars, detergents and shampoos. Based on topographical location, demographics and residence time the quality of greywater varies. Above mentioned factors highly influence the composition of greywater which makes grey water recycling a tough process. Mean COD standards differ from 40 to 371 mg/l between sites [10]. Residence time is
a crucial factor in determining greywater characteristics. Substantial variations in chemical characteristics may take place in a 1 hour time period.

**Major threats/ challenges in recycling Greywater:**
A lot of problems arise when the GW is directly used for irrigation or flushing purposes. Disease spreading due to microbes is one common concern. Reclaimed greywater when used for irrigation raises problems of pollution because of the pollutants present. Greywater might clog the distribution system and the sulphide content may produce offensive odors. Public opinion on recycled greywater as hazardous has become a major obstacle to its implementation. [10].

**Standards in different countries:**
Many countries does not have water reuse standards and some countries has not revised it. In most countries, guidelines and standards for water reuse in buildings either do not exist or are being revised or expanded. Cleanliness, safety, aesthetics, viability and economic practicality are the basis for greywater reuse [11]. Greywater technology varies from simple to more advanced ones based on the quality of water required for a particular use.

| Country  | Application            | BOD (mg/l) | TSS (mg/l) | Turbidity (NTU) | Faecal Coliforms (cfu.100ml/l) | Total Coliforms (cfu.100ml/l) |
|----------|------------------------|------------|------------|-----------------|--------------------------------|-----------------------------|
| India[12]| Drinking Water         | <2         | >6         | -               | -                              | <50                         |
| Japan[12]| Toilet and flushing    | -          | -          | <2              | -                              | <1000                       |
| Israel[12]| Wastewater reuse     | 10         | 10         | -               | <1                             | -                           |
| Spain[12]| Wastewater reuse      | 10         | 3          | 2               | -                              | 2.2                         |
| USA[5]  | Unrestricted water reuse | 20        | 5          | 2-5             | -                              | 2.2 to 23 max in 30 days    |
| Australia[12]| Greywater reuse for garden | 20    | 30         | -               | -                              | 100                         |
| Canada[12]| Unrestricted urban reuse | 10     | 5          | 2               | 2.2                            | -                           |
| Florida[12]| Bathing water        | -          | -          | -               | 2000                           | 100000                      |
| Germany[5]| Water reuse          | -          | 20         | 1-2             | 500                            | 100                         |
| UK (BSIRA)[5]| Water reuse         | -          | -          | -               | Non detectable                 | -                           |
| WHO[5]  | Water reuse           | -          | -          | -               | 1000 (m)                       | 200 (g)                     |

(g), guideline,(m) mandatory

**Greywater recycling Technologies:**
Wide range of technologies is available for greywater recycling. Type of recycling system chosen is based on the quality, quantity and usage. All the greywater technologies can be brought under three major classification; physical, chemical and biological systems. A single filtration method may not give the required quality of reclaimed water. recycling systems are combination of solid-liquid separation step as pre-treatment and disinfection as post treatment. Pre-treatment process is to avoid clogging whereas disinfection process is to kill microbes [12].

| CLASSIFICATION | TECHNIQUE       | DESCRIPTION                                                                 | PROS                                      | CONS.                                      |
|----------------|-----------------|----------------------------------------------------------------------------|-------------------------------------------|--------------------------------------------|
| Simple[9]      | Coarse Filtration | Removes coarse suspended solids that would be deposited on process equipment thus creating | *Construction is very simple.  *Operation is simple  *Easy maintenance | *not economical for filtration of very small quantities.  *There is a high amount |
| Section                | Process Description                                                                 | Advantages                                                                 | Disadvantages                                                                 |
|------------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Disinfection           | The various methods used for the disinfection of grey water are chlorine, ultraviolet and ozone. | * Efficient in killing killing bacteria. *Less operating skills are needed. | *Toxic byproducts are created when chlorine and ozone are used. *It is highly affected due to differences in organic content occur. |
| Physical Filtration    | Sand Filtration                                                                      | *Simple to operate and construct *Cheaper cost *High chemical, physical and bacteriological quality of water. | *Old fashioned and outdated method. *Maintenance cost is more *Needs lots of space. |
| Adsorption             | Adsorption filters forces the liquid to move from bottom to top. This causes the liquid to be in contact with the adsorbent for as long as possible. | *Lower pressure drop. *Effective in treating acid degradation. *Limited use of chemicals. | *More complex in operation. *Higher probability of clogging. *Higher operating cost. |
| Membrane               | It is a physical separation method used to separate molecules of diverse characteristics and sizes. It’s driving force is based on the pressure difference between the two sides of the membrane. | *Very low labor cost *Large area of filtration. *By varying the speed of drum rotation filtration cake thickness can be controlled. | *High capital cost needed *For slurries having low percentage of solids this method is unsuitable *Low membrane life time. |
| Photocatalysis         | To a light of suitable energy, when a semiconducting material is exposed electron-hole pairs are generated. Photocatalysis is the chemicals reaction that happens due to of light and semiconductors. | *Higher efficiency *Convenient to adjust *Membrane damage could be avoided. | *Higher operating cost. *Membrane fouling. *Low quality of permeate. |
| Electrocoagulation     | Metal electrodes are dipped in the effluent and a direct source of current is given in between them, which causes the electrode to dissolve into the effluent. At a certain pH the metal ions yield a larger range of metal hydroxides and coagulated | *No chemicals needed. *Gives colorless and odorless water. *Even the smallest colloidal particle can be removed. | *Regular replacement of anode. *Cathode passivation can occur. *Operating cost can be high in electricity abundant areas. |
| Process          | Description                                                                 | Benefits                                                                                               |
|------------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| **Coagulation**  | To weaken the charges present on the particles, oily materials or colloids in suspension, small and highly charged molecules are introduced into the water. By manipulating electric charges, solids present in water are removed. | *Easy operation.*  
*Low cost.*  
*High efficiency in removal of pollutants.*  
*Can be used for various types of waste water.*  
*High sludge production.*  
*Sludge gives adverse effects to human health.*  
*Increase cost of sludge treatment.* |
| **Aerated Filter** | This system has 2-3m deep bed of comparatively small size filter media that provides a large surface area on which biomass is grown. The steady wastewater is pumped either downwards or upwards though a submerged filter bed. | *Low energy demand.*  
*Low land requirement.*  
*Low sludge production.*  
*Long startup period.*  
*Significant washout of sludge.*  
*Lower gas yield.* |
| **Rotating contactor** | It is a biological fixed-film treatment combined with primary treatment for the treatment of wastewater. | *No specifically skilled person required.*  
*Lower energy.*  
*Lower treatment efficiencies.*  
*Low pathogen removal.* |
| **Membrane bioreactor** | It is the blend of a membrane processes (ultrafiltration or microfiltration), biological wastewater treatment process, and the activated sludge process. It is mostly used for industrial and municipal process. | *High quality effluent.*  
*High loading rate capacity.*  
*Low plant budget.*  
*Easy operation.*  
*High capital coast.*  
*Membrane can be sensitive.*  
*Requires pretreatment.* |

**Decentralized waste water treatment system:**
An on-site wastewater recycling system is a water reuse system that treats and reclaims wastewater on site and distributes the recycled water within or in the vicinity of the buildings for potable or non-potable uses based on the technology incorporated. The purpose of these actions has been to cope with water supply shortages, reduce wastewater load on sewerage systems and treatment facilities, and prevent flooding of urban rivers from storm water flows.[16]. The electrocoagulation process is a feasible onsite recycling technology due to its small size and economic feasibility.[14]. Electrocoagulation has numerous advantages when compared to conventional methods especially in reference to its simplicity in maintenance and operation, production of sludge and ultrafine particle removal efficiency.[17]. A pilot scale electrocoagulation setting was made to inspect on the quality of reclaimed domestic greywater. The reclaimed water follows the general guidelines for water reuse for human noncontact usage. In urban sector, two models were chosen to test the economic. Membrane bioreactor (MBR) system is a compact intensive wastewater treatment technology; and a rotating biological contactor (RBC) system is a more extensive technology. Taking the case of Israel, water charges are 1.16 US$/m³ and sewage charges are 0.3 US$/m³. For a seven storey building (28 flats) RBC is an economically feasible whereas MBR becomes feasible only when the building size is more than 37 storeys. On incorporating several buildings together (each 10 storeys high), MBR
systems found to be economically feasible. The RBC and MBR systems reduces overall water consumption and economically feasible when used properly [15].

**Role of residence time:**
Greywater nature changes over a period of time due to the change in its chemical characteristics. This is due to different sources of greywater generation because of which the quality varies. This causes variation in the quality of feed for the greywater recycling system. Residence has to be taken into consideration to make sure that the greywater is treated at the right time before its quality degrades. Certain value has to be considered as criterion before which the greywater has to be recycled (i.e. 48 hrs) [20].

**Discussion:**
**Physical treatments** involve Sand filtration, coarse filtration, adsorption, and membrane filtration. **Coarse filtration and soil filtration** does not meet the standard required for non-potable reuse as it is less effective in removing physical, microbiological and chemical components present in greywater. **The micro filtration and the Ultra filtration membrane** shows good result in removing pathogens, turbidity and suspended solids but not effective in removing dissolved organics. Adsorption discussed here is a Gravity-governed process. This method proves to be as effective as conventional expensive methods. Adsorption process is also environmentally friendly, feasible and viable. Physical process alone is not enough to obtain the required water quality. Thus it is recommended to combine physical process with some other process. Sand or membrane filtration is used as a post-treatment for polishing purposes. Chemical process involves coagulation and electro-coagulation. Coagulation process is able to achieve non-potable urban reuse standards by recycling low strength greywater. This method is accompanied by filtration or disinfection stage to remove surfactants, suspended solids and organic substance present in low strength grey water [14, 21]. **Electrocoagulation** process is compact, economic, and has numerous advantages over coagulation, especially in reference to operation, maintenance, ultrafine particle removal efficiency and overall cost [17]. Biological treatments involve aerated filters, membrane bioreactors, and rotating contactors. **Aerobic biological process** removes turbidity and organic substance effectively. To eliminate surfactants and organic substance from grey water, anaerobic process is an inappropriate option. E&M (2006) concluded that the RBC system can be used for less number buildings. It is feasible for a seven storeys building (28 flats). Reclaimed water from a MBR system is able to achieve the urban reuse water quality standards without a post filtration and disinfection processes [21]. Onsite MBR system is feasible only for building size more than 37 storeys (148 flats) [15].

**Conclusion:**
Greywater recycling is a viable option to meet the water scarcity but it is highly depend on the water quality standards, quantity and it’s purpose of used for. Different recycling technologies meet different standards. Certain technologies like coagulation followed by membrane filtration is suitable only for low strength greywater whereas biological processes like RBC, SBR can be used to treat medium to high strength greywater. MBR can be used to meet the severe urban reuse standards for non-drinking purpose. Centralized sewer systems are not adequate for sustainable water management. Thus to utilize water resource efficiently a transition to onsite recycling is required. Electro coagulation, RBC and MBR seems to the feasible onsite recycling systems.

**Reference:**
[1] Dieter, K. 1996. Jerkwater recycling: Treatment techniques and cost. World Water Environ. Eng., 2:18-19.
[2] Bruce Jefferson., et al. 2001. Nutrition addition to enhance biological treatment of greywater. Water Res., 35:2702-10.
[3] Ralph otterpohl., et al. 1999. Source control in urban sanitation and waste management: ten systems with reuse of resources. Water Sci. Tech., 39:153-60.
[4] E, E. (2002). Potential and problems related to reuse of water in households. Environment and resources DTU, ISBN 87-89220-69-2.

[5] Al-Jayyousi, O. R. 2003. Greywater reuse: towards sustainable water management. Desalination, 156: 181-192.

[6] Diana Christova-Boal., et al. 1996. An investigation into greywater reuse for urban residential properties. Desalination, 106: 391-397.

[7] VL, L. (2002). Greywater Guidelines. Tucson, Arizona: The water conservation alliance of southern Arizona.

[8] P.A. Wilderer. 2004. Applying sustainable water management concepts in rural and urban areas: Some thoughts about reasons, means and needs. Water sci. Tech., 49(7): 7-16.

[9] B. Jefferson., et al. 1999. Technologies for domestic water recycling. Urban Water., 1: 285-292.

[10] Lucy Allen., et al. (2010). Overview of Greywater Reuse: The Potential of greywater systems to aid sustainable water management. Pacific Institut. Oakland, California. pp 5-32.

[11] Erwin Nolde. 1999. Greywater reuse systems for toilet flushing in multi-storey buildings — over ten years experience in Berlin. Urban Water., 1: 274-84.

[12] Mrc Pidou., et al. 2007. Greywater recycling: A review of treatment options and applications. (vol 160)Institution of civil engineers. Proceedings. Engineering sustainability. pp 119-131.

[13] Fangyue Li., et al. 2009. Review of the technological approaches for greywater treatment and reuses. Sci. Total Environ, 407: 3439-3449.

[14] Chin-Jung Lin., et al. 2005. Pilot-Scale Electrocoagulation with Bipolar Aluminum electrodes for On-site domestic greywater reuse. J Environ Eng, 491-495.

[15] Dr. Nitin Sherje. (2020). Biodegradable Material Alternatives for Industrial Products and Goods Packaging System. International Journal of New Practices in Management and Engineering, 9(03), 15-18.

[16] Liu, S., et al. 2013. Impacts of residence time during storage on potential of water saving for greywater recycling system. Water Res., 1-32.

[17] Chang Y., W. m. (2007). Treatment of greywater urban reuse. Proceedings of Advanced Sanitation Conference. Aachen, Germany. pp 1-32.

[18] Natarajan, B., Obaidat, M.S., Sadoun, B., Manoharan, R., Ramachandran, S. and Velusamy, N., 2020. New Clustering-Based Semantic Service Selection and User Preferential Model. IEEE Systems Journal, DOI: 10.1109/JSYST.2020.3025407.

[19] S. Rubach and I.F. Saur. 1997. Onshore testing of produced water by Electroflocculation. Filter and separation, 10: 877-882.

[20] Dr. Nitin Sherje. (2020). Biodegradable Material Alternatives for Industrial Products and Goods Packaging System. International Journal of New Practices in Management and Engineering, 9(03), 15-18.

[21] S. Rubach and I.F. Saur. 1997. Onshore testing of produced water by Electroflocculation. Filter and separation, 10: 877-882.

[22] Natarajan, B., Obaidat, M.S., Sadoun, B., Manoharan, R., Ramachandran, S. and Velusamy, N., 2020. New Clustering-Based Semantic Service Selection and User Preferential Model. IEEE Systems Journal, DOI: 10.1109/JSYST.2020.3025407.

[23] Babu, R.G., Obaidat, M.S., Amudha, V., Manoharan, R. and Sitharathan, R., 2020. Comparative analysis of distributive linear and non-linear optimised spectrum sensing clustering techniques in cognitive radio network systems. IET Networks, DOI: 10.1049/iet-net.2020.0122.

[24] Sitharathan, R., Yuvaraj, S., Padmanabhan, S., Holm-Nielsen, J.B., Sujith, M., Rajesh, M., Prabaharan, N. and Vengatesan, K., 2021. Piezoelectric energy harvester converting wind aerodynamic energy into electrical energy for microelectronic application. IET Renewable Power Generation, DOI: 10.1049/rpg2.12119.
[27] Sitharthan, R., Sujatha Krishnamoorthy, Padmanaban Sanjeevikumar, Jens Bo Holm-Nielsen, R. Raja Singh, and M. Rajesh. "Torque ripple minimization of PMSM using an adaptive Elman neural network-controlled feedback linearization-based direct torque control strategy." International Transactions on Electrical Energy Systems 31, no. 1 (2021): e12685. DOI: 10.1002/2050-7038.12685.