

CHARACTERIZATION AND TREATABILITY STUDIES ON GREY WATER OF DOMESTIC ACTIVITIES

A

Thesis Report

Submitted in the partial fulfillment for the award of Degree

**MASTER OF TECHNOLOGY
in
ENVIRONMENTAL SCIENCES AND TECHNOLOGY**

Submitted By
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Dated: 12/07/2010

CERTIFICATE

This is to certify that the present thesis entitled "Characterization and Treatability Studies on Greywater of Domestic Activities" being submitted to Thapar University, Patiala, in partial fulfillment of the requirements for the award of the degree of Master of Technology in Environmental Science & Technology, embodies faithful record of original research carried out by Ms. Tarandeep Kaur, Roll No. 600801012. She has worked under our guidance and supervision and this work has not been submitted, in part or full, for award of any other degree or diploma of Thapar University or any other university.

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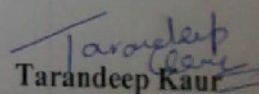


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DECLARATION

I hereby declare that the present thesis entitled “**Characterization and Treatability Studies on Greywater of Domestic Activities**” which is being submitted to the Department of Biotechnology and Environmental Sciences, Thapar University, Patiala, in partial fulfillment of the requirements for the award of the **Master of Technology in Environmental Science & Technology**, is an authentic record of my work during the period from July 2009 to June 2010, under the supervision of **Mr. K.S. Babu, Assistant Professor**, Department of Biotechnology and Environmental Sciences, Thapar University, Patiala. The matter presented in this thesis has previously not formed the basis for award of any other degree or diploma.


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ABSTRACT

Greywater is generated at domestic activities through wash basins, bathrooms, kitchen sinks and automobile cleaning etc. They often contain objectionable parameters, such as solids, organic, nutrients, coliforms etc restricting the disposal into water bodies/its beneficial uses.

A study was performed on greywater generated from six residences of Adarsh Colony, Patiala, collected on monthly intervals and physico-chemical-biological parameters analyzed from the same.

The samples analyzed showed clearly high values of pollution parameters necessitating a simple treatment scheme to suit the reuse as a medium at gardens for irrigation purpose.

Screen → SSF → Charcoal filter → pH Adjustment → Disinfection

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INTRODUCTION

1.1 Background

Water is becoming a rare resource in the world. Consequent to rapid growth in population and increasing water demand, stress on water resources in India is increasing and per capita water availability is reducing day by day. In India per capita surface water availability in the years 1991 and 2001 were 2300 m³ and 1980 m³ respectively and these are projected to reduce to 1401 and 1191 m³ by the years 2025 and 2050 respectively (Kumar et al., 2005).

International Water Management Institute (IWMI) predicts that by 2025, one person in three will live in conditions of absolute water scarcity (IWMI, 2003). It is therefore essential to reduce surface and ground water use in all sectors of consumption, to substitute fresh water with alternative water resources and to optimize water use efficiency through recycle and reuse options. Many Mediterranean countries are investing in wastewater reclamation and reuse due to high evaporation and evapotranspiration, low rainfall and increased demand for water for irrigation and tourism (Angelakis et al., 2001).

Equally, in water scarce developing countries, greywater reuse in schools, hospitals and government institutions is, proving to be an essential alternate water resource to fresh ground, surface or rainwater supplies (Godfrey et al., 2006). Studies from the Middle-East and India indicate that greywater systems have water saving between 3.4% to 33.4% per annum (Jayyousie, 2003). In 1993-94 Victoria University of Technology in conjunction with Melbourne Water works designed, installed, monitored and assessed greywater reuse system on four home sites (Christov et al., 1995).

The application of greywater systems is therefore of particular importance in assisting developing countries in addressing Goal 7: Ensure environmental sustainability of the Millennium Development Goals.

1.2 Concept of Greywater

Residential wastewater or greywater is a mixture of all water discharges within the household including bathroom sinks, bathtubs, toilets, kitchen sinks, and laundry wash-water sources. This wastewater is characteristically divided into three sub-categories related to the organic strength or level of contaminants typically contained in the water:

- i) Light-greywater;
- ii) Dark-greywater, and
- iii) Blackwater.

Light-greywater typically consists of drainage from bathroom sinks, tubs, showers, and often laundry. All three wastewater categories contain a wide range of organic and inorganic contaminants as well as disease-causing micro-organisms; with the type of contaminants and concentrations in light-greywater depending on the specific drainage source (i.e. bathtubs versus laundry). Although light-greywater may have lower concentrations of contaminants than mixed wastewater, research shows that the concentrations can be comparable to, and at times even greater than, mixed wastewater.

Dark-greywater includes both light-greywater sources plus drainage from kitchen sinks, automatic dishwashers, or other sinks involving food preparation. Food waste, grease/oils and cleaning products contribute to increased contaminant loading, including disease-causing microorganisms, even without the presence of garbage.

Blackwater is drainage from toilets and urinals; containing high concentrations of bacteria and organic contaminants in addition to disease causing microorganisms and ingested chemicals (e.g., pharmaceuticals).

The composition of greywater varies greatly and reflects the life style of the residents. Reuse of domestic greywater for non-potable purposes is emerging as an important

approach to the management and conservation of water resources, particularly in rural and developing areas Greywater represents the largest potential source of water savings in domestic residences, accounting for as much as 50–80% of the total water uses. Greywater production is estimated at daily per capita volumes as high as 90–140 L (Carr et al., 2004)

1.3 Benefits of Domestic Greywater

Reuse of greywater serves two purposes of reducing

- i) Freshwater requirements
- ii) Sewage generation

Greywater most easily offsets water demands for **irrigation**. In conjunction with rainwater harvesting, it can supply most, if not all, of the landscape irrigation needs of a domestic dwelling in a semiarid region. Greywater can contain nutrients (e.g. phosphorus and nitrogen from detergents) that can benefit plant growth, reduce the need for fertilizer application, and result in more vigorous vegetation. Utilization of treated greywater for irrigation of indoor plants, agricultural crops and turfs is reported (Bernard et al 2003) In addition to irrigation application; greywater can also be used to offset **potable water demands** for use in toilet and urinal flushing. As previously mentioned, if adequately treated and disinfected, greywater can also be used for a wide range of other non-potable water uses including bathing, showering, laundry, washing, etc.

Removing greywater from a residential or commercial wastewater stream reduces the volume of wastewater that has to be collected and treated and enables the existing water and wastewater infrastructure to service more connections. On-site treatment and reuse also offers potential energy savings over centralized sewerage alternatives, particularly where greywater reuse applications require limited or no treatment, and where the greywater would otherwise have to be pumped to a centralized treatment facility.

Table 1.1: Greywater use at various locations

Use of Greywater	Use of Greywater Purpose
School	Floor cleaning
Government/ non government office	Irrigation
Hospital	Gardening
Theatre	Car washing
Hotel	Construction
Individual household	Toilet flushing
Airport	
Railway station	
Apartment/colony	

Potential of Greywater Reuse

Reuse of greywater serves two purposes:

- Reduces fresh water requirement
- Reduces sewage generation

The amount and quality of greywater will in part determine how it can be reused. Irrigation and toilet flushing are two common uses, but nearly any non-contact use is a possibility. Toilet flushing can be done either by direct bucketing or by pumping treated greywater to an overhead tank connected by suitable piping to the toilets. Possible uses of treated greywater are presented in Table 1.1

1.5.1 Greywater for Agricultural Irrigation

Besides the increased productivity through agriculture, other significant environmental and health benefits, including the increased agricultural productivity through irrigation are:

- Augmentation of potable water supplies through aquifer recharge
- Recycling plant nutrients thereby reducing eutrophication
- Reserving drinking water supplies by substituting with treated greywater e.g. Landscape irrigation, toilet flushing, industrial uses and cooling water.

Other precautions required while irrigating with greywater are:

- Root crops which are eaten uncooked should not be irrigated with greywater
- Plants that thrive only in acid soil should not be watered with greywater, which is alkaline
- Disperse greywater over a large area and rotate with fresh water to avoid build-up of sodium salt.

1.4 Quantification and Characterization of Greywater

Greywater is the component of domestic wastewater, which has not originated from the toilet or urinal. It is majority generated from bathrooms, laundry and kitchen etc. Fig 1.1 shows the various activities involved in generation of greywater and are further discussed below.

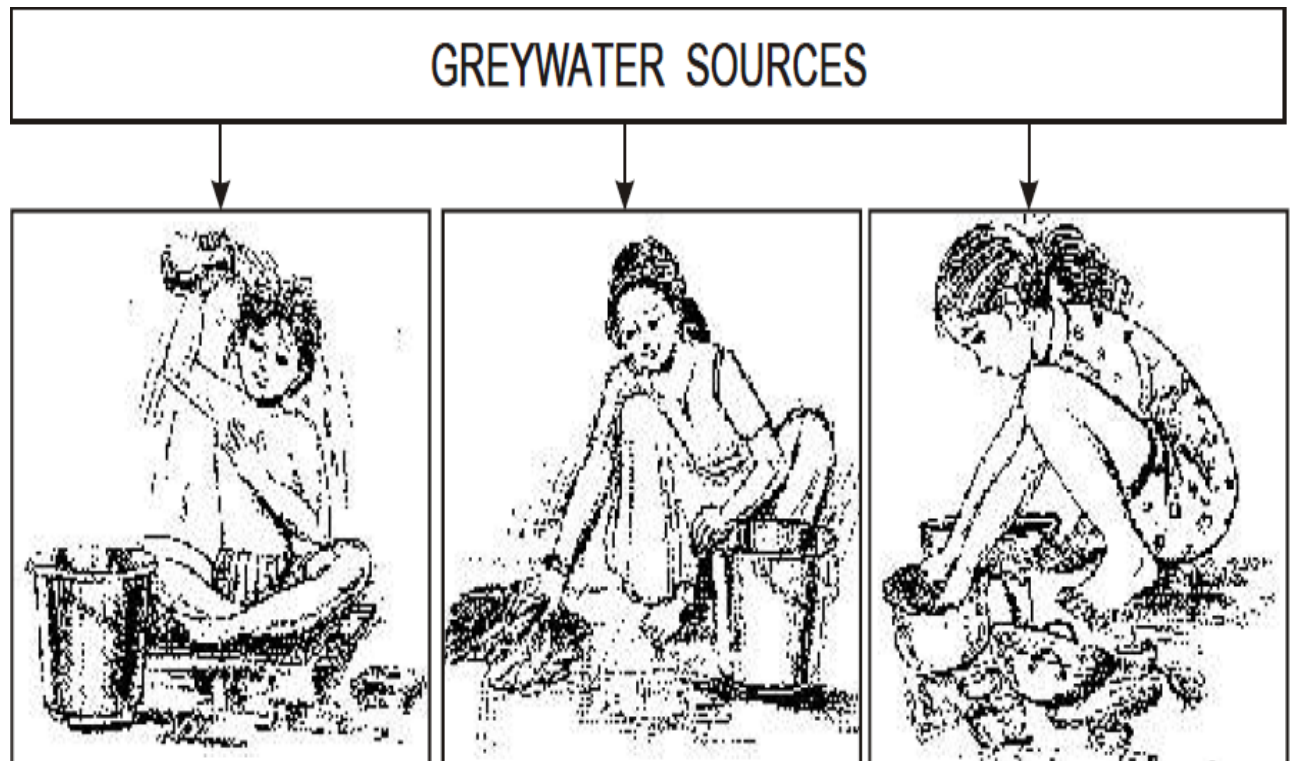


Figure1.1: Activities generating Greywater

1.4.1 Greywater from Bathroom

Water used in hand washing and bathing generates around 50-60% of total greywater and is considered to be the least contaminated type. Common chemical contaminants include soap, shampoo, hair dye, toothpaste and cleaning products. It also has some faecal contamination (and the associated bacteria and viruses) through body washing.

1.4.2 Greywater from Cloth Washing

Water used in cloth washing generates around 25-35% of total greywater. Wastewater from the cloth washing varies in quality from wash water to rinse water to second rinse water. Greywater generated due to cloth washing can have faecal contamination with the associated pathogens and parasites such as bacteria.

1.4.3 Greywater from Kitchen]

Kitchen greywater contributes about 10% of the total greywater volume. It is contaminated with food particles, oils, fats and other wastes. It readily promotes and supports the growth of micro-organisms. Kitchen greywater also contains chemical pollutants such as detergents and cleaning agents which are alkaline in nature and contain various chemicals. Therefore kitchen wastewater may not be well suited for reuse in all types of greywater systems.

Chemical and microbial qualities of greywater vary depending on type of source. A typical qualitative composition of greywater is presented in Table 1.2. Further, treatment requirements vary based on composition and intended use of treated greywater.

Table 1.2: Characteristics of Greywater (Wright, 1986 & Errikson, 2002)

Water Source ⇒	Cloth	Washing	of	Bathing	Kitchen
Quality Parameters ↓	Washing	Utensils			
Bacteria		*		*	*
Chloride					
Food Particles		*		*	
Hair					*
High pH	*	*			
NO₂⁻	*				
Odor		*		*	*
Oil & Grease	*	*		*	*
Org. matter		*			*
Dissolved Oxygen	*	*		*	*
Phosphorous	*				
Salinity	*				
Sodium	*	*			
Soaps	*	*		*	*
Sulfur	*	*			
Turbidity	*	*		*	*

1.4 Defining the Research Problem

From the above discussion, it is evident that domestic activities are major source of greywater.

Major contribution involved in it is washing vehicles, soaking/cleaning fruits, vegetables, cooking food, bathrooms etc; they have intense color, excess solids, milky appearance, and severe odors and often contain high level of organic matter and pathogens etc.

Environmentally they are unsafe as they affect light passage; create unsightly appearance in receiving water body, deplete oxygen levels and cause disease. Hence,

characterisation of greywater and treatment technologies are necessary prior to its disposal into sewers or reuse for a designated purpose.

The present study is made to assess the greywater produced at various domestic sources of Adarsh Colony, Patiala and need for conceptualising a treatment scheme. While carrying out the study, the work elements considered are:

- i) Sources generating greywater and characterisation for various parameters.**
- ii) The concept of a viable treatment scheme for removal of objectionable parameters from greywater.**

The findings of the study will contribute to utilizing the treated greywaters for beneficial purposes and also maintaining the receiving waterbodies pristine.

CHAPTER-2

REVIEW OF LITERATURE

2.1 General

Much of the daily-generated wastewater is recognized as greywater. Greywater is generated from domestic activities, industries, agriculture and automobile garages etc. The total volume of greywater potentially generated each day from the average household is 356 L; this represents about 60% of the total generated wastewater. Greywater can be used for different purposes, such as garden watering, ornamental uses in fountains and waterfalls, landscaping, lawn irrigation, car washing and toilet flushing. As a result of reuse, fresh drinking-water supplies are conserved, which in turn enables the water to remain in natural ecosystems. Greywater reuse also, reduces sewage flows and reduces the public demand on potable water supplies. The load on wastewater disposal systems is reduced, and therefore, the life of the wastewater disposal system is prolonged and capital expenditure required for the upgrading and expansion of systems is delayed.

The information furnished below is collected from research papers, magazines, newspapers and internet etc. The studies performed by several authors on greywater characterization and treatment aspects and technologies and applications of treated greywater are discussed.

2.2 Studies Performed on Greywater

Li et al., (2000) proposed a potable urban greywater reuse standard and treatment alternatives and reuse schemes. They showed that all types of greywater have good biodegradability. The bathroom and the laundry grey water are deficient in both nitrogen and phosphors. The kitchen grey water has a balanced COD: N: P ratio. The review also reveals that physical processes alone are not sufficient to guarantee an adequate reduction of the organics, nutrients and surfactants. The chemical processes can efficiently remove the suspended solids, organic materials and surfactants in the low strength grey water. The combination of aerobic biological process with physical filtration and disinfection is considered to be the most economical and feasible solution for grey water recycling.

Jefferson et al., (2001) described that domestic wastewater recycling is still in its infancy and as such, there is a paucity of reliable information relating to both the nature of grey water and the range of recycling technologies available. The lack of water quality standards and the poor understanding of the nature of grey water have led to the development of a plethora of technologies for recycling application.

Len et al., (2002) studied to determine the concentrations of hypochlorous acid and hypochlorite ions and related those concentrations to the microbicidal activity of the water, to identify the primary component responsible in electrolyzed oxidizing water for inactivation. The ultraviolet absorption spectra were used for this purpose.

Peter et al., (2002) studied to quantify the variability and characteristics of greywater sampled at five different commercial locations in Massachusetts. Parameters such as, BOD₅, SS, TKN, Nitrate, Ortho-Phosphate, pH, Total Coliforms were analyzed from greywater. A column study was also run concurrently with the characterization study to assess the effect of soil depth and loading rate on treatment efficiency. They observed that loading rates doesn't have an adverse effect on treatment efficiency, but that decreasing soil depth does.

Eriksson et al., (2002) indicated that the composition of grey wastewater depends on sources and installations from where the water is drawn, e.g. kitchen, bathroom or laundry. The chemical compounds present originate from household chemicals, cooking, washing and the piping. In general grey wastewater contains lower levels of organic matter and nutrients compared to ordinary wastewater, since urine, faeces and toilet paper are not included. They also identified 900 xenobiotic compounds which are potentially present.

Ottosson, (2003) suggested that wastewater infiltration can also be observed for greywater. Source separation of greywater can be a strategy to enhance recirculation of plant nutrients and/or improve water use. The risk for transmission of disease when reusing greywater is largely dependent on the cross-contamination by faeces. High levels of faecal indicators, mainly thermotolerant coliform bacteria, have been reported in greywater, indicating substantial faecal pollution. Active sludge may not be a suitable technique for greywater due to the low carbon content. Chemical precipitation has the

advantage of removing phosphorus as well as viruses efficiently and it is suggested as one possible method for treating greywater. Otherwise the most common practice for greywater treatment in Sweden is soil infiltration.

Beirut and Shihab, (2003) focused on the methods and results of the Inter-Islamic Network on Water Resources Development and Management (INWRDAM) in greywater treatment and use, in order to make it easily affordable to more Islamic countries. The outcome of this research to date has been the optimization of the modular low-cost units for greywater treatment and use by drip irrigation techniques and selection of crops for home gardens.

Carolan et al., (2004), made a critical look at ecological modernization, particularly with regard to its strong “productivist” orientation of greywater.

Friedler et al., (2005) studied the performance of a pilot plant treating light greywater for seven flats. The pilot plant combines biological treatment (RBC) with physicochemical treatment (sand filtration and disinfection). The pilot plant reduced effluent of excellent quality in terms of BOD, and SS removal. Low COD removal indicated that greywater contains slowly-biodegradable organics. RBC was able to retain most of the solids as a result of flocculation resulting in stable and reliable performance. The treated effluent ensured its safe reuse for toilet flushing.

Birks & Hills, (2005) characterized the organisms and pathogens as indicator in domestic Greywater. Greywater from baths, showers and wash- basins was collected separately from all other domestic wastewater at a university block. Greywater flow and temperature were also monitored and COD and BOD levels appeared to be lower, possibly due to settlement or biodegradation in the storage tanks. Plate counts and indicator organism concentrations were consistently high suggesting a high level of human bacterial contamination necessitating biological treatment and disinfection if the water is to be used for recycling

Gross et al., (2006) reported that reuse of greywater is an attractive addition to water management options. One of the major concerns limiting greywater reuse is the possible presence of harmful microorganisms. In addition to total coliform organisms, enteric organisms (*Salmonella*, *Shigella* and poliovirus Type 1 *Cryptosporidium*,

Giardia) and opportunistic pathogens (*Staphylococcus aureus* and *Pseudomonas aeruginosa*) may be present in greywater. Need for extensive microbiological monitoring of greywater systems and for developing greywater specific standards was emphasized.

Giri et al., (2006), aimed to unveil basic facts on characteristics and organic degradation potential of domestic wastewater in Bangkok with laboratory experiments. The results showed greywater-like qualities of domestic wastewater as a result of continued use of septic tanks and tradition of using water in defecation. A low-cost, closed-loop natural treatment system with source separation to satisfy the local traditional was recommended.

Magid et al., (2006), aimed to develop and evaluate technical solutions for increasing recirculation of nutrients and organic matter from urban areas, Denmark. Integrated systems at 14 urban areas were developed in relation to public health, comfort, cost, durability, user friendliness, energy use and recirculation potential.

Leopoldo et al., (2006) studied the implementation of a greywater reuse scheme for new housing developments in Ensenada that could achieve upto 37% savings in water consumption with the corresponding monetary savings. New housing facilities irrigated with greywater had green areas which would represent ecological and aesthetical benefits to city.

Thanh et al., (2006) studied the greywater flows in Vietnam black-water is treated in in-house septic tanks and is discharged directly into the drainage system. Phosphorous, Nitrogen, Total Solids were analyzed from greywater. The contribution of greywater to the total domestic pollution load was significant (up to 50%). Phosphorous ban in detergents could significantly reduce negative impacts on environment and public health.

Engelbrecht & Murphy discussed the quality of greywater, named a few advantages and disadvantages and suggested a few uses of greywater. The increasing need of sewage for crop irrigation was elaborated. However, the huge cost of sewage treatment was reported discourage this application. Greywater from bathrooms, cloth washing containing low levels of pathogens than sewage is encouraged for irrigation.

Connor et al., (2008), studied the various degraded water types and reuse options and limitations and restrictions to their use. Emphasis is given to reuse scenarios involving degraded water applications to soil. Educational programs, based on hard science developed from long-term field studies, are imperative to convince the public and elected officials of the wisdom and safety of reusing degraded waters.

Gross A et al., (2006) reported on the removal of chemical contaminants, indicator organisms, and opportunistic pathogens from greywater. Reuse of domestic greywater (GW) for non-potable purposes is emerging as an important particularly in rural and developing areas.

Gideon W, (2007) explored the pathogen content of grey water and investigated pathogen removal through treatment and disinfection processes. The impacts of organic and particulate material in grey water on the efficacy of disinfection are investigated. The reuse of grey water, for applications such as toilet flushing and irrigation, represented a sustainable solution to water shortages experienced by regions worldwide. Although reused grey water is not intended for potable use. The potential for transmission of water borne pathogens by aerosol inhalation, topical contact, or indirect ingestion is a key concern for grey water reuse for potable use. The disinfection of greywater is critical prior to reuse.

Zeeman et al., (2008) proposed a new sanitation concept, based on results of pilot scale research with source-separated black water and grey water by treating a UASB (-septic tank) for recovery of CH₄ gas. Kitchen waste was added to the anaerobic reactor for doubling the biogas production. Post-treatment of the effluent was providing recovery of phosphorus and removal of remaining COD and nitrogen.

Naoyuki and Tetsuo, (2008) studied the Onsite Wastewater Differentiable Treatment System and presented it as an ecological sanitation alternative for developing countries and supported by principles such as dry ecological sanitation, ecologically sustainable development; recycle of resources, conservation of water resources, and protection of public health and the prevention of public health risk.

Scheumann et al., (2009) presented the results of four different investigations where greywater was treated with low technology as achieved by a constructed wetland

and a gravel and sand filter as well as with a high-tech option: the membrane bioreactor. The applications were perfectly suited to be operated in small communities with tourist depending variation of discharged wastewater flows.

Sall and Yukio, (2009) established that greywater generated from unsewered suburban areas may be equally or more polluted than CDW and, as such, deserves much more attention from both public authorities and populations themselves. A physical, chemical and microbiological characterization of mixed household greywater was undertaken with the view of determining the extent of health hazards related to the hand carrying disposal of greywater effluents. Samples were collected from a greywater holding tank every 2 hours over a 24-h period and analyzed for temperature, pH, electrical conductivity (EC), faecal coliforms (FC), *E. coli*, dissolved oxygen (DO), BOD₅, COD, TOC, TS, SS, VTS, TN, NH₃ - N, NO₃ - N, TP and PO₄ - P. The organic matter was five times higher in GW and its chemical nature quite different from that of organic matter in CDW. GW was three times higher in solids than CDW but the chemical characteristics and size distributions of solids were found to be quite similar in two samples. GW was slightly lower in nitrogen and phosphorus than CDW. The high GW strength seems to be due to lower flow associated with the presence of large amounts of food particles and the storage of effluents.

Eriksson et al., (2009) studied bathroom greywater plant in Copenhagen, Denmark, the flow ranging from no-flow periods to high-flow periods. Concentrations of both macro- and micro-pollutants were found to range by several orders of magnitude in the influent, based on sampling every 20 min. An organic pollutant, Paraben degradation was proven to occur in the rotating biological contactor (RBC), while the remaining organic matter in the effluent was proved not to be readily degradable. Ammonium content, presumably from urine contamination, was found to undergo nitrification in the RBC. These data were highly relevant for comparing decentralized treatment options with existing end-of-pipe treatments.

Munoz et al., (2009) suggested that the ability to get adapted to environmental changes of the bacterial populations and their microbial enzymatic activities is essential to understand the biological processes. Microbial enzymatic activities such as

Phosphatases, glucosidase, protease, esterase and dehydrogenase activities in a membrane bioreactor system equipped with ultrafiltration membranes for the treatment of urban wastewater were measured at different volatile suspended solid concentrations, total suspended solid concentrations, hydraulic retention times, temperatures and inflow rates.

Eriksson et al., (2010) studied on grey-water intended for non-potable reuse. In this study grey-water sludge originating from bathroom grey-water has been screened with respect to organic matter; particles; short-chain fatty alcohols and acids; selected metals and basic parameters as well as characterization of the organic matter content by oxygen utilization rate.

Chaillou et al., (2010) discussed that the potential treatment steps for greywater were sand bed filtration, adsorption onto granular activated carbon and sanitation by chlorine. Samples of greywater were taken from a few households. Their characterization led to results similar to those in literature. However, they showed a lack of phosphorus in C/N/P ratio. The sand bed which was supplied with sequential feedings led to a very good removal of total suspended solids and consequently of turbidity, as well as to a 30% COD decrease. However, the organic matter withdrawal was more efficient by adsorption onto activated carbon. The chlorination of greywater was efficient to decrease the microbial population. This kind of low-cost device could thus be implemented for reuse such as irrigation, agricultural need, or urban use.

Hamaiedeh et al., (2010) studied the quality of treated and untreated greywater to evaluate the performance of treatment units and the suitability of treated greywater for irrigation. The use of treated grey water for irrigation in home gardens is becoming increasingly common in Jordan. The results showed that salinity, sodium adsorption ratio, and organic content of soil increased as a function of time, therefore leaching of soil with fresh water was highly recommended. The chemical properties of the irrigated olive trees and vegetable crops were not affected, while the biological quality of some vegetable crops was adversely affected.

Moza S, (2010), presented an overview of the hybrid photocatalysis-membrane processes and their possible applications in water and wastewater treatment. Different configurations of photocatalytic membrane reactors are described and characterized.

Advantages and disadvantages of the hybrid photocatalysis-membrane processes in terms of permeate flux, membrane fouling and permeate quality are discussed.

Ghunmi et al., (2010), studied the treatment of grey water for irrigation, focusing on a treatment technology that is robust, simple to operate and with minimum energy consumption. The result is an optimized system consisting of an anaerobic unit operated in upflow mode, with a 1 day operational cycle, a constant effluent flow rate and varying liquid volume. Subsequent aerobic step is equipped with mechanical aeration and the system is insulated for sustaining winter conditions. Aerobic effluent quality, except for pathogens, agrees with the proposed irrigation water quality guidelines for reclaimed water in Jordan.

From the above studies, it is evident that treatment of greywater is very much necessary prior to its disposal into water body or sewer; usage for a designated purpose. The basic principles of greywater treatment technologies are presented below.

Greywater reuse methods can range from low cost methods such as the manual bucketing of greywater from the outlet of kitchen, to primary treatment methods that coarsely screen oils, greases and solids from the greywater before irrigation via small trench systems, to more expensive secondary treatment systems that treat and disinfect the greywater to a high standard before using for irrigation. The choice of system will depend on a number of factors including whether a new system is being installed or a disused wastewater system is being converted because the household has been connected to sewer. Options for reusing greywater are listed below.

The greywater treatment options shown in Figure 2.1 include anaerobic sludge reactors, septic tanks, oxidation ponds etc.

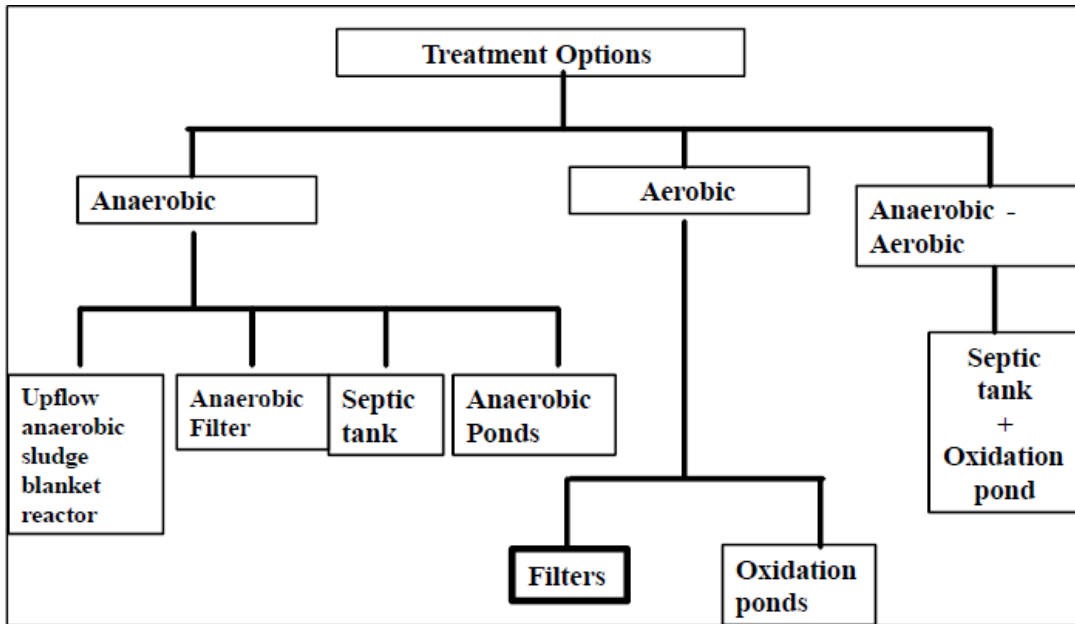


Figure 2.1: Greywater Treatment Options

Among the above mentioned options **the filtration** was followed due to their advantages such as:

- Easy operation and maintenance
- Economical
- Provides extensive physical treatment
- Treated greywater is of better quality
- Use of locally available filter media
- No requirement of external energy source

Anaerobic process require a methanogenic state to complete the destruction of vegetable fatty acids and removal of ammonia

Oxidation ponds are not a complete process and require services of waste stabilization ponds.

Further the treatment schemes are classified into

- i) Primary treatment system
- ii) Secondary treatment system
- iii) Tertiary treatment system

2.3.1 Primary Treatment System

In primary treatment system, a sedimentation tank is used to coarsely screen out oils/greases and solids prior to reuse. This system is recognized as an economically attractive option for greywater reuse because it requires minimal maintenance, and chemicals.

2.3.2 Secondary (Biological) Treatment System

In secondary treatment system, Chemical and Biological treatment process are used to remove most of the organic matter. This reduces health risk at end use with human contact and provides additional safety for reuse. This system is generally more expensive, due to the initial establishment costs associated with the further treatment needs and the periodic maintenance costs.

2.3.3 Tertiary Treatment System

Tertiary treatment processes further improves the quality of greywater or polish it. Fixed film biological rotating drums, membrane bioreactors, biologically aerated filters, activated sludge and membrane treatment systems are all included in this category.



Whilst utilized on larger scales for more general effluent applications, the other tertiary treatment technologies mentioned lack sufficient studies into greywater applications and current literature indicates that costs are high (Jayyousi et al., 2003).

This level of treatment involves utilizing the biological content in greywater to reduce microbial contamination, suspended solids, turbidity and nutrients (nitrogen and phosphorous).

Kitchen greywater is characteristically high in nutrients and this would inhibit the efficiency of biological treatment systems for application at various levels. Consistency in treated greywater quality can also be achieved through greater storage volumes which

assist in the biological treatment process (Jayyousi et al., 2003). However, the consistency of biological treatment systems could vary greatly according to the types of chemicals used at kitchen sources. Some substances or products used such as washing products, soaps with high amounts aluminum or zeolite could poison or hinder the biological process. **Primary and secondary greywater treatment options** are described in Table 2.1.

Table 2.1: Kitchen Greywater Treatment Options

Option of greywater treatment		Advantage	Disadvantage
Primary Treatment		<ul style="list-style-type: none"> ● Provides extensive physical treatment ● Comparatively higher safety and lower health risk 	<ul style="list-style-type: none"> ● Maintenance and monitoring required ● Costly
Secondary Treatment		<ul style="list-style-type: none"> ● Quality of greywater is good ● Directly put to irrigation ● Besides removing BOD, N and P they are very efficient at removing/inactivating microorganisms and helminth eggs 	<ul style="list-style-type: none"> ● Treated greywater for any other purpose is not available ● Skilled persons required

Treatment options described above involve various processes predominantly physical processes for treatment of various parameters of kitchen wastewater. These processes are not necessarily put in sequence and do not form part of treatment systems. Treatment for kitchen wastewater quality variables is provided in Table 2.2

Table 2.2: Treatment for Greywater Quality Variables

Treatment	Bacteria	Chlorine	Foam	Food particles	Nitrate	Odour	Oil & grease	Organic matter	Oxygen demand	pH	Phosphate	Salinity	Soap	Sodium	Suspended solids	Turbidity
Aeration						+		+	+	+						
Alum													+			+
Carbon filtration						+										
Chlorination	+					+										
Crop filtration	-															
Dilution					+	+				+	+	+		+		
Filtration																
Flotation							+									
Hydrogen peroxide	+					+										
Lime	+					+								+		
Settling			+	+	+				+	+					+	
Soil filtration																
Storage																

2.4.1 Odor and Color

There is a possibility of odor generation in kitchen greywater treatment system due to the following:

- A slime layer will develop on the submerged walls of filters, collection sump and possibly in sedimentation tank and as velocity of the greywater through the system sometime is too low to scour the sides
- If aeration is not sufficient dissolved oxygen will reduce substantially and only anaerobic Bacteria will attach to the slime layer.
- The anaerobic condition will lead to release of odorous compounds from the system and build up of hydrogen sulfide may result in a situation hazardous to human health.

2.4.2 Design of Kitchen Greywater Treatment System

Kitchen greywater treatment process varies from simple devices that divert greywater for direct application such as irrigation to complex systems involving sedimentation tanks, filters, bioreactors, pumps and disinfection systems. To design a kitchen greywater system an estimation of its quantity generated is required and the site then needs to be evaluated for the possible reuse of kitchen greywater.

2.4.3 Components of Kitchen Greywater Treatment Systems

The components of kitchen greywater treatment include:

1) Primary treatment - pre-treatment to secondary treatment

- Screening
- Equalization

2) Secondary treatment

- Gravel filtration
- Sand filtration
- Chlorination

1(a) Primary Treatment Systems

Greywater Diversion Devices

These systems do not store or treat greywater and as such are best to reuse greywater for sub-surface applications. The simplest forms of primary greywater reuse systems are described as greywater diversion devices and are the most economical. A simple plumbing device diverts greywater in the wastewater drainage line to a subsurface garden irrigation system via gravity without any external energy. This system does not treat the greywater and as such the sub-surface garden irrigation system must be able to cope with fouling material such as vegetables and cereals peelings (Ludwig, 1994). The land patches irrigated directly with greywater are termed as mini-leach fields which filter the solids and allow sub-surface infiltration. In these applications the soil treats the greywater and consideration must be given to the type and depth of soil available to complete the process.

1(b) Pre-treatment and Secondary Treatment Systems

Primary (pre-treatment) and secondary wastewater treatment systems are useful in hostels, schools and residential complexes to treat greywater to the tune of 1000-2000 l/day. A potential treatment scheme is shown in Figure 2.2

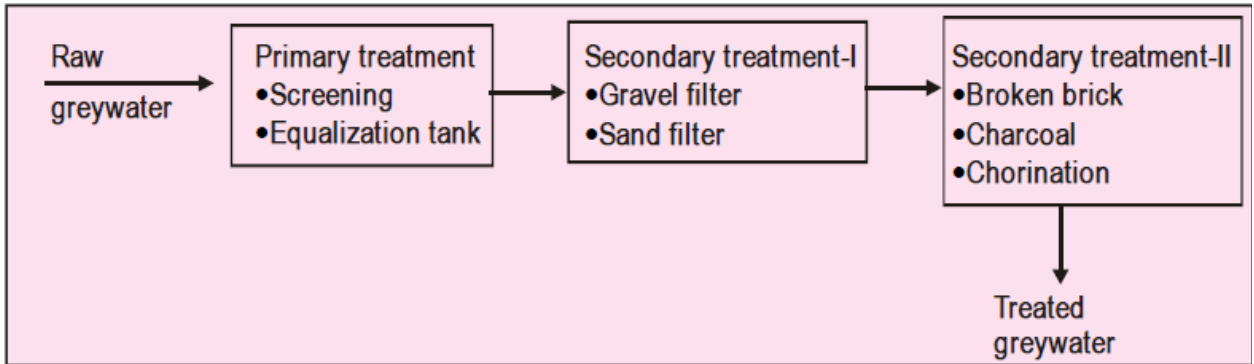


Figure 2.2: Kitchen Greywater Treatment Scheme

The function of various treatment units shown above are presented in Table 2.3. Also the description of the components described in paragraphs below.

Table 2.3: Treatment Units and Functions

Unit of treatment system	Removal
1. Screen	Floating matter, suspended matter
2. Junction chamber	Odour, some of settleable solids
3. Equalization Tank (Holding)	Settleable solids
4. Horizontal Roughing Filter	Turbidity, suspended solids, some amount of BOD
5. Slow Sand Filter	Colour, bacteria, suspended solids and some amount of BOD
6. Disinfection	Bacteria, odour

Screen

Screen is kept at the outlet of pipes collecting wastewater from different sources. Screen can be a mesh with less than 10 mm size to remove coarse particles. The load to common screen can be reduced if mesh is kept at the inlet to the piping system of sources as in kitchen. The screens can be cleaned manually and solids disposed off along with solid waste.

Junction Chamber

Junction chamber is provided to facilitate draining out wastewater from different sources. The dimension of junction chamber is determined based on providing sufficient storage to handle peak hourly volume. A small rack containing sponge or foam can be provided close to the top of junction chamber (or equalization tank) for removal of froth generated from kitchen sink due to use of soap.

Equalization or Settling Tank

The equalization or settling tank is an important component of wastewater treatment system. It is required to balance flow to take into account maximum flow of greywater generating during morning, afternoon and night hours or when most of the cooking and washing activities takes place in kitchen. Adequate aeration by providing baffles and mixing must be provided to prevent odors and solids deposition in equalization tank. Kitchen wastewater is continuously collected in the tank and flows to filters for treatment. In addition to providing constant load to the filter system it facilitates settling of coarse particles.

Filter

The type of filter required for a kitchen wastewater system depends largely upon the amount of wastewater to be filtered, the type of contaminants present and end use. A drain filter is an easy and inexpensive way to filter solids. A simple cloth bag tied over the end of a sink pipe may be sufficient for irrigating outdoors or similar applications. Filtration is one of the most important operations in the greywater purification process.

Though screening and sedimentation process remove a large proportion of suspended matter, they do not effectively remove fine floc particles, color, dissolved minerals and microorganisms. In filtration, water is passed through a filter medium in

order to remove the particulate matter not previously removed by sedimentation. During filtration, the turbidity and colloidal matter of non-settle able type protozoan cysts and helminthes eggs are also removed. It is to be mentioned that protozoa are stopped in the gravels, the bacteria by the medium gravel and the viruses by the sand.

The filter types are:

- Upflow -down flow filter
- Multi Media Filter
- Slow Sand Filter
- Horizontal Roughing Filter.

Collection Sump

A collection sump of an appropriate capacity to handle the average daily generation of treated wastewater is required along with greywater treatment plant. It should be ensured that greywater reuse should also continue along with greywater generation and treatment to avoid accumulation and facilitate overflow of treated greywater from collection sump. Freeboard of 0.2-0.3 m should be provided in collection sump.

Pump

Various types of pumping mechanisms can be employed in greywater reuse systems.

These include manual as well as electrical/mechanically operated pumps. Due to lack of spare parts and fluctuation in electric power supply in many rural buildings and at household level, it may be appropriate to consider manually operated pumps. These may include force lift hand pumps, treddle pumps or play pumps.

Wetland Treatment

Experience has shown that especially constructed wetlands are suitable for greywater/kitchen wastewater treatment including disinfection of the treated greywater when reuse is considered. A mechanical pretreatment is required when constructed wetlands are used as main treatment stage. Using horizontal subsurface flow constructed wetlands, a good removal efficiency for organic matter (>90%) and pathogens (upto a factor of 100) can be achieved. Compared to technical solutions (e.g. rotating biological contactors) constructed wetlands are relatively easy to maintain and economical.

Constructed wetlands are artificial greywater treatment system consisting of shallow (usually less than 0.6 m deep), ponds or channel or tanks planted with aquatic plants and relying upon natural microbial, biological, physical and chemical processes are used as wetland treatment system. Submerged type of wetland treatment minimum can treat upto 4000 l/day of greywater. The flow diagram of greywater treatment system incorporating wetland treatment is shown in Figure 2.3

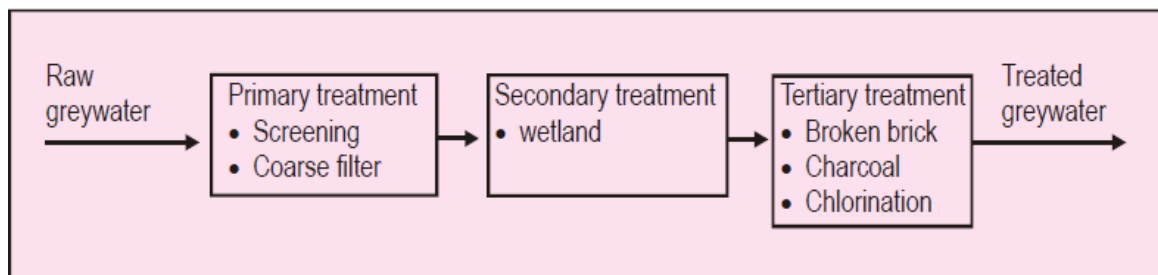


Figure 2.3: Greywater Treatment System with Wetland Treatment

Generation of greywater from various sources, their characteristics and treatment techniques required before reuse for different purposes and studies done on greywater are very significant.

MATERIALS AND METHODS

The chapter discusses the materials used and methodology adopted during the study.

- Chemicals- chemicals used were of analytical grade with sufficient purity
- Instruments- All instruments with accuracy processed from authorized dealers were employed for measurement of characteristics of samples.
- Calibration curves- They were prepared from stock solutions, before estimating the unknown parameters (N, P etc) and were used throughout the study.

3.1 Collection of Samples

Selection of Sources: - A preliminary survey was made in Adarsh Colony, Patiala and habits and activities of residents of residents were observed.

Six residential sources were finalized for greywater collection and were utilized on monthly basis during the study period **July 2009** to **June 2010**. Sources were designated Greywater samples from Source1 to Source-6 from kitchen sinks.

Containers- Greywater samples were collected from outlets of kitchen sinks from each source in acid rinsed, polyethylene containers (Jerry Canes) of 2l capacity.

Sample Proportions and Preservation- At each source, grab samples were collected at four hour intervals on the particular day and a new composite sample was made by considering equal volumes from grab samples. Samples were transported to laboratory and were preserved at 4⁰C refrigeration prior to the analysis. Analysis was completed within 72hrs of collection of samples.

3.2 Parameters of study from greywater and procedures

Greywater samples collected from Source-1 to Source-6 were analyzed for

- i) Physical
- ii) Chemical and
- iii) Biological properties

By using Standard Methods for Examination of Water and Wastewater, (APHA, 1992)

3.2.1 Physical Analysis of Greywater

pH

The pH of samples was measured by electronic meter, after calibrating the pH meter with buffers solutions of pH 4.0, 7.0 & 9.2.

Turbidity

Turbidity of samples was measured by Nephelometer, using optical properties of light.

Total Solids

Total Solids were determined using gravimetric technique for unfiltered Greywater. A well mixed sample was evaporated in a weighed beaker and dried to constant weight in an oven at 103 to 105⁰ C. The increase in weight over that of the empty beaker represents the total solids.

Dissolved Solids

Dissolved Solids were determined in Greywater after filtration through Whatmann Filter 44.

Suspended Solids

Suspended Solids (SS) from sample was calculated as $SS = \text{Total Solids} - \text{Dissolved Solids}$.

3.2.2 Chemical Analysis of Greywater

Chloride (Cl)

Chloride was determined using Argentometric volumetric titration method. Potassium chromate indicates the end point of the silver nitrate titration of chloride. Silver Chloride was precipitated quantitatively before red silver chromate was formed.

Total Kjeldahl Nitrogen (Titrimetric Method)

In the presence of H_2SO_4 , potassium sulfate (K_2SO_4), and cupric sulfate (CuSO_4) catalyst, amino nitrogen of many organic materials is converted to ammonium. Free ammonia also is converted to ammonium. After addition of alkali, the ammonia is distilled and absorbed in boric or sulfuric acid.

Total Phosphorous

Stannous Chloride Method (**Colorimetric Method**) was adopted in which Molybdophosphoric acid was formed and reduced by stannous chloride to intensely colored molybdenum blue.

Chemical Oxygen Demand (COD)

Sample was refluxed in strongly acid solution with a known excess of potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$). After digestion, the remaining unreduced $\text{K}_2\text{Cr}_2\text{O}_7$ was titrated with ferrous ammonium sulfate consumed and the oxidizable matter was calculated in terms of oxygen equivalent.

Biological Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD₅) was measured in the sample by determination of dissolved oxygen before and after a 5-day incubation period.

3.2.3 Biological Analysis of Greywater

Total coliform

The standard test for the coliform group was carried out by the multiple-tube fermentation technique. Bacterial density was estimated by the formula given or from the table using the number of positive tubes in the multiple dilutions.

CHAPTER-4

RESULTS & DISCUSSION

The results of the study performed and discussion on result are presented in this chapter.

4.1 Sources of Greywater

At a domestic activity, the sources contributing to greywater are bathrooms, laundry, washbasins, washing of vehicles and toilets flushing are highly objectionable in terms of pathogens, organic matter. Due to a few constraints, it was not possible to collect greywater generated in activities laundry, bathrooms, and washbasins and washing vehicles. Hence, the greywater was collected form outlets of kitchen sinks from Source-1 to Source-6 of Adarsh Colony, on monthly basis. The grab samples picked up an every four hrs intervals on the day of sampling and further made to composite. Samples were analyzed for physico-chemical and biological characteristics, the results are presented in the subsequent paragraphs.

4.2 Characterization of kitchen greywater

Kitchen greywater analyzed of various physical parameters (pH, Total Solids, Dissolved and Suspended Solids, Turbidity), chemical parameters (BOD, COD, Cl^- , and Total phosphorus and TKN including Ammonical Nitrogen + Organic Nitrogen) and biological characteristics (Coliforms) for February to May period and mean values are represented from table 4.1 - 4.6. The variations of certain parameters, such as TKN, PO_4^{-3} , BOD, COD and Turbidity in greywater are shown in Fig 4.1 (a, b & c)-4.6 (a, b & c)

Table 4.1: Characterization of Greywater at **Source-1**

Time (month) ⇒	February	March	April	May	Mean
Quality Parameters ↓					
pH	5.41	4.75	5.2	5.31	5.17
Turbidity (NTU)	59	169	99.3	250.2	145
PO4 (mg/l)	0.786	0.439	0.386	2.273	0.971
COD (mg/l)	3531	6752	6752	2797	4958
BOD (mg/l)	1060	2040	2010	840	1488
NH₄-N (mg/l)	26.88	27.44	39.76	57.4	38
Org-N (mg/l)	45.42	43.9	66.4	126.3	71
TKN (mg/l)	72.3	71.34	106.16	183.7	108.38
TSS (mg/l)	580	2470	4110	2150	2327.5
TDS (mg/l)	150	1040	2180	1501	1218
TS (mg/l)	730	3510	6290	3651	3995
Cl⁻ (mg/l)	109.9	187.89	237.52	141.8	169
T.Coliform (MPN/100ml)	50000	15000	56000	62000	45750

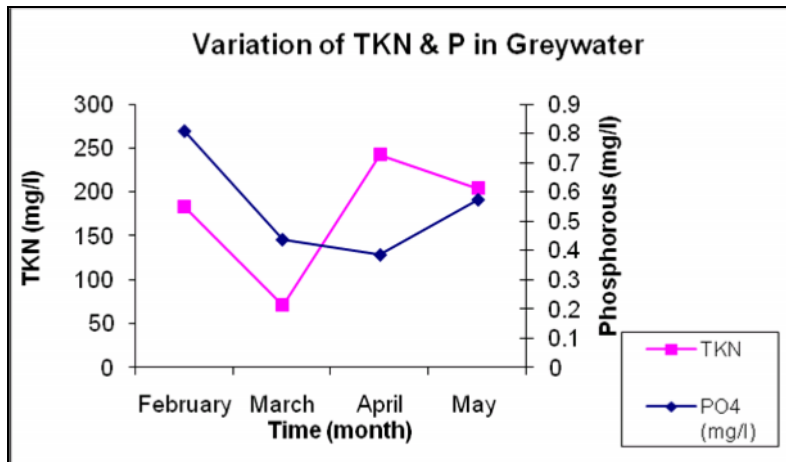


Fig 4.1 (a) Variation of TKN & PO₄⁻³ in Greywater of Source-1

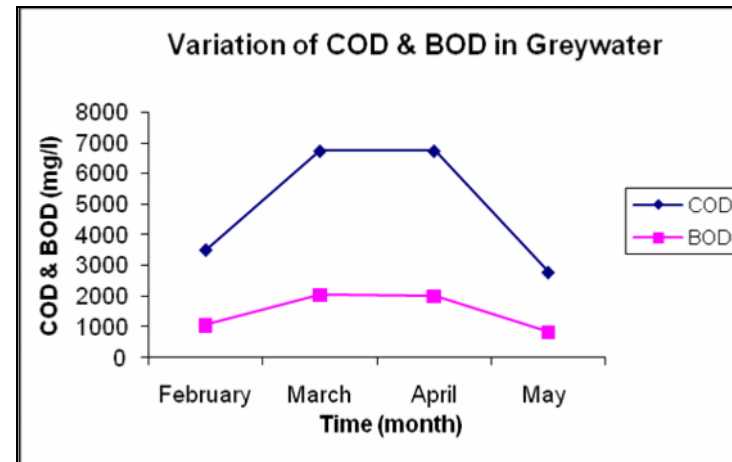


Fig 4.1 (b) Variation of COD & BOD in Greywater of Source-1

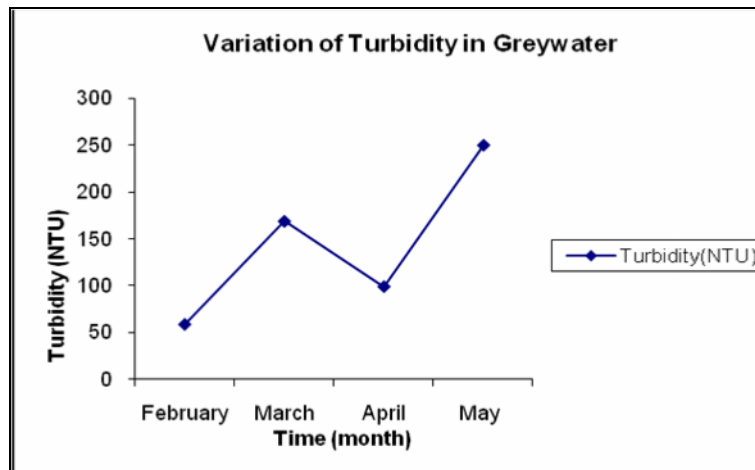


Fig 4.1 (c) Variation of Turbidity in Greywater of Source-1

Table 4.2: Characterization of Greywater at Source-2

Time (month) ⇨	February	March	April	May	Mean
Quality Parameters ⇩					
pH	4.94	4.75	5.6	5.5	5
Turbidity (NTU)	75	169	102	94	110
PO4 (mg/l)	0.809	0.439	0.387	0.575	0.5525
COD (mg/l)	9000	6752	7046	6702	7184
BOD (mg/l)	2560	2040	2273	1970	2127
NH₄-N (mg/l)	58.8	27.44	66.8	61.2	61
Org-N (mg/l)	124	43.9	175.1	143	181
TKN (mg/l)	182.8	71.34	241.9	204.2	175.06
TSS (mg/l)	4498	2470	4393	4312	4373
TDS (mg/l)	7461	1040	5567	6967	6793
TS (mg/l)	11959	3510	9960	11279	11169
Cl⁻ (mg/l)	191.43	187.89	131.2	187.3	154
T.Coliform (MPN/100ml)	80000	90000	12000	60000	60500

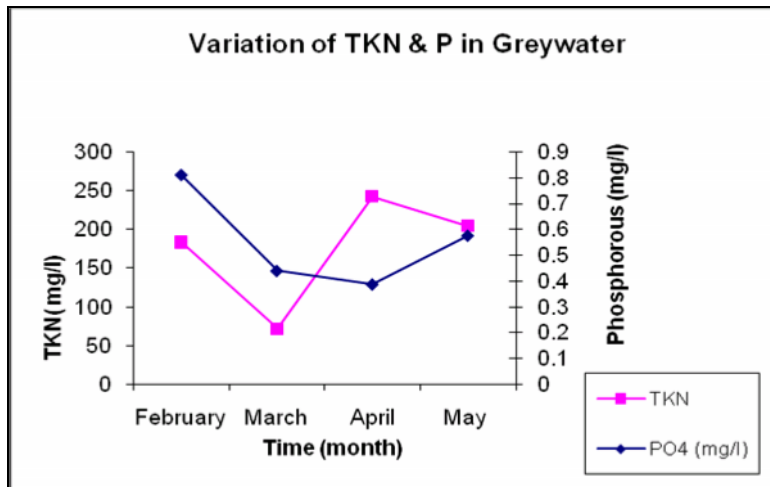


Fig 4.2 (a) Variation of PO_4^{3-} & TKN in Greywater of Source-2

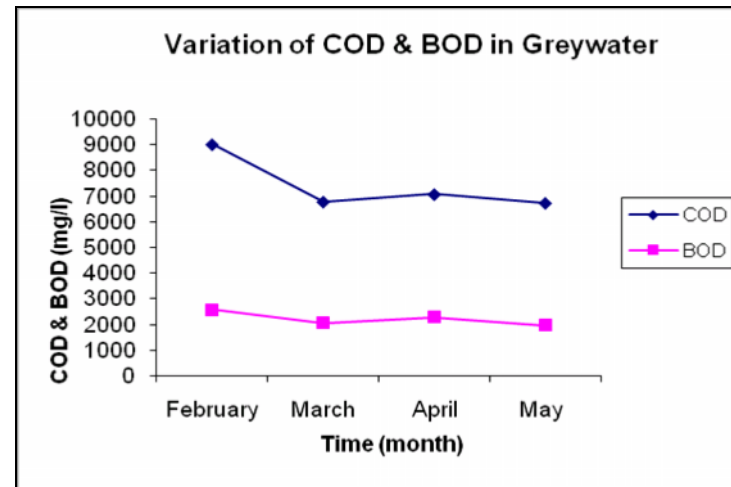


Fig 4.2 (b) Variation of COD & BOD in Greywater of Source-2

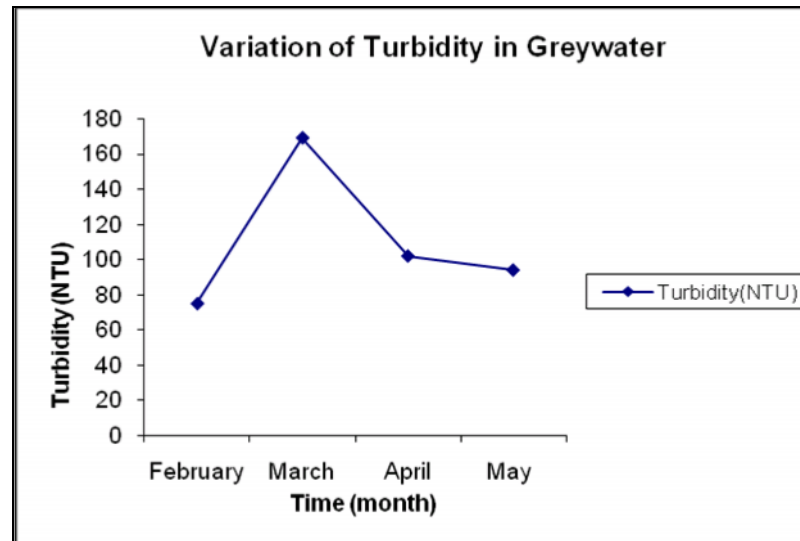


Fig 4.2 (c) Variation of Turbidity in Greywater of Source-2

Table 4.3: Characterization of Greywater at Source-3

Time (month) ⇒	February	March	April	May	Mean
Quality Parameters ↓					
pH	5.2	3.5	4.2	3.9	4
Turbidity (NTU)	586.2	271	198	155	300
PO4 (mg/l)	0.673	1.682	0.786	0.777	0.9795
COD (mg/l)	10200	11275	10740	9520	10434
BOD (mg/l)	2720	3758.3	3240	2510	3057
NH₄-N (mg/l)	65.1	55.75	44.4	49	54
Org-N (mg/l)	151	130	114.3	121	129
TKN (mg/l)	216.1	185.75	158.7	170	182.64
TSS (mg/l)	6730	3287	2985	4250	4313
TDS (mg/l)	2388	6355	7557	7210	5878
TS (mg/l)	9118	9642	10542	11460	10191
Cl⁻ (mg/l)	67.36	230.48	175.8	201.1	169
T.Coliform MPN/100ml)	5000	70000	80000	13000	42000

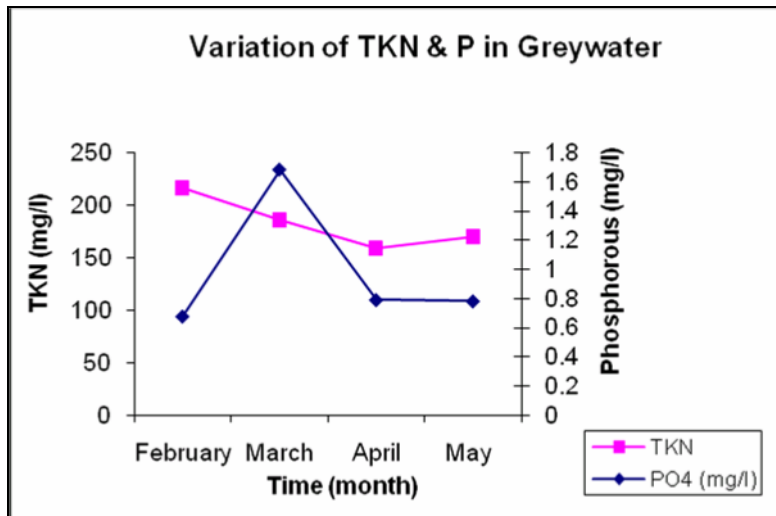


Fig 4.3 (a) Variation of PO_4^{-3} & TKN in Greywater of Source-3

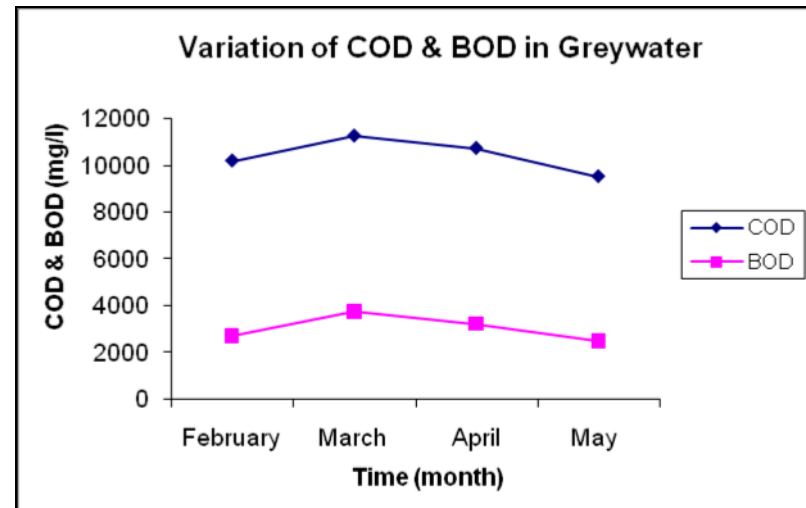


Fig 4.3 (b) Variation of COD & BOD in Greywater of Source-3

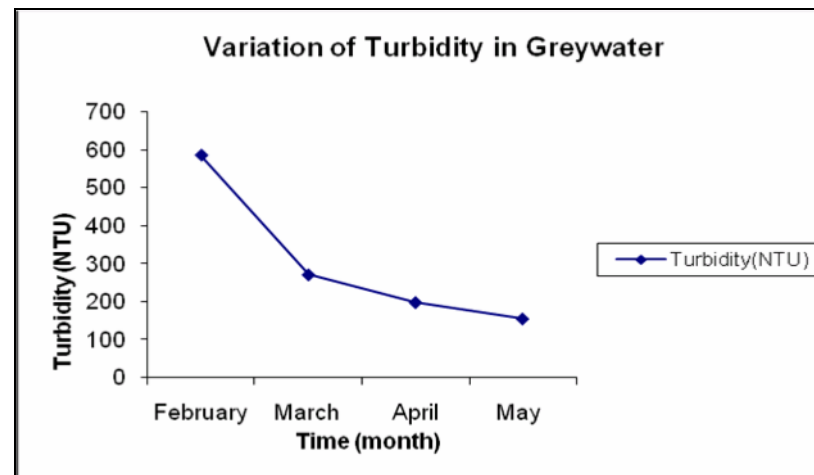


Fig 4.3 (c) Variation of Turbidity in Greywater of Source-3

Table 4.4: Characterization of Greywater at Source-4

Time (month) ⇒	February	March	April	May	Mean
Quality Parameters ↓					
pH	4.54	5.5	5.44	5.6	5
Turbidity (NTU)	155.5	650	310	115	308
PO4 (mg/l)	2.13	0.852	1.979	0.768	1.4322
COD (mg/l)	10750	6502	20585	12310	12537
BOD (mg/l)	8460	2172	6885	5890	5852
NH₄-N (mg/l)	22.4	258.5	76.4	112	117
Org-N (mg/l)	37.8	415	215.1	259	716
TKN (mg/l)	60.2	673.5	291.5	371	349.05
TSS (mg/l)	1355	4331	2150	1560	2349
TDS (mg/l)	9000	8567	1502	7567	6659
TS (mg/l)	10355	12898	3652	9127	9008
Cl⁻ (mg/l)	251.7	121.6	186.5	121.8	171
T.Coliform (MPN/100ml)	75000	49000	100000	120000	86000

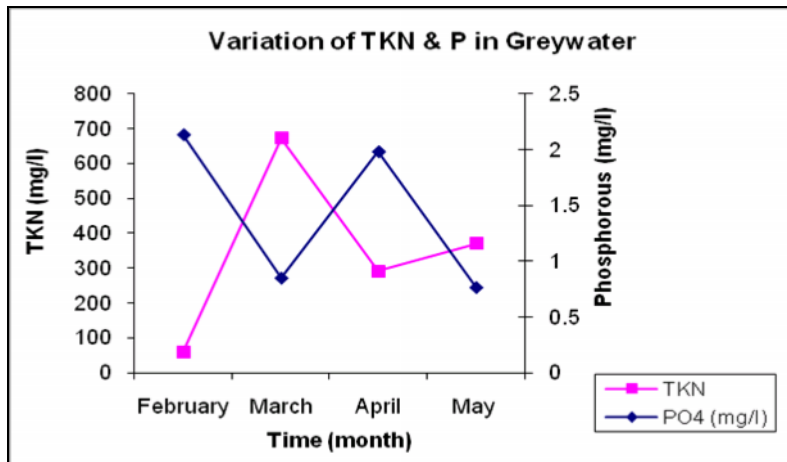


Fig 4.4 (a) Variation of TKN & PO₄⁻³ in Greywater of Source-4

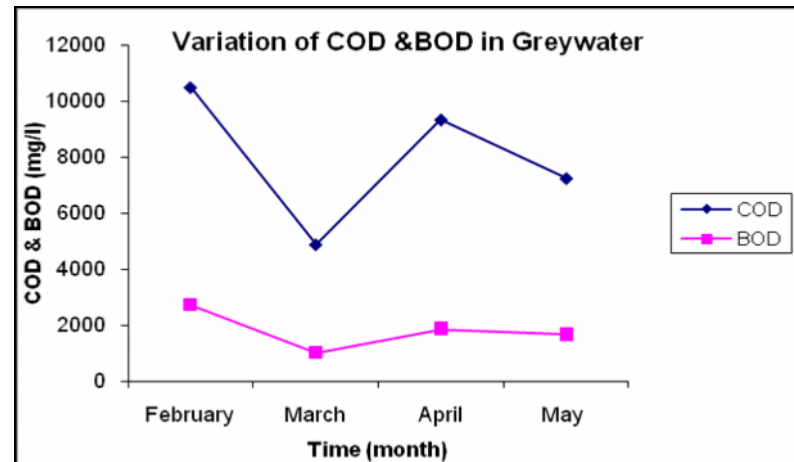


Fig 4.4 (b) Variation of COD & BOD in Greywater of Source-4

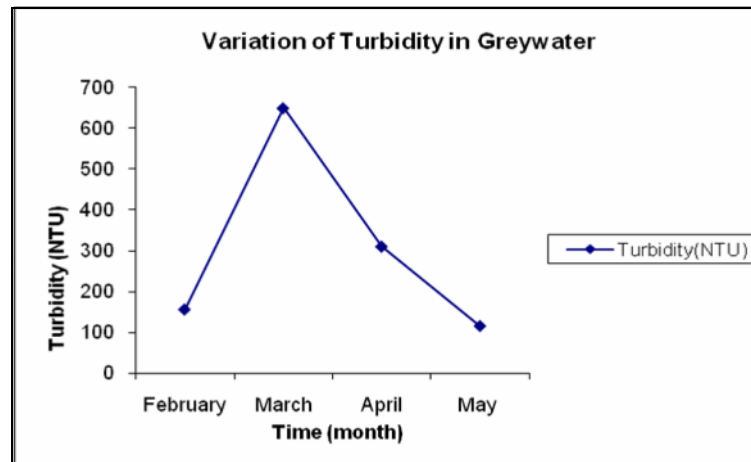


Fig 4.4 (c) Variation of Turbidity in Greywater of Source-4

Table 4.5: Characterization of Greywater at Source-5

Time (month) ⇨	February	March	April	May	Mean
Quality Parameters ⇩					
pH	3.63	4.74	5.8	5.5	5
Turbidity (NTU)	141.6	196	97	73	127
PO4 (mg/l)	2.802	1.632	0.908	0.749	1.52275
COD (mg/l)	10500	4875	9345	7245	8891
BOD (mg/l)	2720	1028	1869	1672	1822
NH₄-N (mg/l)	28	74.6	51.3	62.3	54
Org-N (mg/l)	260	225.4	99.4	151	184
TKN (mg/l)	288	300	150.7	213.3	238
TSS (mg/l)	2725	3324	1942	1810	2450
TDS (mg/l)	7992.9	6574	2031	2121	4680
TS (mg/l)	10717.9	9898	3073	3931	6905
Cl⁻ (mg/l)	297.7	76.3	89.2	102.3	142
T.Coliform (MPN/100ml)	38000	76800	57900	43200	53975

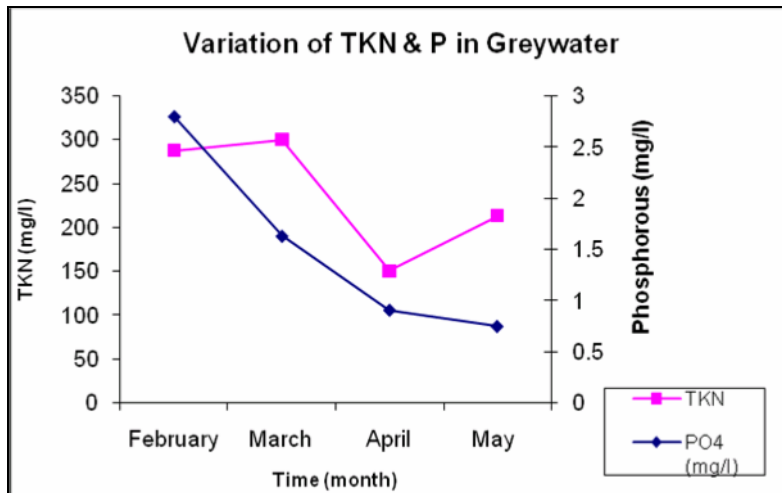


Fig 4.5 (a) Variation of TKN & PO₄⁻³ in Greywater of Source-5

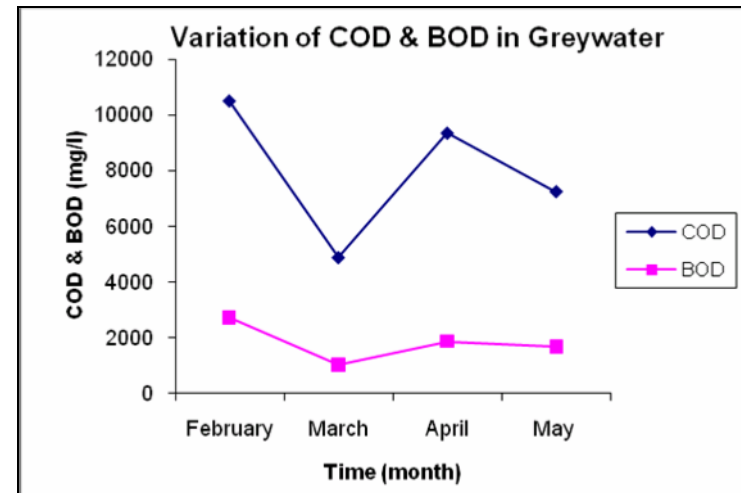


Fig 4.5 (b) Variation of COD & BOD in Greywater of Source-5

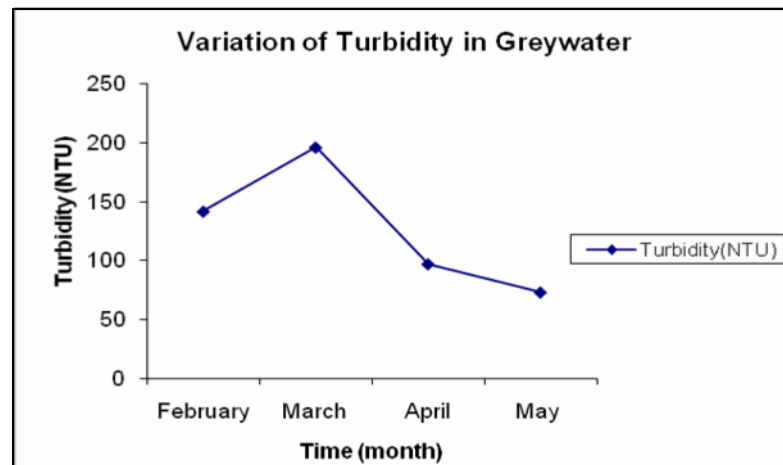


Fig 4.5 (c) Variation of Turbidity in Greywater of Source-5

Table 4.6: Characterization of Greywater at Source-6

Water Source ⇒	February	March	April	May	Mean
Quality Parameters ↓					
pH	3.58	4.95	3.75	5.9	5
Turbidity(NTU)	123.6	67	115	72	95
PO4 (mg/l)	2.375	0.8686	2.02	1.8	1.7659
COD (mg/l)	29850	5327.4	4380	9890	12362
BOD (mg/l)	9950	1366	730	3310	3839
NH₄-N (mg/l)	25.2	14.6	201.5	39.2	73
Org-N (mg/l)	30.8	47.6	212.3	53.1	83
TKN (mg/l)	56	62.2	413.8	92.3	156.08
TSS (mg/l)	3569	1070	2319	2960	2480
TDS (mg/l)	5230	4110	4670	4990	4750
TS (mg/l)	8799	5180	6989	7950	7230
Cl⁻ (mg/l)	450.22	138.8	74.98	86.45	188
T.Coliform (MPN/100ml)	76000	55000	34000	96000	65250

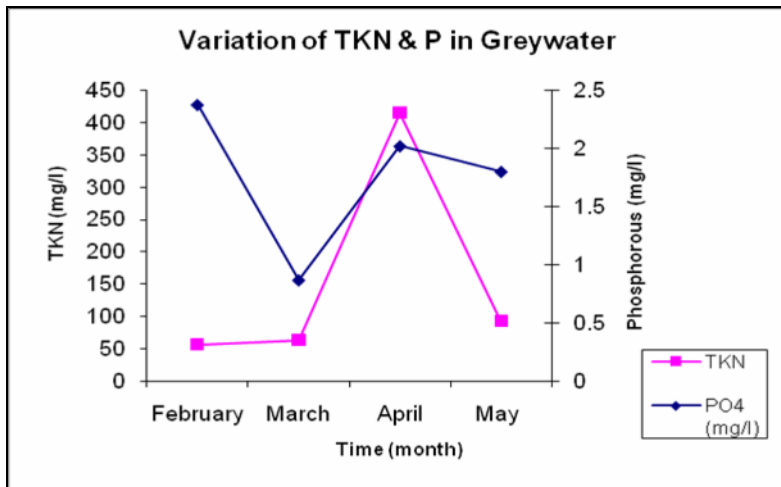


Fig 4.6 (a) Variation of TKN & PO₄³⁻ in Greywater of Source-6

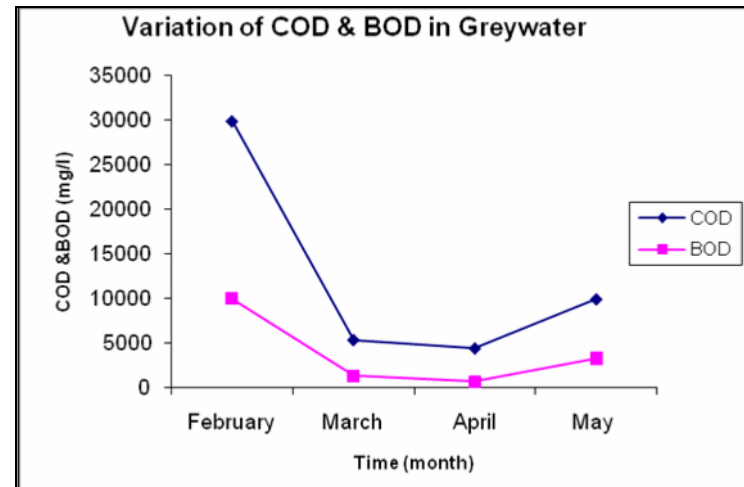


Fig 4.6 (b) Variation of COD & BOD Greywater of Source-6

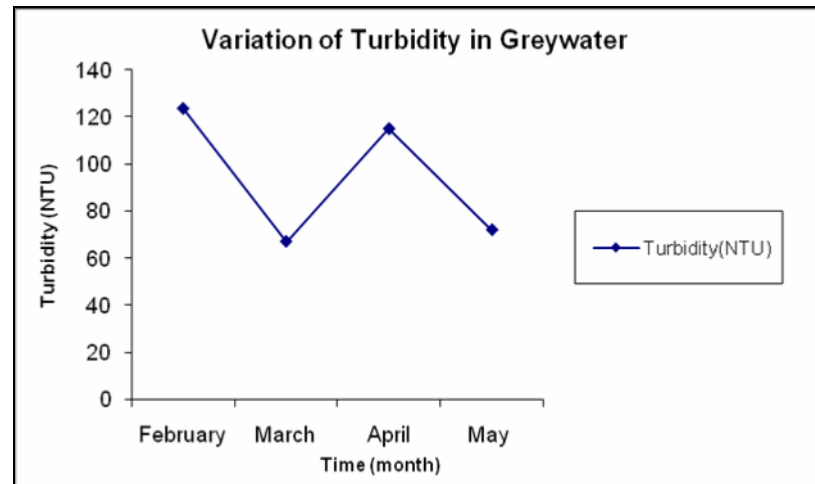


Fig 4.6 (c) Variation of Turbidity in Greywater of Source-6

pH value of sample indicates its intensity of acidity. The appropriate pH suitable for biological waste treatment is 6.0-8.0. The mean pH for Greywater in all sources fluctuates from 3.5-5-9, indicate their acidic nature which is due to the heterogenous nature of greywater.

Total Solids in a sample is the residue obtained after evaporating the liquid at 102-103⁰C. Mean of Total Solids was highest (11169 mg/l) for Source-2 and was lowest (3995 mg/l) in Source-1.

Mean value of Suspended Solid for greywater at Source-2 & 3 were highest (6793 & 5878 mg/l) respectively, whereas it was lowest (1218 mg/l) for Source-1. Typical value of Suspended Solids reported by Siegrist (1977) is 100-360 mg/l in untreated Municipal water. The high values of Suspended Solids obtained in this case could be due to absence of screen in kitchen sinks of sources. The maximum TSS was found in Sources- 2 4373 mg/l and minimum 2327.5 mg/l in Source-1.

Suspended Solids entry into water body affect light passage, occupy river body causing floods, damage vegetation at river banks etc.

The Total Dissolved Solids (TDS) are the measure of the quality of various organic salts that are dissolved in water which is directly proportional to the electrical conductivity. Dissolved Solids in the greywater are not significant unlike suspended solids. Highest Suspended Solids and Total Solids indicate that clogging of soil is likely to occur in case of greywater use for irrigation purpose.

Turbidity is resistance to passage of light, often maintaining the operating cost of filter, lowering the efficiency of chlorine treatment. Mean of Turbidity in greywater was high for Source-3 and Source-4 compared to that of other sources, this could possibly due to absence of screens at kitchen sinks. These values are comparable to typical turbidity values (360 NTU) reported by Chaillou et al., (2010). The pattern of turbidity was shown in Fig. 4.1 (c). The trend of turbidity was almost same (increase and decrease) in all sources except Source-3 (Fig. 4.3(c)), where turbidity found maximum in Feb but keep on decreasing up till May. These results indicate that colloidal particles in Source-3 are kept on decreasing in proceeding months.

The chlorides of Sodium, Potassium, Calcium and Magnesium are highly soluble in water. The Chloride concentration ranges from 142 to 188 mg/l in the different sources. Chloride is used as Sodium Chloride during food preparation and released through greywater. It is utilized by microorganisms during waste treatment. Sudden increase of salinity in ground water indicates its contamination with sewage. Source-1 contributed to a high value of chloride (169 mg/l) greater than average from all sources.

Biological Oxygen Demand (BOD) indicates the pollution strength of wastewater in terms of oxygen depletion at 20⁰C for 5 days. Source-3, 4 & 6 were generating greywater with high BOD values 3057, 5852 and 3839 mg/l respectively. This was more than the average of greywater from all sources. BOD for untreated domestic wastewater ranged from 100-400 mg/l as reported by Siegrist (1977). Sall et al., (2006) and Peter et al., (2002) also observed high amount of BOD in greywater.

Chemical Oxygen Demand (COD), another parameter for measuring pollution strength, measures oxygen demand to stabilize organic matter in the presence of strong chemicals. Similar to BOD, COD values from greywater in Source-3, 4 & 6 were high. The high BOD and COD in greywater indicate the dissolved organic contents. The variation in COD & BOD was showed in Fig. 4.5 (b) to 4.6 (b). The trend of COD in Source-1 showed 3531mg/l, which is just increased to 6752 mg/l in March, April but again decreased in May. Same trend was observed in BOD also Fig. 4.5 (b); whereas in the Source-2 COD & BOD decrease in same manner in the month of March to May. The trend again changes in Source-3 Fig. 4.3 (b) in the month of February COD & BOD observed 10200 and 2702 mg/l, respectively which increases in March and again decreases in April and May. The COD & BOD trend was entirely different in Source-4 & 5, here the maximum COD 10750 mg/l and BOD 8460 mg/l was observed in February and the decrease steeply in March and then again increase in April then decrease in May. In Source-6, the maximum COD 29850 mg/l and BOD 9950 mg/l was found in February which found decrease steeply in March and linear in April then increase slightly in May Fig.4.6 (b). These fluctuations in COD & BOD value indicate the variation in organic matter which is coming in the water through kitchen. Low COD removal indicated that greywater contain slowly-biodegradable organics, which will affect to BOD values also.

Forms of Nitrogen in the wastewater are Ammonical and Organic Nitrogen. Nitrogen is an essential component for making protoplasm as Nitrogen utilized as nutrient for bacteria. Results indicated that Source-4 contributed highest TKN through greywater, 349.05 mg/l Fig. 4.1-4.6 (a) showed the high variation in TKN and Phosphorous values which indicates there is no fixed trend in the release of these nutrients in the sources of greywater.

Phosphate is considered critical nutrients released through synthetic detergents, degraded form of protein. Source-5 & 6 contributed greywater with large Phosphate content 1.52275-1.7659 mg/l, respectively. Phosphate in typical untreated greywater ranged up to 12 mg/l (Klings, 2007). Thanh (2006) reported that PO_4^{-3} ban in detergents could significantly reduce negative impact on environment and public health. Li et al., (2000) reported that kitchen greywater has a balanced COD: N: P; which is safe for irrigation.

Coliforms are indicators of disease causing organisms in wastewater. They are facultative aerobic, gram negative type. Typical values of coliforms range from 42000 MPN/100ml on greywater of Source-6 to 86000 MPN/100ml of Source-1 during the study period. Kitchen wastewater may contain several types of microorganisms caused by the contamination of uncooked food and raw meat. Occasionally enteric pathogenic bacteria, such as Salmonella and Campylobacter can be introduced by food handling in the kitchen (Cogan et al., 1999). There is a certain risk of regrowth of pathogenic bacteria within greywater system (Naturvardaverket, 1995). Gross et al stated even field crops and vegetables can become contaminated with human and animal pathogens and parasites when irrigated with water containing these organisms, by using greywater.

4.2.1 Source Variation of Greywater Characteristics

Characteristics of greywater were found vary from source to source. It appeared that Source-4 produced most polluted kitchen greywater in terms of, PO_4^{-3} , TKN, Turbidity, BOD, COD etc. Source-2 & 3 contributed high values of solids whereas Source-6 contributed to large values of Chlorides in greywater. The variations could be attributed to the living standards of the people, food habits and human attitudes.

4.2.2 Temporal Variation of Greywater Characteristics

The greywater characteristics vary from time to time at a source. These variations are represented from Fig 4.1-4.6 for Source-1 to Source-6. The variations could be due to type of food, cooking, food habits in a particular season. Flow variations from season to season are important. Due to this the type of liquid is strong in summer and weak in rainy season. These variations may be due to flow or due to characteristics, are considered in the design of treatment options.

Greywater released from kitchen generally contain oil and grease. Their release into water courses affect light entry, bring troubles in biological treatment processes. Although it was essential measurement, no effort was made to analyses in grey water during the study period.

The type of parameters selected and observations made above for grey water were similar to that of study done by Zeeman et al., (2008).

The average characteristics for the grey water from Source-1 to Source -6 from Feb to March showed clearly that grey water was highly objectionable. Although no treatment scheme was tried to reduce the objectionable parameters, a conceptualization of treatment scheme for grey water is required. The bold scheme proposed is as under:

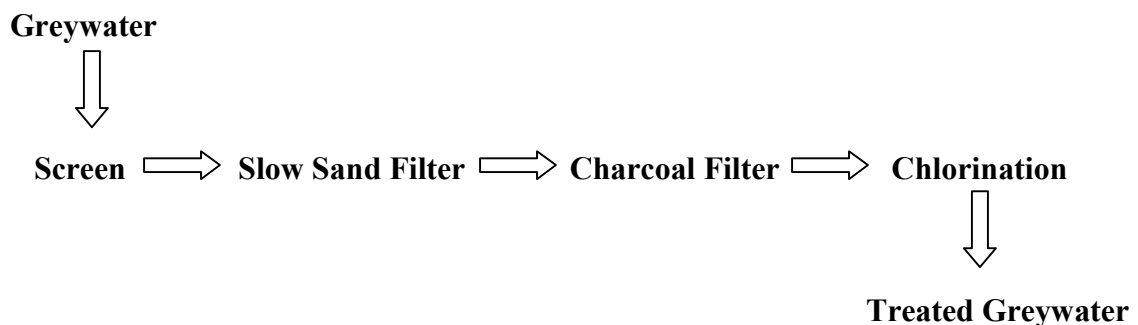


Fig. 4.7: Conceptualization of Kitchen Greywater Treatment

4.3: Kitchen greywater treatment scheme-conceptualization

The grey water on an average has acidic pH, high suspended and dissolved solids, coliforms count, excess N and P. To reduce the objectionable parameters, the following units may be adopted.

Table 4.7: Unit operations necessary for Greywater

Unit	Purpose
Screen	To remove floating matter, coarse food particles(suspended solids)
Sand filter	To remove microorganisms, colloidal organic matter (BOD,COD,etc)
Charcoal	To remove dissolved materials (chlorides, organics etc.)
pH adjustment	To make grey water suitable for disinfection
Disinfection	To destroy disease causing organisms

The treated effluent shows adequate Nitrogen and Phosphorous. This shows clearly it as a promising medium for gardening at the residences. Although the efficiencies of treatment schemes proposed above were not studied, it could be speculated that the treatment system would work out in producing consistent effluent for reuse purpose. Gross et al (2007) reported on the removal of chemical contaminants indicator organisms, and pathogens from greywater for further reuse.

Several authors have also reported the treatment of grey water (Jespersen, 1994; Ludwig, 1994; Scheumann et al., 2009).

CONCLUSION

Based on the study characterization and treatability studies on greywater at domestic activities, the following conclusions are drawn.

- ❖ Greywater at Source-4 has more objectionable parameters compared to that of other sources. Hence, the sample necessitates adequate dilutions prior to the treatment.
- ❖ Greywater from all sources during study period are found possessing pollution creation ability in terms of BOD, solids, coliforms etc. Therefore, its treatment prior to disposal/use for designated purpose is to be considered.
- ❖ The treatment options for greywater such as screen-slow sand filter-charcoal filter-pH adjustment-chlorination may be viable thus making it fit for irrigation. However exact logistic are yet to be worked out.
- ❖ Based on the analysis and treatability studies, the word greywater is not suitable, rather the samples collected can be named as raw kitchen washes, containing liquid and solid waste.

Future Scope

- ❖ Study was limited up to greywater generated at kitchen sink of residences; however, it can be extended up to other greywaters generated from bathrooms, automobile garages, etc.
- ❖ In depth characterization of greywater for other parameters such as heavy metals, oil and grease should be looked at.
- ❖ Study may be taken up to commission the treatment units and evaluate their efficiencies for treating kitchen greywater.

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