MINISTRY OF URBAN DEVELOPMENT

CENTRE OF EXCELLENCE IN URBAN DEVELOPMENT

in the area

SOLID WASTE AND WASTE WATER MANAGEMENT

STRATEGY FOR URBAN WASTE WATER MANAGEMENT

CENTRE FOR ENVIRONMENT AND DEVELOPMENT

THIRUVANANTHAPURAM

NOVEMBER 2011

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PREFACE

The Ministry of Urban Development (MoUD), Government of India, through its activities proposed under the Capacity Building Scheme for Urban Local Bodies (CBULB) established Centres of Excellence (CoE) in reputed institutions in the country to create the necessary knowledge base for improving municipal service delivery and management. The establishment of CoEs is an acknowledgement of the need for high quality Indian-context-specific research and creative interventions in the areas of governance, institution and capacity building, citizen-centric administration and resource and performance management. In establishing the CoEs, the MoUD expected that the CoEs would be able to find solutions to the many issues faced by Urban India. The basic objective of the CoEs is to foster cutting-edge and crosscutting research, capacity building and technical knowledge base in the area of urban development. The CoEs will address urban development issues at national, state and local levels and will provide support to state and local governments in:

The MoUD has approved a project to Centre for Environment and Development to set up a Centre of Excellence on 'Solid Waste and Waste Water Management '. The basic objective was to develop the capacity of the institution to support the Urban Local Bodies (ULB) in the country on solid waste and waste water management related activities. The CoEs will work with selected ULBs to develop strategies and framework to implement activities.

The CoE at CED which is concentrating on 'Solid Waste and Waste Water Management' has been focusing on three major aspects (i) Development of Strategy and Framework for Solid Waste and Waste Water Management in ULBs (ii) Capacity Building, Training and Awareness and (iii) Development of Knowledge Centre and Technical Support Unit on Solid Waste and Waste Water Management. CED is also working with Thiruvananthapuram City Corporation and Payyannur Municipality on these two sectors and trying to integrate the field experience to develop the strategy and framework.

The CoE team at CED has developed eight Resource Materials on SWM such as (1) Strategy and Framework for MSW Management (2) SWM Technology Manual (3) Operation and Maintenance Manual (4) Byelaw for ULBs on Solid Waste(Handling &Management) (5) Strategy and Framework for Wastewater Management,(6) Course Material on Solid Waste Management (7) Course Material on Wastewater Management and (8) Capacity Building and Training Manual. These documents had already submitted to MoUD and also to ASCI for Peer Review and their comments has also been incorporated in this final document.

The present document explains the Strategy and Framework for Urban Waste Water Management with special focus to the Grey Water Recycle and Reuse. It explains the different types of waste water, its characteristics, strategy to be adopted for waste water management especially with the concept of recycle and reuse and the technological aspects. It provides a review of the urban waste water management in Indian cities and other countries and also mentions about the best practices taken place elsewhere in the country and outside. The strategy and framework is developed through analysing the secondary information, discussions with municipal functionaries and experts and also integrating the experiences of CED in working with the ULBs in general and Thiruvananthapuram and Kochi City Corporations and Payyannur Municipality in particular. Each activity components are analysed on the background of field experiences and tried to incorporate those learnings in to the strategy and framework and also deriving technological options.

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Abbreviations

BOD	Biological Oxygen Demand
CBO	Community Based Organization
CED	Centre for Environment and Development
CoE	Centre of Excellence
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CT	Confined Trench
DO	Dissolved Oxygen
FWS wetlands	Free Water Surface wetlands
GAC	Granular Activated Carbon
GDD	Greywater Diversion Devices
GWR	Ground Water Recharge
HRT	Hydraulic Retention Time
IAPMO	International Association of Plumbing and Mechanical Officials
IEC	Information, Education and Communication
IIT	Indian Institute of Technology
LEED	Leadership in Energy and Environment Design
MLD	Million litre per day
NEERI	National Environmental Engineering Research Institute
NGO	Non-governmental Organization
NHG	Neighbourhood Group
NIT	National Institute of Technology
NTU	Nephelometric Turbidity Unit
O&M	Operation & Maintenance
PAC	Powdered Activated Carbon
PCB	Pollution Control Board
PTA	Parent Teachers Association
PVC	Polyvinyl chloride
R&D	Research & Development
RA	Residents' Association
RBC	Rotating Biological Contractor
RCC	Reinforced Cement Concrete
RO	Reverse Osmosis
ROSA	Resource-Oriented Sanitation Concepts for Peri-urban Areas in Africa
SRT	Solids Retention Time
TA	Technical Assistant
TMC	Thiruvananthapuram Municipal Corporation
TSS	Total Suspended Solids
UASB	Upflow Anarobic Sludge Blanket
ULB	Urban Local Body
UNDP	United Nations Development Programme
WW	Wastewater
WWM	Wastewater Management

1.1 Introduction

The Ministry of Urban Development, Government of India has established a Centre of Excellence (CoE) on Solid Waste and Waste Water Management at Centre for Environment and Development .As part of this , CED has prepared a Strategy for Decentralised Wastewater Management mainly focusing on Grey water Recycle and Reuse, in addition to the Solid Waste Management component.

The major objectives of the Waste water Management component under CoE of CED are:

(i) To formulate strategy and methodology for Wastewater Management including development of framework for wastewater recycle and reuse in urban areas
(ii) To prepare capacity building and training strategies for urban local bodies
(iii) To function as Knowledge Hub in the area of Wastewater Management.

1.2 Significance of Wastewater Reuse

The significance of wastewater management is premised on two basic urban issues – (i) the essentiality of safe and scientific management of wastewater for achieving health and hygiene in the urban environment, and (ii) the promises offered by wastewater especially grey water (domestic wastewater with low pollution load) as a freshwater substitute to reduce the increasing demand for potable water. Addressing water scarcity requires a multidisciplinary approach to managing water resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. The lessons to be learned from the social, economic and environmental impacts of earlier water resources development and inevitable prospects of water scarcity calls for a paradigm shift in the way we approach water resources management. The well grounded rationales for water recycling and reuse are the principles of sustainability, environmental ethics and public participation.

In the last two decades, although there has been significant increase in the coverage of drinking water in India as compared to other regions in the world, regional disparities still exist. India"s urban morphology is characterized by abnormal and unprecedented urbanization in the last few decades. Not only was there sizeable increase in the urban population, but the number of cities and towns also has significantly increased in the last two decades. While essential infrastructure systems have been put in most urban centres, their management and optimization to meet growing demands are far from satisfactory. India"s urban water domain is characterized by increasing competing uses, allocation issues, declining sources and inconsistent supplies, service delivery gaps, insufficient models for sustainable urban water management, multiple institutional players, low sensitivity levels towards environmental safeguards etc. With the cities promoting water-intensive developments, the need today is to treat urban water management on a wider canvas in contrast to conventional approaches.

Urban reuse of wastewater has proven the most effective way to reduce water resource consumption and the environmental dangers posed by the disposal of large quantities of insufficiently treated wastewater. Water reuse can be classified as potable, which is defined as all water consumed for drinking, cooking, and personal hygiene and non-potable such as (i) agricultural (ii) urban (iii) industrial and (iv) indirect potable reuse as infiltrated aquifer recharge. The commercial and residential structures, which constitute the major chunk of users, use about 80% of their potable flow for non-potable or “non-drinking” consumption, resulting in a costly and inept use of a limited resource. In select commercial applications, 75% or more of the domestic supply serves toiletry fixtures alone. Conservatively, 70% of the current urban water demand could be substituted by reclaimed or reuse water technology.

On the other side, it is a universal fact that with every increase in the quantity of water used, the quantity of wastewater also will proportionally increase necessitating the management of higher volumes of wastewater. Presently wastewater treatment is a costly affair. Urban areas in India generate about 5 billion liters a day (bld) of wastewater in 1947 which increased to about 30 bld in 1997 (Winrock International India 2007). According to the Central Pollution Control Board (CPCB), 16 bld of wastewater is generated from Class-1 cities (population >100,000), and 1.6 bld from Class-2 cities (population 50,000-100,000). Of the 45,000 km length of Indian rivers, 6,000 km have a bio-oxygen demand above 3 mg/l, making the water unfit for drinking (CPCB 1998). More than 80% of wastewater generated is discharged into natural water bodies without any treatment due to lack of infrastructure and resources for treatment (Winrock International India 2007). Approximately 30,000 mld of pollutants enter into India‟s rivers (CPCB 1995). The Water Act covers industrial effluent standards, but ignores the domestic and municipal effluents even though they constitute 90% of India‟s wastewater volumes (Sawhney 2004).

The use of treated, partially treated and untreated urban wastewater in agriculture has been a common practice for centuries in many countries which is now receiving renewed attention due to rapid urbanization. By 2015, 88% of the one billion-person growth in the global population will occur in cities; the vast majority of this growth will occur in developing countries (UNDP 1998). An increase in urban water supply results in increased wastewater generation, as the depleted fraction of domestic and residential water use is only in the order of 15 to 25% (Scott et al. 2004). The growing wastewater volumes render a cheap and reliable alternative to conventional irrigation systems and a variety of other uses. In this context wastewater is a resource that could be of increased national and global importance, particularly in urban and peri-urban environment. Hussain et al (200) reports that at least 20 million hectares (ha) in 50 countries are irrigated with raw or partially treated wastewater. Strauss and Blumenthal (1990) estimated that 73,000 ha were irrigated with wastewater in India.

In India, though there are few isolated experiments and pilot models for wastewater recycle and reuse for various non-potable purposes, it has not become part of the urban planning/management programme in most of the urban local bodies. In majority of the urban areas, the activities in the wastewater sector are focused mostly on wastewater disposal than recycle and reuse. Moreover, recycle and reuse of wastewater has not received much attention by the policy-decision makers. One major reason may be the lack of viable models with necessary research and technology support, strong policies and legal framework at the national and state levels and lack of sufficient trained manpower in the urban local bodies.

The perspective of establishing Centre of Excellence is to address these issues through research and streamline the viable technology through implementation in selected areas. It also envisages experience documentation in other places to establish a Knowledge Hub on Wastewater Management and capacity building and training and handholding support to replicate the experiences in other urban local bodies.

1.3 Present Wastewater Disposal Practices

The present wastewater disposal practice is characterized by a common plumbing system to let off all types of wastewater. The following are the practices followed in the matter:

- All types of wastewater together are diverted to the municipal sewerage system if such a system exists.
- All types of wastewater together are diverted to the septic tank.

- Water from toilet is diverted to the municipal sewerage system or the septic tank and all other types of wastewater are diverted to any one of (i) municipal drainage (ii) the soak pit constructed at the building compound or (iii) the premises.

The implications of this type of disposal are overload of the municipal sewerage system, wastage of reusable greywater and hazardous environmental and public health impacts.

1.4 Rationale and Benefits of Wastewater Reuse

- Wastewater recycling and reuse is the simplest visible way out to ward off the looming global water crisis. Many factors like availability of water resources, necessity to preserve rather than develop water resources, careful economic considerations, uses of the recycled water, the strategy of waste discharge and public policies that may override the economic and public health considerations or perceptions etc determine whether the recycling is appropriate for a given situation.
- It is an important water management option both to shore up conventional resources and to reduce the environmental impact of discharges.
- Water reclamation and reuse allows for more efficient use of energy and resources by tailoring treatment requirements to serve the end-users of the water and reduces pollution.
- Increasing water demands, water scarcity and droughts, environmental protection and enhancement, socio-economic factors, public health protection, etc., are the major factors driving the need for wastewater reuse.
- Water recycling can decrease diversion of freshwater from sensitive eco-systems thereby enhancing conservation of fresh water supplies significantly. Recycled water could be used to create or enhance wetlands and riparian (stream) habitats.
- Nutrients in reclaimed water may offset the need for supplemental fertilizers, thereby conserving resources. If this water is used to irrigate agricultural land, less fertilizer is required for crop, thus by reducing nutrient (and resulting pollution) flows into waterways, auxiliary activities such as tourism and fisheries could be enhanced.

1.5 Challenges and Issues in Wastewater Recycling

Choosing the most appropriate treatment technology for water reuse is a very complex process. The cascading methodology of recycling water from one source and using it for another destination process must consider multiple source processes with varying outlet utilities, different contaminants, several destination processes with well-defined water quality standards and a large number of applicable treatment technologies. Some of the crucial challenges to be addressed while adopting wastewater recycling and reuse are, (i) water recycling and treatment techniques to be employed can be quite complex and site specific, (ii) technical feasibility, cost and public policy acceptance remains a major challenge, (iii) the broad spectrum of pathogenic micro-organisms present in high concentrations in wastewater may pose potential health risks to the workers or adjacent residents who may be exposed to wastewater recycling activities, and to the public who may consume wastewater irrigated crops or recreate on wastewater irrigated lawns or lakes and (iv) in the case of recycling for potential domestic use, the organic and inorganic toxic chemicals and micro pollutants from industrial and domestic sources are a cause for concern.

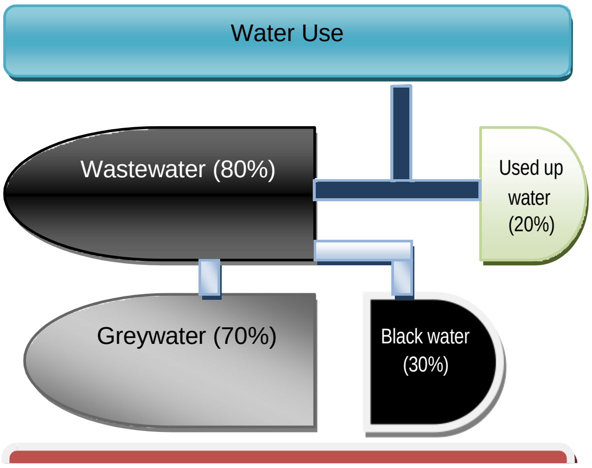
Some of the factors associated with waste water reuse and recycling are (i) the need of centralized wastewater treatment systems, its location, availability of space in and around cities for the treatment plants and topography – all of these factors restrict the use of wastewater to certain areas and for specific purposes, (ii) the high transportation costs of the wastewater from treatment plants to the point of use may encourage use of existing infrastructure (like irrigation canals) so that wastewater is increasingly used in agriculture or on market gardens in the peri-urban areas of the city, rather than in households or by industry, (iii) the ownership of wastewater such as water authority or local bodies and the necessity of dual reticulation system, and (iv) the positive (environmental benefits) and negative externalities (potential groundwater pollution and potential unknown ill effects on human health) associated with wastewater recycling.

1.6 Implications of Wastewater Reuse

There are both positive and negative implications of wastewater reuse. The positive implications include: employment generation, food security for urban and peri-urban poor farmers, reliable supply of irrigation water and the recycling of nutrients in wastewater. Since wastewater is available round the year, the urban poor farmers and migrant laborers are assured of employment throughout the year. Wastewater can also have a positive or negative impact on the property values. In Haroonabad, in Pakistan, the wastewater-irrigated land has a higher value than the canal-irrigated land (Hussain et al. 2001).

On the other hand, because of the partial or no treatment of wastewater, it endangers the very livelihoods it generates over the long term. Long-term use of wastewater for irrigation increases soil salinity, accumulation of heavy metals in the soil, and finally breakdown of the soil structure. Ample evidences are available which show that the groundwater in all wastewater irrigated areas has high salt levels and is unfit for drinking. Further, high groundwater tables and water logging are also common features of these areas. Wastewater contains a number of pathogens of which human parasites such as protozoa and helminth eggs are of special significance which can cause diseases in user communities and consumers. Further, wastewater containing a high level of nutrients may cause eutrophication and cause imbalances in the ecology of the water bodies it is released into.

Fig.1: Water use and Wastewater generation



2.1 Importance of Wastewater Management

The importance of wastewater management lies in the fact that its scientific management is sine qua non for ensuring health and hygiene of the urban population. Absence or improper management of wastewater could make urban living miserable with sordid surroundings, unhealthy physical living conditions and aesthetic damage. As we have already seen, wastewater is a potential freshwater substitute for many practical uses. This fact also reinforces the need for effective management of wastewater aiming at reuse to the maximum possible extent. Fig 1 shows the water use and resultant wastewater generation (based on the study conducted by CED as part of CoE). 80% of the water used for domestic purposes is converted as wastewater. 70% of the wastewater is grey water and the remaining 30% is blackwater, which mainly forms the toilet water. In view of the low pollution load, the grey water could be easily reused.

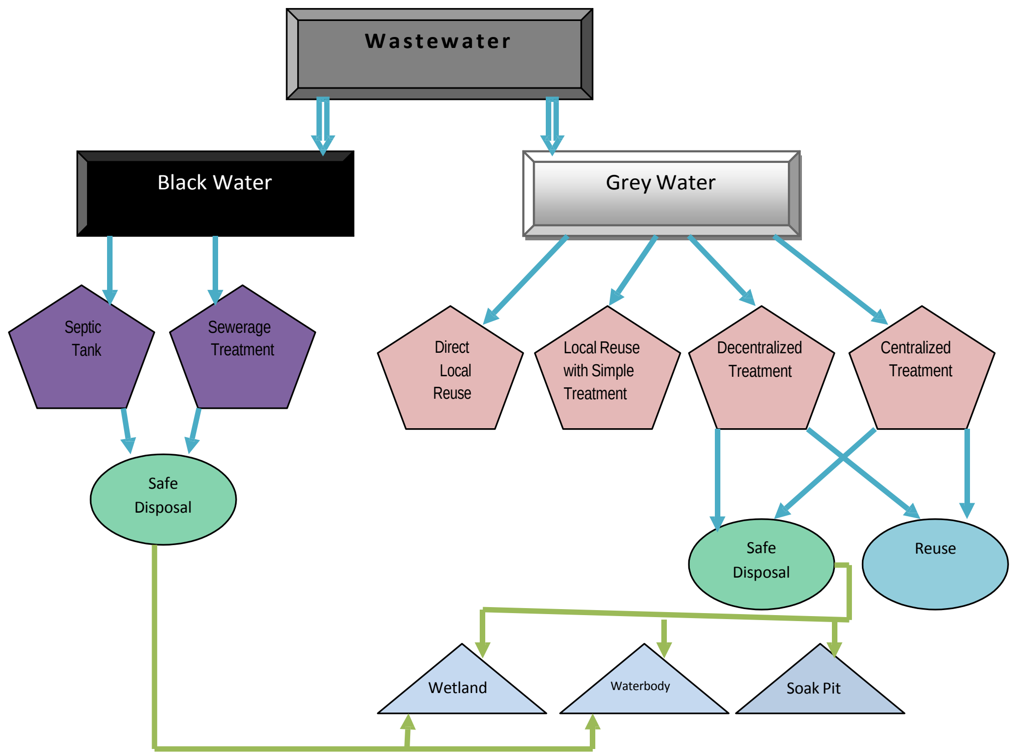
2.2 Framework of Wastewater Management

Wastewater comprises of both blackwater and grey water. The 30% blackwater contains most of the pollution load in the wastewater. The grey water constituting 70% of wastewater has fewer pollutants in it and is easy to reuse; in certain applications it is suitable for reuse even without treatments.

Hence, the strategy for wastewater management should be to deal with black water and grey water separately. The black water can be disposed off after treatment in a central sewerage system or in its absence in a septic tank. The reuse potential of black water is very little. The grey water could be reused for a variety of purposes, which are discussed in detail in the succeeding sections. The general framework of wastewater management is given in Fig.2

The analysis and study conducted by CED as part of CoE led to conclude that a two-pronged approach

Fig 2: Framework for Wastewater Management



would be ideal for urban wastewater management, i.e., sufficing black water treatment on the one hand and developing and promoting grey water reuse mechanisms to the extent possible on the other hand. Since most of the cities have some system to manage the balck water, what is needed in this area is filling the gap between the demand and the availability. Since technology and mechanism for black water treatment is generally available, this component of the CoE mainly aims to focus on greywater treatment and reuse.

2.3 What is Greywater?

Wastewater is made up of “Greywater” and “Blackwater”. Greywater, defined slightly differently in different parts of the world, generally refers to the wastewater generated from household uses like Washing Machines/ Laundry Tubs, Showers/Baths, Wash basins, Kitchen etc.

2.4 Definitions, Terminology, and Characteristics

Greywater is spelled and defined differently in different parts of the world. Also commonly spelled „graywater", „grey water", or „gray water", it refers to untreated household wastewater that has not come into contact with sewage (or "black water"). Common sources of greywater in the home include bathroom, wash basin, and clothes washers. Wastewater from kitchen sinks and automatic dishwashers tend to have high concentrations of organic matter with elevated levels of greases, oil and detergents that encourage the growth of bacteria and hence must be treated before reuse. Jurisdictions in some parts of the world exclude kitchen sink water and diaper wash water from their definition of greywater and these are defined as "dark greywater". In some places this is considered as black water. „Blackwater" is the wastewater from toilets, urinals or bidets. In India, just like many regions in the world, there is lack of clear regulations or standards regarding greywater capture and reuse.

Rainwater, which can also be collected for use, is not considered to be greywater. Greywater is also distinct from reclaimed water, which is wastewater (including black water) that is treated by a centralized wastewater treatment plant for potable or non-potable reuse.

Table 1: Definitions

Term	Definition	Other terms in use
Greywater	Untreated household wastewater that has not come into contact with sewage	Graywater, gray water or grey water
Black water	Wastewater from toilets, bidet, water used to wash diapers (and under some definitions, from kitchens)	Sewage
Dark gray water	Untreated household wastewater that has not come into contact with sewage, but is from lower-quality sources such as kitchen sinks and dishwashers	Sometimes considered to be part of black water

2.5 Greywater and Blackwater: Key Differences

- **Greywater contains far less nitrogen than blackwater**

  Nine-tenths of the nitrogen contained in combined wastewater derives from toilet wastes (i.e., from the blackwater). Nitrogen is one of the most serious and difficult-to-remove pollutants affecting our potential drinking water supply.

- **Greywater contains far fewer pathogens than blackwater**

  Medical and public health professionals view faeces as the most significant source of human pathogens. Keeping toilet wastes out of the wastewater stream dramatically reduces the danger of spreading such organisms via water.

Greywater decomposes much faster than blackwater

The implication of the more rapid decomposition of greywater pollutants is the quicker stabilization and therefore enhanced prevention of water pollution.

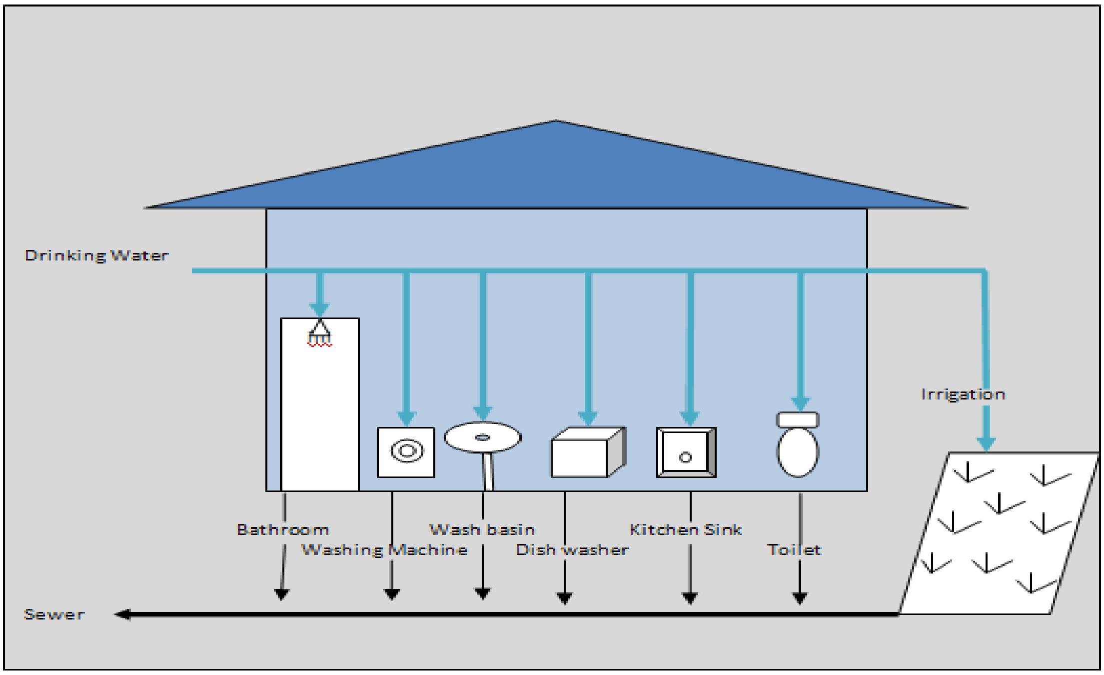
2.6 Greywater Disposal Practices

In many utility systems around the world, greywater is combined with black water in a single domestic wastewater stream. In less developed countries/areas, the grey water is let out to the environment without any treatment and not considering safe disposal practices. Greywater can be of far higher quality than black water because of its low level of contamination and higher scope for reuse. When greywater is reused either on-site or nearby, it has the potential to reduce the demand for new water supply, reduce the energy and carbon footprint of water services, and meet a wide range of social and economic needs. In particular, the reuse of greywater can help reduce demand for more costly high-quality potable water.

By appropriately matching water quality to water need, the reuse of greywater can replace the use of potable water in non-potable applications like toilet flushing and landscaping. For instance, many homes have one set of pipes that bring drinking water in for multiple uses and another that takes wastewater away. In this system, all devices that use water and all applications of water use a single quality of water: highly treated potable drinking water. This water is used once and then it enters a sewer system to be transported and treated again, in places where wastewater treatment occurs. Fig. 3.

In most modern wastewater systems, treated wastewater is then disposed of into the ocean or other water bodies, voiding the reuse potential of this treated wastewater. In other places, once-used wastewater may be disposed of directly in the environment. This system wastes water, energy, and money by not matching the quality of water to its use.

Fig.3: Typical household water infrastructure



A greywater system, on the other hand, captures water that has been used for some purpose, but has not come into contact with high levels of contamination, e.g., sewage or food waste. This water can be reused in a variety of ways. For instance, water that has been used once in a shower, clothes washing machine, or bathroom sink can be diverted outdoors for irrigation. Fig. 4.

Fig.4 : Schematic of typical household sources of greywater, applied to a flower garden

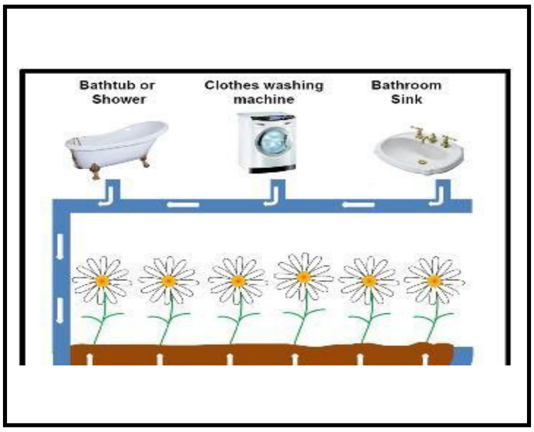
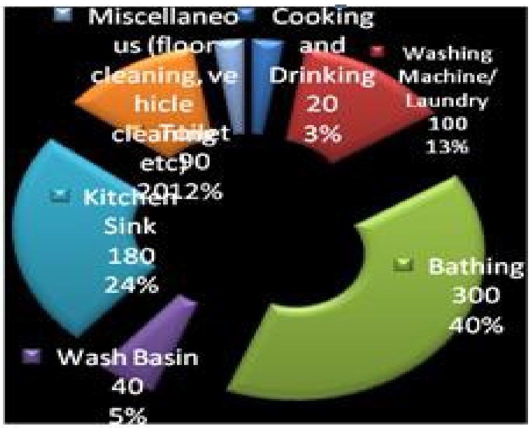


Fig.5: Graphical representation of water use and waste water generation



In this case, the demand for potable water for outdoor irrigation is reduced and the flow out of wastewater produced both by the shower, washing machine, and sink are reduced. When the systems are designed and implemented properly, possible public health concerns with using different water qualities can be addressed.

2.7 Greywater Volumes

Greywater generation will vary according to the water usage practices of each individual in the household and the use of water efficiency devices. As per the survey conducted by CED in Thiruvananthapuram City as part of the CoE, an average house (four persons per house) uses 750 litres of water every day. A small portion of the water (used for drinking, cooking, floor cleaning, simple vehicle cleaning etc) is almost fully consumed and the remaining portion is converted as wastewater. The study showed that about 80% of the water turns out as wastewater. Out of the wastewater produced, 62% is greywater, 25% is dark grey water 13% is blackwater (see Table 2).

Table 2: Water use and waste water generation

NO	SOURCE	QUANTITY IN LITRES	%	CATEGORY
1.	Cooking and Drinking	20	2.7	1
2.	Washing Machine/Laundry	100	13.3	2
3.	Bathing	300	40	2
4.	Wash Basin	40	5.3	2
5.	Kitchen Sink	180	24	3
6.	Toilet	90	12	4
7.	Miscellaneous (floor cleaning, routine vehicle cleaning etc)	20	2.7	1
	Total	**750**	**100**	

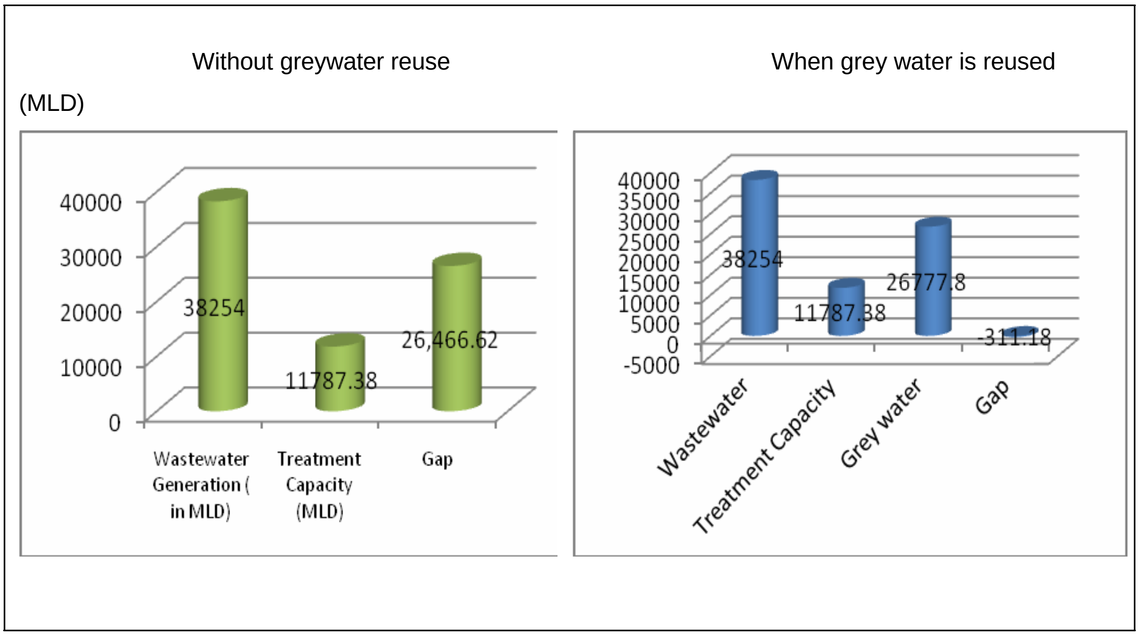
Category 1 indicates water fully consumed and the wastewater generation is nil or insignificant; category 2 indicates grey water; category 3 is dark grey water and category 4 is black water.

2.8 The Need to Focus on Grey Water Reuse

All studies reveal that 60 to 80 percent of domestic wastewater is greywater, which has sizeable reuse potential - either direct reuse or reuse after simple treatment. Apart from domestic sources, there are other sources like commercial establishments (shops, markets), public offices, educational institutions, service organizations (hospitals, hostels) that produce substantial quantity of greywater that could be effectively reused.

The present practice of wastewater disposal is conveying the wastewater (both black water and grey water together) through a common plumbing system to the sewerage, which undergoes expensive treatment before final disposal. In Indian cities the sewerage facility is quite inadequate to cater to the demand mainly because of the huge volume of wastewater due to the inclusion of grey water with black water. If the grey water is separated from the black water, the gap between the requirement and the availability could be substantially reduced. Fig . 6

Fig 6: Reduction in sewerage treatment due to grey water reuse



2.8 Sewage Treatment Status in Urban Areas of India

According to the Central Pollution Control Board (CPCB) report on Status of Water supply, Wastewater generation and Treatment in Class- I cities and Class II towns of India (2009), the estimated sewage generation in 498 Class-I Cities and 410 Class II towns (as per estimation made for the year 2008) is 38254 MLD. Against this, there exist only 11787 MLD treatment capacities. The Summary of water supply, sewage generation and its treatment is shown below:

Table 3: Summary of water supply, sewage generation and its treatment

Category	No. of Cities	Population	Total Water Supply (in MLD)	Wastewater Generation (in MLD)	Treatment Capacity (in MLD)
Class-I City	498	14,30,83,804	44,769.05	35,558.12	11,553.68
Class-II town	410	3,00,18,368	3,324.83	2,696.7	233.7
Total	**908**	**25,77,54,640**	**48,093.88**	**38254**	**11787.38**

Source: Status of Water Supply and Wastewater Generation and Treatment in Class-I cities and Class-II towns of India_CPCB_2009

The existing treatment capacity of sewage generated in Indian cities is just 30 % of present sewage generation. The untreated sewage finds their way into water bodies and thus pollutes ground and surface water. Centralized treatment facilities, though common in developed countries, seem to be a non-viable option in the Indian urban context due to the unplanned urban conglomeration of buildings, non-availability of land, requirement of complicated sewer networks and high cost for infrastructure development. Again, many of the techniques available today for sewage treatment are also high energy consuming. Today combined wastewater-blackwater and greywater- is discharged into sewer lines requiring handling of enormous volumes at treatment plants. Separating these two streams and treating them individually is a viable option, a trend gradually receiving worldwide acceptance. Since the greywater is less polluted, it can be used for non- potable purposes like garden irrigation even without treatment or with simple treatment compared to conventional high-cost wastewater treatment. The substitution of drinking water with treated greywater can be used for purposes other than those for potable water, e.g., toilet flushing and garden irrigation, supporting the sustainability of valuable water resources. Furthermore, considerable amounts of added chemicals, in addition to sludge which arises during drinking water treatment, can be minimized.

In water scarce environments, wastewater reuse and reclamation are often considered as a viable option for increased water resources availability. From a process technology point of view, separate treatment of black water, possibly together with kitchen waste is most logical because faecal matter and urine contained in the wastewater contribute half of the COD, most of the nutrients, pathogens and micro- pollutants.

2.9 Composition of Greywater

The quality of greywater can be highly variable due to factors such as the number of household occupants, their age, lifestyle, health, water source and products used (such as soaps, shampoos, cleaning products) and other site specific characteristics. (Table 4)

Table 4: Physical composition of grey water

• Soaps	• Suspended solids
• Detergents	• Dissolved solids
• Fibres from clothes	• Food particles
• Hair	• Grease
	• Oil

(*Source:* Karma El-Fadl 2007)

In terms of basic water quality parameters (TSS, BOD, turbidity), grey water is considered to be comparable to a low-or medium grade wastewater. Jefferson et al (2004) found that, though similar in organic content to full domestic wastewater, grey water tends to contain fewer solids and is less turbid than full domestic wastewater, suggesting that more of its contaminants are dissolved. The same study also suggested that the COD/BOD ratio in grey water can approach 4:1, much higher than that of domestic wastewater, which is typically around 2:1. The composition of grey water depends on each household"s activities and varies according to the number of household occupants, their age, lifestyle, health, water source and products used (such as soaps, shampoos, cleaning products), socio-economic status, cultural practices, cooking habits and other site specific characteristics. In general, grey water in low and middle-income countries may contain the parameters as given in Table 5. Typical chemical characteristics of grey water are presented in Table 5. Treatment requirements vary based on chemical characteristics and intended use of treated grey water.

Table 5 Chemical characteristics of grey water

	ASHRAM SCHOOLS OF DHAR AND JHABUA DISTRICTS		**RUIZ *ET AL.*, 2000**	
Item	**Range**	**Average**	**Range**	**Average**
Ph	6.4 – 8.1	7.7	6.95 – 8.3	7.8
TSS (Mg/L)	40 – 340	190	116 – 424	226
Turbidity (NTU)	15 – 270	161	NA	NA
Cod_t (Mg/L)	NA	NA	220 – 985	693
Cod_s (Mg/L)	NA	NA	63 – 523	322
BOD_5 (Mg/L)	45 – 330	170	250 – 640	360
Nitrite (Mg/L)	0.1 – 1.0	0.55	NA	NA
Ammonia (Mg/L)	1.0 – 26	13	2 – 34	20
Fats (Mg/L)	NA	NA	57 – 199	100
TKN (Mg/L)	2- 23	12	9.5 – 65	38
Total P (Mg/L)	0.1-0.8	0.62	0.58 – 9.6	5.5
Sulphate (Mg/L)	<0.3 – 12.9	5.6	2.1 – 145	38.5
Conductivity (ms/cm)	325-1140	732	NA	NA
Hardness (Mg $caco_3$/L)	15-50	35	NA	NA
Sodium (Mg/L)	60-250	140	NA	NA
Alkalinity (Mg $caco_3$/L)	NA	NA	54 – 902	281

The microbiological quality in terms of number of thermo-tolerant coliforms of grey water from various sources by different researchers is presented in Table 6. Thermo-tolerant coliforms are also known as faecal coliforms (expressed as colony forming units per 100 ml) and are a type of micro-organism which typically grow in the intestine of warm blooded animals (including humans) and are shed in millions to billions per gram of their faeces. A high faecal coliform count is undesirable and indicates a greater chance of human illness and infections developing through contact with the wastewater. Typical levels of thermo-tolerant coliforms found in raw sewage are in the order of 10^6 to 10^8 cfu/100ml.

Grey water characteristics also vary according to source; each fixture used for the grey water collection system will carry its own particular contaminant load. Friedler (2004) recommends excluding fixtures like the kitchen sink and dishwasher from a grey water system, because they constitute only 25-30% of grey water volume but contribute nearly half of its COD content. For this reason, the least contaminated streams of household grey water are usually prioritized for reuse.

Table 6: Microbiological Quality of Grey Water

SOURCE	THERMO TOLERANT COLIFORMS (CFU)/100 ML			
	Rose *et al.,* 1991	Kapisak *at al.,* 1992	California DHS 1990	Brandes 1978
Bathing	$6x10^3$ cfu	$4x10^5$ MPN	<10 to $2x10^8$	$6x10^3$ cfu
Laundry wash water	126 cfu	$2x10^3$ – 10^7 MPN	--	--
Laundry rinse water	25 cfu	--	--	--
Kitchen	--	--	<10 to $4x10^6$	$2x10^9$
Combined greywater	6 to 80 cfu[A] $1.5x10^3$ cfu[B] $1.8x10^5$ to $8x10^6$ cfu[C] $13x10^6$[D]		$8.8x10^5$[CD] $1.73x10^5$	

Source: Jepperson *et al.,* 1994

Greywater is a resource that can be reused on-site for garden and lawn irrigation or, when treated adequately, for toilet flushing and laundry use (cold-water washing machine only). Substituting the use of drinking water with greywater for these end uses will, not only reduce the demand on drinking water supplies, but also reduce the amount of wastewater discharged to the environment.

Reusing greywater provides a number of benefits including:

- Reducing potable water demand
- Reducing the amount of wastewater discharged to the water bodies or to the environment
- A healthier garden, especially during drought periods.
- Reducing household water bills

The disadvantages of greywater reuse may include:

- The potential for pollution and undesirable health and environmental effects when greywater is not reused appropriately
- Initial cost of setting up a greywater system and plumbing requirements
- Ongoing maintenance and system owner commitment.

3.1 Objective, Approach and Methods

One of the specific objectives of the Centre of Excellence in CED is to develop strategy and methodology for urban wastewater management adopting a practical approach for wastewater recycling and reuse. The issues to be dealt with in this context are encouraging and enforcing differential use of water for different purposes, identifying locale-specific technologies for wastewater treatment and developing necessary legal and institutional framework. Accordingly, CED has made an attempt to understand the national wastewater management scenario and to develop a strategy and framework for effective management of waste water. The activities undertaken as part of CoE for wastewater management are described below:

3.2 Pilot Studies under CoE

For developing the strategy and framework for Urban Waste Water Management, CED conducted two pilot studies on water consumption and wastewater discharge methods in Thiruvananthapuram Municipal Corporation (TMC) area. The study focused on major water consumers, in order to investigate into the water consumption rate, discharge/treatment methods adopted, etc. The characteristics of the grey water generated from these consumers have also been analyzed. The characteristics study was carried out to ascertain the nature of the grey water generated from different types of users with a view to selecting proper treatment technology and to know the extent to which the treatment is required. Characteristics study also helps to understand the need for separation of grey water source based on concentration of pollutants and to explore the possibilities of diversion of grey water for irrigation. Based on the pilot study, the strategy and frame work was developed.

3.3 Activities under the Pilot Study

(i) Review of Literature

The initial activity under the study was review of available literature on the topic-both national and international. The literature review covered areas like the characteristics of grey water, volume of generation, its applications in India and other countries, treatment technologies available, present disposal practices and the regulatory framework across the countries.

(ii) Selection of major wastewater generators

At present, there is no authentic data on quantity of grey wastewater generated from the major water consumers. In order to formulate greywater reuse plan, reliable data is required. Considering the above aspects, the CoE team identified the major wastewater generators of Thiruvananthapuram city like apartments, hotels, hospitals, public offices, service stations, hostels, etc., and data collected through random survey. The surveys were carried out to assess the quantity and characteristics of grey water generated in Thiruvananthapuram city. The survey format is attached as *Annexure I.*

(iii) Data collection Tools

In order to design a questionnaire to gather information from different types of water users, a brainstorming session was organised with the participation of experts from different sectors such as Kerala Water Authority, Kerala State Pollution Control Board, Thiruvananthapuram Municipal Corporation etc. Based on the ideas emerged in the brainstorming session, draft questionnaire was prepared, its effectiveness to capture required information analyzed and finally field tested before actual use. A group of Technical Assistants (TA) was identified to conduct the field survey. Intensive training was given to the Technical Assistants before the field testing of the questionnaire. Based on the outcome from the field test, final questionnaire was prepared. The Sample questionnaire is attached as *Annexure II*.

(iv) Data collection

The project team conducted detailed field survey using the structured questionnaire prepared for the purpose. The information was collected mainly by field visits, observations, person to person discussions and focus group discussions involving different stakeholders.

(v) Situation analysis

Situation analysis was done as part of the pilot study to understand various aspects of wastewater-volume across different categories of generators, difference in characteristics, disposal practices, people‟s perception about wastewater management, regulatory framework and level of enforcement/acceptability etc.

The major grey wastewater generators in the city were identified and data relating to them was collected and analyzed. Accordingly, the apartments produce about 152 lpcd and 1.5 g/l of COD (considered as major pollution indicator).The hotels without lodging facility produce 72 lpcd of grey water per restaurant seat, hotels with lodging facility of less than 50 rooms produce 145 lpcd of grey water per room and hotels with lodging facility with 50 to 150 rooms produces 360 lpcd of grey water per room. The pollution load produced by the hotels in average COD terms is 1.4g/l. The hospitals with less than 100 beds produce 224 lpcd of grey water per bed and hospitals with more than 100 beds produces 328 lpcd of grey water per bed. The pollution load produced by the hospitals in average COD terms is 0.9g/l.

The study revealed that as elsewhere in the developing world, there is only partial connection to the centralized sewerage system, resulting in substantial volumes of wastewater disposed off into the environment including surface water bodies.

(vi) Review of technology options

The technologies presently available for wastewater treatment were reviewed specially focusing on greywater treatment, which are explained under Section 4.

(vii) Identification of specific treatment technologies

The data collected was analyzed to find out appropriate technological solutions to suit different situations. The various methods practised in India are given as Table 10.

(viii) Wastewater discharge/use/recycling

The study revealed that as in the case of most developing countries, in the case study city also wastewater receives very little or no treatment and is discharged either into the premises or natural water bodies. The reuse potential of greywater is seldom captured.

3.4 Major Policy Level Findings of the Study

The amount of grey water produced in a household or commercial construction can greatly vary depending upon the number of occupants and size of the facility.

The composition of grey water greatly varies on the type of building and usage of chemicals for washing, laundry, etc. In general, it contains often high concentrations of easily degradable organic material, i.e. fat, oil and other organic substances, residues from soap, detergents, cleaning agents, etc and generally low concentrations of pathogens.

Grey water in general has low content of any metals or organic pollutants, but depending on the nature of life style of the generators, it can vary.

Grey water from bathtubs, showers, washbasins and washing machines contains little or no pathogens, and ninety percent less nitrogen than black water (toilet waste). Because of this, it does not require the same treatment required for black water or combined wastewater.

By redesigning plumbing systems to separate grey from black water, grey water can be recycled/reused for irrigation, toilets and for many other purposes resulting in water conservation.

If properly planned and executed, the wastewater treatment requirements of upcoming residential and commercial buildings could be significantly reduced, resulting in cost and space savings.

Grey water can be used for a variety of applications such as garden irrigation, irrigation of certain food crops, watering parks, playgrounds and school yards, golf courses, freeway landscaping, car washing, dust control, toilet flushing, fire fighting etc

There is absence of formal and organized system for grey water reuse

There is need for capacity development of municipal planners, administrators and the general public to inculcate the need for grey water reuse.

3.5 Conclusions of the Pilot Study

(i) Greywater reuse is a potential area capable of alleviating the higher demand for fresh water and reducing the sewage treatment demand.

(ii) ULBs should pay prime attention to the so far neglected area of grey water reuse in view of its economic, environmental, health & hygiene and aesthetic impacts on the ULB and its population.

(iii) Appropriate location specific and low cost technology options should be identified and propagated. Encourage research to discover novel, cost-effective, user-friendly and efficient systems.

(iv) Develop appropriate regulatory framework, which should invariably claim community acceptance.

(v) Promote decentralization. The reuse approach should be bottom up, starting from reuse at generator level, passing through locality/area level reuse and finally reaching the centralized reuse system. Crossing boundaries of each level will be only when the lower level options are saturated.

(vi) Any initiative should precede with adequate capacity building through appropriate IEC for changing the mindset and creating public acceptance.

3.6 Preparation of Strategies and framework

Based on the findings of the study, a model strategy and framework for effective wastewater management focusing on greywater reuse has been formulated, which is explained in the last part of this Report.

4.1 Grey Water Treatment Technologies

4.2 Types of Wastewater Re-use and Treatment

Broadly, wastewater is treated in centralized facilities which have mainly three levels - primary, secondary and tertiary levels.

***Primary treatment*:** It is the treatment involving sedimentation (sometimes preceded by screening and grit removal) to remove gross and settleable solids. The remaining settled solids, referred to as sludge, are removed and treated separately.

Secondary treatment: Generally, a level of treatment that removes 85% of Biological Oxygen Demand [BOD] and suspended solids via biological or chemical treatment processes.

Water reclaimed after the secondary treatment usually has a BOD of <50 milligrams per liter (mg/L) and suspended solids of <30 mg/L, but this may increase to >100 mg/L due to algal solids in lagoon systems.

Tertiary treatment: The treatment of reclaimed water beyond the secondary biological stage is termed as tertiary treatment. This normally implies the removal of a high percentage of suspended solids and/or nutrients, followed by disinfection. It may include processes such as coagulation, flocculation and filtration.

Domestic wastewater management in urban and semi-urban areas is based on the conventional approach of collecting the wastewater, both grey and black water in sewerage systems and subjecting to treatment in a conventional sewerage treatment plant. Alternatively, the grey water can be collected, treated and re-used on-site, thereby promoting more efficient water use. There are many methods for reusing grey water, from simple bucketing to complex treatment and recycling systems. However, on-site reuse of domestic wastewater is subject to various restrictions due to concerns about effluent quality, maintenance and health issues.

> The reuse of greywater for toilet flushing and garden irrigation has an estimated potential to reduce domestic water consumption by up to 50% (Maimon et al. 2010).

4.3 Greywater Technologies in Use Worldwide

Greywater can be reused for purposes that do not require potable water – such as landscaping, agriculture, or flushing toilets – thereby reducing potable water use. Greywater after simple treatment can also be allowed to seep into the ground to recharge aquifers and reduce the volume of wastewater needing to be treated. Greywater is often, but not always, treated before it is reused, and the degree of treatment can vary widely. Greywater systems range from simple low-cost devices that divert greywater to direct reuse, such as in toilets or outdoor landscaping, to complex treatment processes incorporating sedimentation tanks, bioreactors, filters, pumps, and disinfection (NovaTec Consultants Inc. 2004). Some greywater systems are home-built, do-it-yourself piping and storage systems, but there are also a variety of commercial greywater systems available that filter water to remove hair, lint, and debris, and remove pollutants, bacteria, salts, pharmaceuticals, and even viruses from greywater. The cost and energy requirements of these systems vary, usually increasing with higher levels of treatment.

Greywater systems that involve storing must be treated to reduce the bacteria and other microorganisms that can multiply in stagnant water. Physical and chemical greywater treatment systems primarily utilize disinfection and filtration to remove contaminants while biological treatment uses aeration and membrane bioreactors.

Fig.7: Toilet designed to re-use the greywater from the sink above it

Before treatment, different types of screens are installed in the greywater stream to remove all solid materials like hair, paper, plastic, etc. The treatment will become more efficient when the solid substances are removed with the help of the screens since the removal of organic materials will reduce the BOD load and the removal of inorganic items will reduce the complexity of treatment. The different types of screens commonly used are illustrated below:

Table 7: Different types of Screens Commonly Used

Screen category	Size of openings (mm)	Application	Types of Screens
Coarse screens	≥ 6	Remove large solids, rags, and debris.	Manually cleaned bar screens/trash racks. Mechanically cleaned bar screens/trash racks, Chain or cable driven with front or back cleaning, Reciprocating rake screens, Continuous self-cleaning screens.
Fine screens	1.5-6	Reduce suspended solids to primary treatment levels	Rotary-drum screens. Rotary-drum screens with outward or inward flow Rotary-vertical-disk screens. Inclined revolving disc screens. Traveling water screens. Endless band screen, Vibrating screens
Very fine screens	0.2-1.5	Reduce suspended solids to primary treatment levels	
Micro screens	0.001-0.3	Upgrade secondary effluent to tertiary standards	

Diversion Systems

There are a number of applications that enable direct grey water reuse like toilet flushing, outdoor irrigation, greywater treatment in wetlands etc. Installation of a grey water diversion system can make use of the grey water for such immediate reuse rather than treating or storing it. The systems may also involve disinfection (e.g., adding chlorine to kill bacteria). Currently, there are a variety of commercially available systems in many parts of the world that divert water from shower and wash basins into toilet water tanks.

These systems re-plumb drain water directly into a toilet tank for flushing or into a receptacle that is then pumped into a toilet tank. Systems that reuse wash basin water to fill toilet tanks are sold primarily in Japan, Australia, Europe, and North America (Fig 7). The toilets are designed to re-use the greywater from the wash basin above it. These systems are relatively low cost and require no additional land area.

A second category of systems diverts drain water to outdoor irrigation, often requiring additional plumbing and irrigation tubing. An electrical pump may also be necessary to move the water outdoors, but simple systems can sometimes rely on gravity to move the water. These systems are also relatively inexpensive and require no additional land area, but are only useful on plots that have vegetation or are unpaved to allow infiltration as many greywater codes do not allow ponding of the greywater.

Finally, there are greywater systems that divert greywater from showers and sinks into treatment wetlands or other plant- and soil-based filters. For example, in Berlin, Germany, a 60 square meter engineered wetland constructed in the courtyard of a housing settlement has been operating successfully for eight years (Nolde Grey Water Recycling).

Greywater from bath tubs, showers, sinks, and washing machines enters the plant-covered soil-filter where it undergoes biological treatment. Ultra violet disinfection has been included as a final safety measure before the use in toilet flushing (Deutsche BauBeCon, 1995, 1996). Extensive investigations over several years of operation have shown that within the soil filter, *E. coli* concentrations were reduced by over 99% and all hygiene requirements have been achieved under the EU-Guidelines for Bathing Waters. The costs of this form of greywater treatment can vary widely and it is also land-intensive.

Currently, there are no uniform requirements for most greywater systems. Many of these basic diversion systems include two-way valves that can be set to an open or closed position. This allows greywater to either be routed to sewer pipes (as they normally would) or be routed to the greywater system. This option can help ensure that greywater systems are properly managed (e.g., can be turned off if someone does not understand how to use the greywater system or when there may have been black water contamination) and are never overwhelmed by a large volume of water.

There are Greywater Diversion Devices (GDD) in use, which incorporates a hand activated switch or tap to divert the greywater to the garden or the sewer without storage or treatment. There are two types of greywater diversion devices (GDD):

<u>i. Gravity GDD</u>

A gravity diversion device incorporates a hand activated valve, switch or tap and is fitted to the outlet of the waste pipe of the plumbing fixture such as a laundry tub. Greywater is diverted directly to a sub-surface irrigation system in the garden.

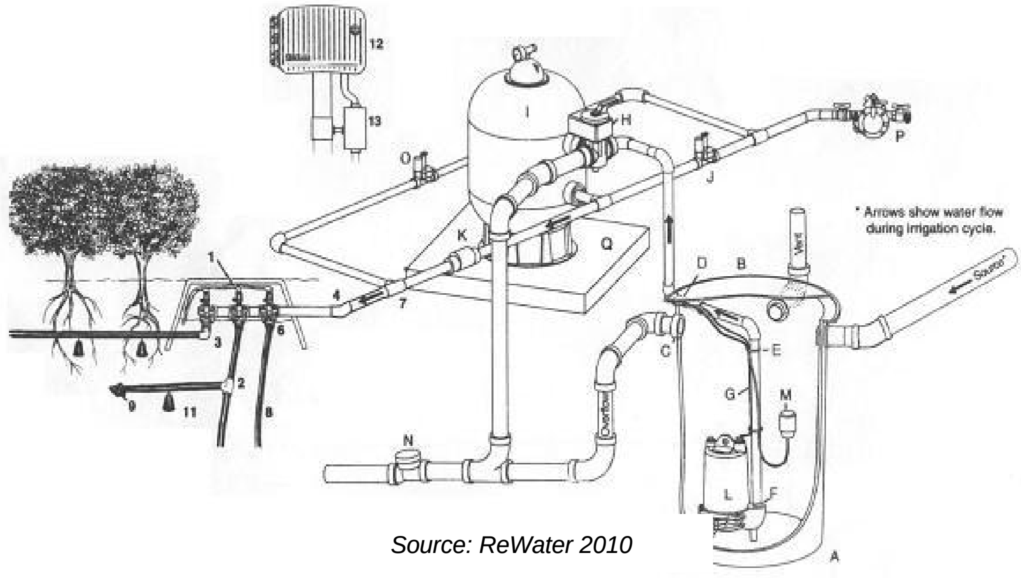
<u>ii. Pump GDD</u>

A pump diversion device incorporates a surge tank to cope with sudden influxes of greywater for distribution of the greywater directly to a sub-surface irrigation system in the garden. The surge tank does not operate as a storage tank.

Physical and chemical treatment systems usually involve holding tanks, filters, and pumps. For example, the major components of the greywater treatment system. (Fig. 8) are a surge tank, sand media filtration tank, and piping to an outdoor irrigation system.

Many basic greywater treatment and storage systems also incorporate activated carbon and/or clay filters and disinfection (e.g., chlorination, purification with ultraviolet radiation). The disadvantage of the system is that it is costly and land-intensive, requiring space for holding tanks and filtration units.

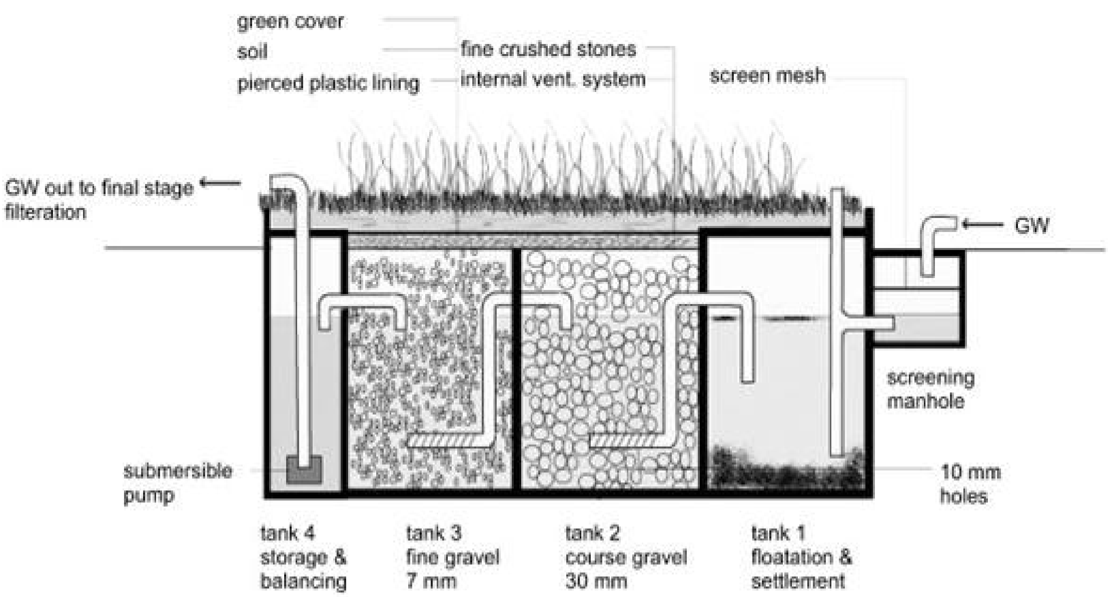
Figure 8: Greywater Treatment System for Outdoor Irrigation



Source: ReWater 2010

Figure 9 is a grey water treatment system set up in Qebia village, Palestine to meet household greywater treatment needs. The system comprised of a gravel filter medium, mostly crushed, hard limestone. The tanks were made of concrete and/or bricks, and were divided into four compartments.

Fig 9 **PHYSICAL GREY WATER TREATMENT SYSTEMS SET UP IN QEBIA VILLAGE, PALESTINE**



The first compartment is a septic tank and grease trap and receives the greywater from the shower, kitchen, wash basins and washing machine – through a 5 or 7.5 cm diameter PVC pipe, via a screened manhole, by means of a T-shaped outlet. One end of this outlet is directed upward and open to atmospheric pressure and the other is at a level of about 30 cm from the bottom of the tank.

The second and third tanks act as up-flow graduated gravel filters. The fourth compartment acts as a balancing tank for the treated greywater, with a submersible pump installed to lift the water to a multilayered aerobic filter. Through a controlled flow from the top tank, the greywater passes through the filter layers (sand, coal, and gravel) to a storage tank from where it can then be supplied to the irrigation network" (Burnat and Eshtayah 2010).

The 4-Barrel System:

Based on an experiment in Jordan, CED established in its compound at Thiruvananthapuram a 4-barrel system for wastewater treatment with slight modifications. The system treats wastewater from the kitchen and washbasin. Four plastic barrels constitute the treatment kit. The four barrels are lined up next to one another and are interconnected with 32 mm PVC pipes.

The first barrel is a grease, oil and solids separator and thus acts as a pre-treatment or primary treatment chamber, where the solid matter from the influent greywater settles and the floating components, such as grease and soap foam, float. This barrel has 200 litre capacity with an effective volume of 160 litre having a large cover, which can be tightly closed. When the cover is opened, the chamber can be cleared of both floating and settled material. The second and the third barrels are of the same capacity and are filled with shredded plastic.

Once solids and floating material settle in the first barrel, the relatively clear water from the first barrel enters into the bottom of the second barrel. Next, the water from the top of the second barrel enters into the bottom of the third barrel. This water passes through the shredded plastics and from the top of the third barrel is taken into the fourth.

Anaerobic treatment is accomplished in the two middle barrels. Anaerobic bacteria gets established on the plastic surface so that when the grey water passes through the plastics, the bacteria works on breaking down components of the organic material found in the grey water. The last barrel acts as a storage tank for treated grey water. Within one to two days of resident time in the treatment kit, the influent greywater is expected to undergo a treatment level equivalent to between primary and secondary treatment.

The modifications made by CED from the Jordan system are:

- Wastewater first enters into a bucket which acts as a settler (this is not in the Jordan model). Thus the first barrel does not suffer any agitating action due to the forceful inflow of water through the plumbing system.

- Shredded Plastic is used as the medium for facilitating microbial action (growth of instead of gravel.

Figure 10: The 4-barrel system at CED, Thiruvananthapuram

The treatment shows more than 50% reduction in BOD and COD. The graphical illustration of the BOD and COD removal percentage is given below:

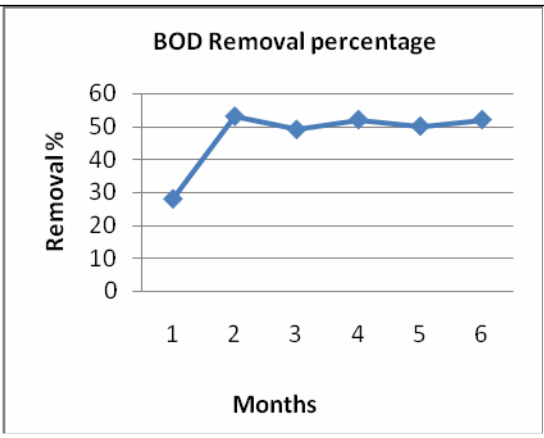


Fig 11: BOD Removal Percentage

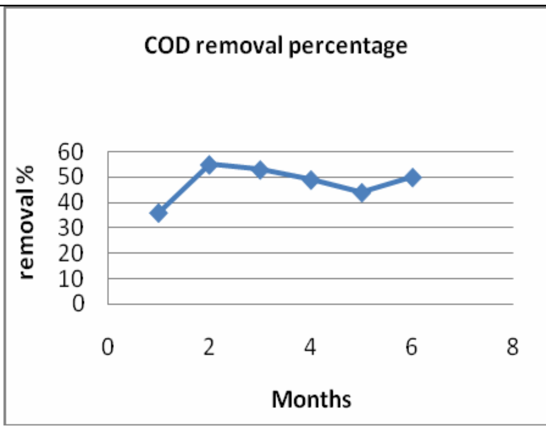


Fig 12: COD Removal Percentage

The Confined Trench (CT) System: Two plastic barrels and a dug trench filled with gravel media constitute the confined trench (CT) unit. The first barrel functions as a grease, oil and solids separator and thus acts as a pretreatment or primary treatment chamber, where the solid matter from the influent grey water settles and the floating components, such as grease and soap foam floats and can be removed regularly. The first barrel of the CT system will have 160 litre capacity and a large cover, which can be tightly closed. When the cover is opened, the chamber can be cleared of both floating and settled material. A trench is dug close to the first barrel with dimensions of approximately 3 m long, 1 m wide and 1 m deep and it is filled with 2-3 cm sized graded gravel. Pre-treated wastewater from the first barrel enters the bottom part of the trench from one side and flows slowly to the other end. The trench is lined with a 400-500 micron thick polyethylene sheet. The sides of the trench are plastered with a mud layer so that the polyethylene liner sheet is not punctured by sharp stones. A 120 litre capacity plastic barrel is perforated and burred in the gravel at the exit end of the trench so that wastewater flows through the trench upwards to fill this barrel. Residence time of grey water in the trench is two to four days under anaerobic conditions.

Septic Tank

A septic tank consists of 2- 3 compartments. The compartment walls extend 15 cm above liquid level. The anaerobic bacteria present in the tanks decompose the solid wastes that have settled to the bottom of the tank thereby transforming most of the wastes in solids and gases. The outflow, through a series of subsurface pipes is distributed throughout the drain field. Here effluents undergo final treatment as the soil absorbs and filters the liquid whereas rest of the material is broken down by the microbes. It is not possible for the septic tanks to dispose of all the materials which enter the system. The solid that is left behind and which is not decomposed need to be removed on a regular basis; otherwise the system will fail.

Fig.13: Septic tank

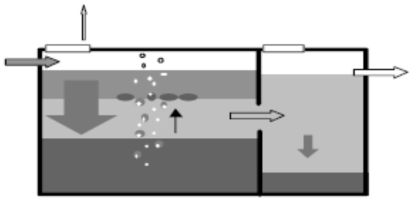
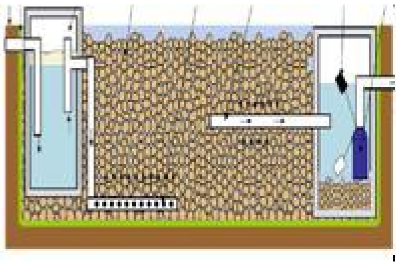


Fig.14: The Confined Trench System



Grease and light particles which form a layer of scum on the top are prevented by the use of baffles installed at the inlet and outlet of the tank. The scum formed is to be removed periodically. The suspended solids removal rate drops drastically when accumulated sludge fills more than 2/3 of the tank. This must be avoided, especially in cases where the effluent is treated further in a sand or gravel filter. The inlet may dive down inside the tank, below the assumed lowest level of the scum or may be above the water level when the inlet pipe is used to evacuate gas. The vent pipe for digester gases should end outside buildings, at a minimum of 2 m above the ground. The treatment quality of a septic tank is in the range of 25% - 50% COD removal. Post treatment may be provided depending on the type of reuse.

Imhoff Tank

Imhoff or Emscher tanks are typically used for domestic or mixed wastewater flows above 3 m^3/d. The tank consists of a settling compartment above the digestion chamber. Funnel-like baffle walls prevent up-flowing foul sludge particles from getting mixed with the effluent and from causing turbulence. The effluent remains fresh and odourless because the suspended and dissolved solids do not have an opportunity to get in contact with the active sludge to become sour and foul. Retention times of much longer than 2 h during peak hours in the flow portion of the tank would jeopardize this effect.

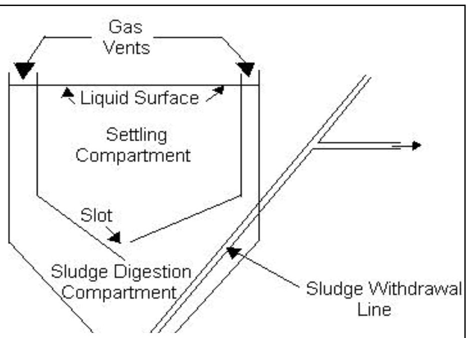


Fig 15: Imhoff Tank

The sludge and scum must be removed regularly at the intervals . Only part of the sludge should be removed so as to always keep some active sludge present. Sludge should be removed right from the bottom to make sure that only fully digested substrate is discharged. When sludge is removed, it should be immediately treated further in drying beds or compost pits for pathogen control. Pipe ventilation must be provided, as biogas is also produced in the Imhoff tank.

Constructed Wetland Treatment System

Reed bed filters and small-scale constructed wetlands, at the household-level, are well developed in recent days. The technology was designed for on-site, confined space wastewater treatment. It uses aquatic plants and the up-flow filter concept to treat wastewater.

The system is unique in that it combines wastewater treatment and resource recovery in a relatively small system that may be suitable for use in urban areas and has been described for use in moderate land-limited conditions for apartments. The system's spatial requirements are lower than conventional aquatic plant treatment processes and facultative pond systems. The free-floating aquatic macrophyte and sub-surface bio-fixed film treatment demonstrates high five-day BOD and nitrogen removal efficiencies of more than 85% at a loading rate of 135 kg/ha/day.

The Horizontal Flow Single Pond System

The horizontal flow single pond system are mostly constructed in a size of 1.2m x 1.0m x 0.5m (Length x Width x Height) each. Generally the total volume of the reactor is about 400L. The volcanic rocks were filled to a depth of 35 cm. The void volume of 220 L and the packing ratio to the total volume was about 0.45. The direction of wastewater flow was horizontal through rock medium and upflow towards the liquid portion and the aquatic plants, and then discharged through the other end of the tank.

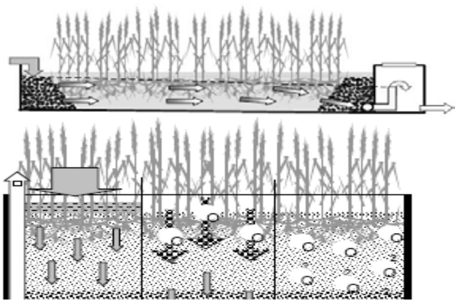
Off-Site Constructed Wetlands

Wetlands constructed specifically for treating wastewater are known as "off-site constructed wetlands" and are effective in the removal of BOD, TSS, and nitrogen (N). The beneficial uses of these systems for wastewater treatment are well established, and the technology continues to develop rapidly. Some of the studies using forested wetlands to treat domestic wastewater demonstrated that nutrients could be removed with a minimum application of expensive and fossil energy consuming technology.

Subsurface Wetlands

Subsurface wetlands are lined ditches that have been filled with gravel, sand or soil substrate and planted with appropriate plant varieties. Treatment in subsurface systems generally occurs when the effluent makes contact with plant roots and the soil or rock bed. Influent enters the treatment system and percolates through the substrate. Organic matter is biodegraded either aerobically or anaerobically and nutrients are eliminated through a variety of biological, physical and chemical processes. One of the major advantages of this treatment system is low maintenance requirements. If local clay for lining and local stone for a root-zone substrate is available, construction costs can be very low.

Fig 16: Constructed Wetland



Free Water Surface Wetlands

Free water surface (FWS) wetlands are typically shallow channels or basins where the water surface is open to the atmosphere and a suitable medium exists to support the growth of emergent or submerged aquatic plants. FWS wetlands support the growth of floating aquatic plants, as well as emergent and submergent varieties.

Wastewater treatment occurs as the plants assimilate nutrients (nitrogen and phosphorus) from the effluent and the resulting biomass is harvested. Two floating aquatic macrophyte plants most commonly used in wastewater treatment systems are water hyacinth (*Eichhornia crassipes*) and duckweed (*Lemnacea sp*., *spirodella sp*.). Macrophyte-based wastewater treatment systems are appropriate because they offer several advantages over mechanized treatment systems such as :

1) They have low operating costs

2) They operate with low energy requirements

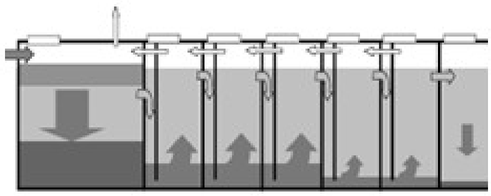
3) They can often be established at the site of wastewater production, and

4) They are more flexible and more tolerant of shock loading.

Baffled Septic Tank

Baffled septic tank or anaerobic baffled reactor in fact is a combination of several anaerobic process principles - the septic tank, the fluidized bed reactor and the UASB. The up-flow velocity of the baffled septic tank, which should never be more than 2 m/h, limits its design. The limited upstream velocity results in large but shallow tanks. It is for this reason that the baffled reactor is not economical for larger plants. However, the baffled septic tank is ideal for grey water treatment because it is simple to build and simple to operate. Hydraulic and organic shock loads have little effect on treatment efficiency. Treatment performance is the range of 65% - 90% COD (70% - 95% BOD) removal.

Fig.17 Baffled Septic Tank



Since the tanks are put in series, a part of the active sludge that is washed out from one chamber is trapped in the next. It also helps to digest difficult degradable substances, predominantly in the rear part, after easily degradable matters have been digested in the front part, already. The baffled septic tank consists of at least four chambers in series. The last chamber could have a filter in its upper part in order to retain eventual solid particles. A settler for post-treatment could also be placed after the baffled septic tank.

Equal distribution of inflow, and widespread contact between new and old substrate are important process features. The fresh influent is mixed as soon as possible with the active sludge present in the reactor in order to get quickly inoculated for digestion. The wastewater flows from bottom to top with the effect that sludge particle settle against the upstream of the liquid. This provides the possibility of intensive contact between resident sludge and newly incoming liquid. The water stream between chambers is directed by baffle walls that form a down-shaft or by down-pipes that are placed on partition walls for better distribution of flow.

Relatively short compartments (length < 50% to 60% of the height) are provided in order to distribute the wastewater over the entire floor area. The final outlet as well as the outlets of each tank should be placed slightly below surface in order to retain any possible scum.

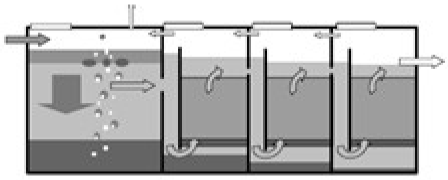
Waste Stabilization Ponds

Ponds (lagoons) or waste stabilization pond system are artificial lakes which consist of sedimentation ponds (pre-treatment ponds with anaerobic sludge stabilization), anaerobic ponds (anaerobic stabilization ponds), oxidation ponds (aerobic cum facultative stabilization ponds) and polishing ponds (post-treatment ponds, placed after stabilization ponds). But all ponds are not ideal for grey water treatment due to large area requirement and in case of facultative or anaerobic ponds, there will be nuisance by mosquito breeding, or bad odour. Polishing ponds can be used as a post treatment pond after gravel filter or constructed wetland, in which use of the fish to control mosquitoes is possible and more over it will give a good aesthetic appearance if it is constructed in a garden.

Aerobic ponds receive most of their oxygen via the water surface. For loading rates below 4 g BOD/m^2/d, surface oxygen can meet the full oxygen demand. Oxygen intake increases at lower temperatures and with surface turbulence caused by wind and rain. Oxygen intake depends further on the actual oxygen deficit up to saturation point and thus may vary at 20°C between 40 g O_2 /m^2/d for fully anaerobic conditions and 10 g O_2 /m^2/d in case of 75% oxygen saturation.

The secondary source of oxygen comes from algae via photosynthesis. However, in general, too intensive growth of algae and highly turbid water prevents sunlight from reaching the lower strata of the pond. Oxygen production is then reduced because photosynthesis cannot take place.

Fig 18: Anaerobic Filter



The result is a foul smell because anaerobic facultative conditions prevail. Algae are important and positive for the treatment process, but are a negative factor when it comes to effluent quality. Consequently, algae growth is desirable in the beginning of treatment, but not desired when it comes to the point of discharge, because algae increase the BOD of the effluent. Algae in the effluent can be reduced by a small last pond with maximum 1 day retention time. Baffles or rock bedding before the outlet of each of the ponds have remarkable effect on retaining of algae.

Anaerobic Treatment

Anaerobic treatment technology is efficient, well demonstrated and provides a cost-effective method of disposing organic wastes and producing fuel and fertilizers without releasing greenhouse gases. Anaerobic digesters have the ability to destroy large numbers of pathogenic organisms in wastewater and to produce energy in the form of methane gas to run water pump engines, electric generators and agricultural machinery. The anaerobic digester also produces sludge which is a fertilizer normally used in agriculture. Biogas is an excellent source of energy and can be used to produce electricity as well as cooking and lighting gas.

A well maintained anaerobic digester should produce 0.1 m^3 gas/ m^3 digester volume and the gas will constitute 70% methane and 30% carbon dioxide and can be easily used for cooking and lighting. Gas produced from the system is primarily used for lighting and cooking. The biogas produced is approximately 70% methane, and that the typical reactor will produce 0.1-0.2 m^3 biogas/ m^3 digester volume /day when 60% of the feed-stock to reactors is grey water. Digestion usually occurs over a five to six day period for maximum biogas generation. Treated slurry is used as a fertilizer, but can also be used as a feed supplement for pigs, mushroom growing media, and vermi-composting substrate.

Anaerobic Filter

The anaerobic filter, also known as fixed bed or fixed film reactor is used for the treatment of non-settelable and dissolved solids by bringing them in close contact with a surplus of active bacterial mass. This surplus together with “hungry” bacteria digests the dispersed or dissolved organic matter within short retention time. Anaerobic filters are reactors consisting of supporting material layers. On the surface of these material layers or bed, fixation of microorganism and the development of biofilm takes place. Anaerobic filters can be applied not only for treating concentrated wastewater but also for those wastewaters that have low organic load (grey water). If they are preceded by a reactor that retains settled solids, they will work better.

It is suitable for domestic wastewater and all industrial wastewater which have a lower content of suspended solids. The bacteria in the filter are immobile and generally attach themselves to solid particles or to the reactor walls. Filter materials like rocks, cinder, plastic, or gravel provide additional surface area for bacteria to settle. Thus, the fresh wastewater is forced to come into contact with active bacteria intensively. The larger surface area for the bacterial growth helps in the quick digestion of the wastes. A good filter material provides a surface area of 90 to 300 m^2 per meter cube reactor volume. Biological oxygen demand up to 70% to 90 % is removed in a well operated anaerobic filter.

Pre-treatment in settlers or septic tanks may be necessary to eliminate solids of larger size before they are allowed to enter the filter. When the bacterial film becomes too thick it has to be removed. This may be done by back-flush of wastewater or by removing the filter mass for cleaning outside the reactor. Nonetheless, the anaerobic filter is very reliable and robust. Anaerobic filters may be operated as down flow or up flow systems. A combination of up-flow and down-flow chambers is also possible.

Activated Sludge Process

The activated-sludge process is an aerobic, continuous-flow system containing a mass of activated micro-organisms that are capable of stabilizing organic matter. The process consists of delivering clarified waste-water, after primary settling, into an aeration basin where it is mixed with an active mass of microorganisms, mainly bacteria and protozoa, which aerobically degrade organic matter into carbon dioxide, water, new cells, and other end products. The bacteria involved in activated sludge systems are primarily Gram-negative species, including carbon oxidizers, nitrogen oxidizers, floc formers and non-floc formers, and aerobes and facultative anaerobes. The protozoa, for their part, include flagellates, amoebas and ciliates. An aerobic environment is maintained in the basin by means of diffused or mechanical aeration, which also serves to keep the contents of the reactor (or mixed liquor) completely mixed. After a specific retention time, the mixed liquor passes into the secondary clarifier, where the sludge is allowed to settle and a clarified effluent is produced for discharge. The process recycles a portion of the settled sludge back to the aeration basin to maintain the required activated sludge concentration. The process also intentionally wastes a portion of the settled sludge to maintain the required solids retention time (SRT) for effective organic removal. Control of the activated-sludge process is important to maintain a high treatment performance level under a wide range of operating conditions. The principal factors in process control are the following:

(a) Maintenance of dissolved oxygen levels in the aeration tanks;

(b) Regulation of the amount of returning activated sludge;

(c)) Control of the waste activated sludge.

The main operational problem encountered in a system of this kind is sludge bulking, which can be caused by the absence of phosphorus, nitrogen and trace elements and wide fluctuations in pH, temperature and dissolved oxygen (DO). Bulky sludge has poor settleability and compatibility due to the excessive growth of filamentous micro-organisms. This problem can be controlled by chlorination of the return sludge.

Aerated Lagoons

An aerated lagoon is a basin between 1 and 4 metres in depth in which waste water is treated either on a flow-through basis or with solids recycling. The microbiology involved in this process is similar to that of the activated-sludge process. However, differences arise because the large surface area of a lagoon may cause more temperature effects than are ordinarily encountered in conventional activated-sludge processes. Waste water is oxygenated by surface, turbine or diffused aerator. The turbulence created by aeration is used to keep the contents of the basin in suspension. Depending on the retention time, aerated lagoon effluent contains approximately one third to one half the incoming BOD value in the form of cellular mass. Most of these solids must be removed in a settling basin before final effluent discharge

Trickling Filters

The trickling filter is the most commonly encountered aerobic attached-growth biological treatment process used for the removal of organic matter from waste water. It consists of a bed of highly permeable medium to which organisms are attached, forming a biological slime layer, and through which wastewater is percolated. The filter medium usually consists of rock or plastic packing material. The organic material present in the wastewater is degraded by adsorption on to the biological slime layer. In the outer portion of that layer, it is degraded by aerobic micro-organisms. As the micro-organisms grow, the thickness of the slime layer increases and the oxygen is depleted before it has penetrated the full depth of the slime layer. An anaerobic environment is thus established near the surface of the filter medium. As the slime layer increases in thickness, the organic matter is degraded before it reaches the micro-organisms near the surface of the medium. Deprived of their external organic source of nourishment, these micro-organisms die and are washed off by the flowing liquid. A new slime layer grows in their place. This phenomenon is referred to as „sloughing". After passing through the filter, the treated liquid is collected in an under drain system, together with any biological solids that have become detached from the medium. The collected liquid then passes to a settling tank where the solids are separated from the treated waste water. A portion of the liquid collected in the under drain system or the settled effluent is recycled to dilute the strength of the incoming waste water and to maintain the biological slime layer in moist condition.

Rotating Biological Contractors

A rotating biological contractor (RBC) is an attached-growth biological process that consists of one or more basins in which large closely-spaced circular disks mounted on horizontal shafts rotate slowly through waste-water. The disks, which are made of high-density polystyrene or polyvinyl chloride (PVC), are partially submerged in the wastewater, so that a bacterial slime layer forms on their wetted surfaces. As the disks rotate, the bacteria are exposed alternately to waste-water, from which they adsorb organic matter, and to air, from which they absorb oxygen.

The rotary movement also allows excess bacteria to be removed from the surfaces of the disks and maintains a suspension of sloughed biological solids. A final clarifier is needed to remove sloughed solids. Organic matter is degraded by means of mechanisms similar to those operating in the trickling filters process. Partially submerged RBCs are used for carbonaceous BOD removal, combined carbon oxidation and nitrification, and nitrification of secondary effluents. Completely submerged RBCs are used for de-nitrification.

Membrane Bio-Reactor (MBR)

Lesjean and Gnirss (2006) investigated grey water treatment with a membrane bioreactor operated at low Sludge Retention Time (SRT) and low Hydraulic Retention Time (HRT). On the site of the Berlin-Stahnsdorf WWTP, ten private apartments and one office building are connected to *the sanitation concept for separate treatment* (SCST) scheme whereby urine, faecal matter and grey water are collected and stored separately.

The MBR unit was constantly fed over 8 months with fresh grey water coming from bathrooms and kitchens, after a buffer tank of maximum of 8 h retention, and was successively operated with 20, 9, 6 and 4 days sludge age. Due to the very short HRT, the sludge concentration was maintained in the approximate range of 10 g to 2 g MLSS/L

The COD is well eliminated (>85% COD-removal), and ammonification and nitrification remained complete (>80% TKN-removal), even with the lower sludge age. However, the nitrification rates were relatively low (<0.7 mgNNH 3/g VSS. h), and nitrogen removal was inconsistent and ranged from 20 to 80%, due to the presence of nitrate in the permeate. Indeed, the main elimination mechanism was bio-assimilation for cell growth, and therefore the removal rate depended strongly on the grey water characteristics (both COD and TN).

A modular MBR plant was installed at CanTho University to treat the heavily loaded grey water from a dormitory of the CanTho University (grey water from kitchens, showers, and hand wash basins). All effluent values met the standards specified for the reuse of treated water for toilet flushing and laundry washing. Also the microbial quality requirements according to Vietnamese standards for irrigation are easily met.

Chemical Precipitation

Chemical coagulation of raw wastewater before sedimentation promotes the flocculation of finely divided solids into more readily settleable flocs, thereby enhancing the efficiency of suspended solid, BOD and phosphorus removal is high as compared to plain sedimentation without coagulation. The degree of clarification obtained depends on the quantity of chemicals used and the care with which the process is controlled. Coagulant selection for enhanced sedimentation is based on performance, reliability and cost.

Table 8: Removal Efficiency of Plain Sedimentation with Chemical Precipitation

Parameter	**Percentage removal**	
	Plain sedimentation	**Chemical precipitation**
Total suspended solids (TSS)	40-90	60-90
BOD	25-40	40-70
COD		30-60
Phosphorus	5-10	70-90
Bacteria loadings	50-60	80-90

Performance evaluation uses jar tests of the actual wastewater to determine dosages and effectiveness. Chemical coagulants that are commonly used in wastewater treatment include alum (Al2(SO4)3.14.3 H2O), ferric chloride (FeCl3.6H2O), ferric sulfate (Fe2(SO4)3), ferrous sulfate (FeSO4.7H2O) and lime (Ca(OH)2). Organic poly electrolytes are sometimes used as flocculation aids. Suspended solids removal through chemical treatment involves a series of three unit operations rapid mixing, flocculation and settling. First, the chemical is added and completely dispersed throughout the wastewater by rapid mixing for 20-30 seconds in a basin with a turbine mixer. Coagulated particles are then brought together via flocculation by mechanically inducing velocity gradients within the liquid. Flocculation takes 15 to 30 minutes in a basin containing turbine or paddle-type mixers. The final step is clarification by gravity. The overflow rates are more consistent. On the other hand, coagulation results in a larger mass of primary sludge that is often more difficult to thicken and dewater. It also entails higher operational costs and demands greater attention on the part of the operator.

Sand Filter

A sand bed filter is a kind of depth filter. Broadly, there are two types of filter for separating particulate solids from fluids:

- Surface filters, where particulates are captured on a permeable surface
- Depth filters, where particulates are captured within a porous body of material.

There are several kinds of sand filters, some employing fibrous material and others employing granular materials. Sand bed filters are an example of a granular loose media depth filter. They are usually used to separate small amounts (<10 parts per million or <10 g per cubic metre) of fine solids (<100 micrometres) from aqueous solutions. In addition, they are usually used to purify the fluid rather than capture the solids as a valuable material. Therefore they find most of their uses in liquid effluent (wastewater) treatment.

The particulate solids can be prevented from being captured by surface charge repulsion if the surface charge of the sand is of the same sign (positive or negative) as that of the particulate solid. Furthermore, it is possible to dislodge captured particulates although they may be re-captured at a greater depth within the bed. Finally, a sand grain that is already contaminated with particulate solids may become more attractive or repel additional particulate solids. This can occur if by adhering to the sand grain the particulate loses surface charge and becomes attractive to additional particulates or the opposite and surface charge is retained repelling further particulates from the sand grain.

In some applications it is necessary to pre-treat the effluent flowing into a sand bed to ensure that the particulate solids can be captured. This can be achieved by one of several methods:

- Adjusting the surface charge on the particles and the sand by changing the pH
- Coagulation – adding small, highly charged cations (aluminium 3+ or calcium 2+ are usually used)
- Flocculation – adding small amounts of charge polymer chains which either form a bridge between the particulate solids (making them bigger) or between the particulate solids and the sand.

The sand filter can be operated either with upward flowing fluids or downward flowing fluids, the latter being much more usual. For downward flowing devices the fluid can flow under pressure or by gravity alone. Pressure sand bed filters tend to be used in industrial applications and often referred to as rapid sand bed filters. Gravity fed units are used in water purification especially drinking water and these filters have found wide use in developing countries (slow sand filters).

The treatment methods are used extensively in the water industry throughout the world. The slow sand filters can produce very high quality water free from pathogens, taste and odour without the need for chemical aids. Passing flocculated water through a rapid gravity sand filter strains out the floc and the particles trapped within it reducing numbers of bacteria and removing most of the solids. The medium of the filter is sand of varying grades. Where taste and odour may be a problem (organoleptic impacts), the sand filter may include a layer of activated carbon to remove such taste and odour.

Sand filters become clogged with floc after a period in use and they are then backwashed or pressure washed to remove the floc. This backwash water is run into settling tanks so that the floc can settle out and it is then disposed of as waste material. The supernatant water is then run back into the treatment process or disposed off as a waste water stream. In some countries the sludge may be used as a soil conditioner. Inadequate filter maintenance has been the cause of occasional drinking water contamination.

Sand filters are occasionally used in the treatment of sewage as a final polishing stage. In these filters the sand traps, residual suspended material and bacteria provides a physical matrix for bacterial decomposition of nitrogenous material, including ammonia and nitrates, into nitrogen gas.

Adsorption with Activated Carbon

Adsorption is the process of collecting soluble substances within a solution on a suitable interface. In wastewater treatment, adsorption with activated carbon-a solid interface-usually follows normal biological treatment, and is aimed at removing a portion of the remaining dissolved organic matter. Particulate matter present in the water may also be removed. Activated carbon is produced by heating char to a high temperature and then activating it by exposure to an oxidizing gas at high temperature. The gas develops a porous structure in the char and thus creates a large internal surface area. The activated char can then be separated into various sizes with different adsorption capacities. The two most common types of activated carbon are granular activated carbon (GAC), which has a diameter greater than 0.1 mm, and powdered activated carbon (PAC), which has a diameter of less than 200 mesh. A fixed-bed column is often used to bring the wastewater into contact with GAC. The water is applied to the top of the column and withdrawn from the bottom, while the carbon is held in place. Backwashing and surface washing are applied to limit head loss build-up. Expanded-bed and moving-bed carbon contactors have been developed to overcome the problem of head loss build-up. In the expanded-bed system, the influent is introduced at the bottom of the column and is allowed to expand. In the moving-bed system, spent carbon is continuously replaced with fresh carbon. Spent granular carbon can be regenerated by removal of the adsorbed organic matter from its surface through oxidation in a furnace. The capacity of the regenerated carbon is slightly less than that of the virgin carbon. Waste-water treatment using PAC involves the addition of the powder directly to the biological treatment effluent or the physiochemical treatment process, as the case may be. PAC is usually added to wastewater in a contacting basin for a certain length of time. It is then allowed to settle to the bottom of the tank and removed. Removal of the powdered carbon may be facilitated by the addition of polyelectrolyte coagulants or filtration through granular-medium filters. A major problem with the use of powdered activated carbon is that the methodology for its regeneration is not well defined.

Disinfection

Disinfection refers to the selective destruction of disease-causing micro-organisms. This process is of importance in wastewater treatment owing to the nature of wastewater, which harbours a number of human enteric organisms that are associated with various waterborne diseases. Commonly used means of disinfection include the following:

(i) Physical agents such as heat and light

(ii) Mechanical means such as screening, sedimentation and filtration

(iii) Radiation, mainly gamma rays

(iv) Chemical agents including chlorine and its compounds, bromine, iodine, ozone, phenol and phenolic compounds, alcohols, heavy metals, dyes, soaps and synthetic detergents, quaternary ammonium compounds, hydrogen peroxide, and various alkalis and acids.

Table 9: Characteristics of Disinfection Chemicals

Characteristic	Chlorine	Sodium hypochlorite	Calcium hypochlorite	Chlorine dioxide	Bromine chloride	Ozone	Ultraviolet light
Chemical formula	Cl2	NaOCl	Ca(OCl)2	ClO2	BrCl	O3	N/A
Form	Liquid, gas	Solution	Powder, pellets or 1 percent solution	Gas	Liquid	Gas	UV energy
Toxicity to micro-organisms	High	High	High	High	High	High	High
Solubility	Slight	High	High	High	Slight	High	N/A
Stability	Stable	Slightly unstable	Relatively stable	Unstable	Slightly unstable	Unstable,	Must be generated as used
Toxicity to higher forms of life	Highly toxic	Toxic	Toxic	Toxic	Toxic	Toxic	Toxic
Effect at ambient temperature	High	High	High	High	High	High	High
Penetration	High	High	High	High	High	High	Moderate
Corrosiveness	Highly corrosive	Corrosive	Corrosive	Highly corrosive	Corrosive	Highly corrosive	N/A
Deodorizing ability	High	Moderate	Moderate	High	Moderate	High	None
Availability/cost	Low cost	Low cost	Low cost	Low cost	Low cost	high cost	high cost

The most common chemical disinfectants are the oxidizing chemicals, and of these, chlorine is the most widely used for altering the cell permeability, altering the colloidal nature of the protoplasm and inhibiting enzyme activity. In applying disinfecting agents, several factors need to be considered: contact time, concentration and type of chemical agent, intensity and nature of physical agent, temperature, number of organisms, and nature of suspending liquid. Table 9 shows the most commonly used disinfectants and their effectiveness.

Table 10: Treatment Systems and its Applications

Categories	Treatment system	Advantages	Disadvantages	Reuse option
Treatment for low quality reuse	Constructed Wetland Treatment System. Horizontal Combined Bio-Fixed Film with Aquatic Plants, Off-Site Constructed Wetlands, Subsurface Wetlands. Floating Aquatic Macrophytes	Simplicity. These systems are simple to construct. Low cost. Cost-effective and environmentally friendly treatment High efficiency. They provide effective and reliable wastewater treatment under fluctuating hydraulic and contaminant loading rates. They require little or no energy to operate They can be aesthetically pleasing additions to homes and neighborhoods. They are viewed as an environmentally friendly technology and are generally well received by the public.	High land area requirements (depending on the design, they may require a relatively large land area compared to a conventional facility), the need for a preliminary treatment before the wastewaters treated by the system, the need of higher retention time, and that they may cause problems with pests. Nutrient-rich waters flowing into a water body may lose some of their nutrient load when passing through wetland vegetation. This means that constructed wetlands may and should be integrated into management plans for conservation of both soil and water resources of a watershed, or integrated as parts of major restoration projects. The performance of wetlands may vary based on usage and climatic conditions. There may be a prolonged initial start-up period before vegetation is adequately established	Reuse of treated wastewater for irrigation and/or other purposes
	Waste stabilization pond	Low cost for construction and O&M, simple operation and maintenance, less skilled labour required Since it is constructed in large area the dilution with rainwater will help the treatment	High Land requirement Quality of effluent will vary in terms of suspended solids Odour problem persists	Reuse of treated wastewater for irrigation and/or other purposes

Treatment for medium reuse	Anaerobic treatment process	Less energy required Less biological sludge produced Lower nutrient demand Methane production: Providing potential energy source with possible revenue both from sale of the energy, and benefit from government tax, and (Kyoto agreement) CDM etc. Methane production: Anaerobic digestion contributes to reducing greenhouse gases by reducing demand for fossil fuels. Smaller reactor volume required. Biomass acclimatization allows most organic compounds to be transformed Rapid response to substrate addition after long periods without feeding End product can be potentially saleable products like biogas, soil conditioner and a liquid fertilizer. Process more effectively provides sanitation/removal of diseases.	Longer start-up time to develop necessary biomass inventory Requires alkalinity and/or specific ion addition Requires further treatment with an aerobic treatment process to meet discharge requirements Biological nitrogen and phosphorus removal is not possible Much more sensitive to the adverse effect of lower temperatures on reaction rates May need heating (often by utilisation of process gas) to achieve adequate reaction rates Hazards arise from leak.	Reuse of treated wastewater for toilet flushing, gardening and/or other purposes
	Activated-sludge process	Can be used in different sizes. Removes organics Oxidation and Nitrification achieved Biological nitrification without adding chemicals Biological Phosphorus removal and Solids/ Liquids separation Stabilization of sludge and Capable of removing ~ 97%	Does not remove color from industrial wastes and may increase the color through formation of highly colored intermediates through oxidation Does not remove nutrients, tertiary treatment is necessary Problem of getting well settled sludge Recycle biomass keeps high biomass, concentration in aeration tanks allowing it to	Reuse of treated wastewater for Toilet flushing, gardening and/or other purposes

		of suspended solids The most widely used wastewater treatment process	be performed in technologically acceptable detention times	
	Aerated lagoons	Require less land than facultative lagoons. Require much less land than facultative ponds, depending on the design conditions. Sludge disposal may be necessary but the quantity will be relatively small compared to other secondary treatment processes.	Aerated lagoons are not as effective as facultative ponds in removing ammonia nitrogen or phosphorous, unless designed for nitrification. Changes in pH and alkalinity that affect removal rates for ammonia nitrogen and phosphorous in facultative ponds do not occur in aerated ponds. Reduced rates of biological activity occur during cold weather. Mosquito and similar insect vectors can be a problem if vegetation on the dikes is not properly maintained. Sludge accumulation rates will be higher in cold climates because low temperature inhibits anaerobic reactions and requires energy input.	Reuse of treated wastewater for toilet flushing, gardening and/or other purposes
	Trickling filters	Simple and reliable process that is suitable in areas where large tracts of land are not available for a WSP treatment system Effective in treating high concentrations of organic material depending on the type of media used; Very efficient in removal of ammonia from wastewater; Appropriate for small- to medium-sized communities With the introduction of plastic filter media to replace the rock media, speed control, and more reliable rotary distributor mechanisms, the performance of trickling filters has been greatly enhanced.	Additional treatment may be needed for the effluent to meet strict discharge standards Generates sludge that must be treated and disposed off and regular operators attention is needed; Relatively high incidence of clogging; Relatively low loadings required depending on the media. Limited flexibility and control in comparison with activated sludge processes.	Reuse of treated wastewater for toilet flushing, gardening and/or other purposes

		Ability to handle and recover from shock loads and relatively low power requirements. They produce less sludge than suspended-growth systems. The sludge tends to settle well because it is compact and heavy. Level of skill and technical expertise needed to manage and operate the system is moderate The cost to operate a trickling filter is very low.	Potential for vector and odor problems	
	Rotating biological contactors	Short contact periods are required because of the large active surface They are capable of handling a wide range of flows Sloughed biomass generally has good settling characteristics and can easily be separated from waste stream Operating costs are low because little skill is required in plant operation Short retention time Low power requirements Elimination of the channeling to which conventional percolators are susceptible Low sludge production and excellent process control	Requirement for covering RBC units in northern climates to protect against freezing Shaft bearings and mechanical drive units require frequent maintenance	Reuse of treated wastewater for toilet flushing, gardening and/or other purposes
Treatment for high quality reuse	Chemical treatment	Easy to control the treatment. Less land required, less capital cost, alteration in flow can be done.	High operation cost. Hazardous sludge produced. Requires skilled manpower	
	Adsorption by activated carbon	Removes dissolved organics and chlorine effectively. Long life (high capacity)	Does not effectively remove particles, pyrogens or bacteria. Coarbon beds can generate fine carbon particles. High maintenance costs over long-term.	
	Reverse osmosis	Effectively removes all types of contaminants to some extent (particles, pyrogens, microorganisms, colloids and	Flow rates are usually limited to a certain gallons/day rating.	

		dissolved inorganics). Requires minimal maintenance and very effective to remove pharmaceutical contaminants almost completely	The small pores in the membrane of a RO plant cannot block dangerous chemicals like pesticides herbicides, and chlorine. In order to remove them, carbon filter has to be used as a complimentary measure. It ends up removing the healthy, naturally occurring minerals (trace minerals) present in the water as well. RO proves to be a very slow option.	
	Ozonation and advanced oxidation processes	Eliminates odors, reduces oxygen demanding matter, turbidity and surfactants, removes most colors, phenolics and cyanides, increases dissolved oxygen, production of no significant toxic side products, increases suspended solids reduction	High capital cost, high electric consumption, highly corrosive, especially with steel or iron.	

5.1 Case Studies

5.2 Sullage Recycle System at Panchgani

Ion Exchange India is operating a sullage recycle system at its training centre in Panchgani, at a capacity of 1,800 litres per day. In the recycling process, sullage from the kitchens and bathrooms is collected in an underground RCC tank where the water is treated by coagulation, filtration and disinfection, and then pumped to the overhead tank from which it is supplied for low-end uses. The treated water is used for toilet flushing and gardening. Simple construction and affordable capital costs make it easy for both new and existing buildings to go in for the system and the payback can be in as little as 15 to 18 months. The company has also installed a sullage recycle plant, capacity 5 cu.m per hour, for a large residential complex at Vasai, near Mumbai; beautiful gardens are now maintained in an otherwise water-stressed area (Ramachandran, 2002).

5.3 Greywater for Irrigation in Chennai

Finding water for gardening in Chennai has been a difficult proposition in recent years with dipping ground water levels and the increasing demand for drinking water. Chennai Corporation recently launched a drive to source recycled grey water for watering avenue trees and plants in parks and for other gardening purposes. Several residents in the city have started turning to grey water to meet their gardening needs. The local body recommends a simple two stage recycling technique which includes creating a primary treatment pit consisting of charcoal and blue metal (which is used for construction) and a secondary pit that will just hold the water and help settle some of the smaller impurities. The outlet of water from kitchen and bathroom needs to be diverted to the primary pit. It would of course be best if a separate pipeline is created for grey water from kitchen and bathrooms to the treatment pits at the time of construction itself.

5.4 Greywater Treatment Plants in Ashram Schools, Madhya Pradesh

Dhar and Jhabua are two districts of Madhya Pradesh which suffer recurrent water quantity and quality problems. Lack of water is major reason for low sanitation coverage in schools. In many residential schools in Dhar and Jhabua districts, limited availability of freshwater has prompted UNICEF, in collaboration with NEERI and other governmental and non-governmental partners, to explore the use of grey water for appropriate purposes such as flushing of toilets. A holistic water management is adopted in these schools by integrating different water usages and corresponding quality requirements. It has been found out in Ashram schools that water requirement is about 60-70 litre per student per day as against drinking/cooking water requirement of 5 litre per day. The grey water treatment plants have been constructed by providing treatment techniques such as screening, equalization, settling, filtration and aeration. This simple treatment has resulted in enabling use of treated grey water in flushing the toilets.

UNICEF and NEERI along with government and non-government partners have constructed six grey water treatment plants at tribal schools in Dhar and Jhabua districts. The purpose of the plants was to make water available to flush toilets, to improve sanitation, to use treated grey water for gardening and for floor washing. The operation and maintenance of these grey water treatment plants are looked after by students and Parent Teachers Association (PTA). Performance evaluation of grey water treatment plant was undertaken by NEERI by collecting samples from the treatment plants. The turbidity removal efficiency of 50% (<200 NTU) is observed in all the grey water treatment plants. Considering direct correlation between turbidity and microorganism, it can be stated that microbial removal efficiency of these grey water treatment plants is also approximately 50%.

The Cost Benefit Analysis study conducted by NEERI concluded that the cost of the system may be recovered in two years. Additionally, the system provides secondary benefit such as improved education, clean environment and time-gain for other activities. Indirect economical benefits are also there. This is a classic example of how a simple application of grey water reuse system can be of tremendous economic benefit and viable on such a micro-level.

5.5 Greywater Recycling System at Hotels in Kerala

There are some hotels in Kerala that treat and reuse greywater. The grey water is let through a multi stage low maintenance system to treat it and recycle it for flushing, gardening and other non-potable end uses. The stages of treatment are given below:

Greywater→ Grease traps (for removal of fat and grease) → Anaerobic filters (for partial BOD removal)→ Submersible pump chamber →Constructed wetlands (for BOD reduction to 30 mg/l)→ Polishing pond (for BOD removal to 0 mg/l)→ Online chlorination (for disinfection)→ Overhead tank for flushing /gardening.

The wastewater from the bathrooms, kitchen and wash areas of cottages and kitchen block is first led to grease traps for removing grease and fat. After the grease trap, the grey water is directed to upflow filters for removal of solid particles and also for partial BOD reduction due to anaerobic action. The effluent from the filter is pumped to multi-stage constructed wetlands /reed beds at the top of the mount. The treated effluent is collected in a polishing pond, where the final polishing and BOD removal is effected mainly by water plants like duck weed. This water is chlorinated and pumped to the overhead tank for flushing, gardening and other non-potable end uses.

5.6 Greywater Tower Demonstration Project in Kitgum Town Council, Uganda

A greywater demonstration project in peri-urban settlements of Kitgum, Uganda, initiated by Resource-Oriented Sanitation Concepts for Peri-urban Areas in Africa (ROSA), built and trained families to use greywater-irrigated tower planters. According to a baseline study conducted by ROSA before implementing the project, greywater was most often disposed of in Kitgum by dumping the untreated wastewater onto the ground or into storm-drains, resulting in pools of water that developed a foul odor, facilitated mosquito breeding, and presented adverse community health outcomes. Despite water shortages in the area, greywater was not being reused (Kulabako et al. 2009).

Fig 19: Grey water tower

Seven households were selected to participate in the demonstration project, representing households from low, middle and upper classes. At each household, three “greywater towers” were built. Greywater towers are columns of soil wrapped in a cloth and supported by stakes, with an inner core of stones. Plants grow sideways out of the tower through cuts in the cloth, and greywater is poured into the core of stones from top of the tower to irrigate the plants (Crosby 2005).This technology was selected because it could be constructed with local materials, is easy to operate and maintain, and can grow food on a small area of land (Kulabako et al. 2009).

Households were trained on how to use the greywater tower effectively, and how to maintain it. At one household a control tower was set up to determine if irrigation with greywater negatively impacted plant growth. This tower was built in the same way as the others, but was irrigated with groundwater rather than greywater. Greywater quality, the amount of greywater produced, and effects on plants were then studied for 6 months (Kulabako et al. 2009).

Overall, the demonstration projects worked well, and showed that plants irrigated with greywater generally performed comparably to those irrigated with groundwater (Kulabako et al. 2009). Interviews with community members indicated wide community awareness and interest in the greywater towers. Furthermore, a walk-through of the area after 6 months revealed that 15 additional households had built and started using greywater towers, and additional households had set up other types of gardens irrigated by greywater (Kulabako et al. 2009).

5.7 Greywater Reuse in Norway

At Klosterenga in Oslo, the capital of Norway, the grey water is treated in an advanced nature based on grey water treatment system in the courtyard of the building. The system consists of a septic tank, pumping to a vertical down-flow single pass aerobic biofilter followed by a subsurface horizontal-flow porous media filter. The Klosterenga system built in 2000 has consistently produced an effluent quality averaging to: COD -19 mg/l, Total nitrogen - 2.5 mg/l, Total phosphorus - 0.03 mg/l and no Faecal coliforms.

The total area requirement is $1m^2$/ person and the effluent meets European Swimming Water Standards with respect to indicator bacteria and WHO Drinking Water Standards with respect to nitrogen. The low area requirement of the system and the high effluent quality facilitates use in urban settings, discharge to small streams, open waterways or irrigation or groundwater recharge (Jenssen 2003).

6.1 Policies and Regulation

6.2 Overview of Greywater Policies, Regulations and Laws around the World

Studying the international scenario, one could see diversity in the approaches to and stringency of greywater regulations, from being legal with few restrictions, to being prohibited in all circumstances (Prathapar et al.,CSBE 2003). Also there are places without clear policies on greywater, where its use may instead be indirectly regulated by building, plumbing, or health codes written without consideration of greywater reuse. For example, a country may have wastewater regulations that do not distinguish between black and greywater, e.g. Oman, Jordan (Maimon et al. 2010), or have a plumbing code that prohibits discharge of non-potable water through outlets such as faucets, such as in Canada"s National Plumbing Code (CMHC 1998).

Greywater reuse is illegal in some Middle Eastern countries, and regarding greywater regulation in Oman, Prathapar et al. (2005) note, "At present, Omani wastewater reuse standards do not distinguish between greywater and blackwater and require that greywater be treated to the standards of potable water. However, there are many households and mosques in Oman (and many parts of the world) that use untreated greywater for home irrigation. In principle such uses are illegal, but the bottom line is that unrealistic laws have poor participation rates." Nevertheless, greywater use is growing, even in regions with laws restricting greywater use and those with no explicit policies regarding greywater. For example, Sheikh estimates that only about 0.01% of greywater systems in California are permitted (2010). It has also been documented that greywater reuse occurs in households in the Middle East regardless of its legality (McIlwaine 2010). Similarly, recognizing that using wastewater for irrigation is a reality in many middle and low-income countries, the World Health Organization has established guidelines to help ensure the safety of wastewater reuse, including greywater reuse, for irrigation.

Further, in his work on greywater use in the Middle East, McIlwaine notes that no country in the Middle East and North African region has "developed a clear approach to its use that clearly states the responsibilities of the users and the regulatory requirements" (McIlwaine 2010). Jordan passed a standard in 2006 regarding greywater reuse in rural areas, however the code does not fully clarify what households must do to be permitted to reuse greywater (McIlwaine 2010). Israel is expected to soon pass a law that would legalize greywater reuse from showers, bathroom sinks, and washing machines outdoors for landscaping and indoors for toilet flushing (Global Water Intelligence 2010).

Australia is often considered to be a leader with respect to greywater policies. Specific regulations and requirements vary by state. For example in New South Wales, untreated greywater can be used for subsurface irrigation (NSW Office of Water 2010), while in Tasmania, all greywater must be treated before reuse (Tasmanian Environment Centre Inc. 2009). At the national level, Australia has developed guidelines for greywater reuse, "*Australian Guidelines for Water Recycling: Managing Health and Environmental Risks,"* and reuse is encouraged through a program that offers $500 rebate for the installation of a greywater system (Australian Government). Several other countries also have incentive programs for installation of greywater systems, including Korea and Cyprus (CWWA 2002, CSBE 2003). In Tokyo, Japan, not only are there incentives for installing greywater systems, but they are mandatory for buildings with an area of over 30,000 square meters, or with a potential to reuse 100 cubic meters per day (CSBE 2003). Several municipalities of Spain, including Sant Cugat del Vallès near Barcelona and several other municipalities in Catalonia, have passed regulations to promote greywater reuse in multistory buildings (Domenech and Sauri 2010).

The European Council Directive 91/271/EEC states that "treated wastewater shall be reused whenever appropriate," However, how to determine if it is appropriate is left ambiguous (Somogyi et al. 2009). Greywater standards are currently under development through the European and International Standards Committees (Anglian Water). Germany has been a leader in Europe in the use of greywater (Nolde, Regulatory Framework and Standards). Domestic greywater reuse systems are legal in Germany, but must be registered with the Health Office (Nolde 2005). The United Kingdom has conducted research into greywater reuse, particularly for toilet reuse, noting a number of problems with maintenance, reliability and costs of these more complex systems (CSBE 2003), and greywater systems are not in wide usage (UK Environment Agency 2008). However, it is legal, provided that it complies with certain building codes and the British Standards Greywater Systems Code of Practice. Sweden and Norway have also done research into greywater and have implemented systems in some student dormitories and apartment buildings (Jenssen 2008). Much of this research has been situated in research into ecological sanitation more broadly, including urine separation (Esrey et al. 1998). With regard to greywater policy in North America, a 2002 report by the Canadian Water Works Association concluded: "traditional regulatory practices prohibiting rainwater harvesting or greywater reuse as substitutes for potable water supply are changing…However, there is a marked reluctance on the part of most jurisdictions in North America to consider these options (CWWA 2002)."

The United States does not have a National Greywater Policy, leaving regulation of greywater to the states. About 30 of the 50 states have greywater regulations of some kind (Sheikh 2010). These regulations vary widely. North Carolina has stringent greywater regulations and only allows reuse of water if it is treated to the same standards that are required for treating sewage water (Sheikh 2010). The state of Arizona has a more flexible greywater policy than many states, and is often seen as a leader in terms of promotion of greywater reuse in the United States.

6.3 Existing Infrastructure

Reuse of greywater requires separating greywater from sewage water, which is not standard plumbing practice in many countries, and therefore requires plumbing retrofits. The difficulty and expense of this retrofit varies widely, depending on the building and complexity of the system (e.g., how many collection points the system will have). For example, in Jordan most houses are constructed of reinforced concrete with pipes cast into floor slabs, making greywater plumbing retrofits difficult and expensive (CSBE 2003). On a larger scale, widespread diversion of greywater could potentially be disruptive to wastewater collection and treatment, as a lower volume of wastewater would be diverted for treatment, and it would contain a higher concentration of contaminants and solids. In pipes with low slopes, this could potentially lead to insufficient flows in sewers to carry waste to the treatment plant (CSBE 2003). Sheikh notes that "as greywater reuse becomes more widespread, it may interfere enough with the operation of sewers and water reclamation facilities to engender legal or legislative action" (Sheikh 2010). On the other hand, some conventional sewers, particularly those that combine storm runoff and municipal sewage, are prone to overflowing. In these cases, greywater reuse can reduce the risk of sewage overflows (Bertrand et al. 2008). Because of these conflicts with existing infrastructure, large scale (i.e., community-wide) greywater reuse may be most feasible for areas without extensive existing water and wastewater infrastructure. While it does not specifically address sanitation, and thus would always need to be implemented in conjunction with sanitation systems, it can reduce loads on septic systems and other decentralized sewage treatment techniques.

6.3. Planning and Plumbing Codes

In addition, greater use of greywater can conflict with established planning and plumbing codes. For instance, the International Association of Plumbing and Mechanical Officials (IAPMO) is an industry group that creates uniform code that plumbers and planners refer to around the world. The most recent 2006 Uniform Code Manual has a section on greywater (Chapter 16, Part 1). The chapter states clearly that a permit is necessary for any greywater system to be installed and it only describes greywater systems that collect and store greywater for outdoor, subsurface irrigation. It does not address diversion systems, a more common and less costly option. In the American Southwest, states and municipalities are increasingly amending their codes to allow small greywater systems (including diversion systems) to be installed without a permit (e.g., Arizona‟s greywater code and California‟s new greywater code). On the other hand, some new green building standards provide incentives for greywater reuse.

The LEED (Leadership in Energy and Environment Design) Green Building Rating System was devised as a voluntary standard for developing high-performance, sustainable buildings. LEED was initially created by the U.S. Green Building Council to establish a common measurement to define "green building." Since its inception in 1998, LEED has grown to encompass more than 14,000 projects in the United States and 30 other countries (citation LEED for existing buildings v2.0 reference guide page pg 11). On average, a LEED certified building uses 30% less water than a conventional building. Projects receive points for each "green" practice that they implement. In LEED 2009, there are 100 possible base points. Buildings can qualify for four levels of certification: LEED Certified -40 - 49 points; Silver - 50 - 59 points; Gold - 60 - 79 points; and Platinum - 80 points and above.

Greywater reuse can earn a significant number of LEED points across several categories: Water Use Reduction: 20% Reduction – 1 point.

o 20% reduction in water use for building using alternative on-site sources of water such as rainwater, stormwater, and greywater

• Water Efficient Landscaping, No Potable Water Use or No Irrigation - 2 points

o Use only captured rainwater, recycled wastewater, or recycled greywater for site irrigation.

• Innovative Wastewater Technologies – 2 points

o Reduce generation of wastewater and potable water demand, while increasing the local aquifer recharge – use captured rainwater or recycled greywater to flush toilets and urinals or treat 50% of wastewater on-site to tertiary standards.

• Water Use Reduction, 30% - 40% reduction – 2-4 points

o Maximize water efficiency within building to reduce the burden on municipal water supply and wastewater systems. Use alternative on-site sources of water such as rainwater, stormwater, and greywater for non-potable applications such as toilet flushing and urinal flushing.

7.1 STRATEGY AND FRAMEWORK FOR GREYWATER REUSE

7.2 Need for strategy and framework

The two contemporary urban issues, viz., scarcity of freshwater and the increase in urban wastewater generation emphasize the need for grey water recycle and reuse. As already elaborated in the previous paragraphs, greywater is a potential substitute for freshwater for a variety of uses, both domestic and industrial. Once the wasted greywater is captured and reused, the demand for potable water will substantially decrease. Also the effort and money spent on waste water management could be considerably reduced. The other benefits of greywater reuse have also been discussed in the previous sections. It is a positive factor that with every increase in the use of water, the volume of greywater also will increase and the greywater is a nascent low cost substitute for domestic, commercial and industrial uses.

Fast growing urban population, changing housing patterns, inadequacy of freshwater sources against the ever growing demand, unscientific wastewater disposal practices, lack of public awareness, etc., exert pressures on the water supply and sanitation system. However, wastewater treatment and reuse has not become vogue in India as in the case of majority of countries in the world. Recently in India, some efforts in this line have been initiated for wastewater recycle and reuse to address the water scarcity. The recycled wastewater is being utilized in many industries and other organizations for uses other than potable purposes. It is high time especially for the major cities in India to implement proper wastewater management. Wastewater management strategy should essentially focus on greywater reuse in view of its latent capability to reduce the volume of wastewater to be treated with expensive treatment methods. Greywater reuse is nothing but water conservation and is capable of reducing the impact of development of new water sources.

In order to effectuate water conservation through reuse, a strategic implementation plan has to be developed. Since waste water reuse demands change of mindset and change of behavioural patterns in water use, the initiative should pervade through all sections of the urban population and should stabilize through stages of evolution. The approach for greywater reuse should premise on the following basic principles:

- Acceptable levels of treatment.
- Requiring low capital investment.

- Requiring minimum operation and maintenance and low costs.
- Requiring less-skilled operator knowledge
- Potential of having longer life-cycles

The ultimate goals of wastewater recycle/ reuse will be:

i. The quantum of wastewater subjected to expensive treatment methods is reduced thereby reducing the pressure on sewage disposal.
ii. The wastewater treated and reused can supplement the water consumption and preserve water for future.
iii. Reduce the overall user-demand for fresh water resources
iv. Facilitate the recovery of nutrient and water resources for reuse in agricultural production, irrigation of municipal greenbelts/parks and maintenance of other landscape amenities, and
v. To reduce the pathogenic risk inherent to wastewater pollution.

In order In order to achieve this goal, a strategy and framework has to be developed for greywater reuse. The main aspect of the strategy will be a synchronized regulatory framework for greywater reuse and a collectively agreed approach for implementation. The stakeholders must have clarity on how the system can be implemented and what are the legal obligations and policy matters. The approach on greywater reuse through decentralized method should take care of the institutional barriers, financial constraints, technological limitations and public opposition. Due importance should be given to creating adequate institutional setting, establishing effective regulatory mechanism and ensuring sound community participation.

7.2. Concept and Strategy

The urban greywater management broadly involves three main aspects, (i) action at source level (generator level actions) for separating the grey water from black water (ii) applying the appropriate technological option/s for converting the grey water to reusable water, and (iii) the ULB initiatives to promote grey water reuse by awareness creation, setting regulatory framework and infrastructure development. In the urban scenario greywater is usually generated from the following sources:

- Domestic sources (Villas, apartments and hostels)
- Commercial establishments (Hotels, restaurants, shops, market stalls)
- Offices, Educational Institutions
- Service facilities (Hospitals, town halls, marriage halls)
- Industries (excluding industrial effluents)

A huge quantity of grey water is generated daily from these sources out of which a major portion could be reused for different purposes without treatment or with simple treatments. An archetypal sequential action for implementing a greywater reuse system in any urban body is given below.

i. Collecting the baseline Information: Information required for preparing a proper plan such as area, population, number of households, number of divisions (wards) of the ULB, number of zones/circles etc
ii. Collecting information relating to grey water: The activities involved are (i) identification of different types of grey water generating sources (ii) quantification survey to assess waste water generation at various sources and various locations/zones (iii) location mapping of waste

generation sources and potential reuse areas and (iv) physico-chemical analysis of grey water generated.

iii. Understanding the present scenario: This includes understanding the present actual reuse, the estimation of reuse potential, understanding the community perception about greywater reuse, availability and adequacy of facilities and staff and the present grey water disposal practices.

iv. Understanding the key issues: The issues generally observed in the context of grey water reuse are absence of separation from black water, separate plumbing for grey water, decentralized and centralized grey water reuse facilities and community/NGO/CBO partnership. The other issues are manpower inadequacy, weak institutional set-up, absence of financial planning, environmental and health issues, lack of awareness on the necessity of scientific grey water management including reuse, poor civic sense of the people, weak political will, inefficiency and lack of motivation of staff, absence of law and law enforcing mechanisms including national, state and ULB level policies etc.

v. A feasible management system which identifies and explains the sources that generate grey water, the internal and external plumbing requirements, treatment systems and the reuse or disposal mechanism. (see Fig 21)

vi. Evolving proper strategies for grey water reuse/management

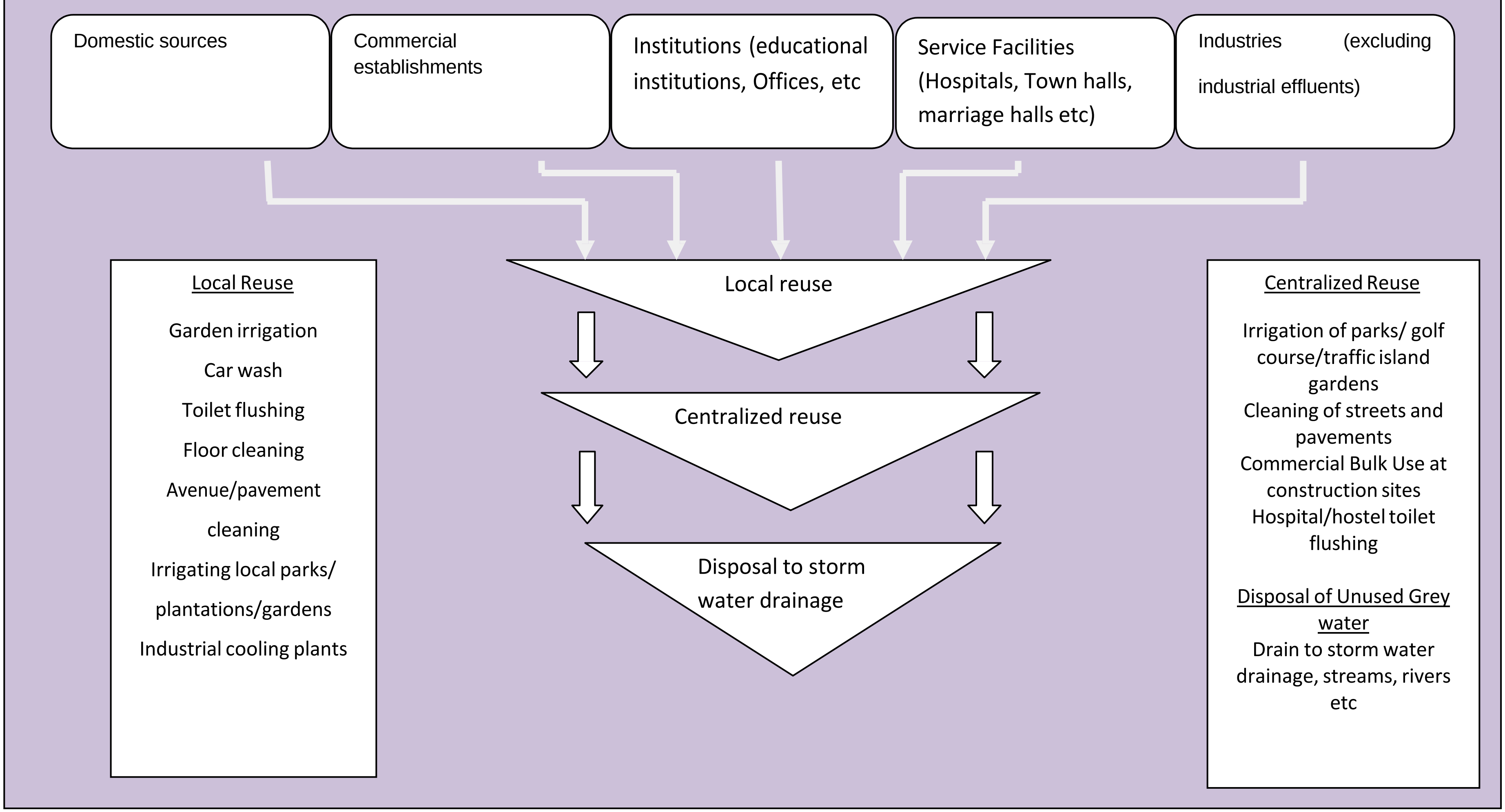
vii. Preparation of plan and cost estimates for additional infrastructure for grey water reuse. This can include treatment facilities, site profile and design approach, layout plan of proposed greywater treatment and reuse/disposal facility (including bulk supply of grey water for commercial/industrial uses etc)

viii. Capacity building and implementation of plan

ix. Operation and maintenance

x. Monitoring

Fig 20: Greywater Reuse Framework



7.3. Strategies for Greywater Reuse

Component	Strategy	Target	Responsibility
Separating grey water from black water	Separate plumbing to lead black water and grey water to different and distinct destinations	Cover all premises through awareness creation, motivation and subsequent enforcement wherever necessary.	Those who generate wastewater- individually by villas and collectively by apartments.
	Motivation for existing generators		Continued and organized motivation by ULB directly or through NGOs
	Motivation and legislation for new generators		Legislation and enforcement by ULB
	Incentives	Existing building owners and new builders	ULB can provide incentives
Initial Reuse	Initial Reuse without treatment - Adopt simple techniques like bucketing and gravity flow. Start with best quality grey water like rinse water from washing machine, bathroom water for car wash, garden irrigation etc.	Find out all possible reuse options in and around the premises	Those who generate wastewater
	Initial Reuse with treatment- Identification and application of the appropriate technology	Find out all possible reuse options in the locality and establish reuse system	Residents‟ Associations (RAs)
Technical support	Provide technical support to individual household level generators and bulk generators	Make available a package of treatment options suited for standard situations. Make available a technical team to provide field level support. Establish a call centre to ensure continued support.	ULB-directly or through competent agencies
Treatment technology selection	Determined by the quantity and quality of grey water, end use and preferences of users	Implementation of the treatment plan with design and cost estimates.	Generators/ULB. ULB should place prime importance for the selection and implementation of best available

			technology
Laying of pipe network to central treatment system	If full local utilization is not possible, grey water from all economically viable sources will be connected to central system.	Establish network from sources to the central system	ULB-Directly or through competent agencies
	All major grey water generating areas will be connected to the central system		
Grey water treatment	Local decentralized treatment plants at local/zonal level	Establishment of as many decentralized treatment plants as there are bulk generators	Bulk Generators
	Centralized treatment plants on need basis (for an area or for very large generators.)	Establishment of centralized treatment plant/s at ULB/ zone/ area level.	ULB
	Excess grey water after local reuse to the centralized treatment plants.		
	Advanced treatment if contamination level is high	Establish appropriate treatment plant	Generator/ULB
	Simple treatment when contamination level is low.	Establish appropriate treatment facilities	Generator
Disposal of treated water	Reuse good quality greywater without treatment to the extent possible.	Identify and establish reuse opportunities.	Generator/ULB
	Reuse of treated grey water based on reuse plan	Based on reuse plan in the following order of preference: (i) premises of the generator (ii) nearby locality (iii) Any other place (considering the cost and technical issues.)	Generator/ULB
	Disposal of excess treated water	After availing all reuse opportunities adopt one or	Generator/ULB

		more of the following disposal options: • To a soak pit for ground water recharge • To water bodies/ wetlands (swamp) ensuring PCB norms	PCB (quality checking)
Disposal of untreated grey water	Drain out to ground water recharge (GWR) structures/water bodies/ wetlands(swamp) when the water is of good quality which satisfy PCB norms	Construct soak pit. Construct GWR structures Provide conveyance to water body.	Generator/ULB PCB (quality checking)
	Drain out to local septic tank intended for sewage treatment or to sewerage system.	Provide suitable conveying system	Generator/ULB
		Establish septic tanks, if not available	Generator/ULB
		Create new sewerage system if not available or increase capacity of existing system, if needed.	ULB
Disposal of grey water from distant/ non-economical sources	Delink from decentralized/ centralized systems	To be locally treated and reused/ appropriately disposed off.	Generator
Safety mechanism	Facilitate easy distinguishing mechanism for pipes and fittings	Provide different colour pipes and fittings for fresh water, grey water, treated grey water and black water.	Govt/ULB to specify standard colours
	Facilitate easy repair and maintenance	Pipes and fittings should be installed enabling easy repair and maintenance	Govt can notify a plumbing code or manual
	Safe custody of related documents (plan, layout etc)	Assign responsibility of custodianship of water and waste water related documents, especially for large wastewater generators	Govt/ULB to assign responsibility. The assigned person to keep the documents
Implementation and O&M	Draw up a comprehensive plan for the ULB	Implement the plan	Generator ULB-Directly or through competent agencies

<table>
<tr><td>Central grey water distribution system</td><td>Distribution/supply of the treated grey water to the potential users.</td><td>Direct pipe line to major permanent users (like parks, bus depots, railway yards, industrial units, fire stations, turfs etc)

Tanker supply to temporary and small scale requirements)</td><td>ULB-Directly or through competent agencies</td></tr>
<tr><td>Documentation</td><td>Mapping of technical interventions

Data collection and record keeping of activities</td><td>Technical interventions like plumbing modifications, installation of new fixtures, establishment of treatment system etc should be documented by the parties responsible for future maintenance. Data collection and analysis should be continuous to facilitate future improvement. Data on the following are required:

1) Quantity of wastewater generated
2) Quality of wastewater generated
3) Cost of treatment
4) Cost involved in institutional setup
5) Quality and quantity of treated water
6) Types of end uses</td><td>Those who are responsible for O&M of the treatment and reuse system.</td></tr>
</table>

7.4 Framework for grey water reuse

Component	Technical/ technological aspects	Institutional/ Responsibility aspects	Financial aspects	Legal/Policy aspects	
				ULB	Wastewater generators
Source separation	Internal Plumbing	Generator	Cost to be borne by the generator ULB can fully or partly subsidize as incentive	Legislation	Adherence to rules
	External plumbing	Generator/Apartment owner/RA	do	do	do
Initial reuse	Establishment of pipeline to the use points; temporary storage (if needed)	Generator/Apartment owner/RA	do	do	do
Treatment technology selection	Determined by the quantity and quality of grey water, end use and preferences of users.	The wastewater generator has to select the service provider by in-house method or by outsourcing a competent agency. The ULBs can support the wastewater generators by identifying the capable wastewater treatment service providers/ agencies and fixing the rates for the treatment systems and operations.	The funds have to be borne by the wastewater generators. The ULBs can subsidize the cost in order to encourage wastewater reuse.	Since there is no legal provision for grey water treatment and reuse the ULBs may formulate a bye law for regulating the wastewater reuse	The wastewater generators can form an association/ society and develop a byelaw for wastewater reuse
Treatment	Establishment of treatment facility	Generator/Apartment owner/RA	Generator/Apartment owner/RA/ULB	Providing technical and institutional support	Adherence to rules

Reuse after treatment	Establishment of pipeline to the use points/disposal points	Generator/Apartment owner/RA/ULB	Generator/Apartment owner/RA/ULB	Do	do
Reuse method	The selected reuse point has to be identified. Establish supply lines to the reuse points. Provide coloured water line for greywater to avoid accidental interlinking	The wastewater generators or ULB as the case may be has to identify and monitor continuously and make arrangements if any problem arises The ULBs has to inspect the system periodically.	Capital expenditure to be met by ULB and operational cost to be met by users.	Since there is no legal provision for grey water treatment and reuse the ULB should issue guidelines	Vigilance in reuse operations

7.5 Roles and Responsibilities

Though many of the roles and responsibilities are already mentioned, the following specific responsibilities are also important for grey water treatment and reuse.

(1) Role of ULB

i. Procuring tankers for supply of grey water for temporary and short distance uses. The ULB can fix the plying schedule of vehicles. The distribution of treated grey water, maintenance of vehicles, collection of user fee (if levied) etc could be entrusted to outside agencies, if found necessary.

ii. Prescribe user fee for supply of grey water (initially this may be free but later when reuse becomes the common practice user fee can be levied)

iii. Maintenance of treatment systems owned by the ULB

iv. Monitoring of quality of grey water treated (whether reused or let out to water bodies)

v. Monitoring of overall activities

vi. Deployment of manpower

vii. Timely intervention at the time of emergency situations

(2) Role of NGOs/Residents' Associations

NGOs and Residents‟ Associations can play a vital role in grey water reuse. Some areas where they can effectively work are indicated below:

- Organizing neighbourhood groups (NHGs) and imparting motivational training for maintaining best practices
- Propagating the reuse concept
- Attempting local reuse initiatives

- Organizing training and equipping the local community for separating grey water from black water and reuse of grey water.
- Generating demand for grey water
- Transportation/sale of grey water for short term uses
- Collection of user fee (if applicable)
- Operation and maintenance of local treatment systems
- Discouraging use of highly polluting/ water contaminating items
- Organizing awareness creation/training programmes
- Establishing community vigilance system to ensure, sustain and improve the greywater management system.

(3) Role of Technical Resource Agency

Wastewater Management involves many complex technical / technological components. The ULB themselves may not be in a position to handle these components by themselves for which they may seek support from some Technical Resource Agency competent in the WWM area.

The National or State level Accredited Agencies in WWM sector / technical institutions like engineering colleges, NIT, IITs and other R&D institutions etc. working in the WW sector can be identified for this purpose. The Centres of Excellence of Ministry of Urban Development, Government of India like Centre for Environment and Development will be able to provide hand holding support to ULBs.

7.6 Transportation

The central treatment system will have a facility for transportation of treated grey water to sites of temporary uses. These may include construction sites (concrete mixing, curing, cleaning of machinery and utensils), dust control at streets, festival grounds, work sites, markets etc. Apart from the central treatment facility, major grey water generators also can be potential suppliers of grey water in tankers.

7.7 Man Power Requirement

- Plumbers - to be mobilized by NGOs/RAs etc
- Workers in treatment plants: Central treatment plant/s –to be mobilized by the ULB
- Workers in local treatment plants: Local treatment plant/s in apartments etc–to be mobilized by the generator institution
- Transportation vehicle drivers: to be mobilized by the ULB (or external agency, if transportation is entrusted to them)
- Supervisory and administrative staff of the ULB.
- Engineering staff.

7.8 Infrastructure requirements

- Internal and external plumbing
- Pipeline leading to Treatment System
- Tankers
- Local and Central Treatment Systems

- Distribution lines to permanent users.

7.9 Site Profile of Treatment Plants

- Identify the most suitable site (initial consultation with community will avoid future resistance).
- As far as possible avoid sites which is surrounded by residential settlements.
- Consider future requirements while finalizing the site.
- Site should be as close to the source as possible– in order to avoid the transportation cost.

7.10 IEC

The activities involved in grey water reuse demand volunteerism and public participation for its success. It is the public attitude and behaviour that are going to make the difference. A paradigm shift in the mindset of the civilian community and polity are essential to achieve public acceptance for grey water reuse. This could be achieved only through well conceived IEC Plan. Hence the IEC Plan on grey water reuse should focus on the following.

- Creating behavioural change and mindset favouring grey water reuse. This will include (i) change in water use pattern (ii) separating grey water from black water at source (iii) imbibing the civic responsibility of keeping the premises clean (iv) willingness to accept the civic responsibilities of citizens, and (v) willingness to part with the ad hoc approach of unscientific wastewater disposal.
- Awareness creation on the dangers of unscientific wastewater management. E.g., (i) health hazards (ii) aesthetic damage (iii) environmental degradation
- Awareness creation on the various technical and technological options for grey water treatment and reuse.
- Converting waste water, especially grey water, as a resource
- Scientific reuse/disposal of grey water at the nearest point of source. E.g., using grey water for toilet flushing, garden irrigation, vehicle washing etc.
- People‟s participation and cooperation at all stages
- Community adherence to rules, orders and directives.

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Abbreviations

BOD	Biological Oxygen Demand
CBO	Community Based Organization
CED	Centre for Environment and Development
CoE	Centre of Excellence
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CT	Confined Trench
DO	Dissolved Oxygen
FWS wetlands	Free Water Surface wetlands
GAC	Granular Activated Carbon
GDD	Greywater Diversion Devices
GWR	Ground Water Recharge
HRT	Hydraulic Retention Time
IAPMO	International Association of Plumbing and Mechanical Officials
IEC	Information, Education and Communication
IIT	Indian Institute of Technology
LEED	Leadership in Energy and Environment Design
MLD	Million litre per day
NEERI	National Environmental Engineering Research Institute
NGO	Non-governmental Organization
NHG	Neighbourhood Group
NIT	National Institute of Technology
NTU	Nephelometric Turbidity Unit
O&M	Operation & Maintenance
PAC	Powdered Activated Carbon
PCB	Pollution Control Board
PTA	Parent Teachers Association
PVC	Polyvinyl chloride
R&D	Research & Development
RA	Residents' Association
RBC	Rotating Biological Contractor
RCC	Reinforced Cement Concrete
RO	Reverse Osmosis
ROSA	Resource-Oriented Sanitation Concepts for Peri-urban Areas in Africa
SRT	Solids Retention Time
TA	Technical Assistant
TMC	Thiruvananthapuram Municipal Corporation
TSS	Total Suspended Solids
UASB	Upflow Anarobic Sludge Blanket
ULB	Urban Local Body
UNDP	United Nations Development Programme
WW	Wastewater
WWM	Wastewater Management

1.1 Introduction

The Ministry of Urban Development, Government of India has established a Centre of Excellence (CoE) on Solid Waste and Waste Water Management at Centre for Environment and Development .As part of this , CED has prepared a Strategy for Decentralised Wastewater Management mainly focusing on Grey water Recycle and Reuse, in addition to the Solid Waste Management component.

The major objectives of the Waste water Management component under CoE of CED are:

(i) To formulate strategy and methodology for Wastewater Management including development of framework for wastewater recycle and reuse in urban areas

(ii) To prepare capacity building and training strategies for urban local bodies

(iii) To function as Knowledge Hub in the area of Wastewater Management.

1.2 Significance of Wastewater Reuse

The significance of wastewater management is premised on two basic urban issues – (i) the essentiality of safe and scientific management of wastewater for achieving health and hygiene in the urban environment, and (ii) the promises offered by wastewater especially grey water (domestic wastewater with low pollution load) as a freshwater substitute to reduce the increasing demand for potable water. Addressing water scarcity requires a multidisciplinary approach to managing water resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. The lessons to be learned from the social, economic and environmental impacts of earlier water resources development and inevitable prospects of water scarcity calls for a paradigm shift in the way we approach water resources management. The well grounded rationales for water recycling and reuse are the principles of sustainability, environmental ethics and public participation.

In the last two decades, although there has been significant increase in the coverage of drinking water in India as compared to other regions in the world, regional disparities still exist. India"s urban morphology is characterized by abnormal and unprecedented urbanization in the last few decades. Not only was there sizeable increase in the urban population, but the number of cities and towns also has significantly increased in the last two decades. While essential infrastructure systems have been put in most urban centres, their management and optimization to meet growing demands are far from satisfactory. India"s urban water domain is characterized by increasing competing uses, allocation issues, declining sources and inconsistent supplies, service delivery gaps, insufficient models for sustainable urban water management, multiple institutional players, low sensitivity levels towards environmental safeguards etc. With the cities promoting water-intensive developments, the need today is to treat urban water management on a wider canvas in contrast to conventional approaches.

Urban reuse of wastewater has proven the most effective way to reduce water resource consumption and the environmental dangers posed by the disposal of large quantities of insufficiently treated wastewater. Water reuse can be classified as potable, which is defined as all water consumed for drinking, cooking, and personal hygiene and non-potable such as (i) agricultural (ii) urban (iii) industrial and (iv) indirect potable reuse as infiltrated aquifer recharge. The commercial and residential structures, which constitute the major chunk of users, use about 80% of their potable flow for non-potable or “non-drinking” consumption, resulting in a costly and inept use of a limited resource. In select commercial applications, 75% or more of the domestic supply serves toiletry fixtures alone. Conservatively, 70% of the current urban water demand could be substituted by reclaimed or reuse water technology.

On the other side, it is a universal fact that with every increase in the quantity of water used, the quantity of wastewater also will proportionally increase necessitating the management of higher volumes of wastewater. Presently wastewater treatment is a costly affair. Urban areas in India generate about 5 billion liters a day (bld) of wastewater in 1947 which increased to about 30 bld in 1997 (Winrock International India 2007). According to the Central Pollution Control Board (CPCB), 16 bld of wastewater is generated from Class-1 cities (population >100,000), and 1.6 bld from Class-2 cities (population 50,000-100,000). Of the 45,000 km length of Indian rivers, 6,000 km have a bio-oxygen demand above 3 mg/l, making the water unfit for drinking (CPCB 1998). More than 80% of wastewater generated is discharged into natural water bodies without any treatment due to lack of infrastructure and resources for treatment (Winrock International India 2007). Approximately 30,000 mld of pollutants enter into India‟s rivers (CPCB 1995). The Water Act covers industrial effluent standards, but ignores the domestic and municipal effluents even though they constitute 90% of India‟s wastewater volumes (Sawhney 2004).

The use of treated, partially treated and untreated urban wastewater in agriculture has been a common practice for centuries in many countries which is now receiving renewed attention due to rapid urbanization. By 2015, 88% of the one billion-person growth in the global population will occur in cities; the vast majority of this growth will occur in developing countries (UNDP 1998). An increase in urban water supply results in increased wastewater generation, as the depleted fraction of domestic and residential water use is only in the order of 15 to 25% (Scott et al. 2004). The growing wastewater volumes render a cheap and reliable alternative to conventional irrigation systems and a variety of other uses. In this context wastewater is a resource that could be of increased national and global importance, particularly in urban and peri-urban environment. Hussain et al (200) reports that at least 20 million hectares (ha) in 50 countries are irrigated with raw or partially treated wastewater. Strauss and Blumenthal (1990) estimated that 73,000 ha were irrigated with wastewater in India.

In India, though there are few isolated experiments and pilot models for wastewater recycle and reuse for various non-potable purposes, it has not become part of the urban planning/management programme in most of the urban local bodies. In majority of the urban areas, the activities in the wastewater sector are focused mostly on wastewater disposal than recycle and reuse. Moreover, recycle and reuse of wastewater has not received much attention by the policy-decision makers. One major reason may be the lack of viable models with necessary research and technology support, strong policies and legal framework at the national and state levels and lack of sufficient trained manpower in the urban local bodies.

The perspective of establishing Centre of Excellence is to address these issues through research and streamline the viable technology through implementation in selected areas. It also envisages experience documentation in other places to establish a Knowledge Hub on Wastewater Management and capacity building and training and handholding support to replicate the experiences in other urban local bodies.

1.3 Present Wastewater Disposal Practices

The present wastewater disposal practice is characterized by a common plumbing system to let off all types of wastewater. The following are the practices followed in the matter:

- All types of wastewater together are diverted to the municipal sewerage system if such a system exists.
- All types of wastewater together are diverted to the septic tank.

- Water from toilet is diverted to the municipal sewerage system or the septic tank and all other types of wastewater are diverted to any one of (i) municipal drainage (ii) the soak pit constructed at the building compound or (iii) the premises.

The implications of this type of disposal are overload of the municipal sewerage system, wastage of reusable greywater and hazardous environmental and public health impacts.

1.4 Rationale and Benefits of Wastewater Reuse

- Wastewater recycling and reuse is the simplest visible way out to ward off the looming global water crisis. Many factors like availability of water resources, necessity to preserve rather than develop water resources, careful economic considerations, uses of the recycled water, the strategy of waste discharge and public policies that may override the economic and public health considerations or perceptions etc determine whether the recycling is appropriate for a given situation.
- It is an important water management option both to shore up conventional resources and to reduce the environmental impact of discharges.
- Water reclamation and reuse allows for more efficient use of energy and resources by tailoring treatment requirements to serve the end-users of the water and reduces pollution.
- Increasing water demands, water scarcity and droughts, environmental protection and enhancement, socio-economic factors, public health protection, etc., are the major factors driving the need for wastewater reuse.

▪ Water recycling can decrease diversion of freshwater from sensitive eco-systems thereby enhancing conservation of fresh water supplies significantly. Recycled water could be used to create or enhance wetlands and riparian (stream) habitats.

▪ Nutrients in reclaimed water may offset the need for supplemental fertilizers, thereby conserving resources. If this water is used to irrigate agricultural land, less fertilizer is required for crop, thus by reducing nutrient (and resulting pollution) flows into waterways, auxiliary activities such as tourism and fisheries could be enhanced.

1.5 Challenges and Issues in Wastewater Recycling

Choosing the most appropriate treatment technology for water reuse is a very complex process. The cascading methodology of recycling water from one source and using it for another destination process must consider multiple source processes with varying outlet utilities, different contaminants, several destination processes with well-defined water quality standards and a large number of applicable treatment technologies. Some of the crucial challenges to be addressed while adopting wastewater recycling and reuse are, (i) water recycling and treatment techniques to be employed can be quite complex and site specific, (ii) technical feasibility, cost and public policy acceptance remains a major challenge, (iii) the broad spectrum of pathogenic micro-organisms present in high concentrations in wastewater may pose potential health risks to the workers or adjacent residents who may be exposed to wastewater recycling activities, and to the public who may consume wastewater irrigated crops or recreate on wastewater irrigated lawns or lakes and (iv) in the case of recycling for potential domestic use, the organic and inorganic toxic chemicals and micro pollutants from industrial and domestic sources are a cause for concern.

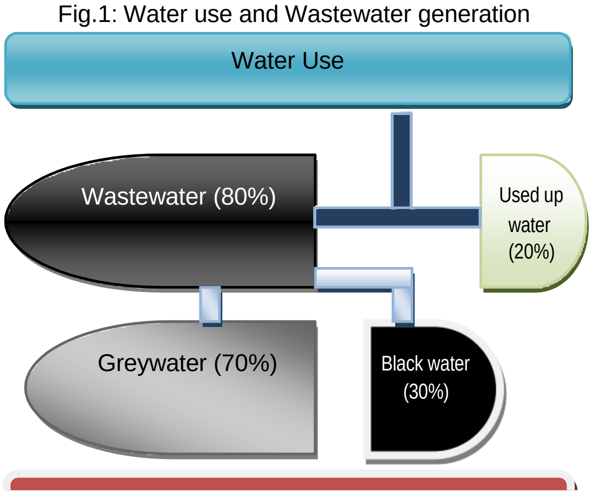
Some of the factors associated with waste water reuse and recycling are (i) the need of centralized wastewater treatment systems, its location, availability of space in and around cities for the treatment plants and topography – all of these factors restrict the use of wastewater to certain areas and for specific purposes, (ii) the high transportation costs of the wastewater from treatment plants to the point of use may encourage use of existing infrastructure (like irrigation canals) so that wastewater is increasingly used in agriculture or on market gardens in the peri-urban areas of the city, rather than in households or by industry, (iii) the ownership of wastewater such as water authority or local bodies and the necessity of dual reticulation system, and (iv) the positive (environmental benefits) and negative externalities (potential groundwater pollution and potential unknown ill effects on human health) associated with wastewater recycling.

1.6 Implications of Wastewater Reuse

There are both positive and negative implications of wastewater reuse. The positive implications include: employment generation, food security for urban and peri-urban poor farmers, reliable supply of irrigation water and the recycling of nutrients in wastewater. Since wastewater is available round the year, the urban poor farmers and migrant laborers are assured of employment throughout the year. Wastewater can also have a positive or negative impact on the property values. In Haroonabad, in Pakistan, the wastewater-irrigated land has a higher value than the canal-irrigated land (Hussain et al. 2001).

On the other hand, because of the partial or no treatment of wastewater, it endangers the very livelihoods it generates over the long term. Long-term use of wastewater for irrigation increases soil salinity, accumulation of heavy metals in the soil, and finally breakdown of the soil structure. Ample evidences are available which show that the groundwater in all wastewater irrigated areas has high salt levels and is unfit for drinking. Further, high groundwater tables and water logging are also common features of these areas. Wastewater contains a number of pathogens of which human parasites such as protozoa and helminth eggs are of special significance which can cause diseases in user communities and consumers. Further, wastewater containing a high level of nutrients may cause eutrophication and cause imbalances in the ecology of the water bodies it is released into.

Fig.1: Water use and Wastewater generation



2.1 Importance of Wastewater Management

The importance of wastewater management lies in the fact that its scientific management is sine qua non for ensuring health and hygiene of the urban population. Absence or improper management of wastewater could make urban living miserable with sordid surroundings, unhealthy physical living conditions and aesthetic damage. As we have already seen, wastewater is a potential freshwater substitute for many practical uses. This fact also reinforces the need for effective management of wastewater aiming at reuse to the maximum possible extent. Fig 1 shows the water use and resultant wastewater generation (based on the study conducted by CED as part of CoE). 80% of the water used for domestic purposes is converted as wastewater. 70% of the wastewater is grey water and the remaining 30% is blackwater, which mainly forms the toilet water. In view of the low pollution load, the grey water could be easily reused.

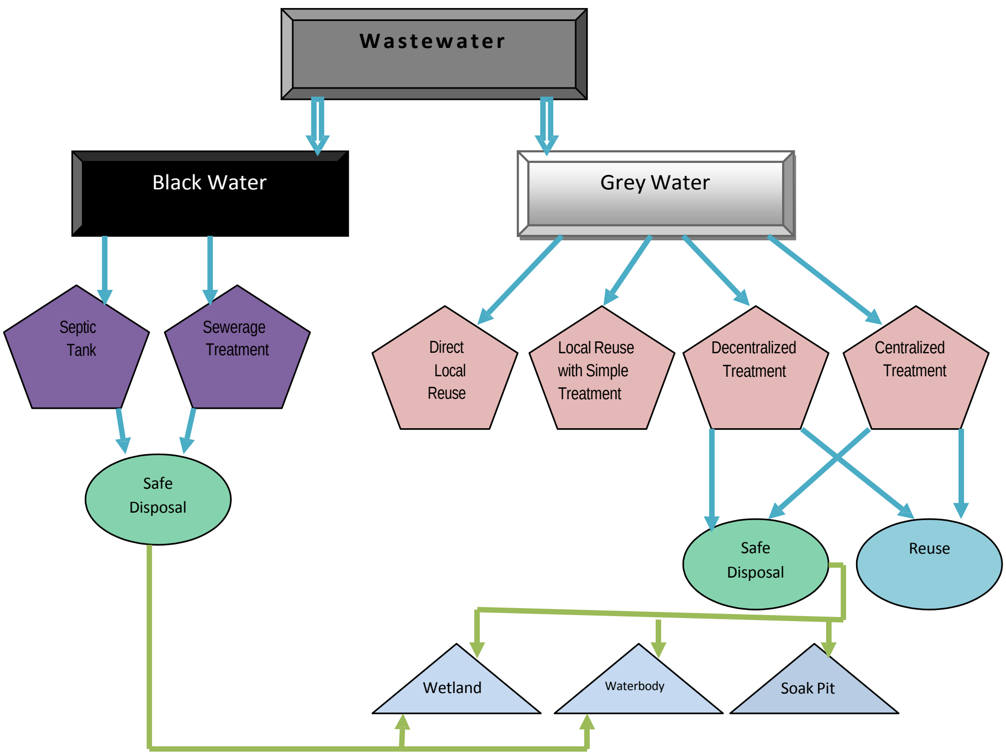
2.2 Framework of Wastewater Management

Wastewater comprises of both blackwater and grey water. The 30% blackwater contains most of the pollution load in the wastewater. The grey water constituting 70% of wastewater has fewer pollutants in it and is easy to reuse; in certain applications it is suitable for reuse even without treatments.

Hence, the strategy for wastewater management should be to deal with black water and grey water separately. The black water can be disposed off after treatment in a central sewerage system or in its absence in a septic tank. The reuse potential of black water is very little. The grey water could be reused for a variety of purposes, which are discussed in detail in the succeeding sections. The general framework of wastewater management is given in Fig.2

The analysis and study conducted by CED as part of CoE led to conclude that a two-pronged approach

Fig 2: Framework for Wastewater Management



would be ideal for urban wastewater management, i.e., sufficing black water treatment on the one hand and developing and promoting grey water reuse mechanisms to the extent possible on the other hand. Since most of the cities have some system to manage the balck water, what is needed in this area is filling the gap between the demand and the availability. Since technology and mechanism for black water treatment is generally available, this component of the CoE mainly aims to focus on greywater treatment and reuse.

2.3 What is Greywater?

Wastewater is made up of “Greywater” and “Blackwater”. Greywater, defined slightly differently in different parts of the world, generally refers to the wastewater generated from household uses like Washing Machines/ Laundry Tubs, Showers/Baths, Wash basins, Kitchen etc.

2.4 Definitions, Terminology, and Characteristics

Greywater is spelled and defined differently in different parts of the world. Also commonly spelled „graywater", „grey water", or „gray water", it refers to untreated household wastewater that has not come into contact with sewage (or "black water"). Common sources of greywater in the home include bathroom, wash basin, and clothes washers. Wastewater from kitchen sinks and automatic dishwashers tend to have high concentrations of organic matter with elevated levels of greases, oil and detergents that encourage the growth of bacteria and hence must be treated before reuse. Jurisdictions in some parts of the world exclude kitchen sink water and diaper wash water from their definition of greywater and these are defined as "dark greywater". In some places this is considered as black water. „Blackwater" is the wastewater from toilets, urinals or bidets. In India, just like many regions in the world, there is lack of clear regulations or standards regarding greywater capture and reuse.

Rainwater, which can also be collected for use, is not considered to be greywater. Greywater is also distinct from reclaimed water, which is wastewater (including black water) that is treated by a centralized wastewater treatment plant for potable or non-potable reuse.

Table 1: Definitions

Term	Definition	Other terms in use
Greywater	Untreated household wastewater that has not come into contact with sewage	Graywater, gray water or grey water
Black water	Wastewater from toilets, bidet, water used to wash diapers (and under some definitions, from kitchens)	Sewage
Dark gray water	Untreated household wastewater that has not come into contact with sewage, but is from lower-quality sources such as kitchen sinks and dishwashers	Sometimes considered to be part of black water

2.5 Greywater and Blackwater: Key Differences

- **Greywater contains far less nitrogen than blackwater**

  Nine-tenths of the nitrogen contained in combined wastewater derives from toilet wastes (i.e., from the blackwater). Nitrogen is one of the most serious and difficult-to-remove pollutants affecting our potential drinking water supply.

- **Greywater contains far fewer pathogens than blackwater**

  Medical and public health professionals view faeces as the most significant source of human pathogens. Keeping toilet wastes out of the wastewater stream dramatically reduces the danger of spreading such organisms via water.

Greywater decomposes much faster than blackwater

The implication of the more rapid decomposition of greywater pollutants is the quicker stabilization and therefore enhanced prevention of water pollution.

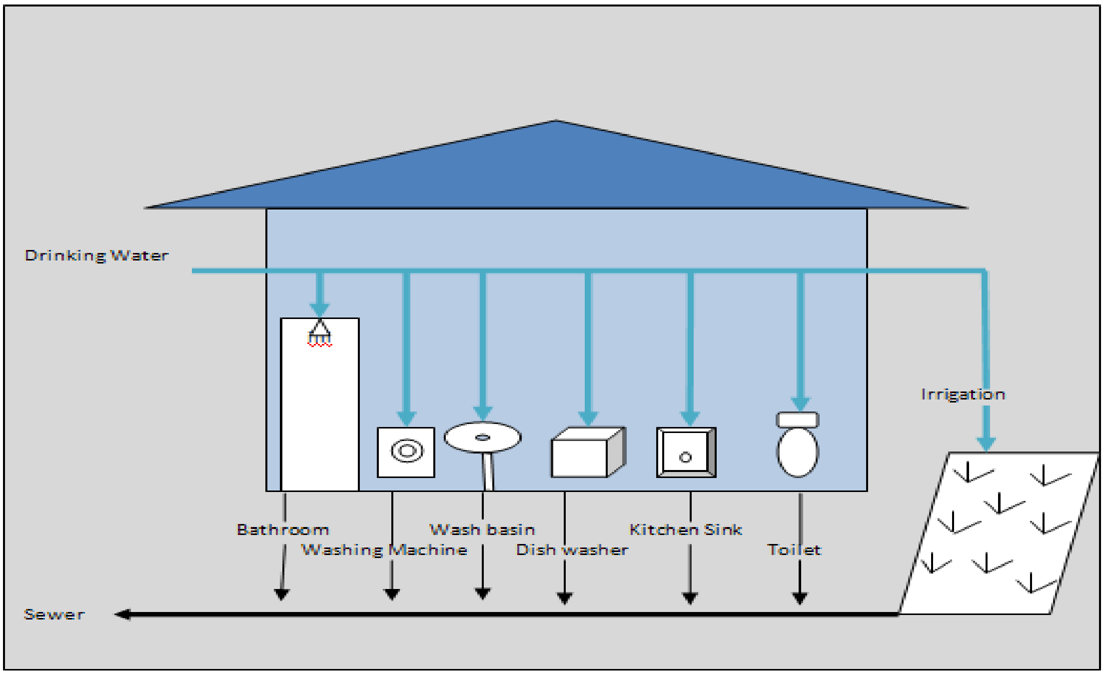
2.6 Greywater Disposal Practices

In many utility systems around the world, greywater is combined with black water in a single domestic wastewater stream. In less developed countries/areas, the grey water is let out to the environment without any treatment and not considering safe disposal practices. Greywater can be of far higher quality than black water because of its low level of contamination and higher scope for reuse. When greywater is reused either on-site or nearby, it has the potential to reduce the demand for new water supply, reduce the energy and carbon footprint of water services, and meet a wide range of social and economic needs. In particular, the reuse of greywater can help reduce demand for more costly high-quality potable water.

By appropriately matching water quality to water need, the reuse of greywater can replace the use of potable water in non-potable applications like toilet flushing and landscaping. For instance, many homes have one set of pipes that bring drinking water in for multiple uses and another that takes wastewater away. In this system, all devices that use water and all applications of water use a single quality of water: highly treated potable drinking water. This water is used once and then it enters a sewer system to be transported and treated again, in places where wastewater treatment occurs. Fig. 3.

In most modern wastewater systems, treated wastewater is then disposed of into the ocean or other water bodies, voiding the reuse potential of this treated wastewater. In other places, once-used wastewater may be disposed of directly in the environment. This system wastes water, energy, and money by not matching the quality of water to its use.

Fig.3: Typical household water infrastructure



A greywater system, on the other hand, captures water that has been used for some purpose, but has not come into contact with high levels of contamination, e.g., sewage or food waste. This water can be reused in a variety of ways. For instance, water that has been used once in a shower, clothes washing machine, or bathroom sink can be diverted outdoors for irrigation. Fig. 4.

Fig.4 : Schematic of typical household sources of greywater, applied to a flower garden

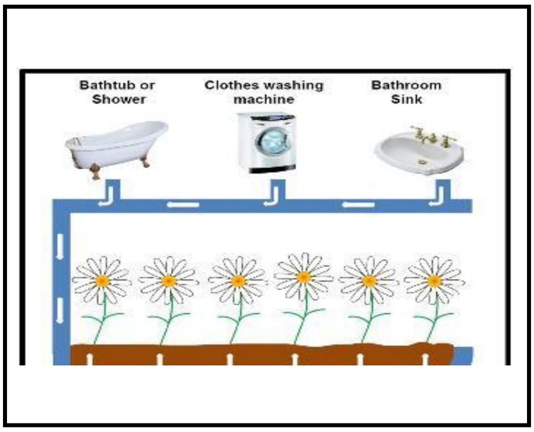
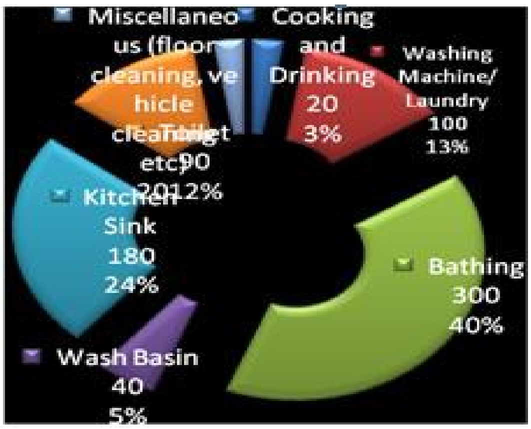


Fig.5: Graphical representation of water use and waste water generation



In this case, the demand for potable water for outdoor irrigation is reduced and the flow out of wastewater produced both by the shower, washing machine, and sink are reduced. When the systems are designed and implemented properly, possible public health concerns with using different water qualities can be addressed.

2.7 Greywater Volumes

Greywater generation will vary according to the water usage practices of each individual in the household and the use of water efficiency devices. As per the survey conducted by CED in Thiruvananthapuram City as part of the CoE, an average house (four persons per house) uses 750 litres of water every day. A small portion of the water (used for drinking, cooking, floor cleaning, simple vehicle cleaning etc) is almost fully consumed and the remaining portion is converted as wastewater. The study showed that about 80% of the water turns out as wastewater. Out of the wastewater produced, 62% is greywater, 25% is dark grey water 13% is blackwater (see Table 2).

Table 2: Water use and waste water generation

NO	SOURCE	QUANTITY IN LITRES	%	CATEGORY
1.	Cooking and Drinking	20	2.7	1
2.	Washing Machine/Laundry	100	13.3	2
3.	Bathing	300	40	2
4.	Wash Basin	40	5.3	2
5.	Kitchen Sink	180	24	3
6.	Toilet	90	12	4
7.	Miscellaneous (floor cleaning, routine vehicle cleaning etc)	20	2.7	1
	Total	**750**	**100**	

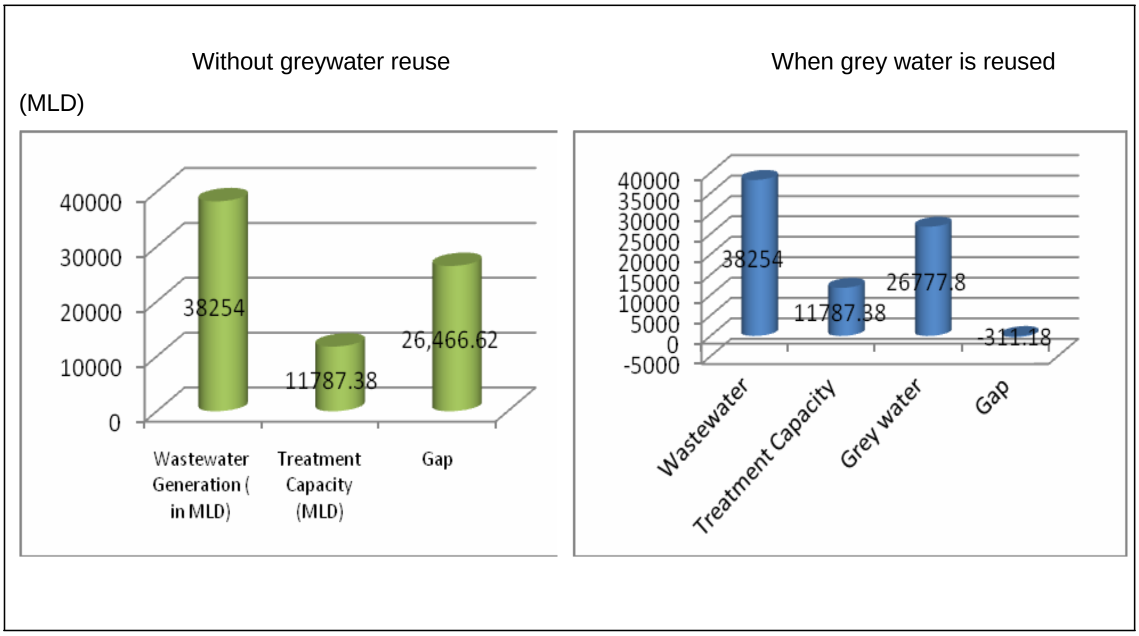
Category 1 indicates water fully consumed and the wastewater generation is nil or insignificant; category 2 indicates grey water; category 3 is dark grey water and category 4 is black water.

2.8 The Need to Focus on Grey Water Reuse

All studies reveal that 60 to 80 percent of domestic wastewater is greywater, which has sizeable reuse potential - either direct reuse or reuse after simple treatment. Apart from domestic sources, there are other sources like commercial establishments (shops, markets), public offices, educational institutions, service organizations (hospitals, hostels) that produce substantial quantity of greywater that could be effectively reused.

The present practice of wastewater disposal is conveying the wastewater (both black water and grey water together) through a common plumbing system to the sewerage, which undergoes expensive treatment before final disposal. In Indian cities the sewerage facility is quite inadequate to cater to the demand mainly because of the huge volume of wastewater due to the inclusion of grey water with black water. If the grey water is separated from the black water, the gap between the requirement and the availability could be substantially reduced. Fig . 6

Fig 6: Reduction in sewerage treatment due to grey water reuse



2.8 Sewage Treatment Status in Urban Areas of India

According to the Central Pollution Control Board (CPCB) report on Status of Water supply, Wastewater generation and Treatment in Class- I cities and Class II towns of India (2009), the estimated sewage generation in 498 Class-I Cities and 410 Class II towns (as per estimation made for the year 2008) is 38254 MLD. Against this, there exist only 11787 MLD treatment capacities. The Summary of water supply, sewage generation and its treatment is shown below:

Table 3: Summary of water supply, sewage generation and its treatment

Category	No. of Cities	Population	Total Water Supply (in MLD)	Wastewater Generation (in MLD)	Treatment Capacity (in MLD)
Class-I City	498	14,30,83,804	44,769.05	35,558.12	11,553.68
Class-II town	410	3,00,18,368	3,324.83	2,696.7	233.7
Total	**908**	**25,77,54,640**	**48,093.88**	**38254**	**11787.38**

Source: Status of Water Supply and Wastewater Generation and Treatment in Class-I cities and Class-II towns of India_CPCB_2009

The existing treatment capacity of sewage generated in Indian cities is just 30 % of present sewage generation. The untreated sewage finds their way into water bodies and thus pollutes ground and surface water. Centralized treatment facilities, though common in developed countries, seem to be a non-viable option in the Indian urban context due to the unplanned urban conglomeration of buildings, non-availability of land, requirement of complicated sewer networks and high cost for infrastructure development. Again, many of the techniques available today for sewage treatment are also high energy consuming. Today combined wastewater-blackwater and greywater- is discharged into sewer lines requiring handling of enormous volumes at treatment plants. Separating these two streams and treating them individually is a viable option, a trend gradually receiving worldwide acceptance. Since the greywater is less polluted, it can be used for non- potable purposes like garden irrigation even without treatment or with simple treatment compared to conventional high-cost wastewater treatment. The substitution of drinking water with treated greywater can be used for purposes other than those for potable water, e.g., toilet flushing and garden irrigation, supporting the sustainability of valuable water resources. Furthermore, considerable amounts of added chemicals, in addition to sludge which arises during drinking water treatment, can be minimized.

In water scarce environments, wastewater reuse and reclamation are often considered as a viable option for increased water resources availability. From a process technology point of view, separate treatment of black water, possibly together with kitchen waste is most logical because faecal matter and urine contained in the wastewater contribute half of the COD, most of the nutrients, pathogens and micro- pollutants.

2.9 Composition of Greywater

The quality of greywater can be highly variable due to factors such as the number of household occupants, their age, lifestyle, health, water source and products used (such as soaps, shampoos, cleaning products) and other site specific characteristics. (Table 4)

Table 4: Physical composition of grey water

• Soaps	• Suspended solids
• Detergents	• Dissolved solids
• Fibres from clothes	• Food particles
• Hair	• Grease
	• Oil

(*Source:* Karma El-Fadl 2007)

In terms of basic water quality parameters (TSS, BOD, turbidity), grey water is considered to be comparable to a low-or medium grade wastewater. Jefferson et al (2004) found that, though similar in organic content to full domestic wastewater, grey water tends to contain fewer solids and is less turbid than full domestic wastewater, suggesting that more of its contaminants are dissolved. The same study also suggested that the COD/BOD ratio in grey water can approach 4:1, much higher than that of domestic wastewater, which is typically around 2:1. The composition of grey water depends on each household‟s activities and varies according to the number of household occupants, their age, lifestyle, health, water source and products used (such as soaps, shampoos, cleaning products), socio-economic status, cultural practices, cooking habits and other site specific characteristics. In general, grey water in low and middle-income countries may contain the parameters as given in Table 5. Typical chemical characteristics of grey water are presented in Table 5. Treatment requirements vary based on chemical characteristics and intended use of treated grey water.

Table 5 Chemical characteristics of grey water

	ASHRAM SCHOOLS OF DHAR AND JHABUA DISTRICTS		**RUIZ *ET AL.*, 2000**	
Item	**Range**	**Average**	**Range**	**Average**
Ph	6.4 – 8.1	7.7	6.95 – 8.3	7.8
TSS (Mg/L)	40 – 340	190	116 – 424	226
Turbidity (NTU)	15 – 270	161	NA	NA
Cod_t (Mg/L)	NA	NA	220 – 985	693
Cod_s (Mg/L)	NA	NA	63 – 523	322
BOD_5 (Mg/L)	45 – 330	170	250 – 640	360
Nitrite (Mg/L)	0.1 – 1.0	0.55	NA	NA
Ammonia (Mg/L)	1.0 – 26	13	2 – 34	20
Fats (Mg/L)	NA	NA	57 – 199	100
TKN (Mg/L)	2- 23	12	9.5 – 65	38
Total P (Mg/L)	0.1-0.8	0.62	0.58 – 9.6	5.5
Sulphate (Mg/L)	<0.3 – 12.9	5.6	2.1 – 145	38.5
Conductivity (ms/cm)	325-1140	732	NA	NA
Hardness (Mg $caco_3$/L)	15-50	35	NA	NA
Sodium (Mg/L)	60-250	140	NA	NA
Alkalinity (Mg $caco_3$/L)	NA	NA	54 – 902	281

The microbiological quality in terms of number of thermo-tolerant coliforms of grey water from various sources by different researchers is presented in Table 6. Thermo-tolerant coliforms are also known as faecal coliforms (expressed as colony forming units per 100 ml) and are a type of micro-organism which typically grow in the intestine of warm blooded animals (including humans) and are shed in millions to billions per gram of their faeces. A high faecal coliform count is undesirable and indicates a greater chance of human illness and infections developing through contact with the wastewater. Typical levels of thermo-tolerant coliforms found in raw sewage are in the order of 10^6 to 10^8 cfu/100ml.

Grey water characteristics also vary according to source; each fixture used for the grey water collection system will carry its own particular contaminant load. Friedler (2004) recommends excluding fixtures like the kitchen sink and dishwasher from a grey water system, because they constitute only 25-30% of grey water volume but contribute nearly half of its COD content. For this reason, the least contaminated streams of household grey water are usually prioritized for reuse.

Table 6: Microbiological Quality of Grey Water

SOURCE	THERMO TOLERANT COLIFORMS (CFU)/100 ML			
	Rose *et al.,* 1991	Kapisak *at al.,* 1992	California DHS 1990	Brandes 1978
Bathing	$6x10^3$ cfu	$4x10^5$ MPN	<10 to $2x10^8$	$6x10^3$ cfu
Laundry wash water	126 cfu	$2x10^3$ – 10^7 MPN	--	--
Laundry rinse water	25 cfu	--	--	--
Kitchen	--	--	<10 to $4x10^6$	$2x10^9$
Combined greywater	6 to 80 cfu[A] $1.5x10^3$ cfu[B] $1.8x10^5$ to $8x10^6$ cfu[C] $13x10^6$[D]		$8.8x10^5$[CD] $1.73x10^5$	

Source: Jepperson *et al.,* 1994

Greywater is a resource that can be reused on-site for garden and lawn irrigation or, when treated adequately, for toilet flushing and laundry use (cold-water washing machine only). Substituting the use of drinking water with greywater for these end uses will, not only reduce the demand on drinking water supplies, but also reduce the amount of wastewater discharged to the environment.

Reusing greywater provides a number of benefits including:

- Reducing potable water demand
- Reducing the amount of wastewater discharged to the water bodies or to the environment
- A healthier garden, especially during drought periods.
- Reducing household water bills

The disadvantages of greywater reuse may include:

- The potential for pollution and undesirable health and environmental effects when greywater is not reused appropriately
- Initial cost of setting up a greywater system and plumbing requirements
- Ongoing maintenance and system owner commitment.

3.1 Objective, Approach and Methods

One of the specific objectives of the Centre of Excellence in CED is to develop strategy and methodology for urban wastewater management adopting a practical approach for wastewater recycling and reuse. The issues to be dealt with in this context are encouraging and enforcing differential use of water for different purposes, identifying locale-specific technologies for wastewater treatment and developing necessary legal and institutional framework. Accordingly, CED has made an attempt to understand the national wastewater management scenario and to develop a strategy and framework for effective management of waste water. The activities undertaken as part of CoE for wastewater management are described below:

3.2 Pilot Studies under CoE

For developing the strategy and framework for Urban Waste Water Management, CED conducted two pilot studies on water consumption and wastewater discharge methods in Thiruvananthapuram Municipal Corporation (TMC) area. The study focused on major water consumers, in order to investigate into the water consumption rate, discharge/treatment methods adopted, etc. The characteristics of the grey water generated from these consumers have also been analyzed. The characteristics study was carried out to ascertain the nature of the grey water generated from different types of users with a view to selecting proper treatment technology and to know the extent to which the treatment is required. Characteristics study also helps to understand the need for separation of grey water source based on concentration of pollutants and to explore the possibilities of diversion of grey water for irrigation. Based on the pilot study, the strategy and frame work was developed.

3.3 Activities under the Pilot Study

(i) Review of Literature

The initial activity under the study was review of available literature on the topic-both national and international. The literature review covered areas like the characteristics of grey water, volume of generation, its applications in India and other countries, treatment technologies available, present disposal practices and the regulatory framework across the countries.

(ii) Selection of major wastewater generators

At present, there is no authentic data on quantity of grey wastewater generated from the major water consumers. In order to formulate greywater reuse plan, reliable data is required. Considering the above aspects, the CoE team identified the major wastewater generators of Thiruvananthapuram city like apartments, hotels, hospitals, public offices, service stations, hostels, etc., and data collected through random survey. The surveys were carried out to assess the quantity and characteristics of grey water generated in Thiruvananthapuram city. The survey format is attached as *Annexure I.*

(iii) Data collection Tools

In order to design a questionnaire to gather information from different types of water users, a brainstorming session was organised with the participation of experts from different sectors such as Kerala Water Authority, Kerala State Pollution Control Board, Thiruvananthapuram Municipal Corporation etc. Based on the ideas emerged in the brainstorming session, draft questionnaire was prepared, its effectiveness to capture required information analyzed and finally field tested before actual use. A group of Technical Assistants (TA) was identified to conduct the field survey. Intensive training was given to the Technical Assistants before the field testing of the questionnaire. Based on the outcome from the field test, final questionnaire was prepared. The Sample questionnaire is attached as *Annexure II*.

(iv) Data collection

The project team conducted detailed field survey using the structured questionnaire prepared for the purpose. The information was collected mainly by field visits, observations, person to person discussions and focus group discussions involving different stakeholders.

(v) Situation analysis

Situation analysis was done as part of the pilot study to understand various aspects of wastewater-volume across different categories of generators, difference in characteristics, disposal practices, people"s perception about wastewater management, regulatory framework and level of enforcement/acceptability etc.

The major grey wastewater generators in the city were identified and data relating to them was collected and analyzed. Accordingly, the apartments produce about 152 lpcd and 1.5 g/l of COD (considered as major pollution indicator).The hotels without lodging facility produce 72 lpcd of grey water per restaurant seat, hotels with lodging facility of less than 50 rooms produce 145 lpcd of grey water per room and hotels with lodging facility with 50 to 150 rooms produces 360 lpcd of grey water per room. The pollution load produced by the hotels in average COD terms is 1.4g/l. The hospitals with less than 100 beds produce 224 lpcd of grey water per bed and hospitals with more than 100 beds produces 328 lpcd of grey water per bed. The pollution load produced by the hospitals in average COD terms is 0.9g/l.

The study revealed that as elsewhere in the developing world, there is only partial connection to the centralized sewerage system, resulting in substantial volumes of wastewater disposed off into the environment including surface water bodies.

(vi) Review of technology options

The technologies presently available for wastewater treatment were reviewed specially focusing on greywater treatment, which are explained under Section 4.

(vii) Identification of specific treatment technologies

The data collected was analyzed to find out appropriate technological solutions to suit different situations. The various methods practised in India are given as Table 10.

(viii) Wastewater discharge/use/recycling

The study revealed that as in the case of most developing countries, in the case study city also wastewater receives very little or no treatment and is discharged either into the premises or natural water bodies. The reuse potential of greywater is seldom captured.

3.4 Major Policy Level Findings of the Study

The amount of grey water produced in a household or commercial construction can greatly vary depending upon the number of occupants and size of the facility.

The composition of grey water greatly varies on the type of building and usage of chemicals for washing, laundry, etc. In general, it contains often high concentrations of easily degradable organic material, i.e. fat, oil and other organic substances, residues from soap, detergents, cleaning agents, etc and generally low concentrations of pathogens.

Grey water in general has low content of any metals or organic pollutants, but depending on the nature of life style of the generators, it can vary.

Grey water from bathtubs, showers, washbasins and washing machines contains little or no pathogens, and ninety percent less nitrogen than black water (toilet waste). Because of this, it does not require the same treatment required for black water or combined wastewater.

By redesigning plumbing systems to separate grey from black water, grey water can be recycled/reused for irrigation, toilets and for many other purposes resulting in water conservation.

If properly planned and executed, the wastewater treatment requirements of upcoming residential and commercial buildings could be significantly reduced, resulting in cost and space savings.

Grey water can be used for a variety of applications such as garden irrigation, irrigation of certain food crops, watering parks, playgrounds and school yards, golf courses, freeway landscaping, car washing, dust control, toilet flushing, fire fighting etc

There is absence of formal and organized system for grey water reuse

There is need for capacity development of municipal planners, administrators and the general public to inculcate the need for grey water reuse.

3.5 Conclusions of the Pilot Study

(i) Greywater reuse is a potential area capable of alleviating the higher demand for fresh water and reducing the sewage treatment demand.

(ii) ULBs should pay prime attention to the so far neglected area of grey water reuse in view of its economic, environmental, health & hygiene and aesthetic impacts on the ULB and its population.

(iii) Appropriate location specific and low cost technology options should be identified and propagated. Encourage research to discover novel, cost-effective, user-friendly and efficient systems.

(iv) Develop appropriate regulatory framework, which should invariably claim community acceptance.

(v) Promote decentralization. The reuse approach should be bottom up, starting from reuse at generator level, passing through locality/area level reuse and finally reaching the centralized reuse system. Crossing boundaries of each level will be only when the lower level options are saturated.

(vi) Any initiative should precede with adequate capacity building through appropriate IEC for changing the mindset and creating public acceptance.

3.6 Preparation of Strategies and framework

Based on the findings of the study, a model strategy and framework for effective wastewater management focusing on greywater reuse has been formulated, which is explained in the last part of this Report.

4.1 Grey Water Treatment Technologies

4.2 Types of Wastewater Re-use and Treatment

Broadly, wastewater is treated in centralized facilities which have mainly three levels - primary, secondary and tertiary levels.

Primary treatment**:** It is the treatment involving sedimentation (sometimes preceded by screening and grit removal) to remove gross and settleable solids. The remaining settled solids, referred to as sludge, are removed and treated separately.

Secondary treatment: Generally, a level of treatment that removes 85% of Biological Oxygen Demand [BOD] and suspended solids via biological or chemical treatment processes.

Water reclaimed after the secondary treatment usually has a BOD of <50 milligrams per liter (mg/L) and suspended solids of <30 mg/L, but this may increase to >100 mg/L due to algal solids in lagoon systems.

Tertiary treatment: The treatment of reclaimed water beyond the secondary biological stage is termed as tertiary treatment. This normally implies the removal of a high percentage of suspended solids and/or nutrients, followed by disinfection. It may include processes such as coagulation, flocculation and filtration.

> The reuse of greywater for toilet flushing and garden irrigation has an estimated potential to reduce domestic water consumption by up to 50% (Maimon et al. 2010).

Domestic wastewater management in urban and semi-urban areas is based on the conventional approach of collecting the wastewater, both grey and black water in sewerage systems and subjecting to treatment in a conventional sewerage treatment plant. Alternatively, the grey water can be collected, treated and re-used on-site, thereby promoting more efficient water use. There are many methods for reusing grey water, from simple bucketing to complex treatment and recycling systems. However, on-site reuse of domestic wastewater is subject to various restrictions due to concerns about effluent quality, maintenance and health issues.

4.3 Greywater Technologies in Use Worldwide

Greywater can be reused for purposes that do not require potable water – such as landscaping, agriculture, or flushing toilets – thereby reducing potable water use. Greywater after simple treatment can also be allowed to seep into the ground to recharge aquifers and reduce the volume of wastewater needing to be treated. Greywater is often, but not always, treated before it is reused, and the degree of treatment can vary widely. Greywater systems range from simple low-cost devices that divert greywater to direct reuse, such as in toilets or outdoor landscaping, to complex treatment processes incorporating sedimentation tanks, bioreactors, filters, pumps, and disinfection (NovaTec Consultants Inc. 2004). Some greywater systems are home-built, do-it-yourself piping and storage systems, but there are also a variety of commercial greywater systems available that filter water to remove hair, lint, and debris, and remove pollutants, bacteria, salts, pharmaceuticals, and even viruses from greywater. The cost and energy requirements of these systems vary, usually increasing with higher levels of treatment.

Greywater systems that involve storing must be treated to reduce the bacteria and other microorganisms that can multiply in stagnant water. Physical and chemical greywater treatment systems primarily utilize disinfection and filtration to remove contaminants while biological treatment uses aeration and membrane bioreactors.

Fig.7: Toilet designed to re-use the greywater from the sink above it

Before treatment, different types of screens are installed in the greywater stream to remove all solid materials like hair, paper, plastic, etc. The treatment will become more efficient when the solid substances are removed with the help of the screens since the removal of organic materials will reduce the BOD load and the removal of inorganic items will reduce the complexity of treatment. The different types of screens commonly used are illustrated below:

Table 7: Different types of Screens Commonly Used

Screen category	Size of openings (mm)	Application	Types of Screens
Coarse screens	≥ 6	Remove large solids, rags, and debris.	Manually cleaned bar screens/trash racks. Mechanically cleaned bar screens/trash racks, Chain or cable driven with front or back cleaning, Reciprocating rake screens, Continuous self-cleaning screens.
Fine screens	1.5-6	Reduce suspended solids to primary treatment levels	Rotary-drum screens. Rotary-drum screens with outward or inward flow Rotary-vertical-disk screens. Inclined revolving disc screens. Traveling water screens. Endless band screen, Vibrating screens
Very fine screens	0.2-1.5	Reduce suspended solids to primary treatment levels	
Micro screens	0.001-0.3	Upgrade secondary effluent to tertiary standards	

Diversion Systems

There are a number of applications that enable direct grey water reuse like toilet flushing, outdoor irrigation, greywater treatment in wetlands etc. Installation of a grey water diversion system can make use of the grey water for such immediate reuse rather than treating or storing it. The systems may also involve disinfection (e.g., adding chlorine to kill bacteria). Currently, there are a variety of commercially available systems in many parts of the world that divert water from shower and wash basins into toilet water tanks.

These systems re-plumb drain water directly into a toilet tank for flushing or into a receptacle that is then pumped into a toilet tank. Systems that reuse wash basin water to fill toilet tanks are sold primarily in Japan, Australia, Europe, and North America (Fig 7). The toilets are designed to re-use the greywater from the wash basin above it. These systems are relatively low cost and require no additional land area.

A second category of systems diverts drain water to outdoor irrigation, often requiring additional plumbing and irrigation tubing. An electrical pump may also be necessary to move the water outdoors, but simple systems can sometimes rely on gravity to move the water. These systems are also relatively inexpensive and require no additional land area, but are only useful on plots that have vegetation or are unpaved to allow infiltration as many greywater codes do not allow ponding of the greywater.

Finally, there are greywater systems that divert greywater from showers and sinks into treatment wetlands or other plant- and soil-based filters. For example, in Berlin, Germany, a 60 square meter engineered wetland constructed in the courtyard of a housing settlement has been operating successfully for eight years (Nolde Grey Water Recycling).

Greywater from bath tubs, showers, sinks, and washing machines enters the plant-covered soil-filter where it undergoes biological treatment. Ultra violet disinfection has been included as a final safety measure before the use in toilet flushing (Deutsche BauBeCon, 1995, 1996). Extensive investigations over several years of operation have shown that within the soil filter, *E. coli* concentrations were reduced by over 99% and all hygiene requirements have been achieved under the EU-Guidelines for Bathing Waters. The costs of this form of greywater treatment can vary widely and it is also land-intensive.

Currently, there are no uniform requirements for most greywater systems. Many of these basic diversion systems include two-way valves that can be set to an open or closed position. This allows greywater to either be routed to sewer pipes (as they normally would) or be routed to the greywater system. This option can help ensure that greywater systems are properly managed (e.g., can be turned off if someone does not understand how to use the greywater system or when there may have been black water contamination) and are never overwhelmed by a large volume of water.

There are Greywater Diversion Devices (GDD) in use, which incorporates a hand activated switch or tap to divert the greywater to the garden or the sewer without storage or treatment. There are two types of greywater diversion devices (GDD):

<u>i. Gravity GDD</u>

A gravity diversion device incorporates a hand activated valve, switch or tap and is fitted to the outlet of the waste pipe of the plumbing fixture such as a laundry tub. Greywater is diverted directly to a sub-surface irrigation system in the garden.

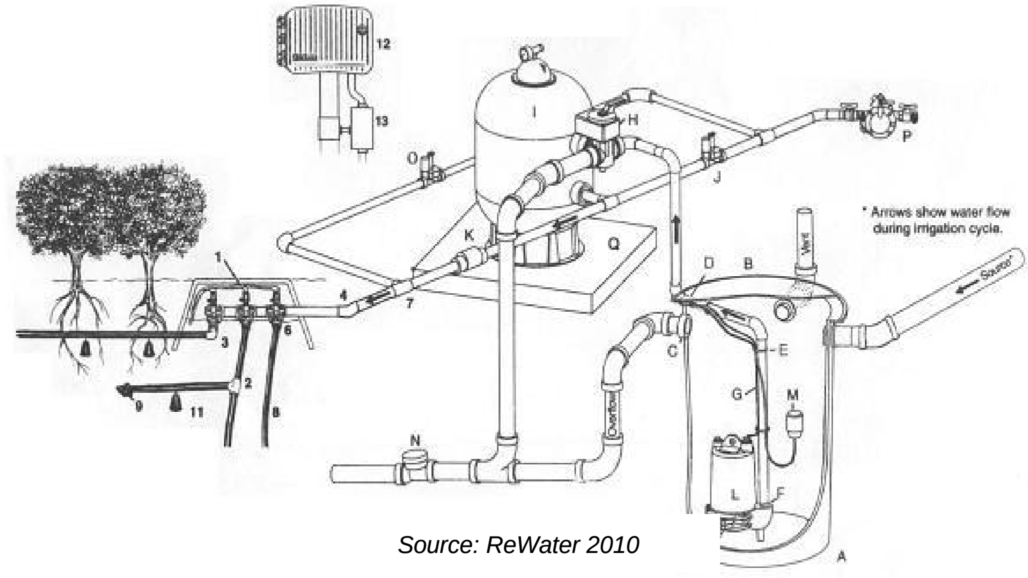
<u>ii. Pump GDD</u>

A pump diversion device incorporates a surge tank to cope with sudden influxes of greywater for distribution of the greywater directly to a sub-surface irrigation system in the garden. The surge tank does not operate as a storage tank.

Physical and chemical treatment systems usually involve holding tanks, filters, and pumps. For example, the major components of the greywater treatment system. (Fig. 8) are a surge tank, sand media filtration tank, and piping to an outdoor irrigation system.

Many basic greywater treatment and storage systems also incorporate activated carbon and/or clay filters and disinfection (e.g., chlorination, purification with ultraviolet radiation). The disadvantage of the system is that it is costly and land-intensive, requiring space for holding tanks and filtration units.

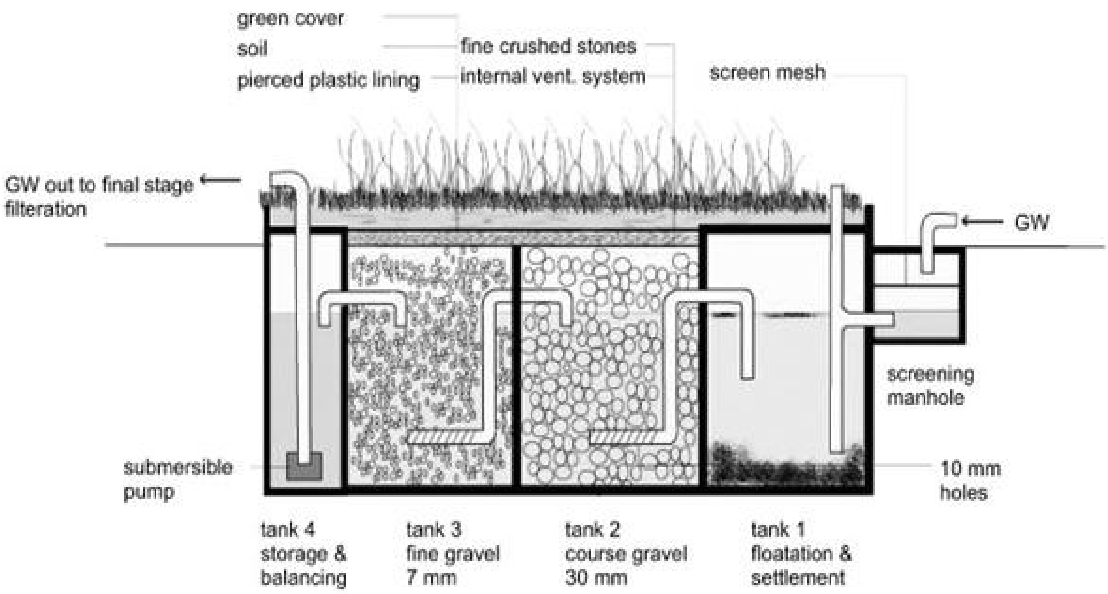
Figure 8: Greywater Treatment System for Outdoor Irrigation



Source: ReWater 2010

Figure 9 is a grey water treatment system set up in Qebia village, Palestine to meet household greywater treatment needs. The system comprised of a gravel filter medium, mostly crushed, hard limestone. The tanks were made of concrete and/or bricks, and were divided into four compartments.

Fig 9 **PHYSICAL GREY WATER TREATMENT SYSTEMS SET UP IN QEBIA VILLAGE, PALESTINE**



The first compartment is a septic tank and grease trap and receives the greywater from the shower, kitchen, wash basins and washing machine – through a 5 or 7.5 cm diameter PVC pipe, via a screened manhole, by means of a T-shaped outlet. One end of this outlet is directed upward and open to atmospheric pressure and the other is at a level of about 30 cm from the bottom of the tank.

The second and third tanks act as up-flow graduated gravel filters. The fourth compartment acts as a balancing tank for the treated greywater, with a submersible pump installed to lift the water to a multilayered aerobic filter. Through a controlled flow from the top tank, the greywater passes through the filter layers (sand, coal, and gravel) to a storage tank from where it can then be supplied to the irrigation network" (Burnat and Eshtayah 2010).

The 4-Barrel System:

Based on an experiment in Jordan, CED established in its compound at Thiruvananthapuram a 4-barrel system for wastewater treatment with slight modifications. The system treats wastewater from the kitchen and washbasin. Four plastic barrels constitute the treatment kit. The four barrels are lined up next to one another and are interconnected with 32 mm PVC pipes.

The first barrel is a grease, oil and solids separator and thus acts as a pre-treatment or primary treatment chamber, where the solid matter from the influent greywater settles and the floating components, such as grease and soap foam, float. This barrel has 200 litre capacity with an effective volume of 160 litre having a large cover, which can be tightly closed. When the cover is opened, the chamber can be cleared of both floating and settled material. The second and the third barrels are of the same capacity and are filled with shredded plastic.

Once solids and floating material settle in the first barrel, the relatively clear water from the first barrel enters into the bottom of the second barrel. Next, the water from the top of the second barrel enters into the bottom of the third barrel. This water passes through the shredded plastics and from the top of the third barrel is taken into the fourth.

Anaerobic treatment is accomplished in the two middle barrels. Anaerobic bacteria gets established on the plastic surface so that when the grey water passes through the plastics, the bacteria works on breaking down components of the organic material found in the grey water. The last barrel acts as a storage tank for treated grey water. Within one to two days of resident time in the treatment kit, the influent greywater is expected to undergo a treatment level equivalent to between primary and secondary treatment.

The modifications made by CED from the Jordan system are:

- Wastewater first enters into a bucket which acts as a settler (this is not in the Jordan model). Thus the first barrel does not suffer any agitating action due to the forceful inflow of water through the plumbing system.

- Shredded Plastic is used as the medium for facilitating microbial action (growth of instead of gravel.

Figure 10: The 4-barrel system at CED, Thiruvananthapuram

The treatment shows more than 50% reduction in BOD and COD. The graphical illustration of the BOD and COD removal percentage is given below:

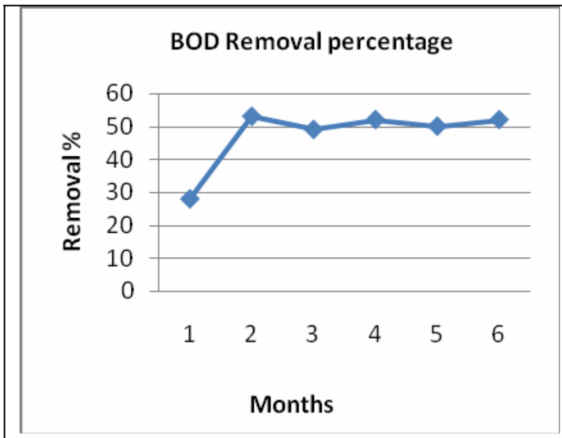


Fig 11: BOD Removal Percentage

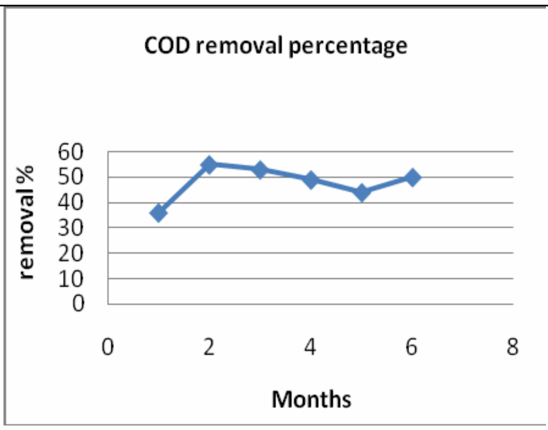


Fig 12: COD Removal Percentage

The Confined Trench (CT) System: Two plastic barrels and a dug trench filled with gravel media constitute the confined trench (CT) unit. The first barrel functions as a grease, oil and solids separator and thus acts as a pretreatment or primary treatment chamber, where the solid matter from the influent grey water settles and the floating components, such as grease and soap foam floats and can be removed regularly. The first barrel of the CT system will have 160 litre capacity and a large cover, which can be tightly closed. When the cover is opened, the chamber can be cleared of both floating and settled material. A trench is dug close to the first barrel with dimensions of approximately 3 m long, 1 m wide and 1 m deep and it is filled with 2-3 cm sized graded gravel. Pre-treated wastewater from the first barrel enters the bottom part of the trench from one side and flows slowly to the other end. The trench is lined with a 400-500 micron thick polyethylene sheet. The sides of the trench are plastered with a mud layer so that the polyethylene liner sheet is not punctured by sharp stones. A 120 litre capacity plastic barrel is perforated and burred in the gravel at the exit end of the trench so that wastewater flows through the trench upwards to fill this barrel. Residence time of grey water in the trench is two to four days under anaerobic conditions.

Septic Tank

A septic tank consists of 2- 3 compartments. The compartment walls extend 15 cm above liquid level. The anaerobic bacteria present in the tanks decompose the solid wastes that have settled to the bottom of the tank thereby transforming most of the wastes in solids and gases. The outflow, through a series of subsurface pipes is distributed throughout the drain field. Here effluents undergo final treatment as the soil absorbs and filters the liquid whereas rest of the material is broken down by the microbes. It is not possible for the septic tanks to dispose of all the materials which enter the system. The solid that is left behind and which is not decomposed need to be removed on a regular basis; otherwise the system will fail.

Fig.13: Septic tank

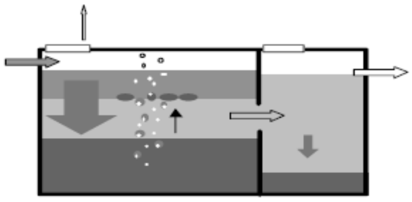
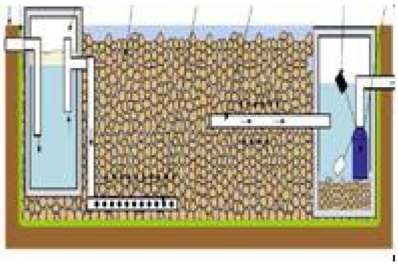


Fig.14: The Confined Trench System



Grease and light particles which form a layer of scum on the top are prevented by the use of baffles installed at the inlet and outlet of the tank. The scum formed is to be removed periodically. The suspended solids removal rate drops drastically when accumulated sludge fills more than 2/3 of the tank. This must be avoided, especially in cases where the effluent is treated further in a sand or gravel filter. The inlet may dive down inside the tank, below the assumed lowest level of the scum or may be above the water level when the inlet pipe is used to evacuate gas. The vent pipe for digester gases should end outside buildings, at a minimum of 2 m above the ground. The treatment quality of a septic tank is in the range of 25% - 50% COD removal. Post treatment may be provided depending on the type of reuse.

Imhoff Tank

Imhoff or Emscher tanks are typically used for domestic or mixed wastewater flows above 3 m^3/d. The tank consists of a settling compartment above the digestion chamber. Funnel-like baffle walls prevent up-flowing foul sludge particles from getting mixed with the effluent and from causing turbulence. The effluent remains fresh and odourless because the suspended and dissolved solids do not have an opportunity to get in contact with the active sludge to become sour and foul. Retention times of much longer than 2 h during peak hours in the flow portion of the tank would jeopardize this effect.

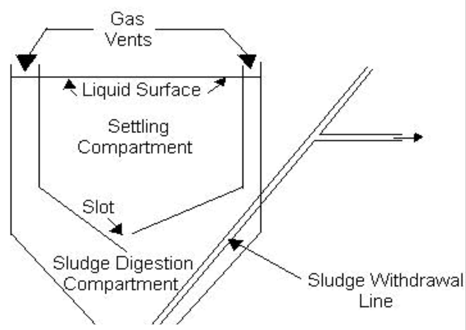


Fig 15: Imhoff Tank

The sludge and scum must be removed regularly at the intervals . Only part of the sludge should be removed so as to always keep some active sludge present. Sludge should be removed right from the bottom to make sure that only fully digested substrate is discharged. When sludge is removed, it should be immediately treated further in drying beds or compost pits for pathogen control. Pipe ventilation must be provided, as biogas is also produced in the Imhoff tank.

Constructed Wetland Treatment System

Reed bed filters and small-scale constructed wetlands, at the household-level, are well developed in recent days. The technology was designed for on-site, confined space wastewater treatment. It uses aquatic plants and the up-flow filter concept to treat wastewater.

The system is unique in that it combines wastewater treatment and resource recovery in a relatively small system that may be suitable for use in urban areas and has been described for use in moderate land-limited conditions for apartments. The system's spatial requirements are lower than conventional aquatic plant treatment processes and facultative pond systems. The free-floating aquatic macrophyte and sub-surface bio-fixed film treatment demonstrates high five-day BOD and nitrogen removal efficiencies of more than 85% at a loading rate of 135 kg/ha/day.

The Horizontal Flow Single Pond System

The horizontal flow single pond system are mostly constructed in a size of 1.2m x 1.0m x 0.5m (Length x Width x Height) each. Generally the total volume of the reactor is about 400L. The volcanic rocks were filled to a depth of 35 cm. The void volume of 220 L and the packing ratio to the total volume was about 0.45. The direction of wastewater flow was horizontal through rock medium and upflow towards the liquid portion and the aquatic plants, and then discharged through the other end of the tank.

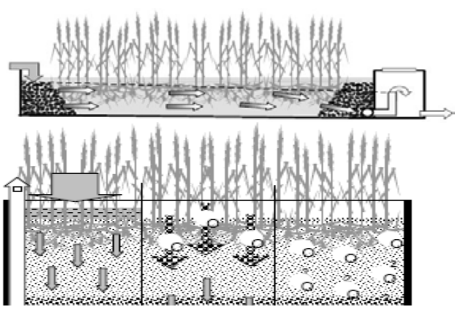
Off-Site Constructed Wetlands

Wetlands constructed specifically for treating wastewater are known as "off-site constructed wetlands" and are effective in the removal of BOD, TSS, and nitrogen (N). The beneficial uses of these systems for wastewater treatment are well established, and the technology continues to develop rapidly. Some of the studies using forested wetlands to treat domestic wastewater demonstrated that nutrients could be removed with a minimum application of expensive and fossil energy consuming technology.

Subsurface Wetlands

Subsurface wetlands are lined ditches that have been filled with gravel, sand or soil substrate and planted with appropriate plant varieties. Treatment in subsurface systems generally occurs when the effluent makes contact with plant roots and the soil or rock bed. Influent enters the treatment system and percolates through the substrate. Organic matter is biodegraded either aerobically or anaerobically and nutrients are eliminated through a variety of biological, physical and chemical processes. One of the major advantages of this treatment system is low maintenance requirements. If local clay for lining and local stone for a root-zone substrate is available, construction costs can be very low.

Fig 16: Constructed Wetland



Free Water Surface Wetlands

Free water surface (FWS) wetlands are typically shallow channels or basins where the water surface is open to the atmosphere and a suitable medium exists to support the growth of emergent or submerged aquatic plants. FWS wetlands support the growth of floating aquatic plants, as well as emergent and submergent varieties.

Wastewater treatment occurs as the plants assimilate nutrients (nitrogen and phosphorus) from the effluent and the resulting biomass is harvested. Two floating aquatic macrophyte plants most commonly used in wastewater treatment systems are water hyacinth (*Eichhornia crassipes*) and duckweed (*Lemnacea sp*., *spirodella sp*.). Macrophyte-based wastewater treatment systems are appropriate because they offer several advantages over mechanized treatment systems such as :

1) They have low operating costs

2) They operate with low energy requirements

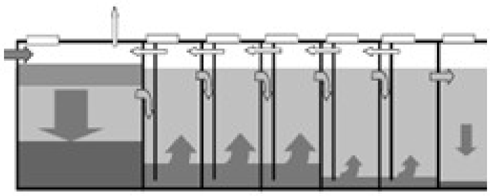
3) They can often be established at the site of wastewater production, and

4) They are more flexible and more tolerant of shock loading.

Baffled Septic Tank

Baffled septic tank or anaerobic baffled reactor in fact is a combination of several anaerobic process principles - the septic tank, the fluidized bed reactor and the UASB. The up-flow velocity of the baffled septic tank, which should never be more than 2 m/h, limits its design. The limited upstream velocity results in large but shallow tanks. It is for this reason that the baffled reactor is not economical for larger plants. However, the baffled septic tank is ideal for grey water treatment because it is simple to build and simple to operate. Hydraulic and organic shock loads have little effect on treatment efficiency. Treatment performance is the range of 65% - 90% COD (70% - 95% BOD) removal.

Fig.17 Baffled Septic Tank



Since the tanks are put in series, a part of the active sludge that is washed out from one chamber is trapped in the next. It also helps to digest difficult degradable substances, predominantly in the rear part, after easily degradable matters have been digested in the front part, already. The baffled septic tank consists of at least four chambers in series. The last chamber could have a filter in its upper part in order to retain eventual solid particles. A settler for post-treatment could also be placed after the baffled septic tank.

Equal distribution of inflow, and widespread contact between new and old substrate are important process features. The fresh influent is mixed as soon as possible with the active sludge present in the reactor in order to get quickly inoculated for digestion. The wastewater flows from bottom to top with the effect that sludge particle settle against the upstream of the liquid. This provides the possibility of intensive contact between resident sludge and newly incoming liquid. The water stream between chambers is directed by baffle walls that form a down-shaft or by down-pipes that are placed on partition walls for better distribution of flow.

Relatively short compartments (length < 50% to 60% of the height) are provided in order to distribute the wastewater over the entire floor area. The final outlet as well as the outlets of each tank should be placed slightly below surface in order to retain any possible scum.

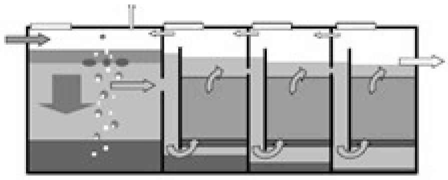
Waste Stabilization Ponds

Ponds (lagoons) or waste stabilization pond system are artificial lakes which consist of sedimentation ponds (pre-treatment ponds with anaerobic sludge stabilization), anaerobic ponds (anaerobic stabilization ponds), oxidation ponds (aerobic cum facultative stabilization ponds) and polishing ponds (post-treatment ponds, placed after stabilization ponds). But all ponds are not ideal for grey water treatment due to large area requirement and in case of facultative or anaerobic ponds, there will be nuisance by mosquito breeding, or bad odour. Polishing ponds can be used as a post treatment pond after gravel filter or constructed wetland, in which use of the fish to control mosquitoes is possible and more over it will give a good aesthetic appearance if it is constructed in a garden.

Aerobic ponds receive most of their oxygen via the water surface. For loading rates below 4 g BOD/m^2/d, surface oxygen can meet the full oxygen demand. Oxygen intake increases at lower temperatures and with surface turbulence caused by wind and rain. Oxygen intake depends further on the actual oxygen deficit up to saturation point and thus may vary at 20°C between 40 g O_2 /m^2/d for fully anaerobic conditions and 10 g O_2 /m^2/d in case of 75% oxygen saturation.

The secondary source of oxygen comes from algae via photosynthesis. However, in general, too intensive growth of algae and highly turbid water prevents sunlight from reaching the lower strata of the pond. Oxygen production is then reduced because photosynthesis cannot take place.

Fig 18: Anaerobic Filter



The result is a foul smell because anaerobic facultative conditions prevail. Algae are important and positive for the treatment process, but are a negative factor when it comes to effluent quality. Consequently, algae growth is desirable in the beginning of treatment, but not desired when it comes to the point of discharge, because algae increase the BOD of the effluent. Algae in the effluent can be reduced by a small last pond with maximum 1 day retention time. Baffles or rock bedding before the outlet of each of the ponds have remarkable effect on retaining of algae.

Anaerobic Treatment

Anaerobic treatment technology is efficient, well demonstrated and provides a cost-effective method of disposing organic wastes and producing fuel and fertilizers without releasing greenhouse gases. Anaerobic digesters have the ability to destroy large numbers of pathogenic organisms in wastewater and to produce energy in the form of methane gas to run water pump engines, electric generators and agricultural machinery. The anaerobic digester also produces sludge which is a fertilizer normally used in agriculture. Biogas is an excellent source of energy and can be used to produce electricity as well as cooking and lighting gas.

A well maintained anaerobic digester should produce 0.1 m^3 gas/ m^3 digester volume and the gas will constitute 70% methane and 30% carbon dioxide and can be easily used for cooking and lighting. Gas produced from the system is primarily used for lighting and cooking. The biogas produced is approximately 70% methane, and that the typical reactor will produce 0.1-0.2 m^3 biogas/ m^3 digester volume /day when 60% of the feed-stock to reactors is grey water. Digestion usually occurs over a five to six day period for maximum biogas generation. Treated slurry is used as a fertilizer, but can also be used as a feed supplement for pigs, mushroom growing media, and vermi-composting substrate.

Anaerobic Filter

The anaerobic filter, also known as fixed bed or fixed film reactor is used for the treatment of non-settelable and dissolved solids by bringing them in close contact with a surplus of active bacterial mass. This surplus together with "hungry" bacteria digests the dispersed or dissolved organic matter within short retention time. Anaerobic filters are reactors consisting of supporting material layers. On the surface of these material layers or bed, fixation of microorganism and the development of biofilm takes place. Anaerobic filters can be applied not only for treating concentrated wastewater but also for those wastewaters that have low organic load (grey water). If they are preceded by a reactor that retains settled solids, they will work better.

It is suitable for domestic wastewater and all industrial wastewater which have a lower content of suspended solids. The bacteria in the filter are immobile and generally attach themselves to solid particles or to the reactor walls. Filter materials like rocks, cinder, plastic, or gravel provide additional surface area for bacteria to settle. Thus, the fresh wastewater is forced to come into contact with active bacteria intensively. The larger surface area for the bacterial growth helps in the quick digestion of the wastes. A good filter material provides a surface area of 90 to 300 m^2 per meter cube reactor volume. Biological oxygen demand up to 70% to 90 % is removed in a well operated anaerobic filter.

Pre-treatment in settlers or septic tanks may be necessary to eliminate solids of larger size before they are allowed to enter the filter. When the bacterial film becomes too thick it has to be removed. This may be done by back-flush of wastewater or by removing the filter mass for cleaning outside the reactor. Nonetheless, the anaerobic filter is very reliable and robust. Anaerobic filters may be operated as down flow or up flow systems. A combination of up-flow and down-flow chambers is also possible.

Activated Sludge Process

The activated-sludge process is an aerobic, continuous-flow system containing a mass of activated micro-organisms that are capable of stabilizing organic matter. The process consists of delivering clarified waste-water, after primary settling, into an aeration basin where it is mixed with an active mass of microorganisms, mainly bacteria and protozoa, which aerobically degrade organic matter into carbon dioxide, water, new cells, and other end products. The bacteria involved in activated sludge systems are primarily Gram-negative species, including carbon oxidizers, nitrogen oxidizers, floc formers and non-floc formers, and aerobes and facultative anaerobes. The protozoa, for their part, include flagellates, amoebas and ciliates. An aerobic environment is maintained in the basin by means of diffused or mechanical aeration, which also serves to keep the contents of the reactor (or mixed liquor) completely mixed. After a specific retention time, the mixed liquor passes into the secondary clarifier, where the sludge is allowed to settle and a clarified effluent is produced for discharge. The process recycles a portion of the settled sludge back to the aeration basin to maintain the required activated sludge concentration. The process also intentionally wastes a portion of the settled sludge to maintain the required solids retention time (SRT) for effective organic removal. Control of the activated-sludge process is important to maintain a high treatment performance level under a wide range of operating conditions. The principal factors in process control are the following:

(a) Maintenance of dissolved oxygen levels in the aeration tanks;

(b) Regulation of the amount of returning activated sludge;

(c)) Control of the waste activated sludge.

The main operational problem encountered in a system of this kind is sludge bulking, which can be caused by the absence of phosphorus, nitrogen and trace elements and wide fluctuations in pH, temperature and dissolved oxygen (DO). Bulky sludge has poor settleability and compatibility due to the excessive growth of filamentous micro-organisms. This problem can be controlled by chlorination of the return sludge.

Aerated Lagoons

An aerated lagoon is a basin between 1 and 4 metres in depth in which waste water is treated either on a flow-through basis or with solids recycling. The microbiology involved in this process is similar to that of the activated-sludge process. However, differences arise because the large surface area of a lagoon may cause more temperature effects than are ordinarily encountered in conventional activated-sludge processes. Waste water is oxygenated by surface, turbine or diffused aerator. The turbulence created by aeration is used to keep the contents of the basin in suspension. Depending on the retention time, aerated lagoon effluent contains approximately one third to one half the incoming BOD value in the form of cellular mass. Most of these solids must be removed in a settling basin before final effluent discharge

Trickling Filters

The trickling filter is the most commonly encountered aerobic attached-growth biological treatment process used for the removal of organic matter from waste water. It consists of a bed of highly permeable medium to which organisms are attached, forming a biological slime layer, and through which wastewater is percolated. The filter medium usually consists of rock or plastic packing material. The organic material present in the wastewater is degraded by adsorption on to the biological slime layer. In the outer portion of that layer, it is degraded by aerobic micro-organisms. As the micro-organisms grow, the thickness of the slime layer increases and the oxygen is depleted before it has penetrated the full depth of the slime layer. An anaerobic environment is thus established near the surface of the filter medium. As the slime layer increases in thickness, the organic matter is degraded before it reaches the micro-organisms near the surface of the medium. Deprived of their external organic source of nourishment, these micro-organisms die and are washed off by the flowing liquid. A new slime layer grows in their place. This phenomenon is referred to as „sloughing‟. After passing through the filter, the treated liquid is collected in an under drain system, together with any biological solids that have become detached from the medium. The collected liquid then passes to a settling tank where the solids are separated from the treated waste water. A portion of the liquid collected in the under drain system or the settled effluent is recycled to dilute the strength of the incoming waste water and to maintain the biological slime layer in moist condition.

Rotating Biological Contractors

A rotating biological contractor (RBC) is an attached-growth biological process that consists of one or more basins in which large closely-spaced circular disks mounted on horizontal shafts rotate slowly through waste-water. The disks, which are made of high-density polystyrene or polyvinyl chloride (PVC), are partially submerged in the wastewater, so that a bacterial slime layer forms on their wetted surfaces. As the disks rotate, the bacteria are exposed alternately to waste-water, from which they adsorb organic matter, and to air, from which they absorb oxygen.

The rotary movement also allows excess bacteria to be removed from the surfaces of the disks and maintains a suspension of sloughed biological solids. A final clarifier is needed to remove sloughed solids. Organic matter is degraded by means of mechanisms similar to those operating in the trickling filters process. Partially submerged RBCs are used for carbonaceous BOD removal, combined carbon oxidation and nitrification, and nitrification of secondary effluents. Completely submerged RBCs are used for de-nitrification.

Membrane Bio-Reactor (MBR)

Lesjean and Gnirss (2006) investigated grey water treatment with a membrane bioreactor operated at low Sludge Retention Time (SRT) and low Hydraulic Retention Time (HRT). On the site of the Berlin-Stahnsdorf WWTP, ten private apartments and one office building are connected to *the sanitation concept for separate treatment* (SCST) scheme whereby urine, faecal matter and grey water are collected and stored separately.

The MBR unit was constantly fed over 8 months with fresh grey water coming from bathrooms and kitchens, after a buffer tank of maximum of 8 h retention, and was successively operated with 20, 9, 6 and 4 days sludge age. Due to the very short HRT, the sludge concentration was maintained in the approximate range of 10 g to 2 g MLSS/L

The COD is well eliminated (>85% COD-removal), and ammonification and nitrification remained complete (>80% TKN-removal), even with the lower sludge age. However, the nitrification rates were relatively low (<0.7 mgNNH 3/g VSS. h), and nitrogen removal was inconsistent and ranged from 20 to 80%, due to the presence of nitrate in the permeate. Indeed, the main elimination mechanism was bio-assimilation for cell growth, and therefore the removal rate depended strongly on the grey water characteristics (both COD and TN).

A modular MBR plant was installed at CanTho University to treat the heavily loaded grey water from a dormitory of the CanTho University (grey water from kitchens, showers, and hand wash basins). All effluent values met the standards specified for the reuse of treated water for toilet flushing and laundry washing. Also the microbial quality requirements according to Vietnamese standards for irrigation are easily met.

Chemical Precipitation

Chemical coagulation of raw wastewater before sedimentation promotes the flocculation of finely divided solids into more readily settleable flocs, thereby enhancing the efficiency of suspended solid, BOD and phosphorus removal is high as compared to plain sedimentation without coagulation. The degree of clarification obtained depends on the quantity of chemicals used and the care with which the process is controlled. Coagulant selection for enhanced sedimentation is based on performance, reliability and cost.

Table 8: Removal Efficiency of Plain Sedimentation with Chemical Precipitation

Parameter	**Percentage removal**	
	Plain sedimentation	**Chemical precipitation**
Total suspended solids (TSS)	40-90	60-90
BOD	25-40	40-70
COD		30-60
Phosphorus	5-10	70-90
Bacteria loadings	50-60	80-90

Performance evaluation uses jar tests of the actual wastewater to determine dosages and effectiveness. Chemical coagulants that are commonly used in wastewater treatment include alum (Al2(SO4)3.14.3 H2O), ferric chloride (FeCl3.6H2O), ferric sulfate (Fe2(SO4)3), ferrous sulfate (FeSO4.7H2O) and lime (Ca(OH)2). Organic poly electrolytes are sometimes used as flocculation aids. Suspended solids removal through chemical treatment involves a series of three unit operations rapid mixing, flocculation and settling. First, the chemical is added and completely dispersed throughout the wastewater by rapid mixing for 20-30 seconds in a basin with a turbine mixer. Coagulated particles are then brought together via flocculation by mechanically inducing velocity gradients within the liquid. Flocculation takes 15 to 30 minutes in a basin containing turbine or paddle-type mixers. The final step is clarification by gravity. The overflow rates are more consistent. On the other hand, coagulation results in a larger mass of primary sludge that is often more difficult to thicken and dewater. It also entails higher operational costs and demands greater attention on the part of the operator.

Sand Filter

A sand bed filter is a kind of depth filter. Broadly, there are two types of filter for separating particulate solids from fluids:

- Surface filters, where particulates are captured on a permeable surface
- Depth filters, where particulates are captured within a porous body of material.

There are several kinds of sand filters, some employing fibrous material and others employing granular materials. Sand bed filters are an example of a granular loose media depth filter. They are usually used to separate small amounts (<10 parts per million or <10 g per cubic metre) of fine solids (<100 micrometres) from aqueous solutions. In addition, they are usually used to purify the fluid rather than capture the solids as a valuable material. Therefore they find most of their uses in liquid effluent (wastewater) treatment.

The particulate solids can be prevented from being captured by surface charge repulsion if the surface charge of the sand is of the same sign (positive or negative) as that of the particulate solid. Furthermore, it is possible to dislodge captured particulates although they may be re-captured at a greater depth within the bed. Finally, a sand grain that is already contaminated with particulate solids may become more attractive or repel additional particulate solids. This can occur if by adhering to the sand grain the particulate loses surface charge and becomes attractive to additional particulates or the opposite and surface charge is retained repelling further particulates from the sand grain.

In some applications it is necessary to pre-treat the effluent flowing into a sand bed to ensure that the particulate solids can be captured. This can be achieved by one of several methods:

- Adjusting the surface charge on the particles and the sand by changing the pH
- Coagulation – adding small, highly charged cations (aluminium 3+ or calcium 2+ are usually used)
- Flocculation – adding small amounts of charge polymer chains which either form a bridge between the particulate solids (making them bigger) or between the particulate solids and the sand.

The sand filter can be operated either with upward flowing fluids or downward flowing fluids, the latter being much more usual. For downward flowing devices the fluid can flow under pressure or by gravity alone. Pressure sand bed filters tend to be used in industrial applications and often referred to as rapid sand bed filters. Gravity fed units are used in water purification especially drinking water and these filters have found wide use in developing countries (slow sand filters).

The treatment methods are used extensively in the water industry throughout the world. The slow sand filters can produce very high quality water free from pathogens, taste and odour without the need for chemical aids. Passing flocculated water through a rapid gravity sand filter strains out the floc and the particles trapped within it reducing numbers of bacteria and removing most of the solids. The medium of the filter is sand of varying grades. Where taste and odour may be a problem (organoleptic impacts), the sand filter may include a layer of activated carbon to remove such taste and odour.

Sand filters become clogged with floc after a period in use and they are then backwashed or pressure washed to remove the floc. This backwash water is run into settling tanks so that the floc can settle out and it is then disposed of as waste material. The supernatant water is then run back into the treatment process or disposed off as a waste water stream. In some countries the sludge may be used as a soil conditioner. Inadequate filter maintenance has been the cause of occasional drinking water contamination.

Sand filters are occasionally used in the treatment of sewage as a final polishing stage. In these filters the sand traps, residual suspended material and bacteria provides a physical matrix for bacterial decomposition of nitrogenous material, including ammonia and nitrates, into nitrogen gas.

Adsorption with Activated Carbon

Adsorption is the process of collecting soluble substances within a solution on a suitable interface. In wastewater treatment, adsorption with activated carbon-a solid interface-usually follows normal biological treatment, and is aimed at removing a portion of the remaining dissolved organic matter. Particulate matter present in the water may also be removed. Activated carbon is produced by heating char to a high temperature and then activating it by exposure to an oxidizing gas at high temperature. The gas develops a porous structure in the char and thus creates a large internal surface area. The activated char can then be separated into various sizes with different adsorption capacities. The two most common types of activated carbon are granular activated carbon (GAC), which has a diameter greater than 0.1 mm, and powdered activated carbon (PAC), which has a diameter of less than 200 mesh. A fixed-bed column is often used to bring the wastewater into contact with GAC. The water is applied to the top of the column and withdrawn from the bottom, while the carbon is held in place. Backwashing and surface washing are applied to limit head loss build-up. Expanded-bed and moving-bed carbon contactors have been developed to overcome the problem of head loss build-up. In the expanded-bed system, the influent is introduced at the bottom of the column and is allowed to expand. In the moving-bed system, spent carbon is continuously replaced with fresh carbon. Spent granular carbon can be regenerated by removal of the adsorbed organic matter from its surface through oxidation in a furnace. The capacity of the regenerated carbon is slightly less than that of the virgin carbon. Waste-water treatment using PAC involves the addition of the powder directly to the biological treatment effluent or the physiochemical treatment process, as the case may be. PAC is usually added to wastewater in a contacting basin for a certain length of time. It is then allowed to settle to the bottom of the tank and removed. Removal of the powdered carbon may be facilitated by the addition of polyelectrolyte coagulants or filtration through granular-medium filters. A major problem with the use of powdered activated carbon is that the methodology for its regeneration is not well defined.

Disinfection

Disinfection refers to the selective destruction of disease-causing micro-organisms. This process is of importance in wastewater treatment owing to the nature of wastewater, which harbours a number of human enteric organisms that are associated with various waterborne diseases. Commonly used means of disinfection include the following:

(i) Physical agents such as heat and light

(ii) Mechanical means such as screening, sedimentation and filtration

(iii) Radiation, mainly gamma rays

(iv) Chemical agents including chlorine and its compounds, bromine, iodine, ozone, phenol and phenolic compounds, alcohols, heavy metals, dyes, soaps and synthetic detergents, quaternary ammonium compounds, hydrogen peroxide, and various alkalis and acids.

Table 9: Characteristics of Disinfection Chemicals

Characteristic	Chlorine	Sodium hypochlorite	Calcium hypochlorite	Chlorine dioxide	Bromine chloride	Ozone	Ultraviolet light
Chemical formula	$Cl2$	NaOCl	Ca(OCl)2	ClO2	BrCl	O3	N/A
Form	Liquid, gas	Solution	Powder, pellets or 1 percent solution	Gas	Liquid	Gas	UV energy
Toxicity to micro-organisms	High	High	High	High	High	High	High
Solubility	Slight	High	High	High	Slight	High	N/A
Stability	Stable	Slightly unstable	Relatively stable	Unstable	Slightly unstable	Unstable,	Must be generated as used
Toxicity to higher forms of life	Highly toxic	Toxic	Toxic	Toxic	Toxic	Toxic	Toxic
Effect at ambient temperature	High	High	High	High	High	High	High
Penetration	High	High	High	High	High	High	Moderate
Corrosiveness	Highly corrosive	Corrosive	Corrosive	Highly corrosive	Corrosive	Highly corrosive	N/A
Deodorizing ability	High	Moderate	Moderate	High	Moderate	High	None
Availability/cost	Low cost	Low cost	Low cost	Low cost	Low cost	high cost	high cost

The most common chemical disinfectants are the oxidizing chemicals, and of these, chlorine is the most widely used for altering the cell permeability, altering the colloidal nature of the protoplasm and inhibiting enzyme activity. In applying disinfecting agents, several factors need to be considered: contact time, concentration and type of chemical agent, intensity and nature of physical agent, temperature, number of organisms, and nature of suspending liquid. Table 9 shows the most commonly used disinfectants and their effectiveness.

Table 10: Treatment Systems and its Applications

Categories	Treatment system	Advantages	Disadvantages	Reuse option
Treatment for low quality reuse	Constructed Wetland Treatment System. Horizontal Combined Bio-Fixed Film with Aquatic Plants, Off-Site Constructed Wetlands, Subsurface Wetlands. Floating Aquatic Macrophytes	Simplicity. These systems are simple to construct. Low cost. Cost-effective and environmentally friendly treatment High efficiency. They provide effective and reliable wastewater treatment under fluctuating hydraulic and contaminant loading rates. They require little or no energy to operate They can be aesthetically pleasing additions to homes and neighborhoods. They are viewed as an environmentally friendly technology and are generally well received by the public.	High land area requirements (depending on the design, they may require a relatively large land area compared to a conventional facility), the need for a preliminary treatment before the wastewaters treated by the system, the need of higher retention time, and that they may cause problems with pests. Nutrient-rich waters flowing into a water body may lose some of their nutrient load when passing through wetland vegetation. This means that constructed wetlands may and should be integrated into management plans for conservation of both soil and water resources of a watershed, or integrated as parts of major restoration projects. The performance of wetlands may vary based on usage and climatic conditions. There may be a prolonged initial start-up period before vegetation is adequately established	Reuse of treated wastewater for irrigation and/or other purposes
	Waste stabilization pond	Low cost for construction and O&M, simple operation and maintenance, less skilled labour required Since it is constructed in large area the dilution with rainwater will help the treatment	High Land requirement Quality of effluent will vary in terms of suspended solids Odour problem persists	Reuse of treated wastewater for irrigation and/or other purposes

Treatment for medium reuse	Anaerobic treatment process	Less energy required Less biological sludge produced Lower nutrient demand Methane production: Providing potential energy source with possible revenue both from sale of the energy, and benefit from government tax, and (Kyoto agreement) CDM etc. Methane production: Anaerobic digestion contributes to reducing greenhouse gases by reducing demand for fossil fuels. Smaller reactor volume required. Biomass acclimatization allows most organic compounds to be transformed Rapid response to substrate addition after long periods without feeding End product can be potentially saleable products like biogas, soil conditioner and a liquid fertilizer. Process more effectively provides sanitation/removal of diseases.	Longer start-up time to develop necessary biomass inventory Requires alkalinity and/or specific ion addition Requires further treatment with an aerobic treatment process to meet discharge requirements Biological nitrogen and phosphorus removal is not possible Much more sensitive to the adverse effect of lower temperatures on reaction rates May need heating (often by utilisation of process gas) to achieve adequate reaction rates Hazards arise from leak.	Reuse of treated wastewater for toilet flushing, gardening and/or other purposes
	Activated-sludge process	Can be used in different sizes. Removes organics Oxidation and Nitrification achieved Biological nitrification without adding chemicals Biological Phosphorus removal and Solids/ Liquids separation Stabilization of sludge and Capable of removing ~ 97%	Does not remove color from industrial wastes and may increase the color through formation of highly colored intermediates through oxidation Does not remove nutrients, tertiary treatment is necessary Problem of getting well settled sludge Recycle biomass keeps high biomass, concentration in aeration tanks allowing it to	Reuse of treated wastewater for Toilet flushing, gardening and/or other purposes

		of suspended solids The most widely used wastewater treatment process	be performed in technologically acceptable detention times	
	Aerated lagoons	Require less land than facultative lagoons. Require much less land than facultative ponds, depending on the design conditions. Sludge disposal may be necessary but the quantity will be relatively small compared to other secondary treatment processes.	Aerated lagoons are not as effective as facultative ponds in removing ammonia nitrogen or phosphorous, unless designed for nitrification. Changes in pH and alkalinity that affect removal rates for ammonia nitrogen and phosphorous in facultative ponds do not occur in aerated ponds. Reduced rates of biological activity occur during cold weather. Mosquito and similar insect vectors can be a problem if vegetation on the dikes is not properly maintained. Sludge accumulation rates will be higher in cold climates because low temperature inhibits anaerobic reactions and requires energy input.	Reuse of treated wastewater for toilet flushing, gardening and/or other purposes
	Trickling filters	Simple and reliable process that is suitable in areas where large tracts of land are not available for a WSP treatment system Effective in treating high concentrations of organic material depending on the type of media used; Very efficient in removal of ammonia from wastewater; Appropriate for small- to medium-sized communities With the introduction of plastic filter media to replace the rock media, speed control, and more reliable rotary distributor mechanisms, the performance of trickling filters has been greatly enhanced.	Additional treatment may be needed for the effluent to meet strict discharge standards Generates sludge that must be treated and disposed off and regular operators attention is needed; Relatively high incidence of clogging; Relatively low loadings required depending on the media. Limited flexibility and control in comparison with activated sludge processes.	Reuse of treated wastewater for toilet flushing, gardening and/or other purposes

		Ability to handle and recover from shock loads and relatively low power requirements. They produce less sludge than suspended-growth systems. The sludge tends to settle well because it is compact and heavy. Level of skill and technical expertise needed to manage and operate the system is moderate The cost to operate a trickling filter is very low.	Potential for vector and odor problems	
	Rotating biological contactors	Short contact periods are required because of the large active surface They are capable of handling a wide range of flows Sloughed biomass generally has good settling characteristics and can easily be separated from waste stream Operating costs are low because little skill is required in plant operation Short retention time Low power requirements Elimination of the channeling to which conventional percolators are susceptible Low sludge production and excellent process control	Requirement for covering RBC units in northern climates to protect against freezing Shaft bearings and mechanical drive units require frequent maintenance	Reuse of treated wastewater for toilet flushing, gardening and/or other purposes
Treatment for high quality reuse	Chemical treatment	Easy to control the treatment. Less land required, less capital cost, alteration in flow can be done.	High operation cost. Hazardous sludge produced. Requires skilled manpower	
	Adsorption by activated carbon	Removes dissolved organics and chlorine effectively. Long life (high capacity)	Does not effectively remove particles, pyrogens or bacteria. Coarbon beds can generate fine carbon particles. High maintenance costs over long-term.	
	Reverse osmosis	Effectively removes all types of contaminants to some extent (particles, pyrogens, microorganisms, colloids and	Flow rates are usually limited to a certain gallons/day rating.	

		dissolved inorganics). Requires minimal maintenance and very effective to remove pharmaceutical contaminants almost completely	The small pores in the membrane of a RO plant cannot block dangerous chemicals like pesticides herbicides, and chlorine. In order to remove them, carbon filter has to be used as a complimentary measure. It ends up removing the healthy, naturally occurring minerals (trace minerals) present in the water as well. RO proves to be a very slow option.	
	Ozonation and advanced oxidation processes	Eliminates odors, reduces oxygen demanding matter, turbidity and surfactants, removes most colors, phenolics and cyanides, increases dissolved oxygen, production of no significant toxic side products, increases suspended solids reduction	High capital cost, high electric consumption, highly corrosive, especially with steel or iron.	

5.1 Case Studies

5.2 Sullage Recycle System at Panchgani

Ion Exchange India is operating a sullage recycle system at its training centre in Panchgani, at a capacity of 1,800 litres per day. In the recycling process, sullage from the kitchens and bathrooms is collected in an underground RCC tank where the water is treated by coagulation, filtration and disinfection, and then pumped to the overhead tank from which it is supplied for low-end uses. The treated water is used for toilet flushing and gardening. Simple construction and affordable capital costs make it easy for both new and existing buildings to go in for the system and the payback can be in as little as 15 to 18 months. The company has also installed a sullage recycle plant, capacity 5 cu.m per hour, for a large residential complex at Vasai, near Mumbai; beautiful gardens are now maintained in an otherwise water-stressed area (Ramachandran, 2002).

5.3 Greywater for Irrigation in Chennai

Finding water for gardening in Chennai has been a difficult proposition in recent years with dipping ground water levels and the increasing demand for drinking water. Chennai Corporation recently launched a drive to source recycled grey water for watering avenue trees and plants in parks and for other gardening purposes. Several residents in the city have started turning to grey water to meet their gardening needs. The local body recommends a simple two stage recycling technique which includes creating a primary treatment pit consisting of charcoal and blue metal (which is used for construction) and a secondary pit that will just hold the water and help settle some of the smaller impurities. The outlet of water from kitchen and bathroom needs to be diverted to the primary pit. It would of course be best if a separate pipeline is created for grey water from kitchen and bathrooms to the treatment pits at the time of construction itself.

5.4 Greywater Treatment Plants in Ashram Schools, Madhya Pradesh

Dhar and Jhabua are two districts of Madhya Pradesh which suffer recurrent water quantity and quality problems. Lack of water is major reason for low sanitation coverage in schools. In many residential schools in Dhar and Jhabua districts, limited availability of freshwater has prompted UNICEF, in collaboration with NEERI and other governmental and non-governmental partners, to explore the use of grey water for appropriate purposes such as flushing of toilets. A holistic water management is adopted in these schools by integrating different water usages and corresponding quality requirements. It has been found out in Ashram schools that water requirement is about 60-70 litre per student per day as against drinking/cooking water requirement of 5 litre per day. The grey water treatment plants have been constructed by providing treatment techniques such as screening, equalization, settling, filtration and aeration. This simple treatment has resulted in enabling use of treated grey water in flushing the toilets.

UNICEF and NEERI along with government and non-government partners have constructed six grey water treatment plants at tribal schools in Dhar and Jhabua districts. The purpose of the plants was to make water available to flush toilets, to improve sanitation, to use treated grey water for gardening and for floor washing. The operation and maintenance of these grey water treatment plants are looked after by students and Parent Teachers Association (PTA). Performance evaluation of grey water treatment plant was undertaken by NEERI by collecting samples from the treatment plants. The turbidity removal efficiency of 50% (<200 NTU) is observed in all the grey water treatment plants. Considering direct correlation between turbidity and microorganism, it can be stated that microbial removal efficiency of these grey water treatment plants is also approximately 50%.

The Cost Benefit Analysis study conducted by NEERI concluded that the cost of the system may be recovered in two years. Additionally, the system provides secondary benefit such as improved education, clean environment and time-gain for other activities. Indirect economical benefits are also there. This is a classic example of how a simple application of grey water reuse system can be of tremendous economic benefit and viable on such a micro-level.

5.5 Greywater Recycling System at Hotels in Kerala

There are some hotels in Kerala that treat and reuse greywater. The grey water is let through a multi stage low maintenance system to treat it and recycle it for flushing, gardening and other non-potable end uses. The stages of treatment are given below:

Greywater→ Grease traps (for removal of fat and grease) → Anaerobic filters (for partial BOD removal)→ Submersible pump chamber →Constructed wetlands (for BOD reduction to 30 mg/l)→ Polishing pond (for BOD removal to 0 mg/l)→ Online chlorination (for disinfection)→ Overhead tank for flushing /gardening.

The wastewater from the bathrooms, kitchen and wash areas of cottages and kitchen block is first led to grease traps for removing grease and fat. After the grease trap, the grey water is directed to upflow filters for removal of solid particles and also for partial BOD reduction due to anaerobic action. The effluent from the filter is pumped to multi-stage constructed wetlands /reed beds at the top of the mount. The treated effluent is collected in a polishing pond, where the final polishing and BOD removal is effected mainly by water plants like duck weed. This water is chlorinated and pumped to the overhead tank for flushing, gardening and other non-potable end uses.

5.6 Greywater Tower Demonstration Project in Kitgum Town Council, Uganda

A greywater demonstration project in peri-urban settlements of Kitgum, Uganda, initiated by Resource-Oriented Sanitation Concepts for Peri-urban Areas in Africa (ROSA), built and trained families to use greywater-irrigated tower planters. According to a baseline study conducted by ROSA before implementing the project, greywater was most often disposed of in Kitgum by dumping the untreated wastewater onto the ground or into storm-drains, resulting in pools of water that developed a foul odor, facilitated mosquito breeding, and presented adverse community health outcomes. Despite water shortages in the area, greywater was not being reused (Kulabako et al. 2009).

Fig 19: Grey water tower

Seven households were selected to participate in the demonstration project, representing households from low, middle and upper classes. At each household, three “greywater towers” were built. Greywater towers are columns of soil wrapped in a cloth and supported by stakes, with an inner core of stones. Plants grow sideways out of the tower through cuts in the cloth, and greywater is poured into the core of stones from top of the tower to irrigate the plants (Crosby 2005).This technology was selected because it could be constructed with local materials, is easy to operate and maintain, and can grow food on a small area of land (Kulabako et al. 2009).

Households were trained on how to use the greywater tower effectively, and how to maintain it. At one household a control tower was set up to determine if irrigation with greywater negatively impacted plant growth. This tower was built in the same way as the others, but was irrigated with groundwater rather than greywater. Greywater quality, the amount of greywater produced, and effects on plants were then studied for 6 months (Kulabako et al. 2009).

Overall, the demonstration projects worked well, and showed that plants irrigated with greywater generally performed comparably to those irrigated with groundwater (Kulabako et al. 2009). Interviews with community members indicated wide community awareness and interest in the greywater towers. Furthermore, a walk-through of the area after 6 months revealed that 15 additional households had built and started using greywater towers, and additional households had set up other types of gardens irrigated by greywater (Kulabako et al. 2009).

5.7 Greywater Reuse in Norway

At Klosterenga in Oslo, the capital of Norway, the grey water is treated in an advanced nature based on grey water treatment system in the courtyard of the building. The system consists of a septic tank, pumping to a vertical down-flow single pass aerobic biofilter followed by a subsurface horizontal-flow porous media filter. The Klosterenga system built in 2000 has consistently produced an effluent quality averaging to: COD -19 mg/l, Total nitrogen - 2.5 mg/l, Total phosphorus - 0.03 mg/l and no Faecal coliforms.

The total area requirement is $1m^2$/ person and the effluent meets European Swimming Water Standards with respect to indicator bacteria and WHO Drinking Water Standards with respect to nitrogen. The low area requirement of the system and the high effluent quality facilitates use in urban settings, discharge to small streams, open waterways or irrigation or groundwater recharge (Jenssen 2003).

6.1 Policies and Regulation

6.2 Overview of Greywater Policies, Regulations and Laws around the World

Studying the international scenario, one could see diversity in the approaches to and stringency of greywater regulations, from being legal with few restrictions, to being prohibited in all circumstances (Prathapar et al.,CSBE 2003). Also there are places without clear policies on greywater, where its use may instead be indirectly regulated by building, plumbing, or health codes written without consideration of greywater reuse. For example, a country may have wastewater regulations that do not distinguish between black and greywater, e.g. Oman, Jordan (Maimon et al. 2010), or have a plumbing code that prohibits discharge of non-potable water through outlets such as faucets, such as in Canada‟s National Plumbing Code (CMHC 1998).

Greywater reuse is illegal in some Middle Eastern countries, and regarding greywater regulation in Oman, Prathapar et al. (2005) note, “At present, Omani wastewater reuse standards do not distinguish between greywater and blackwater and require that greywater be treated to the standards of potable water. However, there are many households and mosques in Oman (and many parts of the world) that use untreated greywater for home irrigation. In principle such uses are illegal, but the bottom line is that unrealistic laws have poor participation rates.” Nevertheless, greywater use is growing, even in regions with laws restricting greywater use and those with no explicit policies regarding greywater. For example, Sheikh estimates that only about 0.01% of greywater systems in California are permitted (2010). It has also been documented that greywater reuse occurs in households in the Middle East regardless of its legality (McIlwaine 2010). Similarly, recognizing that using wastewater for irrigation is a reality in many middle and low-income countries, the World Health Organization has established guidelines to help ensure the safety of wastewater reuse, including greywater reuse, for irrigation.

Further, in his work on greywater use in the Middle East, McIlwaine notes that no country in the Middle East and North African region has “developed a clear approach to its use that clearly states the responsibilities of the users and the regulatory requirements” (McIlwaine 2010). Jordan passed a standard in 2006 regarding greywater reuse in rural areas, however the code does not fully clarify what households must do to be permitted to reuse greywater (McIlwaine 2010). Israel is expected to soon pass a law that would legalize greywater reuse from showers, bathroom sinks, and washing machines outdoors for landscaping and indoors for toilet flushing (Global Water Intelligence 2010).

Australia is often considered to be a leader with respect to greywater policies. Specific regulations and requirements vary by state. For example in New South Wales, untreated greywater can be used for subsurface irrigation (NSW Office of Water 2010), while in Tasmania, all greywater must be treated before reuse (Tasmanian Environment Centre Inc. 2009). At the national level, Australia has developed guidelines for greywater reuse, “*Australian Guidelines for Water Recycling: Managing Health and Environmental Risks,”* and reuse is encouraged through a program that offers $500 rebate for the installation of a greywater system (Australian Government). Several other countries also have incentive programs for installation of greywater systems, including Korea and Cyprus (CWWA 2002, CSBE 2003). In Tokyo, Japan, not only are there incentives for installing greywater systems, but they are mandatory for buildings with an area of over 30,000 square meters, or with a potential to reuse 100 cubic meters per day (CSBE 2003). Several municipalities of Spain, including Sant Cugat del Vallès near Barcelona and several other municipalities in Catalonia, have passed regulations to promote greywater reuse in multistory buildings (Domenech and Sauri 2010).

The European Council Directive 91/271/EEC states that “treated wastewater shall be reused whenever appropriate,” However, how to determine if it is appropriate is left ambiguous (Somogyi et al. 2009). Greywater standards are currently under development through the European and International Standards Committees (Anglian Water). Germany has been a leader in Europe in the use of greywater (Nolde, Regulatory Framework and Standards). Domestic greywater reuse systems are legal in Germany, but must be registered with the Health Office (Nolde 2005). The United Kingdom has conducted research into greywater reuse, particularly for toilet reuse, noting a number of problems with maintenance, reliability and costs of these more complex systems (CSBE 2003), and greywater systems are not in wide usage (UK Environment Agency 2008). However, it is legal, provided that it complies with certain building codes and the British Standards Greywater Systems Code of Practice. Sweden and Norway have also done research into greywater and have implemented systems in some student dormitories and apartment buildings (Jenssen 2008). Much of this research has been situated in research into ecological sanitation more broadly, including urine separation (Esrey et al. 1998). With regard to greywater policy in North America, a 2002 report by the Canadian Water Works Association concluded: “traditional regulatory practices prohibiting rainwater harvesting or greywater reuse as substitutes for potable water supply are changing…However, there is a marked reluctance on the part of most jurisdictions in North America to consider these options (CWWA 2002).”

The United States does not have a National Greywater Policy, leaving regulation of greywater to the states. About 30 of the 50 states have greywater regulations of some kind (Sheikh 2010). These regulations vary widely. North Carolina has stringent greywater regulations and only allows reuse of water if it is treated to the same standards that are required for treating sewage water (Sheikh 2010). The state of Arizona has a more flexible greywater policy than many states, and is often seen as a leader in terms of promotion of greywater reuse in the United States.

6.3 Existing Infrastructure

Reuse of greywater requires separating greywater from sewage water, which is not standard plumbing practice in many countries, and therefore requires plumbing retrofits. The difficulty and expense of this retrofit varies widely, depending on the building and complexity of the system (e.g., how many collection points the system will have). For example, in Jordan most houses are constructed of reinforced concrete with pipes cast into floor slabs, making greywater plumbing retrofits difficult and expensive (CSBE 2003). On a larger scale, widespread diversion of greywater could potentially be disruptive to wastewater collection and treatment, as a lower volume of wastewater would be diverted for treatment, and it would contain a higher concentration of contaminants and solids. In pipes with low slopes, this could potentially lead to insufficient flows in sewers to carry waste to the treatment plant (CSBE 2003). Sheikh notes that “as greywater reuse becomes more widespread, it may interfere enough with the operation of sewers and water reclamation facilities to engender legal or legislative action” (Sheikh 2010). On the other hand, some conventional sewers, particularly those that combine storm runoff and municipal sewage, are prone to overflowing. In these cases, greywater reuse can reduce the risk of sewage overflows (Bertrand et al. 2008). Because of these conflicts with existing infrastructure, large scale (i.e., community-wide) greywater reuse may be most feasible for areas without extensive existing water and wastewater infrastructure. While it does not specifically address sanitation, and thus would always need to be implemented in conjunction with sanitation systems, it can reduce loads on septic systems and other decentralized sewage treatment techniques.

6.3. Planning and Plumbing Codes

In addition, greater use of greywater can conflict with established planning and plumbing codes. For instance, the International Association of Plumbing and Mechanical Officials (IAPMO) is an industry group that creates uniform code that plumbers and planners refer to around the world. The most recent 2006 Uniform Code Manual has a section on greywater (Chapter 16, Part 1). The chapter states clearly that a permit is necessary for any greywater system to be installed and it only describes greywater systems that collect and store greywater for outdoor, subsurface irrigation. It does not address diversion systems, a more common and less costly option. In the American Southwest, states and municipalities are increasingly amending their codes to allow small greywater systems (including diversion systems) to be installed without a permit (e.g., Arizona‟s greywater code and California‟s new greywater code). On the other hand, some new green building standards provide incentives for greywater reuse.

The LEED (Leadership in Energy and Environment Design) Green Building Rating System was devised as a voluntary standard for developing high-performance, sustainable buildings. LEED was initially created by the U.S. Green Building Council to establish a common measurement to define “green building.” Since its inception in 1998, LEED has grown to encompass more than 14,000 projects in the United States and 30 other countries (citation LEED for existing buildings v2.0 reference guide page pg 11). On average, a LEED certified building uses 30% less water than a conventional building. Projects receive points for each “green” practice that they implement. In LEED 2009, there are 100 possible base points. Buildings can qualify for four levels of certification: LEED Certified -40 - 49 points; Silver - 50 - 59 points; Gold - 60 - 79 points; and Platinum - 80 points and above.

Greywater reuse can earn a significant number of LEED points across several categories: Water Use Reduction: 20% Reduction – 1 point.

o 20% reduction in water use for building using alternative on-site sources of water such as rainwater, stormwater, and greywater

• Water Efficient Landscaping, No Potable Water Use or No Irrigation - 2 points

o Use only captured rainwater, recycled wastewater, or recycled greywater for site irrigation.

• Innovative Wastewater Technologies – 2 points

o Reduce generation of wastewater and potable water demand, while increasing the local aquifer recharge – use captured rainwater or recycled greywater to flush toilets and urinals or treat 50% of wastewater on-site to tertiary standards.

• Water Use Reduction, 30% - 40% reduction – 2-4 points

o Maximize water efficiency within building to reduce the burden on municipal water supply and wastewater systems. Use alternative on-site sources of water such as rainwater, stormwater, and greywater for non-potable applications such as toilet flushing and urinal flushing.

7.1 STRATEGY AND FRAMEWORK FOR GREYWATER REUSE

7.2 Need for strategy and framework

The two contemporary urban issues, viz., scarcity of freshwater and the increase in urban wastewater generation emphasize the need for grey water recycle and reuse. As already elaborated in the previous paragraphs, greywater is a potential substitute for freshwater for a variety of uses, both domestic and industrial. Once the wasted greywater is captured and reused, the demand for potable water will substantially decrease. Also the effort and money spent on waste water management could be considerably reduced. The other benefits of greywater reuse have also been discussed in the previous sections. It is a positive factor that with every increase in the use of water, the volume of greywater also will increase and the greywater is a nascent low cost substitute for domestic, commercial and industrial uses.

Fast growing urban population, changing housing patterns, inadequacy of freshwater sources against the ever growing demand, unscientific wastewater disposal practices, lack of public awareness, etc., exert pressures on the water supply and sanitation system. However, wastewater treatment and reuse has not become vogue in India as in the case of majority of countries in the world. Recently in India, some efforts in this line have been initiated for wastewater recycle and reuse to address the water scarcity. The recycled wastewater is being utilized in many industries and other organizations for uses other than potable purposes. It is high time especially for the major cities in India to implement proper wastewater management. Wastewater management strategy should essentially focus on greywater reuse in view of its latent capability to reduce the volume of wastewater to be treated with expensive treatment methods. Greywater reuse is nothing but water conservation and is capable of reducing the impact of development of new water sources.

In order to effectuate water conservation through reuse, a strategic implementation plan has to be developed. Since waste water reuse demands change of mindset and change of behavioural patterns in water use, the initiative should pervade through all sections of the urban population and should stabilize through stages of evolution. The approach for greywater reuse should premise on the following basic principles:

- Acceptable levels of treatment.
- Requiring low capital investment.

- Requiring minimum operation and maintenance and low costs.
- Requiring less-skilled operator knowledge
- Potential of having longer life-cycles

The ultimate goals of wastewater recycle/ reuse will be:

i. The quantum of wastewater subjected to expensive treatment methods is reduced thereby reducing the pressure on sewage disposal.
ii. The wastewater treated and reused can supplement the water consumption and preserve water for future.
iii. Reduce the overall user-demand for fresh water resources
iv. Facilitate the recovery of nutrient and water resources for reuse in agricultural production, irrigation of municipal greenbelts/parks and maintenance of other landscape amenities, and
v. To reduce the pathogenic risk inherent to wastewater pollution.

In order In order to achieve this goal, a strategy and framework has to be developed for greywater reuse. The main aspect of the strategy will be a synchronized regulatory framework for greywater reuse and a collectively agreed approach for implementation. The stakeholders must have clarity on how the system can be implemented and what are the legal obligations and policy matters. The approach on greywater reuse through decentralized method should take care of the institutional barriers, financial constraints, technological limitations and public opposition. Due importance should be given to creating adequate institutional setting, establishing effective regulatory mechanism and ensuring sound community participation.

7.2. Concept and Strategy

The urban greywater management broadly involves three main aspects, (i) action at source level (generator level actions) for separating the grey water from black water (ii) applying the appropriate technological option/s for converting the grey water to reusable water, and (iii) the ULB initiatives to promote grey water reuse by awareness creation, setting regulatory framework and infrastructure development. In the urban scenario greywater is usually generated from the following sources:

- Domestic sources (Villas, apartments and hostels)
- Commercial establishments (Hotels, restaurants, shops, market stalls)
- Offices, Educational Institutions
- Service facilities (Hospitals, town halls, marriage halls)
- Industries (excluding industrial effluents)

A huge quantity of grey water is generated daily from these sources out of which a major portion could be reused for different purposes without treatment or with simple treatments. An archetypal sequential action for implementing a greywater reuse system in any urban body is given below.

i. Collecting the baseline Information: Information required for preparing a proper plan such as area, population, number of households, number of divisions (wards) of the ULB, number of zones/circles etc
ii. Collecting information relating to grey water: The activities involved are (i) identification of different types of grey water generating sources (ii) quantification survey to assess waste water generation at various sources and various locations/zones (iii) location mapping of waste

generation sources and potential reuse areas and (iv) physico-chemical analysis of grey water generated.

iii. Understanding the present scenario: This includes understanding the present actual reuse, the estimation of reuse potential, understanding the community perception about greywater reuse, availability and adequacy of facilities and staff and the present grey water disposal practices.

iv. Understanding the key issues: The issues generally observed in the context of grey water reuse are absence of separation from black water, separate plumbing for grey water, decentralized and centralized grey water reuse facilities and community/NGO/CBO partnership. The other issues are manpower inadequacy, weak institutional set-up, absence of financial planning, environmental and health issues, lack of awareness on the necessity of scientific grey water management including reuse, poor civic sense of the people, weak political will, inefficiency and lack of motivation of staff, absence of law and law enforcing mechanisms including national, state and ULB level policies etc.

v. A feasible management system which identifies and explains the sources that generate grey water, the internal and external plumbing requirements, treatment systems and the reuse or disposal mechanism. (see Fig 21)

vi. Evolving proper strategies for grey water reuse/management

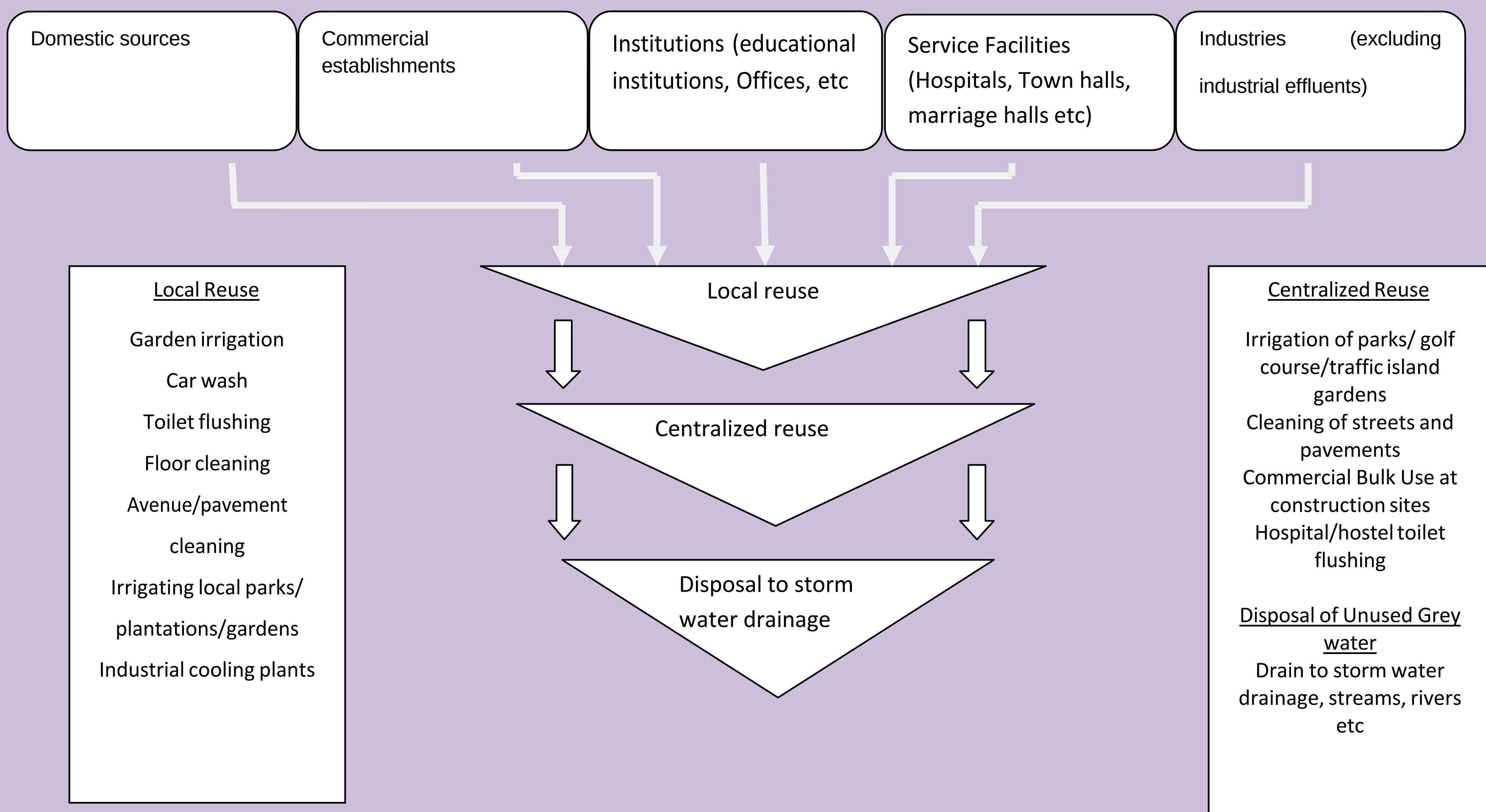
vii. Preparation of plan and cost estimates for additional infrastructure for grey water reuse. This can include treatment facilities, site profile and design approach, layout plan of proposed greywater treatment and reuse/disposal facility (including bulk supply of grey water for commercial/industrial uses etc)

viii. Capacity building and implementation of plan

ix. Operation and maintenance

x. Monitoring

Fig 20: Greywater Reuse Framework



7.3. Strategies for Greywater Reuse

Component	Strategy	Target	Responsibility
Separating grey water from black water	Separate plumbing to lead black water and grey water to different and distinct destinations	Cover all premises through awareness creation, motivation and subsequent enforcement wherever necessary.	Those who generate wastewater- individually by villas and collectively by apartments.
	Motivation for existing generators		Continued and organized motivation by ULB directly or through NGOs
	Motivation and legislation for new generators		Legislation and enforcement by ULB
	Incentives	Existing building owners and new builders	ULB can provide incentives
Initial Reuse	Initial Reuse without treatment - Adopt simple techniques like bucketing and gravity flow. Start with best quality grey water like rinse water from washing machine, bathroom water for car wash, garden irrigation etc.	Find out all possible reuse options in and around the premises	Those who generate wastewater
	Initial Reuse with treatment- Identification and application of the appropriate technology	Find out all possible reuse options in the locality and establish reuse system	Residents" Associations (RAs)
Technical support	Provide technical support to individual household level generators and bulk generators	Make available a package of treatment options suited for standard situations. Make available a technical team to provide field level support. Establish a call centre to ensure continued support.	ULB-directly or through competent agencies
Treatment technology selection	Determined by the quantity and quality of grey water, end use and preferences of users	Implementation of the treatment plan with design and cost estimates.	Generators/ULB. ULB should place prime importance for the selection and implementation of best available

			technology
Laying of pipe network to central treatment system	If full local utilization is not possible, grey water from all economically viable sources will be connected to central system. All major grey water generating areas will be connected to the central system	Establish network from sources to the central system	ULB-Directly or through competent agencies
Grey water treatment	Local decentralized treatment plants at local/zonal level	Establishment of as many decentralized treatment plants as there are bulk generators	Bulk Generators
	Centralized treatment plants on need basis (for an area or for very large generators.) Excess grey water after local reuse to the centralized treatment plants.	Establishment of centralized treatment plant/s at ULB/ zone/ area level.	ULB
	Advanced treatment if contamination level is high	Establish appropriate treatment plant	Generator/ULB
	Simple treatment when contamination level is low.	Establish appropriate treatment facilities	Generator
Disposal of treated water	Reuse good quality greywater without treatment to the extent possible.	Identify and establish reuse opportunities.	Generator/ULB
	Reuse of treated grey water based on reuse plan	Based on reuse plan in the following order of preference: (i) premises of the generator (ii) nearby locality (iii) Any other place (considering the cost and technical issues.)	Generator/ULB
	Disposal of excess treated water	After availing all reuse opportunities adopt one or	Generator/ULB

		more of the following disposal options: • To a soak pit for ground water recharge • To water bodies/ wetlands (swamp) ensuring PCB norms	PCB (quality checking)
Disposal of untreated grey water	Drain out to ground water recharge (GWR) structures/water bodies/ wetlands(swamp) when the water is of good quality which satisfy PCB norms	Construct soak pit. Construct GWR structures Provide conveyance to water body.	Generator/ULB PCB (quality checking)
	Drain out to local septic tank intended for sewage treatment or to sewerage system.	Provide suitable conveying system	Generator/ULB
		Establish septic tanks, if not available	Generator/ULB
		Create new sewerage system if not available or increase capacity of existing system, if needed.	ULB
Disposal of grey water from distant/ non-economical sources	Delink from decentralized/ centralized systems	To be locally treated and reused/ appropriately disposed off.	Generator
Safety mechanism	Facilitate easy distinguishing mechanism for pipes and fittings	Provide different colour pipes and fittings for fresh water, grey water, treated grey water and black water.	Govt/ULB to specify standard colours
	Facilitate easy repair and maintenance	Pipes and fittings should be installed enabling easy repair and maintenance	Govt can notify a plumbing code or manual
	Safe custody of related documents (plan, layout etc)	Assign responsibility of custodianship of water and waste water related documents, especially for large wastewater generators	Govt/ULB to assign responsibility. The assigned person to keep the documents
Implementation and O&M	Draw up a comprehensive plan for the ULB	Implement the plan	Generator ULB-Directly or through competent agencies

Central grey water distribution system	Distribution/supply of the treated grey water to the potential users.	Direct pipe line to major permanent users (like parks, bus depots, railway yards, industrial units, fire stations, turfs etc) Tanker supply to temporary and small scale requirements)	ULB-Directly or through competent agencies
Documentation	Mapping of technical interventions Data collection and record keeping of activities	Technical interventions like plumbing modifications, installation of new fixtures, establishment of treatment system etc should be documented by the parties responsible for future maintenance. Data collection and analysis should be continuous to facilitate future improvement. Data on the following are required: 1) Quantity of wastewater generated 2) Quality of wastewater generated 3) Cost of treatment 4) Cost involved in institutional setup 5) Quality and quantity of treated water 6) Types of end uses	Those who are responsible for O&M of the treatment and reuse system.

7.4 Framework for grey water reuse

Component	Technical/ technological aspects	Institutional/ Responsibility aspects	Financial aspects	Legal/Policy aspects	
				ULB	Wastewater generators
Source separation	Internal Plumbing	Generator	Cost to be borne by the generator ULB can fully or partly subsidize as incentive	Legislation	Adherence to rules
	External plumbing	Generator/Apartment owner/RA	do	do	do
Initial reuse	Establishment of pipeline to the use points; temporary storage (if needed)	Generator/Apartment owner/RA	do	do	do
Treatment technology selection	Determined by the quantity and quality of grey water, end use and preferences of users.	The wastewater generator has to select the service provider by in-house method or by outsourcing a competent agency. The ULBs can support the wastewater generators by identifying the capable wastewater treatment service providers/ agencies and fixing the rates for the treatment systems and operations.	The funds have to be borne by the wastewater generators. The ULBs can subsidize the cost in order to encourage wastewater reuse.	Since there is no legal provision for grey water treatment and reuse the ULBs may formulate a bye law for regulating the wastewater reuse	The wastewater generators can form an association/ society and develop a byelaw for wastewater reuse
Treatment	Establishment of treatment facility	Generator/Apartment owner/RA	Generator/Apartment owner/RA/ULB	Providing technical and institutional support	Adherence to rules

Reuse after treatment	Establishment of pipeline to the use points/disposa l points	Generator/Apart ment owner/RA/ULB	Generator/Apartment owner/RA/ULB	Do	do
Reuse method	The selected reuse point has to be identified. Establish supply lines to the reuse points. Provide coloured water line for greywater to avoid accidental interlinking	The wastewater generators or ULB as the case may be has to identify and monitor continuously and make arrangements if any problem arises The ULBs has to inspect the system periodically.	Capital expenditure to be met by ULB and operational cost to be met by users.	Since there is no legal provision for grey water treatment and reuse the ULB should issue guidelines	Vigilance in reuse operations

7.5 Roles and Responsibilities

Though many of the roles and responsibilities are already mentioned, the following specific responsibilities are also important for grey water treatment and reuse.

(1) Role of ULB

i. Procuring tankers for supply of grey water for temporary and short distance uses. The ULB can fix the plying schedule of vehicles. The distribution of treated grey water, maintenance of vehicles, collection of user fee (if levied) etc could be entrusted to outside agencies, if found necessary.

ii. Prescribe user fee for supply of grey water (initially this may be free but later when reuse becomes the common practice user fee can be levied)

iii. Maintenance of treatment systems owned by the ULB

iv. Monitoring of quality of grey water treated (whether reused or let out to water bodies)

v. Monitoring of overall activities

vi. Deployment of manpower

vii. Timely intervention at the time of emergency situations

(2) Role of NGOs/Residents' Associations

NGOs and Residents‟ Associations can play a vital role in grey water reuse. Some areas where they can effectively work are indicated below:

- Organizing neighbourhood groups (NHGs) and imparting motivational training for maintaining best practices
- Propagating the reuse concept
- Attempting local reuse initiatives

- Organizing training and equipping the local community for separating grey water from black water and reuse of grey water.
- Generating demand for grey water
- Transportation/sale of grey water for short term uses
- Collection of user fee (if applicable)
- Operation and maintenance of local treatment systems
- Discouraging use of highly polluting/ water contaminating items
- Organizing awareness creation/training programmes
- Establishing community vigilance system to ensure, sustain and improve the greywater management system.

(3) Role of Technical Resource Agency

Wastewater Management involves many complex technical / technological components. The ULB themselves may not be in a position to handle these components by themselves for which they may seek support from some Technical Resource Agency competent in the WWM area.

The National or State level Accredited Agencies in WWM sector / technical institutions like engineering colleges, NIT, IITs and other R&D institutions etc. working in the WW sector can be identified for this purpose. The Centres of Excellence of Ministry of Urban Development, Government of India like Centre for Environment and Development will be able to provide hand holding support to ULBs.

7.6 Transportation

The central treatment system will have a facility for transportation of treated grey water to sites of temporary uses. These may include construction sites (concrete mixing, curing, cleaning of machinery and utensils), dust control at streets, festival grounds, work sites, markets etc. Apart from the central treatment facility, major grey water generators also can be potential suppliers of grey water in tankers.

7.7 Man Power Requirement

- Plumbers - to be mobilized by NGOs/RAs etc
- Workers in treatment plants: Central treatment plant/s –to be mobilized by the ULB
- Workers in local treatment plants: Local treatment plant/s in apartments etc–to be mobilized by the generator institution
- Transportation vehicle drivers: to be mobilized by the ULB (or external agency, if transportation is entrusted to them)
- Supervisory and administrative staff of the ULB.
- Engineering staff.

7.8 Infrastructure requirements

- Internal and external plumbing
- Pipeline leading to Treatment System
- Tankers
- Local and Central Treatment Systems

- Distribution lines to permanent users.

7.9 Site Profile of Treatment Plants

- Identify the most suitable site (initial consultation with community will avoid future resistance).
- As far as possible avoid sites which is surrounded by residential settlements.
- Consider future requirements while finalizing the site.
- Site should be as close to the source as possible– in order to avoid the transportation cost.

7.10 IEC

The activities involved in grey water reuse demand volunteerism and public participation for its success. It is the public attitude and behaviour that are going to make the difference. A paradigm shift in the mindset of the civilian community and polity are essential to achieve public acceptance for grey water reuse. This could be achieved only through well conceived IEC Plan. Hence the IEC Plan on grey water reuse should focus on the following.

- Creating behavioural change and mindset favouring grey water reuse. This will include (i) change in water use pattern (ii) separating grey water from black water at source (iii) imbibing the civic responsibility of keeping the premises clean (iv) willingness to accept the civic responsibilities of citizens, and (v) willingness to part with the ad hoc approach of unscientific wastewater disposal.
- Awareness creation on the dangers of unscientific wastewater management. E.g., (i) health hazards (ii) aesthetic damage (iii) environmental degradation
- Awareness creation on the various technical and technological options for grey water treatment and reuse.
- Converting waste water, especially grey water, as a resource
- Scientific reuse/disposal of grey water at the nearest point of source. E.g., using grey water for toilet flushing, garden irrigation, vehicle washing etc.
- People‟s participation and cooperation at all stages
- Community adherence to rules, orders and directives.

Annexure - 1

CENTRE FOR ENVIRONMENT AND DEVELOPMENT

THIRUVANANTHAPURAM

Survey on Waste Generation and Disposal Practices in Hospitals

(As part of Centre of Excellence on Solid Waste and Liquid Waste Management,

Ministry of Urban Development, GoI)

Name of Enumerator :………………………………. City: ……………………………………………

Date of Survey: ………………………………………….

Hospital Address: ………………………………………………………………………………………

1. Type of hospital and total number of beds?

   a) Small (<100 beds) b) Medium (100-250) c) Large (>250 beds)

2. Does the hospital include canteen facility? If yes, provide water demand details:
3. Daily population associated with hospital

   a) Outpatient b) In patient c) Staff d) Others, specify

4. Number of Bathrooms, Toilets and Urinals?
5. Laundering facility at hospital, details?
6. Does the hospital include a common garden? Details
7. Rainwater harvesting structures provided? If any, Details:
8. Source of water supply, quantity?

   a) Public Water Supply b) Open well c) Bore well d) Dual System e) Others specify

9. Details of collection tanks?

Sump capacity	Tank capacity	Pump HP	Frequency of filling

10. Waste Water disposal?

    a) Central sewage system b) Roadside drain c) Nearby water body d) Others specify

11. Whether separate lines provided for grey and black water?

12. Any water saving measures adopted?

    a) Using wastewater for garden watering b) For toilet flushing c) Others: specify

13. How do you manage solid waste?

    a) In association with IMAGE b) Others

14. Collection fee payment details?

CENTRE FOR ENVIRONMENT AND DEVELOPMENT

THIRUVANANTHAPURAM

Survey on Waste Generation and Disposal Practices in Apartments

(As part of Centre of Excellence on Solid Waste and Liquid Waste Management,

Ministry of Urban Development, GoI)

Name of Enumerator:……………………………….. City:………………………………………

Date of Survey: ………………………………………… Residential Area………………………………

Apartment Address……………………………………………………………………………………

1: Residential Complex Profile Data

1. Size of building?

   a) Small (<50 Apartments) b) Medium (50-100) c) Large (>100 Apartments)

2. Total Number of apartments:
3. Number of bathrooms in each line, and total?
4. Number of kitchens in each line, and total?
5. Number of occupied apartments:

a) Permanent b) Temporary (details) c) Vacant

6. Does the apartment include a common garden / swimming pool, Details?
7. Rainwater harvesting structures provided ? If any, Details:

2. Water Amenities and Service Data

8. Source of Water Supply, Quantity?

a) Public Water Supply b) Open Well c) Bore Well d) Dual System e) Others specify

9. Details of collection tanks?

Sump capacity	Purpose	Tank capacity	Pump HP	Frequency of filling

10. Waste Water disposal facility, if any?

a) Central sewerage system b) Roadside drain c) Nearby water body d) Others specify

11. Any water saving measures adopted?

a) Using kitchen water for gardening b) For toilet flushing c) Other; specify

12. Whether separate lines provided for grey and black water?

3. Household Water Use Behaviour and Perception Data

13. Family member profiles:

Member	Gender	Age

14. Does your household use water for?

a) Gardening b) Car washing c) other specify

15. The major water using appliances

a) Number of washing machines and frequency of use (in week)

b) Others specify

4. Household Solid Waste Management

16. Household level segregation of waste Y / N?

17. Collection mechanisms at household level:

a) Through SHG b) Local Arrangement c) By ULB

18. Disposal Mechanisms

a) Independent system, specify process

b) Common facility by ULB, specify process:

19. Collection fee payment details?

a) Individually b) Common

CENTRE FOR ENVIRONMENT AND DEVELOPMENT

THIRUVANANTHAPURAM

Survey on Waste Generation and Disposal Practices in Restaurants/Hotels

(As part of Centre of Excellence on Solid Waste and Liquid Waste Management,

Ministry of Urban Development, GoI)

Name of Enumerator: …………………………… **City:** ………………………………………

Date of Survey: ………………………………………….

Hotel/Restaurant Address: ……………………………………………………………………….

1 Size of restaurant/hotel?

a) Small (<50seats) b) Medium (50-100) c) Large (>100seats)

2 Number of bathrooms, Toilets and Urinals? :

3 Does the hotel/restaurant include a common garden/swimming pool, Details? :

4 Rainwater harvesting structures provided? If any, Details:

5 Source of water supply, quantity?

a) Public Water Supply b) Open well c) Bore well d) Dual system

e) Others specify:

6 Details of collection Tanks?

Sump capacity	Tank capacity	Pump HP	Frequency of filling

7 Waste water disposal?

a) Central sewerage system b) Roadside drain c) Nearby water body

d) Others specify:

8 Whether separate lines provided for grey and black water?

9 Any water saving measures adopted?

a) Using kitchen water for garden watering b) For toilet flushing

c) Other: Specify

17 Do you segregate solid waste Y/N?

10 Collection mechanisms at hotel/restaurant level:

a) Through SHG b) Local Arrangement c) By ULB

11 Disposal Mechanisms: a) Independent system, specify process:

b) Common facility by ULB

12 Collection fee payment details?

CENTRE FOR ENVIRONMENT AND DEVELOPMENT

THIRUVANANTHAPURAM

Survey on Waste Generation and Disposal Practices in Households

(As part of Centre of Excellence on Solid Waste and Liquid Waste Management,

Ministry of Urban Development, GoI)

Name of Enumerator: ……………. City: ……………………………………………………………

Date:…………………………………………

Residential Address: ……………………………………………………………………………….

A. Biodegradable wastes

I. Kitchen wastes

1. Number of individuals in the house

   a. □ 1to 2

   b. □ 3 to 4

   c. □ 5 to 6

   d. □ More than 6

2.Type of food generally taken

   a.Vegatarian

   b.Non-vegetarian

3. How often in a day do you collect Kitchen wastes? (Inside the house)

   a. □ Once

   b. □ Twice

   c. □ after each meal

   d. □ others (specify)

4. Do you store/collect the waste before final disposal outside?

   a. □Yes

b □ No

5. If yes,where do you collect this waste?

a. □ put in the dust bin/bucket inside the kitchen

b. □ put in the dust bin/bucket outside the house

c. □ any other (specify)

d. □ Disposed at Once

6. Do you segregate the waste? (Vegetable waste, plastics, paper etc)

a. □ Yes

b. □ No

7.If yes,do you keep separate collection bins for degradable and non-degradables

a. □ Yes

b. □ No

8. Where do you finally dispose the waste?

a. □ Put into the coconut pit

b. □ put into the special/compost pit.

c. □ use in the garden for plants

d. □ garbage collector collects it

e. □ put it in the dust bin in the road

f. □ put in the common place in the colony (specify location)

g. □ any other (specify)

9. On the Average how much degradable waste (vegetables, tea leaves, egg shells etc) is generated in the kitchen per day?

Estimate

a. □ <250 g
b. □ 250-500 g
c. □ 500-750 g
d. □ 750-1000 g
e. □ Others (specify)

10. Actual measured waste

a. [ ] gm
b. Timing over which it is generated______to_______hrs

II Garden waste

1. How often do you collect garden wastes? (eg: by sweeping leaves etc)

a. □ Daily

b. □ twice a week

c. □ weekly

d. □ other

2. How do you finally dispose the garden wastes?

a. □ Put into the coconut pit

b. □ put into the special/compost pit.

c. □ use in the garden for plants

d. □ garbage collector collects it

e. □ put it in the dust bin in the road

f. □ put in the common place in the colony (specify location)

g. □ any other (specify)

III. Paper wastes

(News papers, note books etc)

1. How many news papers do you subscribe to?

a. [ ]

2. □ how frequently do you dispose paper?

a. □ Monthly
b. □ Once in three months
c. □ Half yearly
d. □ Annually
e. □ Others specify

3. How do you dispose the paper?

a. □ a person comes and collects for a price

b. □ Sell at the local shop

c. □ others(specify)

4. What is the approximate quantity/value disposed?

a. [ ] Kg

b. □ Rs.

B. Non bio degradable waste:

I Plastic covers

1. What are the kinds of plastics covers generated as waste?

a. □ Milk Cover

b. □ Bread cover

c. □ other packing covers

2. Which of these covers do you reuse?

a. □ Milk Cover

b. □ Bread cover

c. □Other packing covers

d. □ Do not reuse (Go to 23)

3. For what purpose do you use milk covers?

Ans.

4. For what purpose bread covers are used?

Ans.

5. For what purpose other packing covers are used?

Ans.

6. Do you sell/dispose the covers?

Ans.

7.

Disposal practices

A. *Someone comes and collect for a price*

Type of covers	**Frequency**	**Quantity**	**Disposal practices**
Milk Cover			
Bread cover			
Others			

B. *Give it free to the maid who later sells it and earn money*
C. *Collect the covers and sell at the shop*
D. *Other (specify)*

II Tins and bottles

1. How often do you dispose tins and bottles?

a. □ Weekly

b. □ Fortnightly

c. □ Monthly

d. □ half yearly

e. □ Annually

f. □ Others (Specify)

2. How do you dispose them?

a. □ Someone comes and collect for a price
b. □ Sell at the shop
c. □ Dispose along with other waste
d. □ Dump them at a common place (specify location)

III Battery, Electronics cells etc

1. How do you dispose them?

a. □ mixed with other waste

b. □ Burn them with other waste

c. □ Burn them separately

d. □ let the children play with them

e. □ others (specify)

C- Wastewater from kitchen, bath etc

1. How is the water from the kitchen, bath etc disposed?

    a. □ closed drainage system with in the compound

    b. □ open drainage system ending in a pit.

    c. □ open drainage system into coconut pit

    d. □ Connected to open drainage on the road

    e. □ other (specify)

D-Awareness

1. Are all the areas equally clean?

a. □ all areas are clean

b. □ some areas are clean

c. □ others (specify)

2. What is your assessment of cleanliness of Payyannur?

a. □Very good

b. □ Good

c. □ fair

d. □ Poor

3. What do you think is the best way to dispose the plastic waste?

a. □ Burn

b. □ putting into the pit

c. □ Recycling

d. □ Others (Specify)

4. Do you think if you can take the waste water from the bathroom to the garden it will solve the problem of garden water?

a. Yes

b. No

5. If yes why?

6. If no why?

Hotel and tea shop (Including Bar)

1. Type of meals served	: Tiffin/Meals/Both/other
2. Dishes are served in	: Plates/Plantain leaf
3. Water is supplied in	: Metal glasses/Ceramic cups/Plastic cups
4. Type of waste (Qty/day)	: 1.Degradable Food waste Vegetable waste Leaf Others 2. No degradable Ice cream cups Ceramic items Metals Glass
5. Waste water connected to	: Opening to the drainage channel on the road Open drainage system ending in a pit Other methods (Specify)
6. Disposal method of waste	: A. Degradable a. Put it in compost/special pit b. put it in the dust bin on the road c. Other methods (Specify) B. Non degradable

a. Somebody comes and collect it for a price

b. Open dumping system.

c. Other methods (Specify)

Small shops (including fruit stall, flower shops)

1. Type of shop : Fruits/General items/flower/others

2. Water is supplied in : a. Plastic cups
   b. Glasses
   c. Steel Glass
   d. Other (Specify)

3. Fruits/Flowers are packed by using : a. Papers
   b. Plastic carry bags
   c. Wooden boxes
   d. Others (Specify)

4. Disposal of wastewater : To open drainage/Pit inside the compound/On road side/others

5. Disposal of degradable waste (Qty/day):

6.Mode of disposal
   a. put in the dust on the road side
   b. Somebody will come and collect it.
   c. Put it in compost/special pit
   d. Others (Specify)

7. Disposal of degradable waste (Qty/day):

8. Mode of disposal — a. somebody will come and collect it at a price

b. open dumping system
c. Other methods (specify)

Textile shops

1. Name of business : Ready wears/clothing's/others

2. Is tailoring work attached : Yes/No

If yes how many machines? :

3. Cover used for packing is made of : a. Paper

b. Plastic

c. Gunny bags

d. Rexin

e. Others

4. Disposal of the waste material?

(Qty/day) :

5.Disposal method a. burning

b. Put it in the dust bin kept at the road side.

c. Selling it at a price (Plastic items)

d. Others

Foot wear shops

1. Business dealing in : a. Company goods only

b. Company goods and local goods

c. Local goods only

2. Material used for packing : a. Paper boxes

b. Plastic carry bags

3. How will you dispose the old footwear?

(Discarded by customers) : a. selling at a price

b. Dumping at a common palace

c. Cleaning through pickers

d. Other methods

Fish/Vegetable shops

1. Nature of business : Permanent/Temporary

2. Disposal of wastes (Qty/day) :

3.Mode of disposal a. Collected by somebody for animal food

b. dumping it into a common place

c. Other methods

Slaughter House

1. Frequency of functioning : a. daily

b. Weekly

c. Other intervals

2. Nature of site : a. Permanent building

b. Temporary shed with facilities

c. road side

d. Others

3. Animal slaughtered : a. Beef

b. Chicken

c. Mutton

d. pig

e. Others

4. Type and method of disposal of

wastes (Qty/day) :

5.Disposal method a. Dumping at the dust bin

b. Dumping at the road side/public place

c. Other methods (specify)

Hair cutting saloons

1.Quantity of waste produced (Qty/day)

2.Method of disposal : a. roadside/dustbin dumping

b. Regularly taken by vendors

c. Other methods (Specify)

3. Frequency of disposal : a. daily

b. Weekly

c. Other intervals