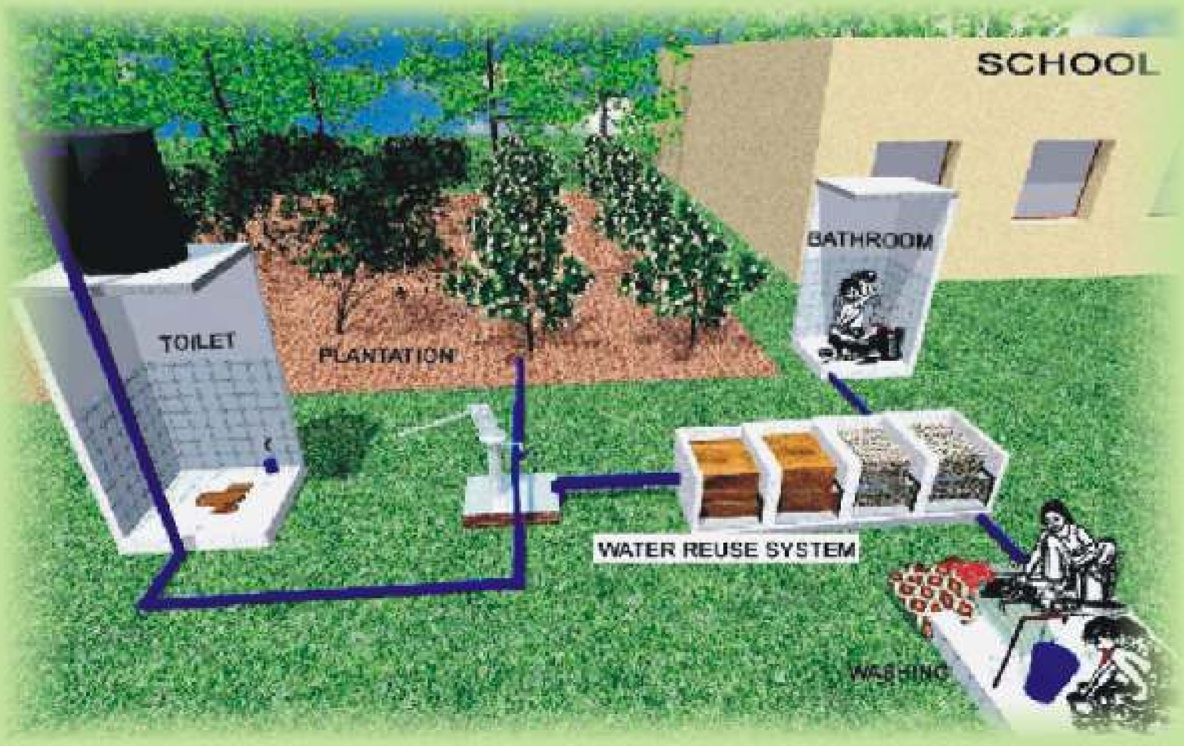
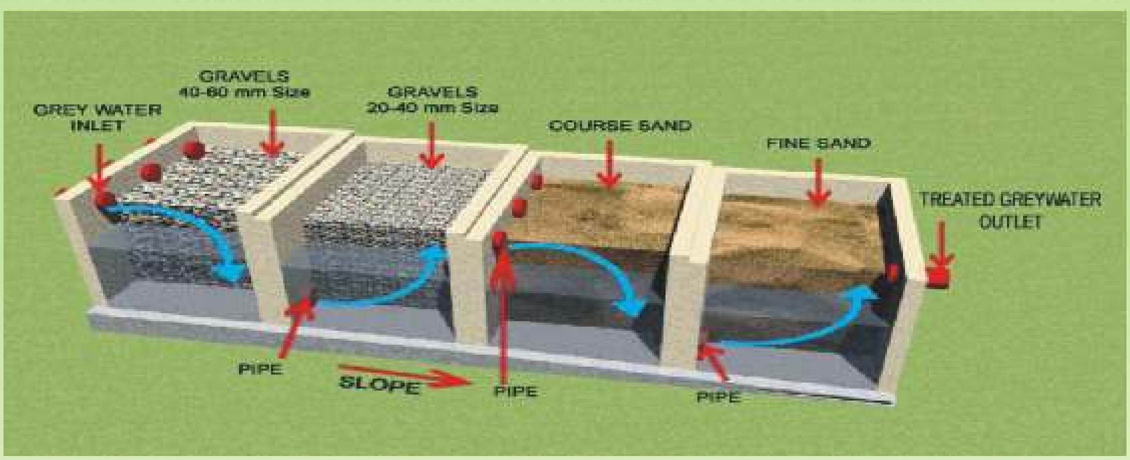
GREYWATER REUSE IN RURAL SCHOOLS

GUIDANCE MANUAL





National Environmental Engineering Research Institute
Nehru Marg, Nagpur - 440 020, India

United Nations Children's Fund
UNICEF, Madhya Pradesh, India

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Wise Water Management

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Preface

India is facing a water crisis and by 2025 it is estimated that India's population will be suffering from severe water scarcity. Although India occupies only 3.29 million km^2 geographical area which forms 2.4% of the worlds land area, it supports over 15% of world's population with only 4% of the world's water resources. With increased population growth and development, there is a need to critically look at alternative approaches to ensure water availability. Conventional groundwater and surface water sources are becoming increasingly vulnerable to anthropogenic, industrial and natural pollution. Groundwater sources are being over extracted, resulting in leaching of fluorides and nitrates. Surface water bodies are becoming susceptible to unregulated industrial discharge resulting in increased eutrophication and algal blooms.

To resolve the problem, there is a need to look for alternative water resources. These include rainwater harvesting, wastewater reuse and desalination. Concerns over desalination include mineral decomposition of potable water and limited inland availability. Additionally, limitations of rainwater harvesting include the quantity and quality that may be available, given the increased threats of global warming and air pollution.

In this light, National Environmental Engineering Research Institute (NEERI) Nagpur and UNICEF Bhopal, Madhya Pradesh have developed, implemented and evaluated greywater reuse systems for small buildings (schools) in rural areas. During 2005 and 2006, NEERI and UNICEF collaborated to investigate the possibility of recycling greywater (bathroom water) in residential tribal schools in rural Western Madhya Pradesh. The water reuse or recycling systems collected, treated and reused bathroom water (shower non toilet/black water) for recycling and flushing of toilets. The drive for this technology was a result of decreasing availability of water, lowering of groundwater table and increase in fluoride concentration in groundwater. Additionally, with the increase in demand for water due to increased coverage of rural areas with toilets under the Total Sanitation Campaign (TSC), there was a need for augmentation through appropriate technologies, to provide water for sanitation.

This publication is a result of evaluation of greywater systems that were built, verified and optimized in Madhya Pradesh in collaboration with UNICEF. The book provides guidance to governmental, non-governmental and scientific agencies, who are interested in implementing similar water reuse/ recycling projects in other states in India and beyond.

I am deeply grateful to UNICEF, Bhopal for their support in the development of this book, as well as to others who have directly and indirectly contributed during the course of the development of this manual and various consultative workshops.

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International Scientific Review of Manual

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Content

1.0 Introduction

1.1 Background

Water is becoming a rare resource in the world. In India alone the International Water Management Institute (IWMI) predicts that by 2025, one person in three will live in conditions of absolute water scarcity (IWMI, 2003). It is therefore essential to reduce surface and ground water use in all sectors of consumption, to substitute fresh water with alternative water resources and to optimize water use efficiency through reuse options. These alternative resources include rainwater and greywater. This manual will focus on greywater treatment and its use as an alternative water resource in rural areas.

Greywater is commonly defined as wastewater generated from bathroom, laundry and kitchen. Due to rapid industrialization and development, there is an increased opportunity for greywater reuse in developing countries such as India. This Manual provides theory and practices for greywater reuse in residential complexes with particular emphasis on schools.

Although India occupies only 3.29 million km^2 geographical area, which forms 2.4% of the world's land area, it supports over 15% of world's population. The population of India as of March 1, 2001 was 1,027,015,247 persons (Census, 2001). India also has a livestock population of 500 million, which is about 20% of world's total livestock. However total annual utilizable water resources of the country are 1086 km^3 which is only 4% of world's water resources (Kumar et al., 2005). Total annual utilizable resources of surface water and ground water are 690 km^3 and 396 km^3 respectively (Ministry of Water Resources, 1999).

Consequent to rapid growth in population and increasing water demand, stress on water resources in India is increasing and per capita water availability is reducing day by day. In India per capita surface water availability in the years 1991 and 2001 were 2300 m^3 (6.3 m^3/day) and 1980 m^3 (5.7 m^3/day) respectively and these are projected to reduce to 1401 and 1191 m^3 by the years 2025 and 2050 respectively (Kumar *et al*., 2005). Total water requirement of the country in 2050 is estimated to be 1450 km^3 which is higher than the current availability of 1086 km^3. Various options including rainwater harvesting and wastewater reuse will have to be considered to meet the anticipated deficit.

1.2 Organization of Manual

This Manual is organized in five chapters as depicted in Fig. 1 in addition to Chapter 1. Chapter 2 describes details on greywater such as sources, quantities, composition and greywater treatment options. Chapter 3 provides design specifications of various greywater treatment systems inclusive of components such as collection, filtration and application for possible reuse.

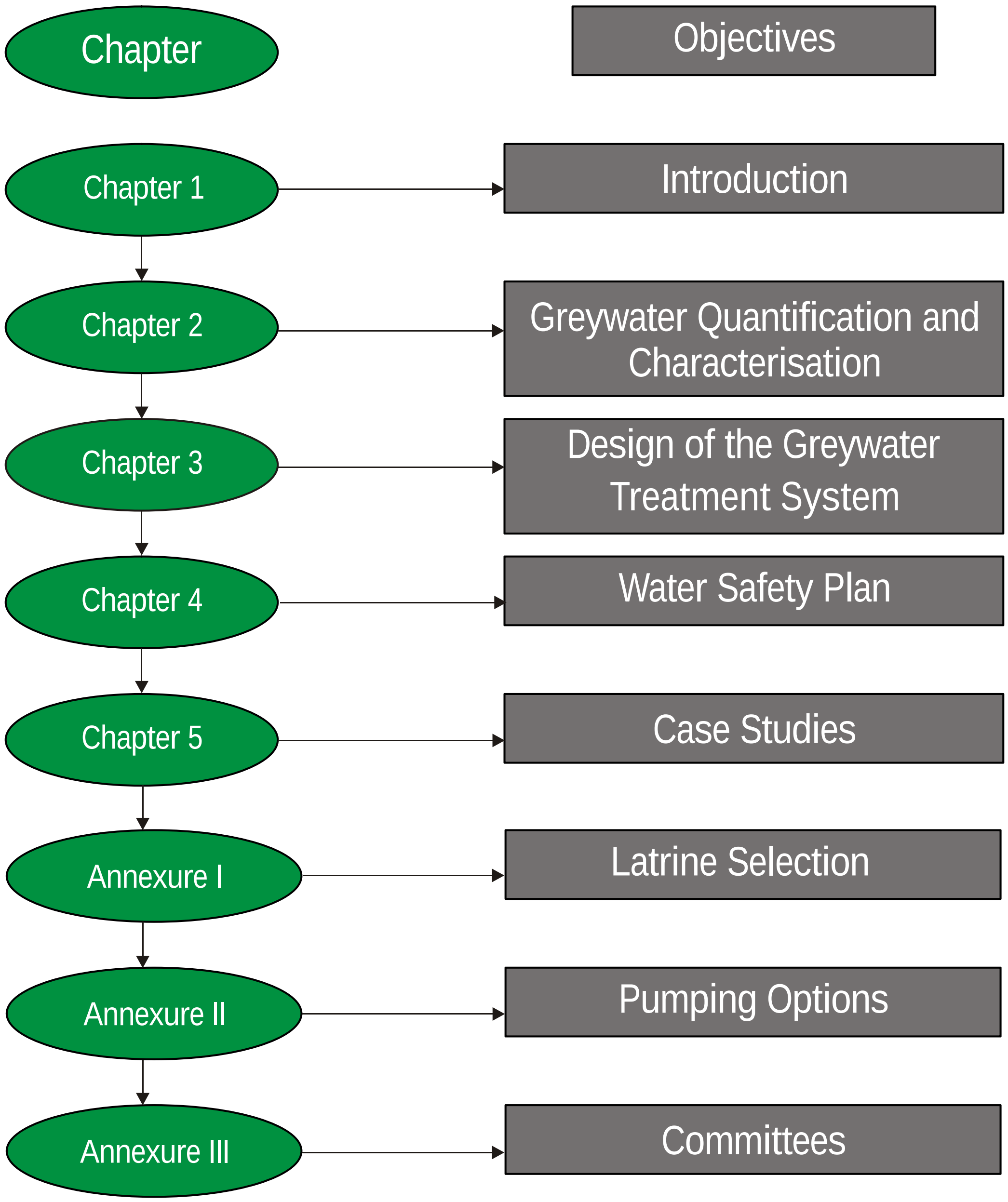

Figure 1: Chapters with Objectives

Chapter 4 describes water safety plans for small systems and its utility for minimizing/eliminating health risks. Health and safety requirements for greywater treatment and application are also included in Chapter 4. A case study of greywater treatment system in Ashram school (hostel) is presented in Chapter 5.

1.3 Objectives and Target Audience

The objectives of this Manual are to assist in the promotion of acceptable long term greywater reuse practices and to promote conservation of good quality ground and surface water supplies by:

- Establishing acceptable means for greywater reuse as a guide for local government and Ashram schools
- Setting minimum standards for design, installation and maintenance
- Preparation and execution of WATER SAFETY PLANS for minimizing health risks associated with greywater reuse

Greywater treatment process varies from simple devices that divert greywater for direct application such as irrigation to complex systems involving sedimentation tanks, filters, bioreactors, pumps and disinfection systems. However, the basic objective of this manual is to initiate process of greywater treatment in India and keeping cost-effectiveness as a basis theme. Simple treatment systems for non-contact use are also described. This manual provides acceptable solutions for reuse of greywater in unsewered areas that satisfies the performance objective and requirements. It may be appropriate for persons contemplating a greywater reuse system to consult a wastewater system designer or other suitably qualified person to consider the options available.

This manual has been written specifically for practitioners involved in the operation, maintenance and management of water supplies in the developing countries.

These practitioners include the engineers, water quality analysts, scientists, sociologists and the professionals involved in monitoring and control of water safety in water supplies. The manual is designed to provide guidance to the practitioners on how to design, build and use a greywater system. It is written exclusively to enable the water suppliers to develop the greywater reuse system without having to depend on the external input.

1.4 Water Scarcity and Need for Greywater Reuse

With increase in population, there will be an increase in stress on sanitation and wastewater disposal system. Gupta et al., (2004) predicted that recyclable wastewater will meet 15% of total water requirement in 2050.

The amount of water in the world is finite. A third of the world's population lives in water-stressed countries. By 2025, this is expected to rise to two-thirds. The UN recommends that people need a minimum of 50 liters of water a day for drinking, washing, cooking and sanitation (www.water.org). The Department of Drinking Water Supply, Government of India recommends 40 litres per capita per day (lpcd) water supply in rural areas to meet the requirements for drinking, cooking, bathing, washing utensils and anal ablution (DDWS, 2001).

In water scarce environments, wastewater reuse and reclamation are often considered as a viable option for increased water resources availability. For example, many Mediterranean countries are investing in wastewater reclamation and reuse due to high evaporation and evapotranspiration, low rainfall and increased demand for water for irrigation and tourism (Angelakis *et al.,* 2001). Equally, in water scarce developing countries, greywater reuse in schools, hospitals and government institutions is proving to be an essential alternate water resource to fresh ground, surface or rainwater supplies (Godfrey *et al.,* 2006). Studies from the Middle-East and India for example indicate that greywater systems have a water saving of between 3.4% to 33.4% per annum (Al-Jayyousie, 2003 & 2005). In 1993-94 Victoria University of Technology in conjunction with Melbourne Water designed, installed, monitored and assessed greywater reuse system on four home sites (Christov a-boal *et al*., 1995).

The application of greywater systems is therefore of particular importance in assisting developing countries in addressing *Goal 7: Ensure environmental sustainability* of the Millennium Development Goals (MDGs). Specifically, greywater recycle augments existing water use efficiency. The equitable use of this resource can aid in halving the world's population without access to safe water and sanitation and therefore in achieving Goal 7 of the MDGs. In a recent global study of greywater reuse by the Canadian Water and Wastewater Association (CWWA), sanitary uses of greywater (i.e. toilet flushing and cleaning) were the primary use (CWWA, 2005).

While rainwater harvesting and Integrated Water Resource Management (IWRM) are water conservation measures, reuse of water is an important undeveloped technology. Reuse of water is important because it restricts water demand and reduces stress on treatment system.

1.4.1 Water Reuse in India

Reuse of water particularly greywater is important in the context of availability of rainwater and over-extraction of ground water for meeting water demand during annual cycle. An analysis of rainwater and groundwater availability and water demand in Ashram schools of Madhya Pradesh highlights the importance of greywater treatment and reuse. Figure 2 depicts annual water demand, water availability and extraction pattern that clearly justifies (grey)/water reuse system. In Madhya Pradesh and in several other states, groundwater is a major source and temporarily supplemented by surface/rainwater during the monsoon. The greywater reuse will substantially reduce groundwater abstraction since majority of water demand for toilet flushing and gardening in Ashram school can be met from treated greywater.

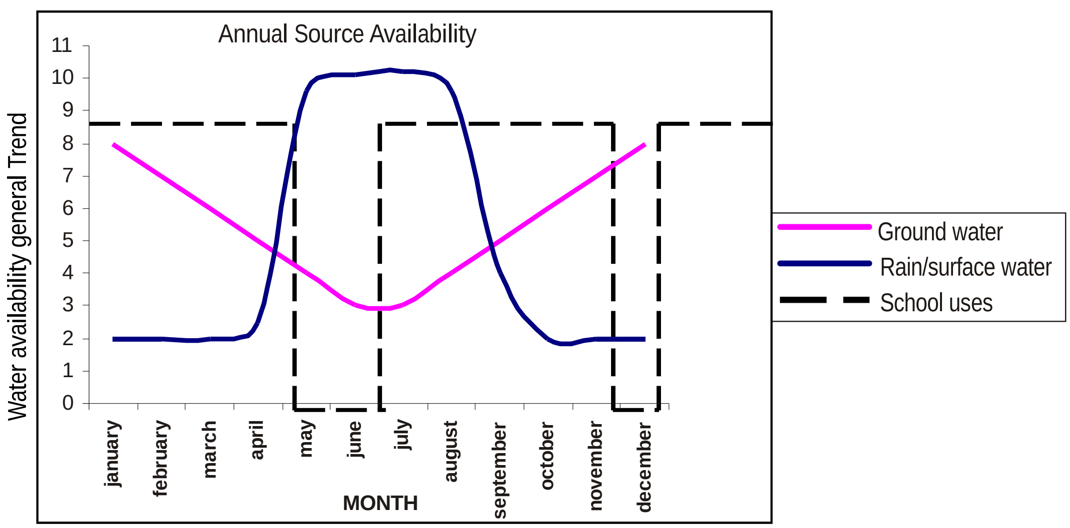

Figure 2 : Annual Water Demand and Supply Cycle Typical Case of Ashram School

Government of India is committed to cover all uncovered rural schools with water and sanitation facility and also imparting hygiene education by the end of 2007. School Sanitation and Hygiene Education (SSHE) is a major component of Total Sanitation Campaign (TSC) programme of Department of Drinking Water Supply (DDWS) of Ministry of Rural Development to ensure child friendly water supply, toilet and hand washing facilities in the schools and promote behavioral change by hygiene education.

SSHE gives special attention by following the proven route of teacher-children-family-community where child is a change-agent playing an effective role on sustained basis to spread the message of improved sanitary and healthy practices. The operation and maintenance of sanitary complex is also one of the major goals of SSHE programme (DDWS, 2005).

Table 1 : Status of Water and Sanitation Facilities in schools in Madhya Pradesh

Level	No. of rural Schools	No. of Students	Schools with Toilets	Schools without Toilets	Schools with water facility	Schools without water facility	Schools with hand washing facilities	Schools without hand washing facilities
Primary + EGS	60662	2013609	8856 (14.6%)	51806 (85.4%)	40881 (67.4%)	19781 (32.6%)	8856 (14.6%)	51806 (85.4%)
Upper Primary	16016	548191	4174 (26.1%)	11842 (73.9%)	7339 (45.8%)	8677 (54.2%)	4174 (26.1%)	11842 (73.9%)
Higher Secondary	3082	158685	1542 (50%)	1540 (50%)	2248 (72.9%)	834 (27.1%)	1542 (50%)	1540 (50%)
Total	79760	2720485	14572 (18.3%)	65188 (81.7%)	50468 (63.3%)	29292 (36.7%)	14572 (18.3%)	65188 (81.7%)

Source : Government of Madhya Pradesh, 2004

The statistics above clearly indicate non-availability of sanitation facilities in majority of the schools. It is also observed that the sanitation facilities built in the schools remain non-functional due to non-availability of water. The greywater treatment and reuse particularly in boarding (Ashram) schools is an attempt to provide water for toilet cleaning so as to make the sanitation complexes functional. These systems are currently operating in 9 Ashram schools in Dhar and Jhabua district of Madhya Pradesh.

The lessons learnt in constructing, operating and maintaining the system are utilized to prepare this Manual. Water Safety Plans are prepared as part of the operation and maintenance of greywater reuse system based on the following documents :

- Drinking Water Quality Standards (WHO, 2004)
- Water Safety Plans Book I (Godfrey *et al*., 2005)
- Water Safety Plans Book II (Godfrey *et al*., 2005)

Case Study of Madhya Prades, India



- Demonstration of wise water management in 9 Ashram schools
- Above ground greywater reuse as an alternative and appropriate technology in Madhya Pradesh
- Construction of roofwater harvesting structures
- Reuse of hand washing water in schools
- Installation of play pumps in schools
- Operation and maintenance of systems by students, members of water safety club, warden and Parent Teachers Association
- Funds for O & M provided by Department of Tribal Welfare
- Construction of greywater reuse system in 48 Ashram schools in Dhar and Jhabua districts and in 7 other district by end of 2006 by Public Health Engineering Department
- Funds from Jalabhishek Programme launched by Government of Madhya Pradesh

1.5 Concept of Greywater Reuse

Water can be classified as freshwater, greywater and blackwater based on characteristics and potential for (re)/use as presented in Table 2.

Table 2 : Type of Water and Possible Uses

Water	Sources	Possible uses
Fresh water	Ground & surface water	Drinking, cooking, bathing
Greywater	Bathing, cloth washing	Toilet cleaning, irrigation, floor washing, construction after treatment
Black water	Toilet, urinal	No use in majority of the cases and requires extensive treatment - ECOSAN toilet can be an option

Asano (2004) reiterated (re)/use of treated wastewater in many forms such as direct-potable, indirect-potable, direct-non-potable and indirect non-potable to overcome water scarcity as depicted in Figure 3. The technologies are available to make sewage potable; however, cost effectiveness will be a key parameter in deciding feasibility of wastewater treatment and reuse.

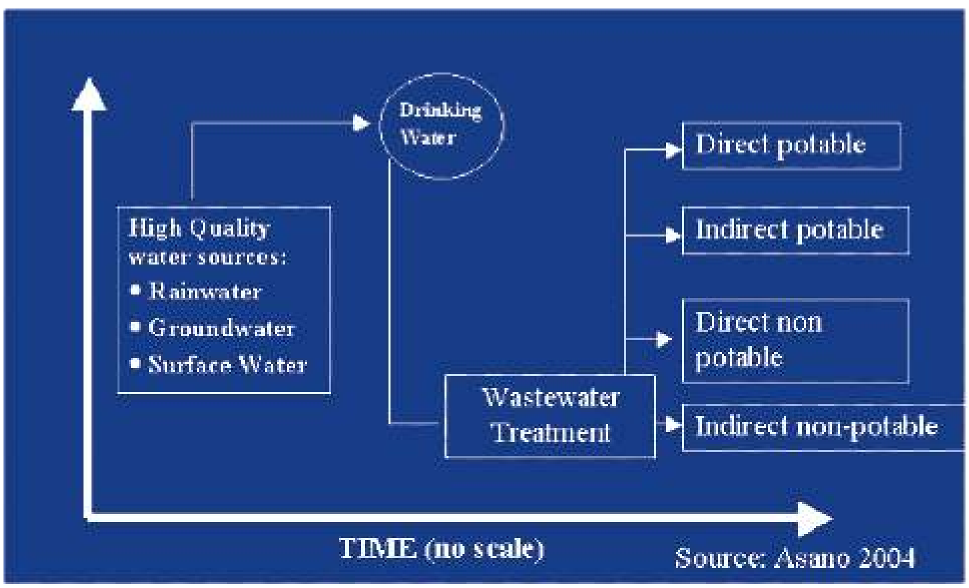

Figure 3 : Wastewater as a Substitute for Higher Quality Water Resources

1.5.1 Potential of Greywater Reuse

Reuse of greywater serves two purposes:

- Reduces fresh water requirement
- Reduces sewage generation

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

Possible uses of treated greywater are presented in Table 3.

Table 3 : Use of Greywater

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

Details of applications, design, and use of greywater can be found in the following books or references:

- Ludwing A, 1995, Builder's Greywater Guide, Published by Oasis design, Santa Barbara, CA , *www.oasisdesign.net*
- Ludwing A, 1994, Create an Oasis with Greywater Choosing, Building and Using Greywater, Published by Oasis Design, Santa Barbara , CA , *www.oasisdesign.net*
- WHO 2006, Guidelines for safe use of wastewater, excreta and greywater: Wastewater use in agriculture (Volume 2). *www.who.int/water _sanitation_ health/wastewater/*en

- Legette DJ, Brown R, Stanfield G, Brewer D and Holiday E, 2001, Rainwater and greyawater in buildings : Decision making for water conservation, CIRIA Publication PR 80, London ISBN 0 86071 8803
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1.5.1.1 Greywater for Agricultural Irrigation

The use of greywater for agricultural irrigation purposes is occurring more frequently because of water scarcity and population growth (Bernard *et al*., 2003). The treated greywater can be supplied for irrigation of indoor plants as the greywater is most suitable for this purpose. However this application must meet the stringent requirements from possible exposures to greywater. The treated greywater can also be used for irrigating agricultural crops and turfs and for maintaining decorative fountains or landscape impoundments.

Agricultural irrigation using greywater to support crop production is a well-established practice in arid and semiarid regions. A significant portion from existing greywater can meet the demand for agricultural irrigation. A number of guidelines for the quality of reclaimed water for irrigation can be found in the references (USEPA 1992 and Lee *et al*., 2003).

The application of the greywater system is therefore of particular importance, hence the excess water in the system can be applied elsewhere for which the system has to be carried out properly so that the practice of reclamation and reuse can bring significant environmental and health benefits, including the increased agricultural productivity through irrigation.

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

The excess amount of the treated greywater can be made suitable for irrigating lawns, trees and ornamental food crops. Though irrigation methods in the greenhouse may differ greatly from outdoor irrigation, several guidelines for use of greywater apply to both situations. The guidelines below should be followed when irrigation is practised with treated greywater:

- Apply greywater directly to the soil, not through the sprinkler or any method that would allow contact with the above ground portion of the plants which are eaten uncooked
- Root crops which are eaten uncooked should not be irrigated with greywater
- Plants that thrive only in acid soil should not be watered with greywater, which is alkaline
- Use greywater only on well- established plants
- Disperse greywater over a large area and rotate with fresh water to avoid build-up of sodium salt

1.6 Site Selection

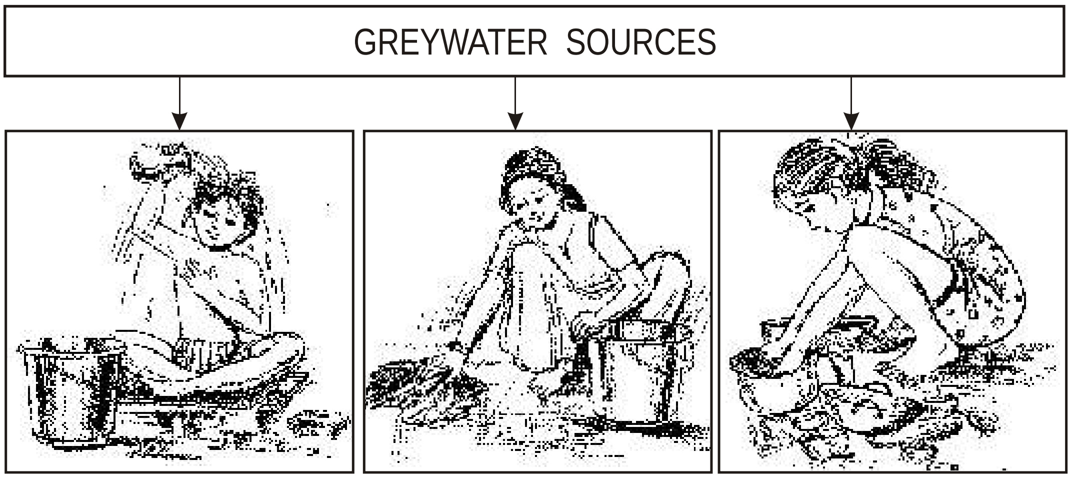
In the process of assessing the suitability of sites for constructing greywater treatment system, important considerations are as below:

- Approximate size of 15 - 20 m^2 land in the school campus for reuse system has been considered
- Topography and natural slope : the topography of the sites and contours can be established using standard surveying procedures. The slope of the site is an important factor in controlling surface ponding, runoff and erosion. A minimum of 2% slope of area is recommended.
- Soil type : Soil type and properties are the key factors in the design and operation of greywater reuse systems. The main characteristics necessary for the evaluation of the soil for the purpose of greywater reuse are soil texture, soil structure, corrosiveness, submergence, infiltration rate through topsoil and percolation rate in the sub-strata. Percolation rates can be determined using percolation tests and compared with textural classification charts. Infiltration rates can be determined using a cylinder infiltrometer (Christov *et al.*, 1995). As sandy lighter soils can absorb more greywater, and heavier soils with a high clay content absorb less (Greenhouse People's Environmental Centre, 2002) therefore soil having structural stability i.e., stable clay/silt, hard strata soil is recommended for greywater reuse system construction. Black cotton soil and sandy soil should be strictly avoided

2.0 Greywater Quantification and Characterization

2.1 Background

Greywater is the wastewater generated in the bathroom, laundry and kitchen. Greywater is therefore the component of domestic wastewater, which has not originated from the toilet or urinal.



The water requirement and greywater generation for Ashram school is presented in Table 4. It is evident from Table 4 that about 50-60% of water use results in greywater generation.

Table 4 : Water Requirement for Students of Ashram Schools

Description	Quantity of water (lppd)	Greywater generation (lppd)
Bathing	12-18	12-18
Washing of clothes	8-12	8-12
Flushing of W. C.	5-10	-
Washing the floor	2-5	-
Washing of utensils	3-5	3-5
Cooking	5	-
Drinking	5	-
Total	40-60	23-35

Based on study in Ashram schools in Dhar and Jhabua districts

2.2 Composition of Greywater

Greywater from Bathroom

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

Greywater from Cloth Washing

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

Greywater from Kitchen

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

2.3 Characteristics of Greywater

There is variation in chemical and microbial quality of greywater depending on source types. A typical qualitative composition of greywater is presented in Table 5.

Table 5 : Characteristics of Greywater

Water Source	Bacteria	Chlorine	Foam	Food Particles	Hair	High pH	Nitrate	Odor	Oil & Grease	Organics matter	Oxygen demand	Phosphate	Salinity	Soaps	Sodium	Suspended solids	Turbidity
Cloth washing			*			*	*		*		*	*	*	*	*	*	*
Washing of utensils	*		*	*		*		*	*	*	*			*	*	*	*
Bathing	*				*			*	*		*			*		*	*
Kitchen	*			*				*	*	*	*			*		*	*

(Wright, 1986 & Errikson, 2002)

The chemical characteristics of greywater typically are presented in Table 6. Treatment requirements vary based on chemical characteristics and intended use of treated greywater.

Table 6: Typical Characteristics of Greywater

Parameter	Unit	Greywater*		Raw sewage
		Range	Mean	
pH	-	6.4 - 8.1	7.7	6.5 - 8.5
Suspended solids	mg/l	40 - 340	190	90 - 400
Turbidity	NTU	15 - 270	161	NA
BOD_5	mg/l	45 - 330	170	150 - 400
Nitrite	mg/l	0.1 - 1.0	0.55	1-10
Ammonia	mg/l	1.0 - 26	13	10 - 35
Total kjeldhal nitrogen (TKN)	mg/l	2 - 23	12	40 - 50
Total phosphorus	mg/l	0.1 - 0.8	12	5 - 30
Sulphate	mg/l	<0.3 - 12.9	62	12 - 40
Conductivity	mS/cm	325 - 1140	732	300 - 1400
Hardness	mg/l	15 - 50	35	200 - 700
Sodium	mg/l	60 - 250	140	70 - 300

* Based on the analysis undertaken in Ashram schools of Dhar and Jhabua districts

The microbiological quality in terms of number of thermotolerant coliforms of greywater from various sources in an Ashram schools is presented in Table 7. Thermotolerant 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 thermotolerant coliforms found in raw sewage are in the order of 10^6 to 10^8 cfu/100ml.

Table 7 : Faecal Coliforms in Greywater

Source	Thermo tolerant coliforms (cfu)/100ml			
	Rose et. al. (1991)	Kapisak et.al (1992)	California DHS (1990)	Brandes (1978)
Bathing	6×10^3 cfu	4×10^5 MPN	< 10 to 2×10^8	6×10^3 cfu
Laundry wash water	126 cfu	2×10^3 - 10^7 MPN	–	–
Laundry rinse water	25 cfu	–	–	–
Kitchen	--	–	<10 to 4×10^6	2×10^9
Combined greywater	6 to 80 cfu[A] 1.5×10^3 cfu[B] 1.8×10^5 to 8×10^6 cfu 13×10^6[D]		8.8×10^5[CD] 1.73×10^5	

A Family without children

B Families with children

C Other study quoted cfu- colony forming units/100ml

D Kitchen and bath only MPN- most probable number

Note : For all practical purposes, cfu can be considered similar or of the same magnitude order as MPN

Source: Jepperson et al., 1994

2.4 Greywater Treatment Options

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

The greywater treatment options as shown in Figure 4 include anaerobic sludge reactors, septic tanks, oxidation ponds etc.

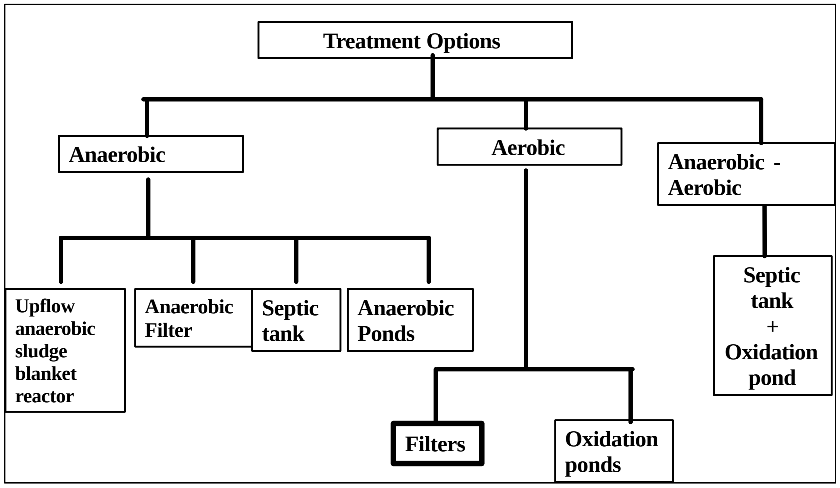


Figure 4 : Greywater Treatment Options

Among the above mentioned options the filtration was followed due to their advantages mentioned below:

- Easy operation and maintenance
- Economical
- Provides extensive physical treatment
- Treated greywater is of better quality
- Use of locally available filter media
- No requirement of external energy source
- Anaerobic process require a methogenic state to complete the destruction of vegetable fatty acids and removal of ammonia
- Oxidation ponds are not a complete process and requires servies of waste stabilization ponds

2.4.1 Primary Treatment System

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

2.4.2 Secondary Treatment System

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

2.4.3 Tertiary Treatment System

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

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

2.4.4 Biological Treatment System

This level of treatment involves utilising the biological content in greywater to reduce microbial contamination, suspended solids, turbidity and nutrients (nitrogen and phosphorous). The treatment process requires a significant level of automation and energy to power the aeration technology as well as pumps and disinfection systems.

Greywater is characteristically low in nutrients and this would inhibit the efficiency of biological treatment systems for application in Ashram schools. Consistency in treated greywater quality can also be achieved through greater storage volumes which assist in the biological treatment process (Al-Jayyousi, 2003). However, the consistency of biological treatment systems could vary greatly according to the types of chemicals used at greywater sources. Some substances or products used such as laundry washing products, soaps or shampoos with high amounts aluminum or zeolite could poison or hinder the biological process (Christova-Boal *et al*., 1995).

Other examples of greywater reuse systems that do not incorporate typical primary or secondary treatment include systems that physically capture/filter out solids from specific greywater streams prior to reuse and will require ongoing maintenance to regularly clean the system.

Due to limitations in applying these systems in Ashram schools, no further discussion on tertiary and biological systems are included in this Manual. Primary and secondary greywater treatment options are described in Table 8.

Table 8 : Greywater Treatment Options

Option of greywater treatment		Advantage	Disadvantage
Primary Treatment		• Provides extensive physical treatment • Comparatively higher safety and lower health risk	• Maintenance and monitoring required • Costly
Secondary Treatment		• Quality of greywater is good • Directly put to irrigation • Besides removing BOD, N and P they are very efficient at removing/inactivating microorganisms and helminth eggs	• Treated greywater for any other purpose is not available • Skilled persons required

Treatment options described above involve various processes predominantly physical processes for treatment of various parameters of greywater. These processes are not necessarily put in sequence and do not form part of treatment systems. Treatment for greywater quality variables is provided in Table 9.

Table 9 : Treatment for Greywater Quality Variables

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

(Wright, 1986)

2.4.5 Odour and Colour

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

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

3.0 Design of Greywater Treatment System

3.1 Background

Greywater treatment process varies from simple devices that divert greywater for direct application such as irrigation to complex systems involving sedimentation tanks, filters, bioreactors, pumps and disinfection systems. However, the basic objective of this Manual is to initiate process of greywater treatment in India and keeping cost-effectiveness as a basic theme, simple treatment systems for non-contact use are described. This manual provides acceptable solutions for reuse of greywater in unsewered areas that satisfies the performance objective and requirements. It may be appropriate for persons contemplating a greywater reuse system to consult a wastewater system designer or other suitably qualified person to consider the options available.

To design a greywater system an estimation of greywater generation is required and the site then needs to be evaluated for the possible reuse of greywater.

3.2 Quantification of Greywater

Determination of greywater generation and flow rate is the first requirement in the design of greywater collection, treatment and reuse system. Reliable data on existing and projected flow rate must be available for the cost-effective greywater treatment system design. The possible reuse options as previously described also determines treatment design. Following methods are proposed for quantification of greywater:

Method	Type
Direct method	Water meter Bucket method
Indirect method	Water consumption Types of uses

3.2.1 Direct Method

3.2.1.1 Water Meter

In the water meter method, a meter is provided at the outlet of the drain connecting bathrooms, kitchen and cloth washing place (laundry). If not possible, the meter can be placed at the inlet of the greywater collection tank which can be connected to bathroom, kitchen and laundry.

Small plumbing modification in the piping system will allow collection of greywater system which can be easily measured. This system can be fitted in residential schools where variation in greywater quantity is not expected.

3.2.1.2 Bucket Method

This is the simplest form of greywater quantification wherein greywater is collected in a bucket of known volume at the outlet of bathroom, laundry or kitchen. This method is cheap and suitable where greywater quantity remains almost constant for a substantial time period. The method is manual and precautions are required to avoid any human contact with greywater. The method is described below:

- Identify outlet
- Keep a 20 liter bucket at outlet of bathroom and laundry
- Start stop watch and measure time for filling of 20 liter bucket
- Measure during 24 hour cycle
- Measure once per month
- Measure only during February, March and April
- Find out average value of greywater per day

3.2.2 Indirect Method

As mentioned earlier, greywater quantity is about 50-60% of total water consumption. The quantity of water consumed can also be used to quantify greywater.Table 4 can be used for quantification of greywater in Ashram school.

Indirect method also includes correlation between a variable and greywater generation. A correlation is developed between number of students occupying an Ashram and greywater generation based on the data collected by NEERI and UNICEF in rural Madhya Pradesh as presented in Figure 5.

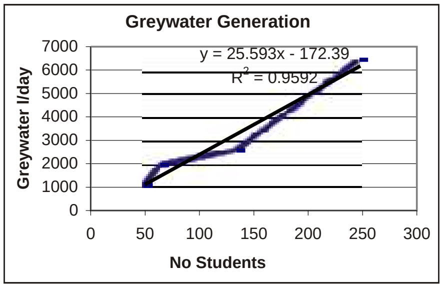


Figure 5: Correlation Between Number of Students and Greywater Generation in Ashram School

3.3 Components of Greywater Treatment Systems

Advances in the effectiveness and reliability of wastewater technologies have improved the capacity to produce reused water that can serve as alternative water source in addition to meeting water quality protection and pollution abatement requirements (Lazarova, 2000). In southern European Union (EU) countries, additional resources brought by water reuse can bring significant advantages to agriculture e.g. crop irrigation (Angelakis *et al*., 2003).

A number of technologies have been applied for greywater treatment worldwide varying in both complexity and performance (Jefferson *et al*., 2001). The following greywater systems considering non-contact application are considered in this Manual:

Primary treatment - pre-treatment to secondary treatment

- Screening
- Equalization

Secondary treatment

- Gravel filtration
- Sand filtration
- Chlorination

3.3.1 Primary Treatment Systems

3.3.1.1 Greywater Diversion Devices

These systems do not store or treat greywater and as such are best to reuse greywater for sub-surface applications. The simplest forms of primary greywater reuse systems are best described as greywater diversion devices (Ludwig, 1994) and are the most economical.

A simple plumbing device diverts greywater in the wastewater drainage line to a sub-surface garden irrigation system via gravity without any external energy. This system does not treat the greywater and as such the sub-surface garden irrigation system must be able to cope with fouling material such as hair and lint (Ludwig, 1994). The land patches irrigated directly with greywater are termed as mini-leachfields which filter the solids and allow sub-surface infiltration. In these applications the soil treats the greywater and consideration must be given to the type and depth of soil available to complete the process.

3.3.2 Primary (Pre-treatment) and Secondary Greywater Treatment Systems

Primary (pre-treatment) and secondary greywater treatment systems are useful in hostels, schools and residential complexes to treat greywater to the tune of 1000-2000 l/day. A potential treatment scheme is shown in Figure 6.

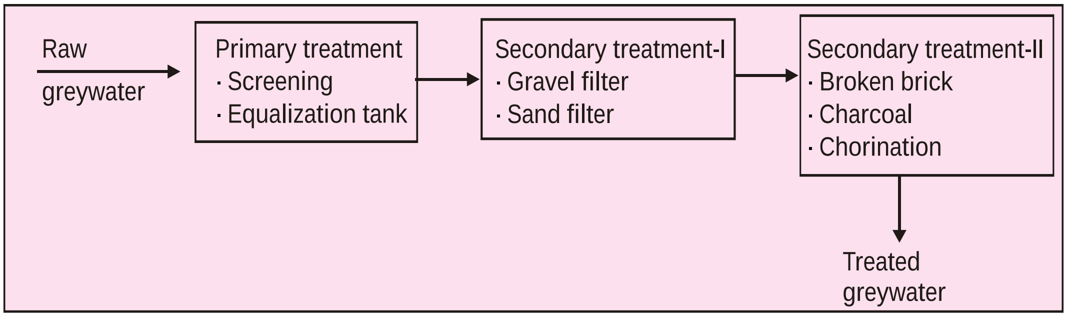


Figure 6 : Greywater Treatment Scheme

The function of various treatment units are presented in Table 10.

Table 10 : Treatment Units and Functions

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

The design of various components of treatment system based on the application in Ashram schools in Dhar and Jhabua districts is provided below:

3.3.2.1 Screen

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

3.3.2.2 Junction Chamber

Junction chamber is provided to facilitate draining out greywater from different sources. The dimension of junction chamber is kept about 0.3 m x 0.3 m x 0.5 m for a hostel having greywater generation of 2000-3000 l/day. The dimension of junction chamber is determined based on providing sufficient storage to handle peak hourly volume. A small rack containing sponge or foam can be provided close to the top of junction chamber (or equalization tank) for removal of froth generated from bathroom and washing place due to use of soap.

3.3.2.3 Equalization or Settling Tank

An equalization or settling tank is an important component of greywater treatment system. It is required to balance flow to take into account maximum flow of greywater is generate during morning hours due to bathroom use. Adequate aeration by providing baffles and mixing must be provided to prevent odors and solids deposition in equalization tank. Baffles can also be provided in equalization tank though it may restrict settling of particles. Greywater is continuously collected in the tank and flows to filters for treatment. In addition to providing constant load to the filter system it facilitates settling of coarse particles (>10mm size).

3.3.2.4 Filter

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

Though screening and sedimentation process remove a large proportion of suspended matter, they do not effectively remove fine flock particles, colour, dissolved minerals and microorganisms. In filtration, water is passed through a filter medium in order to remove the particulate matter not previously removed by sedimentation. During filtration, the turbidity and colloidal matter of non-settleable type protozoan cysts and helminth eggs are also removed. It is to be mentioned that protozoa are stopped in the gravels, the bacteria by the medium gravel and the viruses by the sand.

The filter types are as below:

- Upflow -downflow filter
- Multi Media Filter
- Slow Sand Filter
- Horizontal Roughing Filter

Upflow-downflow filter

As the name suggests, raw greywater is put into the bottom of first column of filter and collected at the top of second column. This water is again fed to the third column of filter from the bottom and is collected at the top of fourth column. The number of columns depends on quality of greywater and expected use of greywater and optimally upflow-downflow filter contains four columns. The filter media varies with the column and may contain gravel, coarse sand, fine sand and other material such as wooden chips, charcoal etc. The upflow - downflow filter is shown in Figure 7.

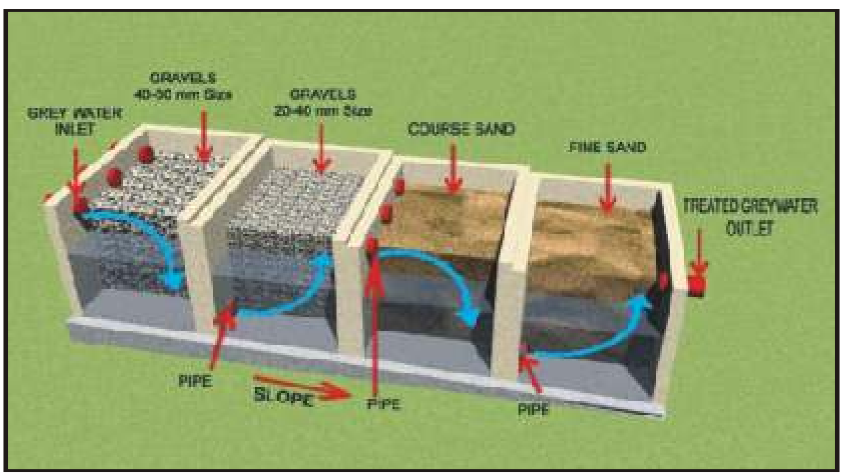


Figure 7 : Upflow Downflow Filter

Multi-media filter

Multi-media filters are filled with a variety of media in order of increasing size, for example, fine sand, coarse sand, gravel, stone, and wood chips to a total depth of 0.75 m to 1 m. The inlet is provided at the top so that the filtered water is collected through outlet in the bottom. A vent is provided at the top for letting out odorous emissions, if generated in the filter. Media can be taken out for washing periodically depending on the greywater characteristics and quantity. Replacement of local filter media is also a feasible alternative.

Slow sand filter

Slow sand filters are shallow layers of stone, medium gravel, and pea gravel beneath a deep layer of sand. A slow sand filter will have greywater load of 0.1 to 0.2 $m^3/m^2/hr$. The slow sand filter is shown in Figure 8.

These gravity filters may be constructed in a 200 liter drum or similar container that is of suitable size. Features that should be part of a filter include a perforated plate or some other device to distribute water evenly over the top, a concrete funnel in the bottom to help water drain to the perforated drain pipe, and a cover and vent to prevent odors. The bottom of the filter should be filled with stones that are too large to enter the drain pipe.

Slow sand filters require regular cleaning and replacement of the top layer of media. Multi-media filters require less frequent cleaning, but all layers must be cleaned or replaced when maintenance is required.

Routing greywater through a settling tank before filtering reduces contaminant load and can lengthen the interval between cleanings.

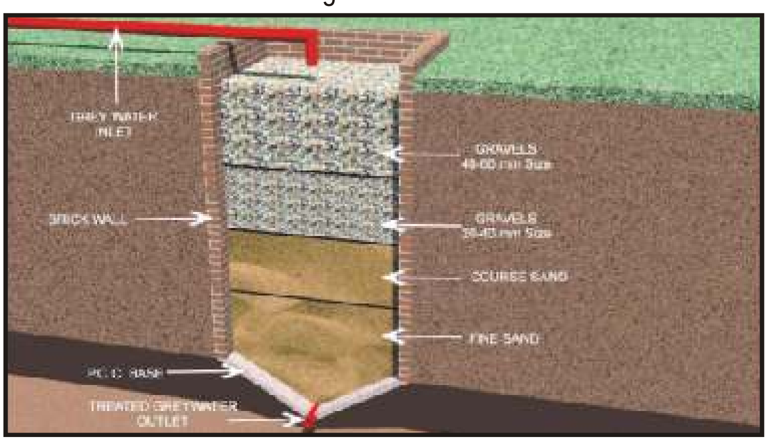


Figure 8 : Slow Sand Filter

Horizontal Roughing Filter

The horizontal flow prefiltration technique using coarse gravel or crushed stone as a filter media is also a sound alternative in handling turbid waters. The main advantage of the horizontal flow prefilter is that when the raw water flows through it, a combination of filtration and gravity settling takes place which invariably reduces the concentration of suspended solids. The effluent from the pre-filter, being less turbid, can be further easily treated with slow sand filter.

Horizontal flow prefiltration may be carried out in a rectangular box similar to a basin used for plain sedimentation filled with various filter media. The raw water inlet is situated at one side of the box and the outlet at the opposite side. In the main direction of flow the water passes through various layers of graded coarse materials in the sequence coarse-medium-fine.

3.3.2.5 Collection Sump

A collection sump of an appropriate capacity to handle the average daily generation of treated greywater is required along with greywater treatment plant. In case the greywater generation is large (more than 4000 liter/day), collection sump may have capacity to handle half of the quantity of greywater generated per day. It should be ensured that greywater reuse should also continue along with greywater generation and treatment to avoid accumulation and facilitate overflow of treated greywater from collection sump. Freeboard of 0.2-0.3 m should be provided in collection sump.

3.3.2.6 Pump

Various types of pumping mechanisms can be employed in greywater reuse systems. These include manual as well as electrical/mechanically operated pumps. Due to lack of spare parts and fluctuation in electric power supply in many rural buildings, it may be appropriate to consider manually operated pumps. These may include force lift handpumps, treddle pumps or play pumps. The pump should have a minimal yield (Q) of 1000 liter/hour and should be a high head/low discharge pump (see annex 2 for details).

3.3.3 Wetland Treatment

Advances in the effectiveness and reliability of wastewater technologies have improved the capacity to produce recycled water that can serve as alternative water source in addition to meeting water quality protection and pollution abatement requirements (Lazarova, 2000).

A study indicates that in the southern European Union (EU) countries, additional resources brought by water reuse can bring significant advantages to agriculture e.g. crop irrigation (Angelakis *et al*., 2003).

A number of technologies have been applied for greywater treatment worldwide varying in both complexity and performance (Jefferson *et al*., 2001).

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

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

The flow diagram of greywater treatment system incorporating wetland treatment is shown in Figure 9.

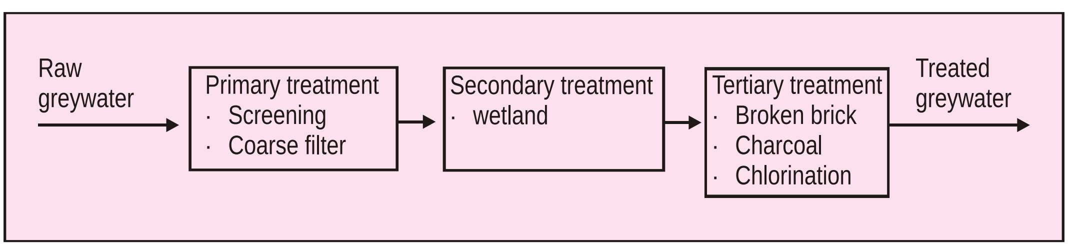


Figure 9 : Greywater Treatment System with Wetland Treatment

3.4 Design of Greywater Treatment Systems

The technologies that best address the factors that effect greywater reuse must primarily consider the biological characteristics of greywater (Al-Jayyousi, 2003). The design of greywater reuse system primarily will depend on quantity to be treated and reuse applications. Treatment technologies can be best described in either user-based or technology-based terms.

The technology utilised in greywater reuse systems can be differentiated into primary, secondary and tertiary levels (Jeppesen, 1994). Greywater generated in Ashram schools is reused in garden watering/ irrigation (external) and toilet flushing (internal) and mainly developed as part of integrated water management.

Design Parameters for Greywater Reuse System

- Water availability/scarcity
- Quantity of greywater
- Land availability
- Ground slope
- Soil type
- Reuse type such as toilet flushing, gardening, floor washing etc.
- Availability and cost of filter media

3.4.1 General Design Consideration

Compared to wastewater, greywater which is predominantly from bathroom and laundry sources is high in dissolved solids (mostly salts) and turbidity, low in nutrients and is likely to contain significant amounts of pathogens (Al-Jayyousi, 2003). The suspended solids that are present are mostly in the form of hair and lint from bath and laundry waste (Jeppesen, 1996).

The treated greywater which is generated from bathroom and clothes washing in Ashram schools is used for toilet flushing and watering plant in the garden of school premises. However, treatment for kitchen wastewater, will generally require more sophisticated technologies and processes to address the high BOD and fatty solids generated (Al-Jayyousi, 2003), hence kitchen wastewater is not considered in this application.

As greywater reuse for toilet flushing and/or gardening water with extremely low possibility of human contact, disinfection may not be required. The greywater reuse system is connected to the septic tank available in these Ashram schools as a precaution. If the greywater reuse system malfunctions or if maintenance is to be carried out, the system is capable of being manually or automatically diverted. This would avoid an unlikely event where the greywater is not collected and disposed of which would increase the risk of human contact.

3.4.2 Standard Design of Greywater Treatment Systems

The greywater treatment system designs vary based on the site conditions and greywater characteristics. However, designs should incorporate the following features to optimize treatment efficiency considering sustainable performance of greywater treatment system:

Tips for Design Optimization

- Treatment unit orientation parallel to surface contours
- Equalization with time dosing with peak flow storage
- Uniform application of greywater over filter media
- Multiple cells to provide periodic resting, standby capacity and space for future repairs or replacement
- Rough surface gravel media
- Organic loading equal to hydraulic loading rate
- Loading to filtration unit with preferably TSS less than 20 mg/l
- Use of natural coagulants such as ground drumstick seeds for odour removal
- Rough surface of partition walls of filters to avoid short circuiting
- Provision of baffles at the inlet and outlet of treatment system

Greywater treatment plants mainly consist of sedimentation or settling unit and filters. Process of sedimentation allows removal of suspended solids by gravity and natural aggregation of the particles without use of coagulants. Removal efficiency of suspended solids in sedimentation tanks depends on surface area and depth of tank. Surface loading rate is the basic guidance parameter for determining size of tank. The design criteria for sedimentation or settling tank presented in Table 11 can be considered.

Table 11 : Design Criteria for Sedimentation Tank

S.No	Parameter	Range
1.	Detention time (hours)	1-2
2.	Surface loading rate ($l/hr/m^2$)	500-750
3.	Depth of tank (m)	0.6-1.0
4.	Length to width ratio	3:1 to 4:1

The major processes in filtration are sedimentation in the pore spaces, adhesion to the media particles, and bio-chemical degradation of captured particles in slow-sand filter. The design features of upflow-downflow and horizontal roughing filters in greywater treatment system are provided in Table 12.

Table 12 : Design Criteria for Roughing Filters

Sr. No.	Parameter	Roughing filter	
		Upflow - downflow	Horizontal
1.	Number of compartments	3-4	3-4
2.	Media and size (mm)	Gravel (20-40) Gravel (5-20) Coarse sand (1-5) Fine sand (0.1-1)	Gravel (20-40) Gravel (5-20) Coarse sand (1-5) Fine sand (0.1-1)
3.	Hydraulic loading (m^3/m^2-hr)	0.1-0.3	0.1-0.2
4.	Depth of media (m)	0.4-0.6	0.5-0.7

Standard design for greywater treatment systems have been worked out for different quantities of greywater generation based on the design criteria described above. Various treatment options, possible greywater reuse, construction and maintenance costs and associated health risks are presented in Table 13.

Table 13 : Details of Greywater Treatment System

Parameter	500 to 2000 l/day	> 2000 l/day
Treatment	➢ Sedimentation ➢ Horizontal filter ➢ Slow sand filter ➢ Disinfection	➢ Sedimentation ➢ Horizontal filter ➢ Slow sand filter ➢ Disinfection OR ➢ Sedimentation ➢ Wetland
Uses	➢ Toilet flushing ➢ Irrigation ➢ Floor washing ➢ Construction	➢ Toilet flushing ➢ Irrigation ➢ Floor washing ➢ Construction
Construction Cost	USD 250-600 based on flow*	USD 500 1000 based on flow*
Maintenance Cost per year	USD 12-25*	USD 25-50*
Water saving per year	200,000 to 400,000 litre	More than 400,000 litre
Monitoring/ Maintenance	High	High
Health risk	Low	Low

* Cost established in India

3.4.3 Odour Control

Good design and maintenance practices will reduce odour problems in greywater treatment system without the use of chemical addition or air treatment. However, the following measures are recommended to minimize odour problem:

- A minimum slope of 2-3 % should be provided so as to ensure sufficient flow through system when in operation
- Baffles should be provided at the entrance of sedimentation tank and in collection sump for aeration
- The closed conduit system should be avoided. If a closed conduit system is unavoidable, length should be minimal with adequate velocity to scour the pipe.
- Deposited solids should periodically be removed from sedimentation tank
- Natural coagulants such as ground seeds of drumsticks should be added to sedimentation tank

- Addition of chemicals such as calcium nitrate, hydrogen peroxide, potassium permanganate, hypochlorite and chlorine added to the system to oxidize the sulphate bearing ingredients of greywater. This is only necessary if the system can not be designed in such a way to prevent formation of anaerobic conditions
- Filters should be washed with clean water and filter media should be periodically replaced as mentioned in O&M
- Chlorination of final effluent also helps in minimizing odour
- Collection sump can be covered and vent pipe can be provided to let out the odourous compounds

3.5 Maintenance of Greywater Treatment System

The success of a greywater reuse system will depend on an individual's efforts in maintaining the system. Once a greywater system is installed it becomes the users responsibility to ensure it is managed in accordance with the designer or this manual. Any defect must be rectified as soon as it becomes apparent. Greywater systems require regular maintenance e.g. weekly cleaning or replacing filters, periodic desludging, and manually diverting greywater back to sewer and flushing of drainage lines.

Operation and maintenance of systems will be at a cost to the user. Costs include the initial construction costs, power to operate pumps, replacement filters, cleaning of irrigation lines and desludging of sedimentation tanks.

The user of greywater system may be required to undertake certain commitments after system start-up including but not limited to the following:

- Weekly maintenance of systems with filtering devices
- Systems with two reuse areas require regular diversion
- Sedimentation tanks require desludging every month
- Warning signs should be maintained in good order
- Irrigation area should be maintained to prevent the entry of rainfall runoff
- Ensure excess watering does not occur. Over watering can lead to waterlogging and plant death. When conducting maintenance (e.g. cleaning filters etc) involving greywater the user should avoid direct contact with the skin by using rubber gloves

- Protection from any contact with greywater to ensure that exposed body areas that come into contact with greywater are immediately washed; not make contact with the mouth or face either directly (e.g. fingers, hands)
- Use of greywater only for toilet flushing and to completely avoid use for anal cleaning or handwashing

Normal maintenance activities for the greywater system are presented in Table 14.

Table 14 : Maintenance of Greywater Treatment System

Treatment Units	Activity	Frequency of Cleaning	Purpose
Equalization cum settling tank	De-sludging	Every week	Maintain the volume of equalization tank
Horizontal filter	Cleaning of filter media	Every10 days	Maintain the efficiency of sand filter
Coarse sand filter	Cleaning of filter media	Every week	Maintain the efficiency of sand filter
Sand filter	Refill the upper layer	Every week	Overcome chocking problem
	Cleaning of filter media	Every 10 days	Maintain effective filtration
Filter Broken bricks	Cleaning of filter media	Every 10 days	Colour removal
Wetland	Removal of unwanted grass & plants	Every 2 months	Maintain the efficiency of system
Chlorination	Maintain proper dose	Every day	Disinfection
Collection tank	Reuse of water	Every 2 days	Maintain the quality of greywater

4.0 Water Safety Plan

4.1 Background

Water reuse in schools should be promoted with due consideration for ease of monitoring and operation and maintenance. To achieve this, appropriate hygiene promotion and participatory tools are required. This may be achieved using *Learn by Play* techniques, as well as involvement of Parent Teacher Association (PTA) and children in the water quality monitoring and operation and maintenance of greywater reuse system. To achieve this in Madhya Pradesh, a new approach termed *Water Safety Plans* has been promoted. The *Water Safety Plan* is an improved risk assessment and management tool developed by the World Health Organisation to improve process monitoring of water quality. Conventionally, water quality has been assessed using microbiological and chemical water quality testing. Based on these results reactive maintenance may be undertaken to improve the process monitoring of water quality. The third edition of Guidelines for Drinking Water Quality (WHO, 2004) recommends a comprehensive risk assessment and risk management plan comprising of following two components:

1. Health based targets-using Quantitative Microbial Risk Assessment (QMRA) techniques to establish appropriate water quality performance targets, and;
2. Risk Management-Water Safety Plans to manage the water supply system to ensure that the system performs to the specified target.

Detailed work on Quantitative Microbial Risk Assessment (QMRA) has been undertaken for greywater (Godfrey *et al.,* 2006, Westrell *et al.,* 2004, Hass *et al*., 1999 and Oloffson *et al.,* 2004). Instead, this section will focus on Water Safety Plans for greywater reuse system.

4.2 Water Safety Plans

Godfrey *et al*., (2006) observed that risk management of greywater reuse should be developed to minimize the risk of exposure of users to greywater. Risk management is more advantageous that conventional water quality monitoring as it provides complete management of the greywater system from the "*tap* to the *toilet."* It identifies risk points in the greywater system and suggests appropriate critical limits for monitoring the system based on QMRA. Once these limits are exceeded, the Water Safety Plan has the additional advantage in that it provides operation and maintenance solutions. Systematically, the Water Safety Plan links water quality to operation and maintenance to ensure the safe delivery and use of greywater at minimal risk.

Water Safety Plans are a new concept in the global water sector. Conventionally, Water Safety Plans are developed based on the four steps. However, special consideration must be given to the simplification of the Water Safety Plans for rural schools in developing countries. Outlined below are examples of the application of Water Safety Plans for rural schools based on experience from Madhya Pradesh, India:

Water Safety Plans have four main steps:

1. System description - detailed description of the greywater system developed by Parent Teacher Association (PTA) and children's groups
2. Hazard assessment - identification of main hazards in the greywater system
3. Matrix development - detailing of who, what, how and where hazards will be monitored as well as suggested corrective actions or maintenance
4. Monitoring and maintenance - limits for physico-chemical monitoring and maintenance of greywater system

4.2.1 System description

As noted in Godfrey *et al.,* (2005) and Davison *et al.,* (2004), the first step of establishing a Water Safety Plan is to describe the system. This should be undertaken by an interdisciplinary team. In schools, this may comprise of the head teacher, selected members of the Parent Teacher Association (PTA) and student representatives of the school *Water Safety Club.*

System Description

- Water Safety steering group is formed comprising PTA and children
- Group undertakes a structured observation of the system
- System is drawn on the wall of the school

4.2.2 Hazard Assessment

Based on the system description, specific sources of the microbiological hazards are identified. These microbiological hazards are identified using standardized sanitary inspection (SI) forms and *Learn by Play* hygiene promotion techniques such as those outlined below:

a) Sanitary inspection

The PTA and children's groups undertake the sanitary inspection to prioritize which hazards exist within the greywater reuse system. It is suggested that for the initial hazard assessment, the SI form as shown in Figure 10 is filled in by three groups comprising one member of the PTA with assistance from selected children. The results of the assessments are then shared to provide further improvements in the clarity of the questions and also to prioritise which hazards are of greatest significance.

I. Sanitary inspection forms for the greywater systems

1. General Information: Village Name:
   Water Source Type:
   Year of Installation:
   Water Source No.:
2. Date of Visit :
3. Water sample taken? …….Sample No. ………:

II Specific Diagnostic Information for Assessment

		Remark
1.	Do the children use the treated water for cleaning toilets?	Y/N
2.	Are the inlet and outlet greywater collection tanks properly covered with the lid?	Y/N
3.	Do the animals have access to the area around the greywater storage tank?	Y/N
4.	Does the untreated water belong to the greywater coming from bathing as well as laundries?	Y/N
5.	Are the bathrooms being regularly cleaned and is the treated water is being used for washing purposes?	Y/N
6.	Are there any other sources of pollution?	Y/N
7.	Is there any problem regarding the overflow in the greywater system?	Y/N
8.	Are the pipes cracked from where the treated greywater is supplied to the tanks placed on the roofs?	Y/N
9.	Does the split greywater collect in the area nearby the system?	Y/N
10.	Is the treated greywater being properly chlorinated ?	Y/N
	Total Score of Risks	…. /10

Risk score: 9-10 = Very high; 6-8 = High; 3-5 = Medium; 0-3 = Low

Figure 10 : Sanitary Inspection Form for Greywater Reuse System

b) Greywater reuse hazard assessment

To encourage the involvement of children in the hazard assessment, *Learn by Play* techniques of hygiene promotion may be used. Outlined below are two examples and the results are depicted in Figure 11.

Example 1: Hazard Assessment of Greywater Reuse System

*Learn as you play - Grey*water reuse system performance monitoring

- Children are organized by PTA into three lines
- The children join hands in three rows with the tallest children at the front (representing the gravel filters) followed by medium height children (medium gravels) and then the small children (representing the sand filter)
- Children are then asked to walk under the hands of the children
- The biggest children are prevented from passing through the first row, followed by medium children in second row and small in the third, only the smallest children escape
- The PTA then explain that the three rows represent the filtration in the greywater
- The protozoa are stopped in the gravels, the bacteria by the medium gravel and the viruses by the sand

Example 2: Exposure Assessment

Learn as you Play - Exposure Assessment

- Children draw all the identified hazards in the greywater system
- Under the guidance of the PTA, the children are given one stone
- Using a pocket chart voting technique, the children vote on which hazard they think is most detrimental to their health
- The stones are counted and results are discussed with the children to prioritise the hazards

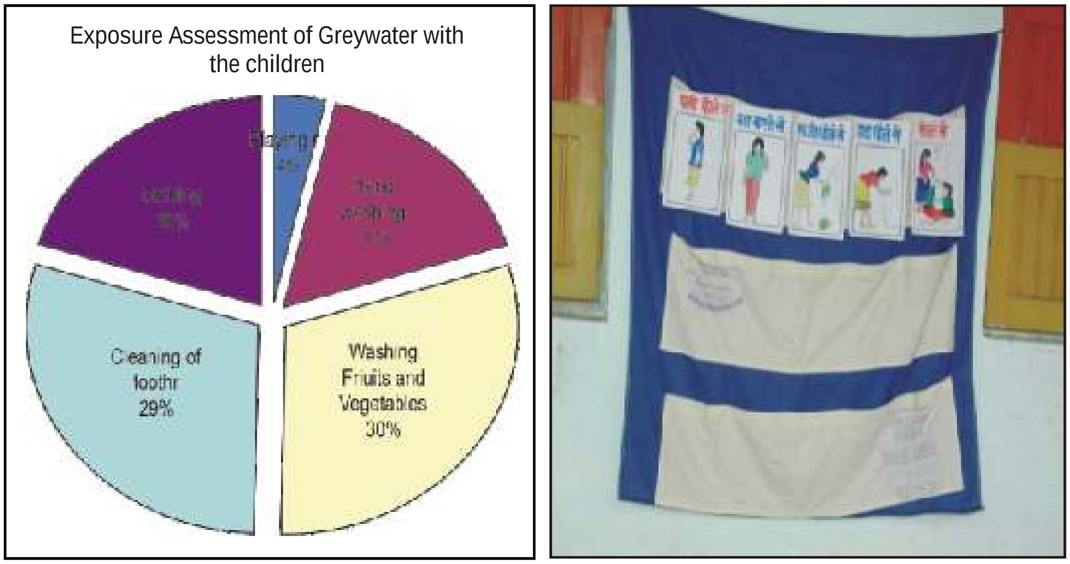


Figure 11 : Exposure Assessment of Greywater with Children

The results of the exposure assessment are described in Table 15, the size and the nature of the population exposed and the routes, concentrations and distribution of hazards are determined (Roseberry *et al*., 1992).

Table 15 : Exposure Assessment for Greywater Reuse

Type of Exposure	Volume ingested (ml)	Frequency (Times per year)	Number of persons affected
(UN) intentional ingestion of greywater during handwashing	30	1	100
Child playing in greywater	1	2	30
Child drinking greywater	100	10	100
(UN) intentional ingestion of greywater during tooth brushing	30	1	2

Greywater used for the reuse may expose people directly via inhalation as well as through ingestion. The dose of a pathogen is calculated from the density of organism in the water times the volume ingested (Ottoson *et al.,* 2003). Further to the exposure assessment, the response of the individual is required to assist in ranking the risks associated with the system. Each of these risks is then prioritized and monitored accordingly in a *Water Safety Plan* as indicated in Figure 12.

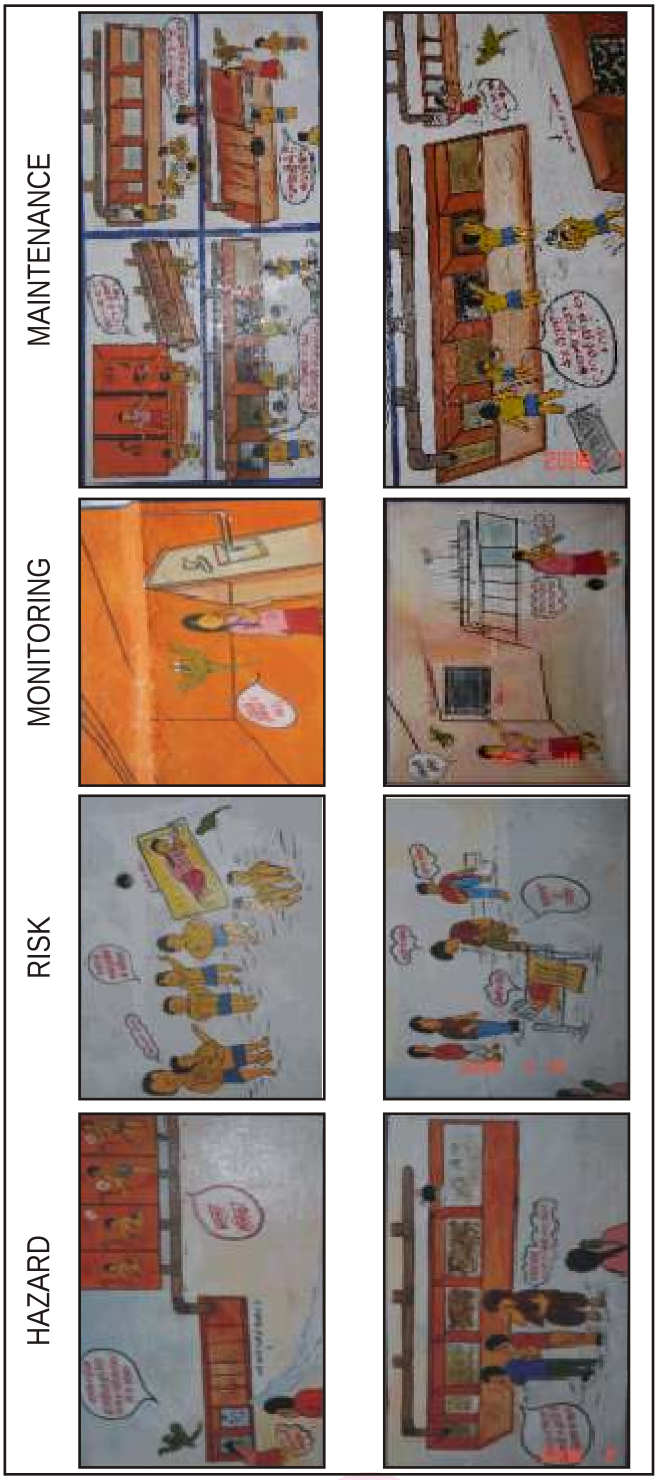


Figure 12 : Water Safety Plan for Greywater Reuse System

4.2.3 Matrix Development

The Water Safety Plan matrix comprises four major activities :

1. Hazard event-this can be defined as the source of the microbiological contamination affecting the system. This is identified through the sanitary inspection form outlined earlier
2. Risk- this can be defined as the severity of impact of the hazard event on the children (i.e. number of children falling ill due to exposure to the greywater) combined with the frequency of occurrence of the hazard event occurrence
3. Monitoring-this includes details on the regular monitoring of physico-chemical surrogates as well as sanitary inspection required by the PTA and children water safety clubs
4. Maintenance- the maintenance if and when the hazard event occurs

To explain this in schools, it is recommended that cartoon drawings are used and painted on the school wall. This has the advantage as it makes the matrix attractive to the children and also a permanent feature of the school. Outlined below are examples of the main components of a Water Safety Plan matrix in photographic and pictorial form.

4.2.4 Monitoring and Maintenance

To ensure involvement of the user, it is recommended that full participation is encouraged in both the monitoring of simple physico-chemical indicators and verification by microbial parameters. As noted in the Water Safety Plan methodology, there is a distinction between monitoring and verification of the water quality. The monitoring includes monitoring of simple physico-chemical parameters which may be used as surrogates of microbial presence. These may include turbidity, H_2S, temperature or pH. These parameters are then verified through the use of selected microbial parameters such as Thermotolerant Coliforms, Enterococci or Coliphage spores. For example, the use of turbidity tubes for monitoring of turbidity of the inlet and outlet water may be done by the user. Using the guideline values as indicated by WHO, inlet values of 500 NTU to 50 NTU (1_{log} reduction) may be considered. Where 50 NTU is then exceeded then a change in the filter media in the system plus a further verification of microbial quality may be required.

Further infrastructural precautions are also essential to ensure non-mixing of fresh and greywater in the water supply system. These precautions include:

- No cross connection with the potable water supply
- Encouragement of use of greywater to irrigate fruit plants where the fruit does not make contact with the greywater and non-leafy vegetables
- Prevention of mosquito breeding in the system
- Use of different colour pipe network for fresh and greywater
- Signage to ensure effective cautioning for those entering the area that greywater is being used for irrigation. The sign should be on a white background with red lettering at least 40mm high

5.0 Case Studies

5.1 Background

The case studies of construction and successful operation and maintenance of greywater treatment plants in Ashram schools in tribal districts of westerns Madhya Pradesh are presented in this chapter. Dhar and Jhabua are two districts of Madhya Pradesh in Central Province of India which suffers 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 greywater for appropriate purposes such as flushing of toilets. A holistic water management is adopted in these Ashram 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 liter per student per day as against drinking/cooking water requirement of 5 liter per day.

Considering the consumptive use of 20-30%, greywater generation is in the range of 23-35 liter per student per day. The greywater treatment plants have been constructed by providing treatment techniques such as screening, equalization, settling, filtration and aeration. This simple treatment has resulted in use of treated greywater in flushing the toilets which were otherwise unclean and hence not used by the students.

5.2 Greywater Treatment Plant in Kokawad Ashram School

Greywater treatment plant is constructed in Girls Ashram School in Kokawad, District Jhabua in Madhya Pradesh. The details of the Ashram school are provided below:

- Total number of students : 50 tribal girls from rural area
- Education : 1st to 8th standard
- Age group : 5 to 14 years
- Distance from pucca road : 8 km
- Total water requirement for Drinking and cooking (For ten months/ 300 days) : 90000 liter /year
- Total water requirement for bath, toilets, etc. (For ten months/ 300 days) : 375000 liter / year

- Water source : One tube well
- Sanitation facility : Four latrines and three bathrooms
- Greywater generation : 1500 - 1750 l / day

The greywater treatment plant with details given in Table 16 is constructed in Ashram school to make water available to flush toilets, to improve sanitation, to use treated greywater for gardening and for floor washing.

Table 16: Design Details of Greywater Treatment System in Kokawad Ashram School

Sr.No.	Specification	Size of tank in cm	Filter material
1.	Equalization tank	75 x 75 x 60 75 x 75 x 60	
2.	Filter I	40 x 75 x 60	Gravels (40 to 50 mm)
3.	Filter II	35 x 75 x 60	Gravels (10 to 30 mm)
4.	Filter III	50 x 75 x 60	Coarse sand (1 to 1.4 mm)
5	Filter IV	35 x 75 x 60	Burnt bricks (15 to 30 mm)
6	Filter V	35 x 75 x 60	Fine sand (1 to 0.07 mm)
7	Collection tank	100 x 100 x 100	
8	Greywater storage tank	200 x 100 x 100	
9	Overhead tank	100 x100 x 100	

5.3 Greywater Treatment Plants in other Schools

UNICEF and NEERI along with Government and Non-government partners have constructed six greywater treatment plants in Dhar and Jhabua districts to data as presented in Table 18. The operation and maintenance of these greywater treatment plants are looked after by students and Parent Teachers Association (PTA). Department of Tribal Welfare, Government of Madhya Pradesh has committed funds for regular maintenance of these plants. It is proposed to build similar greywater treatment plants in 60 Ashram schools in Dhar and Jhabua districts using funds available with Government of Madhya Pradesh.

5.4 Performance Evaluation of Greywater Treatment Plants

5.4.1 Microbial Performance

Performance evaluation of greywater treatment plant was undertaken by NEERI by collecting samples from seven greywater treatment plants in Dhar and Jhabua district. Physical and microbial parameters were analyzed and results were compared to the Australian guideline show in Figure 13. The turbidity removal efficiency of 50% (<200 NTU) is observed in all the greywater treatment plants. Considering direct correlation between turbidity and microorganism, it can be stated that microbial removal efficiency of these greywater treatment plants is also approximately 50%. This corresponds with studies undertaken by Metcalf & Eddy (2003), which indicate that filtration treatments remove between 20-80% of microbial pollution. To further ascertain the level of microbial hazard, results of the microbiological analysis were compared to established guidelines for greywater outlined by WHO, the Government of India and the Government of Australia (see Table 17)

Table 17: Suggested Guideline Values for Greywater Quality

Parameter	Direct Potable (recycled drinking water)	Indirect Potable (recycled effluent pumped to surface water for drinking)	Direct Non Potable	Indirect Non Potable (recycled effluent into surface water for irrigation)
Thermotolerant Coliform (*E.coli*) cfu/100ml	<1cfu/100ml (WHO)	<1cfu/100ml (WHO)	<10 cfu/100ml (Australia) post disinfection ≤ 10000 cfu/100ml (leaf crops) (WHO)	≤ 100,000 cfu/100ml (root crops) (WHO)
Helminth eggs (no./1lt)	≤ 1	≤ 1	≤ 1	≤ 1
BOD_5 (mg/l)	2 mg/l (CPCB-Class A)	10 mg/l (WHO)*	30mg/l (Australia)	30mg/l (Australia)
Sodium (mg/l)	70 (Australia)	70 (Australia)	70-300 (Australia)	70-300 (Australia)
Nitrite (mg/l)	0.3 (Australia)	0.3 (Australia)	0.3 (Australia)	0.3 (Australia)

* Sufficient dilution should be available so as to bring down ultimate BOD concentration to 3 mg/l to meet CPCB Central Pollution Control Board Class C Standard

CPCB Inland Surface Water Classification

Class A Drinking water source without conventional treatment

Class C Drinking water source with conventional treatment followed by disinfection

The Australian Guideline value for safe use of greywater is =10,000 cfu/100ml of Thermotolerant Coliforms (Department of Health 2002). Figure 13 below outlines results from 7 greywater reuse systems in schools in Madhya Pradesh, India.

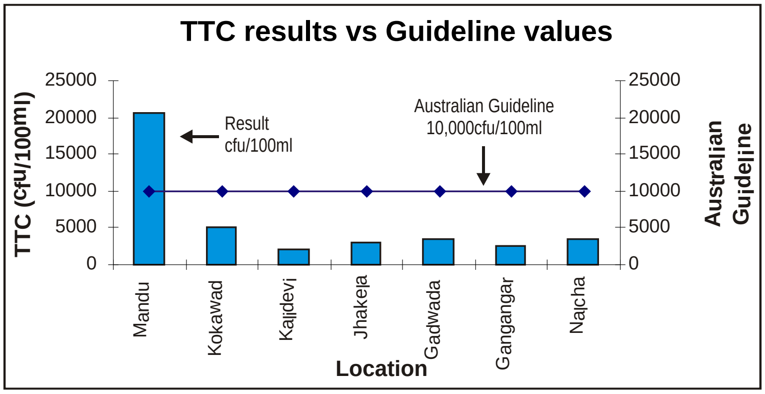


Figure 13: Greywater Quality Results

The results indicate a high level of compliance of the rural schools in Madhya Pradesh with these guideline values. However, the results show a low level of compliance from the Mandu as the system suffered from severe short circuiting. Higher levels of compliance were noted in Kalidevi, Jhakela, Gadwada, Ganganagar and Nalcha schools.

5.4.2 Financial Aspect

The acceptance of setting up greywater reuse system in Ashram school using Government funds indicates that the financial implications of greywater treatment systems provide greater environmental and social benefits. Greywater treatment technologies adopted in these systems are economically feasible which make these systems more attractive

Like the development of the other utilities, the implementation of greywater reuse facilities generally requires a substantial capital expense. In addition to capital costs associated to greywater reuse facilities, there are also additional operations, maintenance and replacement (OM and R) costs.

The main objective of the greywater reuse system is to satisfy the water related needs to the community at the lowest cost to the society whilst minimizing the environmental and social impacts. Thus the financial aspect focuses on two types of the costs mentioned below:

- Capital costs of greywater reuse system
- Operation and maintenance cost of the greywater reuse system

The cost of existing greywater treatment plants constructed in Madhya Pradesh is presented in Table 18.

Table 18 : Cost of the Existing Greywater Reuse System in Madhya Pradesh

Ashram School	Greywater generation (l/d)	Treatment units	Size L x B x H (m)	Slope (%)	Collection Tank (liter)	Cost (USD)
Kalidevi (50 Students)	1000	1) Equalization 2) Gravel (30-50 mm) 3) Gravel (10-30 mm) 4) Coarse sand (1-2 mm) 5) Fine sand (0.5-0.8 mm) 6) Broken Brick (20-40 mm)	3x2x0.5 0.4x2x0.5 0.35x2x0.5 0.5x2x0.5 0.35x2x0.5 0.35x2x0.5	2	2000	600
Kokavad (50 Students)	1000	1) Equalization 2) Gravel (30-50 mm) 3) Gravel (10-30 mm) 4) Coarse sand (1-1.4 mm) 5) Broken Brick (20-40 mm) 6) Fine sand (0.5-0.8 mm)	3x2x0.5 0.4x2x0.5 0.35x2x0.5 0.5x2x0.5 0.35x2x0.5 0.35x2x0.5	2	2000	650
Mandu (135 Students)	2500	1) Equalization 2) Gravel (15-25 mm) 3) Gravel (8-15 mm) 4) Coarse sand (1-1.4 mm) 5) Fine sand (0.5-0.8 mm) 6) Charcoal 7) Chlorination	1.7x1.2x0.6 0.5x2.3x0.6 0.5x1.5x0.6 0.7x1.2x0.6 0.3x1.2.x0.6 0.25x1.2x0.6 -	2	2500	870
Nalchha (65 Students)	1825	1) Equalization 2) Gravel (15-25 mm) 3) Gravel (8-15 mm) 4) Coarse sand (1-1.4 mm) 5) Broken Brick (20-40 mm) 6) Fine sand (0.5-0.8 mm) 7) Charcoal 8) Chlorination	3.0x0.7x0.5 0.5x0.7x0.5 0.5x0.7x0.5 0.6x0.7x0.5 0.4x0.7x0.5 0.35x0.7x0.5 0.35x0.7x0.5 0.3x0.7x0.5	2.5	2000	$610

Ashram School	Greywater generation (l/d)	Treatment units	Size L x B x H (m)	Slope (%)	Collection Tank (liter)	Cost (USD)
Kakalpura (400 Students)	4500	1) Equalization 2) Gravel (15-25 mm) 3) Gravel (8-15 mm) 4) Coarse sand (1-1.4 mm) 5) Wet land 6) Charcoal (0.5-0.8 mm) 7) Chlorination	3.9x1.5x0.6 0.8x1.5x0.6 0.8x1.5x0.6 1.0x1.5x0.6 2 x 7.0x0.6 0.5x1.5x0.6 0.5x1.5x0.6	2	4500	1100
Ganganagar (235 Students)	4500	1) Equalization 2) Gravel (15-25 mm) 3) Gravel (8-15 mm) 4) Coarse sand (1-1.4 mm) 5) Wet land 6) Charcoal (0.5-0.8 mm) 7) Chlorination	3.9x1.5x0.6 0.8x1.5x0.6 0.8x1.5x0.6 1.0x1.5x0.6 2.0x7x0.6 0.5x1.5x0.6 0.5x1.5x0.6	2	4500	1200

On the basis of above case study the capital cost can be estimated and summarized in the typical unit cost as presented in Table 19.

Table 19 : Typically Levelised Cost of Greywater Reuse System

Item	Cost (USD)
Excavation	16
PCC	33
Brick Work	215
Plaster	335
GI pipes	192
P.V.C pipe	44

5.5 Cost Benefit Analysis

The Cost Benefit Analysis (CBA) considers the capital cost, maintenance and operating costs of greywater reuse systems against the savings in particularly potable water uses for such purpose. Cost savings for the Cost Benefit Analysis (CBA) were benchmarked against the calculated potable water cost savings of reusing greywater for the Ashram schools applications such as toilet flushing, garden watering and floor washing.

The case study of Ganganagar Ashram school considers cost of well water as nil because the well is in the school premise. However, cost of tankered water is considered during water scarcity because water is to be bought from local entrepreneurs. Direct and indirect costs as presented earlier were considered in CBA, whereas maintenance cost is equivalent of 10% of greywater treatment system.

Findings of cost benefit analysis are presented in Table 20.

The following input parameters were considered while undertaking CBA for greywater reuse system in Ganganagar Ashram School:

- 250 girls in the Ashram school
- School period July 1st to April 30th
- Daily water requirement of 10,000 l

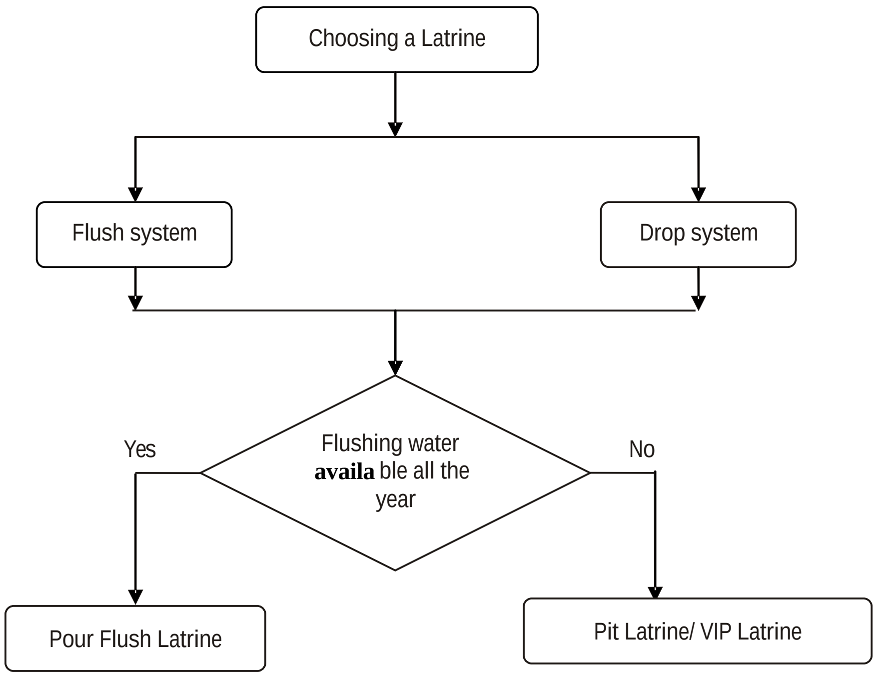
Table 20 : Cost Benefit Analysis of Ganganagar Ashram School

Parameter	Before Construction of greywater reuse system	After construction of greywater reuse system
Water source between July and December	Dug well (10000 l)	Dug well (5000 l) and greywater reuse (5000 1)
Water source between . January and April	Dug well (5000 l) and tanker water (5000 l)	Dug well (5000 l) and greywater reuse (5000 l)
Annual cost of water	• Monthly expenditure on purchase of water is IR 9000 (USD 225) since January • Annual expenditure of IR 36,000/- (USD 900)	• Interest on capital expenditure IR 4,000 (USD 100) • O & M cost of system is IR 5,000 (USD 125)
Annual cost saving	-	INR 27,000
Payback period of greywater reuse system	-	~ 2 years

5.6 Conclusion

The study concluded that the cost of the system may be recovered in two years furthermore; Studies by Godfrey *et al* (2007) indicate a reduction of the number of disability adjusted life years (DALYs) of 10^{-6} to 10^{-3} based an improved availability of greywater at school. This translate to 56 as average life expectancy in MP compared to 80 used global (difference of 24) years. Therefore the system results in10^{-6} to 10^{-3} (24-12) =12 years of improved a life years. Additionally, the system provides secondary benefit such as improved education, clean environment and time available for other activities. Indirect economical benefits therefore include more assistance children in day to day activity.

Latrine selection



LATRINE COMPARISONS								
LATRINE	Rural applic -ation	Urban applic -ation	Cost to build	Ease of construction	Water require - ment	Best cleaning material	Hygiene	Fertilizer produ ction
Pit Latrine	Suitable in all areas	not in high density suburbs	Low	Simple-except in wet and rocky ground	None	Any	Moderate	Can do
VIP Latrine	Suitable in all areas	not in high density suburbs	Low	Simple-except in wet and rocky ground	None	Any	Good	Not easily
Pour flush latrine	Suitable	Not suitable	High	Requires skilled builder	Water source near privy	Water	Good	No

According to need of the area and to reduce water requirement following types of sanitary pans are recommended to be used in the low cost toilet construction.

- Ceramic pan
- Mosaic pan
- Fiber or plastic pan

Except the ceramic pan, all other type of the pan can be produced locally.

Design parameters are mainly focused on deeper slope to minimize the use of water and optimum size of leach pit and its duration to clean.

Flushing

If water is used for flushing and anal ablution, then two water inlet are required in the toilet. One intel is required for greywater which cane be used for flushing and the other one for freshwater which can be used for anal ablution.

Pumps for Wise Water Management

The pumping requirement for greywater reuse system is to lift the water from the storage tank to the overhead tank.

The pumps for greywater reuse system are (1) manually operated pumps (2) conventional power operated electric motors (3) solar operated pumps. These pumps are popular because they are relatively easy to operate, require low maintenance cost and available in the local market.

1. Manually operated pumps

(a) Hand pump with force lift attachment

Hand pumps used in India to lift water in schools are popularly known as India Mark III (IM3). The pumps are operated by the up and down movement of the handle.

These pumps are an improved & VLOM (Village Level Operation & Maintenance) version of the India Mark II. India Mark III has many common components with India Mark II. With following differences:

- Riser Pipe. India Mark III uses riser pipe of 65mm Nominal Bore
- Cylinder Assembly. This assembly is an area for cylinder facilitates the removal of the foot valve
- Bottom cap is to suit the check valve and top cap is to facilitate extraction of the plunger and check valve assemblies for repairs without lifting the riser main.

(b) Force lift Hand Pump

To get the delivery head through the hand pump, an extra one-way valve operating accessory is fixed on the top this is called a modified third plat. This provides the head of 3-4 meter without any extra level of fatigue and with same pump efficiency. The additional attachment can be fabricated in the workshop as the design is made simple, while the standard parts like bearings, bolts and nuts, etc., are readily available locally.

The discharge rate of any pump with force lift arrangement is proportionate with function of piston diameter, stroke, number of strokes per minute (or revolutions per minute) and the volumetric efficiency, which is the percentage of swept volume that is actually pumped per stroke. It is an average of 800-1000 Ql/h

The play pump is one example of new strategy to help the poor escape poverty's snares. UNICEF Bhopal has taken the initiative to support the developed a play pump making necessary changes suitable to Indian conditions.

The play pump could be the one of the best pumping devices to install in the Ashrams for lifting water for greywater reuse system.

As indicated in the picture, while children have fun spinning on the play pump, clean water is pumped from underground into a 2,500-liter tank standing seven meters above the ground.

A simple tap makes it easy for women and children to draw water. Excess water is diverted from the storage tank back down into the borehole. The water storage tank provides a rare opportunity to advertise in rural communities. All four sides of the tank are leased as billboards, with two sides for consumer advertising and the other two sides for health and educational messages. The revenue generated by this unique model pays for pump maintenance.

The play pump is capable of producing up to 1,000 liters of water per hour at a rate of 16 rotations per minute. It has a pump depth of 65 meter and a delivery head of 30 meter. It is effective up to a depth of 100 meters. The play pump's storage tank can hold 2,500 liters of water.

The play pump requires less effort than any other manually operated pump. Hand pumps are difficult for most people to operate and require great effort.

2. Conventional Power Operated Electric Motors

Efficient centrifugal pumps are ideal where water requirements are substantial and only single-phase power, and sufficient power available.

These are normally low cost balanced and with rigged construction. It has no centrifugal switch, require less operational and maintenance cost with no air lock problems.

3. Solar Pumps

The solar water pumping system is a stand-alone system operating on power generated using solar PV (photovoltaic) system. The power generated by solar cells is used for operating DC surface centrifugal mono-block pumpset for lifting water from bore/open well. The system requires a shadow-free area for installation of the Solar Panel.

Brief Details

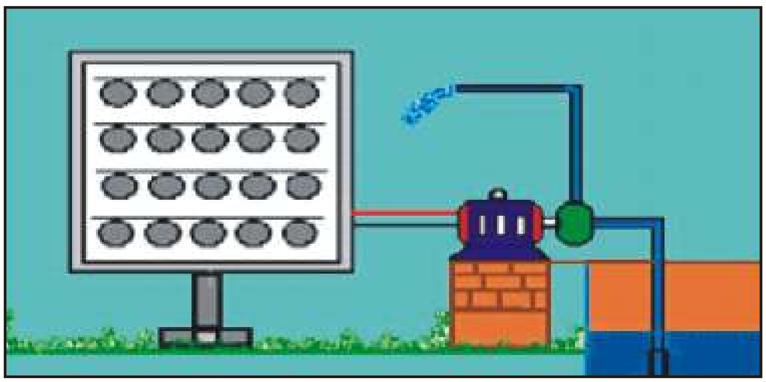
The system is provided with 1800 W solar PV panel (24 nos. X 75 Wp) and 2 HP centrifugal DC mono-block / AC submersible with inverter. The average water delivery of 2 HP solar pump will be around 6000 l/h, for a suction head of 6 metres and dynamic head of 10 metres. The size of suction & delivery lines is 2.5 inches (62.5 mm).

System Cost and Subsidy Scheme

The cost of the system depends on upon the size and BHP of the pump. The cost of solar pump is 3000 USD. Ministry of Non conventional Energy Sources, Government of India is providing the subsidy to support the initial cost.

Advantages of solar pump sets are as follows :

- No fuel cost-uses abundantly available free sun light
- No conventional grid electricity required
- Long operating life
- Highly reliable and durable - free performance
- Easy to operate and maintain



National Review Committee Members

Date : 27-28th June 2006

Venue : National Environmental Engineering Research Institute (NEERI), Nagpur

Topic : Brainstorming on Water Reuse for Schools and Households in Rural Area

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Abbreviation

IWMI	International Water Management Institute
MDG	Millennium Development Goals
CWWA	Canadian Water and Wastewater Association
SSHE	School Sanitation and Hygiene Education
TSC	Total Sanitation Campaign
DDWS	Department of Drinking Water Supply
W.C	Water closet
BOD_5	Biochemical Oxygen Demand
TKN	Total Kjeldhal Nitrogen
NTU	Nephelometric Turbidity Unit
MPN	Most Probable Number
cfu	Colony forming units/100ml
TSS	Total suspended solids
USD	US-Dollar
O & M	Operation and Maintenance
PTA	Parent Teacher Association
WHO	World Health Organisation
QMRA	Quantitative Microbial Risk Assessment
SI	Sanitary Inspection
CBA	Cost Benefit Analysis
INR	Indian Rupees
VLOM	Village Level Operation & Maintenance
H.P.	Horsepower
BHP	Brake Horsepower

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