Egyptian-German Private Sector Development Programme

GREY WATER RECYCLING & REUSE

Towards a Sustainable Unitization of Domestic Water

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Preface

The Egyptian-German Private Sector Development Programme (PSDP) was established in 2005 with a planned duration of 9 years. It is a bilateral programme financed by the German Ministry for Economic Cooperation and Development (BMZ) and implemented in cooperation with the Egyptian Ministry for Trade and Industry (MTI), with technical assistance provided by the German Technical Cooperation (GTZ). PSDP focuses on private sector enterprises as its main target group and aims at enhancing their competitiveness through innovations, which can result in new or improved products or production processes. This results, through resource efficiency - oriented BDS, in concrete improvements in the enterprises, and improved conditions within the value chain, e.g. through the upgraded status of smaller companies (formalization) or through enhanced supply chains.

Water is increasingly becoming a scarce resource. Large and small scale users need to take action to conserve it not only because it is prudent practice to do so for their own benefit, but also because it is an active demonstration of their concern about the global pollution and environmental problems.

35% reduction of water consumption in residential units can be achieved with simple technology if grey-water is recycled and reused in toilet flushing and irrigation. Also Industrial waste water treatment and reuse is a vital technology for Egypt. It saves money on all levels; water-heavy-consumption-industry can reduce its consumption by 80% through recycling processes thus save money and even make benefit after reasonable return of investment period. The government's saving through reduction in the annual subsidy is definitively higher as the water is heavily subsidized in Egypt.

Acquiring innovation capacity in developing and implementing waste water recovery technology on the residential and industrial sectors is essential to improve the competitiveness of the Egyptian industry from both supply and demand aspects.

Therefore PSDP supported the establishment of Re-Water Innovation Network that consists of various stakeholders with the aim to acquire local capacity for innovation and develop number of local technologies for waste water recovery. This book is documenting side of the research and development efforts done by the network to develop Grey-Water Recovery Unit for residential buildings. Efforts are continuing to cover industrial applications.

Foreword

Main focus of the present work is placed on describing and illustrating a wide range of grey water management and treatment options to facilitate informed decision-making when confronted with the task of developing a sanitation concept. This report is not a design manual for grey water management systems, although design principles and construction plans of treatment chains are provided whenever possible. The report mainly aims at sensitizing and encouraging national, regional and municipal water and environmental sanitation authorities and agencies to integrate grey water management into their development policies and programmers. NGOs working in the field of environmental sanitation are invited to include grey water management into their neighborhood upgrading projects. This report will hopefully support them in their efforts and provide assistance to house owners during pre-selection of grey water management schemes adapted to their specific requirements and prior to soliciting expert advice. This report prepared as an activity of a project conducted at the Projects Developments and Scientific Research Technology Center (**R&D TECH**) a privet research center located in Upper Egypt and funded by the GIZ.

The report consists of four chapters. Chapter one includes general introduction about grey water definition, uses, recycling health concerns, volumes, resources, and characteristics. Chapter two summarizes the different grey water treatment methodologies based on literature review. Chapter three represents case study for the application of grey water treatment systems in some developing countries. Chapter four, deals with the evaluation of different grey water treatment systems produced commercially worldwide. In addition, based on the obtained data, R&D TECH team developed an evaluation strategy for these systems based on specific grading ranking system and finally. As an outcome form the project, R&D TECH designed a software to be used for cost analysis gray water treatment systems.

Chapter one:

Introduction & Background

1. Introduction

As pressures on freshwater resources grow around the world and as new sources of supply become increasingly scarce, expensive, or politically controversial, efforts are underway to identify new ways for meeting water needs by increasing the efficiency of water use and to expand the usefulness of alternative sources of water previously considered unusable, among these potential new sources of supply is ***"grey water".*** [1]

Figure 1 shows a typical application of grey water recycling from several households.[2]

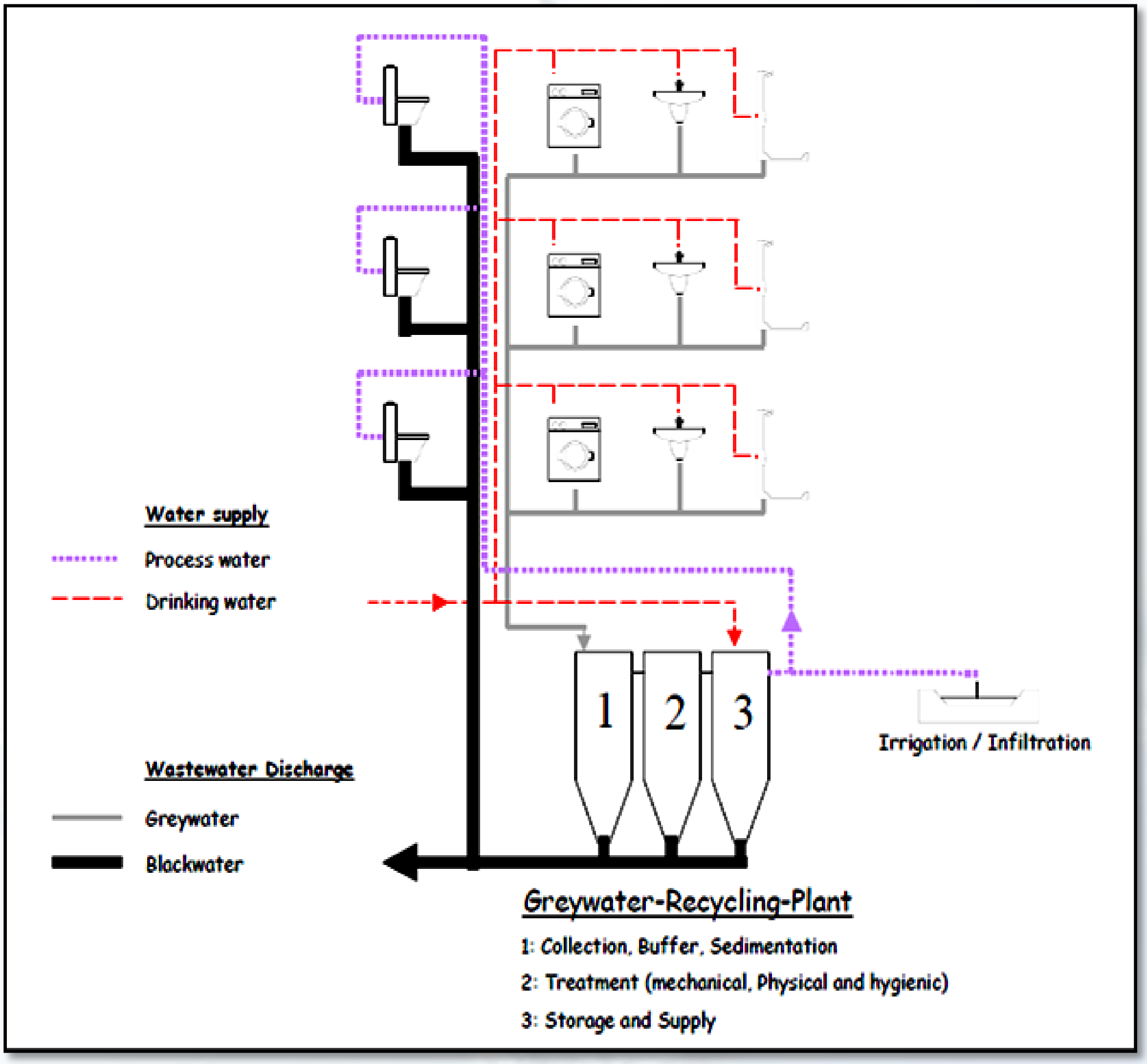


Figure 1: Typical application of grey water recycling from several households

1.1 Grey Water Definition

Grey water gets its name from its cloudy appearance and from its status as being between fresh, potable water (known as "white water") and sewage water ("black water"). Grey water is wastewater from showers, baths, washbasins, washing machines and kitchen sinks. [3]

While kitchen wastewater is not recommended for use as grey water if untreated. Grey water does not include wastewater from toilets, urinals, or bidets. This is referred to as black water (water containing human excrement). Grey water can be collected from some or all of these sources and, after treatment, used for purposes around the home such as toilet flushing or garden watering that do not require drinking water quality.[4]

1.2 Benefits of Grey Water Treatment

Recycling grey water not only reduces the consumption of water, it also reduces the volume of water discharged into the sewerage system. Consumers with water meters could therefore save money on both their water supply and wastewater bills.

There are many ecological benefits of grey water recycling could be sumerized as follows:

- **Lowering the fresh water use**

Grey water can replace fresh water in many instances, saving money and increasing the effective water supply in regions where irrigation is needed. Residential water use is almost evenly split between indoor and outdoor. All except toilet water could be recycled outdoors, achieving the same result with significantly less water diverted from nature.

- **Less strain on septic tank or treatment plant**

Grey water use greatly extends the useful life and capacity of septic systems. For municipal treatment system by decreasing the wastewater flow which in turn means higher treatment effectiveness and lower treatment costs.

- **Less energy and chemical use**

Less energy and chemicals are used due to the reduced amount of both freshwater and wastewater that needs pumping and treatment. For those providing their own water or electricity, the advantage of a reduced burden on the infrastructure is felt directly. Also, treating your wastewater in the soil under your own fruit trees definitely encourages you to dump fewer toxic chemicals down the drain.

- **Highly effective purification**

Grey water is purified to a spectacularly high degree in the upper, most biologically active region of the soil. This protects the quality of natural surface and ground waters.

- **Groundwater recharge**

Grey water application in excess of plant needs recharges groundwater.

- **Plant growth**

Grey water enables a landscape to flourish where water may not otherwise be available to support much plant growth.

- **Reclamation of otherwise wasted nutrients**

Loss of nutrients through wastewater disposal in rivers or oceans is a subtle, but highly significant form of erosion. Reclaiming nutrients in grey water helps to maintain the fertility of the land. [5]

1.3 Uses of Recycled Grey Water

Grey water can be used untreated, or it can be treated to varying degrees to reduce nutrients and disease-causing microorganisms. The appropriate uses of grey water depend on both the source of grey water and the level of treatment.[6]

Recycled water is most commonly used for non potable (not for drinking) purposes, such as agriculture, landscape, public parks, and golf course irrigation. Other non potable applications include cooling water for power plants and oil refineries, industrial process water for such facilities as paper mills and carpet dyers, toilet flushing, dust control, construction activities, concrete mixing, and artificial lakes.

Although most water recycling projects have been developed to meet non potable water demands, a number of projects use recycled water indirectly for potable purposes. These projects include recharging ground water aquifers and augmenting surface water reservoirs with recycled water. In ground water recharge projects, recycled water can be spread or injected into ground water aquifers to augment ground water supplies, and to prevent salt water intrusion in coastal areas. [7]

The use of gray water at decentralized sites for landscape irrigation and toilet flushing reduces the amount of potable water distributed to these sites, the amount of fertilizer needed, and the amount of wastewater generated, transported, and treated at wastewater treatment facilities. In other words, water reuse saves water, energy, and money. [8]

1.4 Grey Water Recycling Health Concerns

Health risks are often cited by regulators as reasons for requiring high-tech expensive systems although there are no recorded instances of grey water transmitted illness in the US. However, grey water may contain infectious organisms. Bear this in mind when designing and using a system. A poorly designed system could become a pathway for infecting people. There are two main principles for safety are considered as follows:

1. Grey water must pass slowly through healthy topsoil for natural purification to occur.
2. Design your grey water system so no grey water-to-human contact occurs before purification (i.e. passing through the soil or mulch basin).

- **Precautions:**

1. Prevent contact or consumption by using gloves when cleaning grey water filters, and washing your hands after contact with grey water.
2. Avoid accidental connections between freshwater and grey water by labeling grey water plumbing, including garden hoses.

3. Don't apply untreated grey water onto lawns, or fruits and vegetables that are eaten raw (i.e. strawberries, lettuce, carrots).
4. Use only grey water that is fairly clean to start with – Grey water containing water used to launder diapers or generated by anyone with an infectious disease should be diverted to a sewer or septic system.
5. Don't store grey water, use it within 24 hours before bacteria multiply. After 24 hours it goes its way to become black water.
6. Don't overload your system. If you're having company and your system is designed for 2 people, divert the grey water to the sewer.
7. Divert grey water containing harmful chemicals to the sewer or septic system
8. Prevent contamination of surface water. Discharge grey water underground or into a mulch filled basin.
9. Don't apply grey water to saturated soils.

1.5 Grey water Volumes and Sources

The percentage of household water that is grey water varies regionally and between households, depending on the primary uses of water in a home and how efficiently water is used, but is generally between 50% and 80% of the total water used.[9]

Figure 2 shows a typical water use in a new home.[10]

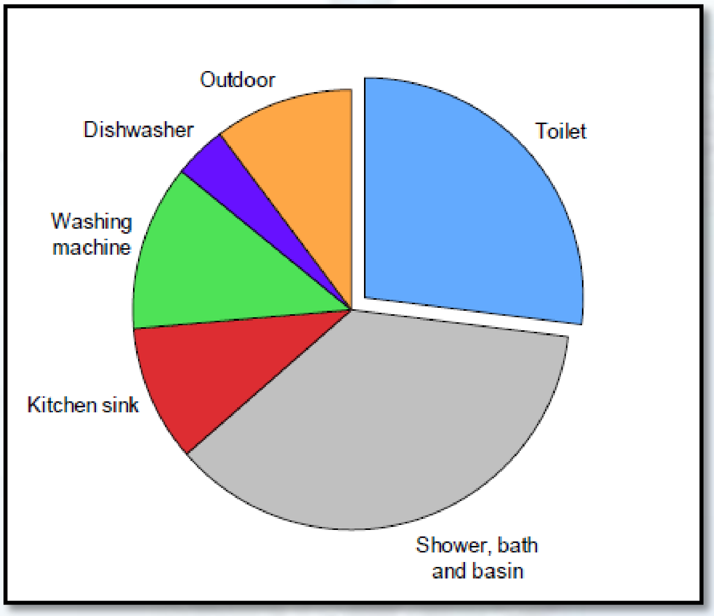


Figure 2: Typical water use in a new home

On average the volume of water use in the house per day is 135 L/person/day. Approximately 84% (113 L/person/day) of this water can be captured and recycled from the grey water. In the follwing, the different sources of grey water are classified and explaned.

Bathroom grey water (bath, basin and shower) contributes approximately 50% of the total grey water volume. Bathroom grey water can be contaminated with hair, soaps, shampoos, hair dyes, toothpaste, lint, nutrients, body fats, oils and cleaning products.

Laundry grey water contributes approximately 30% of total grey water volume. Wastewater from the laundry varies in quality from wash water to rinse water to second rinse water. Laundry grey water can be contaminated with lint, oils, grease, laundry detergents, chemicals, soaps, nutrients and other compounds.

Kitchen wastewater is sometimes considered as a grey water source. If a suitable treatment is not available, kitchen wastewater should not be used due to the amount of contaminants (food particles, oil, grease, etc.) it contains. Fortunately kitchen grey water contributes a relatively small portion of the total available grey water (15%).[11]

1.6 Typical Composition of Grey Water Compared With Raw Sewage

Grey water composition is varied according to the source of the grey water. Table 1 shows the contaminants of grey water from different sources.

Table 1: Water-quality characteristics of selected domestic grey water [12]

Water Source	Characteristics
Automatic Clothes Washer	Bleach, Foam, High pH, Hot water, Nitrate, Oil and Grease, Oxygen demand, Phosphate, Salinity, Soaps, Sodium, Suspended solids, and Turbidity
Automatic Dish Washer	Bacteria, Foam, Food particles, High pH, Hot water, Odor, Oil and grease, Organic matter, Oxygen demand, Salinity, Soaps, Suspended solids, and Turbidity
Bath tub and shower	Bacteria, Hair, Hot water, Odor, Oil and grease, Oxygen demand, Soaps, Suspended solids, and Turbidity
Sinks, including kitchen	Bacteria, Food particles, Hot water, Odor, Oil and grease, Organic matter, Oxygen demand, Soaps, Suspended solids, and Turbidity

As could be seen in Table 1, grey water contains oils, fats, detergents, soaps, nutrients, salts and particles of hair, food and lint, which can impact on operational performance and life of a grey water irrigation system. If these contaminants aren't managed correctly they can degrade soil structure, clog groundwater flow paths or even cause non wetting characteristics in garden soils. In addtion, grey water can contain pathogenic microorganisms including bacteria, protozoa, viruses and parasites in concentrations high enough to present a health risk. Therefore, a level of caution must be exercised with grey water reuse. This can be achieved by not allowing *unnecessary human contact with grey water*, or by treating the grey water to remove or destroy the microorganisms.

The chemical and physical quality of grey water compared with raw sewage is shown in Table 2.[13]

Table 2: chemical and physical quality of grey water compared with raw sewage

Parameter	Unit	Grey water		Raw sewage
		Range	Mean	
Suspended Solids	mg/l	45 - 330	115	100 – 500
Turbidity	NTU	22 - > 200	100	NA
BOD_5	mg/l	90 - 290	160	100 – 500
Nitrite	mg/l	<0.1 – 0.8	0.3	1 - 10
Ammonia	mg/l	<1.0 – 25.4	5.3	10 – 30
Total phosphorous	mg/l	0.6 – 27.3	8	5 – 30
Sulphate	mg/l	7.9 - 110	35	25 - 100
pH		6.6 – 8.7	7.5	6.5 – 8.5
Conductivity	mS/cm	325 - 1140	600	300 – 800
Hardness (Ca & Mg)	mg/l	15 - 55	45	200 - 700
Sodium	mg/l	29 – 230	70	70 - 300

NA: Not Applicable.

Chapter TWO:

Grey Water Treatment Methodologies

2. Grey Water Treatment Methodologies

2.1 Introduction

Grey water treatment methodologies range from simple low-cost devices that divert grey water to direct reuse, such as in toilets or outdoor landscaping, to complex treatment processes incorporating sedimentation tanks, bioreactors, filters, pumps, and disinfection. Some grey water plants are home-built, do-it-yourself style through piping and storage systems. On the other hand, there are also a variety of commercial grey water systems available that filter water to remove hair, lint, and debris, and remove pollutants, bacteria, salts, pharmaceuticals, and even viruses from grey water. In short, the avilable treatment technologies in both scientific literatures and market could are shown in Table 3 according to the treatment level.

Table 3: Grey water treatment technologies

systems	Level of treatment	Application
Direct reuse	No treatment	Garden irrigation
Short retention	Very basic treatment technique such as skimming debris off the surface and allowing particles to settle to the bottom of the tank.	Garden irrigation
Basic physical, chemical and biological	Filter, chemical disinfectants, and aeration process are used in such systems	Garden irrigation, Toilet flushing

2.2 Grey water Treatment methods

The different studies carried out concerning the grey water showed that all types of grey water have good biodegradability. Therefore, the treatment methods applied for grey water reuse included physical, chemical, and biological systems. Most of these methods are preceded by a solid-liquid separation step as pre-treatment and followed by a disinfection step as post treatment. To avoid the clogging of the subsequent treatment, the pre-treatments such as septic tank, filter bags, screen and filters are applied to reduce the amount of particles and oil & grease. The disinfection step is used to meet the microbiological requirements. In the following based on scientific research, we are going to give a brief description for the three different treatment routes.

- **Physical treatment**

The physical treatments include coarse sand, soil, and membrane filtration followed mostly by a disinfection step. The coarse filter alone has limited effect on the removal of the pollutants present in the grey water.

Chiemchaisri et al. (1992) used membrane filtration for grey water treatment. Membrane Bio-Reactor (MBR) installed with two types of membranes (pore size 0.1 and 0.03 μm) was able to achieve the same as biological treatment although the membrane pore sizes are larger than the size of viruses (25 nm), revealing effective removal of mico-organisms by membranes. Nevertheless, the relative higher residual organic substances in the treated grey water by membrane filtration often promote the re-growth of the micro-organisms in the storage and transportation system. Furthermore, the membrane fouling and its consequences in term of operating and maintenance costs can restrict the widespread application of membrane technologies for grey water treatment. Data on the removal of detergents by physical grey water treatment processes were not available.

Birks (1998) reported a medium strength UF membrane grey water treatment system, in which the COD and the BOD were reduced from 451 mg/l and 274 mg/l in the influent to 117 mg/l and 53 mg/l respectively in the effluent

March et al. (2004) reported a low strength bath grey water treatment system, which used a nylon sock type filter, followed by a sedimentation step and a disinfection step. The COD, the turbidity, the SS and TN were reduced from 171 mg/l, 20 NTU, 44 mg/l and 11.4 mg/l in the influent to 78 mg/l, 16.5 NTU, 18.6 mg/l and 7.1 mg/l respectively in the effluent. He claimed that the reclaimed grey water can be used for toilet flushing under controlled working conditions (storage time be 48 h and the residual chlorine concentration N1 mg/l in the toilet tank).

Itayama et al. (2004), used a slanted soil filter (The main components of the soil are alumina and hydrated silica) to remove organic pollutants and total phosphors partially from kitchen sink grey water. The COD, the BOD, the SS, the TN and the TP were reduced from 271 mg/l, 477 mg/l, 105 mg/l, 20.7 mg/l and 3.8 mg/l in the influent to 40.6 mg/l, 81 mg/l, 23 mg/l, 4.4 mg/l and 0.6 mg/l, respectively, in the effluent. Due to the nitrification and de-nitrification reactions in the soil treatment system, nitrogen was eliminated effectively. Obviously, the soil filter applied in this study cannot be regarded as a single filtration but a combination of filtration and biodegradation.

Ramon et al. (2004) reported a low strength grey water treatment system with direct nano-filtration membrane, which was able to achieve an organic removal rate of 93%.

Turk et al. (2005) investigated the use of a UF membrane (0.05 μm pore size) for the treatment of laundry grey water.

Sostar-Turk et al. (2005) reported that the membrane after the UF membrane was able to reduce the BOD from 86 to 2 mg/l corresponding to a removal rate of 98% However, one shall keep in mind that the higher energy consumption and the membrane fouling are often the key factors limiting the economic viability of membrane systems.

Funamizu and Kikyo (2007) reported a high strength grey water treatment system by different nano-filtration membranes. 92–98% anionic surfactant (LAS) and 88–92% of nonionic surfactant were rejected by the nano-filtration membranes. The LAS concentrations in the permeate were still higher than the predicted no-effect concentration and further treatments are required. There were few data available on the removal of micro-organisms by membranes.

Li et al. (2008) evaluated the performance and suitability of a resource and nutrient oriented decentralized grey water treatment system which uses a submerged spiral wound module. The study revealed that the direct UF membrane filtration system was able to reduce TOC from the influent value of 161 mg/l to 28.6 mg/l in the permeate, corresponding an average elimination rate of 83.4%. In addition, soluble nutrients like ammonia and phosphors can pass through the UF membrane and remain in the permeate. The total nitrogen and total phosphors in the permeate were 16.7 mg/l and 6.7 mg/l respectively. The permeate was low in turbidity (below 1 NTU) and free of suspended solids and E. coli and had an excellent physical appearance. The rejects generated in this system can be treated with black water and kitchen waste in an anaerobic digester at a later stage for producing biogas or compost.

***Based on the above review it could be concluded that physical processes alone are not sufficient for grey water treatments and reuses*.**

Table 4: The standards for non-potable grey water reuses and applications

Categories		Treatments goals	Applications
Recreational impoundments, lakes	Unrestricted reuses	BOD_5: ≤10 mg/l TN: ≤1.0 mg/l TP: ≤0.05 mg/l Turbidity: ≤2 NTU pH: 6–9 Faecal coliform: ≤10/ml Total coliforms ≤100/ml	Ornamental fountains; recreational impoundments, lakes and ponds for swimming
	Restricted reuses	BOD_5: ≤30 mg/l TN: ≤1.0 mg/l TP: ≤0.05 mg/l TSS: ≤30 mg/l pH: 6–9 Faecal coliforms ≤10/ml Total coliforms ≤100/ ml	Lakes and ponds for recreational without body contact
Urban reuses and agricultural irrigation	Unrestricted reuses	BOD_5: ≤10 mg/l Turbidity: ≤2 NTU pH: 6–9 Faecal coliform: ≤10 / ml Total coliforms ≤100/ ml Residual chlorine: ≤1 mg/l	Toilet flushing; laundry; air conditioning, process water; landscape irrigation; fire protection; construction; surface irrigation of food crops and vegetables (consumed uncooked) and street washing
	Restricted reuses	BOD_5: ≤30 mg/l Deterge t (anionic): ≤1 mg/l TSS: ≤30 mg/l pH: 6–9 Faecal coliforms ≤10/ml Total coliforms ≤100/ml Residual chlorine: ≤1 mg/l	Landscape irrigation, where public access is infrequent and controlled; subsurface irrigation of non-food crops and food crops and vegetables (consumed after processing)

- **Chemical treatments**

Very few chemical processes were reported for grey water treatments and reuses. The chemical processes applied for grey water treatments include coagulation, photo-catalytic oxidation, ion exchange and granular activated carbon.

(Parsons et al., 2000). reported that an advanced oxidation process based on photo-catalytic oxidation with titanium dioxide and UV was applied for grey water treatment and a 90% removal of the organics.

Lin et al. (2005) reported a combined chemical grey water treatment system, in which electrocoagulation was followed by a disinfection step. The COD, the BOD, the turbidity and the SS in the lows strength grey water were reduced from 55 mg/l, 23 mg/l, 43 NTU and 29 mg/l in the influent to 22 mg/l, 9 mg/l, 4 NTU and 9 mg/l respectively in the effluent. The total coli forms were not detected in the reclaimed grey water. The effluent water quality meets the restricted grey water reuse standards proposed in this study. But the raw grey water fed into the treatment plant was low in organic strength.

Sostar-Turk et al. (2005) reported the treatment of low strength laundry grey water treatment process using a combination of coagulation, sand filter and granular activated carbon (GAC). This grey water treatment process reduced the COD, the BOD and the suspended solids from 280 mg/l, 195 mg/l and 35 mg/l in the influent to 20 mg/l, 10 mg/l and less than 5 mg/l respectively in the effluent and achieved a good treatment performance with the coagulation stage itself achieving 51% of the BOD removal and 100% of the suspended solids removal.

Chang et al. (2007) investigated the flocculation process for grey water treatment (coagulation with aluminum salt). The COD and the anionic surfactant concentration were reduced by 70% and 90% respectively. The study showed that the flocculation process alone is not able to reduce the organic substances to the required reuse standard, thus necessitating the application of biological processes. In a study lead by **Pidou et al. (2008)**, the coagulation processes and the magnetic ion exchange resin process were applied for shower grey water treatment. At optimal conditions, coagulation with aluminum salt reduced the COD, the BOD, the turbidity, TN and PO_4^{3-} in from 791 mg/l, 205 mg/l, 46.6 NTU, 18 mg/l and 1.66 mg/l in the influent to 287 mg/l, 23 mg/l, 4.28 NTU, 15.7 mg/l and 0.09 mg/l respectively. The total coli forms, the E. coli and the faucal enterococci in the reclaimed grey water are all less than 1/100 ml. Coagulation with ferric salt achieved similar treatment efficiencies as that obtained with aluminum salt. The coagulation processes. In another study by the same research group, (**Pidou et al ,2008)** they were able to reduce the BOD concentration to less than 30 mg/l but fail to decrease the turbidity to less than 5 NTU. The COD, BOD, turbidity, TN and PO_4^{3-} were decreased by the magnetic ion exchange resin to 272 mg/l, 33 mg/l, 8.14 NTU, 15.3 mg/l and 0.91 mg/l respectively. The total coliforms, the E. coli and the faecal enterococci in the reclaimed grey water are 59/100 ml, 8/100 ml and less than 1/ 100 ml. The magnetic ion exchange resin process failed to reduce the turbidity and the BOD to the levels required for both unrestricted and restricted reuses. The coagulation process and the magnetic ion exchange resin process have minor effects on the removals of both TN and PO_4^{3-}.

- **Biological treatments**

Several biological processes, including rotating biological contactor (RBC) (**Nolde, 1999; Friedler et al., 2005; Eriksson et al., 2007**), sequencing batch reactor (SBR) (**Shin et al., 1998; Hernandez et al., 2008**), anaerobic sludge blanket (UASB) (**Elmitwalli and Otterpohl, 2007; Hernandez et al., 2008**), constructed wetland (CW) (**Li et al., 2003; Gross et al., 2007**) and membrane bioreactors (MBR) (**Lesjean and Gnirss, 2006; Liu et al., 2005; Merz et al., 2007**), have been applied for grey water treatment. The biological processes were often preceded by a physical pre-treatment step such as sedimentation, usage of septic tanks (**Nolde, 1999; Li et al., 2003**) or screening.

Nolde (1999) studied a RBC grey water treatment system. The process comprises a sedimentation tank followed by a four-stage RBC and a final UV disinfection stage. The BOD7 was reduced from the inffluent value of 50–250 mg/l to below 5 mg/l by the biological step. After the UV disinfection step, bacteriological effluent quality mostly meets water reuse standards. Similarly, **Eriksson et al. (2007)** reported a pilot RBC low strength pilot grey water treatment plant. The grey water plant treats effluents from showers and hand basins from bathrooms in 84 apartments and the treated water is utilized for toilet flushing. The plant consists of a primary settling tank which is also used for equalising the flow, biological treatment with 3 rotating biological contactors (RBC) in series, followed by secondary settling, a sand filter and UV treatment. The treated water is kept in two storage tanks. The pilot grey water treatment plant was able to reduced the COD, the BOD, the TOC, the NH4–N and the ortho-phosphate from 142 mg/l, 93 mg/l, 72 mg/l 5.2 mg/l and 0.66 mg/l in the influent to 25 mg/l, 6 mg/l, 13 mg/l, 0.031

mg/l and 0.26 mg/l in the final effluent respectively. Surprisingly the COD, the BOD and the TOC were increased from 20 mg/l, 1.6 mg/l and 0.5 mg/l in the effluent of the sand filter to 25 mg/l, 6 mg/l and 13 mg/l in the final effluent respectively. However, the study from **Eriksson et al. (2007)** also showed that the BOD can be reduced by the RBC step to below 5 mg/l. He also examined the removal efficiencies of 5 selected trace organic substances by the pilot grey water treatment plant. Their study showed that the five selected paraben biocides (methyl-, ethyl-, propyl-, butyl-, and iso-butyl-esters of parahydroxy benzoic acid) can be removed effectively by the treatment plant showing that the micro-organisms has adapted to the parabens as a carbon source for their growth.

Friedler et al. (2005) studied a low strength grey water treatment system, which combined Rotating Biological Contactors (RBC), sand filtration and chlorination. The RBC step was preceded by a fine screen for the removal of gross solids and hairs larger than 1 mm and followed by a sedimentation step in a sedimentation basin to separate sludge from the effluents. The TSS, Turbidity, COD, BOD and faecal coliform were reduced from 43 mg/l, 33 NTU, 158 mg/l, 59 mg/l and 5.6×105 /100 ml in the influent to 16 mg/l, 1.9 NTU, 46 mg/l, 6.6 mg/l and 9.7×103 /100 ml respectively in the effluent of the sedimentation basin. The sand filtration step, acting as a polishing stage, further reduced the TSS, turbidity, COD and BOD to 7.9 mg/l, 0.61 NTU, 40 mg/l and 2.3 mg/l respectively. Astonishingly, the faecal coliform level increased from 9.7×103 / 100 ml to 5.2×104\ /100 ml after the sand filtration, demanding a disinfection step thereafter. The faecal coliform level was reduced to 0.1/100ml by the disinfection step in the final effluent. The pilot plant successfully reduced the TP, TKN, ammonia and organic nitrogen from 4.8 mg/l, 8.1 mg/l, 4.9 mg/l and 3.2 mg/l in the inffluent to 2 mg/l, 1 mg/l, 0.16 mg/l and 0.97 mg/l respectively in the final effluent.

Liu et al. (2005) reported a submerged MBR from Mitsubishi Rayon (poly- ethylene, pore size 0.4 µm) for low strength bath grey water treatment. This study revealed that the COD was reduced from the influent value of 130–322 to 18 mg/l on average in permeate. NH4–N concentration was reported to have decreased from 0.6–1.0 mg/l in influent to less than 0.5 mg/l in the effluent. BOD5 was reduced from the influent value of 99–221 mg/l to less than 5 mg/l in the permeate. Anionic surfactants (AS) were reduced from 3.5–8.9 mg/l in the influent to less than 0.5mg/l in the effluent. The effluent was colorless and odorless and free of SS and faecal coliform concentrations were below the determination threshold. This study demonstrated that biological degradation removed most of the pollutants and membrane separation further eliminated the rest of the pollutants, thus ensuring a stable and excellent effluent water quality.

Lesjean and Gnirss (2006), studied a submerged plate and frame MBR grey water (including kitchen grey water) treatment unit was operated under low SRT (down to 4 d) and low HRT (set as 2 h) condition. The COD was reduced from the influent value of 493 mg/l to 24 mg/l in permeate and the elimination rate was greater than 85%. Nitrogen was decreased from 21 mg/l to 10 mg/l, but its elimination rate was not consistent (ranging from 20 to 80%). Phosphors was reduced by around 50%, decreasing fromthe influent value of 7.4 mg/l to 3.5mg/l in effluent. SS in permeate was reported to be less than 1 mg/l during the whole observation period. The stable permeate flux achieved in this study was 7 l/m^2.h.

Merz et al. (2007) studied a submerged MBR from Zeno (membrane pore size, 01 µm) for low strength grey water from a sports and leisure club. The turbidity, COD, BOD5, TKN, ammonia, TP, LAS and faecal coliforms were reduced from 29 NTU, 109 mg/l, 59 mg/l, 15.2 mg/l, 11.8 mg/l, 1.6 mg/l, 299 µg/l and 1.4×105/100 ml in the influent to 0.5mg/l, 15 mg/l, 5 mg/l, 5.7 mg/l, 3.3 mg/l, 1.3 mg/l, 10 µg/l and 68 /100 ml respectively in the effluent. The effluent was free of colour and odourless. The detection of the faecal coliforms in the permeate was probably caused by the accidental contamination in the distribution system. The sTablepermeate flux obtained in this study ranged from 8 to 10 l/m^{2}h

Gross et al. (2007), studied a recycled vertical flow constructed wetland was applied for a high strength mixed grey water treatment. The TSS, BOD5, COD, TN, TP, anionic surfactants, boron and faecal coliform were reduced from 158 mg/l, 466 mg/l, 839 mg/l, 34.3 mg/l, 22.8 mg/l, 7.9 mg/l, 1.6 mg/l and 5×107 /100ml in the influent to 3mg/l, 0.7mg/l, 157mg/l, 10.8mg/l, 6.6 mg/l, 0.6 mg/l, 0.6 mg/l and 2×105 /100 ml respectively in the effluent. The constructed wetland reported in the literature showed good treatment performance to treat grey water.

Hernandez et al., (2008) used a sequencing batch reactor (SBR) for a high strength grey water treatment. The sludge retention time and hydraulic retention time were set as 15 days and 11.7 h respectively. The COD, TP, TN and ammonia was reduced from

830 mg/l, 7.7 mg/l, 53.6 mg/l and 1.2 mg/l in the inffluent tom91 mg/l, 6.5 mg/l, 34.4 mg/l and 0.41 mg/l respectively in the effluent. Another sequencing batch reactor (SBR) was operated for a high strength grey water treatment. During this period, the sludge retention time was increased to 378 days and the hydraulic retention time was reduced to 5.9 hours. The COD, TP, TN and ammonia was reduced from 827 mg/l, 8.5 mg/l, 29.9 mg/l and 0.8mg/l in the influent to 100mg/l, 5.8mg/l, 26.5mg/l and 0.44mg/l respectively in the effluent. The organic nitrogen in the effluents accounts for 90% and 74% of the TN, indicating that the transformation of particulate organic nitrogen to ammonia during the aerobic treatment was very limited. This study also revealed that 97% of anionic surfactants were eliminated by the aerobic degradation.

To get a clear and quick review for the different treatment methodologies, the following Table provides a summary for the different grey water treatment methodologies and some of their respective advantages and disadvantages.

Table 5: common grey water treatment methodologies

Treatment Technique	Description	Advantages	Disadvantages
Sand filter	Beds of sand or in some cases coarse bark or mulch which trap and adsorb contaminants as grey water flows through.	Simple operation, low maintenance, low operation costs.	High capital cost, reduces pathogens but does not eliminate them, subject to clogging and flooding if overloaded.
Membrane bioreactor	Uses aerobic biological treatment and filtration together to encourage consumption of organic contaminants and filtration of all pathogens.	Highly effective if designed and operated properly, high degree of operations flexibility to accommodate grey water of varying qualities and quantities, allows treated water to be stored indefinitely.	High capital cost, high operating cost, complex operational requirements.

Activated carbon filter	Activated carbon has been treated with oxygen to open up millions of tiny pores between the carbon atoms. These filters thus are widely used to adsorb odorous or colored substances from gases or liquids.	Simple operation, activated carbon is particularly good at trapping organic chemicals, as well as inorganic compounds like chlorine.	High capital cost, many other chemicals are not attracted to carbon at all -- sodium, nitrates, etc. This means that an activated carbon filter will only remove certain impurities. It also means that, once all of the bonding sites are filled, an activated carbon filter stops working.
Disinfection	Chlorine, ozone, or Ultraviolet light can all be used to disinfect grey water.	Highly effective in killing bacteria if properly designed and operated, low operator skill requirement.	Chlorine and ozone can create toxic byproducts, ozone and ultraviolet can be adversely affected by variations in organic content of grey water.
Aerobic biological treatment	Air is bubbled to transfer oxygen from the air into the grey water. Bacteria present consume the dissolved oxygen and digest the organic contaminants, reducing the concentration of contaminants.	High degree of operations flexibility to accommodate grey water of varying qualities and quantities, allows treated water to be stored indefinitely.	High capital cost, high operating cost, complex operational requirements, does not remove all pathogens.

Chapter Three:

Previous Case Studies

. Previous Case Studies[14]

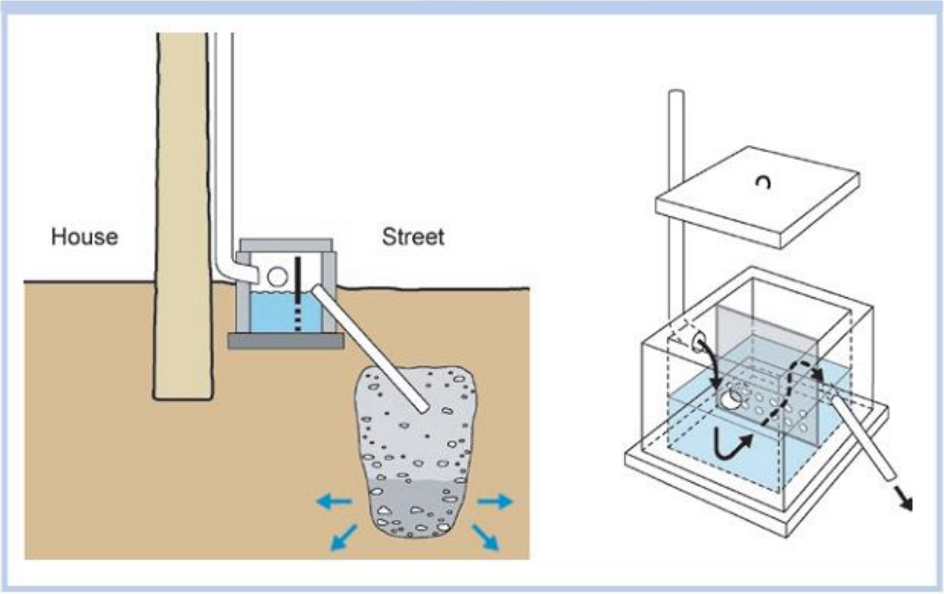
3.1 Djenne, Mali, (Local infiltration of domestic grey water)

3.1.1 Project background and rationale

The city of Djenné with its approx. 20,000 inhabitants is situated in the inner delta of the Niger River. In 2000, a study was conducted to evaluate possible options to mitigate the grey water problem. Local grey water infiltration was piloted in 2002. Within the project framework, one hundred infiltration systems were built throughout the city using local material and labor. By 2004, already 600 households were connected to a grey water infiltration system.

3.1.2 Grey water management system

Grey water from kitchen, bath and laundry flows through a PVC pipe, covered with local pottery so as to blend in with the adobe buildings, into a grease and grit trap (Figure 3-1). The trap, located at the bottom of the outer wall of the house, is easily accessible for maintenance. The pretreated grey water leaves the grease and grit trap through a small bore pipe entering the infiltration trench.



3-1 Grease and grit trap and infiltration trench, Djenné, Mali

3.1.3 Performance

One year after completion of the pilot project, the streets with adjacent infiltration systems were dry and clean (see Figures 3-2a, 3-2b). Transport costs of goods decreased significantly due to improved road conditions. Water samples taken from 10 wells did not reveal any groundwater contamination caused by the grey water disposal system.

3-2a, 3-2b Street in Djenné before and after implementation

3.1.4 Operation and maintenance

Clogging of the grease and grit trap was frequently reported. Such system failures were caused by a lack of maintenance of the trap and clogging of the subsurface outlet pipe by plastic bags. Meetings with the local community, especially the women, were consequently held to raise awareness and to train them in infiltration system maintenance. Furthermore, design of the grease and grit trap was modified to prevent floating material from clogging the outlet.

3.1.5 Practical experience and lessons learned

Success of the project strongly depends on local community involvement. The basic principle and impact of the infiltration system were demonstrated at two strategic locations: at the house of a person of rank and of the mayor and willingness of the community to cooperate increased significantly. Organization of instruction meetings with woman groups before, during and after construction of the infiltration system with special focus on maintenance of the grease and grit trap also contributed to successful implementation of the system. Much effort was put into training local craftsmen who were organized in teams of one mason and two laborers. After intensive training, the first team further disseminated its knowledge to other teams. Upon project evaluation in January 2003, the various teams trained could set up an infiltration system in two days. In September 2004, over 600 houses were equipped with infiltration facilities whose number is further increasing. This case study is a good example for successful implementation of a simple but effective grey water treatment system.

3.1.6 Project Framework

Type of project	Supervision	Funding	Project period	Project scale
Project for the restoration and renovation of the city of Djenne	Mission Culturelle, Djenne National Museum of Ethnology, Leiden, The Netherlands	Dutch government	Jan. 2000 – Jan. 2003	100 single households (2004: 600 households)

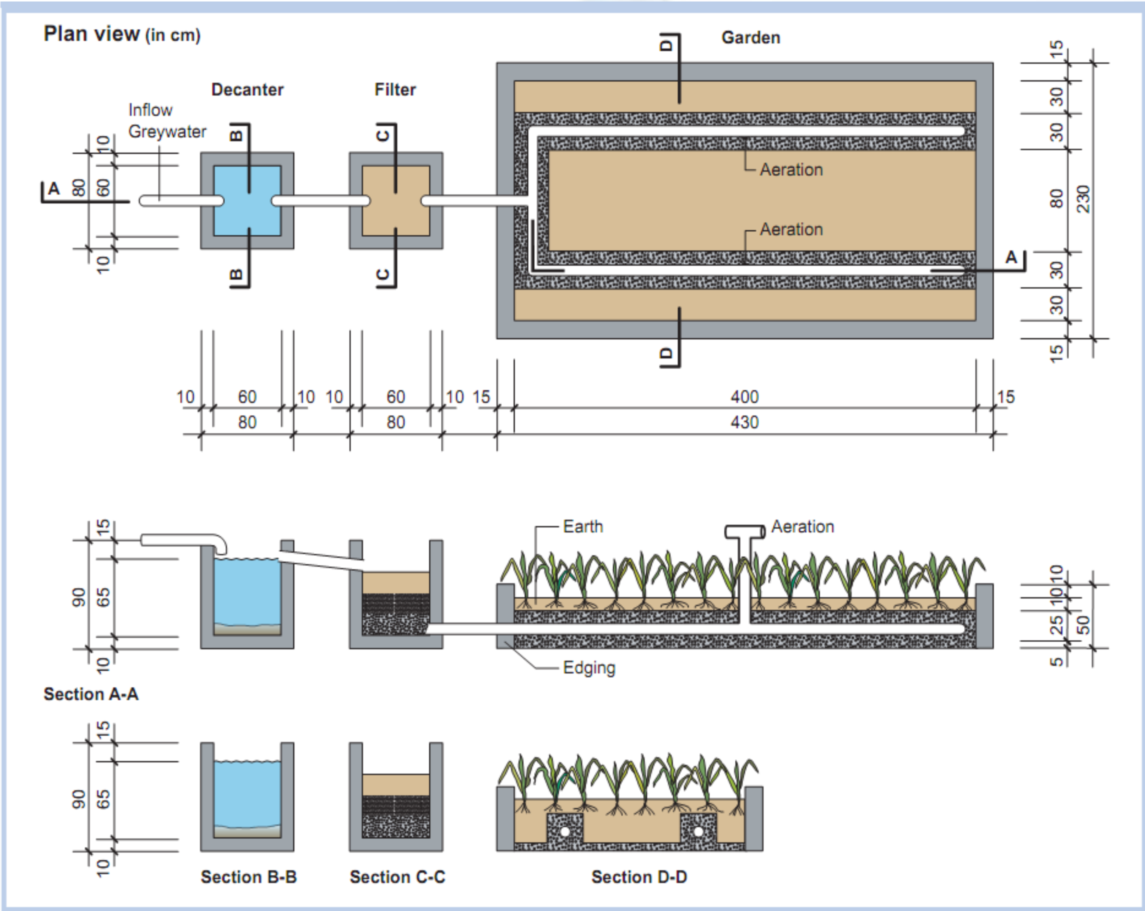
3.2 Koulikoro, Mali, (Grey water garden)

3.2.1 Project background and rationale

Koulikoro with its 26,000 inhabitants is the capital of Mali's second largest administrative area. The average household numbers 10–25 persons, all residing in a spacious compound (300–400 m2) and sharing a single sanitation facility. Infiltration of wastewater is difficult given the high groundwater table in the river valley area and the rocky subsurface in the other neighborhoods. Within the framework of a pilot project headed by the German Technical Cooperation (GTZ) and aiming at establishing appropriate, sustainable, low-tech and low-cost sanitation systems, a treatment system was implemented for bathroom grey water using planted filters for combined vegetable production.

3.2.2 Grey water management system

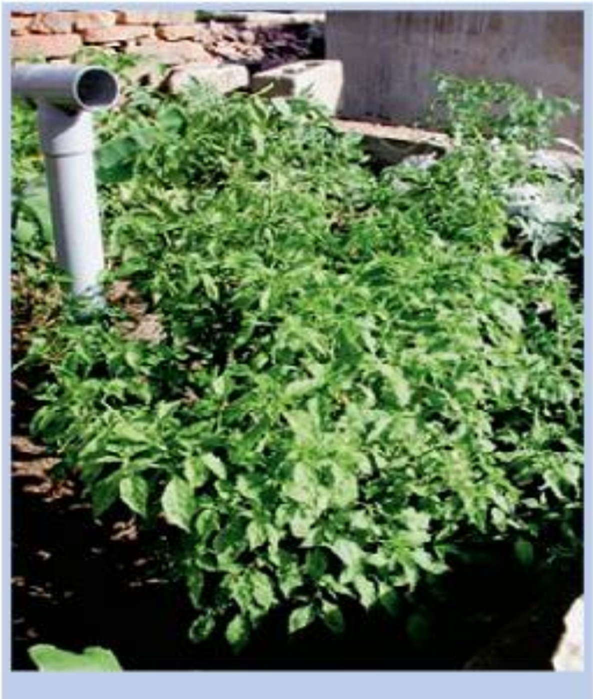
A wire mesh covering the outlet of the shower prevents large particles from being washed into the open grease and grit trap. The collected grey water from the grease and grit trap is then conveyed into a vertical-flow filter with an upper layer of sand, a middle layer of charcoal and a bottom layer of gravel. The thereby filtered water then enters a subsurface irrigated bed planted with fruits and vegetables (see Figure 3-3 and 3-4). The grey water fed through perforated pipes into this garden is equipped with two aeration pipes. For hygienic reasons, only crops with above-ground edible parts are planted. The garden is fenced off to prevent damage by domestic animals.



3-3 Plan view and cross-sections of the grey water garden implemented in Koulikoro.

3.2.3 Performance

The garden initially provided access to vegetables, a fact highly appreciated by all families. Within a short time however the system failed for lack of maintenance. As the wire mesh started to rust, it was removed and caused the solids load on the filter to increase and the filter material to clog. Users subsequently removed the filter material to water at least the garden, however, the untreated grey water eventually clogged the perforated irrigation pipes and surrounding substrate.



3-4 Planted grey water garden and aeration pipe Koulikoro.

3.2.4 Operation and maintenance

Frequent maintenance of all components seems the key factor in achieving appropriate system operation. Since daily cleaning of the wire mesh is necessary, it has to be easily accessible and removable. The grease and grit trap has to be emptied periodically to avoid washout of coarse solids, oil and fat into the vertical filter. If the filter material shows signs of clogging (surface covered with sludge, remaining water on the surface), the different layers need to be removed and either cleaned or replaced. Maintenance and repair of the fence around the garden is also an important aspect to ensure proper functioning of the grey water garden.

3.2.5 Practical experience and lessons learned

Despite an extensive exchange of information and communication among all stakeholders, long-term commitment of the users was rather limited. Lack of awareness for regular maintenance finally led to failure of the system. Similar projects should in future be structurally less complex to facilitate maintenance and ensure adequate operation over longer periods. The filter material currently used (inert sand and gravel) could for example be substituted for wood chips or other natural substrates, which are replaceable after degradation.

3.2.6 Project Framework

Type of project	Planning institution	Project period	Project scale
Urban upgrading project	Otter Wasser mbH, Lübeck Executing Institution. German Technical Cooperation, BOATA GmbH, Mali.	Start of construction: April 2000 Start of operation: July–Dec. 2001	11decentralised treatment units, each for ca. 10–25 inhabitants

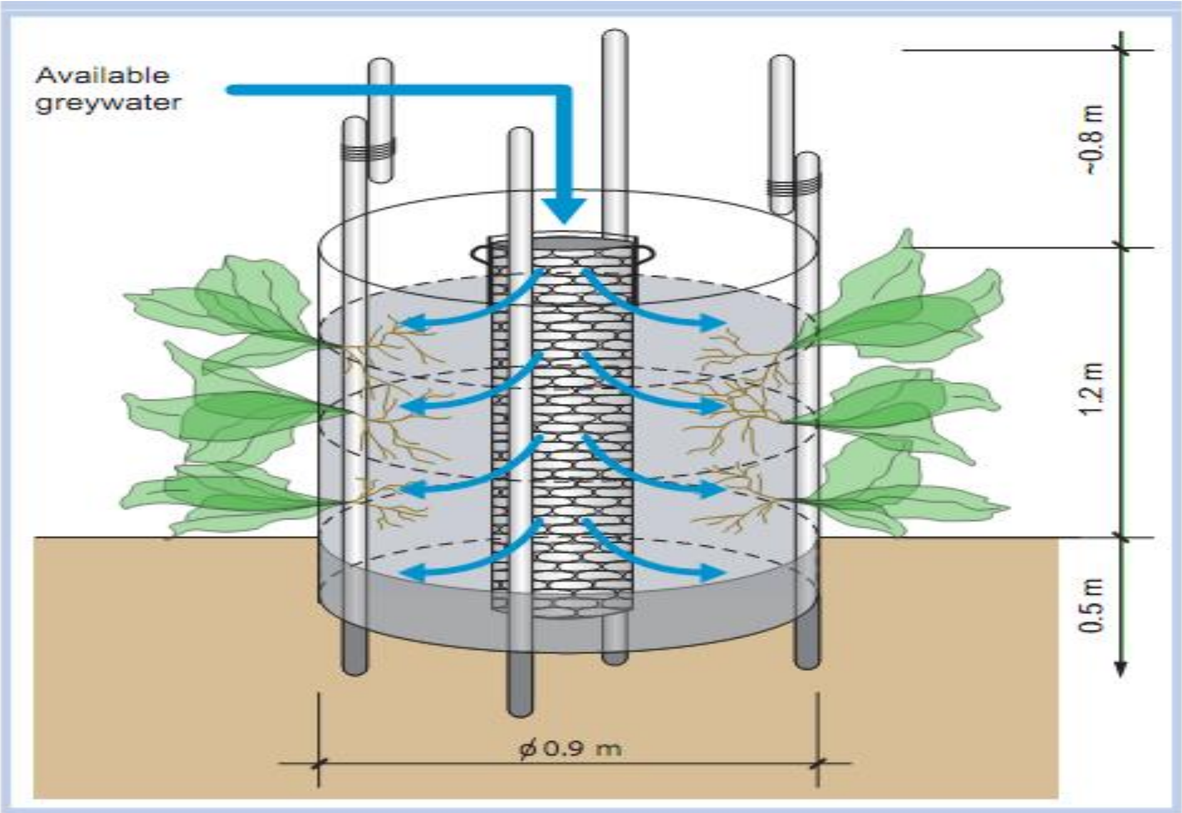
3.3 Gauteng Province, South Africa (Grey water tower garden)

3.3.1 Project background and rationale

For a number of reasons, many rural South African villages hardly practice gardening. Despite available land, finding and transporting water is generally the main barrier. Water collected at the nearest standpipe and carried home will not be used for irrigation. Scientists describe a user-friendly, low-cost and low-tech grey water reuse system, where gardening does not have to rely on rainfall and where nutrients are derived from grey water originating from washing clothes, kitchen utensils etc.

3.3.2 Grey water management system

The external structure of the grey water garden consists of poles (iron bars or fence posts) and shading material (see Figures 3-5, 3-6) surrounding soil and a central stone-packed drain. The purpose of the stones is to spread the water flow throughout the column. Grey water is poured daily with buckets on top of the central stone core. The water trickles through the stone core and is more or less evenly distributed within the soil column. Tomatoes or onions may be planted on top of the column. The most appropriate filling material mix for the tower should be composed of three parts soil, two parts animal manure and one part wood ash.



3-5 Schematic view of a tower garden.

3.3.3 Performance

Information on treatment efficiency of the garden tower is not available. However, the vegetables planted grew well and thrived even in severe heat not tolerated by conventionally planted crops in gardens. Several possible reasons are attributed to this benefit: Lower soil temperatures caused by air circulation in the core and cooling by evapotranspiration or higher elevation of the plants away from the hot ground.

3-6 Tower garden during growing (left) and before harvesting (right)

3.3.4 Operation and maintenance

Two to three buckets of grey water have to be applied daily to prevent the soil from drying out. A puddle forming around the bottom of the tower indicates excess water. Tower gardens are best located in the courtyard so as to minimize transport distance of grey water.

3.3.5 Practical experience and lessons learned

Finding the right type of material to wrap around the sides of the tower is difficult. In South Africa, shading material did not last for more than one season, since black plastic sheets deteriorate rapidly when exposed to sunlight. The core material should consist of flat stones or building rubble, thus preventing the soil from being evenly moistened. One of the main strengths of the system is its minimal labor, monitoring and maintenance requirements. Once familiar with the towers, the users prefer to position them in their courtyards for easy pouring of the grey water into the stone core. Such grey water reuse can thus effectively contribute to increasing food security. However, the risk of plant contamination with pathogens by some splashing water should be avoided. Raw consumption of the harvested vegetables is not recommended. To prevent toxic effects on plants and soil deterioration, household detergents must be selected carefully. To prevent clogging in the stone column and soil, a grease and grit trap for primary treatment should be installed.

3.4 Monteverde, Costa Rica (Horizontal-flow planted filter for domestic grey water treatment of four households)

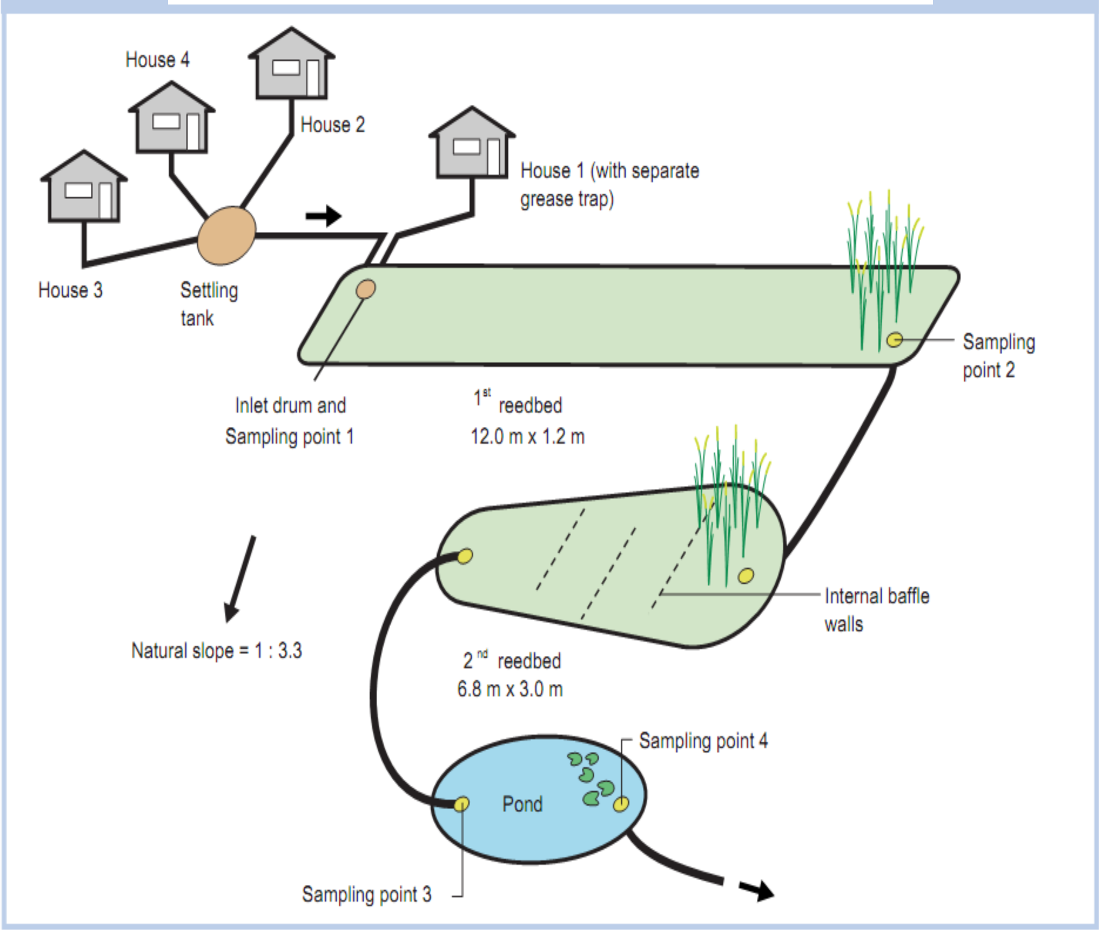
3.4.1 Project background and rationale

Typically for rural Latin America, separation of wastewater at the source is common, and Monteverde is no exception. Black water is treated in septic tanks while grey water is mostly discharged directly onto streets and into streams. Given this unacceptable situation, a local resident, inspired by a demonstration grey water reed bed project, offered the necessary land for implementation of a suitable grey water treatment system provided additional funding was raised.

3.4.2 Grey water management system

The grey water system was designed to receive water from four households with an average of 4.5 persons per household and an average water consumption of 139 l/p/d. Although only three homes have currently been connected to the system at any one time. PVC pipes convey the grey water from the houses to a concrete settling tank. A steel mesh inside this settling tank allows easier manual emptying (see Figures 3-7a, 3-7b). The secondary treatment step consists of two horizontal-flow planted filters in series. The first planted filter (reed bed) is rectangular, the second planted filter has an oval shape (see Figure 3-8). The second reed bed has internal plastic baffle walls. The locally available crushed rock in the bed allows for an effective storage volume, corresponding to a minimum hydraulic retention time (HRT) of 7.9 days (4.5 d in filter one, 3.4 d in filter two).

3-7a Settling tank



3-8 Layout of the four-household planted filter system for grey water treatment

3.4.3 Performance

System performance was generally satisfactory. From a public health perspective, the treated water quality in the final grey water treatment step was equivalent to some of Monteverde's most pristine streams. Fish and frogs have colonized the pond and are assumed to be responsible for the lack of mosquito larvae.

3-7b Build up of 1st Reed bed

3.4.4 Operation and maintenance

Manual de sludging of the settling tank has been reported as a necessary maintenance activity. It is carried out annually by the owner's son at a cost of USD 7 and requires about three hours. The removed sludge is buried in the owner's garden. The installed removable and reinforced mesh basket simplifies this task. Having all houses connected to one main settling tank eases maintenance. Other maintenance tasks include occasional weeding of the planted filters, pruning of overhanging branches, removing of leaves and rubbish from the pond, and thinning of aquatic plants, all of which are relatively straightforward and not very time-consuming tasks.

3.4.5 Practical experience and lessons learned

Some clogging near the inlet of the first filter was observed after two years of operation. Liner leakage discovered in the second filter bed highlighted the importance of avoiding joints in the liner as well as the need for a geotextile layer to protect the liner.

Dissemination and replication of the concept is largely dictated by installation and maintenance costs as well as opportunity costs caused by further land requirements.

Use of conventional crushed rock influenced construction and operation for the following reasons:

- Responsible for 25% of the total costs.
- Increased salary costs, as handling this heavy material was more labor-intensive.
- Increased clogging risk, as fine sand was also present in the crushed rock material.
- Difficult and expensive repair work (e.g. unclogging inlet section or repairing liner). Relatively low porosity and hydraulic conductivity.

3.4.6 Project Framework

Type of project	Supervision	Funding	Project period	Project scale
Private initiative funded project	Monteverde Institute	Ford Motors Co Environment Award	March 2001–August 2002	Four single households (total 18 persons)

3.5 Kathmandu, Nepal (Vertical-flow planted filter (constructed wetland) for single households)

3.5.1 Project background and rationale

In Nepal, many urban rivers have already turned into open sewers due to the discharge of untreated wastewater from households and, in some cases, toxic industrial waste. Appropriate wastewater treatment and reuse are neglected and often considered unaffordable. In the 1970s, four large-scale wastewater treatment plants were constructed around Kathmandu Valley. However, since they are no longer in operation, an increasing number of small-scale and decentralised alternative wastewater treatment systems have been developed and implemented.

3.5.2 Grey water management system

A constructed wetland system was built for a 7-person household. The system was designed to treat grey water from bathroom, laundry and kitchen. The grey water is collected in two-chambered settling tank. A subsequent dosing tank with a mechanical siphon discharges grey water onto a vertical-flow planted filter 3–4 times a day through a perforated pipe fixed above the surface level of the bed. The filter material of the bed is composed of a layer of gravel at the bottom, fine gravel in the middle and coarse sand on the top (see Figures 3-9a, 3-9b). The treated grey water is then collected in a tank before it is used for irrigation, washing vehicles and toilet flushing. An average of 500 liters of grey water is treated daily. Hydraulic retention time (HRT) in the settling tank averages 24 hours and hydraulic loading rate (HLR) of the constructed wetland amounts to 8.3 cm/d.

3-9a , 3-9b Vertical-flow planted filter shortly after completion and in use

3.5.3 Performance

In the planted filter, NH_4-N is transformed to nitrate (NO_3-N) by nitrification processes. Although ammonia removal efficiency exceeds 90%, total nitrogen removal probably does not exceed 60-70% given the missing denitrification step.

3.5.4 Operation and maintenance

The system has been in operation since April 1998 and monitored from April 1998 to May 2000. During this time, treatment efficiency was stable. The following maintenance was performed to ensure proper operation of the system:

- Annual sludge removal from the settling tank.
- Regular inspection of dosing chamber to ensure operation of the siphon and intermittently grey water-charged bed.
- Annual plant cutting.
- During monitoring, neither storage tank nor filter bed surface was cleaned.

3.5.5 Practical experience and lessons learned

The experience suggests that this system is appropriate for a country like Nepal, whose growing cities have little regard for demographic, municipal and regional planning. After five years of research and development, this technology proved to be useful in Nepal and is now ready for large-scale application.

3.5.6 Project Framework

Type of project	Supervision	Project period	Project scale
PhD thesis	Institute for Water Provision University of Agricultural Sciences Vienna, Austria	Implementation: April 1998 Monitoring period: April 1998– May 2000	Single household (7 persons)

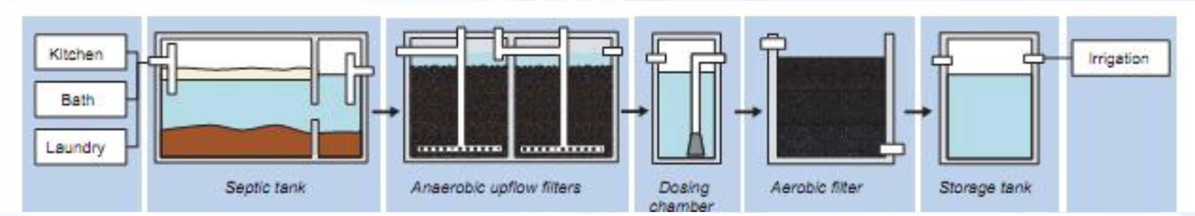
3.6 Bilien, Palestine (Anaerobic and aerobic filter system for single ouseholds)

3.6.1 Project background and rationale

Many rural communities of the West Bank, Palestine, do not have access to sufficient water to meet their daily needs. Rural water supply is provided by the Israeli Water Supply Company. The systems are old and water supply is often interrupted for months at a time. Rainwater collected in winter and stored in wells is used up within a few weeks of water supply interruptions. The population therefore relies on tankers or spring water. This project, four pilot household gravel filter systems for grey water treatment of single houses in Bilien village are being monitored.

3.6.2 Grey water management system

The grey water treatment system comprises a simple screen, a septic tank, two anaerobic up-flow filters in series, and a vertical-flow aerobic filter. The grey water first flows by gravity through bar screens into a septic tank at a hydraulic retention time (HRT) of 1.5–2 days. The effluent from the septic tank then passes through a T-shaped pipe into a double-chambered up-flow anaerobic gravel filter. The anaerobic filter works at maximum flow during the day and zero flow at night. Effluent from the subsequent dosing chamber is pumped onto an aerobic filter composed of three layers (sand, coal, gravel). Finally, the treated grey water is stored in a plastic tank and used for irrigation of non-edible crops as shown in figure 3-10.



3-10 The system

3.6.3 Performance

Overall analysis of the grey water from 25 families in Biet-Diko and Bilien revealed very high COD and BOD5 concentrations of 1,270 mg/l and 590 mg/l, respectively. The removal rate for both COD and BOD5 in these household treatment systems ranges between 75% and 95%.

3.6.4 Operation and maintenance

The bar screen is cleaned twice a week. The septic tank is de sludged every other year. The author of the study recommends back flushing of the anaerobic filters every three years. The system has been in operation since 2000.

3.6.5 Practical experience and lessons learned

The high COD and BOD5 concentration of the raw grey water is probably attributed to the low water consumption and cooking habits typical for the region. Discarding remaining food and used cooking oil in kitchen sinks is believed to be the main reason for the high grey water pollution loads in the Middle East. Although grey water is treated prior to reuse, it has a high pollution and impact potential on irrigated soils. To avoid operation of a pump, topography of the area and use of a mechanically driven dosing chamber (siphon) are recommended. Since the entire system chain seems quite complex, one or several components could be omitted to simplify the treatment system. Monitoring of each treatment component could provide information on its treatment efficiency and necessity.

3.6.6 Project Framework

Type of project	Implementing agency	Project period	Project scale
Urban upgrading project	Palestinian Wastewater Engineers Group (PWEG)	2000–2002	Four single households (total 37 persons)

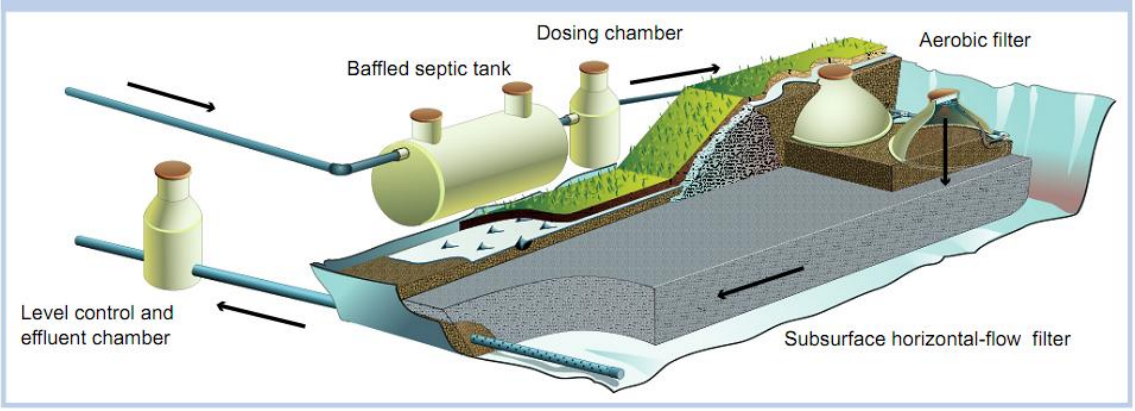
3.7 Kuching, Malaysia (EcoSan grey water demonstration project)

3.7.1 Project background and rationale

Kuching, the capital of the Malaysian State of Sarawak. The city of Kuching is currently lacking a wastewater treatment plant, and the local subsurface conditions make a conventional centralized wastewater system expensive to implement. Most buildings in Kuching are equipped with two separate wastewater outlets, one outlet for black water and one or more for grey water, although this is not the required building standard. Black water flows into septic tanks, either within the housing plot or at communal level serving commercial buildings or residential complexes. The septic tanks subsequently discharge their effluents directly into the storm water drains from where they are conveyed into the nearest aquatic system. Grey water is also discharged into the storm water network or directly into receiving waters. Some oil and grease traps have been installed at large food outlets at the request of Kuching. These facilities are, however, generally undersized and often only emptied irregularly.

3.7.2 Grey water management system

The system treats grey water from nine households. Total grey water production amounts to approximately 225 l/p/d. The grey water treatment system (see Figure 3-11) comprises a baffled septic tank as primary treatment unit to remove oil, grease and settleable solids, followed by a dosing chamber. The grey water then flows into four vertical down-flow, single-pass aerobic bio filters before reaching a subsurface horizontal-flow planted filter. The treated grey water then exits the system into the storm water drain through an outlet comprising an integrated tip-bucket flow measurement system. The baffled septic tank stores grey water for about 24 hours. Baffles divide the trap into four chambers to ensure the highest possible retention time for oil, grease and settleable solids. Four polyethylene bio filters received grey water over a period of 24 hours. The grey water percolates through the aerobic filter comprising lightweight clay aggregate. Grey water then flows into the subsurface horizontal-flow planted filter (see Figure 3-12).



3-11 Schematic layout of the EcoSan grey water treatment facility in Kuching

3-12 Aerobic filters and planted filter under construction and completed

3.7.3 Operation and maintenance

Different operation and maintenance activities are carried out on a regular basis. De sludging of the oil and grease trap (baffled septic tank) takes place every three months. The pump is inspected weekly to assess or avoid damage by particulate matter. Inspection and if necessary cleaning of the spray-nozzles in the vertical bio filter is also conducted regularly to ensure filter efficiency.

3.7.4 Practical experience and lessons learned

The initial purpose of the project was to prove that the concept chosen is a technically viable approach to decentralized grey water treatment in Sarawak. The second and equally important aspect was to ascertain whether the grey water facility would be accepted in an urban residential setting. The project yielded highly promising treatment results and fulfilled its purpose since its operation in 2003. A social survey of the nine families serviced was conducted in 2004. Occasional odors are believed to be emitted after clogging of the bio filters given the extremely high levels of oil and grease used in the preparation of traditional Malaysian food. The capital costs of this grey water treatment system are high and probably not affordable by single households. Nevertheless, this system can be a suitable solution for neighborhoods, as per capita costs decrease with increasing household connections. Since system performance is extremely high due to the low-strength inflowing grey water.

3.7.5 Project Framework

Type of project	Coordination	Implementation	In operation since	Project scale
EcoSan demonstration project	Urban Environmental Management System (UEMS)	Natural Resources and Environmental Board (NREB)	December 2003	nine households (5persons/house)

3.8 Sri Lanka (Grey water treatment systems for hotel premises)

3.8.1 Project background and rationale

Sri Lanka belongs to the rapidly developing countries. In the last two decades migration from rural to urban areas has increase the pressure on authorities in finding wastewater management solutions. Every new building plan has to include an on-site wastewater disposal system approved by the authorities. However, the existing regulations or guidelines do not stipulate any system design requirements. Scientists selected, evaluated and implemented appropriate, cost-effective technologies for on-site wastewater management systems in urban and suburban Sri Lanka. The goal was to develop practical selection and design guidelines. The project presents different treatment technologies with main focus on hotel grey water and black water treatment systems. This study describes grey water treatment plant was constructed for the Swiss Residence Hotel.

3.8.2 Grey water management system

In a 40-room tourist hotel in Kandy, a treatment system for kitchen and laundry grey water was set up to extend an already existing black water treatment system following complaints from neighboring residents and regulatory authorities (grey water treatment was originally not considered in the sanitation plan). For lack of space, the system had to be installed underground, with setback distances of less than three meters between treatment unit, road and building. The plant includes a grease trap, a septic tank and a vertical-flow planted filter fed by an electric pump. The septic tank was designed for an assumed de sludging frequency of five years.

3.8.3 Performance

During start-up, the average system load amounted to 19.7 m3/d, representing almost three times the hydraulic load of the originally designed grey water system. BOD removal of the system averaged 44%. The septic tank effluent was turbid, milky white and had a strong sour odor.

3.8.4 Operation and maintenance

The grease and grit trap was originally supposed to be cleaned once a month. However, the hotel maintenance staff failed to do so and the accumulated scum and grease in the trap started emitting strong foul odors. Large amounts of oil and grease escaped into the system and further contributed to system failure. Thereupon, a smaller, daily-cleaned grease and grit trap was installed instead. It prevents anaerobic degradation of the trapped oil and grease and is thus cleaned without much opposition by the staff.

3.8.5 Practical experience and lessons learned

This example emphasizes the importance of stakeholder involvement. By taking into account the perceptions and feelings of the hotel staff regarding the lack of maintenance, one reason leading to system failure could be identified and corrected. Based on this manifold experience, the following was suggested:

- An annual sludge accumulation rate of 18–20 l/person. must be assumed in septic tanks treating grey water.
- Hotel septic tanks should be designed for a larger scum to sludge ratio (0.5 instead of the usual 0.4 value) when allocating storage volumes.
- The nominal HRT in anaerobic filters should range between 0.7 and 1.5 days. Surface loading should be limited to maximum 2.8 m/d.
- Kitchen wastewater from hotels should always be pretreated in grease traps and designed for daily cleaning. Daily-cleaned traps perform better and are more easily maintained than larger grease and grit traps.
- Since percolation beds can be buried, they should be chosen for sites with restricted space.

Chapter Four:

Evaluation of Different Available Systems for Grey Water Treatment

4. Evaluation of Different Available Systems for Grey Water Treatment

There is a great number of grey water recycling systems available which vary greatly in complexity, performance and cost. These systems range between simple one house systems to very advanced treatment processes for large scale reuse. It can be generally stated that the expense of a system is related to the final quality of treated waste water. It should also be noted that different reuse applications require different water quality specifications which demand different treatments which account for the range in complexity of available systems.

4.1 The evaluating strategy

Our strategy was built on evaluating the different grey water treatment systems that already applicable in different countries. The evaluation process was carried out according to a specific grading and ranking system developed by R&D TECH team. Table 6 describes this system, in which the most important parameters for evaluation were given weighing based on ranking points starting from one to ten. The evaluating parameters were:

1- The scalability:

This parameter gives indication about the easiness of the scaling up procedure of the selected system.

2- The mode of operation:

This parameter gives indication about whether the operation will be done manually, partial automatic or full automatic.

3- The system running:

This parameter gives indication about the periodic interaction to the system to maintain a safe running.

4- The periodic Maintenance:

This parameter gives indication about the maintenance of the different systems.

Table 6: Parameters of the grading and ranking system

Ranking points	Capacity L/day	Operation	Running	Maintenance
1	Up to 300	Manual	Daily interaction	After 1 - 4 months
2			Half week interaction	
3		Partial automatic		
4	Up to 7200		weekly interaction	
5				After 5 - 9 months
6				
7			Monthly interaction	
8	Up to 28800			
9				
10	More than 28800	Full automatic		≥10 months

4.2 Description and evaluation of the different systems

In this report 20 systems for grey water treatment have been studied and evaluated based on the above described strategy. Finally the systems are summarized and compared to have a clear view to help in selecting the suitable system for our targeted prototype. In the following we are going to describe and explain the different evaluated systems.

4.2.1 Earthsafe Waterbank WBJO GWTS

This system is designed to treat all domestic grey water for a maximum of 10 persons (1130 liter/day). The key processing steps in the system involves the treatment of the grey water in an aeration chamber followed by membrane filtration and UV disinfection. The raw grey water firstly passes through a lint filter located at the inlet of the tank, then flows into a raw water equalization chamber (outer portion of the tank) where air is introduced under a controlled on-off cycle ensuring the grey water is well mixed and biological breakdown occurs through oxidation. During the off period an anoxic condition is developed that contributes to a reduction in the total nitrogen level in the treated water. The treated grey water flows into a 400 L inner clarification chamber containing a 100 micron membrane filter. The filter removes any remaining solids prior to transfer of the treated water to the UV disinfection unit and the final pump chamber.

The treated water from the clarification chamber is continually recycled through the UV disinfection unit by way of an airlift pump through a quartz glass sleeve or self-cleaning Teflon coil, which creates a natural turbulence and ensures that the water is thoroughly radiated as it passes through the tube. The final effluent is collected in a pump chamber ready for toilet flushing, washing machine use or external use such as garden irrigation. Figure 4.1 shows a simple block flow diagram for the system.

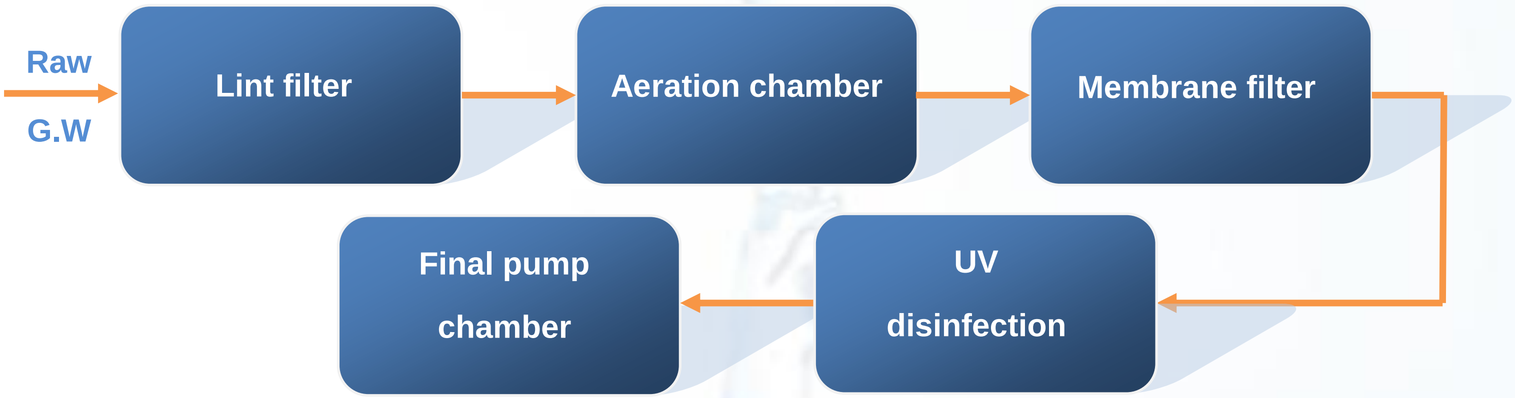
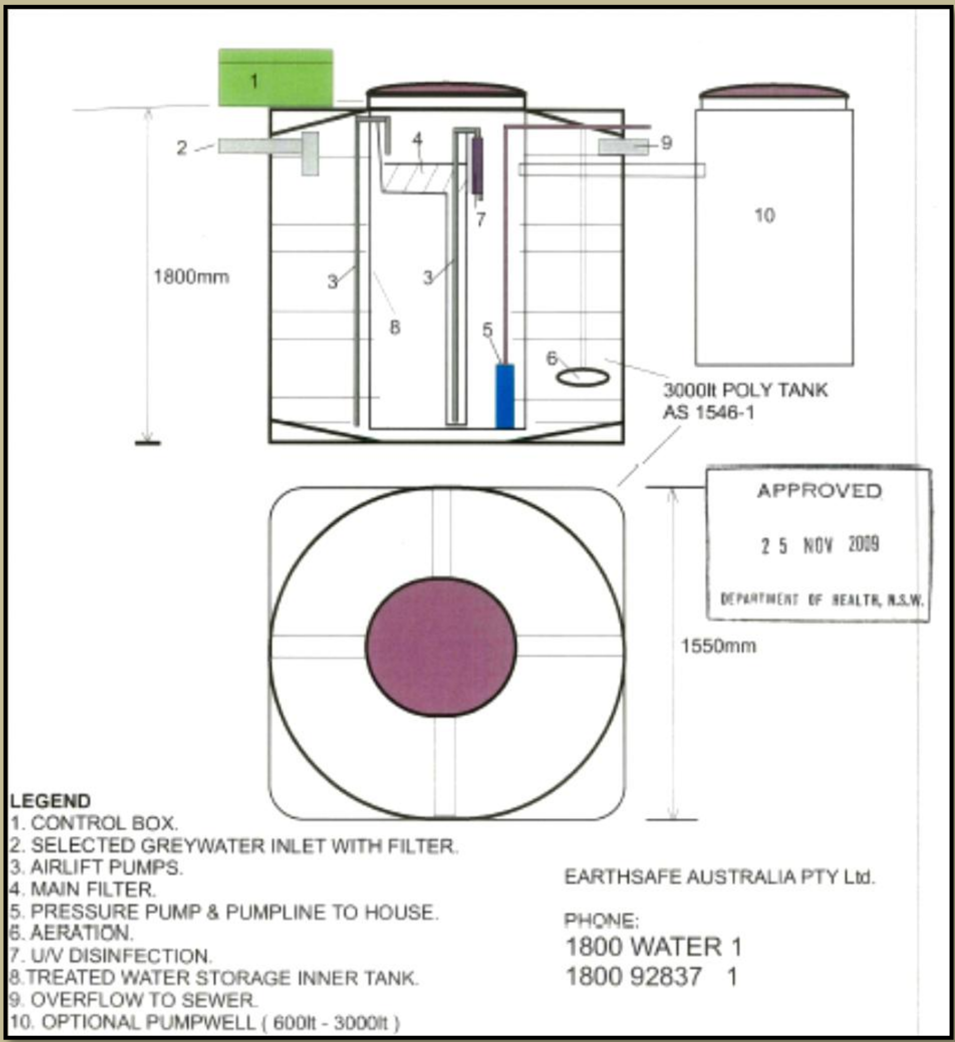


Fig. 4.1: Simple block flow diagram for Earthsafe Waterbank WBJO GWTS



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**7.5**									

Fig. 4.2: Earthsafe Waterbank WBJO GWTS and its evaluation sheet

4.2.2 Nubian GT600 GWTS

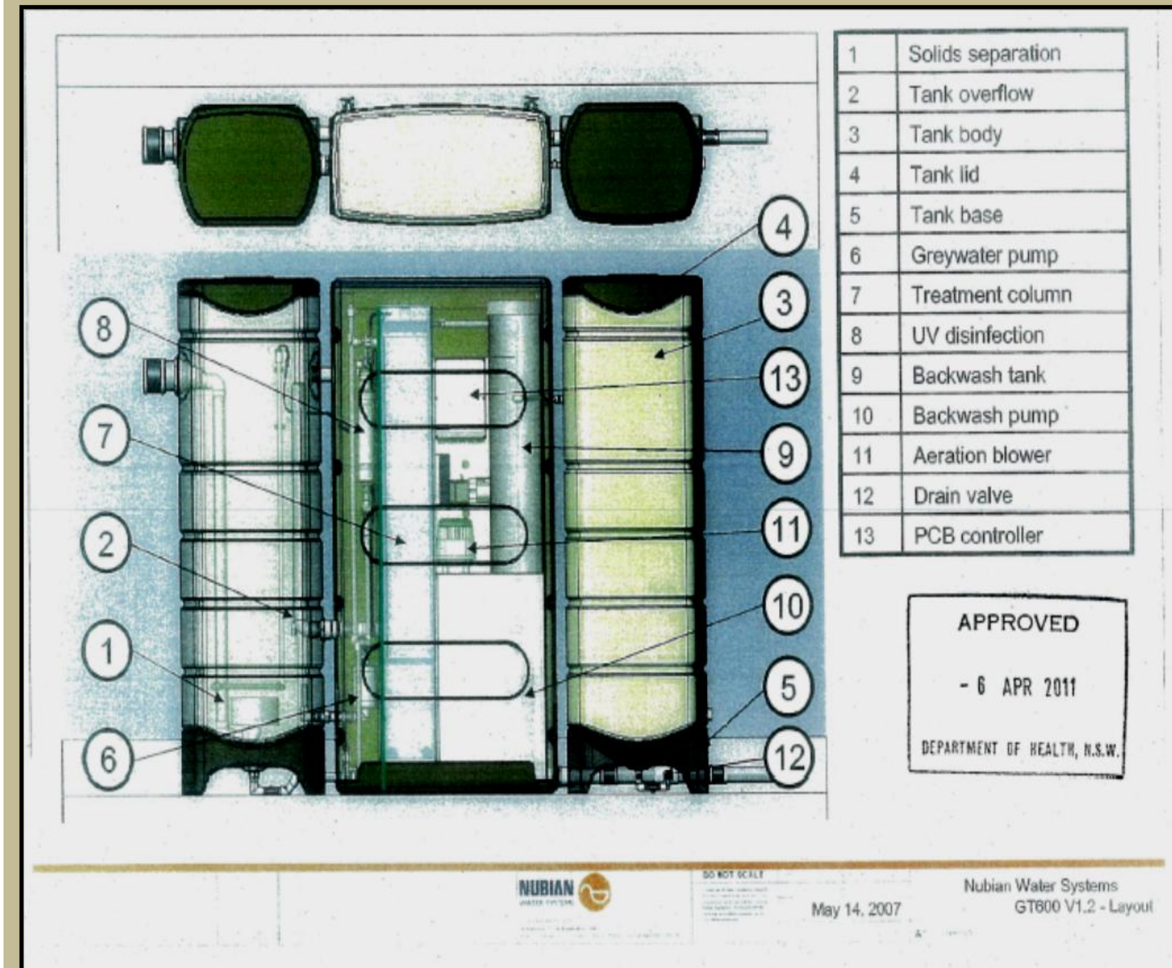
This system is designed to treat the grey water from the showers/baths, laundry and hand basin (excluding kitchen wastewater) from a residential dwelling occupied by a maximum of 8 persons (904 liter/day).

The system comprises the following components:

1. Grey water solids separation - Lint and other coarse material is removed to prevent blockages and fouling of the system. Collected material is removed automatically on a periodic basis.
2. Feed tank - Separated grey water is collected and aerated before delivery to the treatment module. Aeration occurs by direct injection of pressurized air.
3. Treatment module – Grey water flows into the treatment module where contaminants are removed through filtration, adsorption and biological treatment. The treatment module is regularly backwashed, removing built-up contaminants to the sewer.
4. Disinfection - Ultraviolet (UV) disinfection of the treated grey water completes the treatment process.
5. Treated water storage tank - Treated water is stored in the final storage tank for reuse applications.

Figure 4.3 shows a simple block flow diagram for the system.

Fig. 4.3: Simple block flow diagram for Nubian GT600 GWTS .



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**6.75**									

Fig. 4.4: Nubian GT600 GWTS and its evaluation sheet

4.2.3 Micro-nova 8EP GWTS

This system treats shower, bath, basin and laundry wastewaters from a domestic dwelling. The system is assembled within a single tank that divided into an aeration chamber, a clarifier and a chlorine contact irrigation pump well.

Chambers	single tank (3000 liters polymer tank)
Aeration chamber	1985 L
Clarifier	430 L
Irrigation	393 L
Operational water level in aeration chamber	1350 mm

The aeration chamber contains three aeration diffusers and submerged media. Air is supplied at 100 liters/minute by an air blower mounted on the top of the tank. The submerged media provides surface area for the growth of bacteria to allow for the biodegradation of organic material in the grey water.

Treated wastewaters flows to the 430 liters clarifier. Solids settling on the bottom of the clarifier are transferred to the inlet of the aeration chamber for further treatment. Treated wastewaters from the clarifier flow through a chlorine disinfection unit into irrigation pump well. A submersible irrigation pump is installed in the irrigation pump well. The treated wastewater is filtered through a small sand filter before being directed to the land application area.

Figure 4.5 shows a simple block flow diagram for the system.

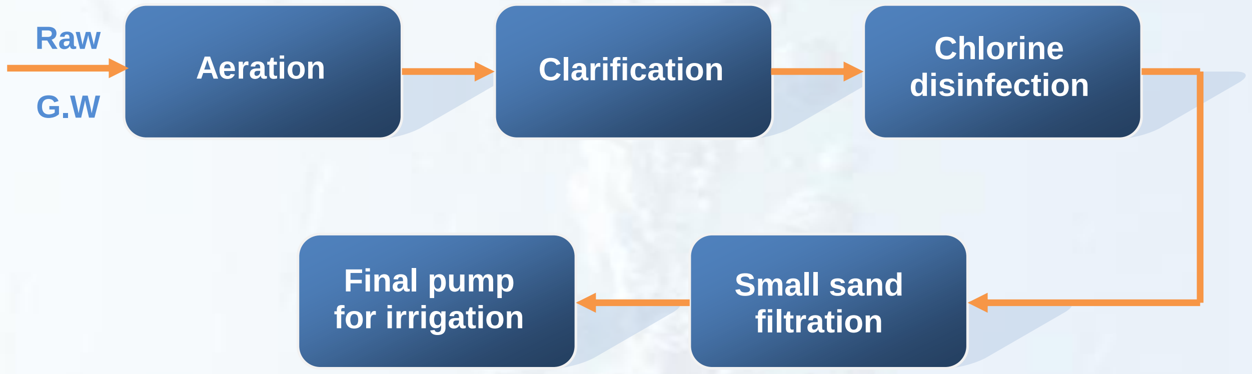
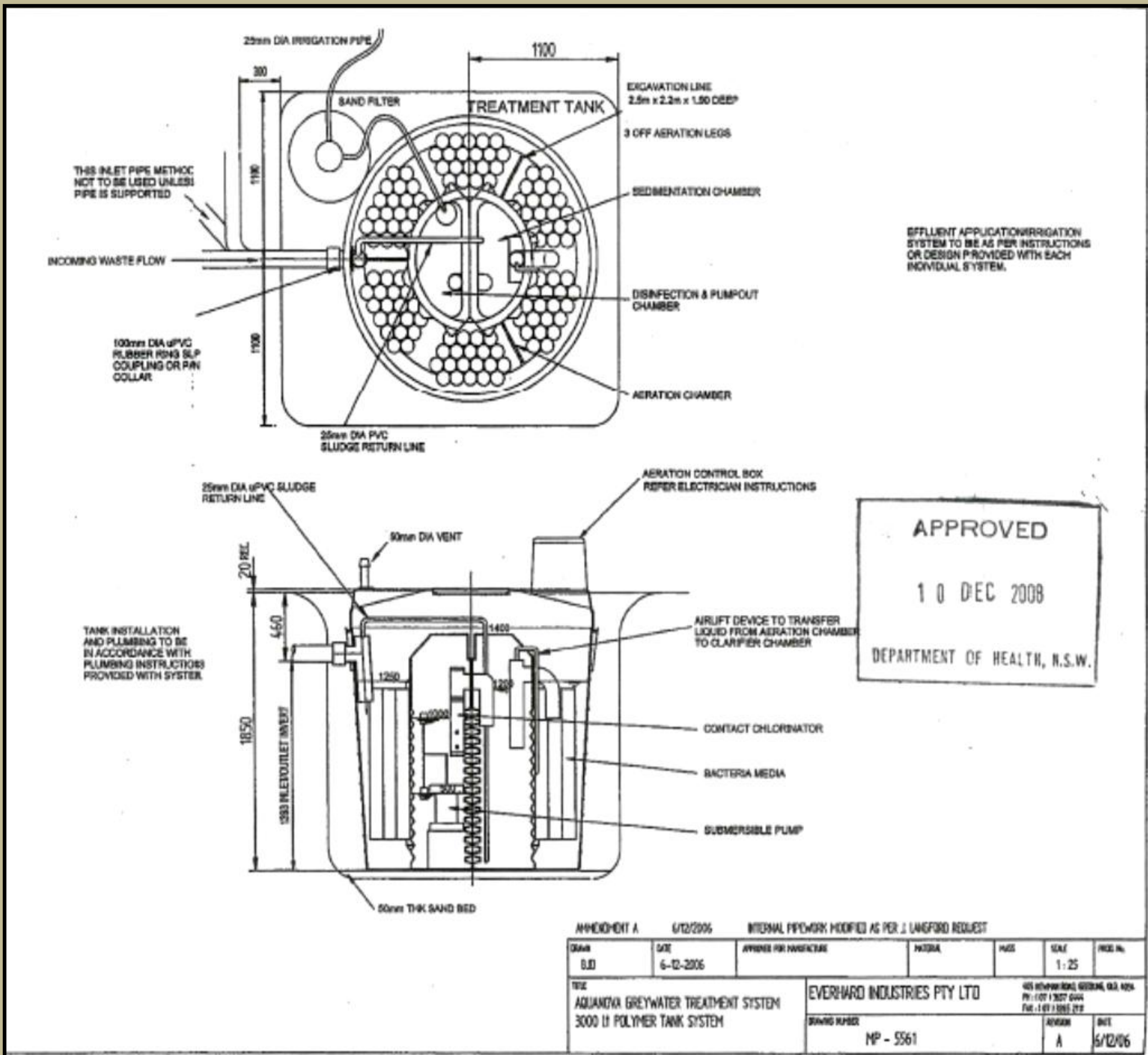


Fig. 4.5: Simple block flow diagram for Micro-nova 8EP GWTS



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**6.5**									

Fig. 4.6: Micro-nova 8EP GWTS and its evaluation sheet

4.2.4 NovaGrey GWTS

This system is designed to treat the wastewater from the shower, bath, basin and laundry from a domestic dwelling. The system is assembled within a MBR chamber that contains the membrane housing, membranes and diffuser assembly, along with the MBR working level float switch. The operation of the system is set out below:

- Grey water from the dwelling is directed to a pump well which is designed to have an overflow to the sewer to cater for high-flow periods during the day.
- The system contains a pump to transfer the untreated grey water from the pump well to the MBR chamber which is aerated by a diffuser attached to the bottom of the membrane housing. Air is continuously supplied by an air blower mounted above the MBR chamber.
- The membrane housing within the MBR chamber contains 7 flat sheet membranes with a pore size of 0.2 microns. Transfer of the treated grey water through the membranes to the internal effluent tank is controlled by a working level float which is set to operate at a differential of 200 mm.
- When the MBR working level float is in the up position, a suction pump is activated transferring the treated grey water through the membranes and through an UV disinfection unit to the internal effluent tank.
- When the internal effluent tank reaches an adequate volume a float switch activates an effluent pump which directs the treated grey water to the household re-use storage tank.

Figure 4.7 shows a simple block flow diagram for the system.

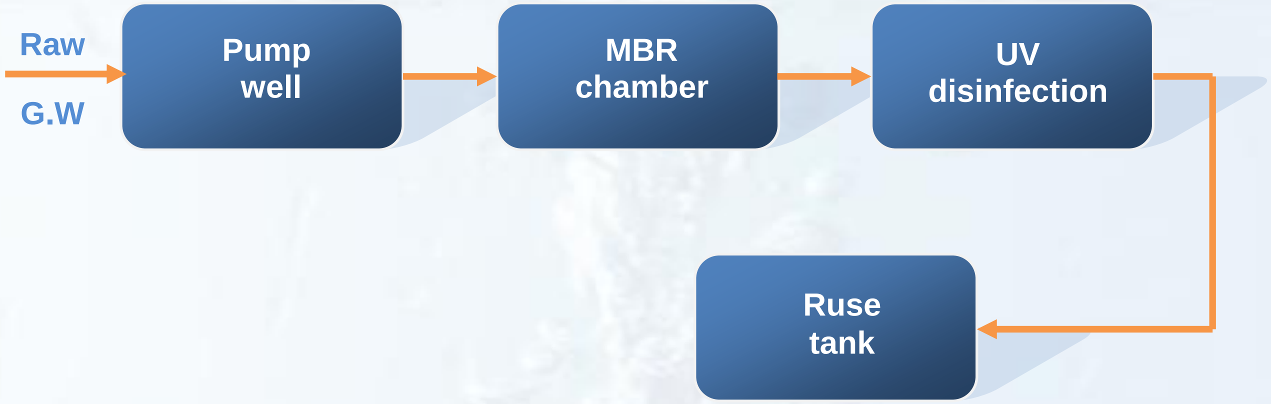
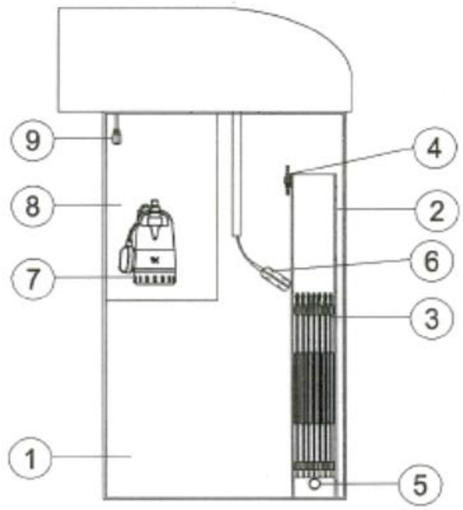


Fig. 4.7: Simple block flow diagram for NovaGrey GWTS

MBR CHAMBER SPECIFICATION



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MBR TANK SPECS				
NUMBER	PART	MATERIAL	QUANTITY	SPEC
1	MBR Chamber	H.D.P.E	1	410L capacity
2	Membrane cassette	PVC	1	Membrane housing
3	Membranes	Polyethersulphone	7	Microfiltration
4	Suction Manifold	Aluminium	1	7 x 10 mm nipple
5	Diffuser	PVC	1	Coarse Bubble
6	Working Level float switch	n/a	1x12v	Mac3
7	Internal Effluent Pump with Automatic Float	n/a	1 x 240 v	CLAYTECH
8	Internal Effluent Tank	H.D.P.E	1	55 L Capacity
9	Internal Effluent Tank H/L	n/a	1x12v	micro float

Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**7**									

Fig. 4.8: NovaGrey GWTS and its evaluation sheet

4.2.5 UltraGTS GWTS

This system is designed to treat the grey water from the shower, bath, laundry and basin from a residential dwelling occupied by a maximum of 10 persons (1130 liter/day). It is assembled within an above ground treatment tank contains the membrane filter module and diffuser assembly pipe system along with the working level float switch. The operation of the system is set out below:

- Grey water is fitted with a submersible pump which transfers the grey water at regular intervals to the system. The collection chamber is designed with an inbuilt overflow to the sewer to cater for high loads.
- The system is a Membrane Bio-Reactor which uses a combination of biological treatment and advanced membrane filtration. Air is introduced into the base of the system via a course bubble aeration pipe system to ensure proper mixing and the biological treatment is achieved through the oxidation of the wastewater.

The transfer of the wastewater through the membrane module and the UV disinfection unit is controlled by a suction pump. The treated grey water is collected and stored in the above ground storage tank ready for internal re-use.

Figure 3.9 shows a simple block flow diagram for the system.

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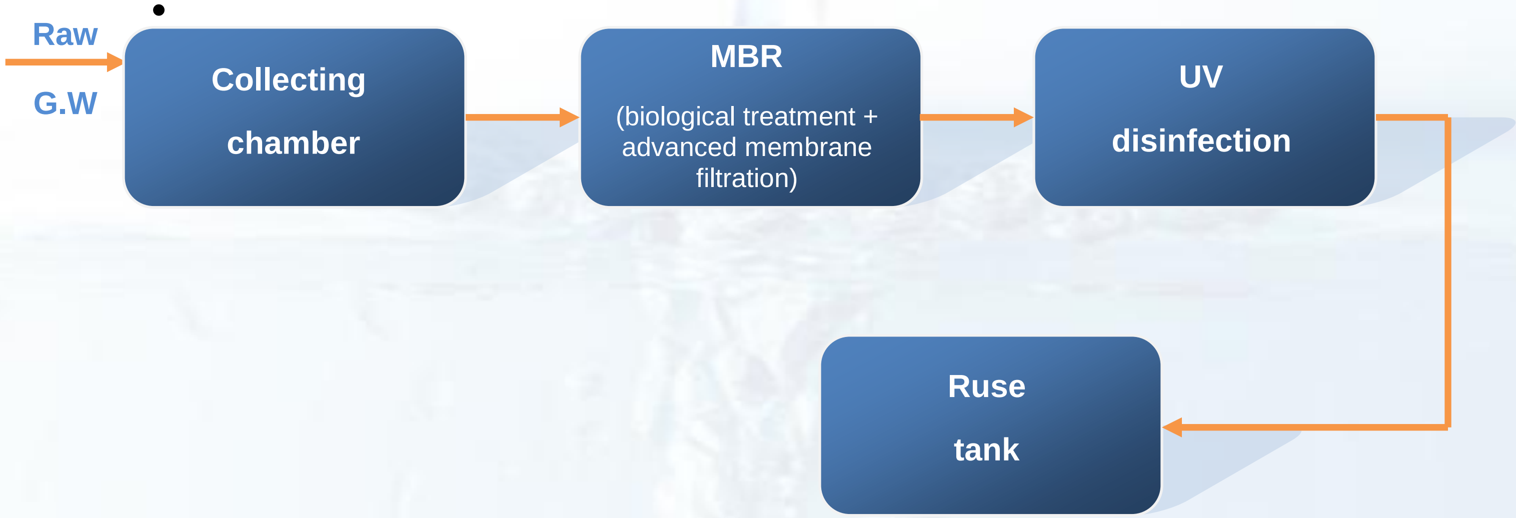
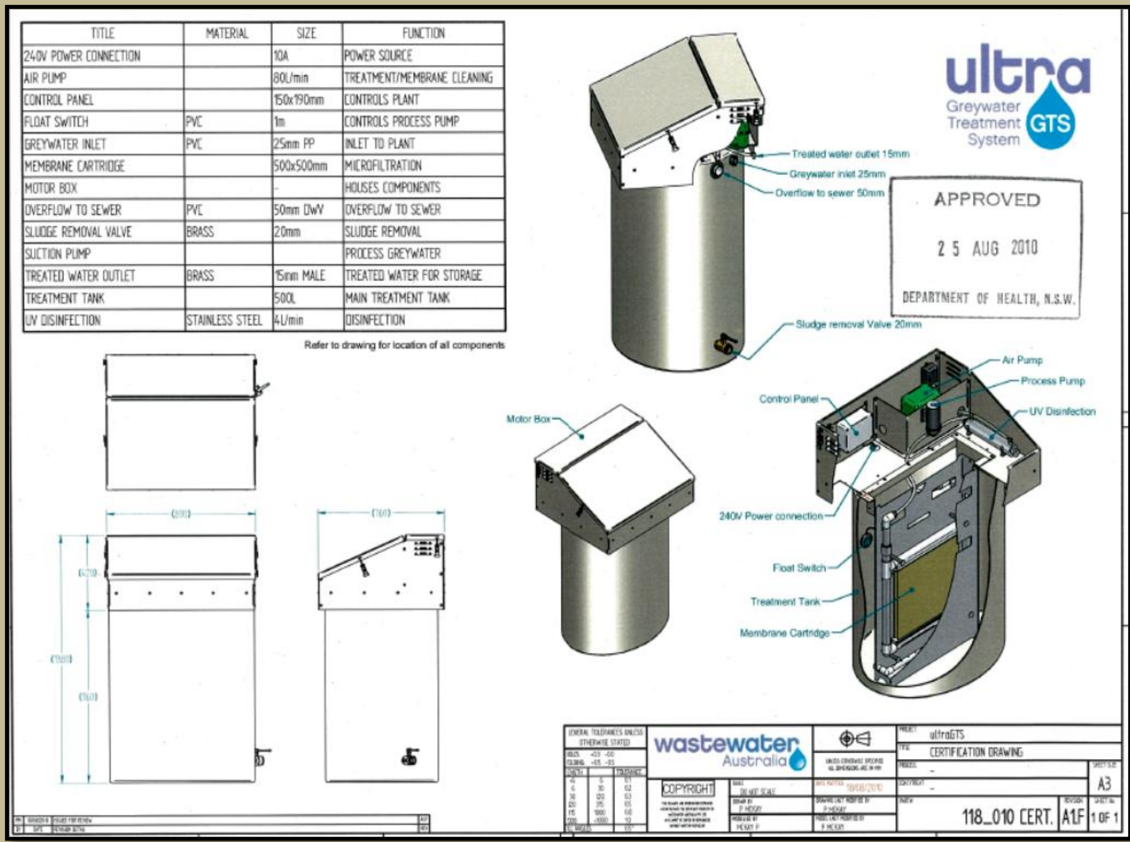


Fig. 4.9: Simple block flow diagram for UltraGTS GWTS



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**7**									

Fig. 4.10: UltraGTS and its evaluation sheet

4.2.6 Aqua Clarus AG 720 GWTS

This system is designed to treat all domestic grey water from a residential dwelling occupied by a maximum of 8 people (904 liter/day). The key processing steps in this system involves the treatment of the grey water in a bioreactor followed by membrane filtration and UV disinfection.

The grey water is pumped from an external pump well to the bioreactor that consisting of a trickle bed and a collection chamber at the base of the bioreactor. The liquid collected in the base is re-circulated to the top of the trickle bed.

During recirculation a quantity of liquid is diverted to a membrane tank from where it is pumped through a membrane filter and UV disinfection unit into a small internal tank. At this stage the treated water is pumped to irrigation or pumped to a small above-ground external tank if reused for toilet flushing and laundry use.

A small amount of bio-solids build up in the trickle bed and feed tank and is pumped from the system to the sewer or directed to a sub-soil vegetation cell outside the system. Figure 4.11 shows a simple block flow diagram for the system.

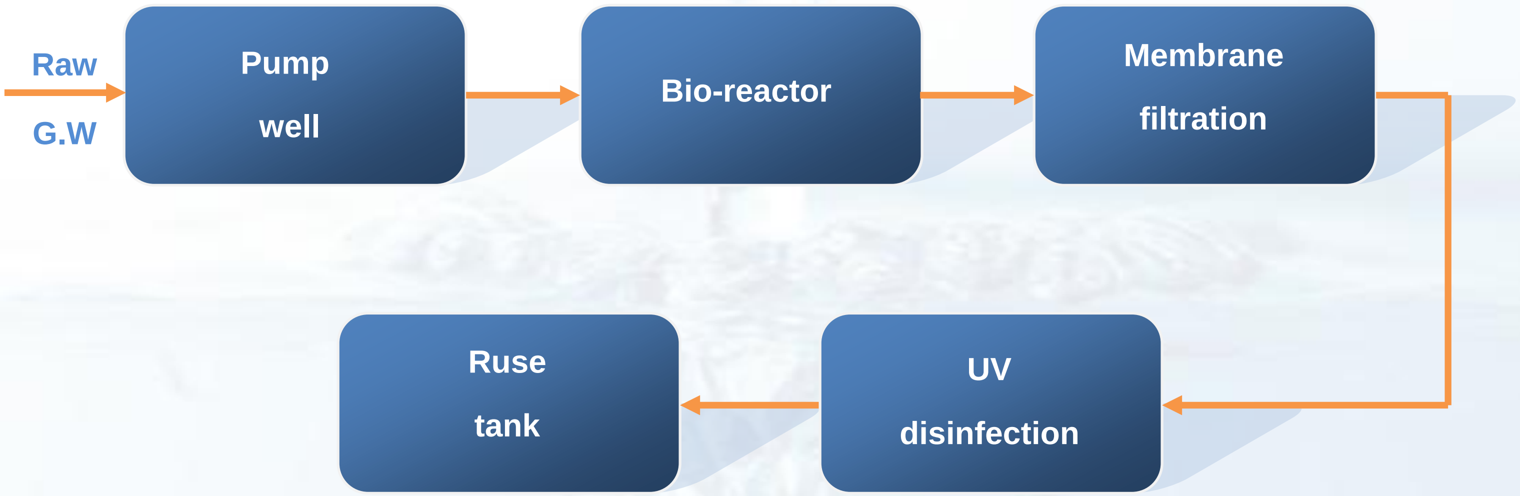
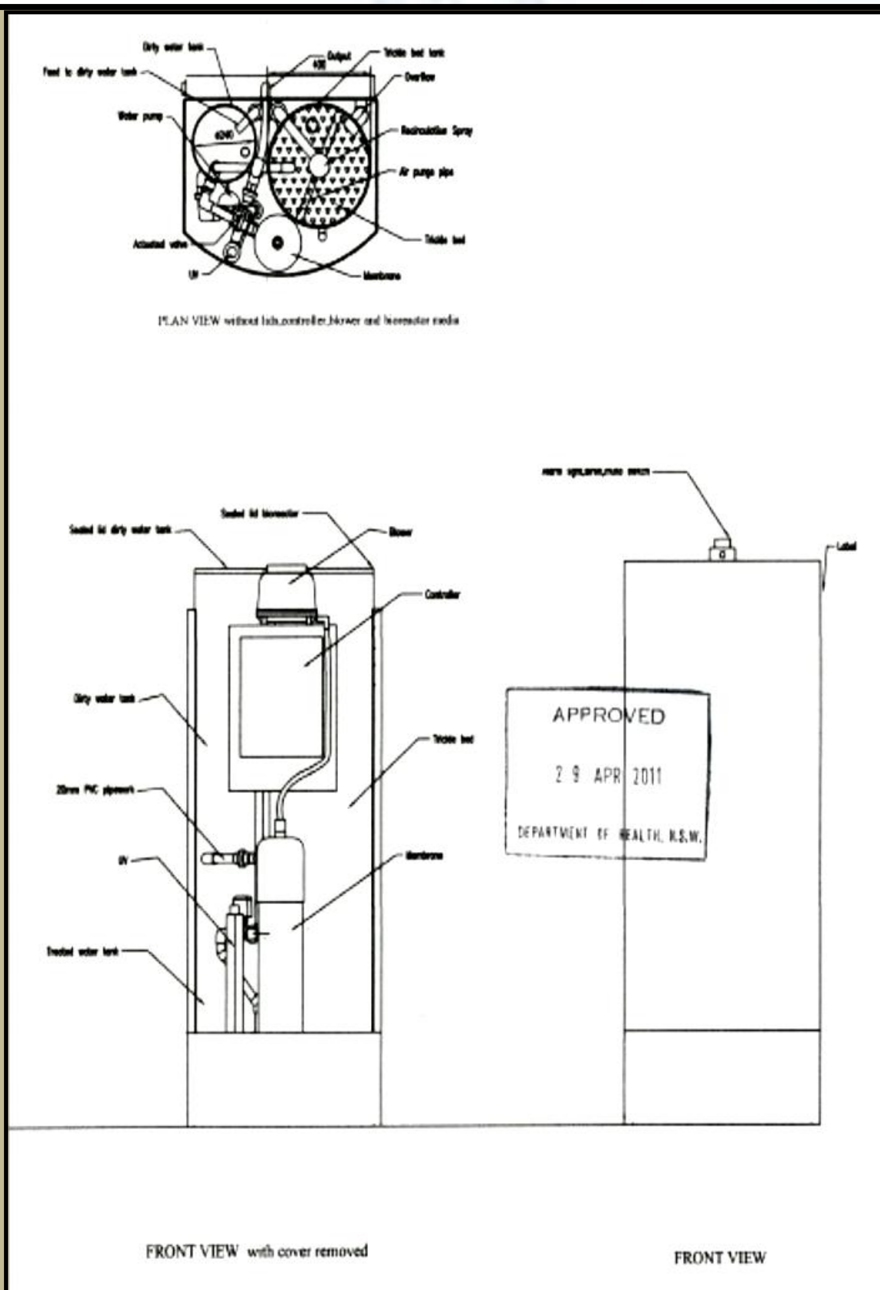


Fig. 4.11: Simple block flow diagram for Aqua Clarus AG 720 GWTS



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**7**									

Fig. 4.12: Aqua Clarus AG 720 GWTS and its evaluation sheet

4.2.7 Aqua Reviva GWTS

This system is designed to treat the grey water from the shower, bath, laundry and basin from a residential dwelling occupied by a maximum of 10 persons (1130 liter/day). The system comprises of the following major components:

1. Grey water collection cell can be sized to suite the usage of the household.

The critical process parameters for the collection cell are:

- Inclusion of an automatic over flow to sewer
- Isolation of the collection cells

2. Treatment cell

Grey water is pumped through a submersible pump to the treatment cells at which the biological process takes place. The treatment cell combines the biological reactions by fixed growth reactor (FGR) technology with enhanced filtration capability.

3. Disinfection cell

This system use Bromine as a chemical disinfectant. Detention, concentration, mixing and time are the main parameters and a minimum of 30 min. retention will be included.

4. Re-use cell

The nature of re-use cell is not specified as it is up to the householder.

Figure 4.13 shows a simple block flow diagram for the system.

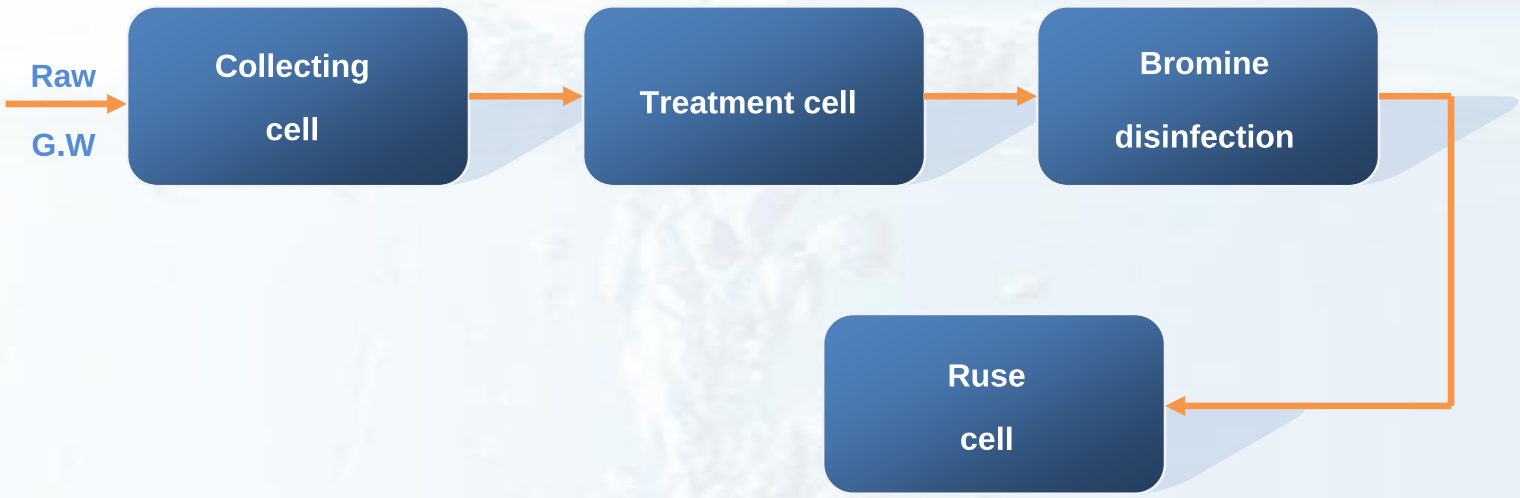
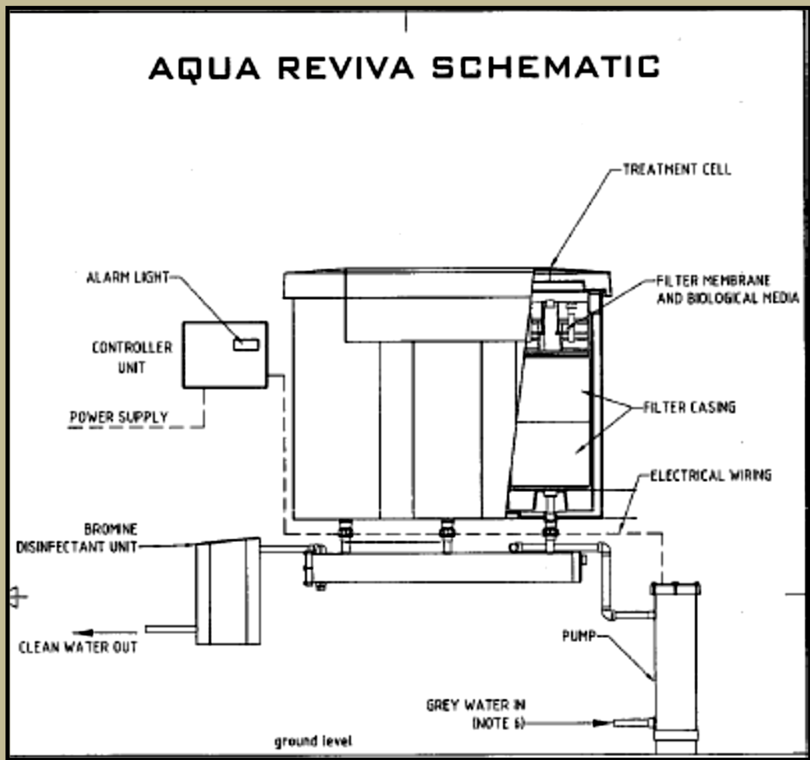


Fig. 4.13: Simple block flow diagram for Aqua Reviva GWTS



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**6.5**									

Fig. 4.14: Aqua Reviva GWTS and its evaluation sheet

3.2.8 Aqua Hytech GWTS

This system is designed for maximum hydraulic rate 800 L/day. Aqua Hytech system uses state of the art hollow fiber ceramic filtration membranes to process all household grey waste water to a standard suitable for reuse for, toilet flushing, washing paths, walls, vehicles, cold water supply for washing machines and garden spray irrigation. Figure 4.15 shows a simple block flow diagram for the system.

The treatment process includes two types of filtration: primary filtration through simple lint and hair strainer, secondary filtration with membrane filter. The collecting tank has an automatic over flow that will discharge direct to sewer in case of reaching its full capacity.

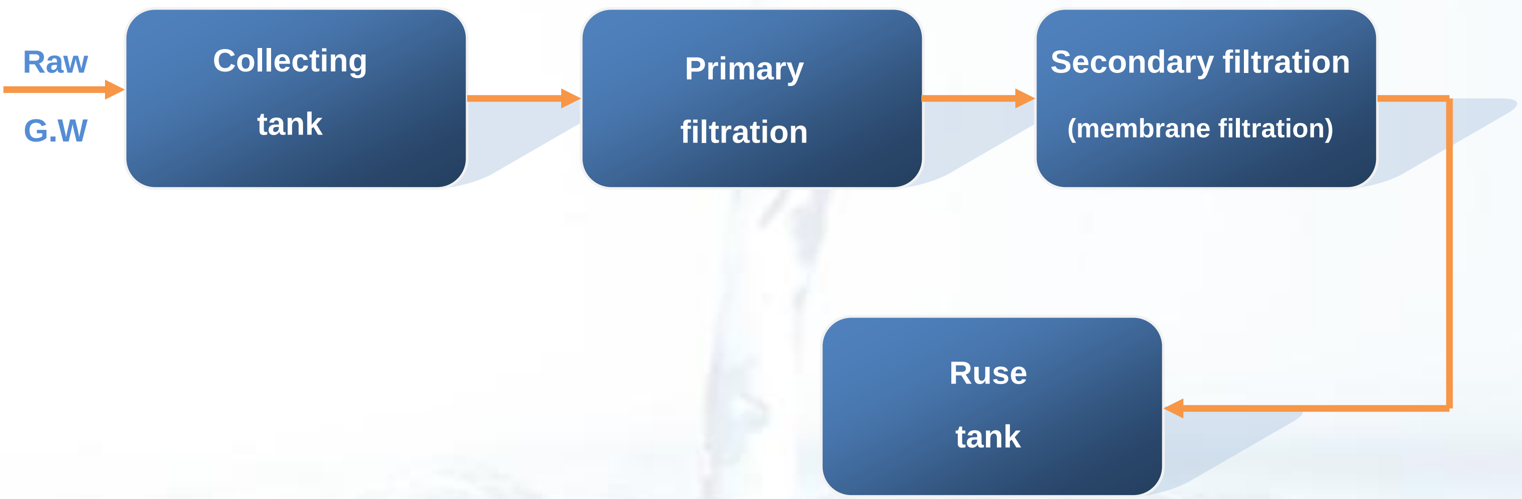
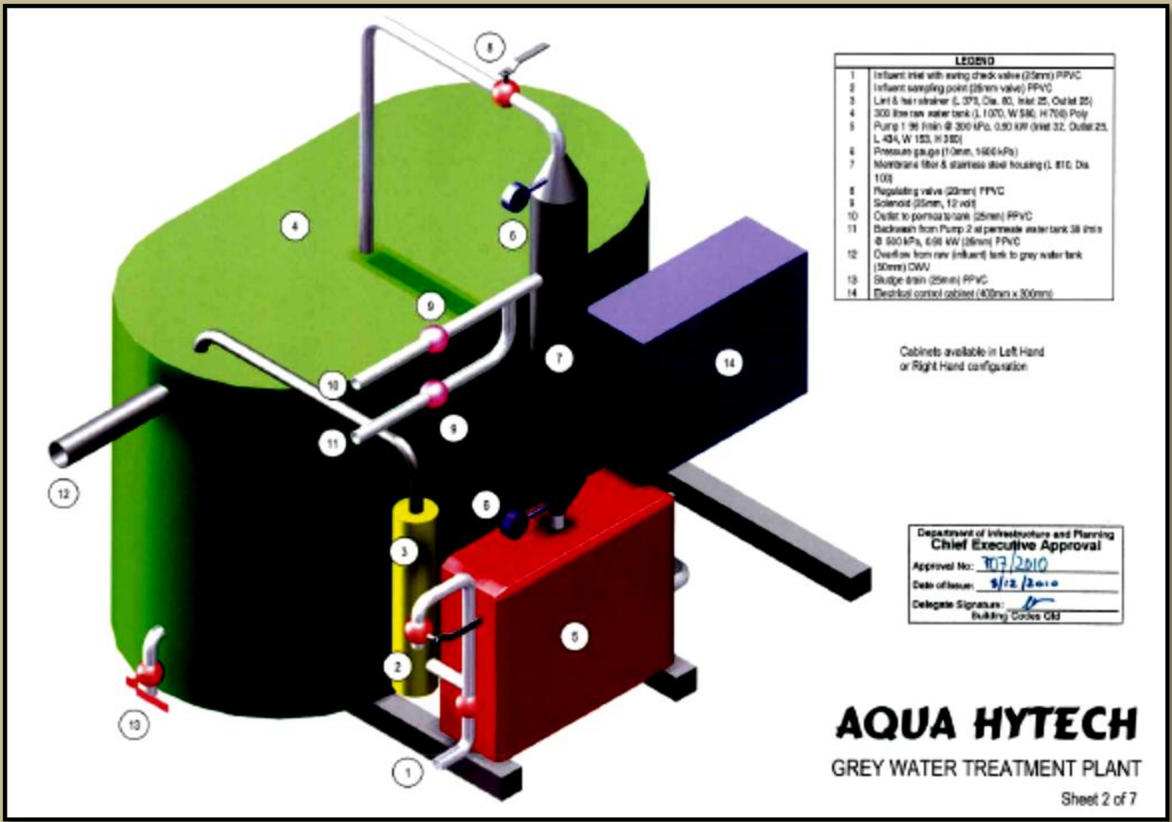


Fig. 4.15: Simple block flow diagram for Aqua Hytech GWTS



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**6.75**									

Fig. 4.16: Aqua Hytech GWTS and its evaluation sheet

3.2.9 Aquacell G10 GWTS

This system is designed for maximum hydraulic rate 14000 L/day. The system comprises of the following major components:

1. Pretreatment screening with minimum 2 mm screen
2. Biological aeration tank
3. Membranes includes flat sheet and ultra filtration
4. Disinfection is achieved with UV disinfection followed by chlorine disinfection

Integrated programmable automatic controller and alarming function systems are used for monitoring the system.

Figure 4.17 shows a simple block flow diagram for the system.

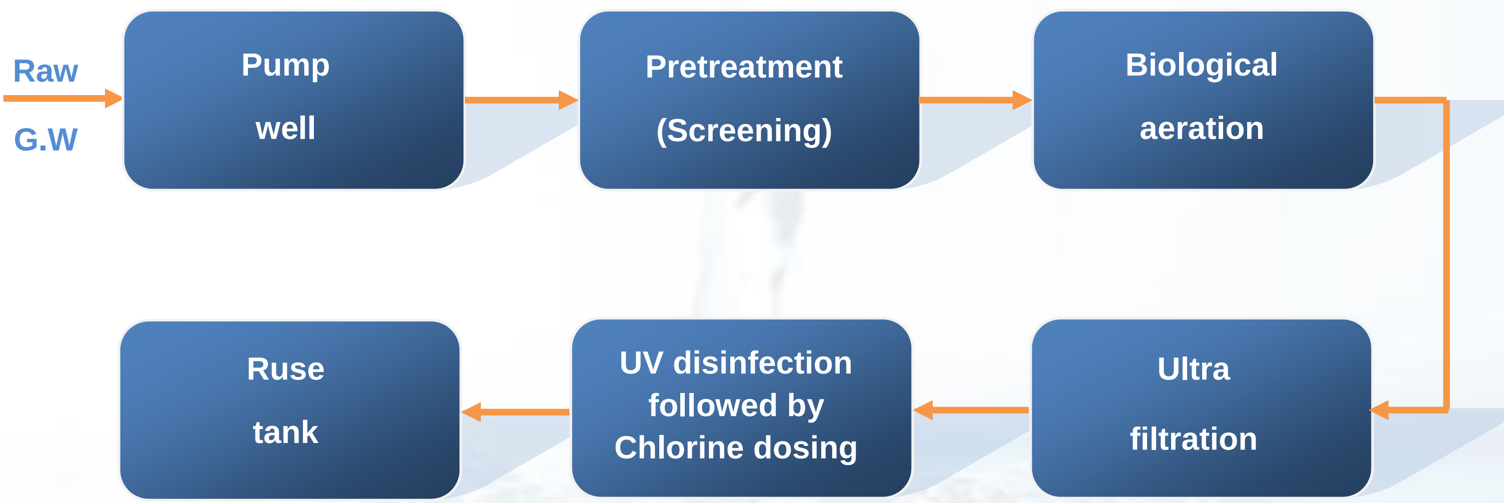
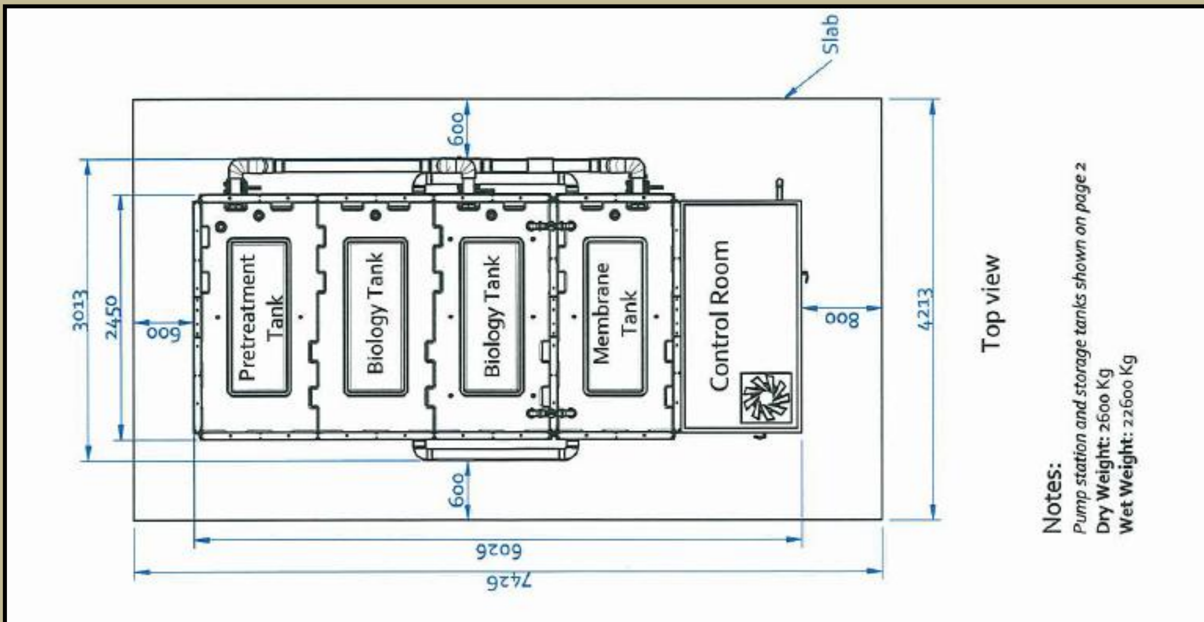


Fig. 4.17: Simple block flow diagram for Aquacell G10 GWTS



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**9.5**									

Fig. 4.18: Aquacell G10 GWTS and its evaluation sheet

3.2.10 H_2O Pure GWTS

This system is designed for maximum hydraulic rate 10000 L/day. The H20 Pure Plus system is a very compact system to install as shown below. Figure 4.19 shows a simple block flow diagram for the system. The majority of the components of our systems are below ground except access lids for primary and pump well tank which is brought up to finished ground level for ease of maintenance and it requires once a year servicing which is a huge cost saving. This system does not need to rely on chemicals or membranes technology to produce advanced secondary quality effluent with nutrient reduction. It is an anaerobic treatment system which does not produce odors even at times when the system is under shock loads period (High volume of Wastewater discharging into our system in a short period of time).

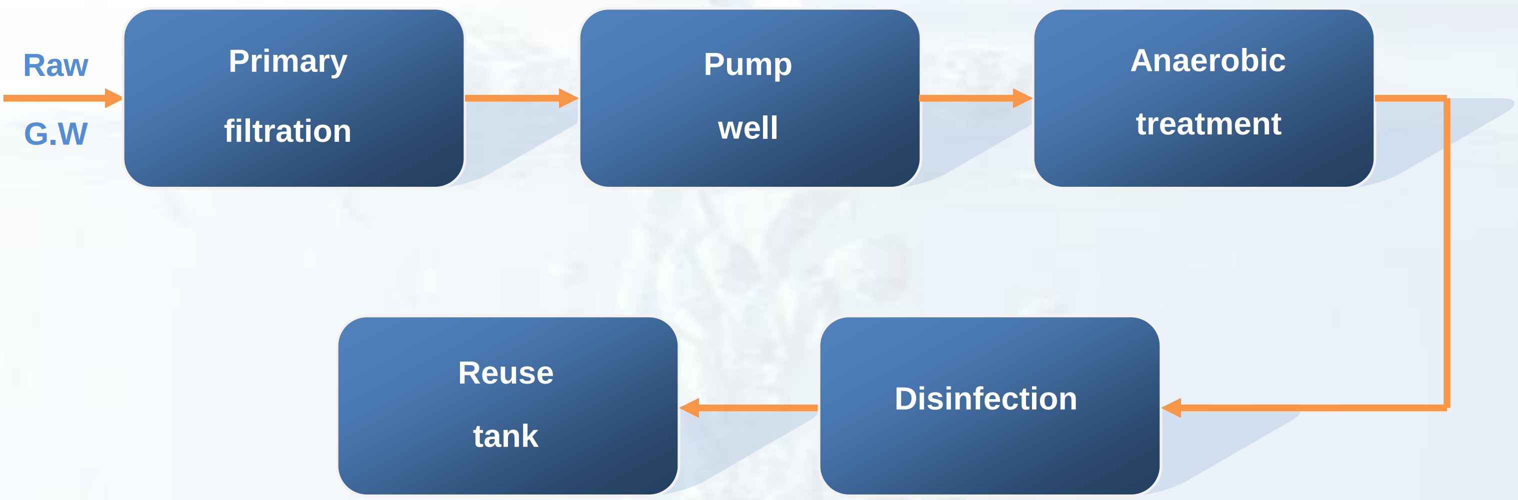
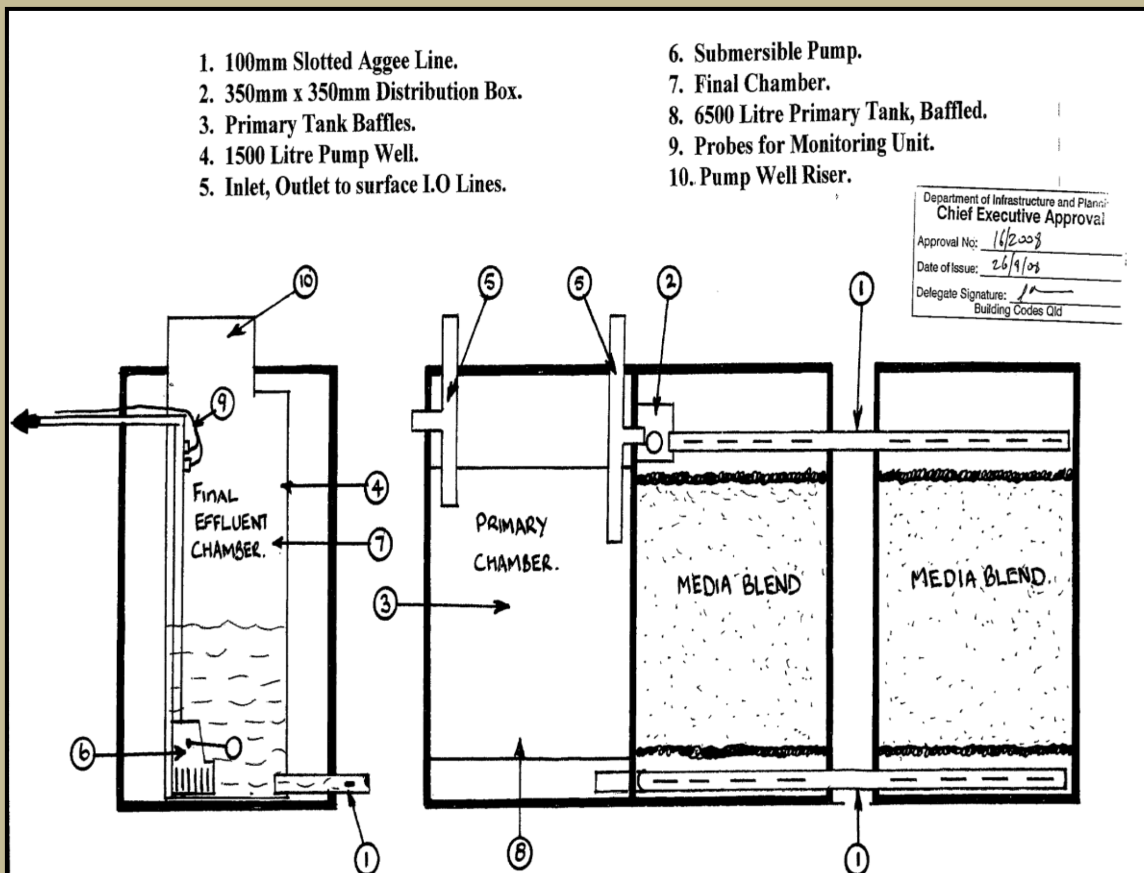


Fig. 4.19: Simple block flow diagram for H2O Pure GWTS



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**10**									

Fig. 4.20: H2O Pure GWTS and its evaluation sheet

4.2.11 Catchment 72OLTM Domestic GWTS

This system is designed to treat the grey water from the shower, bath, basin and laundry (excluding kitchen wastewater) from a domestic dwelling occupied by a maximum of 8 persons (904 liter/day). Figure 4.21 shows a simple block flow diagram for the system. There are 3 main parts included in the system:

Sump – A grey water flow from the dwelling into a sump tank that contains a transfer pump fitted with float level switches and is used to transfer grey water to the settling tank. During the transfer the grey water is dosed with aluminum sulfate (alum) causing the solid contaminants in the grey water to flocculate into large particles that settle to the bottom of the settling tank under gravity.

Settling process - The settling tank has a capacity stores all of the grey water generated during the day, nominally from 7am to 10pm, and allows the flocculated particles to settle out leaving a clear supernatant. At 10pm the system goes into "settling mode". The system is then ready to complete the backwash cycle and by about 7am is ready to receive the grey water from the sump well again.

Filtration cabinet - The filter cabinet houses the filters, chemicals (alum and sodium hypochlorite) used in the process as well as the automated control panel. The ballotini filter acts as a coarse filter protecting the main Active Adsorption Filter (AAF) from contamination from any flocculated particles that didn't settle overnight. The AAF removes from the water all soaps, shampoos and conditioners, toothpastes and other microbiological contaminants. The water passes through a UV disinfection unit, the chlorine dosing unit and then flows into the clean water reuse tank. The whole process is completed using the action of the settling tank discharge pump.

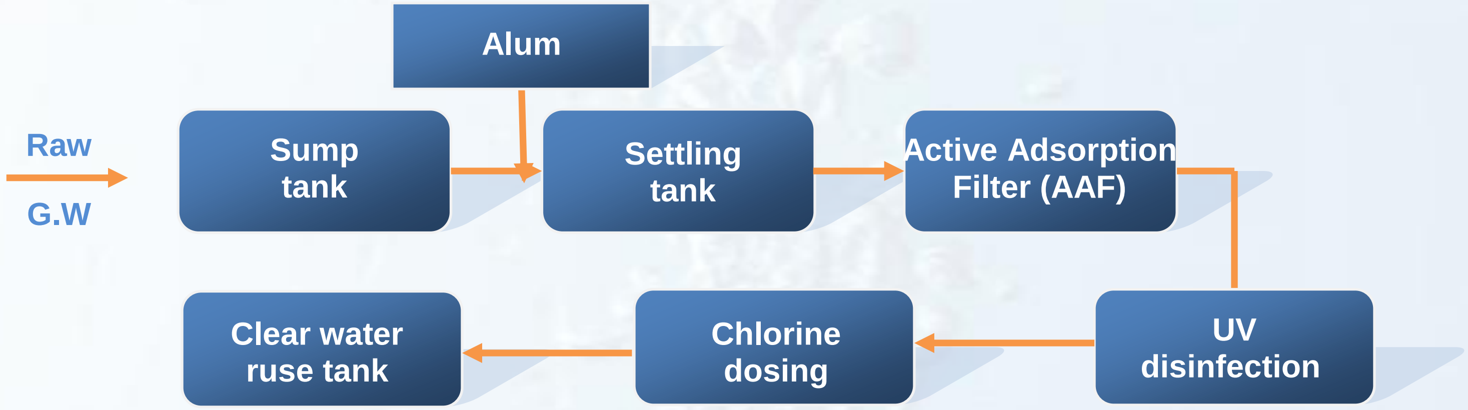
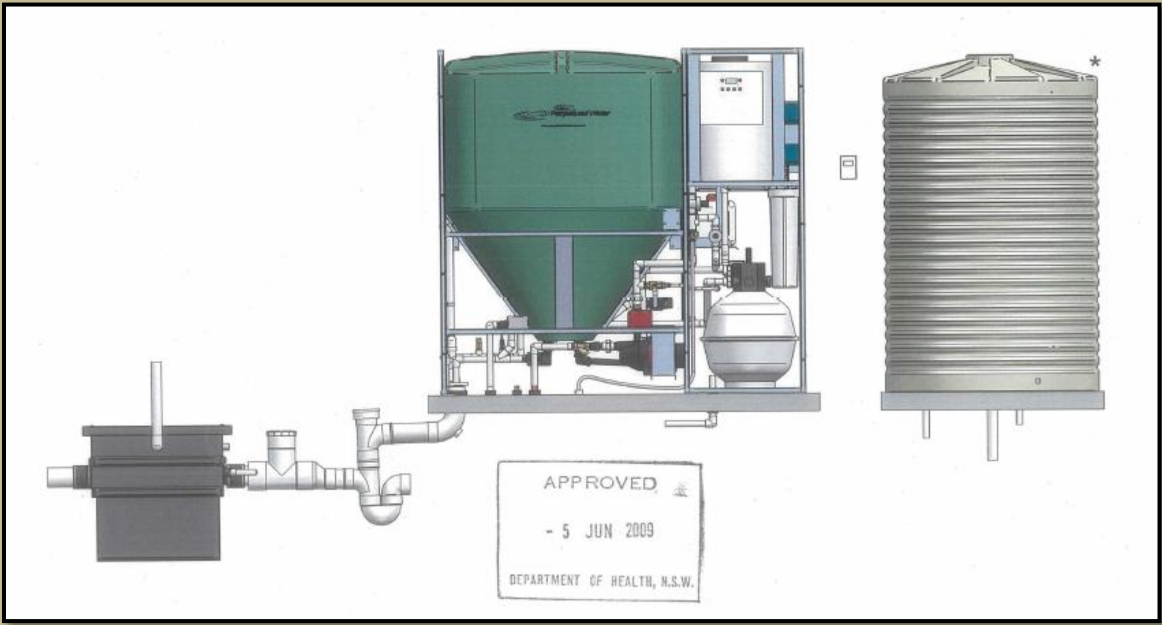


Fig. 4.21: Simple block flow diagram for Catchment 72OLTM Domestic GWTS



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**6**									

Fig. 4.22: Catchment 72OLTM Domestic GWTS and its evaluation sheet

3.2.12 Nature Clear GWTS

This system is designed to treat 2700 L/day. It contains two main tanks; filtration tank and clear pump well having specifications as follows; medium density grade PE as a material of construction, UV established with high stress resistance, an average thickness of 5 mm. Figure 4.23 shows a simple block flow diagram for the system.

The filtration tank must be partially dug into the ground; it should be laid flat on a bed of sand and it should be no longitudinal incline. The filter contains gravel, sand and a medium course pine bark.

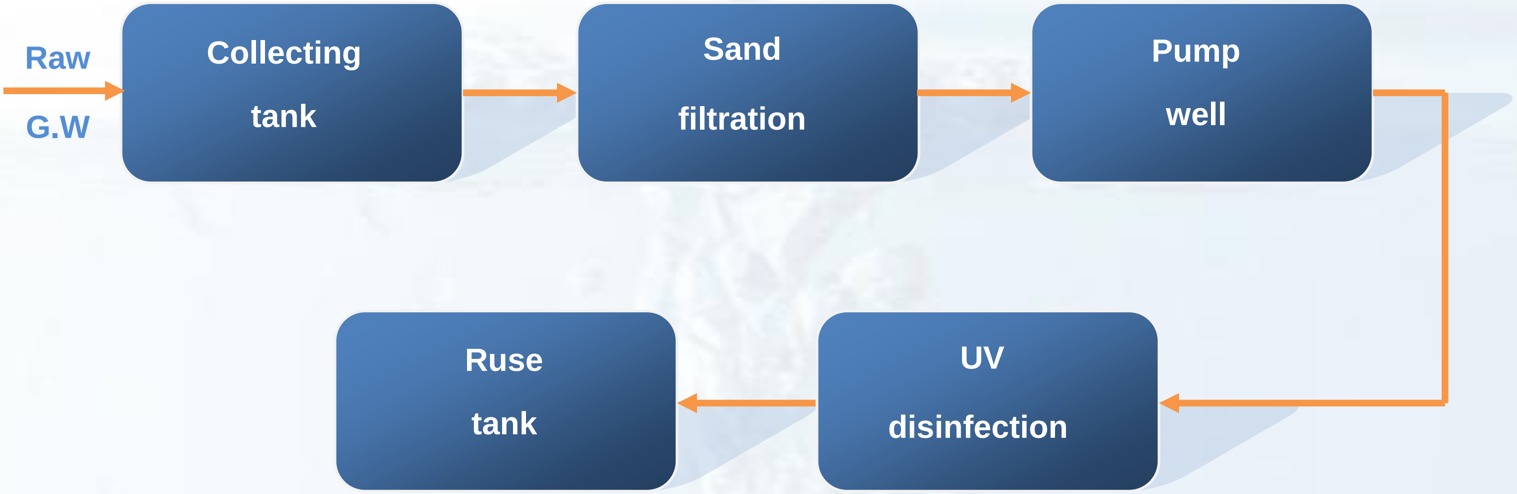
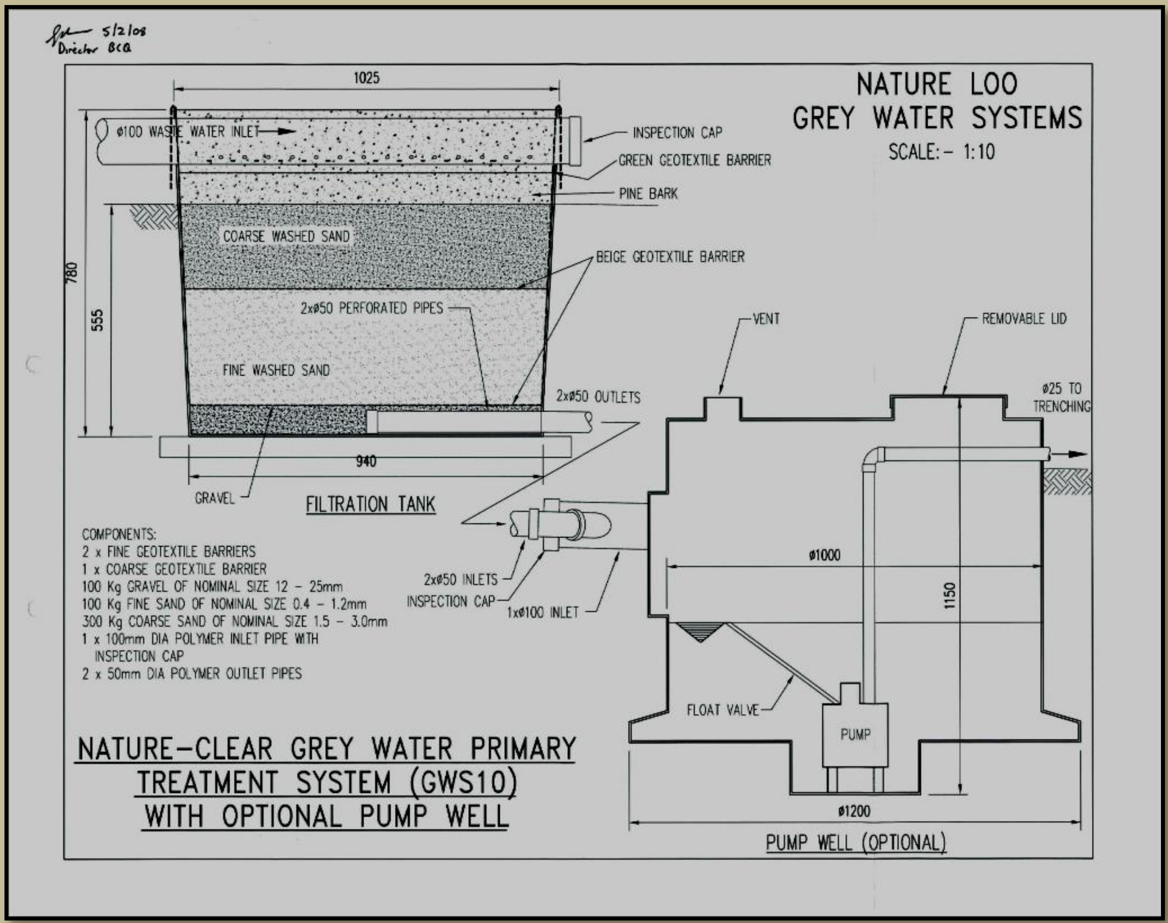


Fig 4.23: Simple block flow diagram for Nature Clear GWTS



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**7**									

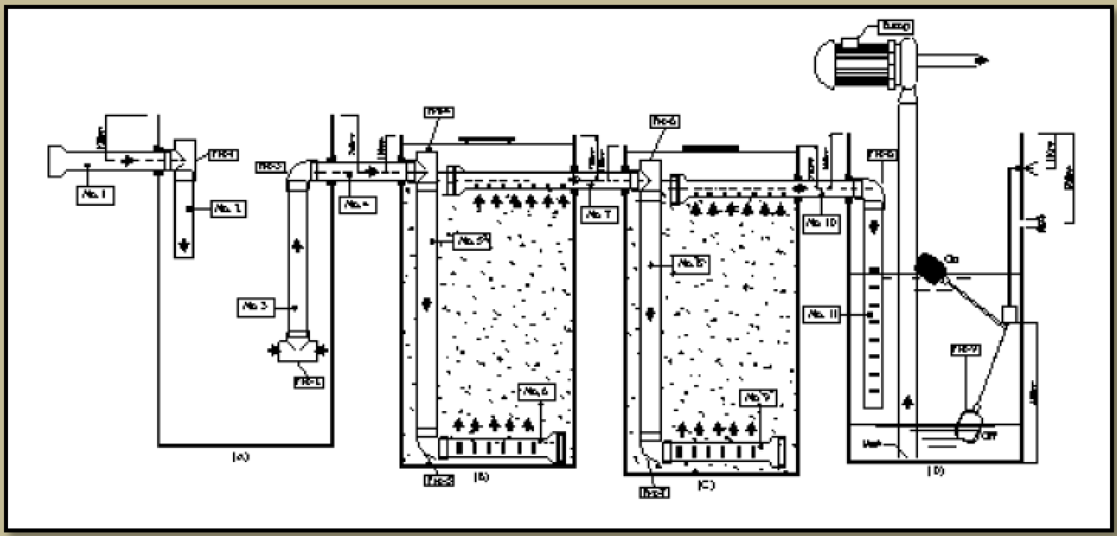
Fig. 4.24: Nature Clear GWTS and its evaluation sheet

4.2.13 The 4 Barrel System

This system treats wastewater from the kitchen and washbasin. Figure 4.25 shows a simple block flow diagram for the system. Four plastic barrels constitute the treatment kit. The four barrels are lined up next to one another and are interconnected with PVC pipes. The first barrel is a grease, oil and solids separator and thus acts as a pre-treatment or primary treatment chamber, where the solid matter from the influent grey water settles and the floating components, such as grease and soap foam, float. This barrel has 200 L capacity with an effective volume of 160 L having a large cover, which can be tightly closed. When the cover is opened, the chamber can be cleared of both floating and settled material. The second and the third barrels are of the same capacity and are filled with shredded plastic.

Once solids and floating material settle in the first barrel, the relatively clear water from the first barrel enters into the bottom of the second barrel. Next, the water from the top of the second barrel enters into the bottom of the third barrel. The water from the top of the third barrel is taken into the fourth. Anaerobic treatment is accomplished in the two middle barrels. Anaerobic bacteria gets established on the plastic surface so that when the grey water passes through the plastics, the bacteria works on breaking down components of the organic material found in the grey water. The last barrel acts as a storage tank for treated grey water. Within one to two days of resident time in the treatment kit, the influent grey water is expected to undergo a treatment level equivalent to between primary and secondary treatment.

Fig. 4.25: Simple block flow diagram for The 4 Barrel System



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**3.25**									

Fig. 4.26: The 4 Barrel System and its evaluation sheet

4.2.14 AquaCycle GWTS

How the AquaCycle® System Works

1. **Pre-Filtration:** Larger particles like hair and textile fragments are collected. The filter is automatically flushed by a special spray pump - sediments are washed away into the main wastewater drain.

2. **Two-fold biological treatment:** In the main and secondary recycling chambers the dirt particles are decomposed by bio-cultures. The water is pumped to the next station in three hour intervals.

3. **Sediment disposal:** The organic sediments which are produced during the recycling process are regularly sucked out from the chambers and diverted into the wastewater drain.

4. **UV-Sterilisation:** On the way to the storage chamber the recycled water flows through a UV-light lamp which disinfects it. The high quality of the water now conforms to the E.U. Directive for Recreational Water.

5. **Automatic freshwater feed on demand:** freshwater will automatically be fed into this chamber to ensure there is enough supply for flushing toilets. Figure 3.27 shows a simple block flow diagram for the system.

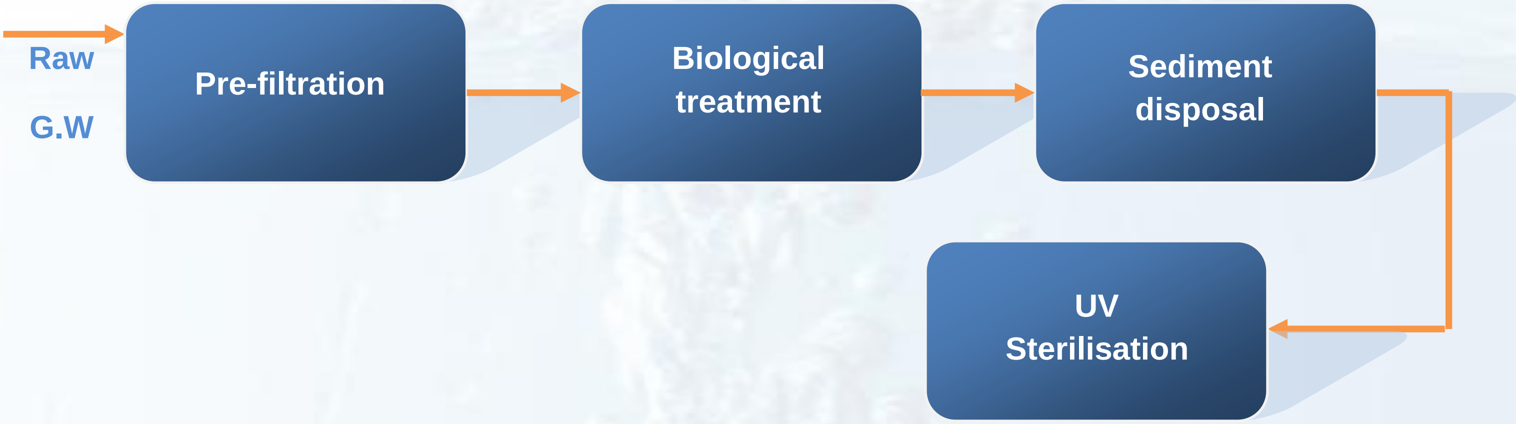
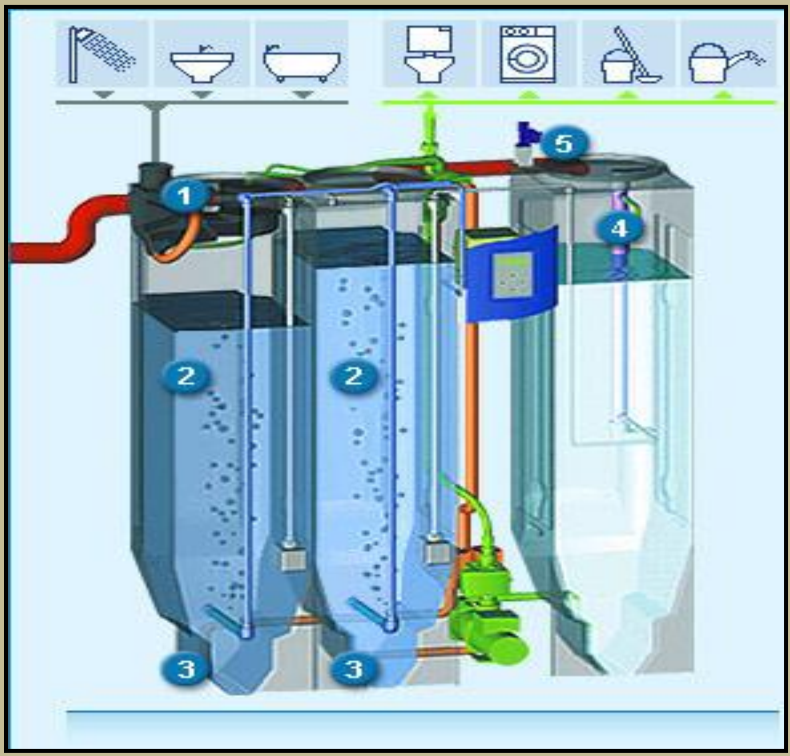


Fig. 4.27: Simple block flow diagram for AquaCycle GWTS

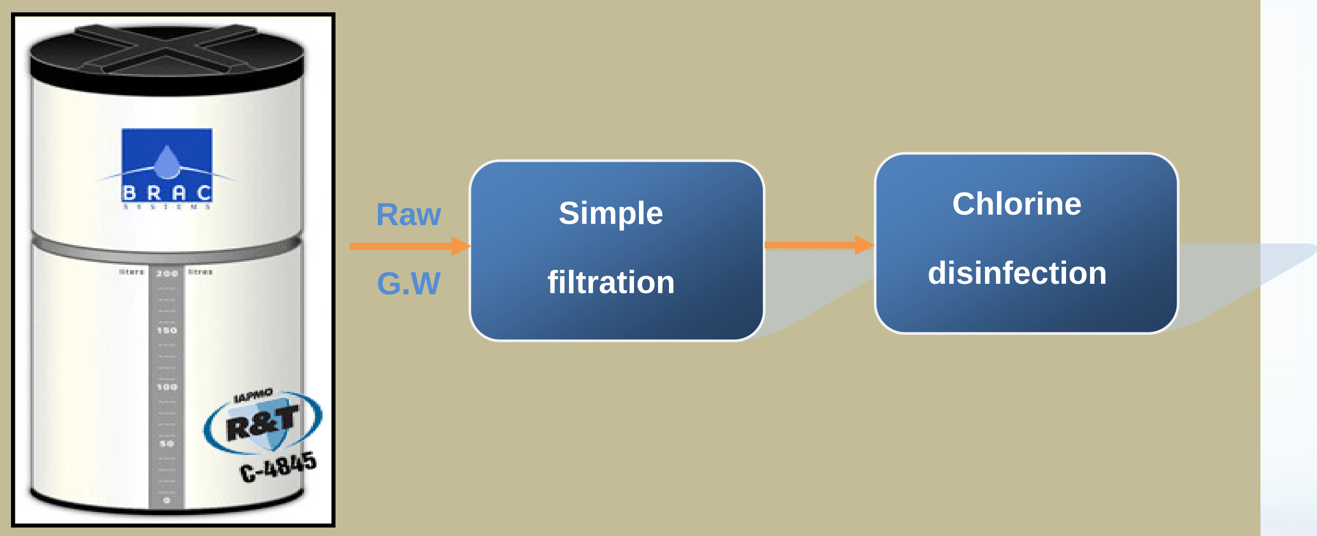


Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**8.5**									

Fig. 4.28: AquaCycle GWTS and its evaluation sheet

4.2.15 BRAC 450 GWTS

Brac system requires connection to your home's sewer system directly. This system includes simple filtration and chlorine disinfection that occurs in the two parts of the system. To avoid damage to the fresh water inlet valve during transport, float can be used to control the fresh water inlet valve, insuring that a minimum amount of water is always in the system, allowing the system to operate without running the pump dry. The float level only controls the minimum level of water in the tank. If your water usage habits always provide more than the minimum level of water, the fresh water inlet system may never need to open during normal operation.



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**8**									

Fig. 4.29: BRAC 450 GWTS and its evaluation sheet

4.2.16 Rotating Biological Contactors

Rotating biological contactors (RBC) are a conventional aerobic biological wastewater treatment unit. Conventional biological treatment means activated sludge systems and fixed film systems such as trickling filters, or RBC. The advantage of all these systems is that they are compact and that they efficiently reduce organic matter. However, they are high-tech and generally require skilled staff for construction as well as for operation.

A series of circular lightweight rotating discs are mounted on a shaft through which wastewater flows. The partially submerged discs rotate through the wastewater slowly. The disks are most commonly made of high-density plastic sheets and are usually ridged, corrugated, or lattice-like to increase the area. The surface of the disks provides an attachment site for bacteria and as the discs rotate, a film of biomass grows on their surfaces. This biofilm is alternately exposed to either the air or the wastewater as it rotates. The oxygen necessary for the growth of these microorganisms is obtained by adsorption from the air as the biofilm on the disk is rotated out of the liquid. As the biofilm passes through the liquid phase, nutrients and *organic* pollutants are taken up. All oxygen, nutrients and organic pollutants are necessary for the growth of the microorganism and the conversion of the organic matter to CO_2. Nitrogen is removed by nitrification and subsequent denitrification transforming it to gaseous N_2, which is released to the air. The process is optimized by adjusting the speed of rotation and the depth of submergence. In some designs, air is added to the bottom of the tank to provide additional oxygen in case of high-strength influents.

Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**7.75**									

Fig. 4.30: Rotating Biological Contactors and its evaluation sheet

4.2.17 Ozzi Kleen modl GTSIO GWTS

This system is designed to treat all domestic grey water excluding kitchen wastewater from a maximum of 10 persons (1130 liter/day). The system is assembled in a single cylindrical vertical axis type roto molded polyethylene tank. Figure 3.31 shows a simple block flow diagram for the system. The treatment process within this system involves an aeration process consisting of three main cycles:

- ***Aeration cycle:*** the incoming grey water is aerated and oxygenated with air supplied by the air blower. The aeration cycle is maintained for a period of time to allow for a biological breakdown of the organic waste and establish an activated sludge within the wastewater,
- ***Settling cycle:*** After the aeration cycle, aeration ceases for approximately 60 minutes, allowing the activated sludge to settle to the bottom of the aeration tank. A layer of clear effluent is formed at the top of the aeration tank, and
- ***Decanting cycle:*** After a predetermined settling period, a decanting cycle takes place. The decanter device draws off the clear effluent from the top of the aeration tank. The decanting cycle continues until either the liquid level in the tank reaches the minimum level or the process timer activates the system back into the aeration cycle.

While decanting the effluent is chlorinated and stored in a 520 liters effluent storage tank to ensure sufficient chlorine contact time prior to discharge. The operation of the submersible pump within the storage tank is controlled by a pressure switch and three float switches. When there is a water demand from the services within the dwelling, the pressure switch senses the pressure drop and turns on the pump.

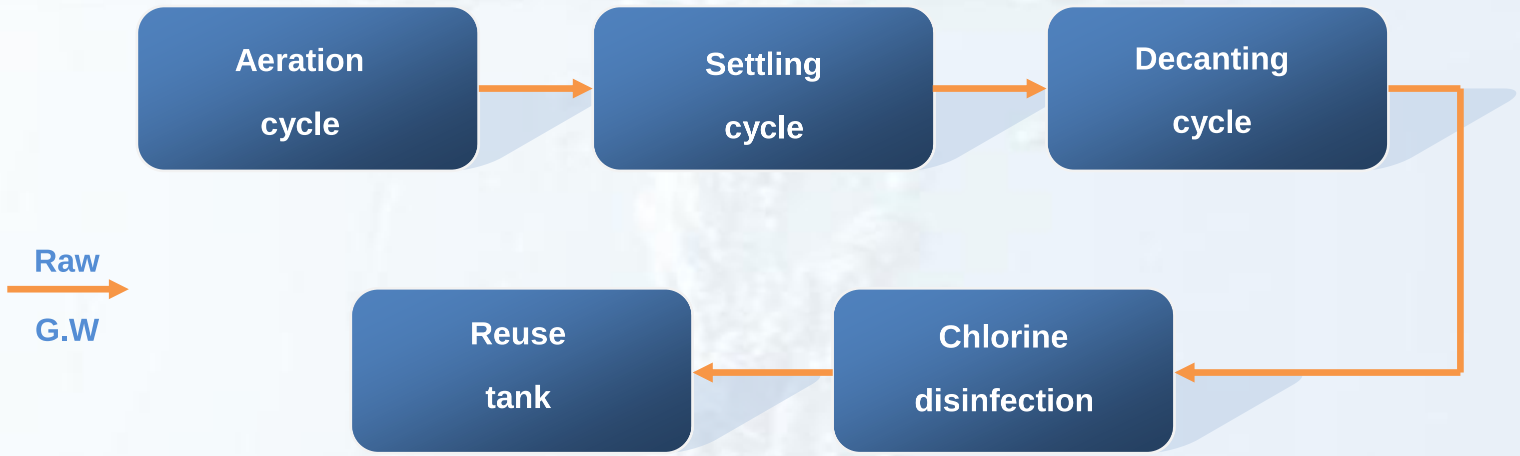
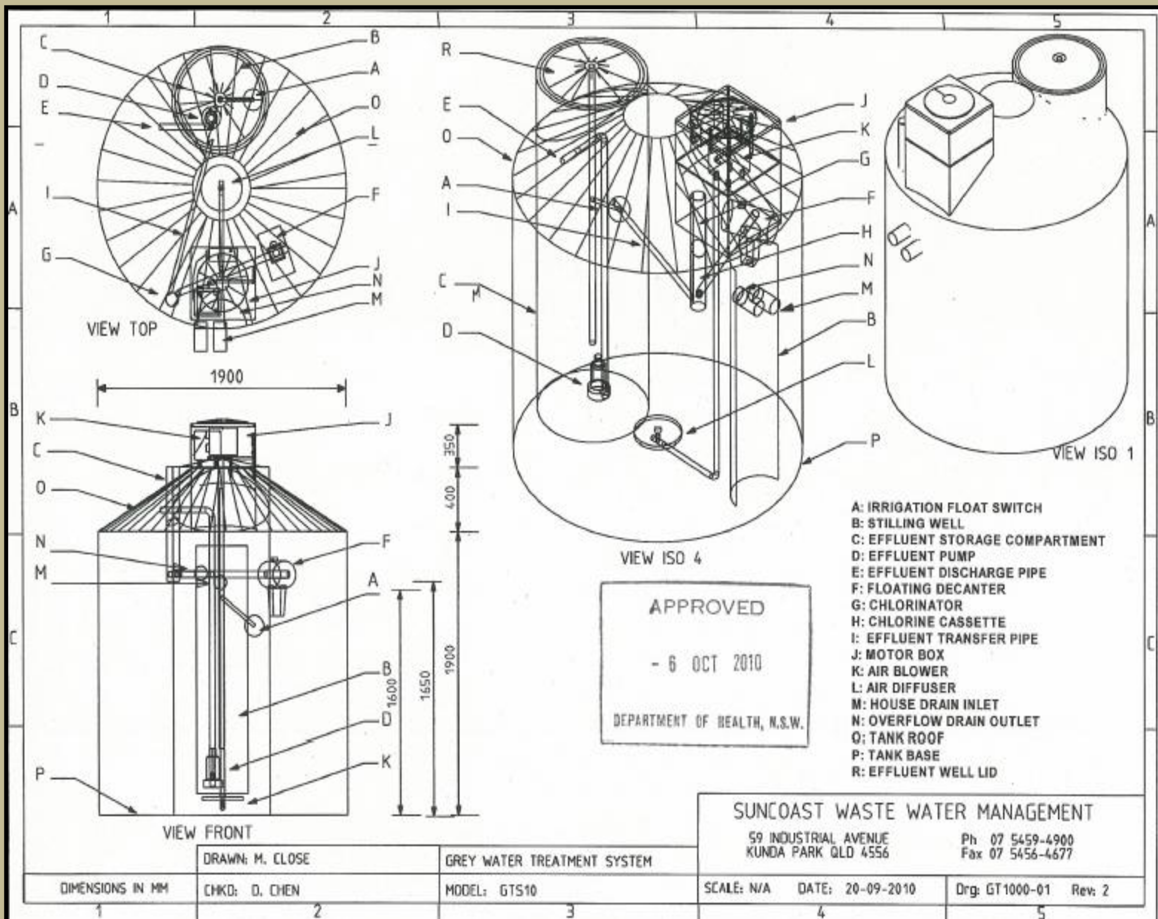


Fig. 4.31: Simple block flow diagram for Ozzi Kleen modl GTSIO



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**6.75**									

Fig. 4.32: Ozzi Kleen model GTSIO GWTS and its evaluation sheet

4.2.18 Rootzone model G-700 GWTS

This system is designed to treat the grey water from a residential dwelling occupied by a maximum of 8 persons (904 liter/day). Figure 3.33 shows a simple block flow diagram for the system. The treatment process could be explained as follows:

- Where the vertical distance between the grey water outlet pipe from the dwelling and the top of the reed bed filter is less than half a meter, the raw grey water is collected in a pump well and then pumped into the distribution pipe at the top of the vertical flow reed bed filter. On a sloping site raw grey water flows directly from the dwelling to the reed bed filter.
- Grey water trickles vertical through the filter media into the gravel storage area below.
- At the base of the gravel the treated effluent flows into the irrigation pump well from where the effluent is pumped to an external UV disinfection unit and then to the dwelling for internal reuse and/or to a land application system for irrigation. Disinfection is not required for sub-surface irrigation.

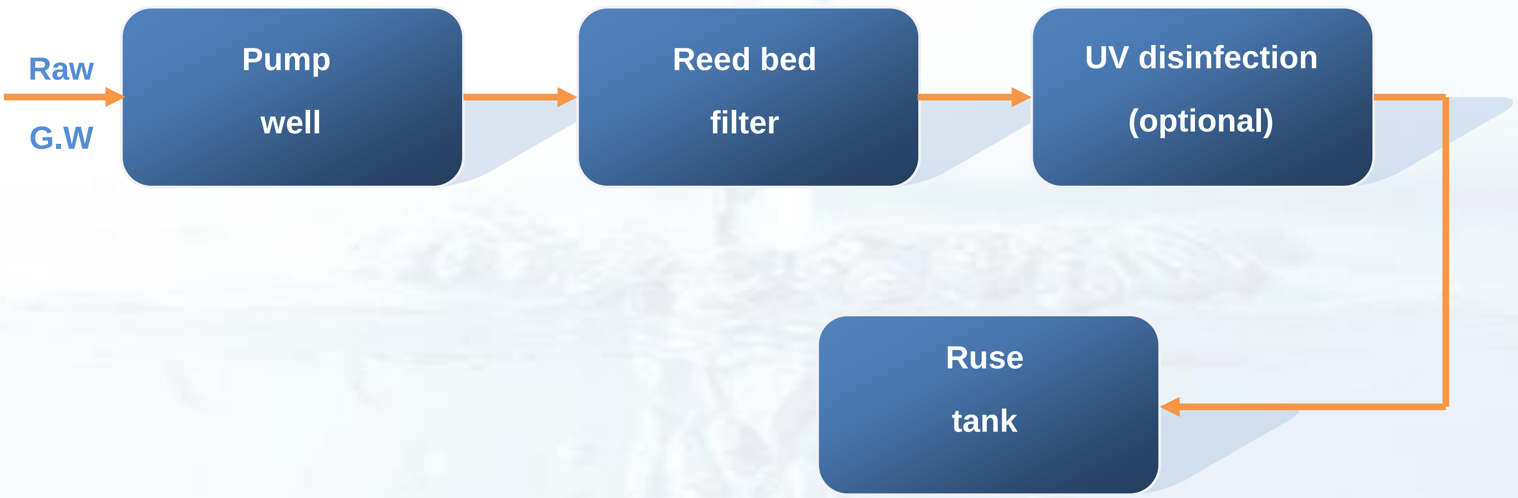
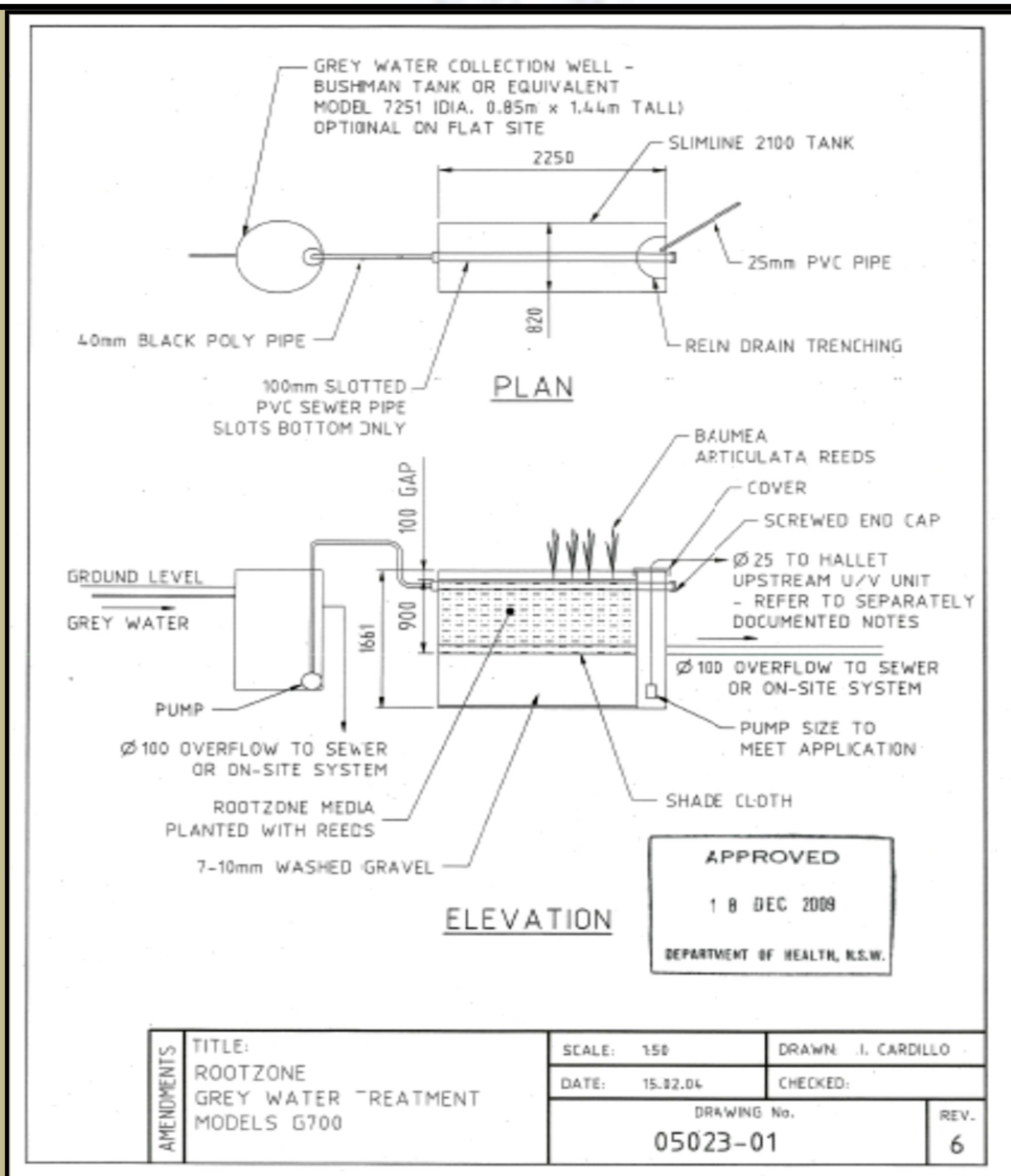


Fig. 4.33: Simple block flow diagram for Rootzone model G-700



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	6.75									

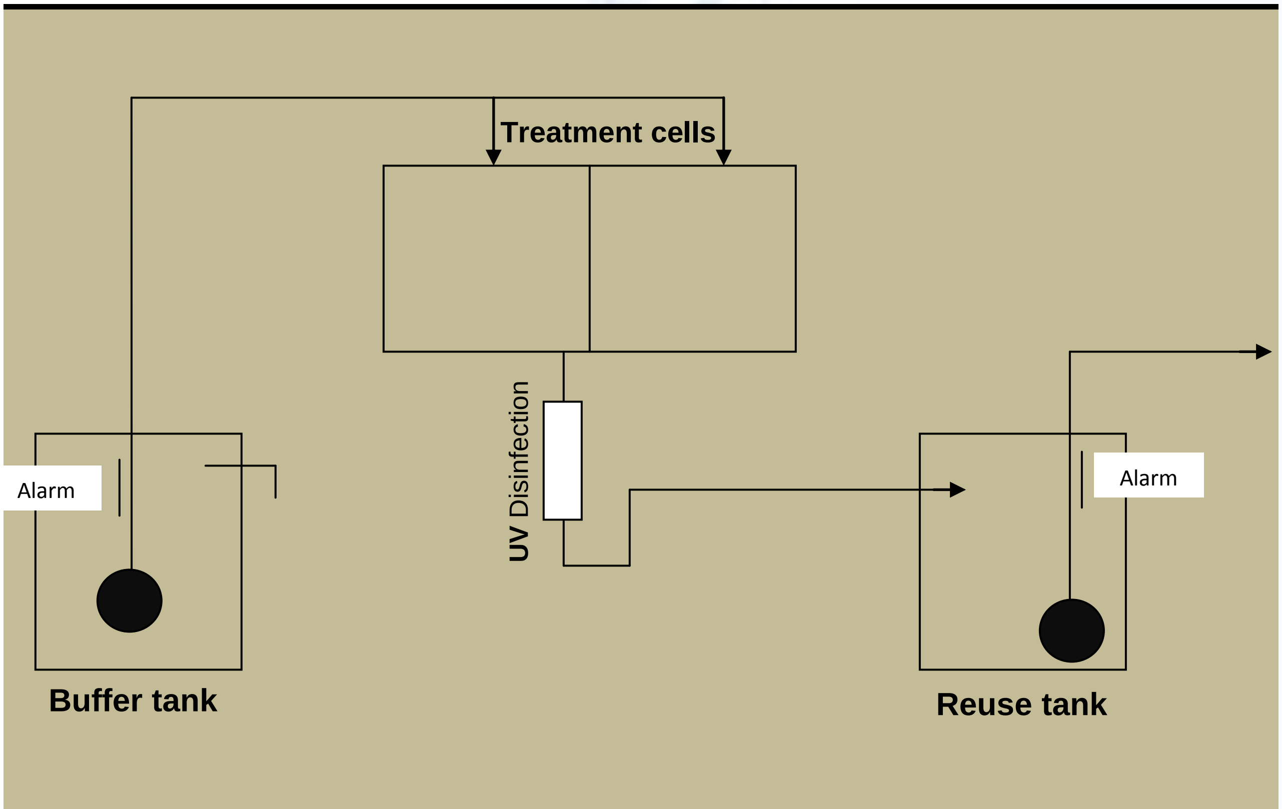
Fig. 4.34: Rootzone model G-700 GWTS and its evaluation sheet

4.2.19 Aqua reuses domestic GWTS

This system is designed to treat the grey water from the shower, bath, laundry and basin from a residential dwelling occupied by a maximum of 10 persons (1130 liter/day). Figure 3.35 shows a simple block flow diagram for the system. The components of the system could be summarized as follows:

- **Underground buffer tank** – This tank receives the grey water and absorbs the hydraulic load from impacting on the filter beds located in the serious of cells. A submersible pump located in the buffer tank is fitted with a high level alarm float switch to indicate a pump failure. The buffer tank is fitted with an overflow pipe connected to the sewerage system.
- **Process rack** - The process rack comprises four identical process columns, which share the waste water delivered from the buffer tank. Each column consists of a stack of four process cells and a storage cell stacked onto each other enabling the wastewater to feed through the column by gravitation. Each cell is a matrix of filter clothes, peat and earthworms, which slows the wastewater flow down to enable the living ecosystem to consume the organic matter in the wastewater. The whole treatment process within the cells takes about 15 hours. The treated effluent is collected in the base storage cell and after passing through the UV disinfection unit is directed to the reuse effluent storage tank.
- **Reuse effluent storage tank** – This tank receives the treated effluent for reuse for toilet flushing, cold water supply to the washing machine or garden irrigation. The submersible pump is fitted with a high and low level alarm float switches to indicate filter blockage, pump failure or lack of grey water flow. The effluent storage tank is fitted with an overflow pipe back to the buffer tank.

Fig. 4.35: Simple block flow diagram for Aqua reuses domestic GWTS



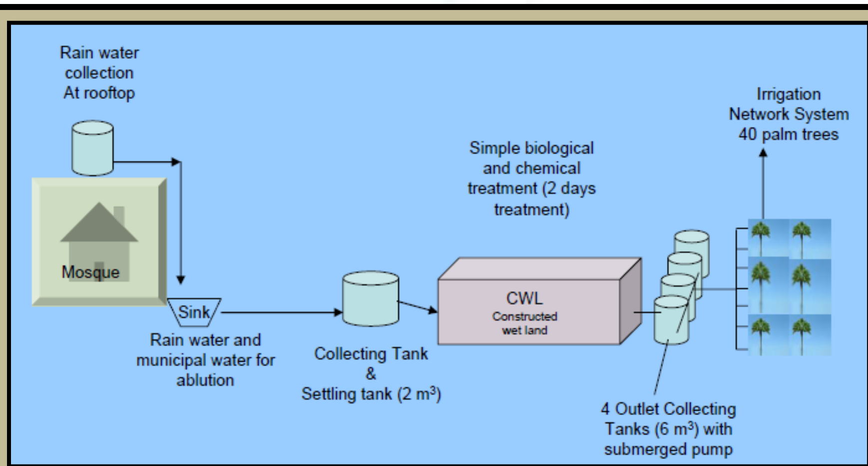
Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**6.75**									

Fig. 4.36: Aqua reuses domestic GWTS and its evaluation sheet

4.2.20 Constructed Wet Lands CWL

Constructed Wet Lands (CWL) is a relatively new technology in Jordan. CWL was introduced as a replacement for the two-tank system for the treatment of gray water. Treatment processes in CWL systems include simple filtration, chemical precipitation, volatilization, oxidation and both aerobic and non-aerobic decomposition as shown in figure 3.37.

Fig. 4.37: Simple block flow diagram for Constructed Wet Lands CWL



Item	Ranking points									
	1	2	3	4	5	6	7	8	9	10
Capacity										
Operation										
Running										
Maintenance										
Overall Ranking	**6.75**									

Fig. 4.38: Constructed Wet Lands CWL and its evaluation sheet

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