NHS National Services Scotland

Scottish Health Technical Memorandum 04-02

The control of *Legionella*, hygiene, 'safe' hot water, cold water and drinking water systems

Emerging technologies

Part C: Grey Water Recovery

Health Facilities Scotland
Engineering and Environment

July 2015

Contents

Disclaimer

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Acknowledgements

This Scottish Health Technical Memorandum (SHTM) was originally produced as a Research Paper at the instigation of the National Water Services Advisory Group.

It was felt that it merited a higher profile and accessibility for NHS Boards and designers and has been converted into SHTM format. Health Facilities Scotland would like to thank the Group for their encouragement and contributions to its publication.

Preface

About Scottish Health Technical Memoranda

Engineering Scottish Health Technical Memoranda (SHTMs) give comprehensive advice and guidance on the design, installation and operation of specialised building and engineering technology used in the delivery of healthcare.

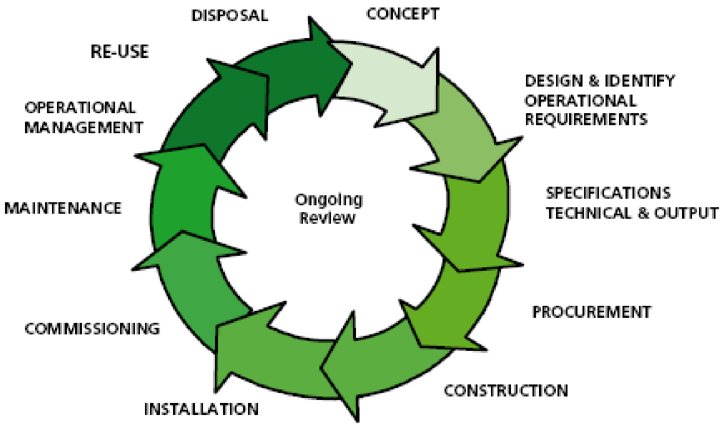
The focus of SHTM guidance remains on healthcare-specific elements of standards, policies and up-to-date established best practice. They are applicable to new and existing sites, and are for use at various stages during the whole building lifecycle: Healthcare providers have a duty of care to ensure that appropriate engineering governance arrangements are in place and are managed effectively. The Engineering Scottish Health Technical Memorandum series provides best practice engineering standards and policy to enable management of this duty of care.

It is not the intention within this suite of documents to repeat unnecessarily international or European standards, industry standards or UK Government legislation. Where appropriate, these will be referenced.

Healthcare-specific technical engineering guidance is a vital tool in the safe and efficient operation of healthcare facilities. Scottish Health Technical Memorandum guidance is the main source of specific healthcare-related guidance for estates and facilities professionals.

The core suite of eight subject areas provides access to guidance which:

- is more streamlined and accessible;
- encapsulates the latest standards and best practice in healthcare engineering;
- provides a structured reference for healthcare engineering.



Healthcare building life-cycle

Structure of the Scottish Health Technical Memorandum suite

The series of engineering-specific guidance contains a suite of eight core subjects:

Scottish Health Technical Memorandum 00: Policies and principles (applicable to all Scottish Health Technical Memoranda in this series)

Scottish Health Technical Memorandum 01: Decontamination

Scottish Health Technical Memorandum 02: Medical gases

Scottish Health Technical Memorandum 03: Heating and ventilation systems

Scottish Health Technical Memorandum 04: Water systems

Scottish Health Technical Memorandum 05: Reserved for future use

Scottish Health Technical Memorandum 06: Electrical services

Scottish Health Technical Memorandum 07: Environment and sustainability

Scottish Health Technical Memorandum 08: Specialist services

Some subject areas may be further developed into topics shown as -01, -02 etc and further referenced into Parts A, B etc.

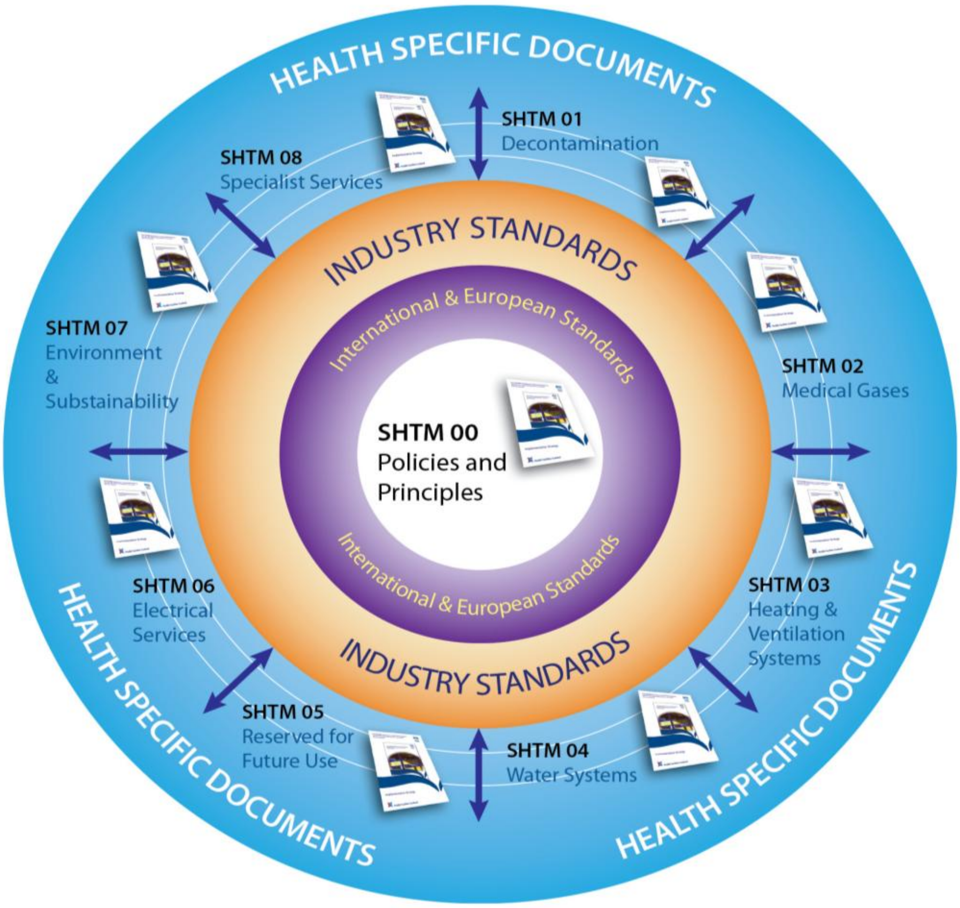
Example: Scottish Health Technical Memorandum 06-02 Part A will represent: Electrical safety guidance for low voltage systems

In a similar way Scottish Health Technical Memorandum 07-02 will simply represent: Environment and Sustainability – $EnCO_2de$.

All Scottish Health Technical Memoranda are supported by the initial document Scottish Health Technical Memorandum 00 which embraces the management and operational policies from previous documents and explores risk management issues.

Some variation in style and structure is reflected by the topic and approach of the different review working groups.

Health Facilities Scotland wishes to acknowledge the contribution made by professional bodies, engineering consultants, healthcare specialists and NHS staff who have contributed to the review.



Engineering guidance structure

Executive summary

Background information

The Building Research Establishment Environmental Assessment Method (BREEAM) rating of buildings awards credits which can be gained from reducing carbon emissions and, to that end, encourages incorporation of systems and controls making use of emerging technologies such as Grey Water recovery. To assess healthcare buildings a rating system has been created, entitled 'BREEAM Healthcare XB'. This credit-based self-assessment tool replaces and improves upon the former NHS Environmental Assessment Tool (NEAT) that was used previously for existing sites. BREEAM Healthcare XB has been endorsed by all health authorities within the UK, and can be used for both public and private health developments. It applies to all buildings that contain medical facilities.

There is, however, the temptation to seek credits awarded according to performance and incorporation of technologies seen to reduce carbon emissions yet having the potential to create other problems relating to control of infection. SHTM 04-01 Part A warns against taking such decisions without due consideration of the issues or the likely payback for the capital expenditure and revenue implications. This SHTM attempts to set out the relevant facts with exemplars to inform decisions.

Note: The information contained in this SHTM is equally applicable to both new and existing sites.

1. Introduction

Background information

Note: Under no circumstances should Grey Water recovery systems be used in areas treating immunocompromised patients. By definition, these patients are extremely sensitive to any pathogens. Whilst a properly functioning Grey Water recovery system used for toilet flushing may be unlikely to increase the concentration of pathogens, reduced system performance or failure introduces an unacceptable risk to these patients.

1.1 Health Facilities Scotland had identified a need for national research into the implications of using Grey Water recovery for toilet flushing as a means of conserving water. There is a growing need to balance existing water supplies with growing water demand. This is the case all over the world even in countries that appear to have adequate water supplies (Water UK position paper, March 2007).

1.2 The increase in population to 7bn world wide and urbanisation in developing countries, coupled with the recent evidence of climate change, may result in insufficient water being available to meet the urban population demand (Ruth *et al*., 2007). Freshwater supplies including surface waters, rivers, and groundwater reservoirs, face increasing pressures from this growing population. Water demand resulting from this population growth is typically met by importing large volumes of treated water, across large distances and at considerable cost, from reservoirs via water treatment plants. At the same time large volumes of Grey Water enter the sewerage system drained from sanitary fittings such as wash hand basins, showers and baths.

Note: As rainwater harvesting and grey water recycling have very different collection, storage and treatment concerns, they have been considered separately in Parts B & C, respectively, of this SHTM.

Purpose of this Scottish Health Technical Memorandum

1.3 This SHTM discusses the implications of using Grey Water recovery as a water conservation measure in a hospital environment.

1.4 Possible uses include:

- toilet flushing;
- garden watering;
- outside cleaning (including vehicles).

1.5 Issues discussed include the design considerations, recycled water quality and decontamination. Current BREEAM advice recommends the use of these recovery technologies whereas SHTM 04-01 Part A discourages their incorporation at this stage as they should not have the potential to put patients at risk from bacteria such as *Legionella, Salmonella, Staphylococcus* and *Pseudomonas.*

1.6 Grey Water recovery could be advantageous in terms of making healthcare facilities more sustainable. However, evidence has suggested that there is a potential infection risk from utilisation of these processes. This SHTM aims to give background information with regard to the potential for recovered Grey Water to harbour microorganisms or chemical contamination that may cause infection within the healthcare environment.

BREEAM Healthcare XB

1.7 The Building Research Establishment Environmental Assessment Method (BREEAM New Construction 2011) rating of the building would be improved as there are credits to be gained from the sustainability arising from this technology. To assess healthcare buildings a rating system has been created; entitled 'BREEAM Healthcare XB'. This is a credit-based self-assessment tool that replaces and improves upon the former NHS Environmental Assessment Tool (NEAT) that was used previously for existing sites.

1.8 BREEAM Healthcare XB has been endorsed by all health authorities within the UK, and can be used for both public and private health developments. It applies to all buildings that contain medical facilities. Credits are awarded according to performance. A set of environmental weightings then enables the credits to be added together to produce a single overall score. The building is then rated on a scale of: 'pass', 'good', 'very good', 'excellent' or 'outstanding', and a certificate awarded to the development.

Aims of this SHTM

1.9 The aim of Part C of this SHTM is to investigate the use of Grey Water recovery and its use for toilet flushing, looking specifically at the quality of water and effectiveness of treatment systems.

Garden watering and vehicle washing are also possible applications for healthcare use, but these would have to be assessed in terms of infection control. These applications may not be the only uses for Grey Water recovery, but they are the only ones that have been discussed in any way with reference to water quality standards, and are the only uses of this water described in any detail.

This SHTM therefore concentrates on those aspects for which published water quality standards exist at present but does not preclude the use of such water resources in other systems, providing a full Risk Assessment is carried out beforehand and appropriate measures are built into any design.

2. Grey Water Recovery to Reduce Demand

Water Use in the UK

2.1 Grey Water recovery in the UK represents a large resource which could help reduce the load on the water supply. In 2007 the UK water companies supplied sixteen billion litres of potable water per day and collected and treated ten billion litres of waste water (Water UK position paper March, 2007). 4.52 billion litres were being lost through leakage in the mains (Water UK, 2008), with the remainder being used through day-to-day activities such as manufacturing, leakage in non-water company-owned water systems and, other consumer uses.

2.2 The volume demands on both the supply and the subsequent waste could be reduced by supplementing current water supplies with alternate sources, such as recycled Grey Water for non-potable applications. This would reduce demands on stretched water supplies and reduce the load on drinking water and waste water treatment works.

2.3 In the case of grey water, a percentage of waste water which would normally go to treatment is diverted and reused for flushing (for example). Therefore the volume of grey water that is being reused for flushing reduces the demand from the potable supply by the same volume. That reduction on demand also corresponds in a reduction of volume going to the waste water treatment works, as basically the water is used twice before going to waste.

2.4 Maintaining supplies to meet consumer demand is becoming increasingly difficult. In recent years several water suppliers in the UK have reported a water shortage in the summer months, mainly due to reduced rainfall and population growth. Another factor is the growing number of single person households. Water UK (March 2007) consider typical daily water use for a family of three to be 150 litres, compared to 165 litres per day for a single person. Watermark (2003) suggest that a single person healthcare worker residing on site uses 115-155 litres per day. It can generally be accepted that single person households use more water as a result of the reduced opportunity for sharing water, for example in cooking.

2.5 Daily water usage figures are important for specifying water reuse systems. One of the main considerations will be the size of storage tank required. It is important to note that each individual site is likely to have a different demand profile that needs to be determined before any system design is carried out. Although the above figures from Water UK and Watermark can provide estimated figures, it must be recognized that these figures are averages taken from large samples, and as such cannot be applied to any one building.

2.6 The water industry has taken steps to meet the growing demand. They have reduced the leakage in pipes and in 2007 losses were 30% less than in 1995 (Water UK position paper, March 2007). Also in summer months hose pipe and sprinkler bans come into effect under extreme weather conditions, mainly in England, although in recent years parts of southern Scotland have also been affected.

2.7 In the past there has been no financial incentive for U.K. consumers to conserve water because charges were not based upon the volume used. Water meters can provide an increased incentive to reduce water use as water can then be charged by volume used. The Water UK "Sustainable Water, State of the Water Sector" report (UK Water, 2008), states that over 35% of the UK population have a water meter. However, water meter uptake in Scotland remains at less than 1% of households (www.waterwatchscotland.org).

2.8 Water charges in Scotland are made through the domestic water change which is collected by local authorities. This remains substantially cheaper than the cost of meter installation and monthly billing (www.waterwatchscotland.org). In the case of NHSScotland, water meters are installed in most healthcare facilities.

Note: As water costs increase, Grey Water recycling systems may become more financially viable. However, at the present time, it is difficult to assess viability as this would depend on site-specific factors. These systems certainly become more viable where they are designed into new build properties, or where grant funding is available.

Healthcare Usage

2.9 There is an opportunity in Scotland for the development of water recovery in healthcare environments to reduce demands on the mains water supply. However, this demand must firstly be established to determine if financial savings will offset installation costs. SHTM 04-01 Part A, 2011, states that the upper limit of water storage for a district general hospital is 900 litres per bed per day, and for a teaching hospital, 1,350 litres per bed per day - excluding provision for the staff residences, laundries and any special storage for fire-fighting purposes.

2.10 Average figures for daily water use per bed in different healthcare facility types are given in the appendix of SHTM 04-01 Part A. Daily water consumption estimates range from 127 litres per bed to 1,227 litres per bed, depending on the type and size of building. *Again, it must be made clear that individual surveys of buildings will be required to determine the water demand profile, and the recovered water resource.* A more accurate source of consumption data is the eMART web tool, which records actual consumption for the majority of NHSScotland buildings, based on water meter readings and water bills.

Note: This is not broken down into "per bed" figures, and is hard to relate to individuals using the building.

2.11 In order to assess demand from potential non-potable uses such as toilet flushing, the proportion of water used for that activity must be measured. Some estimates can be made based on data published in HTM 07-04 (2009). This document gives estimates on the proportion of water used for WC flushing, urinal flushing and tap use, as shown in Table 1, below.

Item	Typical percentage of total healthcare consumption
WC	25%
Urinals	5%

Table 1: Water demand from WC's and toilets in a healthcare facility (Source: Adapted from HTM 07-04)

2.12 An estimation of water volume demand and waste water volume produced can be made using these proportions, and applying them to total building consumption figures.

Water Demand Reduction

2.13 Prior to introducing a grey water recovery system, measures may be taken to reduce demand for each of the specific domestic water outlets. All of the main outlets and suggested upgrades to reduce demand are discussed as follows:

Urinals

2.14 The flushing of urinals uses a significant amount of water, with the frequency of the flushing determining the amount of water used. A standard system uses a 7.5 -12 litre cistern which fills slowly. Once filled, it flushes the urinals and fills again. Although dependent upon the setting of the needle valve, this flushing typically occurs once every 20 minutes.

2.15 Over a year, one single 7.5 litre cistern will consume over 197 m^3 of water, incurring both water and sewerage charges. By fitting a flush control, for example, a passive infra-red (PIR) detector, flushing is limited to a pre-set number of uses, in addition to hygiene flushes. In many instances, where use of the urinal is limited to only eight to twelve hours a day, savings of over 60% can be achieved corresponding to about $118m^3$ / year per cistern (HTM 07-04).

WCs

2.16 The volume of water used for flushing can be reduced in a number of ways. The most significant reduction can be made by replacing all of the old toilets (which can use up to 13 litres of water in one flush) within a healthcare facility with more water-efficient dual-flush toilets. It is proposed that all toilets should be replaced with more water-efficient dual-flush toilets that use only six litres for a full flush and four litres for a reduced flush. Additionally, water demand can be reduced through adjustment of the internal ball-cock and setting it to a minimum value. Installation of a cistern volume adjuster, cistern dams or cistern bags should also be implemented.

Note: WC pans and flushing cisterns that use more than six litres per flush are now prohibited by Scottish Water Byelaws (2004).

3. Grey Water Recycling

Background

3.1 Grey water is water that goes to waste from domestic uses other than toilet flushing, such as bath water, hand wash basin water, shower water, kitchen sink water and kitchen appliance water. It is estimated that between 50% and 80% of domestic waste water is grey water. For the purposes of this Report, the recyclable proportion of grey water is taken as that fraction that comes from lesser polluted sources such as wash hand basins, showers, and baths. BS8525 suggests that the average person produces 50 litres of grey water per day from these sources.

3.2 Grey water can be considered suitable for reuse for non-potable purposes, as it is readily available near to the point of use (Winward *et al*., 2008b). It is generally split into two categories depending on the source; low load and high load.

3.3 **Low load grey water** results from the use of hand basins, showers and baths, where the water greatly dilutes the concentrations of detergent and organic soil.

3.4 **High load grey water** is produced by washing machines and dishwashers. This carries a higher organic and chemical contamination, due to higher soil levels coming from clothes and dishes, and a higher chemical content due to the stronger nature of detergents used (Winward *et al*., 2008).

3.5 Grey water will require treatment prior to use. The level of treatment will depend on the final use of the water (Li *et al*., 2009). It has been shown that grey water can be used for toilet flushing and irrigation (Li *et al*., 2009; Nolde, 1999).In general, the higher the level of human contact, the more intensive the treatment will need to be (Li *et al*., 2009). However, a system in Berlin for domestic recycling of grey water and its disinfection has been shown to be economically feasible with high treatment standards (Nolde, 1999).

Note: A major issue in implementation of grey water recycling is the lack of water quality standards or guidelines. Where systems are in use, quality standards have been put in place, but these vary from country to country (Nolde, 1999).

Grey Water Recycling in the UK

3.6 Examples of grey water recycling in the UK are difficult to find. This may in part be due to the generally low cost of potable water, making investment in systems uneconomical (Burkhard *et al*., 2000). However, recent increases in water costs and concerns over supply security may make grey water recycling a more attractive option.

3.7 The inclusion of water re-use systems in the governments' Enhanced Capital Allowance Scheme may help to spread the use of this technology. Businesses which pay income or corporation tax can write off 100% cost of an eligible investment against their taxable profits. However, this does not apply to the NHS.

3.8 The BREEAM Healthcare XB Assessor Manual states that two credits can be obtained where;

'Waste water from wash hand basins and showers is collected from ≥80% of fittings and recycled to meet part (minimum of 10%) or the total of WC/urinal flushing demand within the building(s)'

Grey Water Quality

3.9 Contaminants in grey water are mainly organic, from human washing, or chemical, related to the detergents used for washing. This results in high suspended solids, high biological and chemical oxygen demand (BOD and COD) and elevated counts of faecal coliforms.

3.10 The characteristics of grey water are variable as its production depends on the habits of the person/people producing the water (Li *et al*., 2009). Li *et al*. (2009) reviewed available data on grey water quality and found the following ranges of characteristics for bathroom water;

- pH - 6.4 to 8.1;
- Suspended Solids – 7 to 505 mg/l;
- COD – 100 to 633 mg/l;
- BOD – 50 to 300 mg/l;
- Total coliforms – 10 to $2.4x10^7$;
- Faecal coliforms – 0 to $3.5x10^5$.

Microbiological Contamination

3.11 Grey water from showers, baths and wash hand basins can contain harmful bacteria as well as organic matter such as skin particles and hair (Environment Agency, 2008). It will often also be contaminated with cosmetics, soaps and detergents, which may contain nutrients that promote the growth of bacteria (Environment Agency, 2008). This and the high temperature of the wastewater provides ideal conditions for bacterial growth, meaning that raw grey water must be treated within a few hours of its production (Environment Agency, 2008).

3.12 Raw or inadequately treated grey water presents a health risk to humans due to the potential presence of faecally transmitted pathogens, such as *Pseudomonas aeruginosa*, and the protozoa *Cryptosporidium* and *Giardia* (Winward *et al*., 2008). Indicator bacteria, such as *Eschericia coli* and *enterococci* are consistently detected in grey water, demonstrating the potential for the growth of several enteric bacteria such as *Salmonella* and

Campylobacter (Winward *et al*. 2008a). However, a study by Winward *et al*. (2008) found no occurrence of *campylobacter spp.* in 9 tested samples, and no occurrence of *salmonella spp.* in 13 tested samples. In the same study, *Pseudomonas aeruginosa* and *Staphylococcus aureus* were found in raw grey water samples. The occurrence of *P. aeruginosa*, was strongly correlated to detection of total coliforms, and less strongly correlated to detection of *Eschericia coli* (Winward *et al*. 2008).

3.13 In Nolde's 1999 study of grey water systems in Berlin, it was found that a 4-stage rotary biological contactor (RBC) could reduce the occurrence of faecal *streptococci* and faecal coliforms to below the detectable limit. However, two out of 46 samples exceeded the Berlin standard for *P. aeruginosa* at 4.3 bacteria per ml. It was concluded that grey water could be produced at a consistent quality to meet the Berlin standards by following the 4-stage RBC with an ultraviolet (UV) disinfection stage before being passed to the point of use.

3.14 Microbiological standards and guidelines for recycled grey water quality vary worldwide, and are dependent of the intended final use. In the UK there is no current regulation of grey water quality. However, the Government's Market Transformation Program has developed a guideline standard based on the EU Bathing Waters Directive (http://ec.europa.eu/environment/water/water-bathing/index_en.html), the principle being that water that is safe for total immersion and occasional ingestion, will be safe for toilet flushing, outside cleaning and garden watering (Environment Agency, 2008). These proposed standards are the same as those for reclaimed rainwater, and are shown in Table 2.

Category	A	B	C	Possible application
Indicative use	External cleansing	Drip irrigation	WC flushing	
Total coliforms number /100ml	10	1,000	1,000	All grey water systems. Single-site and community rainwater systems
Eschericia coli number /100ml	1	250	250	Single-site and community systems. Grey water systems if required
Intestinal enterococci number /100ml	1	100	100	Single-site and community systems. Grey water systems if required
Legionella number /litre	100	100	100	Where analysis is indicated by risk assessment
Residual chlorine (if used) ppm total chlorine	<0.5	<0.5	<2	All systems where used
Residual bromine (if used) ppm total bromine	n/a	n/a	<2	All systems where used
Dissolved oxygen in stored reclaimed water	>10% saturation or > 1mg/litre O_2 (whichever is least)			All systems
Suspended solids	Visually clear and free from floating debris			All systems
Colour	Not objectionable	n/a	Not objection able	All systems
Opacity	<60% at 254 nm	n/a	<60% at 254 nm	<10% for all categories if UV disinfection is used
Turbidity (if applicable) NTU	<10	n/a	<10	<10% for all categories if UV disinfection is used
pH	6-8	6-8	6-8	Larger grey water systems using chlorine disinfection

Table 2: MTP guideline water quality values for harvested rainwater use (Source: MTP 2007)

Note: Risk assessments will require to take into account the implications of whether or not WCs have lids.

3.15 The MTP standard for external cleansing is much stricter than those for garden watering or toilet flushing, due to the potential for producing aerosols when using spray devices.

Note: Patients who are allowed to water gardens as part of their therapy would use hose pipes with spray nozzles having the potential for exposure to increased aerosol associated risks.

3.16 A set of standards for recycled grey water quality for toilet flushing was developed in Berlin in 1995. These standards were developed as a result of the first grey water pilot plants in Germany introduced in 1988. The plants were able consistently to achieve water quality standards based on the EU recreational waters guidelines. The standard set parameters of BOD < 5mg/litre, total coliforms < 100ml/litre, faecal coliforms <10ml/litre and *Pseudomonas aeruginosa* <1mg/litre (Nolde, 1999).

3.17 A stricter standard is put forward by the United States Environment Protection Agency's (USEPA) 1992 'Guidelines for Water Reuse' states that water should undergo filtration and disinfection, and sets parameters for toilet flush water as; no detectable faecal coliforms in 100ml of the water, BOD ≤ 10mg/l, and a residual Cl_2 of ≥ 1mg/litre, (Nolde, 1999).

Design Considerations – Grey Water Recycling

Note: It should be noted that healthcare premises should only consider biological or bio-mechanical systems, as the others on this list either do not provide thorough enough treatment, or rely too heavily on hazardous chemicals. Biological systems are unable to remove heavy metals, which is an important consideration if using the recycled water for garden watering.

3.18 There are several different types of grey water systems, which can be grouped by the type of treatment the water receives. The type of system to be installed will depend on the final use of the recycled water. In the British Standards they are grouped as follows:

Direct reuse systems (no treatment)

3.19 These systems use simple devices to collect grey water from appliances and deliver it directly to the points of use, with no treatment and minimal, or no, storage, e.g. a grey water diverter valve.

Note: It is possible to reuse grey water without any treatment, provided that extended storage is not required. As untreated grey water quality deteriorates rapidly, the collected grey water ideally needs to be reused as soon as it has cooled.

Where no treatment is included in the grey water system, applications are restricted to sub-surface irrigation and non-spray applications.

Short retention systems

3.20 These systems apply a very basic filtration or treatment technique, such as skimming debris off the surface of the collected grey water and allowing particles to settle to the bottom of the tank. They aim to avoid odour and water quality issues by ensuring that the treated grey water is not stored for an extended period (e.g. more than an hour).

Basic physical/chemical systems

3.21 These systems use a filter to remove debris from the collected grey water prior to storage while chemical disinfectants are generally used to stop bacterial growth during storage.

Biological systems

3.22 These systems use aerobic or anaerobic bacteria to digest any unwanted organic material in the collected grey water. In the case of aerobic treatment, pumps or aquatic plants can be used to aerate the water.

Bio-mechanical systems

3.23 These systems, the most advanced for domestic grey water reuse, combine biological and physical treatment, e.g. removing organic matter by microbial cultures and solid material by settlement. They encourage bacterial activity by bubbling oxygen through the collected grey water.

3.24 Some care has to be taken when specifying one of these systems as they may have individual risks associated with them. For example, in short retention systems what is considered an ‘extended’ storage time will need to be defined. CIBSE (2005) suggests that grey water can be safely stored for 3 days after treatment. In practice this is likely to be determined by several factors, including the organic load of the grey water and size of the system. Aerated water also promotes the breeding of *Legionellae*, an issue that would require resolution when specifying a bio-mechanical system.

3.25 In general, a grey water recycling system requires the diversion of grey water sources to storage and treatment tanks. The grey water will normally pass through a filter before passing to the tanks. Treatment of the water will normally occur in the storage tank. The grey water drainage system should be designed in compliance with section 3 of Chartered Institution of Building Services Engineers (CIBSE) Guide G: Public Health Engineering (CIBSE, 2004), and with reference to British Standard BS8525; Grey Water Systems Code of Practice.

Collection and Storage of Water

3.26 Collection of grey water will require diversion of bath and sink, etc. drainage from the foul sewer. This will normally necessitate a new stack for grey water, which will need to be vented. Any pipes transporting grey water will need to be marked accordingly to prevent accidental contamination of non-grey water sources, such as new WC connections.

3.27 Due to the high organic content and risk of microbial and bacterial growth, untreated grey water should only be stored for short periods of time, not longer than an hour. Generally, grey water storage time will depend on the type of treatment the water will be receiving, but short retention times should not affect the efficiency of the system, as grey water supply is reasonably constant

(CIBSE, 2005). Generally the storage tank will be at or below ground level, with treated water being pumped on demand to a high level header tank.

3.28 The components of typical system are:

- separate and marked grey water piping, transporting water from sinks, showers and baths;
- a filter which excludes solid and particulate matter;
- a storage tank;
- a water treatment system;
- a submersible pump which pumps water to a header tank located at high level;
- a secondary water system that is clearly labeled as using non-potable, grey water.

3.29 The storage tank should be constructed from materials that create watertight structures and prevent microbial growth (BS8525: 2010). All tanks and cisterns should have screened ventilation, an overflow and sealed lids to prevent contamination of the water, as described in SHTM 04-01 Part E.

3.30 Due to the nature of grey water, it must be treated before being stored. All tanks and cisterns should be sited to minimise the likelihood of the stored water temperature increasing so as to reduce the risk of bacterial growth occurring as far as possible (BS8525: 2010), and with regard to the guidance given in SHTM 04-01 Part E. Consideration may also need to be given to any possible periods when the system will not be used. This is likely to require disinfection of the whole system to eliminate any bacterial growth.

3.31 The initial storage tank may be small enough to require only a single warning-cum-overflow pipe and the second tank will almost always need to be longer, consequently this tank will require separate pipes (warning as well as overflow). The mains water top up should go to the second treated water tank and this tank should be arranged to prevent back-syphonage.

Other Considerations

3.32 A back up water supply will also be required to top up the tank when water levels are low, this back up water must have a back flow prevention device to prevent any grey water entering the public water supply. Grey water should be considered a Category 5 fluid under the Water Supply (Water Fittings) Regulations (1999), and any backflow prevention device would need to be appropriate for this classification. Acceptable devices include; unrestricted type ‘AA’ air gaps and, unrestricted type ‘AB’ air gap with a non-circular overflow. Examples of these are given in Figure 3 of Part B of this SHTM.

3.33 An overflow to the public sewer will also be required on the storage tank to make sure any excess grey water does not back up back to sink and bath drains. The grey water shall then be filtered and treated before pumping the water to the header tank from which it will be distributed (CIBSE, 2005).

Grey Water Treatment Systems

3.34 One of the major concerns when using grey water systems is ensuring the water quality is consistently fit for purpose. This is exacerbated by the lack of regulations setting a legal standard for minimum acceptable biological and chemical content of the treated water. However, the Government MTP standards somewhat address this problem by providing a set of guideline values for different grey water applications. The main types of grey water treatment systems discussed by the literature are outlined in Table 3.

Grey water treatment system	Description
Sequencing Batch Reactor (SBR)	*"The sequencing batch reactor (SBR) is a fill-and draw activated sludge system for wastewater treatment. In this system, wastewater is added to a single "batch" reactor, treated to remove undesirable components, and then discharged. Equalization, aeration, and clarification can all be achieved using a single batch reactor. To optimize the performance of the system, two or more batch reactors are used in a predetermined sequence of operations. SBR systems have been successfully used to treat both municipal and industrial wastewater. They are uniquely suited for wastewater treatment applications characterized by low or intermittent flow conditions."* SBR's are applicable to waste water flows of approximately 45 m^3 per day, to over 18,000 m^3 per day. The USEPA states that such a system has a typical footprint of 5.5m x 3.7m. (EPA 1999 - http://www.epa.gov/owm/mtb/sbr_new.pdf)
Membrane Bioreactor (MBR) Membrane Chemical Reactor (MCR)	*"The use of microfiltration membrane bioreactors (MBRs), a technology that has become increasingly used in the past 10 years, overcomes many of the limitations of conventional systems. These systems have the advantage of combining a suspended growth biological reactor with solids removal via filtration. The membranes can be designed for and operated in small spaces and with high removal efficiency of contaminants such as nitrogen, phosphorus, bacteria, bio-chemical oxygen demand, and total suspended solids. The membrane filtration system in effect can replace the secondary clarifier and sand filters in a typical activated sludge treatment system. Membrane filtration allows a higher biomass concentration to be maintained, thereby allowing smaller bioreactors to be used. A Membrane chemical reactor works in a similar way, but using chemical processes instead of biological to decontaminate water."* (EPA 2007 - http://www.epa.gov/owm/mtb/etfs_membrane-bioreactors.pdf)

Table 3: Grey water treatment systems

Grey water treatment system	Description
Rotating Biological Contactor (RBC)	*"Rotating biological contactors are large discs on rotating shafts that are mounted in wastewater tanks, but only partly submerged. As the discs turn, the microorganisms on them repeatedly contact both air and the organic substances in the water. A rotating biological contactor can be used where wastewater is amenable to biological treatment. Rotating biological contactors can be used in many ways to accomplish varied degrees of carbonaceous or nitrogenous oxygen demand reductions. Rotating biological contactors are fixed-film reactors similar to biofilters in that organisms are attached to support media. The support media are the slowly rotating discs that are partially submerged in flowing wastewater in the reactor. A rotating discs contactor is an agitated column extractor that can carry out liquid-to-liquid extraction processes. The rotating disc contactor (RDC) is a vertical column, consisting of a series of compartments formed by stator rings. In the middle of each compartment a central shaft drives a rotor ring."* http://www.globalspec.com/LearnMore/Manufacturing_Process_Equipment/ Environmental_Instruments_Equipment/Rotating_Biological_Contactors
Vertical Flow Reed Bed (VFRB)	*"The liquid from a grey water settlement tank contains very little oxygen and lots of organic material and ammonia, making it very dirty and smelly. Vertical flow reed beds are designed to provide 'secondary treatment' by adding oxygen to this effluent and removing t he pollutants. A layered sand and gravel bed is planted with Phragmites australis, otherwise known as common reed. Effluent is introduced to the surface in doses so as to cover the whole bed. It percolates through the sand, gravel and plant roots, then flows out from the bottom. The bed always contains air spaces and is never waterlogged. The organic material and fine particles are removed from the water as they become attached to the sand, gravel and plant roots, forming a slime. Aerobic micro-organisms in the slime break down the pollutants, while the reeds help provide these microorganisms with oxygen, enabling them to work effectively and prevent the bed from blocking. The micro-organisms also reduce the levels of ammonia, which is toxic to most plants and animals, as well as very smelly. At least two parallel vertical flow beds are necessary in a treatment system, so one can rest while the other is in use."* http://files.uniteddiversity.com/Water_and_Sanitation/Constructed-Wetlands-and-Reed-Beds.pdf

Table 3 continued: Grey water treatment systems

Grey water treatment system	Description
Horizontal Flow Reed Bed (HFRB)	*"Horizontal flow reed beds are suitable for 'tertiary treatment'. They are like a gravel-filled stream and constantly waterlogged. Dirty water flows in one end horizontally then through the bed and out of the other end. They provide an oxygen-depleted environment, which allows certain hungry bacteria to turn undesirable nitrates into harmless nitrogen gas (by poaching oxygen from the nitrate molecule).* *This form of tertiary treatment also provides a great environment for single-celled organisms such as free-swimming ciliates and amoebae, which feed on smaller micro-organisms including human pathogens. As there is no need for oxygenation in this bed, a variety of bogloving plants can be used, including yellow flag (Iris pseudacorus), marsh marigold (Caltha palustris), reedmace or 'bulrush' (Typha latifolia), true bulrush (Scirpus lacustris) or water mint (Mentha aquatica)."* (http://files.uniteddiversity.com/Water_and_Sanitation/Constructed-Wetlands-and-Reed-Beds.pdf)
Green Roof Water Recycling System (GROW)	*"The Green Roof Water Recycling System (GROW) is an innovative grey water recycling scheme designed by Water Works UK for low-rise, multi-storey, multi-occupancy urban dwellings. Planted roof-top troughs cleanse the grey water and return it via a dedicated pipework system for use in toilet flushing.* *Grey water is captured, filtered to remove debris, and stored in an underground sump. It is then pumped up to roof level by a solar-powered pump, where, by gravity, it descends through the network of gravel and aquatic-plant filled troughs. The water passes through the roots where bacteria cleanse it."* (http://www.ciwem.org/policy-and-international/current-topics/water-management/water-reuse/domestic-water-reuse/green-roof-water-recycling-system.aspx)

Table 3 continued: Grey water treatment systems

3.35 Li *et al*. (2009) carried out a review of literature on grey water treatment technologies and their efficacy. This review suggested a set of guideline standards for use of recycled grey water and compared the findings of studies of treatment methods against them. The guideline suggests limits of; BOD ≤ 10mg/l, turbidity ≤ 2 NTU, pH 6-9, faecal coliforms ≤ 10 ml/litre, total coliforms ≤ 100 ml/litre, residual chlorine ≤ 1mg/litre, for unrestricted urban uses such as toilet flushing, landscape irrigation and street washing. Li *et al*. found that no single treatment method could produce recycled water to the quality of this standard. However, a combination of treatments such as a Sequencing Batch Reactor (SBR) followed by chemical disinfection or filtration, or Membrane BioReactors (MBR) would be able to consistently meet this standard.

3.36 Nolde (1999) carried out a case study of grey water treatment in a residential multi-storey building in Berlin housing 70 people. This system used rotary biological contactors (RBC's). Initially a 2 stage system was installed, which was upgraded to a 4 stage systems after 8 years. This reduced the amount of maintenance needed from 2 hours per week to 0.2 hours per week. A contamination test was carried out, artificially contaminating the incoming grey water with faecal coliforms. On testing water from the toilet flushing system, faecal colifoms were found to be below the control value, and no bacterial regrowth was detected. Further testing showed that there was no increase in pathogenic micro-organisms, and a continuous death rate was observed with all tested micro-organisms. The RBC system tested in this study was able to consistently meet the Berlin guidelines for recycled grey water (Table 2).

3.37 Winward et al. (2008) studied 5 different grey water treatment technologies. These were; horizontal flow reed bed (HFRB), vertical flow reed bed (VFRB), green roof water recycling system (GROW), membrane bioreactor (MBR) and membrane chemical reactor (MCR). HFRB, VFRB and GROW are constructed wetlands. In this study, the HFRB and VFRB had a surface area of 6m^2 and a depth of 0.7m. The GROW was approximately 1.2m^2 surface area with a depth of 0.1m.

3.38 These systems were compared against 3 grey water standards from; Germany, USEPA, and a California State specific standard (also USEPA). The parameters are shown in Table 4 below.

Urban water reuse standards/guidelines Water quality Microbiological (CFU 100mL−1)		
USEPA (2004)	BOD5 ≤10mgL−1 Turbidity≤2 NTU pH 6–9	Faecal coliforms =ND Viable pathogens =ND
USA, California (USEPA, 2004)	Turbidity = 2 NTU Avg (5 NTU Max)	Total coliforms = 2.2 Avg (23 Max in 30 days)
Berlin, Germany (Nolde, 1999)	BOD7 <5mgL−1	Total coliforms < 10000 Faecal coliforms < 1000 Pseudomonas aeruginosa < 100
Avg = average, Max = maximum, ND = none detectable.		

Table 4: International grey water quality standards examples

3.39 For low strength grey water, taken from hand wash basins, showers and baths, all technologies achieved the German standard. None of the constructed wetland technologies could consistently achieve the USEPA or the California State standard. MBR met the California standard in 74% of samples.

3.40 Winward *et al*. (2008) suggest that VFRB and MBR technologies reduce the potential for microbial re-growth due to their ability to remove organics. This reduces the chemical disinfectant demand which may be required depending on final use. Disinfecting where human contact is a risk may be necessary as viruses are small enough to pass through these systems. Winward *et al*.'s (2008b) results also show that for those parameters measured (total coliforms, enterococci, Eschericia coli, turbidity and pH) MBR treatment is sufficient to meet the MTP standards proposed for the UK, for both WC flushing applications, and the stricter limits for external cleaning. However, further investigation would be needed to determine if all MTP parameters can be met.

3.41 It has been recommended that recycled grey water being used in human contact situations receives some form of disinfection after treatment (Winward *et al*., 2008; Nolde, 1999). This treatment should ensure water qualities that meet the guideline standards set out by the MTP (2007).

3.42 Water disinfection techniques are discussed in detail in a separate report; Report on the Disinfection of Domestic Water Systems in Healthcare Premises (SHTM 04-01 Part D, 2011) which considers standards for potable water. However, when treating grey water for non-potable uses, these techniques become more flexible as higher chemical loads can be tolerated.

Applicability to different uses

3.43 It is possible to use grey water for the applications suggested in this document; garden watering, toilet flushing and vehicle cleaning. There are constraints for each different use that need to be considered.

Toilet flushing

3.44 Grey water is acceptable for toilet flushing. The water is likely to require storage for differing lengths of time, depending on usage patterns. For example, shower water gathered in the evenings may not get used until the next morning. The grey water therefore needs to be treated sufficiently to reduce the microbiological load and prevent microbiological growth. If the water is purely reserved for toilet flushing, it can be disinfected chemically. A higher concentration of chemical disinfection is acceptable compared to potable water, as there is unlikely to by any significant human contact, and the waste water is disposed through the sewerage system. Scottish Water should be informed of any proposals for chemical disinfectant use to ensure concentrations are not detrimental to the sewerage system.

Garden watering

3.45 The Environment Agency states that it is possible to use grey water for garden watering without any treatment, as long as it is not stored for longer than an hour. However, this may not be practical in a hospital, as the systems available for doing this tend to be aimed at individual householders. (The Note following paragraph 3.15 also refers).

3.46 Treated grey water can be used for garden watering. However, this must meet the MTP water quality parameters. Treatment must reduce the microbiological load and chemical content to below the MTP values. Care must be taken if chemical disinfection is used. A higher chemical residual is allowed for toilet flushing, as this is passed on for treatment at a sewage treatments works. The same standard cannot be applied to garden watering, as there is the potential risk of contaminating soil, and ground or surface water, or accidental ingestion by humans or wildlife. Grey water for use in sprinkler systems must be treated to the same standard of that given for outdoor cleaning (explained in the outdoor cleaning paragraph below).

Outdoor cleaning

3.47 The MTP standards are strictest for outside cleaning. This is due to the risk of aerosols arising from spray washing. As there is increased potential for inhalation of water particles, it is important that the water is treated to a high standard. It is important to note that the stricter standards also apply where sprinkler systems are used for gardening.

4. Demand and Yield Estimation

Note: Retrofitting grey water systems is not recommended without first having investigated other water efficiency options. There are less intrusive and more cost effective measures that should be considered first. For example; identifying and fixing leakage, installing more water efficient fittings, and changing water use behaviour.

It is recommended that, if possible, a water audit is carried out to identify where water savings can be made. Water audits can be carried out internally, or can be done by external consultants. Scottish Water Business stream offer this service, as well as a number of consultancies.

Grey water retrofitting should only be considered after other water efficiency options have been implemented, as any subsequent changes to water demand may affect the functioning of these systems.

Demand and Yield Caveat: The following calculations are intended to allow estates managers to make estimates regarding the water demand and grey water yield within their healthcare facility. These estimates should only be used to give a rough estimate as to whether or not installation of these systems will be viable.

The accuracy of the individual water use figures given in Table 5 is unknown, as these figures are based on an Audit Commission report from 1993. The BS daily grey water yield figure, used to estimate the proportion of grey water produced in a healthcare facility, is based on an average persons grey water production in the course of a day. It is unknown how this relates to actual grey water produced by staff and patients in healthcare facilities.

It is felt that these calculations can be used as an indication of viability only. If the estimated yield suggests that installing grey water systems is viable, the next stage would be to engage experienced professionals to carry out a more in depth and accurate analysis.

Water Demand

4.1 To assess the demand for grey water, the applications in which they will be used must be identified. BS8515 and BS8525 provide in depth guidance on how this can be done. In hospitals the most likely use for recycled water is toilet and urinal flushing. HTM 07-04 quotes the proportion of water used for toilet flushing as 30% of the potable water supply. This allows a simple estimation of demand, either using the figures for average consumption given in the appendix of SHTM 04-01, or using specific building data submitted to the eMART web tool.

4.2 Using Stirling Royal Infirmary as an example, the estimated demand figures from both sources of data are;

SHTM 04-01

Identifying the hospital as partly acute (type 3), and having between 401 and 600 beds, water consumption is given as 0.599 m^3 per bed per day, which is a total of 218.6m^3 per bed per year. With 486 beds in the hospital, the annual consumption is estimated as;

Annual consumption = 106,257m^3 per annum

Assuming 30% of this volume is used for toilet flushing, the demand can be calculated as;

Toilet flushing water demand = 31,877m^3 per annum

eMART

The data submitted to eMART for annual water consumption at Stirling Royal Infirmary for 2009/10 was;

Annual consumption = 86,512m^3 per annum

Assuming 30% of this volume is used for toilet flushing, the demand can be calculated as;

Toilet flushing demand = 25,954m^3 per annum

Grey water yield

4.3 BS8525 suggests a simple estimate for grey water production per person domestically as 50 litres per day. Water Watch Scotland state that in 2006, average personal water consumption in Scotland was 140 litres per day (http://www.waterwatchscotland.org/water-efficiency/water-consumption-the-facts/). These two figures can be used to estimate a proportion of grey water production compared to consumption of 36%. In the absence of specific proportionality figures for employees, this ratio can be applied to make a very rough estimate of grey water yield per person in a healthcare facility. Applying the 36% proportion to figures produced by the Audit Commission (Audit Commission NHS occasional papers, May 1993), the figures for grey water yield per person in Table 5, overleaf, are produced.

Person	Average water use per day per person	Average grey water production per day per person
Employee (full time no canteen)	25-50 litres	9-18 litres
Employee (full time canteen)	40-90 litres	14.4-32.4 litres
Resident employee	180 litres	50 litres
Hospital patient (in-patient)	450 litres	50 litres

Table 5: Estimated grey water yield per person (Source: Adapted from Audit Commission NHS occasional papers no. 5 May 1993, and BS8525)

4.4 Resident employees and hospital in-patients are considered to be in the healthcare facility 24 hours a day, therefore their grey water production figures remain at 50 litres per day. This is an assumption that 50 litres per day is a fixed maximum volume of grey water produced per day.

4.5 In order to estimate grey water yield for a range of healthcare facilities, some assumptions must be made about out-patient water consumption and staff water consumption in facilities that are not staffed or occupied 24 hours a day. Suggested assumptions are

- the employee (no canteen) figure will be roughly the same for employees in out-patient only buildings such as clinics and health centres;
- outpatients do not use any water in the course of their visit (on the basis that underestimation of resource is preferable to overestimation).

4.6 Taking these assumptions into account, grey water yield can be estimated as;

Estimated Total Yield = $(Y_1 \times N_1) + (Y_2 \times N_2) + (Y_3 \times N_3) + (Y_4 \times N_4)$

Where

$\mathbf{Y_1}$ = Grey water production per employee in an out-patient facility

$\mathbf{N_1}$ = Number of employees in the out-patient facility

$\mathbf{Y_2}$ = Grey water production per employee in an in-patient facility

$\mathbf{N_2}$ = Number of staff in the in-patient facility

$\mathbf{Y_3}$ = Grey water production per resident employee

$\mathbf{N_3}$ = Number of resident employees

$\mathbf{Y_4}$ = Grey water production per in-patient

$\mathbf{N_4}$ = Number of in-patients

This figure for yield should not be used as an indication of the grey water resource available, as it does not take into account any site specific data. Instead, it should be used to calculate a proportion of grey water consumption to total water consumption. This can be done by using the same figures to estimate total water consumption.

Estimated Total Consumption = $(C_1 \times N_1) + (C_2 \times N_2) + (C_3 \times N_3)\ (C_4 \times N_4)$

Where;

$\mathbf{C_1}$ = Average water consumption per employee in an out-patient facility

$\mathbf{N_1}$ = Number of employees in the out-patient facility

$\mathbf{C_2}$ = Average water consumption per employee in an in-patient facility

N_2 = Number of staff in the in-patient facility

C_3 = Average water consumption per resident employee

N_3 = Number of resident employees

C_4 = Average water consumption per in-patient

N_4 = Number of in-patients

The ratio of grey water produced to total water consumption can then be estimated as

Estimated Total Yield / Estimated Total Consumption

4.7 For an example calculation, taking Blawarthhill Nursing Home, Glasgow, with 60 beds and assuming a 100% residency and 20 non-resident staff, the estimated grey water yield would be estimated as

Total Yield = (0 x 0) + (18 x 20) + (0 x 0) + (50 x 60)

= 3,360 litres per day

= 1,226 m^3 per year.

4.8 This calculation was made assuming that the staff do not have access to a canteen, and eat off-premises. It is important to note, that compared to eMART data, this is approximately a third of the total water consumption recorded at this site. However, we can estimate total consumption at this site based on the figures in Table 5, and then work out a proportionality for the site which can then be applied to the recorded water consumption.

Water Consumption = (0 x 0) + (50 x 20) + (0 x 0) + (450 x 60)

= 10,220 m^3 per year

Therefore the estimated proportion of grey water to total water consumed is

$1{,}226m^3 / 10{,}220m^3 = 0.12$

4.9 This ratio can then be applied to the actual eMART recorded figure or the estimated figure in SHTM 04-01 for water consumption in the facility to estimate the actual grey water resource. In the case of Blawarthill, the actual consumption is recorded as 3,990m^3 per annum. Applying the proportionality, this estimates the resource available as 478m^3 per annum.

Note: Where no record of water consumption is available through eMART or using the SHTM 04-01 appendix, the estimated total yield figure can be used. However, this should be done with extreme caution. As can be seen from the Blawarthill example, there is no guarantee that the total water consumption figure will be accurate. This method estimates consumption at Blawarthill to be two and a half times the actual recorded consumption.

4.10 BS8525 has a more detailed approach to estimating grey water resource and demand. It is recommended that this approach is followed if possible. Estimates should only be used as an initial assessment of feasibility, and qualified consultants should be used for in depth assessments.

5. Costs and savings

5.1 As previously noted, in the past there has been no financial incentive for U.K. consumers to conserve water because charges were not based upon the volume used. However, businesses and public sector organisations are now required to have a water meter and water is charged volumetrically.

5.2 For NHSScotland, this means that these water-harvesting systems are becoming more financially viable. The average cost to NHSScotland per cubic metre in 2009/10 was £0.80 for mains supplied water, and £0.94 for waste water collection (HFS eMART data, 2009-2010). Health Facilities Scotland measured the total mains water consumption at over 5.5 million cubic metres for 2009/10, at a cost of almost £45 million. Therefore, substantial savings may be possible by using reclaimed water sources such as grey water.

5.3 In order to make use of the grey water available at the lowest cost, the collection and treatment system should be carefully designed. Costs are difficult to estimate for such systems as they will greatly depend on site specific details (Nolde, 1999). It is necessary to determine both the minimum volume of grey water that can be recovered, and the volume that can be reused.

5.4 For grey water systems it is important that recovered grey water be treated as soon after recovery as possible to minimise the potential for bacterial re-growth. Therefore, a study is required to determine the potential demand for recycled grey water demand and the size of the grey water resource.

5.5 New buildings are much more water efficient than existing buildings, through improved efficiency of appliances and fittings. The economics of retrofitting water reuse systems to newer buildings are therefore much less beneficial, although with new builds, there is the potential to incorporate a water recycling system during building design.

5.6 A building that uses a high volume of water for flushing WCs and urinals will achieve much better simple payback than an efficient building. However, in terms of economics, improving the efficiency of water fittings will provide a much greater benefit compared to capital expenditure.

Using the calculations given for estimating non-potable water demand and grey water resource, and the potable water and waste water annual expenditure information on eMART, an estimate can be made of potential savings. Taking the example of Blawarthill Hospital again, the potential saving can be estimated as a 12% reduction in the annual expenditure on potable and waste water. This assumes that the full 12% resource is recoverable and that cost is directly related to volume. The estimated savings for Blawarthill are;

Savings = 12% x (annual potable water cost + annual waste water costs)

= £890.45 per year.

This can be used to provide a very rough assessment of financial viability if an estimate of installation costs can be made.

Case Studies

5.7 Faber Maunsell's (2004) feasibility study on water recycling systems for Birmingham Council, covered various types of property. Healthcare properties were not included but hotels may be comparable to hospitals in terms of grey water production and demand, and a domestic property may be comparable to a smaller healthcare facility. Two examples of estimated payback periods are shown below:

Example: 350 bed hotel at 75% occupancy.

- waste water generated: 18,615m^3 per year;
- water saved: 11,169m^3 per year;
- assumed cost of capital infrastructure i.e. tanks, treatment, controls etc: £100,000 *;
- assumed cost of distribution network i.e. pipework etc: £52,500 (£150 per room);
- cost savings approximately £14,530 per year;
- simple payback = 10.5 years.

*Estimated at high cost due to the likely high quality treatment required.

NB No maintenance or operating costs have been included in the calculations

Example: 2 person home with standard sanitaryware in line with Water Regulations

- grey water system used for flushing WCs only;
- assume that all grey water is harvested and offsets all WC flushing requirement (i.e. best case scenario);
- assume system cost of approximately £1000*;
- water savings approximately 17.5m^3 per year;
- cost savings approximately £22.70 per year;
- simple payback = 44 years.

*This does not include any operating cost or maintenance.

Source : Faber Maunsell, (2004).

Note: It must be stressed that these figures are indicative only, as the type and complexity of the installation will be dependent on the site.

6. Conclusions

Grey Water Recycling

6.1 Grey water recycling has been shown to be technically and financially feasible in domestic situations in Germany (Nolde, 1999). There is potential for water savings by recycling grey water in healthcare buildings. However, feasibility will depend on factors such as:

- cost of installation;
- effectiveness of treatment;
- risk to patients.

6.2 The cost of installation will be dependent on site factors, as some sites will be more awkward than others to fit a recycling, treatment and recirculation system. The standards proposed by the Market Transformation Programme (MTP) need to be assessed for suitability and achievability in healthcare facilities.

Note: Under no circumstances should harvested grey water be used where immunocompromised patients are being treated.

6.3 Treatment options such as Mechanical Biological Contactors and Rotary Biological Contactors appear to be sufficient to meet MTP toilet flushing and drip irrigation standards. Disinfection can be combined with these systems to remove any final infection risks. Chemical disinfection can more flexible where the final use will be toilet flushing since water does not need to meet drinking water standards. However, if the water is to be used for gardening or outdoor cleaning, care must be taken not to exceed SEPA discharge limits. Any system will need fully tested under different contamination conditions before use, to ensure it is fit for use.

6.4 Costs and savings need further investigation as it is difficult to assess accurately what the savings might be. Savings will be dependent on individual site water and waste water usage. Water and waste water consumption are recorded on eMART, but individual site studies would be required to assess accurately the proportion of grey water produced. In addition, although the incoming water volumes on eMART are accurate, there is some doubt as to the accuracy of the waste water volumes recorded. However, since incoming water is charged by unit volume, and wastewater is charged on the assumption of 95% incoming water going to waste, then whatever proportion of grey water can be recycled should directly relate to savings on total supplied mains water and waste water collection costs.

6.5 The cost of installing a recycling and treatment system will depend on the site. These estimates would have to be provided by a contractor. When costs are being calculated, ongoing maintenance must be taken into account.

Water Quality Standards

6.6 There are no legally binding standards for reclaimed water, either rainwater or grey water. This may be due to there being no clear organisation where responsibility should lie.

6.7 Scottish Water is responsible for providing clean drinking water, the quality of which is regulated by the Drinking Water Quality Regulator (DWQR). Beyond this they are responsible for collecting and treating waste water. Between the water outlet and the public sewer, they have no responsibilities. As a result Scottish Water are unlikely to have an interest in trying to enforce standards on privately run water re-use systems. It is also outwith the DWQR's remit, as they deal purely with the quality of drinking water. SEPA's responsibility lies with ensuring the abstraction of water from the natural environment and the discharge of treated wastewater is carried out within the regulations. As such they have no reason to set and enforce standards for recycled water It may be that the Health and Safety Executive is best placed to regulate these systems where they are installed in public buildings or places of work, as the concern is for human health impacts in a workplace (in the case of NHSScotland facilities). However, as yet no responsibility has been apportioned. The MTP has supplied guideline values, based on the EU Bathing Waters Directive, and these are comparable to standards in Germany and the USA.

6.8 One of the major concerns with using reclaimed water for toilet flushing is the risk it would pose to immune compromised patients. Previous research suggests that there is no significant spread of bacteria in this way (Newsom 1972; Kay *et al*. 2006) when considering normal flushing with potable water.

6.9 It may be necessary to support this evidence with studies specifically with grey water in hospitals, particularly where patients and staff washing might be carrying higher than normal levels of pathogenic bacteria.

Areas for Further Investigation

6.10 Individual site investigations are required into:

- size of resource;
- suitability of use;
- cost of installation.

The recorded unit volume cost of supplied mains water and collected waste water differs significantly between different facilities. This may be an area that needs to be investigated with Scottish Water to ensure that NHSScotland are getting charged correctly.

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