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 B: Rainwater harvesting

Health Facilities Scotland
Engineering and Environment

July 2015

Contents

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.

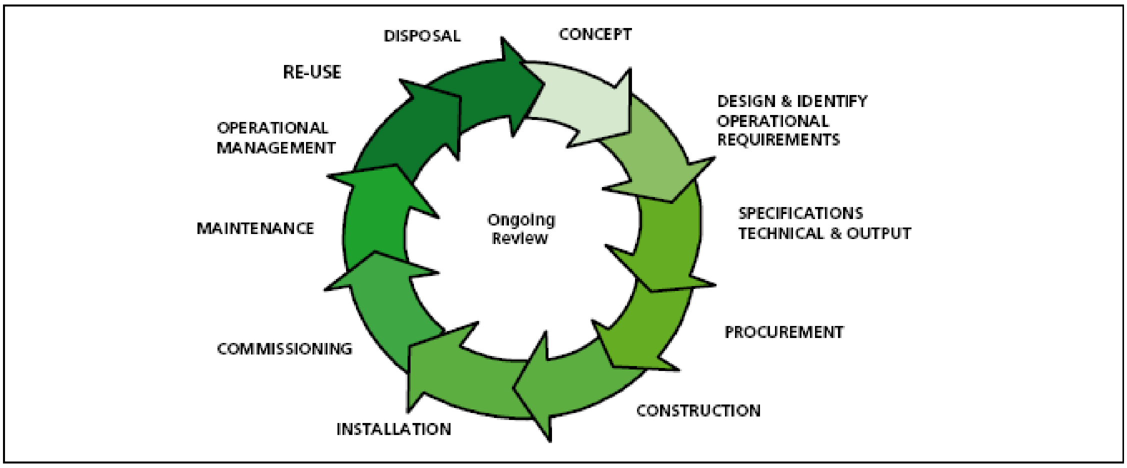
The focus of SHTM guidance remains on healthcare-specific elements of standards, policies and up-to-date established best practice. They are applicable to new and existing sites, and are for use at various stages during the whole building lifecycle: Healthcare providers have a duty of care to ensure 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.

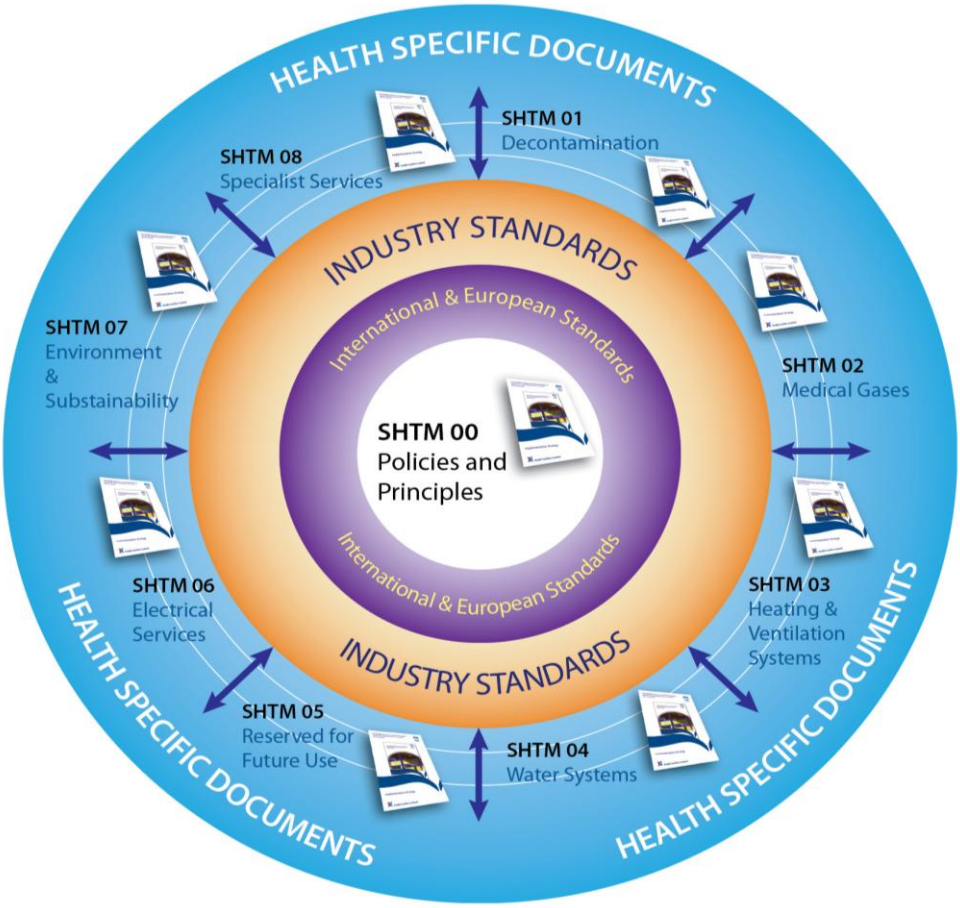
Example: Scottish Health Technical Memorandum 06-02 Part A will represent: Electrical safety guidance for low voltage systems

In a similar way Scottish Health Technical Memorandum 07-02 will simply represent: Environment and Sustainability – EnCO$_2$de.

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 new construction 2011) 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 rainwater harvesting. To assess healthcare buildings a rating system has been created, entitled 'BREEAM Healthcare XB'. This is 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 rainwater harvesting systems be used in areas treating immunocompromised patients. By definition, these patients are extremely sensitive to any pathogens. Whilst a properly functioning rainwater reclamation 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 rainwater harvesting 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 growing population 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 rainwater enter the sewerage system drained from roofs and impermeable surfaces.

> **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 of this SHTM.

Purpose of this Scottish Health Technical Memorandum

1.3 This SHTM discusses the implications of rainwater harvesting 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. However, SHTM 04-01 Part A discourages their incorporation at this stage and they should not have the potential to put the patients at risk from bacteria such as *Legionella, Salmonella, Staphylococcus* and *Pseudomonas.*

1.6 Rainwater harvesting 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 recycled rainwater 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) 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 B of this SHTM is to investigate the use of harvested rainwater and on 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 rainwater harvesting, but they are the only ones that have been discussed in any way in terms of 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, such as roof and window cleaning, providing a full Risk Assessment is carried out beforehand and appropriate measures related to generation and dispersal of aerosols are built into any design.

2. Rainwater harvesting to reduce demand

Water use in the UK

2.1 Rainwater harvesting 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 rainwater 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 rainwater, its use reduces demand on potable water by the volume of rainwater that is used in place of potable water e.g. for toilet flushing. For example, if a household only uses rainwater for toilet flushing, there is no demand for that volume of water from the potable supply.

2.4 Even without considering re-use of rainwater, it is possible to divert surface run-off away from the sewerage system. The Practical Guide (2011) produced to aid compliance with Water Environment Controlled Activities (Scotland) Regulations states that as long as certain conditions given in the Controlled Activities Regulations (CAR) Practical Guide can be met, surface run off can be discharged through a Sustainable Urban Drainage System (SUDS). Further information on this general binding rule is given overleaf.

Note
SEPA's General Building Rule 10 (GBR10) states that discharge of surface water run-off from a surface water drainage system to the water environment from construction sites, buildings, roads, yards and any other built-up areas

Rules

a. If the surface water run-off is from areas constructed after 1 April 2007, the site must be drained by a Sustainable Urban Drainage System (SUDS). If the surface water run-off is from a construction site operated after 1 April 2007, the site must be drained by SUDS or equivalent. The only exceptions are if the run-off is from a single dwelling and its curtilage, or if the discharge is to coastal water.
b. All reasonable steps must be taken to ensure that the discharge will not result in pollution of the water environment.
c. The discharge must not contain any trade effluent and must not result in visible discolouration, iridescence, foaming or sewage fungus in the water environment.
d. The discharge must not result in the destabilisation of the banks or bed of the receiving surface water.
e. The discharge must not contain any water run-off from any of the following areas constructed after 1 April 2007:

- fuel delivery areas and areas where vehicles, plant and equipment are re-fuelled;
- vehicle loading or unloading bays where potentially polluting matter is handled;
- oil and chemical storage, handling and delivery areas.

f. All treatment systems (including oil interceptors, silt traps and SUDS) must be maintained in a good state of repair.
g. All reasonable steps must be taken to ensure that any matter liable to block, obstruct, or otherwise impair the ability of the SUDS is prevented from entering the system.
h. The construction and maintenance of the outfall must not result in pollution to the environment."

(SEPA, 2011)

2.5 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) suggests 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.

2.6 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.

2.7 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.

2.8 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).

2.9 Water charges in Scotland are made through a domestic water charge 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, rainwater harvesting 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

2.10 There is an opportunity in Scotland for the development of rainwater harvesting 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.

2.11 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.

2.12 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)

2.13 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

2.14 Prior to introducing a rainwater harvesting 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

2.15 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.

2.16 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 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 - about 118m^3 / year per cistern (HTM 07-04).

WCs

2.17 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. Rainwater harvesting

Background information

3.1 Rainwater harvesting, which Boers and Ben-Asher (1982) define as "*methods to induce, collect, and store runoff from various sources and for various purposes"*, has the potential to reduce the demand on domestic water supplies. The installation of rainwater harvesting systems also has the potential to result in both environmental and economic benefits (Coombes et al., 2000).

3.2 There is a growing need worldwide to balance existing water supplies with demand (Water UK Position Paper, March 2007). The increase in population and urbanisation, coupled with climate change concerns, may result in insufficient water supplies to meet increasing urban population needs (Ruth *et al.*, 2007). Freshwater supplies including surface waters, rivers and groundwater reservoirs, face increasing pressures worldwide from the growing population.

Dealing with limited resources

3.3 In countries such as Australia the resulting water demand is typically met by importing large volumes of treated water from reservoirs across substantial distances at considerable cost (Johnson & Rix, 1993). At the same time, similar volumes of rainwater are collected from roofs and discharged unused from urban developments via expensive drainage systems. Harvesting and using this rainwater may be one of the best available methods for recovering natural hydrological cycles (Kim et al., 2005a R.-H. Kim, S. Lee, J.-H. Lee, Y.-M. Kim and J.-Y. Suh, Developing technologies for rainwater utilization in urbanized areas, Environ Technol 26 (2005), pp. 401–410. Full Text via CrossRef | View Record in Scopus | Cited By in Scopus (2)Kim et al., 2005).

3.4 Rainwater collection systems are now being developed worldwide for non-potable uses such as gardening, toilet flushing and washing clothes. Countries pioneering in this field are Germany, Denmark, India, Japan and Australia (Albrechtsen, 2002 H.-J. Albrechtsen, Microbiological investigations of rainwater and graywater collected for toilet flushing, Water Sci Technol 46 (6–7) (2002), pp. 311–316. View Record in Scopus | Cited By in Scopus (15)Albrechtsen, 2002); many of which are incorporating rainwater harvesting systems for the purposes of flushing toilets and external uses in their legislation (Lye, 2009). However, a continuing worldwide problem is that there are very few guidelines available outlining the range of chemical and microbiological qualities that are suitable for both potable and non-potable applications of roof-runoff water (Lye, 2009).

3.5 There are two main types of rainwater collection systems:

- those that use surface/ground catchment areas; and

- those that use above-ground rooftop catchment areas.

3.6 The available literature is focused on rooftop catchments; therefore this report is heavily weighted towards that area. Surface/ground catchments also tend to have more varied and complex contamination profiles due to ground traffic such as vehicles, people and wildlife as well as local rainwater quality profiles. Rooftop catchments are likely to be less variable in terms of pollutant.

Rainwater harvesting in the UK

3.7 Many water authorities around the world have adopted the idea of integrated water cycle management which involves the use of water-efficient appliances to manage residential water demand and the inclusion of multiple water sources such as rainwater, wastewater and municipal supplies (Barry *et al*., 2005). At present, the United Kingdom has not adopted this approach. However, with the growing water demand, cost increases in the UK, and the known impacts that substantial water use can have on the local environment, the UK market demand for rainwater recycling is rising.

3.8 Rainwater harvesting in the UK is still in its infancy and only 1,200 systems were installed in 2006 (Hassell, 2007). However, this industry is growing rapidly, mainly due to the introduction of government initiatives such as the Enhanced Capital Allowance Scheme, to which rainwater harvesting equipment was added in August 2004. Through this programme, businesses who pay income or corporation tax can write off one hundred percent cost on an eligible investment against their taxable profits. *However, this scheme is not available to the NHS.*

Implications of BREEAM

3.9 BREEAM Healthcare XB provides incentives for healthcare premises to reduce their water use through water recycling systems. Two credits can be obtained from utilising a rainwater harvesting system in healthcare premises. The criterion encourages the use of a rainwater system for toilet flushing to reduce demand on potable water. To qualify for these credits the design must collect either fifty percent of the predicted rainwater run-off, or collect 50% of the flushing demand defined for the period of collection (in this instance, eighteen days) (BREEAM, 2011).

3.10 BREEAM Healthcare XB states that; for new build facilities a BREEAM rating of “excellent” is required, and; for refurbishments a rating of “very good” is required.

Note: Care must be taken to ensure that systems are not just installed to gain credits, as in some cases *the payback periods will be too long to make financial sense.*

Harvested rainwater quality

3.11 Roof-harvested rainwater is generally contaminated by microorganisms such as *Salmonella, Cryptosporidium* and *Aeromonas*, and heavy metals such as, zinc, copper and lead (Simmons *et al*., 2001) . Additional pollutants in roof run-off include organic matter, inert solids, faecal deposits from animals and birds, trace amounts of some metals, and complex organic compounds (Forster, 1991). Although initial pollution levels from rainwater roof collection have been found to be high, evidence shows that they decrease significantly as collection continues (Forster, 1991; Yazziz *et al*., 1989).

3.12 Harvested rainwater quality can be affected by the roof surface that receives the rainwater. Villareal and Dixon (2005) explain that,

"Recent research in roof water quality and the health implications of using harvested rainwater have shown that exposure to UV, heat, and desiccation on the roof top destroy many bacteria, while wind removes some heavy metals accumulated from atmospheric fallout".

3.13 Water quality can vary with location. For example, locations next to busy roads may have a higher load of atmospheric pollutants (Villareal & Dixon, 2005). Therefore, when retro-fitting or deciding on the roof type for a new building, if a rainwater device is being utilised, the above factors must all be taken into consideration. In general, the rain water quality would have to be tested for a particular site prior to implementation to establish the quality of water in that area.

Weather effects

3.14 In Forster's (1991) study it was identified that pollution levels of run-off from different roofs within a small area were highly variable and dependent upon season. In addition, the various pollutants from the atmosphere that form on the roof surfaces during a dry period greatly influence the run-off water quality from roof catchment systems, and the longer the dry period in between rainfall events, the greater the amount of pollutants deposited on the roof surfaces (Villarreal & Dixon, 2005).

Roof material

3.15 An important factor in determining the amount and quality of rainwater obtained is the surface where the water is collected. A paper by Albrechtsen *et al*. (2002) suggests that rainwater collected from different surfaces may contain different types of micro-organisms such as *Aeromonas sp*., *Pseudomonas aeruginosa*, *Legionella* non-*pneumophila*, *Campylobacter jejuni, Mycobacterium avium*, and *Cryptosporidium sp*.

3.16 Roof material represents a problem when the roof itself consists of heavy metals. However, this can be avoided by using a different roofing product. Yaziz *et al*. (1989) found that a galvanized-iron roof gives a markedly better quality from run off water than a concrete tile roof due to the nature of its surface. The smoother the roof surface means that fewer pollutants are entrapped from the atmosphere.

3.17 Roofing materials in a building will often be specified in the construction brief, whether for new build PFI/PPP projects or re-roofing projects. These briefs will often call for long lifespan (30 years or more). It is likely that the preferred material will be well suited to gathering rainwater for this reason. Profiled Aluminium is one roofing material which has been used recently to achieve the briefed life-span.

First Flush

3.18 One of the main techniques used to eradicate contaminants during rainwater collection is a 'first flush', whereby the initial run off water is discarded. During a storm event, the first flush of run-off water has been reported to contain a high proportion of the pollutant load (Fewkes, 1996; Yaziz, 1989), due to the deposition and accumulation of pollutant material on the roof during dry periods. As a result, by rejecting the first flush, water quality can be dramatically increased (Kim *et al*., 2005). However, not enough is known about geographical parameters, the effects of weather patterns, the volumes required, and properties of catchment surfaces to identify exactly what constitutes a first flush (Lye, 2009).

3.19 Research suggests that the first flush volumes are unique to each collection area and as a result, the volume of run-off required to disperse the initial high contaminant concentrations can vary. For instance, neighbouring rooftop collection areas often require the diversion of very different volumes of rainwater before the water quality of the run-off improves (Kim et al., 2005).

Note: More research is needed in this area to establish the time required for first flush under different conditions such as geographical regions and roof types.

Microbiological Contamination

3.20 Microbiological water quality standards range from relatively simple to relatively complex. For instance, if the water is intended for drinking, it must be treated to the fully potable standards required by the individual country. For other applications, such as toilet flushing, a lesser standard is allowed. There are no legally binding microbiological limits for recovered water in the UK, possibly because it is not clear where the duty would lie for enforcement.

3.21 The Environment Agency recommends the parameters given in the UK Governments "Market Transformation Program. Rainwater and Grey Water: Technical and Economic Feasibility" (2007) report. This sets guideline standards for three possible end uses of reclaimed water. These values are based on the EU Bathing Water Directive, with the assumption that water of a quality that is safe to bathe in and ingest small quantities of, will be safe for non-potable uses where human contact is minimal. Where there is a risk from aerosols, such as with external cleansing with a spray, or a sprinkler system for garden watering, the guideline values are more strict reflecting the risk of inhalation. These values are set out Table 2, overleaf.

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
Escheria 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 objectionable	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
n/a - not applicable				

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.

3.22 The MTP (2007) feasibility study suggests that the current generation of reclamation systems can easily achieve the C standard. One can deduce from this that until a system can be proven to achieve the A or B standard, rainwater should only be used for WC flushing.

3.23 In 1996, Hollander *et al*. reported on a study involving 102 German rainwater storage tanks which were installed in systems used for toilet flushing and garden irrigation (Hollander et al., 1996). In this case seven different potential microbial pathogens were surveyed. One pathogen, *Pseudomonas*, was detected in 12% of the samples. However, there have also been reports of rainwater systems not meeting microbial standards for use for non-potable contact. For instance, Simmons *et al*. (2001) investigated 125 domestic rooftop rainwater systems in four rural Auckland districts, and analysed cold water samples for chemical and microbiological contaminants. Here, it was found that rooftop rainwater was of relatively poor quality and potential microbial pathogens such as *Salmonella, Aeromonas* and *Cryptosporidium* were identified in some of the collected samples. Their survey also suggested a significant association between the presence of *Aeromonas* and increased gastroenteric symptoms among household users.

3.24 In addition to this, Albrechtsen *et al*. (2002) found that twelve out of twenty seven analysed samples for rainwater used for the flushing of toilets were contaminated with one or more pathogens. These pathogens were not found in any of the thirty two toilets that were flushed with water from the incoming mains. This means that the use of rainwater introduced microorganisms to the water supply that do not occur in water supplied by incoming mains. These results, again, could be due to geographical location.

Rainwater Harvesting Design Considerations

3.25 A simple rooftop rainwater harvesting system consists of its catchment area; a treatment facility, storage tank(s), supply facility and, piping (Han and Mun, 2007) Examples of this system can be seen in Figure 1 overleaf. The storage capacity for a rainwater system is based on rainwater availability and the non-potable water demand of the user. The three factors to consider when designing a rainwater harvester system are:

- the amount of rainfall;
- the size of the collection surface;
- the number of supplied domestic water services outlets (BS8515:2009).

Methods for determining the size of these water storage tanks can be found in document BS8515: 2009.

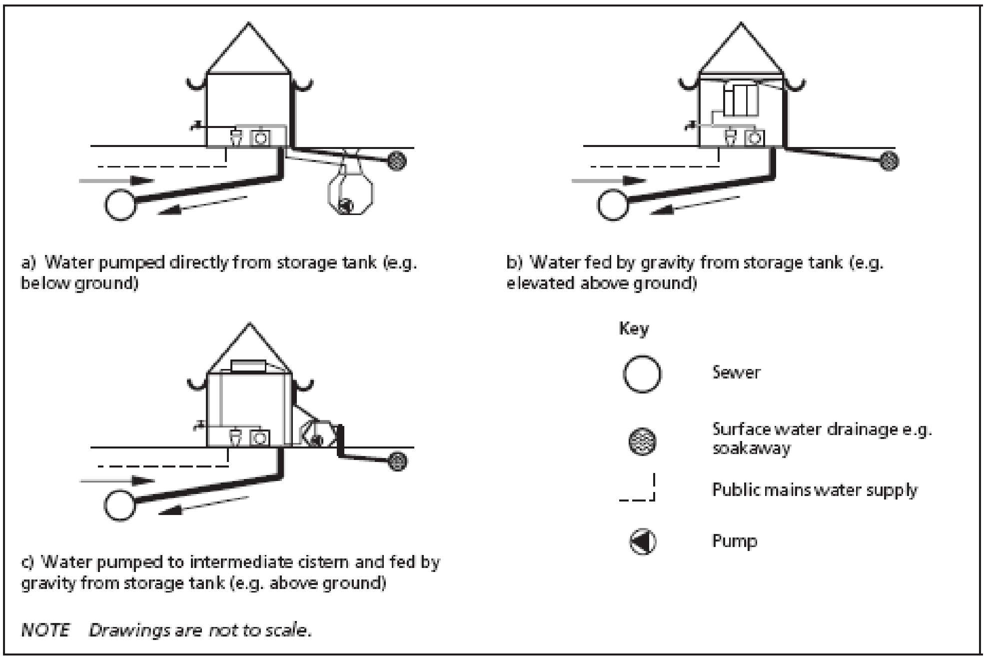


Figure 1: Outline examples of rainwater harvesting systems (Source - BS: 8515)

Collection of Rainwater

3.26 Roofs are the most common method of rainwater collection, followed by areas such as driveways and car parks. Roof catchments are an old method of rainwater harvesting that have been widely used to provide houses in urban areas with potable water supply in many parts of the developing world (Kumar, 2004).

- **Hard roof surfaces** are considered the most suitable for rainwater collection, although many common roofing materials may also be used depending on the purpose of the collected water.
- **Metal roofs** in particular are the material of choice as they are smoother, cleaner, more impervious and more durable than other types of roofing materials (Hart and White, 2003).
- Conversely, **asphalt and wood roofs** tend to collect bacteria, and organic and inorganic chemicals such as asbestos, which can contaminate the water. Metal may also contaminate the water, although a coating may be applied to the roof surface to prevent this from occurring (Hart and White, 2003).

3.27 Guttering and collection pipework connected to the roof outlets are integral parts of the harvesting system and, as a result, must be routinely maintained and cleaned. The pipework allows the rainwater to flow directly into the storage tank by gravity or via a pumping system to serve a tank at high level. The pipes used should be free draining to avoid stagnation and should incorporate a filtration system to prevent gross debris entering the storage tank. BS8515 (2009) states that the filter system should include a filter that is:

- water and weather resistant;

- removable and readily accessible for maintenance purposes;
- has an efficiency of at least 90%;
- passes a maximum particle size of <1.25mm.

3.28 Extant NHS Guidance (SHTM 04-01 Part E, 2011) indicates the need for much tighter levels of filtration exclusion. Although rainwater will only be used in situations where human contact will be minimal, it is prudent to apply as high a level of treatment as practicable. Reference should be made to SHTM 04-01 Part E in the design of any water system in a healthcare facility.

3.29 The sizing of the rainwater system will be dependent on site-specific factors. It is important to assess the site to take into account the rainwater resource available as well as the demand from the proposed uses. BS8515 has guidance on how this should be assessed. BS8515 states:

'As the optimum storage capacity for a rainwater harvesting system is a function of the rainwater availability and the non-potable water demand, the following factors should be identified in order to calculate the size of the system:

- *the amount and intensity of rainfall;*
- *the size and type of the collection surface;*
- *the number and type of intended applications, both present and future'.*

Note: Annex A gives recommendations on the sizing of rainwater harvesting systems which provide additional storage for stormwater control.

BS8515

3.30 Once these details are known for the site, BS8515 contains calculation methods for determining the sizing of rainwater systems. It is recommended that rainwater systems are designed and installed by experienced personnel. It is recommended to follow this guidance when estimating system size.

Treatment and Distribution of Harvested Rainwater

3.31 One of the major concerns when utilising a rainwater system is that the quality and volume of rainwater collected can vary by location. This is problematic for designers, as it is unclear what level of filtration and disinfection is required. For instance, where the harvested water shall be used as non-potable water for toilet flushing, it is difficult to be precise about the type of process that would be appropriate for decontamination, as *each site must be assessed individually for the level of rainfall and contaminants in the water*. CIBSE (2005) suggest that rainwater can be stored safely for between 10 and 20 days, or longer with treatment.

3.32 Where specifiying the design of storage and distribution systems, it may be appropriate to follow SHTM 04-01 Part E guidance on domestic water systems. This provides advice on installing pipework, filters and storage tanks in a way that reduces the potential for bacterial growth within the system. For example, thermoplastic piping and a 5 micron filter should minimise the possibility of biofilm formation (SHTM 04-01 Part E).

3.33 In general, it should be ensured that harvested rainwater should meet the water quality parameters stated in Table 2.

Storage of Rainwater

3.34 In order to provide sufficient storage of rainwater to make the system viable, a large storage tank is usually installed. Storage at high level is possible, but with the majority of systems available, an underground storage tank is used, which feeds a smaller header tank at high level. The diagram below shows an installation without the header tank, pumped directly to the toilet system.

Figure 2: Typical rainwater harvester installation. (Source: http://capitolgreenroofs.groupsite.com/discussion/topic/show/48709.html?page=2)

3.35 The above illustration shows a simple rainwater harvesting system. The components of this system are:

- a filter which excludes leaves and other debris from the roof;
- a storage tank;
- a submersible pump which pumps water to the higher tan;
- a header tank located at high level;
- a secondary water system that is clearly labelled as using non-potable water.

3.36 The main storage tank should be constructed from materials that create watertight structures and prevent bacterial growth (BS8515: 2009). All tanks and cisterns should have screened ventilation and sealed lids to prevent contamination of the water, and should be sited so that the stored water does not reach temperatures which may encourage multiplication of Legionella (BS8515: 2009).

3.37 The storage volume provided must take into account likely volumes of rainwater. BS8515 provides guidance on calculating storage needs. The Met Office holds annual rainfall data from the past 50 years which is updated every month. This can vary significantly from location to location across the country. Table 3 below shows the difference in average rainfall between weather stations on the east and west coasts of Scotland.

Average Monthly Rainfall (mm)		
Month	**Leuchars 1957-2010**	**Paisley 1959-2010**
January	65.82	131.09
February	45.22	91.74
March	46.87	98.21
April	42.81	64.12
May	50.53	68.46
June	52.19	64.23
July	58.59	70.91
August	62.63	90.90
September	59.03	110.26
October	67.74	129.92
November	62.50	126.72
December	61.10	127.05

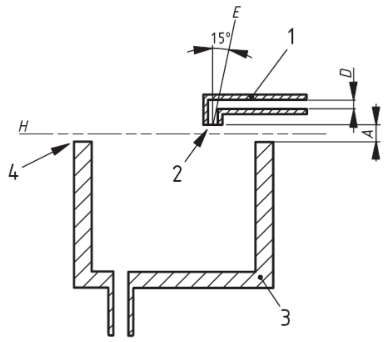
Table 3: Scottish annual rainfall examples

3.38 As with domestic cold water derived from the water authority’s incoming supplies and as required by SHTM 04-01 (2011) the system should be designed to reduce deadlegs. The determining factor when dealing with long term storage precautions will be temperature. The temperature of stored and delivered water should not exceed 20°C in order to avoid breeding of *Legionella* bacteria and this should be monitored by the Building & Energy Management System (BEMS). It may be prudent to introduce some form of treatment of the stored water to reduce the risk of bacterial growth.

Other Considerations

3.39 In the described system, a back up water supply will also be required to top up the header tank when water levels are low. However this system must have a back flow prevention device to prevent any rainwater entering the public water supply (SHTM 04-01 Part B, 2011). Rainwater 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. BS guidance suggests acceptable devices being; unrestricted type ‘AA’ air gaps (see Figure 3) and, Unrestricted type 'AB' air gaps with non-circular overflow (see Figure 3).

Unrestricted type AA airgap



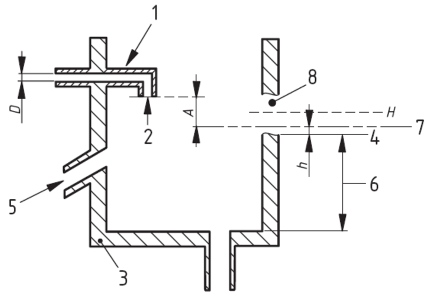
Key

1	Feed pipe	*A*	Air gap
2	Feed orifice	*H*	Maximum level
3	Receiving vessel	*E*	15° maximum from the vertical
4	Spillover level	*D*	Internal diameter of feed pipe (bore)

NOTE 1 This arrangement may be used where the discharge point from the public mains water or potable water supply can be placed above the spillover level of the rim of the storage cistern.

NOTE 2 Overflows and warning pipes have not been shown for clarity.

Unrestricted type AB airgap with non-circular overflow



Key

1	Feed pipe	7	Critical water level (distance *h*)
2	Feed orifice	8	Type AB air gap
3	Receiving vessel	*A*	Air gap
4	Spillover level	*H*	Maximum level
5	Overflow warning pipe	*D*	Internal diameter of feed pipe (bore)
6	Upstream face of the overflow arrangement *Uw* (*Uw* ≥ 5*h*)		

NOTE 1 This arrangement may be used where the discharge point from the public mains water or potable water supply is to be enclosed within the storage cistern. The slot that provides the spillover level is provided within the side of the cistern body (see item 8) and below the outlet of the inlet device. The size of the spill slot needs to conform to BS EN 13077 within critical limits. Owing to the complexities in sizing, detailed guidance is not given in this standard; however, a free-to-access online Type AB Air Gap Calculator is available from the Water Regulations Advisory Scheme [19]. The overflow warning pipe (see item 5) is generally of a standard size, governed by the inlet device to the tank/cistern.

NOTE 2 The critical water level is the physical or piezometric level of the liquid reached in any part of the appliance 2 seconds after closing the water inlet starting from maximum level.

Figure 3: Backflow prevention devices (Source: BS8525)

3.40 The rainwater collected should also be filtered and disinfected prior to entering the system for use. Some sophisticated systems are available which discard the 'first flush' of rainfall (which is likely to be the most contaminated) and therefore reduces the risk of bacterial growth in the tank.

Potential Spread of Bacteria through use of Harvested Rainwater

3.41 Toilet flushing has the potential to spread harmful pathogens in several ways, for example, through dissipation of aerosols and splashing (Newsom, 1972), or poor condition of plumbing (Kay *et al*., 2006). There has been some concern that harmful organisms may be transported to such surfaces through aerosols as a result of toilet flushing.

3.42 Newsom's 1972 study found that bacteria spread by toilet flushing in a hospital was a lot lower than expected, possibly due to regular cleaning. Kay *et al*. (2006) explains that increased risk comes from bacteria normally present in human waste being disturbed by the flushing action, with risk from specific pathogens increasing if a toilet user is already infected. Newsom (1972) suggests that infection from hospital toilets is unlikely as the required number of bacteria for colonisation is unlikely to be found in aerosols or splashes.

3.43 Dispersal of aerosols is also a concern when considering vehicle washing by spraying of harvested rainwater. The higher risk of this occurring compared to toilet flushing can be inferred from the MTP guidelines stricter water quality standard where rainwater is to be used for external cleansing (MTP, 2007). The environment agency (2010) also suggest this standard should be applicable to garden sprinklers, but in general garden watering is considered the lowest risk activity, as indicated by the MTP guidelines (2007). See also paragraph 1.13 in Section 1.

Applicability to different uses

3.44 Rainwater can be harvested for the uses suggested in this document; toilet flushing, garden watering and vehicle washing. Rainwater itself is generally low in contaminants, therefore often does not require treatment before use. However if it is being stored before use, some form of treatment may be prudent as rainwater can harbour harmful bacteria which could multiply in the storage vessel.

3.45 It is important to test the quality of the water harvested to ensure that it is fit for purpose. The Market Transformation Programme (MTP) guidelines suggest chemical and microbiological standards for three different uses; drip irrigation, WC flushing and external cleansing (see Table 2).

3.46 The construction material of the roof and the risk of contamination from animal and bird faeces need to be taken into account. Some roof materials, such as lead, may pollute the harvested water, making it unsuitable for outdoor uses, while remaining suitable for toilet flushing. *It should be noted, however, that harvested rainwater should not be used in accommodation where there are immuno-compromised patients.*

4. Demand and Yield Estimation

Note: Retrofitting rainwater 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.

Rainwater 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 rainwater 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.

It is felt that the calculations can be used as an indication of viability only. If the estimated yield suggests that installing rainwater or 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 rainwater, 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

4.3 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

4.4 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

Rainwater Yield

4.5 CIBSE gives the following calculation for estimating the rainwater resource;

$$Y_r = A_c \times R_m \times C_r \times \eta_f$$

Where:

$\mathbf{Y_r}$ = Annual rainfall yield (litre/year)

$\mathbf{A_c}$ = Collection area

$\mathbf{R_m}$ = The average annual rainfall

$\mathbf{C_r}$ = The run-off coefficient

$\boldsymbol{\eta_f}$ = The fractional collector efficiency

4.6 Annual rainfall data across Scotland is available from the Met Office website (http://www.metoffice.gov.uk/climate/uk/stationdata/), and the CIBSE Guide gives examples of run-off coefficients and collector efficiencies. Coefficients for materials not included in the CIBSE guidance can be found by carrying out an internet search. As the met office data can be represented as monthly averages, it is also possible to calculate a monthly yield with the above equation. As demand is likely to be constant throughout the year, it is possible to estimate the monthly ratio of yield to demand.

4.7 An estimate for rainwater yield can be made, taking Stirling Royal Infirmary as an example again. As Stirling lies almost equidistant between two different weather stations, a yield figure for the average annual rainfall of each has been calculated. The fractional collector efficiency (filter efficiency) is typically 80% to 90% (CIBSE). For this example 80% has been used. A value of 1 m^2 has been used for area, to determine the yield per m^2 of roof space. It is assumed that the roofing material has a high run-off coefficient of 0.9.

4.8 Average rainfall figures for the two nearest weather stations, Paisley and Leuchers are 1,173.71mm and 675.03mm respectively.

Given these assumptions, the rainfall yield figures work out as;

845 litres per m^2 per annum based on Paisley rainfall data

486 litres per m^2 per annum based on Leuchars rainfall data

The variability here shows the importance of assessing rainfall at the location. It should also be recognised that this is a maximum figure and actual yield may be lower due to losses in the collection and storage system.

BS8515 has a more detailed approach to estimating rainwater resource and storage. 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 engaged to carry out 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 rainwater.

5.3 Since much of the cost associated with rainwater collection is directly related to the size of the tank required, it is necessary to determine both the minimum collection area and the size of the tank in order to make use of the available rain at the lowest cost. A study is therefore required to establish the rainfall in that particular area and determine the required tank volume for the catchment area. The Met Office holds annual rainfall data by weather station, which is available from their website (http://www.metoffice.gov.uk/climate/uk/stationdata/).

5.4 New buildings are much more water efficient than existing buildings, through improved efficiency of appliances and fittings. The economics of retrofitting a 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.

5.5 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.

Rainwater Costs and Savings

5.6 Potential savings from a rainwater harvesting system can be roughly estimated by calculating the annual recoverable volume of rainfall, and the cost per cubic metre of supplied potable water.

5.7 Using the calculation given for estimating rainwater resource, potential savings can be estimated. Taking Paisley as an example location, the MET Office data has recorded an average annual rainfall of 1,181.5mm per year between 1959 and 2009 (inclusive). Assuming a pitched roof with slate tiles and a collector efficiency of 80%, the estimated rainwater yield per m^2 is estimated as;

Rainwater yield = $1m^2$ x 1,181.5mm x 0.8 x 0.8

= 756.16 litres per year per m^2 of collection surface

= 0.75616 m^3 per year per m^2 of collection surface

5.8 Estimating capital costs for installation is difficult as site specific issues will lead to variation in costs, making it impossible to generalise on payback periods. For example, whether or not an installation is part of a new build or retrofitted and how the storage tank and other equipment are connected. However, these figures do suggest that rainwater harvesting viability improves with the size of roof-space available.

Case study

5.9 Faber Maunsell carried out a feasibility study into rainwater harvesting from a variety of different buildings in Birmingham. The following example has been highlighted as it would be a system on similar scale to that of a large hospital. Again, it is difficult to draw parallels with this example as site specific details will affect costs. The example is provided as an illustration only.

Example: 350 bed hotel with roof area of 3,000m^2

- rainwater harvested is approximately 1,640m^3 per year;
- assume all rainwater collected used on site for WC flushing or irrigation;
- assume cost for central storage and control system = £30,000;
- assume cost of distribution network = £52,000 (£150 per room);
- water savings approximately 1,640m^3 per year;
- cost savings approximately £2,133 per year;
- simple payback = 38.4 years.

Note: No maintenance or operating costs have been included in the calculations (Faber Maunsell 2004, Page 19)

6. Conclusions

6.1 Site-specific investigations would have to be undertaken to determine rainwater resource and cost of installation to assess if rainwater harvesting is financially viable. From the case study described in this SHTM, and rough estimates of rainfall resource,

- it is unlikely that retrofitting rainwater harvesting is a financially viable option;
- It is likely that rainwater systems will only be feasible when specified on new build properties.

6.2 From a safety standpoint the rainwater at any particular location would have to be analysed to establish if it is safe for use in a healthcare setting. A more stringent approach must be adopted if the water is to be used for anything more than the flushing of toilets (Environment Agency, 2010; MTP, 2007). To prevent growth of microorganisms such as; *Legionella, Aeromonas, Cryptosporidia, Mycobacterium* and others, the storage temperature of this water must remain outwith the range that promotes this growth.

Note: In any case, rainwater use should be discussed with the infection control team.

Under no circumstances should harvested rainwater be used where immunocompromised patients are being treated.

Water Quality Standards

6.3 There are no legally binding standards for reclaimed rainwater. This may be due to there being no clear organisation where responsibility should lie.

6.4 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. Consequently 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.

6.5 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.

6.6 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.

6.7 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

6.8 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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