Technical Note TN 7/2001

RAINWATER AND GREYWATER IN BUILDINGS:

Project report and case studies

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FORWARD

Rainwater and Greywater Use In Buildings is a series of documents resulting from research projects undertaken by CIRIA and BSRIA, collectively known as Buildings That Save Water (BTSW). There are three main outputs to the series:

Decision-making for Water Conservation provides a background to the use of rainwater and greywater and identifies the barriers and benefits of water re-use and recycling. It discusses the issues surrounding rainwater and greywater use, including regulation, water quality, hazards of operation, economics, design and selection of systems and installation. The document is aimed at water utilities, local authorities and environmental regulators. In addition the guidance is aimed at private individuals and house builders with an interest in conserving water resources.

Best Practice Guidance provides practical guidance on the specification and implementation of rainwater and greywater systems. The Guidance is based on the findings from demonstration sites, monitored throughout the BTSW project, consultation with stakeholders and contact with other sites not directly monitored by the project. The Guidance expands further the issues discussed in *Decision-making for Water Conservation*, by providing further detail and specific best practice recommendations for rainwater and greywater re-use. The Guidance is aimed at developers, building owners and their consultants and contractors. The Guidance will also be of interest to water utilities, local authorities, environmental regulators and house builders wishing further detail than that provided in *Decision-making for Water Conservation*.

Project Report and Case Studies details the monitoring of demonstration sites, with rainwater or greywater systems, in the UK. It provides a background to the systems monitored, their operational and maintenance requirements, system reliability and user perception. Details of the monitoring results for water savings, financial analysis and microbiological data are also given. In addition to this the document reports on the experience from other sites using rainwater or greywater systems. Experience gained from this part of the project was used to develop the *Best Practice Guidance*. This Report will be of use to those responsible for the direct installation or monitoring of rainwater or greywater systems and those who wish to see the underlying data and information captured from the rainwater and greywater systems monitored.

Training Pack complements *the Decision-making for Water Conservation* and *Best Practice Guidance* as a training aid. The pack is in the form of a Microsoft PowerPoint presentation with separate slides to illustrate various points.

EXECUTIVE SUMMARY

The increasing demand for mains water and threat from global warming has put increasing pressure on our water resources. This has led to the adoption of water conservation measures to reduce mains water use. These measures include rainwater and greywater use. To date there are few rainwater and greywater systems in the UK and little independent evaluation of their operation and the water savings achieved. The Buildings That Save Water Project set out to investigate these systems by obtaining in-depth information from seven research sites and general contact with 30 active sites which utilised either rainwater or greywater.

Three of the sites used rainwater for drinking but most used rainwater only for toilet flushing. Disinfection is not necessary on rainwater systems which are well designed and maintained where the water is used for toilet flushing. Acceptable water quality is maintained provided debris does not enter the collection tank. Where disinfection was believed necessary (e.g. drinking supplies) UV disinfection was found to be effective, although it increased the operating cost of a system.

There are fewer greywater systems installed in the UK than rainwater systems. The majority serve single houses with a very few examples of multi-residential or larger scale systems. The supply of greywater is not dependent on rainfall so savings can be made even in times of drought. Disinfection of greywater is required as the proliferation of harmful bacteria could potentially pose a health hazard. Systems required periodic topping up of disinfectant and cleaning or replacement of filters so operating and maintenance costs were higher than for similarly sized rainwater systems.

Several of the domestic greywater systems investigated suffered persistent reliability problems related to poor installation. Another issue was the lack of instruction and feedback provided to users. They often did not know whether the system was operating or had failed. Larger greywater systems were better installed and benefited from professional management and maintenance arrangements.

There are no specific regulations for rainwater or greywater reuse but systems must adhere to relevant provisions of the Water Supply (Water Fittings) Regulations 1999. Of particular importance is the prevention of backflow to the mains makeup supply. Where storage is installed at or below ground level, measures for the prevention of backflow from the foul drain are also strongly recommended.

Rainwater and greywater use has been demonstrated to save mains water. The proportion saved is very site dependent with each site requiring individual evaluation. Rainwater and greywater systems can also save money however the initial outlay and operating costs make achieving a sensible payback (within 10 years) impracticable for the majority of small scale systems using current technology. The majority of systems investigated were therefore installed by people or organisations who were environmentally committed, or for research purposes, with the direct economic benefits possibly less important than the environmental ones. In some situations however, extraneous factors e.g. local constraints on drainage, can provide a positive economic argument for rainwater or greywater use even with current technology.

Any major unplanned maintenance, such as a pump replacement, can outweigh the financial savings from reduced water charges so a high standard of reliability is essential to achieving a net saving on operating costs as well as safe operation of the system.

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LIST OF ABBREVIATIONS

ABS	Acrylonitrile Butadiene Styrene
BCDMH	1-Bromo-3-chloro-5,5-dimethylhydantoin (or 3-Bromo-1-chloro-5,5-dimethylhydantoin)
BS	British Standard
BSRIA	Building Services Research and Information Association
BTSW	Buildings that Save Water
CIBSE	Chartered Institution of Building Services Engineers
CIRIA	Construction Industry Research and Information Association
DETR	Department of the Environment Transport and the Regions
DPD	N,N-diethyl-*p*-phenylenediamine
DWI	Drinking Water Inspectorate
EA	Environment Agency
GAC	Granular Activated Carbon
GRP	Glass Reinforced Plastic
HAZOP	Hazards of Operability
HDPE	High Density Polyethylene
IEE	Institution of Electrical Engineers
NAMAS	National Accreditation of Measurement And Sampling
PEX	Cross linked polyethylene
PHLS	Public Health Laboratory Service
PVC	Poly Vinyl Chloride
UKAS	United Kingdom Accreditation Service
UV	Ultra Violet
WC	Water Closet (Toilet)
WRAS	Water Regulations Advisory Scheme
WROCS	Water Recycling Opportunities for City Sustainability

GLOSSARY

Term	Definition
Aerobic	In the presence of oxygen.
Anaerobic	In the absence of oxygen.
Biological reactor	A vessel in which microbial activity breaks down contaminants.
Cartridge filters	A permeable barrier that allows the passage of water but retains varying sizes of particulates which can include bacteria dependent on the pore size. They can be made from various materials including ceramics, carbon, wound string or woven fabric. They are usually disposable.
Cistern	A fixed container for holding water at atmospheric pressure.
Coliforms	A group of bacteria found in the intestines, faeces of most animals, nutrient-rich waters, soil and decaying plant material.
Dark repair	Dark repair is the ability of some bacteria to resuscitate having been exposed to UV irradiation and been kept in the dark after exposure.
Escherichia *coli* (E.*coli*)	Specific bacteria of the coliform group which is regarded as a specific indicator of faecal pollution.
Faecal coliforms	A sub-group of coliforms, almost exclusively faecal in origin.
Granular activated carbon (GAC)	Fine granules of carbon which are used in a filter to polish treated water by primarily removing odour and colour.
Pathogen	An organism which causes disease.
Stagnant water	A volume of water through which there is little or no flow and anaerobic conditions can develop.
Suspended solids	Undissolved particles in a liquid
Turbidity	Reduction of transparency of a liquid caused by the presence of undissolved matter.

1 INTRODUCTION

1.1 BACKGROUND TO THE PROJECT

Rainwater and greywater systems have not yet been widely adopted in the UK, despite the fact that they can produce significant water savings. Well-publicised water shortages, pressure from environmental regulators and the increasing availability of the necessary technology has raised the profile of water conservation measures. As a result of these factors, CIRIA and BSRIA identified the need to demonstrate and assess the current generation of rainwater and greywater systems, and to develop best practice guidance for users, developers, manufacturers and regulators.

CIRIA and BSRIA therefore proposed the research project 'Buildings That Save Water' with the primary objective of promoting water conservation in new, refurbished and existing buildings, by increasing the use of rainwater and greywater. Also recognised was the importance of assessing whether the use of reclaimed water presented an infection hazard to consumers (or those working on these systems) and of establishing whether precautions need to be taken to minimise that risk.

A series of UK demonstration projects were used to encourage the development and adoption of best practice and a network for sharing information and experience was set up.

1.2 SCOPE OF THE PROJECT REPORT AND CASE STUDIES

This report forms one of the published outputs of 'Buildings That Save Water', a major research project undertaken by CIRIA and BSRIA between February 1998 and June 2000. Detailed monitoring took place at seven demonstration sites where rainwater or greywater systems were installed. Each site was monitored for up to twelve months to evaluate the operational performance of the system.

Additional information was obtained from a variety of other sites and studies, which were available during the course of the project. This report is targeted at those installing rainwater and greywater systems or monitoring them. General recommendations on best practice for rainwater and greywater use have been included in the project outputs as described below.

1.3 BACKGROUND TO RAINWATER AND GREYWATER USE

Water demand in buildings can be reduced by substituting rainwater or greywater for mains water in certain applications, such as toilet flushing. If the building mains water supply is metered this may produce cost savings for the building owner or operator. Wider environmental benefits will also result from a reduced demand on water resources, and where greywater is used, reduced volumes of waste water going to sewer. Water supply undertakers and, ultimately their customers, will benefit from a reduction in the need for expensive new water and treatment supply infrastructure as demand for water sources increases.

Report definitions: Rainwater and greywater.

Rainwater is the original source of all our water supplies, as it supplies reservoirs, rivers and aquifers with fresh water. A rainwater use system collects this water from where it falls rather than allowing it to drain away. This project is concerned with water that is collected within the boundaries of a property, from roofs and surrounding surfaces.

Greywater is the wastewater from sinks, baths, showers and domestic appliances. A greywater use system captures this water before it reaches the sewer (or septic tank system). Kitchen sink or dishwasher wastewater is not generally collected for use as it has high levels of contamination from detergents, fats and food waste, making filtering and treatment difficult and costly. Water from these sources is thus not covered in detail in this project.

In many applications the largest savings in mains water are likely to be obtained by using reclaimed water for toilet flushing.

Report definition: Reuse, recycle, reclaim and use.

Reclamation, recycling and reuse are terms often used to express the use of rainwater or greywater. Rainwater does not actually undergo "reuse" (or recycling), as it has not yet been "used".

Greywater can be recycled, as it has undergone initial use e.g. washing hands. Recycling of water utilises some form of treatment. Greywater can also be reused (without treatment) as in the example of direct irrigation. This project refers to the collective of rainwater use and greywater reuse or recycling as "rainwater and greywater use".

Reclaimed water is water that has been collected and treated so that it is suitable for its intended use. Rainwater and greywater are both water sources for reclaimed water.

Rainwater and greywater systems vary in design, size and origin. Buildings may utilise rainwater, greywater or both. Systems range in size from those designed for single households to those designed for groups of multi-storey buildings. Systems may be purchased as complete, ready-to-install units, as individual modules and components for 'DIY' or specialist installation or purpose designed. Modular systems can potentially be used in a wide range of applications and building types, albeit with varying degrees of safety and "success".

Potential uses for reclaimed rainwater and greywater depend on the quantity and quality of water available. The quality depends both on the constituents of the collected water and the effectiveness of the treatment processes.

Report definition: Disinfection and treatment.

Total disinfection will remove any form of infection within the water. Within the context of this report disinfection relates to various forms of disinfection process and can include chemical dosing (e.g. using chlorine, bromine or ozone) and ultra violet irradiation. It should be recognised that where disinfection is referenced within this report it may be partial disinfection, as opposed to total disinfection. (See Decision-making for water conservation).

Treatment of water is a collective term for methods of improving the water quality by physical, chemical or biological means. Whilst the water quality will be improved it should be noted that forms of infection may still be contained within the water if the appropriate total disinfection method is not applied.

Typical uses of rainwater and greywater include:

Rainwater or greywater:	toilet/urinal flushing and irrigation
Rainwater:	vehicle washing, laundry, makeup water for steam boilers and cooling towers

A more detailed discussion of reuse possibilities and associated quality requirement is contained in companion report *Rainwater and Greywater Use In Buildings: Decision-making for Water Conservation*.

The technology for water recycling systems is developing rapidly and there are numerous companies world wide, including the UK, involved in the manufacture, supply and installation of systems and components. Not all systems produced overseas are appropriate for use in the UK. Many of the greywater systems sold in the USA, for example, are specifically designed for direct sub-surface landscape irrigation in arid regions[1].

The key information sources for the use of rainwater and greywater systems, both from the UK and overseas, are listed and described in the bibliography.

APPENDICES

APPENDIX A - OFFICE RAINWATER SYSTEM DATA

Collection tank
MONTHLY TESTS

DATE	TIME	Temp °C	COLIFORMS (CFU/100ml)	E COLI (CFU/100ml)	TVCs 22°C (CFU/ml)	TVCs 37°C (CFU/ml)	COD mg/l	TURBIDITY (FTU)	Free Chlorine mg/l (ppm)	Combined Chlorine mg/l (ppm)	Total Chlorine mg/l (ppm)	Chloride mg/l (ppm)
03/12/98	-	8.5	>200	8	>30000	680	<10	3.2	No sample	No sample	No sample	-
05/01/99	-	9	>200	5	5100	212	11.3	6.78	ND	ND	ND	0.61
01/02/99	-	8	>200	0	350	23	10.4	2.76	ND	ND	ND	0.61
01/03/99	-	8.5	>200	0	3800	32	26	3.7	ND	ND	ND	2.35
12/03/99	09:30	8	145	0	1680	220	<10	1.97	ND	ND	ND	1.7
12/03/99	12:30	8	-	-	-	-	-	4.5	-	-	-	-
12/03/99	14:00	8.5	200	0	660	95	13	4.5	-	-	-	-
12/03/99	17:00	7	145	0	910	164	<10	4.5	ND	ND	ND	3
29/03/99	-	9.5	>200	0	3800	120	22	5.39	ND	ND	ND	-
30/04/99	09:30	10.5	>200	3	16000	180	25.3	7.76	ND	ND	ND	1.7
30/04/99	12:30	10.5	-	-	-	-	-	11.35	-	-	-	-
30/04/99	13:30	11.5	>200	1	8000	204	36.8	10.84	-	-	-	-
30/04/99	16:00	12	>200	1	10100	174	26.7	6.87	ND	ND	ND	1.04
27/05/99	-	12.5	>200	29	7900	>30000	214	20.81	ND	ND	ND	4.31
28/06/99	-	-	>200	130	>30000	>30000	73	1.72	ND	ND	ND	5.40
26/07/99	-	15	>24190	>24190	>30000	12600	666	15.48	ND	ND	ND	-
10/08/99	10:00	17	130	70	14300	0	<10	6.44	ND	ND	ND	-
10/08/99	11:30	17	-	-	-	-	-	5.74	-	-	-	-
10/08/99	13:30	17	101	56	3000	0	<10	7.99	ND	ND	ND	-
10/08/99	16:30	19	78	41	20300	0	<10	5.38	ND	ND	ND	-
06/09/99	Empty	11	-	-	-	-	-	-	-	-	-	-
06/10/99	-	14	1100	228	8300	120	<10	3.21	ND	ND	ND	8.45
08/11/99	-	11	1733	173	11200	9400	17	69	ND	ND	ND	3.44

Loft cistern inlet
MONTHLY TESTS

DATE	TIME	Temp °C	COLIFORMS (CFU/100ml)	E COLI (CFU/100ml)	TVCs 22°C (CFU/ml)	TVCs 37°C (CFU/ml)	COD mg/l	TURBIDITY (FTU)	Free Chlorine mg/l (ppm)	Combined Chlorine mg/l (ppm)	Total Chlorine mg/l (ppm)	Chloride mg/l (ppm)
03/12/98		18	>200	6	21700	1130	<10	2.68	No sample	No sample	No sample	-
05/01/99		11.5	22	1	610	86	11.7	3.49	ND	ND	ND	0.61
01/02/99		8.5	0	0	61	8	<10	0.73	ND	ND	ND	<0.5
01/03/99		19	0	0	64	1	82	4.37	ND	ND	ND	0.83
29/03/99		11	0	0	360	6	19	4.12	ND	ND	ND	-
30/04/99	9:30	20.5	0	0	81	192	101	7.76	ND	ND	ND	2.57
30/04/99	12:30	14	-	-	-	-	-	3.38	ND	ND	ND	ND
30/04/99	13:30	14	0	0	3	3	24.2	3.11	ND	ND	ND	ND
30/04/99	16:30	12.5	0	0	0	15	25.3	2.5	ND	ND	ND	1.70
28/06/99		-	>200	19	18900	3000	96	2.24	ND	ND	ND	3.01
10/08/99	10:00	19.5	0	0	75	0	<10	2.93	ND	ND	ND	-
10/08/99	11:30	19	-	-	-	-	-	3.55	-	-	-	-
10/08/99	13:30	18	0	0	18	0	<10	4.15	0.03	0.01	0.04	-
10/08/99	16:30	20	0	0	46	0	<10	3.69	ND	ND	ND	-
06/09/99		-	-	-	-	-	-	-	-	-	-	-
06/10/99		16	-	-	-	`	-	2.54	ND	ND	ND	-
08/11/99		18	0	0	29100	29100	12	1.27	ND	ND	ND	6.92

Loft cistern content
MONTHLY TESTS

DATE	TIME	Temp °C	COLIFORMS (CFU/100ml)	E COLI (CFU/100ml)	TVCs 22°C (CFU/ml)	TVCs 37°C (CFU/ml)	COD mg/l	TURBIDITY (FTU)	Free Chlorine mg/l (ppm)	Combined Chlorine mg/l (ppm)	Total Chlorine mg/l (ppm)	Chloride mg/l (ppm)
01/03/99		16.5	0	0	1040	160	12	0	ND	ND	ND	4.31
12/03/99	9:30	10.5	0	16	3	<10	0	0.01	ND	ND	ND	
12/03/99	12:30	9	-	-	-	-	0	-	ND	ND	ND	
12/03/99	14:00	9	0	3	0	<10	0	-	ND	ND	ND	
12/03/99	17:00	9	0	3	0	<10	0	0.01	ND	ND	ND	
29/03/99		14.5	0	0	4100	360	21	1.95	ND	ND	ND	-
30/04/99	9:30	-	0	0	1	0	<10	0.86	ND	ND	ND	17.80
30/04/99	12:30	13	-	-	-	-	-	2.81	ND	ND	ND	ND
30/04/99	13:30	14	0	0	270	12	21.9	3.22	ND	ND	ND	ND
30/04/99	16:00	14	0	0	65	24	26.3	3.22	ND	ND	ND	3.22
27/05/99		15	0	0	380	1	10	0	ND	ND	ND	1.92
28/06/99		-	>200	1	17800	4100	31	2.48	ND	ND	ND	18.24
26/07/99		20	1	0	3100	12	<10	2.45	ND	ND	ND	-
10/08/99	10:00	20	0	0	19600	0	<10	2.79	ND	ND	ND	-
10/08/99	13:30	17.5	0	0	7600	0	<10	2.73	ND	ND	ND	-
10/08/99	16:30	19.5	0	0	980	0	<10	2.71	ND	ND	ND	-
06/09/99		21	0	0	178	8	<10	0	ND	ND	ND	-
06/10/99		17	0	0	340	196	<10	1.6	ND	ND	ND	-
08/11/99		17	0	0	>3000	3600	60	2.42	ND	ND	ND	-

ND – Not Detected
Where 0 cfu/100ml is used it refers to the limit of detection which is <1 cfu/100ml