Greywater: a study of greywater characteristics and treatment feasibility at the University of Reading

WATEF - Water Efficiency Conference 2013

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What is Greywater?

- For the purpose of the British Standard (BS:8525, 2011), greywater is defined as water originating from bathrooms, including:
  - water used in baths, showers, washbasins and for laundry

- Characterised by its cloudy appearance and richness in organic matter (Pidou 2007)
Benefits

- Reduction of the use of mains water for non-potable applications
- Reduction in water bills
- Reduces the pressure on existing freshwater sources
- Natural recharge of soils
Aim and Objectives of UoR Greywater Study

Aim

To evaluate the characteristics of greywater and the feasibility for implementing greywater treatment systems at the University of Reading

Objectives

- Determine the chemical and biological characteristics of untreated greywater at the UoR
- Evaluate the effectiveness of treatment on the characteristics of greywater
- Evaluate the quality of untreated and treated greywater, and the potential for greywater reuse
- Examine the installation costs of greywater system at the UoR
Greywater was sourced from two hall’s of residences

1. **Sibly Hall** – Located in close proximity to UoR’s Whiteknights campus

2. **Wessex Hall** – Located within the UoR’s Whiteknights campus
Methodology

Collection of GW From Washbasins

Transfer to UoR's Engineering Department

Transfer to Settlement Bucket and Mixing

Transport to Storage Bucket

Chemical & Microbiological Analysis

Filtered GW Sample Taken

Treatment

Unfiltered GW Sample Taken

Approach to Greywater Collection & Analysis
Treatment System

- Comprising of two brewing buckets and a ‘Intex Krystal Clear’ 604 cartridge filter pump
  - Capacity of pump - 2000 litres an hour.
  - Cartridge filter - Dacron (PET, Polyethylene terephthalate)
  - Filter pore size rating ~0.45 μm
  - Storage capacity of buckets – 15 and 25 litres.
- Treatment - 12 minute cycles per batch of greywater
Chemical Analysis

- Analysis took place on the same day as greywater collection and treatment.
- In total 24 samples were analysed, yielding 12 untreated and 12 treated samples.
- In line with standard methods, repeat and blank samples were analysed for each sample.
- The standard analytical procedures were carried out in an accredited UKAS laboratory at the University of Reading.
Chemical Analysis

- Following parameters were analysed:
  - pH
  - Electrical conductivity (EC)
  - Total Solids (TS) & Total dissolved solids (TDS)
  - Anions – Ion chromatography
## Water Quality Standards

<table>
<thead>
<tr>
<th>Parameter and maximum concentration</th>
<th>pH</th>
<th>EC (μs/cm)</th>
<th>TDS (mg/l)</th>
<th>Chloride (mg/l)</th>
<th>Fluoride (mg/l)</th>
<th>Nitrate (mg/l)</th>
<th>Phosphate (mg/l)</th>
<th>Sulphate (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) for greywater</td>
<td>6.0 – 9.5 Y</td>
<td>450 – 550 Ψ</td>
<td>&lt;1500 Ψ</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>b) for bathing and drinking</td>
<td>6.5 – 7.9 Ω</td>
<td>&lt;2,500 Ω C</td>
<td>300 h – 500 Α</td>
<td>&lt;250 Α</td>
<td>&lt;1.5 Ω C</td>
<td>&lt;45 Α</td>
<td>*</td>
<td>&lt;250 Α</td>
</tr>
</tbody>
</table>

Information on standards for greywater, bathing and drinking water was obtained from a range of sources and these are denoted as follows:

For greywater:
- BS: 8525-1/2 (2011);
- CSIRO (Diaper et al, 2008);
- Chinese Greywater Standard (Ernst et al, 2006)

For Bathing and drinking water:
- Health Protection Agency Drinking Water Standard (2009);
- Safe Drinking Water Foundation Standard (2009);
- Thames Water Drinking Water Standard (2011);
- US Environmental Protection Agency Standards (2009)
Results – Electrical Conductivity and TS

- **Electrical Conductivity Results**
  - Reduction of 12% following treatment
  - Unfiltered – within a range acceptable for potable water
  - Filtered - within a range acceptable for potable water (MRCCC 2007)

- **Total Solids Results**
  - Unfiltered Greywater – 442 mg/l
  - Filtered Greywater - 269 mg/l
  - 63% Reduction in TS.

- **TDS concentrations, compliant with standards**
  - Unfiltered – classed as ‘Good’ (SDWF 2009)
  - Filtered – classed as ‘Excellent’ (SDWF 2009)
Results

- **pH concentration**
  - Treated samples are slightly more alkaline
  - This is most probably linked to removal of:
    - Buffering agents
    - Surfactants and micelles
  - Unfiltered greywater – compliant with all standards
  - Filtered greywater – compliant with 7 out of 9 standards
**Chloride Concentrations**

- Concentrations are controlled to reduce conductivity and corrosive nature within pipes
- Increase of 8% from tap water levels, in untreated greywater
- Removal rate of 16% as a result of treatment
- Concentrations recorded in untreated and treated samples were below the 250mg/l limit, set in potable and non potable water standards
Nitrate concentrations

Concentrations recorded in untreated and treated samples were below the 45-50mg/l limits set in potable and non potable water standards.
Results - Sulphate

- **Sulphate concentration**
  - Concentrations in drinking water controlled to prevent intestinal discomfort
  - No significant reduction in sulphate concentrations as a result of treatment
  - Concentrations within untreated and treated samples below the 250mg/l - 500mg/l limit
Results - Fluoride

Fluoride concentration

- Negligible difference between treated and untreated greywater
- Low concentrations of fluoride in both untreated and treated samples
- Levels within untreated and treated samples below the 1.5 – 3mg/l limit for potable water
### Economic Feasibility at UoR

#### Potential Annual Greywater Yield -
- Science and Technology Centre 2,477 m³
- Wessex Hall 1,881 m³
- East Lodge 766 m³

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<thead>
<tr>
<th></th>
<th>Science and Technology Centre</th>
<th>Wessex Hall</th>
<th>East Lodge</th>
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<tbody>
<tr>
<td>Output of GW (L/Day)</td>
<td>6,250</td>
<td>5,153</td>
<td>2,090</td>
</tr>
<tr>
<td>Size of System (L/Day)</td>
<td>6,500</td>
<td>5,500</td>
<td>2,500</td>
</tr>
<tr>
<td>Capital Cost (£)</td>
<td>£15,000</td>
<td>£12,650</td>
<td>£5,750</td>
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<td>Total Annual Savings (£)</td>
<td>£4,000</td>
<td>£3,308</td>
<td>£1,347</td>
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<td>Annual Depreciation (£)</td>
<td>£1,000</td>
<td>£843</td>
<td>£338</td>
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<td>NPV (5%)</td>
<td>£16,211</td>
<td>£12,942</td>
<td>£5,723</td>
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<tr>
<td>IRR (%)</td>
<td>18%</td>
<td>18%</td>
<td>16%</td>
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<tr>
<td>Simple Payback</td>
<td>5</td>
<td>5.1</td>
<td>5.7</td>
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15 Year Lifetime of System
Implications

- Despite using a filtration system having a relatively limited technical specification, the characteristics of the greywater quality improvement exemplified the potential for treating greywater for reuse at the University of Reading.

- The chemical constituents in the treated greywater complied with the BS:8525 requirements for greywater supplies.

- The outcomes regarding the efficacy of using an inexpensive system of greywater treatment may be applied in future to small throughput, lightly loaded systems, provided that chlorination or other disinfection were to be added to the process.
The feasibility study indicated that the early-stage benefits of implementing greywater treatment and of using distributed greywater at the University can be tentatively demonstrated on the grounds of technical, environmental and financial viability.

Research conducted during the feasibility study indicated that water savings and cost savings will be made following the installation of greywater treatment on the campus.

When taking into consideration the calculation of the potential annual supply of greywater within those buildings, savings in potable water supply and effluent charges will be likely to be achieved.
Conclusions

- Greywater sourced from washbasins is chemically suitable for reuse
- Simple biological treatment is required to remove biological contaminates
- The payback period for a greywater systems at UoR is within the range of 5-6 years
- Greywater systems at the UoR can offer water based savings of between £4,000 and £1,347 annually
In order to obtain more substantial estimates of these variables and to determine whether the technology would be suitable for roll-out throughout the University estate, it would be appropriate to implement a pilot project in one or more buildings to enable more detailed testing.

Future research is also needed to assess the rates at which greywater can be recovered, as a proportion of incoming mains water, from a variety of uses.
References

Bristol Water (2009) Drinking water quality, the standards explained, Bristol: Bristol Water


Milton Keynes: BSI.


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Costs - Assumptions

- **Total Water Consumption**
  - Based on water readings for 4 months.
  - Water consumption is constant throughout 15 year lifetime of system.

- **Sewerage**
  - Assumed to be 95% of all water consumed (Southern Water 2012).

- **Greywater Yield**
  - 30% of sewerage available as greywater (Parliamentary Office of Science and Technology 2000).

- **Capital Costs**
  - 5 stage system – including physical and biological treatment.
  - Do not include O&M costs.
  - Based on a retrofit system.

- **Discount Rate**
  - 5% (Glick et al 2009).