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Monitoring Drainage Water Quality During Green Roof Irrigation Trials Using Synthetic Greywater

Overview

- Project Aims & Objectives
- Antecedence and previous work with greywater
- Experiment and method design
- Observations & outcomes, including sodium (Na)
- Effective green roof management & next steps
- Conclusions
- References

Project Aims & Objectives

- Aims: To investigate the effect of greywater applied to a typical (*Sedum*) and non-typical (*Stachys byzantina*) green roof plant and examine the accumulation of Na, from greywater within the growing medium, leaf tissue and effluent waters.
- 1) Assessing the quality of irrigation water following application;
- 2) Assessing the effects that greywater irrigation has on plants and soils within the green roof system;
- 3) Evaluation regarding the application of greywater as a viable alternative to the use of mains water for irrigation of green roofs; in terms of water quality and in terms of the potential effects on plants from Na in greywater.

Antecedance & previous work

- Team involvement in BS:8525, 2010 & 2011 committees.
- The British Standard (BS:8525,2011), defines greywater as:

  water originating from sources including water used in baths, showers, washbasins and for laundry.
- Synthetic greywater :
  - Recipe devised by the British standards (BS:8525, 2011).
  - Adapted at UoR for experimental purposes.

Components	Amounts
Mains Water	9.913 l
Shower gel (Johnson's Baby Soft Wash)	8.6 ml
Oil (Sunflower)	1 ml

Experiment and Method Design

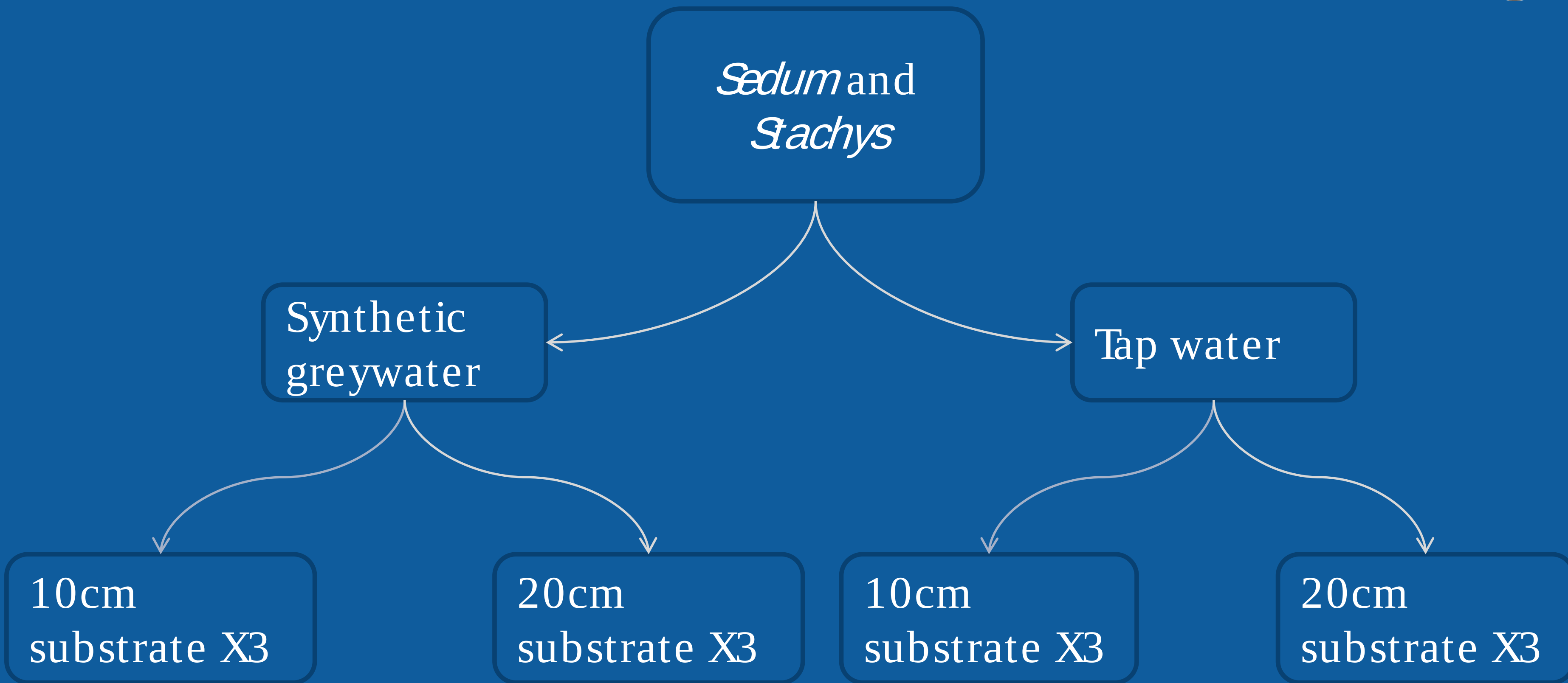
- Experiment: 28 days
- Thirty-two boxes (0.4m by 0.6m) contained eight drainage holes.
- 2 plant types used
- Irrigated with tap or Synthetic greywater
- 2 substrates depths (10cm or 20cm).
- Substrate: John Innis Compost No.2
- No extra fertiliser used.

Plants

Sedum: Succulent, helps withstand drought conditions.

Stachys: White hairs help passive cooling of building due to albedo effect and shading.

Experiment and Method Design

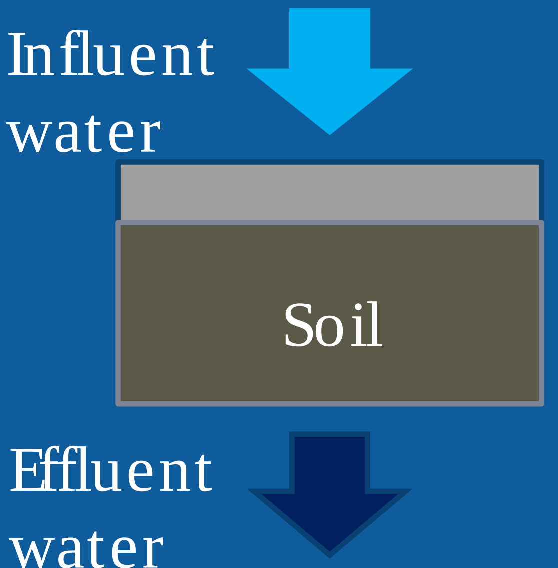


- Control Boxes: Bare soil, *8 boxes (4x10cm, 4x20 cm substrate)*
- *Half irrigated with tap water other half greywater*

Sampling

- Soil moisture content
  - Determined when boxes would be irrigated. Bare soil and *Stachys*: irrigated when moisture content fell below $0.25m^3/m^{-3}$, *Sedum*: irrigated when moisture fell below $0.20m^3/m^{-3}$.

- Water sampling
  - Influent (day 0, 14 and 28).
  - Effluent water, Soils from planting boxes, Leaf tissue (day 0 and 28).



Principal parameters measured

- Total dissolved solids (TDS)
- pH
- Electrical conductivity (EC)
- Sodium extraction and flame photometry
  - Ammonium nitrate extraction (soils)
  - Nitric acid digestion (plant tissues)

Observations & outcomes

- Influent composition

	pH		Conductivity (µScm-1)		Sodium (mg/l)	
Day	Mains water	Greywater	Mains water	Greywater	Mains water	Greywater
0	8	7.6	560	610	13.6	22.7
14	7.8	7.6	595	510	17.7	26.3
28	7.7	7.3	580	600	18	29.2

- pH & conductivity: little change
- pH: within ranges seen in literature (Ernst et al 2006, Asano 2007)
- Conductivity: low compared to other studies. Li et al 2008 suggests 1000µS cm-1, (highly variable).
- Higher sodium concentrations in greywater expected. Chemical composition of detergent included "Sodium Laureth Sulfate, Sodium Lauroamphoacetate, Sodium Chloride, Sodium Hydroxide and Sodium Benzoate".

Total dissolved solids (TDS)

- Effluent samples: little difference in TDS comparing tap and greywater irrigated boxes.
  - Substrate: high influence on TDS compared to difference in waters.
- TDS decreased in planted boxes (for both substrates depths) when compared to bare soil control.
  - TDS may have increased in plant boxes due to the release of exudates from plant roots and/or microbial release of ions upon decomposition of dead plant roots (Coleman et al, 2001).
- High transpiration rates & water uptake by plants: factor in the decrease of effluent TDS
  - *Stachys* boxes show a decrease in effluent TDS.
  - The 20cm substrate showed the highest decrease of TDS.
  - The TDS of bare soil boxes seem relatively stable in comparison.

pH

- Comparing pH in influent and effluent water
  - pH decreases once water has interacted with soil matrix (both tap and greywater) also seen by Anwar (2011).
  - Soil pH seems unaffected by irrigation with tap or greywater.
  - Christova-boal et al (1996) suggested that more polluted greywater would affect soil pH more severely. Product variability, activity in which greywater is generated and the quality of water supply affect greywater composition.
- Substrate depths and plants
  - Higher variability of pH (of effluent and soils) are seen in the deeper substrate boxes, likely due to higher volumes of irrigation and soil.
  - Plants seem to have little or no influence on effluent and soil pH.

Electrical Conductivity, EC

- Comparing influent and effluent water results
  - Water conductivity increases as it passes though soil matrix.
  - Thicker substrates: higher influence on EC of effluent water.
  - Effluent EC is affected more by soils than the greywater.
- Plants influence on EC
  - Soil & effluent samples: decrease in EC when plants were present. Expected as plants should absorb some charged ions.
  - Na is absorbed by plants, over the experiment, therefore it is assumed other charged ions were also absorbed.

Sodium analysis

- Effluent Na Concentrations
  - Increased once passed through soil matrix.
  - Larger substrate boxes produced effluent with higher Na concentration: likely due to higher retention times.
  - When irrigating, all boxes displayed signs of ponding . A higher presence of moisture, lower in the substrate may have led to increased Na concentration, due to its highly soluble nature and leaching potential.
  - The presence of moisture weakens the bond between Na and the soil allowing to be transported in the box.
- Plant tissue sodium
  - Na accumulation of between 0.55 to 0.72 (mg/g.l).
  - Deeper substrate depths and irrigation with greywater led to an increase of Na concentration in leaf tissue of plants in these box types.

Secondary moisture experiment

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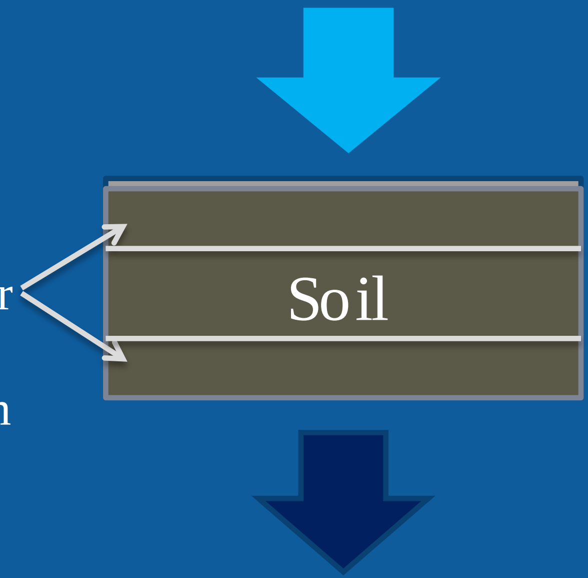
- Establish moisture differences between the top and bottom of substrate (5cm).
- Soil moisture probe: used to test the substrate and compared how the moisture varied after 1, 3 and 7 days.
- Results showed moisture content of the bottom 5cm was constantly higher (44%, 27% and 34% respectively).
- A constant presence of moisture likely kept Na, due to its soluble nature, in an aqueous solution in the lower parts of the substrate for the experiment period.
- Over irrigation is likely to have occurred.

Moisture content tested, after 1, 3 and 7 days. (20cm box)



Green roof system: Sodium (Na) mass balance

- For each box, the total amount of Na applied, through irrigation, was calculated by multiplying the total volume of water irrigated by the average Na concentrations seen in either the tap or greywater samples.
- In all cases the mass balance equation showed an excess of Na that was not accounted for, either by storage in the plants or soils, or losses through effluent water.
- There are a number of reasons for this…

Green roof system: Sodium (Na) mass balance

1. Water that was collected during the flushing event was not representative of the entire box. Box design enabled water to collected – meaning it was unable to leave the system.

2. The soil sampling method is suspected to have led to an under-representation of soil sodium.

3. Undetected leakage after irrigation may have also led to amounts of Na being unaccounted for in the mass balance equation.

4. The roots may also account for a small % of the total Na.

Effective green roof management and next steps

- Substrate types needs further investigation into how they affect effluent water quality.
- Different types of greywater need classification and only certain types should be used for irrigation.
- Increased numbers of long term studies are required into affects of greywater/synthetic greywater irrigation on green roofs to help with management plans.
- Can green roofs improve greywater quality?

Conclusions

- Green roofs important in urban areas, but need effective management plans to reach their full potential.
- Water quality has been seen to decreases once passed though the soil matrix.
- With careful planning, greywater may be used for irrigation as a replacement for mains tap water.
- Greywater is a precious resource which can be utilised to benefit climate change adaptation and mitigation measures, including green roofs.

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