Measuring the performance of Green Facades irrigated with greywater in a Mediterranean Climate

Land use / development type	Scale
Institutional - School	Lot
Water source/supply	Scale
Greywater	Irrigation/Non-potable
Efficient use of water	Scale
Green wall	Building
Other Benefits	Benefits measure
Thermal comfort	Moderate
Aesthetics	Significant
Increase property value	Significant
Improved air quality	Moderate
Wind reduction	Low
Biodiversity	Moderate
Local government	Location
City of Canning	Bentley Primary School

Green walls/facades have been used for millennia for thermal comfort and aesthetics. Biophilic design, the practice of connecting people and nature within our built environments and communities, has been recommended to enhance the sustainable development of urban centres. In biophilic cities, green infrastructure aspires to mimic and support the natural environment. The benefits of green walls are shading and blockage of solar radiation, evapotranspiration cooling, energy saving, cost, environmental, health and well-being benefits.

This case study provides a summary of how the pilot study of several green facades irrigated with greywater has been conducted at Bentley Primary School. It outlines the objectives of the research and the thermal and water performance of the facades. This case study provides information on suitable plant species for Perth's Mediterranean climate that could survive greywater irrigation, based on diurnal water use and end-use of outflow, as well as their ability to improve water quality.

The case study site: Bentley Primary School

Bentley Primary School is situated about 10 km south-east of the Perth city centre. The site was selected through collaboration with the Department of Communities and the Department of Education. The objective of the case study was to utilise greywater to irrigate the green wall, which also acts as a treatment system for greywater.

The greywater used for irrigation was generated from hand basins in the senior students' toilet block and from drinking water fountains. The green facade locations were selected facing east (E), west (W) and north (N1, N2, C). The location of the green facades are indicated in Figure 1.

To avoid any physical contact, the greywater was stored in an underground sump(polypit) and pumped to irrigate the green walls. Gingin loam was selected as a soil media for use in the green facade planter boxes.

Outflow pipes were installed in the bottom of the planter boxes to collect drained water. Pressure sensors and ultrasonic flow meters were installed to measure the inflow and outflow from the polypit. Soil moisture was monitored with moisture sensors. After the installation of monitoring equipment, data was collected regularly for water quantity and quality assessment.

Figure 1: Aerial image of Bentley Primary school showing location of green facades.

Measuring performance

The water balance of the green facades was calculated based on inflow, outflow, evapotranspiration and soil moisture. The monitoring project commenced in June 2019 and finished in December 2020.

The long-term plant water use or evapotranspiration accounted for plant transpiration via plant stomata, plant evaporation and soil evaporation. The stomatal conductance was measured in triplets using a portable photosynthetic system. *Hibbertia scandens* and *Hardenbergia violacea* plant species were selected for the case study.

Water samples from the potable water tap, greywater influent and planter effluents were collected and analysed in the field for temperature, pH, electrical conductivity (EC) and dissolved oxygen (DO). The water samples were analysed in a laboratory for nutrients [total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS)], metals and pathogens. The analysis was conducted using standard laboratory methods.

The study measured the thermal performance of the green façades and sought to understand the role that plants had on the cooling effect of green façades at Bentley Primary School.

The building's energy saving was calculated by measuring external wall temperatures with and without the green façade. Gap cooling was measured and compared with ambient air temperature. A heat map of the external green wall was generated to measure the effect of leaf morphology of the green façade on thermal performance.

Key findings

Water Usage

In 2019, the average rates of evapotranspiration for planter boxes with non-deciduous climbers was 3 L/day in cool months and 9 L/day during warmer months. For planter boxes with deciduous climbers, evapotranspiration was estimated to be 2 L/day and 9 L/day, respectively.

In 2020, the estimated average rates of evapotranspiration for planter boxes with non-deciduous climbers increased to 4 L/day in cool months and 10 L/day in warmer months, and planter boxes with deciduous climbers increased to 3 L/day and 10 L/day, respectively.

The stomatal conductance, which is an indicator of plant water status or use, of *Hardenbergia* reached its maximum in the afternoon. Whereas for *Hibbertia,* the maximum was in the morning. Soil water storage started to reduce after the planter boxes were irrigated around 8am and reached a maximum decline around midday when the plant transpiration rate was high. The hourly transpiration rate of *Hardenbergia* was almost double that of *Hibbertia* for most of the day, suggesting that *Hardenbergia* uses more water than *Hibbertia*.

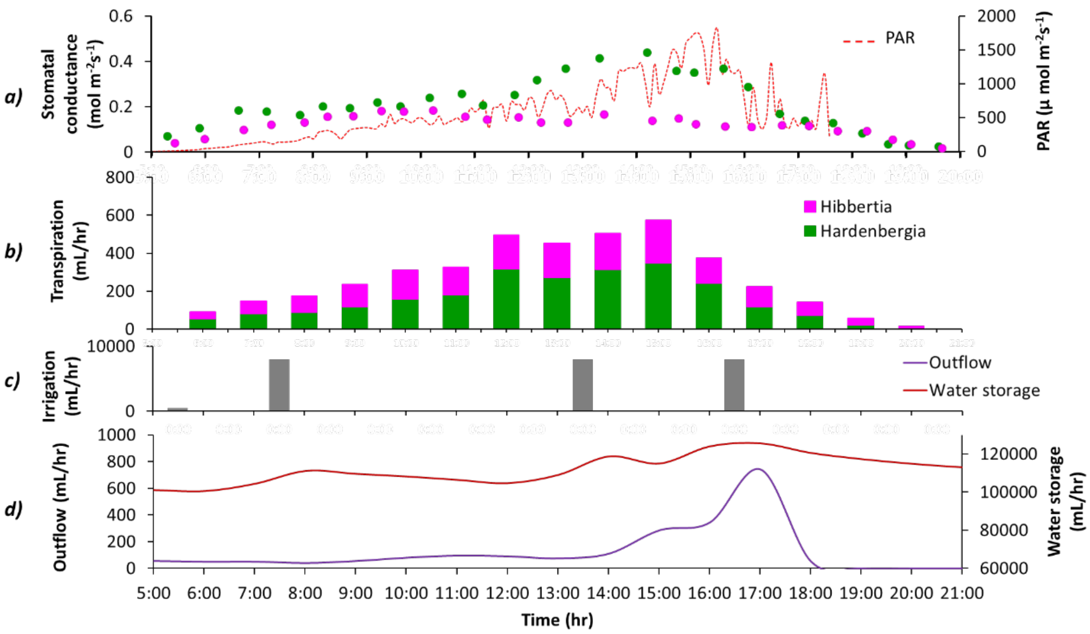

Figure 2: a) Stomatal conductance and solar radiation (PAR), b) transpiration, c) irrigation, d) water storage and outflow from green façade

Nutrient and pathogen removal performance

The inflow and outflow temperature ranged from 14–29 °C; pH 6.4–7.9; EC 0.1–1.2 mS/cm and DO 0.5–12.1 mg/L during June–December 2019. The outflows test results for heavy metals, pH and EC indicated a satisfactory range for most of the green facades.

The green facades achieved 50-100% reduction in TN and TP loads. No specific trend or impact of vegetation was observed for pathogen removal by the green facades.

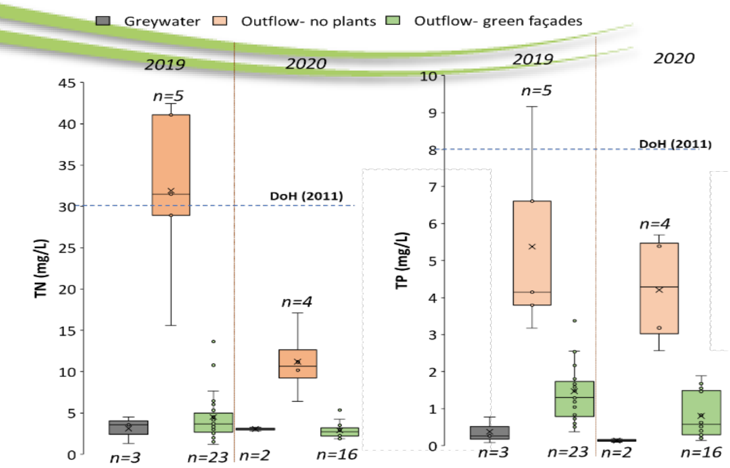

Figure 3: Total nitrogen and total phosphorus in greywater inflow and outflow discharged from the controls and green facades

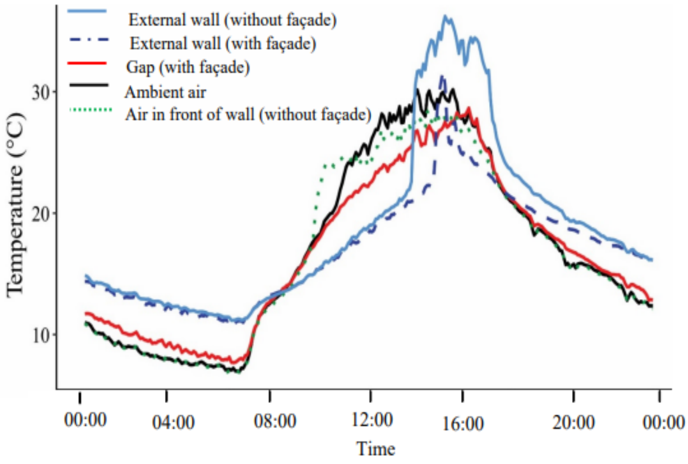

Figure 4: External wall and air temperatures

Thermal comfort

- The gap temperature with facade was up to 4 °C cooler than ambient air during warm and hot weather.
- The gap temperature with facade was up to 2 °C warmer than ambient air during cool periods.
- The thermal performance of a shade sail was also tested. It achieved approximately half the cooling of the green facade.
- The external wall with facade was more than 17 °C cooler than the external wall without facade during warm periods.
- The external wall with facade was about 4 times cooler than the wall with a shade sail during warm periods.
- A north facing facade can prevent losing heat energy from external walls during cool periods (2 times warmer than without facade).

Outcomes

The results of the case study suggests that green facades irrigated with greywater are viable in Perth. It was observed that when sufficient outflow was available to analyse, nutrient attenuation is very good and that air temperatures behind the green facades were substantially lower than ambient temperatures. Plant species selection is an important consideration for the management of outflow, as it is dependent on the type and evapotranspiration rate of plants.

Way Forward

This study confirms that green facades watered with greywater can be considered for residential properties in Perth. As this study was done on a pilot scale, limited data is available to comprehensively evaluate all the aspects that influence design and performance (e.g. how different plant species influence outflow). It is recommended that the environmental, social and economic performance of green facades are studied in a larger scale application. Consideration should also be given to the impact of higher winds (which is applicable in apartments) and the long-term build-up of salts in media.

References and resources

CRC for Water Sensitive Cities (CRCWSC), *Green façades in Mediterranean climates: Water use, treatment and re-use*, case study presentation by Azrina Karima and Reza Bakhshoodeh.

The University of Western Australia, *Performance of green façades irrigated with greywater under a Mediterranean climate*: A pilot-scale study Research Proposal and Progress Report for the Degree of Doctor of Philosophy.

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Water Sensitive Cities

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www.newwaterways.org.au
info@newwaterways.org.au
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