

Evaluating vertical greenery system: Impacts on indoor air quality, water management and energy performance in a controlled chamber.

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SUMMARY

This study examines the combined impacts of vertical greenery systems (VGS) on indoor environmental quality through a multidisciplinary approach integrating energy performance, thermal comfort, indoor air quality (IAQ), and water management. Experiments were conducted in a climatic chamber under summer and winter office conditions. Results show that VGS influence both energy demand and IAQ: in winter, they improve indoor humidity but increase heating demand, while in summer they reduce cooling demand but raise relative humidity. VGS also modify VOC profiles and reduce certain air pollutants. Grey water reuse (without kitchen water) proved feasible without affecting plant health and reduced wastewater pollutant loads. These findings highlight both benefits and trade-offs of VGS, underlining the need for further studies to optimize management strategies.

KEYWORDS

Vertical greenery systems (VGS); Indoor air quality (IAQ); Energy performance; Water reuse.

INTRODUCTION

Urban vegetation improves environmental quality by lowering temperatures, capturing pollutants, enhancing biodiversity, and supporting social well-being (Ghazalli et al. 2018; González-Lezcano 2023; Brilli et al. 2018). Vertical greenery systems (VGS) offer a way to integrate such vegetation into dense urban areas while reducing building energy demand through decreased heating and cooling needs. They improved indoor air quality via pollutant deposition and plant uptake (González-Lezcano 2023). These systems, however, increase water use due to irrigation requirements. Using grey water for irrigating green roofs and VGS enables water reuse without compromising performance and is crucial for sustainable deployment, addressing both water scarcity and urban resilience (Prodanovic et al. 2017). Within this context, the Green4Indoor Wallonia (G4iW) project conducted a multidisciplinary assessment of VGS impacts.

METHOD

This study is conducted in a climate-controlled chamber (l: 4.8m, w: 3.7m, h: 2.6m, floor area: 18m², volume: 47m³) that enables the reproducibility of both indoor and outdoor conditions. The chamber is equipped with sensors measuring air temperature (T), relative humidity (RH), and energy consumption (EC). Two VGS units (2 units 1.4m x 2.1m = 5.9m²; 60% covering of the supporting wall) are installed on one of the interior walls to quantify their effects on energy demand and indoor air quality (IAQ) under winter (2 to 10°C) and summer (14 to 31°C) conditions. Two 50 Watts light (LED CREE) stationed in front of the walls are put on for a 10 hour a day period to ensure the provision of artificial light, for photosynthesis purposes. Heating and air-conditioning use is continuously monitored, while ventilation rates (with ventilation: 50m³/h; natural ventilation: ~2m³/h) are adjusted to assess the combined impacts on IAQ and energy performance. IAQ is evaluated through spot sampling of total VOCs, formaldehyde (Form.), and airborne spores. In parallel, water management is studied through a detailed water balance, including the volumes and compositions of incoming and outgoing water. One VGS is

irrigated with a nutrient solution and the other with synthetic greywater to compare pollutant removal performance and impact on plants health.

RESULTS & DISCUSSION

During winter, the presence of VGS maintains indoor humidity within the comfort range but increases heating demand, whereas in summer it leads to humidity exceeding comfort levels while lowering cooling energy use at a setpoint of 24 °C. Excess moisture can promote mold growth (MG) and affect indoor air quality (IAQ), with season-dependent variations observed in VOC patterns and formaldehyde emissions. Greywater reuse did not impair VGS health, and pollutant removal efficiency would allow the treated water to be reused for non-potable applications. System operation proved highly sensitive to season, control strategy, and irrigation regime: excessive watering enhanced microbial development, while controlled irrigation mitigated it. Overall, the results emphasize the importance of integrated management of ventilation, thermal regulation, and irrigation to optimize energy efficiency, IAQ, and moisture control in spaces equipped with VGS. Table 1 summarizes the results.

Table 1. Results synthesis for multidimensional study of VGS impact on IEQ.

	T	RH	EC	MG	Irrigation	VOC	Form.
¹ Winter	↘	↗	↗	☄	28,52L/wall; f: 15 days	 Profiles modification	↘ x10
² Summer AC	↘	↗	—	☄ x2			↘ x2
³ Summer AC	↘	↗	↘	☄ x2			
Summer AC/AC				☄ x10	9,51L/wall; f: 3-4 days		

¹T_{indoor}=21°C; ²T_{indoor}=free; ³T_{indoor}=24°C; AC=with cooling; AC=without cooling; ☄=mold spore

CONCLUSIONS

The controlled chamber methodology offers researchers a reproducible basis to develop coupled energy–IAQ–water models and to test integrated control strategies. For designers and owners, the benefits in cooling demand reduction, humidity control, and pollutant mitigation clearly depend on coordinated design of HVAC, irrigation, and ventilation. For occupants, the study highlights improved perceived comfort but also the need for appropriate operation during unoccupied periods, positioning VGS as key components of resilient, water-conscious buildings.

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