Proceedings of the 6th International Conference on Environmental Science and Applications (ICESA 2025)
Barcelona , Spain - October 27 - 29, 2025
DOI: 10.11159/icesa25.001

Enhancing Indoor Air Quality in Higher Education through Biophilic Design: A Sustainable Approach for Healthier Learning Environments

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Abstract

Indoor Air Quality (IAQ) plays a critical role in ensuring healthy, productive, and conducive learning environments, especially in higher education institutions where students spend significant amounts of time. Despite extensive research on IAQ in primary and secondary schools, few studies have focused on the impact of biophilic solutions within universities, which are often characterized by high occupant density and complex indoor pollution sources. Recognizing this gap, the present study investigates the efficacy of natural green structures (NGS) as a sustainable, biophilic intervention to improve IAQ in an eco-campus classroom at a higher-education institution (HEI).

The research methodology involved installing a native plant-based green structure in one classroom (intervention site) and comparing its IAQ parameters to an adjacent classroom without such a structure (control site). To assess the impact, various environmental and indoor air pollutants were monitored over a specified period, including carbon dioxide (CO_2), total volatile organic compounds (TVOCs), and suspended particulate matter ($PM_{2.5}$ and PM_{10}). Additionally, thermal comfort indicators—air temperature (T) and relative humidity (RH)—were recorded, given their influence on occupant well-being.

The findings strongly suggest that integrating biophilic green structures significantly enhances IAQ within the assessment environment. The classroom with the NGS exhibited notably reduced levels of CO_2, TVOCs, and particulate matter, alongside more stable thermal conditions, indicating a healthier indoor environment. These improvements not only contribute to better physical health outcomes but may also positively influence students' cognitive performance and psychological well-being—factors crucial in academic contexts.

Aligned with the United Nations Sustainable Development Goals (SDGs), particularly those targeting health and well-being (Goal 3), sustainable cities (Goal 11), and quality education (Goal 4), this research underscores the importance of incorporating sustainable, nature-based solutions into educational settings. The integration of biophilic design within HEIs can serve as an innovative strategy to promote environmental awareness, foster resilience, and create healthier communities. Additionally, the study emphasizes the role of educational institutions as catalysts for sustainability education and research, highlighting pathways to embed these principles into curricula.

The study also discusses broader implications for urban sustainability, stressing that biophilic solutions are accessible, low-cost, and scalable interventions capable of producing substantial benefits for indoor environmental quality. By improving IAQ through the deployment of natural green structures, higher-education institutions can contribute toward addressing global environmental challenges while enhancing students' health, learning capacity, and overall well-being. As such, this research advocates for the wider adoption of biophilic design strategies across educational and urban environments to foster sustainable development and healthier future communities.