Trends in Indoor Environmental Quality in Non-Domestic Energy-Efficient Buildings in Ireland: The BENEFIT Project

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SUMMARY

The BENEFIT project seeks to assess indoor environmental quality and occupant comfort in energy efficient non-domestic Irish buildings with the aim of developing ventilation guidelines for future retrofits and new builds. The project, in collaboration with SEAI's Pathfinder programme, aims to conduct a comprehensive and scientifically robust assessment of the impacts of energy-efficient policies in non-domestic settings across Ireland, with a particular focus on newly constructed energy-efficient buildings. Multizone monitoring with an innovative hybrid methodology, via low-cost and high-grade sensors, is used to assess IEQ, capturing longer-term trends through precise measurements of indoor pollutants ($PM_{2.5}$, Radon, TVOC, BTEX, Formaldehyde, Ozone, NO_2, CO and CO_2).

KEYWORDS

Indoor Environmental Quality (IEQ), Energy Efficiency, Long-term monitoring, Schools, Offices

1 INTRODUCTION

The 2021 Glasgow Agreement (UNFCCC, 2021) underscores the continued global emphasis on reducing carbon emissions as a key political goal, and the International Energy Agency recognises the significance of energy efficiency advancements in their crucial role in achieving a low-carbon future. However, energy efficiency does not always equate to good indoor environmental quality (IEQ) as a consequence of compromises in ventilation rates and buildings' airtightness.

In recent years, significant research has concentrated on exploring the implications of energy improvements in the residential sector. Although much research has focused on residential energy enhancements, offices and schools have not received comparable attention. Addressing indoor air quality in such environments is critical for the health, well-being, and productivity of employees and students.

The maintenance of thermal comfort, in addition to indoor air quality, presents a further challenge when energy efficiency improvements are considered in public buildings. With expected increases in temperature due to future climate change, thermal comfort preservation requires not only the assurance of adequate warmth in buildings during the winter period, but also adequate cooling during summer, and this latter aspect has not been widely addressed in literature to date.

Vardoulakis et al. (Vardoulakis, et al., 2015) found that newly constructed, highly insulated buildings are at higher risk of overheating compared to older buildings. However, Fosas et al. (Fosas, et al., 2018) argue that while increased insulation can cause overheating in poorly designed buildings, it reduces overheating in well-designed buildings. The current findings suggest that maintaining comfortable indoor conditions will become increasingly challenging as the climate warms, which is coupled at this stage with a deficit in studies, analysis, and data. The BENEFIT project aims to fill this research gap by assessing IEQ in energy-efficient offices and schools across Ireland. Utilising real-time monitoring, the project measures key pollutants such as $PM_{2.5}$, TVOCs, formaldehyde, BTEX, ozone, radon, NO_2, and CO_2. The BENEFIT project aims to fill this research gap by conducting an assessment of IEQ in energy-efficient offices and schools across Ireland. Utilising real-time monitoring, the project measures key pollutants such as $PM_{2.5}$, TVOCs, formaldehyde, BTEX, ozone, radon, NO_2, and CO_2.

2 METHODOLOGY

The research focuses on evaluating IEQ within newly constructed energy-efficient offices and schools. The methodology includes capturing data from various indoor environments, spanning different student age groups (5 to 18 years old) and multiple office settings. Newly constructed energy-efficient buildings across Ireland will be sampled using a combination of multizone real-time monitoring and hybrid methodologies. This involves deploying both high-grade and low-cost sensors, utilising real-time, active, and passive sampling approaches. (Table 1).

This approach enables a detailed assessment of IEQ by capturing longer-term trends and conducting precise measurements of critical indoor pollutants. The key pollutants monitored include $PM_{2.5}$, Total Volatile Organic Compounds (TVOCs), formaldehyde, BTEX (benzene, toluene, ethylbenzene, and xylenes), ozone, radon, nitrogen dioxide (NO_2), and carbon dioxide (CO_2). Alongside monitoring pollutants, the study will collect data on thermal comfort (Temperature and Relative Humidity (RH)), occupant satisfaction, building and ventilation attributes, and activity and occupancy patterns through surveys.

Table 1: Sensor Specifications and Pollutant Detection in the BENEFIT Project

Sensor	Sampling	Level	Detectable Pollutants
Graywolf Direct Sense II	Real-time	High-Grade	TVOCs, CO, CO_2, RH, Temp., NO_2, O_3
TSI SidePak AM520	Real-time	High-Grade	Particulate Matter ($PM_{2.5}$)
Airthings Space Wave Plus	Real-time	Low-Cost	Radon, TVOCs, RH, Temp., CO_2
GRADKO Sorbent tubes	Active	High-Grade	Individual VOCs (via GC-MS)
GRADKO Diffusion Tube NO	Passive	Low-cost	Nitrogen Oxides (NO_x)
SKC UMEx 100	Passive	Low-cost	Formaldehyde
SKC VOC Check 575	Passive	Low-cost	BTEX, Pinene, Limonene

3 RESULTS AND DISCUSSION

The results of this project include time series for $PM_{2.5}$, Radon, TVOC, NO_2, CO, CO_2, Temperature and Relative Humidity from real-time measurements. Data analysis include identifying trends, assessing seasonality, and examining correlations between various pollutants. Air exchange rates, as well as statistical measures such as mean, median, and standard deviation, are estimated for all pollutants and will be contextualised and compared to guideline values for indoor environmental quality.

Furthermore, the quantification of individual VOCs, BTEX, and formaldehyde will be compared to guideline values, providing detailed information on exposure levels for workers and students in newly constructed buildings with energy-efficient mechanisms.

A system to visually evaluate each sampled room throughout all non-domestic buildings will be used for fast and qualitative evaluation of IEQ, identifying exceeding values, and concerning pollutants, thus contextualising building properties and ventilation effectiveness. This comprehensive analysis will offer valuable insights into the effectiveness of energy-efficient designs in maintaining healthy indoor air quality.

4 CONCLUSIONS

The data collected during this project will provide unique insight into the increased energy performance standard in non-domestic buildings and provide a detailed assessment of the ventilation approach with accompanying indoor air pollution concentrations.

The analysis of all data will provide policymakers with insights into effective guidelines for energy-efficient buildings and integrate environmental standards into building regulations. Additionally, the extensive air quality and thermal comfort data will support the development of smarter ventilation controls, enhancing Ireland's capacity for energy research and fostering advancements in indoor environmental quality.

The study findings from indoor air quality monitoring will clarify if and how energy-efficient buildings maintain healthy indoor environments amidst changing climate conditions. This offers a comprehensive view of the effectiveness of current guidelines and regulations, addressing critical knowledge gaps and comparing outcomes between newly constructed and retrofitted buildings to inform future strategies and advancements.

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