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Effects of Energy Retrofits on Indoor Air Quality in Three Northern European Countries

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Abstract

According to an assessment protocol developed as a part of the INSULAtE project, indoor air quality measurements were conducted in three Finnish and Lithuanian multifamily buildings before and after energy retrofits. Additional cases from Estonia included one retrofitted and two non-retrofitted buildings. Measured gaseous pollutants included carbon dioxide (CO_2), volatile organic compounds (VOCs), formaldehyde (CH_2O), and nitrogen dioxide (NO_2). Low CO_2 concentrations in Finland could be attributed to common use of mechanical exhaust ventilation. WHO guidelines for CH_2O were not exceeded in any of the measured apartments. No statistically significant changes were seen in VOC or NO_2 after retrofits.

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Keywords: retrofits; multi-family buildings; indoor air quality; thermal comfort; gaseous pollutants; questionnaire

1. Introduction

Assessment of building retrofits improving energy efficiency (EE) has traditionally been based on economic aspects – performing cost-effective retrofit actions assuming further savings in energy costs, whereas possible changes

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in indoor environmental quality (IEQ) has not been considered in depth. The World Health Organization (WHO) resolution on environment and health has called for policies to protect public health from the impacts of major environment-related hazards such as those arising from climate change and housing [1]. Therefore, a more comprehensive analysis on IEQ is essential. Recent research has demonstrated that it is possible to improve indoor environmental quality (IEQ), health and wellbeing of building occupants along with improved energy efficiency. However, the impacts are influenced by several factors (e.g., building, climatic, cultural, social, economic) and often differ from country to country [2].

The countries within European Union have assumed commitments to build energy efficient buildings from 2019 to 2021 [3]. Especially new buildings are targeted, promoting nearly zero-energy buildings [4], but also existing buildings should be improved by energy retrofits [5,6,7,8]. This usually means improving air tightness of the building envelope. The modifications, including changes in structures (e.g. insulation of external walls), and heating, ventilation and air conditioning (HVAC) systems, as well as installing new building materials, may have a significant influence on indoor air quality (IAQ) [9,10,11]. Release of pollutants from some building materials may decay in days or weeks, such as the smell of fresh wood or new carpet, while others may persist as long as the material is present [12]. IAQ is one of the main indoor environment parameters contributing to satisfactory indoor environment [13, 14], which in turn affects human health. There are examples when indoor climate has either improved or decreased as a result of improved EE [15,16].

In many Northern European countries (including Finland, Estonia, and Lithuania) the renovation programs for multifamily apartment buildings are gaining their momentum. Along with demonstrating the effects of improving energy efficiency on IEQ and health, the INSUALtE project (www.insulateproject.eu) has developed a comprehensive assessment protocol. The assessment protocol has been tested in numerous case studies performed in multi-family buildings in Finland, Estonia and Lithuania. In this paper we present the results of the selected case study buildings from three countries and discuss about observed differences before and after retrofits.

2. Methods and materials

2.1. Case study buildings and retrofit actions

The case study buildings were selected from different regions in Finland (Tampere, Lempäälä), Tallinn region in Estonia, and Kaunas region in Lithuania. The primary criteria were planned retrofits, which had to be related to EE. Recruited apartments were selected from volunteering occupants, who did not receive any monetary compensation for participating in the study. In Finland and Lithuania, IEQ was assessed in the same buildings before and after retrofit activities. The retrofit usually took place in the following year after the baseline measurements.

In this paper we present results from one 6-storey (retrofit activities were completed in 2014) and two 8-storey (retrofit activities completed in 2015) buildings from Finland. The buildings were more than 40 years old (built before 1975). Nineteen apartments were measured in the 8-storey buildings with average occupancy of 1-2 persons per apartment (maximum 3), while five apartments were measured in the 6-storey building with average of one person per apartment. Both of these buildings had mechanical ventilation.

In Estonia two buildings (5- and 9-storey) were controls (no retrofits took place) and one was assessed after completion of retrofit activities (9-storey building, retrofit finished in 2014). All buildings were situated near busy roads. The average age of the buildings was about 40 years. Eight apartments were measured in the control buildings with average occupancy of 3-4 persons per apartment, while two apartments were measured in the retrofitted building with two persons per apartment. Control buildings had natural ventilation, while mechanical ventilation with heat recovery (exhaust air heat pump) was installed in the retrofitted building.

From Lithuania, results from one 5-storey (retrofitted in 2015) and two 9-storey buildings (both retrofitted in 2014) are presented. All buildings were located in densely populated areas and they had natural ventilation before and after retrofits. The average age of the buildings was about 35 years (built before 1982). Ten apartments were measured in the 9-storey buildings with average occupancy of two persons per apartment (maximum 4), while five apartments were measured in the 5-storey building with average of two persons per apartment. Lithuanian buildings were same construction type as the Estonian buildings: large-panel concrete and bricks were used as construction materials. This