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Assessment of energy efficiency measures on indoor air quality and microclimate in buildings of Liepaja municipality

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Abstract

Eight municipality buildings that have undergone major energy efficiency improvements have been studied. The main aim is to assess indoor air quality and microclimate in the context of energy efficiency, indoor air quality and thermal comfort dilemma in the studied buildings. Microclimate and CO_2 measurements were carried out. Tracer gas method was used to determine air exchange rate and blower door tests were conducted to determine building tightness. Results show that ventilation systems are underperforming because they are not used as expected, thus leading to decreased indoor air quality and thermal comfort. Further assessment of economic aspects would be necessary to evaluate the indoor air quality impact on student and teacher health and productivity and its impact on municipality budgets.

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Keywords: indoor air quality; energy efficiency; thermal comfort; EE-TC-IAQ dilemma

1. Introduction

There are a lot of negative effects on human health that are caused by poor indoor air quality. When CO_2 levels reach 1000–2500 ppm, humans begin to feel tired and sleepy. If levels rise to 2500–5000 ppm, health can be affected even more – increases in heart rate, respiratory rate and signs similar to intoxication. Higher CO_2 concentrations cause headaches, nausea, faintness or even fatality. CO_2 concentrations of 600–1000 ppm are not harmful for humans according to the American Society of Heating Refrigerating and Air-Conditioning Engineers

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guidelines [1] while Occupational Safety and Health Administration recommends not to exceed 5000 ppm in one 8-hour working day [2]. According to the European standard EN 13779:2007 Requirements for Ventilation and Room-Conditioning Systems, indoor air quality is arranged in four categories (CO_2 concentration level in air) – IDA 1 high (≤ 400 ppm), IDA 2 medium (400–600 ppm), IDA 3 moderate (600–1000 ppm) and IDA 4 low (> 1000 ppm). This classification is used to help select necessary criteria and apply it to specific buildings and their usage type. [3]

The study carried out by Satish et al. shows the impact of CO_2 levels on human decision making skills. 22 participants took part in the experiment in three different air quality conditions. Participants spent 2.5 hours in several circumstances and took a computerized decision making test and a survey about their health conditions and feeling. Results showed that the ability to make a decision if the CO_2 level is 600 and 1000 is worse in six out of nine activities and in seven if CO_2 is 2500 ppm. There is relatively low productivity loss at CO_2 level of 1000 ppm that may seem insignificant for one person but at the corporate level, even small changes can cause significant economic impact. Authors indicate that research results may limit the extent to which outdoor air supply per person can be reasonably reduced in buildings to save energy [4].

Myhrvold et al. investigated reaction and decision making time as well as word-colour alertness test when fresh air inflow was reduced from 8 l/s to 1 l/s per person and found a drop in monotonous performance [5]. Kajtár and Herczeg researched the heart rate variability and drew conclusions that mental exercises require higher effort [6].

William Fisk indicates that outside air inflow rates in standards and guidelines are out of date and pointed out that 80% participants evaluated indoor air as moderate, while ventilation inflow was 7.5 l/s per person in laboratory conditions. There are more studies that show air exchange rates affect human performance so it is necessary to consider improving standards that are adapted to the latest research [7]. Science and industry provide new and innovative technological solutions for air conditioning, ventilation and other indoor climate control technology that solves the problem of providing an energy efficient environment for human, gives a positive impact on human feeling, health and productivity. There is a conflict of desire to provide optimal, comfortable indoor climate conditions and aim to reduce energy consumption [8].

Building energy efficiency is one of the main priorities for the European Union in the energy field. The system dynamics model shows Liepaja municipality owned building energy efficiency increase till year 2050 [9]. Indoor air quality and thermal comfort are important factors in the high quality building design, planning and renovation of existing buildings. Kamendere et al. [10] has done a research about energy efficiency in two resident buildings that illustrates the ventilation system problem in terms of indoor air quality. However, often the desire to provide optimal, comfortable indoor climate conditions is in conflict with the aim of reducing energy consumption [11, 12]. The main goal of this study is to assess the indoor air quality and microclimate in the context of the energy efficiency-indoor air quality-thermal comfort dilemma in eight municipality buildings that have recently implemented major energy efficiency measures.

2. Methodology

Assessment of the indoor air quality and microclimate of five educational institution buildings and three municipality buildings of the Liepaja municipality was carried out. All selected buildings have undergone major energy efficiency improvements in recent years, including insulation of the building envelope, change of windows and installation of mechanical ventilation systems.

Indoor air quality and microclimate measurements were taken during the heating season. Each room was monitored for one week. Two rooms in each of the buildings were selected for monitoring. The main criteria for selection of test rooms in each building were:

- Average room in a building;
- Most distant room from air handling unit;
- Both rooms have to be used daily.

Tracer gas method was used to determine the air exchange rate. The concentration decay method with sulfur hexafluoride (SF6) was used. The measurements were carried out with LumaSense Technologies INNOVA 1303 [13]. Concentration exponential reduction is calculated by Eq. (1). C represents concentration: