Povilas Barkauskas

T6616KA

INDOOR CLIMATE REQUIREMENTS OF OFFICES IN LITHUANIA AND FINLAND

Bachelor's Thesis
Double Degree Program
Building Services Engineering

January 2017

MAMK
University of Applied Sciences

DESCRIPTION

MAMK University of Applied Sciences	**Date of the bachelor's thesis** 15th of January 2017
Author(s) Povilas Barkauskas	**Degree programme and option** Double Degree Program in Building Services Engineering

Name of the bachelor's thesis

Indoor climate requirements of offices in Lithuania and Finland

Abstract

The subject of this Bachelor's Thesis is indoor climate requirements of offices in Lithuania and Finland. Good indoor climate in the offices is very important because people spend big part of their life working. Lithuania and Finland has its own regulations and guidelines for indoor climate requirements in their offices.

The main documents, which were analysed for Lithuanian office was HN 69:2003 ″Thermal comfort and adequate thermal environment in workplaces. Normative values of parameters and measurement requirements.″ and STR 2.09.02:2005 "Heating, ventilation and air conditioning". Lithuanian regulations and guidelines". The main documents, which were analysed for Finnish office was D2 ″Indoor Climate and Ventilation of buildings 2003″ and LVI 05-10440en ″Classification of indoor environment 2008″.

The main purpose of thesis was to measure indoor climate parameters (air temperature, relative humidity, air flow rates and CO_2 concentration) in two similar offices, one located in Lithuania and another in Finland, to see if they meet Lithuanian or Finnish regulations and guidelines. Another purpose of the thesis was to analyse the requirements and to see what the main differences between them are.

Thesis was based on information of regulations and guidelines, literature and investigations. Discussion is done at the end of the thesis, where measured indoor climate parameters of office in Lithuania and of office in Finland are compared with Lithuanian and Finnish Regulations and Guidelines. Furthermore, Lithuanian and Finnish requirements are compared.

Subject headings, (keywords)

Indoor climate, Requirements, Regulations and Guidelines, Lithuanian, Finnish, Office, Temperature, Humidity, Air flow rates, CO_2 concentration

Pages	Language	URN
47 pages	English	

Remarks, notes on appendices

Tutor	Bachelor's thesis assigned by
Marianna Luoma	

CONTENTS

1 INTRODUCTION

Before the time when robots will do multitude of jobs, majority of jobs is still done by humans. If in average a person lives till 80 years, he has a job for 40 years, and works 40 hours per week, he spends about 85 thousand hours only working. This is a huge amount of time. It is very important for person to work in good and healthy environment. If not, an employee can get sick or some kind of allergy after staying a few days in bad and unhealthy work environment. Employee can get serious health problems in a long-time. Low productivity and competitiveness can be another problem of bad and unhealthy environment in offices. A big percent of office jobs influence adults, kids and elders life. That is why to have a good and healthy environment in offices is very important for employees, employers and for all other people.

Nowadays a lot of people have started to complain about discomfort in offices. Discomfort is related to indoor climate parameters and it can be caused by fluctuation of temperature, humidity, CO_2 concentration, air flow rates and other reasons as well (VOCs and microbes).

The main purpose of bachelor thesis is to measure indoor climate parameters in two similar offices, one located in Lithuania and another in Finland, to see if they meet Lithuanian or Finnish standards.

The first part of thesis will present theoretical background about indoor climate and its parameters. It will show what parameters are the most important and how they can affect an employee. After that, Lithuanian and Finnish regulations and guidelines will be compared. It will show what the main differences between regulations of these countries are.

The second part of thesis will present measurements of temperature, humidity, CO_2 concentration and air flow rates in offices. Measurements will be compared regulations and guidelines standards to see if they meet it. The employees will be the ones, who will be working at the area and at the time, when measurements will take place.

2 THEORETICAL BACKGROUND

2.1 Main parameters of indoor climate

Workers' comfort with the surrounding conditions of indoor climate directly affects their workplace happiness, which highly influence their working well and getting a lot done. Comfort is defined by a not being present of unpleasant feeling, this way providing positive effects on well-being. There are different types of comfort in an office. Air quality, climate, noise is physical comfort. Disturbances, distance from work is functional comfort. Privacy is mental comfort. Basically, comfort is a result of personal health, mood and environmental factors. /1 p.372-373./

In this bachelor thesis physical comfort will be mostly studied. There are eight factors, which affect the productivity and satisfaction of workers. They are indoor air quality and ventilation, thermal comfort, lighting and day lighting, noise and acoustics, office layout, biophilia and views, look and feel and location and amenities. /1 p.372-373./ Four main parameters of physical factors, which mostly affects indoor climate are air temperature, humidity, air flow rates and CO_2 concentration.

2.1.1 Air temperature

Heat loss of a human body is managed by a mix of few heat transfer ways, for example convection, radiation, respiration and evaporation. Human convective boundary layer is known as a layer of upward natural convective flow. The air which exists all around a person and the surface all around a person in the room are delimited with human convective boundary layer. The result of convective heat exchange between warm surfaces of the human body and cooler air, which exists all around a person, is this convective flow. The layer of upward convective flow (human convective boundary layer) increases near the warm surface of the human body. The human convective boundary layer develops into a human thermal plume above the shoulders and the head. Air flow features around the human body (velocity, air temperature, and turbulence intensity) and the distribution of particles in the human surrounding conditions affect occupant’s thermal comfort, indoor air quality and health. /2 p.39./

The thickness of the human convective boundary layer under different room air temperatures and body positions has been studied. For example, if a standing person wasn't breathing, when the room air temperature was 20^{o}C, the thickness of the convective boundary layer in front of the mouth was 0,09m. If a sitting person wasn't breathing, when the room air temperature was 20^{o}C, the thickness of the convective boundary layer in front of the mouth was 0,45 m. Convective boundary layer of sitting person was five times wider due to additional convective flows from the lower legs and thighs. For example, if we would increase air temperature to 26^{o}C in the room, then the convective boundary layer flow gets weaker and increases its thickness. Person in a supine posture has a convective boundary layer, which provides a lower thermal protection, and higher convective heat loss than the standing person. Convective boundary layer is usually cooler when it is further to the surface and usually warmer when it is closer to the surface. /2 p.39./

Temperature boundary layer is also very important to a person. Thickness of it is defined by the distance at which the temperature of the air surrounding the person body equals or closely approaches the temperature of undisturbed room. Bigger body parts, for example chest or back are surrounded with thicker temperature boundary layer. The thicker temperature boundary layer is, the smaller convective heat losses are. Human temperature boundary layer thickness is bigger at the upper part of torso in comparison with lower part of torso. For example, air temperature surplus compared to the surrounding air around the person was 0,5^{o}C at the distance 0,0025m from the ankle. Air temperature surplus compared to the surrounding air around the person was 1^{o}C in the thermal plume at 0,3m above the head. Air temperature surplus at 0,1-0,15m above the head was 1,5^{o}C. /2 p.39-40./

2.1.2 Humidity

Factors, that influence thermal feeling of person's body has been well known for long time. It is humidity and temperature of indoor climate. Dry and cool air provides a feeling of cooling of the breathing and lung related area (respiratory) each time air is inhaled. It causes a feeling of pleasant freshness. Air can be perceived as stuffy, stale and unacceptable if there is lack of proper evaporative and convective cooling of the respiratory, when the enthalpy is high. 10% of the total heat loss from the body is heat loss through respiration. Researchers have proved that temperature and humidity of the inhaled air have therefore only a small effect on thermal feeling for the person's body as a whole. It probably explains why the effect of humidity has before now been ignored. /4 p.155-156./ After some time, exposure to low humidity can inflame and dry out the mucous membrane lining person's respiratory tract. When mucuos membrane, which is lining of person's respiratory tract is no longer working properly in may cause some problems, for example, it increases risk of colds, the flu and other infections. Some viruses can survive longer in low humidity and because of that these viruses can increase risk of contracting an infection. /5./

When level of humidity is rising people are feeling hotter and we start to feel more uncomfortable. But that is not the only problem. The biggest problem is that core temperature of a human is rising and bodies are working harder and harder to cool it down. If body is working harder and harder to cool a person down but it doesn't work (for example, sweating doesn't work), a person is continuing to heat up. After that, overheating results. Overheating might cause loss of water, salt and chemicals, which body needs. Overheating, also known as heat exhaustion, can lead to chemical imbalances within the body and dehydration. Heat cramps, heat syncope or fainting, heat exhaustion and heatstroke can be other problems caused by overheating (staying in a place where humidity level is too high. The longer you stay in that place, the bigger chances of overheating are). /6./ In figure 1 it is explained, what relative humidity percent is most suitable for men and women, when indoor air temperature is 25^{o}C.

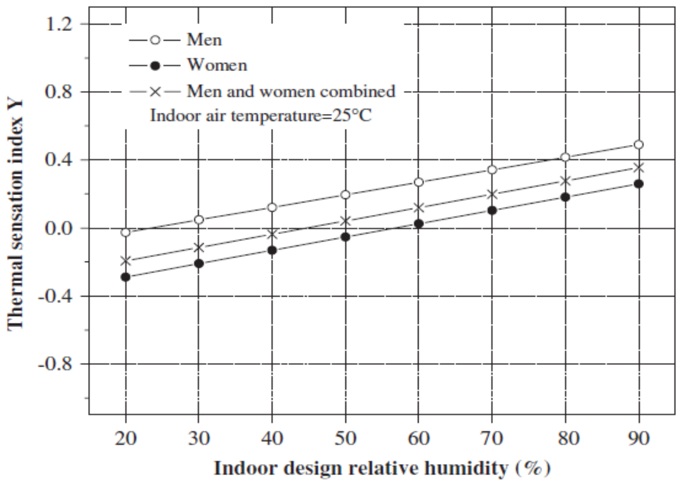

FIGURE 1. Indoor relative humidity affection on human thermal sensation. 0- neutral, -1- slightly cool, +1- slightly warm /3 p.414-415/

2.1.3 Air flow rates

Indoor air pollution sources, outdoor air quality, ventilation effectiveness and the desired air quality are the main components whereby the required ventilation rate is depending on. According to CEN CR 1752 (CEN, 1998) technical report it is possible to select perceived air quality. There are three categories of indoor environmental quality which are specified according to CEN CR 1752 (CEN, 1998) report. First category is category A. This category matches up to a high level of expectation. Second category is category B. This category matches up to a medium level of expectation. Third (and the lowest) category is category C. This category matches up to a modest level of expectation. These three categories of perceived indoor air quality are shown in table 1. /4 p.152./

TABLE 1. Perceived air quality categories /4 p.152/

Air quality	Percentage dissatisfied	Perceived air quality decipol	Ventilation rate l/s per olf
A (high)	15	1.0	10
B (medium)	20	1.4	7
C (modest)	30	2.5	4

It is possible to see in figure 2 the relationship between the percentage dissatisfied and ventilation rate per olf for three categories of perceived indoor air quality according to CEN CR 1752 (CEN, 1998) technical report /4 p.152/.

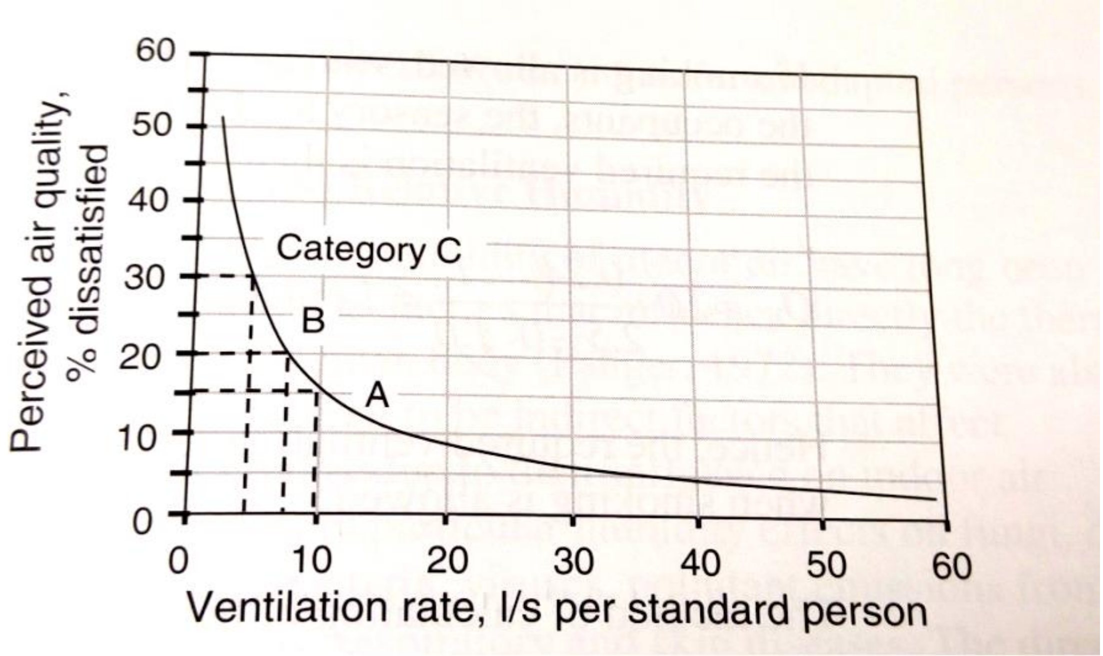

FIGURE 2. Dissatisfaction caused by one olf (one person) at three ventilation rate categories /4 p.153/

In a perfect world pollutants from the source should be drawn by exhaust airflow into the exhaust and away from occupants. It is very important where source of pollutants is located. It should be located between the occupants and the exhaust. Areas, places, rooms which have major sources of pollutants should be under negative pressure in a relation to the surrounding spaces. Some sources are more difficult to exhaust, for example, cooking stoves and laboratory benches. That’s why cooking stoves and laboratory benches may require exhaust hoods. People, building materials and office equipment are contaminants from area sources. Usually, they are diluted with fresh outdoor air from mechanical or natural ventilation. /7./

It is very important to have as good air as it is possible in rooms. It depends on ventilation system, which has to be able to provide good enough outdoor air to a room. It is not advisable to reduce outdoor air ventilation rates. If outdoor air ventilation rates are reduced below required levels, it saves little energy, but doesn’t create sufficient indoor climate. It is advisable and required that outdoor air ventilation rates should meet related standards under all operating conditions. To sustain efficient ventilation all problems with reduced outdoor air during part-load in certain VAV systems should be addressed and looked at. /7./

Very long ago, has been rocognised that the control of air flow is an extremely important and built-in part of moisture and heat control in nowadays modern building enclosures. Sufficient control of air flow is necessary for all weather conditions. But awareness of controlling air has been developed not very long ago. Uncontrolled air leakage is a fraction of a well-insulated, modern building‘s space conditioning energy load. /8./

There are two major sources of moisture in the enclosure of modern building. One major source of moisture is water vapor‘s condensation in exfiltrating air. It occurs usually in wintertime and this building performance related problem is common and well-known in cold climates. Condensation of water vapor in infiltrating air is the same major source of moisture as mentioned before, but instead of wintertime it occurs in summetime. This building performance related problem is common and well-known in warm and humid climates (sometimes this problem can occur in cool climates, too, for example when air conditioning or cooling used in arenas or sport halls). /8./

Second major source of moisture in the enclosure of modern building is driving rain. Air flow can carry, exhaust gases, odours, sounds, mold spores through the enclosure and off gassing generated within the enclosure. If air leakage through the enclosure is uncontrolled it usually causes some productivity and performance problems, for example durability, health, comfort, energy and etc. Water vapor diffusion is also source of moisture in modern building envelopes but it is very insignificant source of moisture. /8./

Control of air flow has a significant value related to building performance. There are three most important classes of reasons why it has a significant value related to building performance:

1. Moisture control. Serious durability, health, performance and other problems may occur if water vapor in the air would be deposited by condensation within the building‘s envelope. /8./

2. Energy savings. To replace air leaking out of a building with outdoor air energy is required to condition it. About 30% to 50% energy use for space conditioning is because of air leakage through the building even in many well-insulated buildings. Too much energy is moving across the envelope. It happens, because effectiveness of thermal insulation is reduced by wind bashing and convective circulation. /8./

3. Comfort and health. Human comfot is directly affected by cold drafts and the extremely dry wintertime air that results from undue air leakage. Condensation in building‘s envelope is promoted by wind-cooled portions of the interior of the enclosure. After that, biological growth is promoted by condensation in building‘s envelope. Biological growth affects indoor air quality. Good airflow control is demanded because of airborne sound transmission. Gases and odours from buildings next to often create discomfort which may cause serious health problems. /8./

Air flow control is required by other circumstances, too, for example, to control fire and smoke spread through building shafts, voids and through air spaces. But usually these are the circumstances not for regular service, but when extreme events occur. /8./

2.1.4 CO_2 concentration

Humans are the significant source of producing CO_2. CO_2 is important indicator for indoor air. By looking at CO_2 as the important indicator, it is possible to see the quality of the indoor air. Some amount of CO_2 is always outdoors. Outdoor air (including CO_2 in it) is usually used as supply air to a building. CO_2 concentrations indoors are affected by outdoor air (including CO_2 in it). /4 p.141./

CO_2 concentration outdoors (in the atmosphere) according to many books and researches is asserted to be about 350-400 ppm (parts per million). There are many different pollution sources that have a big affection for the CO_2 concentration outdoors. There were many studies done about CO_2 concentrations outdoors. For example, two researchers, Ekberg and Strindehag 1996, were measuring CO_2. Measurements have been done for nine days outside an office building, which was built in Gothenburg, Sweden. Height of measurements was three meters above ground level. Building was located near a busy street. The result of CO_2 concentration was between 370 ppm and 440 ppm. Similar measurements of CO_2 were done in other place, 25 km away from building mentioned before (building which was located near a busy street) in Gothenburg, Sweden. This place wasn't strongly influenced by traffic or by other sources of outdoor pollution. The result of CO_2 concentration was between 350 ppm to 370 ppm. Average value was about 360 ppm. /4 p.141-143./

The most obvious source of pollutants, particles and carbon dioxide indoors are humans ant their activity. But CO_2 concentration changes in an occupied room not only because of humans and their activity but because of bio-effluents concentration, too. Carbon dioxide is very good indicator of indoor air quality, because instruments used to measure carbon dioxide aren't expensive and it is easy to use them. Because of that, one of the mostly used indicators for indoor air quality is carbon dioxide. It is often stated, that if CO_2 concentration indoors is about 1050 ppm (or 700 ppm above the CO_2 concentration outdoors), then CO_2 has reached its upper limit and a big majority of occupants in a building might be annoyed by bio-effluents. If CO_2 concentration indoors is below 1050 ppm, then a big majority of occupants in a building might be not annoyed by bio-effluents. /4 p.142./

Human is producing carbon dioxide. Amount of produced CO_2 is changing in accordance with the level of person's physical activity. For example, amount of produced CO_2 by an adult can be from 10 l/h to 170 l/h. About 10 l/h of CO_2 is produced when adult is sleeping. About 170 l/h of CO_2 is produced when adult is at high level of physical activity. People with different body weight, may produce different CO_2 amount, even if they are doing the same activity. Also, CO_2 production and metabolic rate relationship is not the same for children and adults. CO_2 production by humans at different activity levels is shown in table 2. /4 p.143./

TABLE 2. CO_2 production by humans at different activity levels /4 p.144/

Activity	**Carbon dioxide (l/h per person)**
Adults, sedentary (1.0-1.2 met)	19
Adults, low level of physical exercise (3 met)	50
Adults, medium level of physical exercise (6 met)	100
Adults, high level of physical exercise, athletes (10 met)	170
Children in a kindergarten age, 3-6 old (2.7 met)	18
Children in a school age, 14-16 years old (1.0-1.2 met)	19

2.1.5 Other parameters

Building Materials and Building Products

It is possible to find a relatively large fraction of the air pollution indoors, which starts from building materials. For example, radon is affecting indoor environmental quality and it is exhaled from shale based lightweight blue concrete (or normal concrete). Another example would be formaldehyde. Formaldehyde is emitted from fibre-boards. What's more, a lot of other harmful, unstable and volatile organic compounds are emitted. They can be emitted from commonly used building materials and even from furniture. /4 p.147./

A big part of the materials contains unstable and volatile organic compounds. Because of that, many of building materials are sources of pollution, especially when they are new. Furthermore, an added emission might occur because of bad installation of a material. For example, if floor covering is fitted to a concrete slab, which is not completely dry. If material is installed not correctly, because of decomposition of the material under the influence of alkaline an additional emission can be expected. Hydrolysis of plasticizers in plastic floor coverings and the saponification of floor covering adhesive are one of the best examples. /4 p.147./

What's more, maintenance of materials is a normal procedure after some time. Some amount of the emission of pollutants might be related to this procedure. For example, linoleum, which is covering floor, is polished not good enough. Because of that, it can release some odorous compounds. If that linoleum has damaged surface layer because of too strong cleaning agents, it can also emit some pollutants. /4 p.147./

Radioactive Ground and Building Materials

One of the main sources in nature of radon is soil and rocks with high content of uranium. Content of radon of the ground is changing with different location. In some locations ground has high amount of radon, which can cause increase of radon inside buildings. In some buildings, radon can be introduced to indoors by air filtration. If building materials are radioactive enough, for example, blue concrete (shale based lightweight concrete), radon exhaled from these materials can be added to the radon content in indoor air. What's more, radon might be found even in tap water from wells drilled in rocks. It is possible to find radon in tap water only in certain regions, not every tap water has significant amount of radon. To identify radon might be little difficult, because special equipment has to be used, and radon progeny measurement is much harder than radon gas measurement. /4 p.149./

Office equipment

Nowadays, it is not a secret that electrical equipment, which is generating electrical and electromagnetic fields, indoors might influence the indoor climate. There are many different types of equipment in the office, which can influence the indoor climate. For example, TV sets and computers can produce some volatile organic compounds and flame retardants. Another example can be photocopiers and laser printers. They can generate air pollutants (even ozone). All this office equipment has some amount of influence on perceived air quality. Harmful, unstable and volatile compounds might be also released when it is too hot inside (especially if the equipment is new). /4 p.149-150./

Sound

Noise in other words can be called as unwanted sound. Noise is very subjective parameter, as good sound level is different for some people. For some people that sound can be good enough to hear, for some it can be very irritating and too loud. For example, music. /4 p.170./

Unwanted sound (noise) is not always the sound, which is too loud. Sound, which is usually hidden by other sounds and because of that can't be heard, in some conditions can be heard very clearly. Dripping of water from a tap or ticking of a clock can be good examples of that. Furthermore, sound of low frequency, for example, noise from fans in ventilation systems, can be seen as very annoying and disturbing, even at low levels of sound. Also, this type of sound might have a negative effect on psyche or health of a person. /4 p.170./

The main thing, how sound can be transported to the receiver is a direct transmission of sound from its source. In addition to that, sound can also be reflected from walls, ceilings, and floors and taken to the receiver that way. Vibration is another transportation method of sound. Vibration goes through building structure, and this way sound is taken to receiver. Noise doesn't let for a person to understand and to concentrate on other person's speech the way he wants. Speaker has to raise his voice by about 10 dB above background level. It happens unconsciously, but only this way a person can be heard well. /4 p.171./

Light

Light is a well-known indoor climate factor, because it influences the person's perception of surrounding conditions. Light in environment can be described in many ways- dark light, warm light, cold light, bright light and etc. Light is similar to music, as it is very subjective, and can be perceived by different people in very different ways. For person to clearly and comfortably see the surroundings of indoor environment, both- daylight and illumination by light fittings is needed. Requirements of light indoors are very simple, clear and are explained in general terms. For example, some of the required conditions: when rooms are occupied for a longer period people have to be able to easily access to daylight. Another condition- lighting has to improve and ensure good indoor light environment. But as requirements for light are very subjective, it leaves wide variety of interpretation of standards and guidelines of indoor lighting. /4 p.202./

2.2 Climate in Lithuania and Finland

The climate is changing now as faster and more drastically than never before. Climate change is one of the major things, why atmospheric temperatures are rising. Because of temperature rise, historic (20 years old) used temperatures for energy planning now won't be as precise and as good, as it was 20 years ago. The rate of temperature rise in the near future will command how reliable these values will be for setting energy budgets. Outdoor temperature is affecting directly many systems, for example, power generation, water resources, agriculture, and construction. Furthermore, it is affecting energy use for heating and cooling in buildings. Outdoor temperature change is very important for people, especially for HVAC designers. In fact, more than two case studies have showed relatively large effects of temperature changes on energy use in buildings. For example, if the temperature outdoors decreases below exact heating point value, more energy is used because of the bigger energy necessity for space heating. Another example would be, (vice-versa) if temperature outdoors increases below exact heating point value, more energy is used because of the bigger energy necessity for space conditioning and refrigeration. /9 p.83./ In figure 3 European climate zones are displayed.

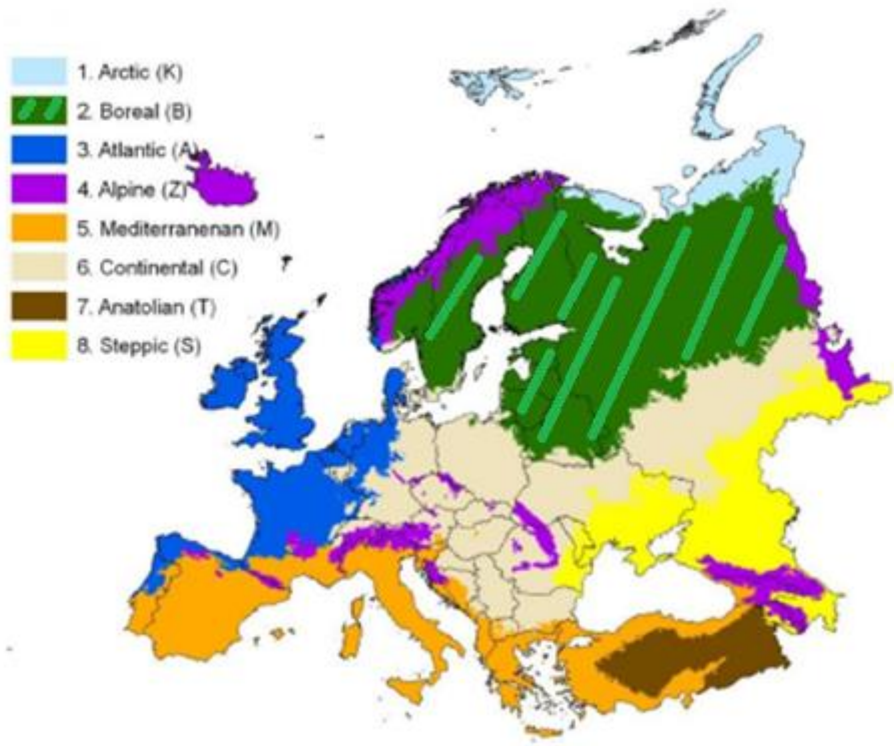

FIGURE 3. European climate zones /9 p.84/

Measurements of indoor climate parameters will be done in two similar offices, one located in Lithuania and another in Finland. Looking at figure 3 it is possible to see, that both, Lithuania and Finland countries are located in Boreal climate zone. Because of that, climate won’t have relatively big influence difference on Lithuanian and on Finnish office. Boreal climate is the most specific one, because variation of temperature is very extreme. In winter air temperature can reach -40^{o}C, and in summer air temperature can reach +30^{o}C. Cold period is longer, as summer period lasts only for 2-3 months. /9 p.84./

Continental portion and a peninsula are the main parts of European region. Although, it is the third most populated continent in the world, it is relatively small continent, even one of the smallest. Almost all part of European region is surrounded by seas and oceans. Europe has a border with Asia on the eastern part of region. European climate is relatively strongly influenced by the Gulf Stream. Gulf Stream keeps mild air in Europe in the winter months, especially in the North-Western part of Europe. /9 p.84./

2.3 Cellular office layout

For some employers the layout of the office isn't taken in to account as a significant factor for workers. But it is a significant factor; a good and well designed office layout is functional and is affecting workers. It is important to know what work will be done in the office; a suitable layout of office can increase efficiency of workers. /10./ The main purpose of this bachelor thesis is to measure indoor climate parameters in two similar offices, one located in Lithuania and another in Finland, to see if they meet Lithuanian or Finnish standards. Both offices will be cellular type.

A cellular office layout could be described as an organizational arrangement. This type of office has separate rooms which are set aside to different sections of division of the office. Usually in these rooms there are one, two or three workers, and that room is like an individual office to them. Cellular layout of office could also be called a private or closed office. Individual offices are separated usually with a walls or panels. It is very important to form separate offices in this layout of office. This type of office layout is suitable for workers, who should not be disturbed by other noises. This type of office layout has started to become popular in the late 60's. This type of office layout was created by designer and planner Robert Probst. Cellular office layout has its own advantages and disadvantages. /11./

Advantages of cellular office layout:

1. Confidentiality. It is easy for workers to keep private information and to discuss private information. Employers can make their room (mini office) as cozy as they want, to make them feel better. Suitable coziness and ease can increase productivity of the worker. This type of office layout is best suitable for business, where employees' are needed to do their job in high privacy. /11./

2. Focus. Not like open office, cellular type of office layout can offer and employees free and peaceful environment for the staff. This results in employees' concentration and focus on their work. /11./

3. Imagination. Imaginative and innovative jobs require a silent space is. A silent place is extremely important and can be offered by cellular office type. Cellular type of office layout reduces movement of other people all around you, reduces sound levels in worker's place and lets workers to be more efficient in their work. /11./

4. Little gossip. Unlike open office, where there are many employees in one place which can easily interact with each other, gossips are born, which reduces quality and concentration of their work. In cellular office, workers can't easily interact with other workers while working, so they can keep concentrated and not be distracted. /11./

5. Good for health. If a worker in open office is sick, he can easily spread his microbes and bacteria to other workers and make them sick too, because all workers are tightly placed in one big area of an office. It won't happen in cellular type of office layout, because people are working in their own mini-offices, which are separated one to another. That keeps more workers healthy and reduces possibility to get them sick because of one other worker. /11./

6. Adjust room temperature and lighting as per convenience. It might be very big problem for some workers in open office layout. Heating, ventilation, lighting is adjusted for all at common levels. If one worker feels too cold, too hot or etc. he can't change anything, because it won't be good for other workers. In some cellular type of offices, workers can adjust room temperature, lighting and etc. as much as they want and it won't have any influence on other workers. /11./

7. Loud equipment can be isolated. Cellular type of office layout is good because, loud equipment can be placed in separated from other rooms room. It will ensure quiet and high quality of office environment to concentrate and not be distracted. /11./

8. Better Security. In the cellular type office layout, where a lot of work and a lot of documents and belongings are confidential and private, it is good, that people can lock their workplace to ensure safety of their work. While in open office you never know, who could have looked on your documents while you were gone. /11./

9. Perfect for long duration group ventures. Cellular type of office layout creates perfect conditions for teams to work on long duration projects, for them to stay in place. Furthermore, cellular type of office layout lets team to communicate more easily person to person and also creates confidential and safe environment to discuss confidential projects or things. /11./

10. Typically has a window, letting sunlight and fresh air. Unlike open plan office, cellular type of office has many separated rooms (mini offices). Usually, in most of these rooms there is a window. Workers can open windows to get natural ventilation and also get plenty of sunlight which cheers up and shows an office as a bright and beautiful place to work. /11./

Disadvantages of cellular office layouts:

1. Consumes huge space. In cellular type of office, rooms have to be separate, and one person statistically gets more area, than in open office. In addition, as there are more rooms, so there is more space, which can’t be utilized as workplace, like doors or passageways. /11./

2. Employees becoming unproductive. In a cellular type of office layout workers’ efficiency can be often slowed down and reduced by this type of layout. Cellular office offers a lot of privacy for a worker, as he is separated from other workers and is able to waste his time and the company time and money and be not seen. /11./

3. Ineffective communication. In open office it is very easy to communicate with each other, as every worker is just next to you. But in cellular type of office it doesn’t work that way. Usually, workers in cellular typo of office layout can’t communicate very easily with each other, because they work in separated rooms. They can communicate via email, but it is not as powerful as verbal communication. /11./

4. Costly. To construct and after that to manage a cellular type of office might be expensive, if it would be compared to open office layout. Firstly, all workers are working in their individual rooms (mini offices) and that requires much more space. And in some bigger cities, where all space is very expensive, every small area counts.

All rooms are separated with walls, doors and panels which cost much. Furthermore, every room has to be provided with heating, air conditioning, lighting and etc. /11./

5. Equipment cannot be shared. Operational costs in cellular type office are way bigger than in open plan office type. Some rooms of cellular type office have to have its own fax, printer, photocopier, telephone and etc. And this type of equipment is not shared in cellular office type in comparison with open office type, where for example, one printer but be shared will all office. /11./

6. Difficult to adjust work space to match work load. After the office is created and after that built, with all rooms is will be very hard (almost impossible) to change the dimensions of the cubicle. For example, if a company wants to expand, needs more workers and then needs more workspace. It would be a really big problem, as there won't be much possibilities to expand and to add more separated rooms. /11./

7. It's tougher for the junior employees to approach senior managers. Unlike open-plan office, where all workers are easily approachable, in cellular office type for a junior employee to approach senior manager might be a problem. All managers and supervisors are disconnected, because they have their own cubicles, and it creates quite uncomfortable, problematic and unapproachable environment for juniors. /11./

8. The sense of seclusion. All employees are separated and are sitting in their own mini offices. It can become a problem, as employees might not feel part of a group. They are isolated and can't have support or assistance if they are required at the moment. It can affect and decrease their productivity. /11./

9. Training employees can be a long process. All employees are working in their own rooms so to address all employees together at a time can be difficult. Only small groups from each mini office (room) can be trained at a time, because training has to be scheduled, which might be hard. It becomes waste of time. /11./

10. Flow of information might be decelerated. In cellular type of office, it is much harder for workers to reach each other's. Because of that, flow of information might be decreased. It would take more time for communication and for coordinating the work flow. /11./

2.4 Importance of good indoor climate in offices

Indoor climate has a significant influence on the offices. Indoor climate can affect worker's health, productivity, and building in which particular office is located.

Poor indoor climate in the office can cause discomfort and health problems for workers. For example, he can get allergies, irritation (in mucous membranes or skin), infection, inflammation, toxic reactions, negative effects on reproduction and cancer. /4 p.162./

Poor indoor climate in the office can create problems for a building, where that office is located. For example, because of poor indoor climate, building can get non-specific building related health symptoms (Sick Building Syndrome symptoms), building related allergy and other possibly building-related health effects. /4 p.162./

The studies have shown that if supply airflow rate is increased (in that way air quality is improved) and then productivity of workers is increased, too. Studies have estimated some relationships between air quality, sensory pollution load, ventilation rate and the performance of office work. In this way, performance can be estimated. Some of the relationships estimated are- every 10% reduction of workers, which are dissatisfied with the air quality increase performance by 1.1%; performance would be increased by 1.6% if pollution load would be decreased doubly; performance would be increased by 1.8% if ventilation rate would be increased doubly. /4 p.165./

If the building envelope and the HVAC systems are designed properly, and if building and furnishing materials are properly selected, providing good air quality indoors might not cost more and might not require more energy. The easiest way to increase productivity would be just by increasing ventilation rate. It is important to have efficient energy recovery systems, because it reduces extra heat energy used, when air flow rates are increased. If we would compare productivity, when air quality is neither good nor bad with very good indoor air quality, the difference would be about 5%. If you look it in long term perspective, annual loss of productivity would cost much more, than just costs to increase air quality indoors. /4 p.166./

3 THE REQUIREMENTS OF LITHUANIAN REGULATIONS AND GUIDELINES

Lithuanian regulations and guidelines, which will be analyzed and according to it, will be checked if office in Lithuania meets its requirements, is HN 69:2003 “Thermal comfort and adequate thermal environment in workplaces. Normative values of parameters and measurement requirements.“ and STR 2.09.02:2005 “Heating, ventilation and air conditioning“. The most important parameters from these regulations and guidelines are: air temperature, relative humidity, air flow rates and CO_2 concentration.

3.1 Air temperature

Table 3 shows what air temperature has to be in the office, depending on period of the year and depending on the work catogory to meet the requirements.

TABLE 3. Work space thermal comfort of the ambient air temperature normative values /12 p.4/

Period of the year	Work categories	Air temperature, ^oC
Cold	Easy - Ia	22-24
	Easy - Ib	21-23
	Modest - IIa	18-20
	Modest - IIb	17-19
	Hard - III	16-18
Warm	Easy - Ia	23-25
	Easy - Ib	22-24
	Modest - IIa	21-23
	Modest - IIb	20-22
	Hard - III	18-20

Workers were working in the room, when indoor climate parameters were monitored. Their work belong to Easy (Ib) work category. Period of the year was warm. Air temperature had to be between 22-24^{o}C to meet the requirements, set in the regulations and guidelines.

3.2 Relative humidity

Table 4 shows what relative humidity has to be in the office, depending on period of the year and depending on the work catogory to meet the requirements.

TABLE 4. Work space ambient air relative humidity normative values /12 p.4/

Period of the year	Work categories	Relative humidity, %
Cold	Easy - Ia	40-60
	Easy - Ib	40-60
	Modest - IIa	40-60
	Modest - IIb	40-60
	Hard - III	40-60
Warm	Easy - Ia	40-60
	Easy - Ib	40-60
	Modest - IIa	40-60
	Modest - IIb	40-60
	Hard - III	40-60

Workers were working in the room, when indoor climate parameters were monitored. Their work belongs to Easy (Ib) work category. Period of the year was warm. Relative humidity had to be between 40-60% to meet the requirements, set in the regulations and guidelines.

3.3 Air flow rates

Table 5 shows what supply and exhaust air flow rates has to be in the office, to meet the requirements.

TABLE 5. Supply and exhaust air design values /14 p.32/

The building and the room name	Supply air flow rate				Extract air flow rate	
2. Administrative buildings	For 1 person		For 1m^2 floor area			
	dm^3/s	m^3/h	dm^3/s	m^3/h	dm^3/s. unit	m^3/h. unit
2.1. Work room	10	36	1	3,6	-	-

When values are set only for supply or exhaust air flow rate, in the same and adjacent rooms air flow rates have to be supported by the air balance, that air would go from cleaner air space to more polluted /14 p.34/. Office has to be in under-pressure. That means, that extract air flow value has to be by about 5% bigger than supply air flow value. /14 p.16./

3.4 CO_2 concentration

There are no limits set of CO_2 concentration in HN 69:2003 or STR 2.09.02:2005 Lithuanian regulations and guidelines. Although, there are some regulations set in another- HN 23:2011 Lithuanian regulations and guidelines. Long-term exposure limit value of CO_2 concentration has to be 5000 ppm /13 p.11/. Long term exposure limit value is a maximum allowable size of chemical worker's breathing zone concentration of dynamic weighted average of the measured or computed over an 8 hour shift and 40 hours per week /13 p.3/. There are no regulations and guidelines, where would be possible to see CO_2 normative values in the offices, but according to all the studies in Lithuania and according all the Lithuanian literature of CO_2, CO_2 concentration should not reach more than 1000 ppm in the offices.

4 THE REQUIREMENTS OF FINNISH REGULATIONS AND GUIDELINES

Finnish regulations and guidelines, which will be analyze and according to it, will be checked if office in Finland meets its requirements, is D2 “Indoor climate and ventilation of buildings regulations and guidelines 2003” and LVI 05-10440en ”Classification of indoor environment 2008”. The most important parameters from these regulations and guidelines are: air temperature, relative humidity, air flow rates and CO_2 concentration.

4.1 Air temperature

According to D2 /16/, the indoor temperature design value for the heating season is 21°C. The maximum acceptable deviation from the designed value in the centre of the room at 1.1m height is ±1°C. /16 p.8/.

Table 6 shows what indoor air temperature has to be to reach one of the classification value.

TABLE 6. Target values for thermal environment /15 p.5/

	S1	**S2**	**S3**
Operative temperature, t_{op} (°C), when $t_{outside}$ <10°C	21.5	21.5	21.0
Deviation allowed from set value, °C	±0.5	±0.5	±1.0
Maximum value of operative temperature, °C,	t_{op}+1.5	t_{op}+1.5 (when $t_{outdoor}$ <10°C)	t_{op}+1.5 (when $t_{outdoor}$ <15°C)
Minimum value of operative temperature, °C	20	20	18

S1 category is the highest and S3 category is the lowest category. During the time of measurements average outdoor temperature in Mikkeli was <10°C.

4.2 Relative humidity

According to D2 /16/ ”the humidity of indoor air shall not be harmfully high on a continual basis, nor shall humidity be allowed to concentrate on structures or on their surfaces or in the ventilation system in such a way that it will cause moisture damage, growth of microbes or micro-organisms or any other health hazards /16 p.10."

"The relative humidity of the air must be below 60 % /15 p. 14." Relative humidity is mentioned only in category S1, as it has to be more than 25 %. Categories S2 and S3 don't have any requirements set for relative humidity. /15 p.14./

4.3 Air flow rates

Table 7 shows what supply and exhaust air flow rates has to be in the office, to meet the requirements.

TABLE 7. Supply and exhaust air design values for office /16 p.33/

Space type	Outdoor air flow, $dm^3/s/m^2$	Extract air flow, $dm^3/s/m^2$
Offices and similar rooms	1,5	-

When values are set only for supply or exhaust air flow rate, in the same and adjacent rooms air flow rates have to be supported by the air balance, that air would go from cleaner air space to more polluted. /16 p.22./

4.4 CO_2 concentration

Table 8 shows carbon dioxide concentration requirements for each category.

TABLE 8 Carbon dioxide concentration requirements /15 p.6/

	S1	S2	S3
Carbon dioxide concentration (ppm)	<750	<900	<1200

S1 category is the highest and S3 category is the lowest category. D2 /16/ is similar to the requirements set in S3.

5 INVESTIGATION OF OFFICE IN LITHUANIA

5.1 Measurement setup

A cellular type of office was selected for measurements. This type of office is representative type of offices in Lithuania, as it is most common type of office in Lithuania. Office is located in Vilnius, Lithuania. It is located in the centre of a town. Building was renovated in the year of 1999. Ventilation system is constant air volume (CAV), mechanical supply and exhaust ventilation. This office is heated with district heating system. Measurements were taken with data loggers who save all the information. Air temperature and CO_2 concentration were measured starting from 18.05.2016 00.00 till 25.05.2016 00.00 for seven days. Sampling interval during the measurements was 5 minutes. Humidity was measured starting from 24.05.2016 08.00 till 24.05.2016 17.00 for one working day. Sampling interval during the measurements was 5 minutes. Amount of workers in this office is 14. On these days, on working time, two persons were working in the studied office room

Air can be exchanged between rooms through open doors and corridor in this office. Office was located in the first floor of the building. The room, where indoor climate parameters were monitored, had one external wall, two internal walls, and one internal wall with automatic doors and windows above the doors. Both workers were sitting next to an external wall. Both workers were males. Measurements were taken at 1.1 m height. Workers were doing the work, which belongs to category- Easy (Ib). This kind of work can be explained like this- it is a work, involving a human energy consumption of more than 139 W, but not more than 175 W, requires modest physical tension while sitting, standing or walking. This work they were doing requires 1,2 met. People were wearing regular work clothes, of clo value about 0,7.

Office building consists of two floors. The first floor had four rooms. Room Nr.1 has about 15 m^2 of floor area and it was the room where indoor climate parameters were monitored. Studied office room has mechanical supply and exhaust ventilation. Figure 4 shows 1st floor office plan. It has 3 rooms, where people are working (Nr.1, Nr. 2, Nr.3). Nr.4 room is storage room.

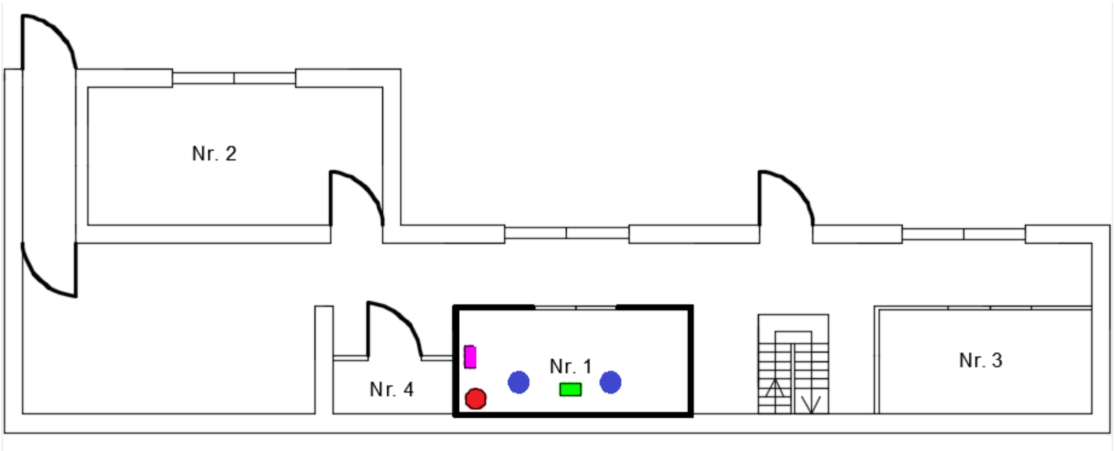

FIGURE 4. 1st floor office plan

Blue circles shows place in the office, where workers were working. Red circle shows place in the office, where monitoring device was placed. Green rectangle shows place, where supply air device is located (on the ceiling). Purple rectangle shows place, where extract air device is located (on the wall).

Table 9 shows office working hours. Office working hours were usual, 8 hours a day, 40 hours a week.

TABLE 9. Office working hours

Day of the week	**Monday, Tuesday, Wednesday, Thursday, Friday**	**Saturday, Sunday**
Time when people were working in the room	08.00-12.00 13.00-17.00	-
Total hours	8 hours	-

Figure 5 shows room, where indoor climate parameters were monitored. Two workers were working in this room during the time, when measurements were taken.

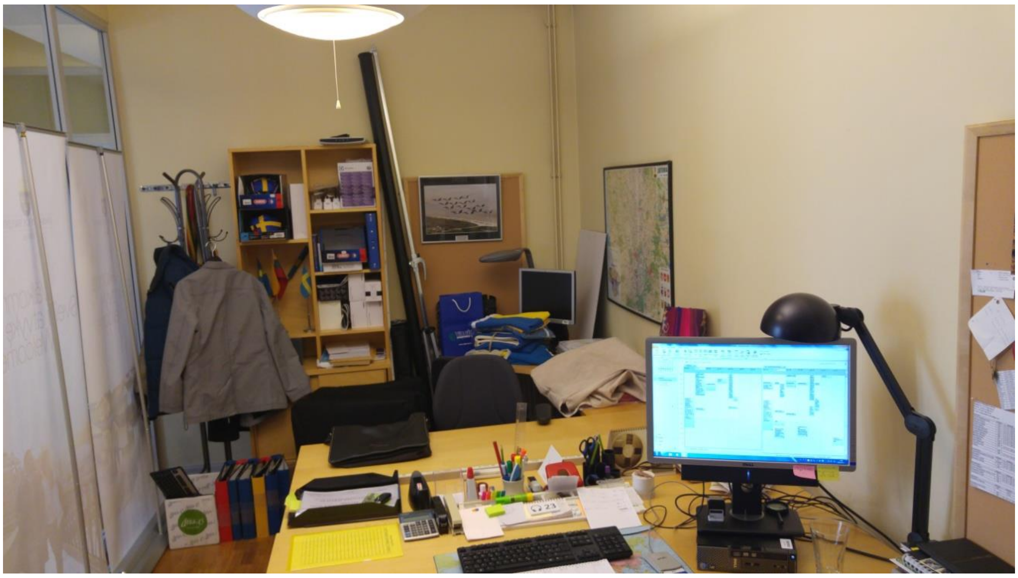

FIGURE 5. Room where indoor climate parameters were monitored

Figure 6 shows devices used for monitoring CO_2 concentration and air temperature.

FIGURE 6. The devices for measurements

Using these devices, air temperature and CO_2 concentration was measured. Duration of the measurements was one week. The device, which measures air temperature, is the device on the right, with square on the bottom and thin roll. The device, which measures CO_2 concentration, is pointed with an arrow. The box, which is connected to the measuring device, is a device where collected data is logged and saved. The measurement for humidity was placed next day by other person in the same spot. Measurements were taken at 1.1 m height.

5.2 Measurement results

Table 10 shows air temperature results during the time, when air temperature was monitored. Minimum outside air temperature value during the time of measurements was 3°C and maximum air temperature value during the time of measurements was 21°C.

TABLE 10. Air temperature results

	Max. value	Min. value	Average value
Air temperature, °C	23.2	20.6	22.4

Maximum value was reached at 23.05.2016 (Monday) at 16:00. Minimum value was reached at 18.05.2016 (Wednesday) at 09:20. Average value of air temperature was 22.4°C at the time of measurements. To see how air temperature changed during the time of measurements we need to look at figure 7.

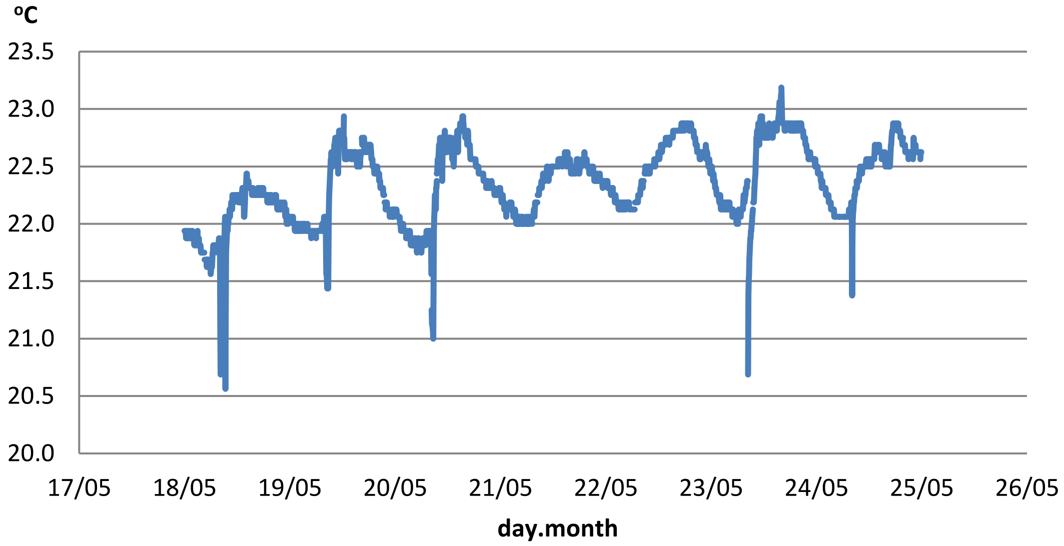

FIGURE 7. Air temperature values at the time of measurements

Looking at the figure we can see, that air temperature was fluctuating with the same pattern each day, except for 21.05 and 22.05, because it was weekend, and no workers were in the office. To see how air temperature changed in one working day we need to look at figure 8.

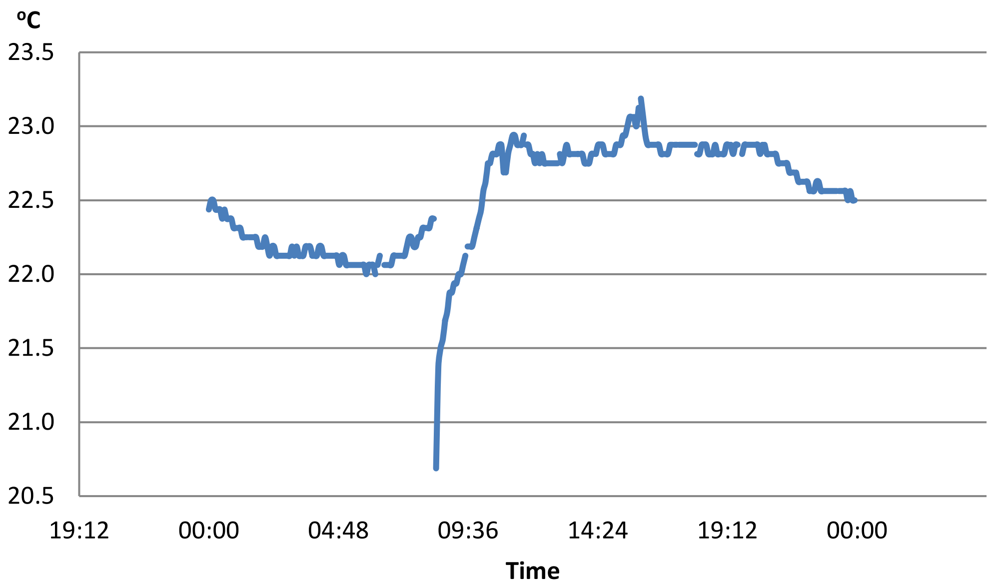

FIGURE 8. Air temperature on Monday the 23.5.2016

In the night temperature wasn't changing, but in the morning workers ventilated their room a little, that's why temperature decreased so fast and then started to increase.

Table 11 shows humidity results during the time, when humidity was monitored. Minimum outside relative humidity value during the time of measurements was 55 % and maximum relative humidity value during the time of measurements was 70 %.

TABLE 11. Relative humidity results

	Max. value	Min. value	Average value
Relative humidity, %	54	48	51
Absolute humidity, g/kg	9,3	8,1	8,8

Maximum value of RH was reached at 24.05.2016 (Tuesday) at 09:15. Minimum value was reached at 24.05.2016 (Tuesday) at 15:50. Average value of relative humidity was 51 % at the time of measurements. Maximum value of AH was reached at 24.05.2016 (Tuesday) at 13:00. Minimum value was reached at 24.05.2016 (Tuesday) at 8:10. Average value of relative humidity was 51 % at the time of measurements. Average value of absolute humidity was 8,8 g/kg at the time of measurements. To see how relative humidity changed in one working day we need to look at figure 9.

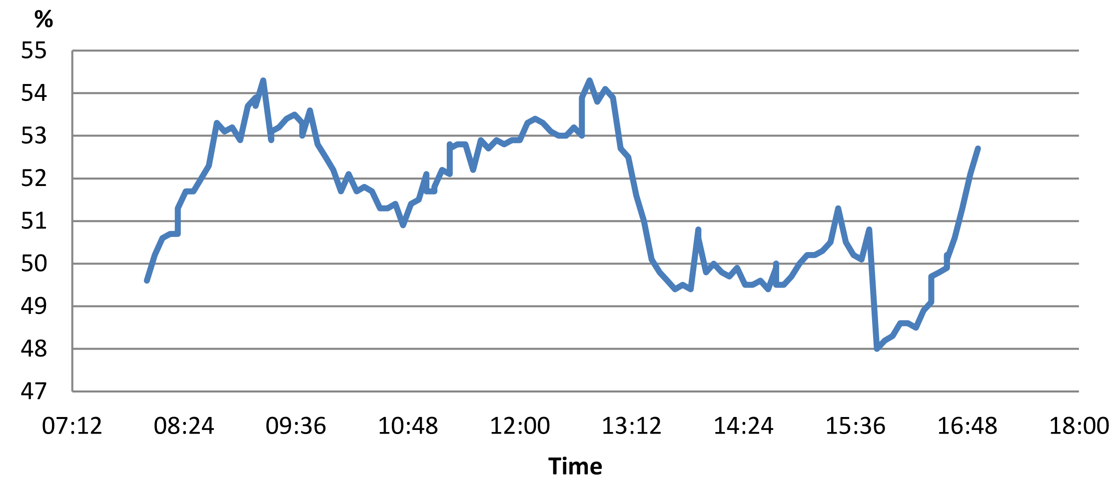

FIGURE 9. Relative humidity on Tuesday the 24.5.2016

Relative humidity fluctuated all day. It started to increase in the morning, when workers came to work and then changed all day, depending on their activity. To see how absolute humidity changed in one working day we need to look at figure 10.

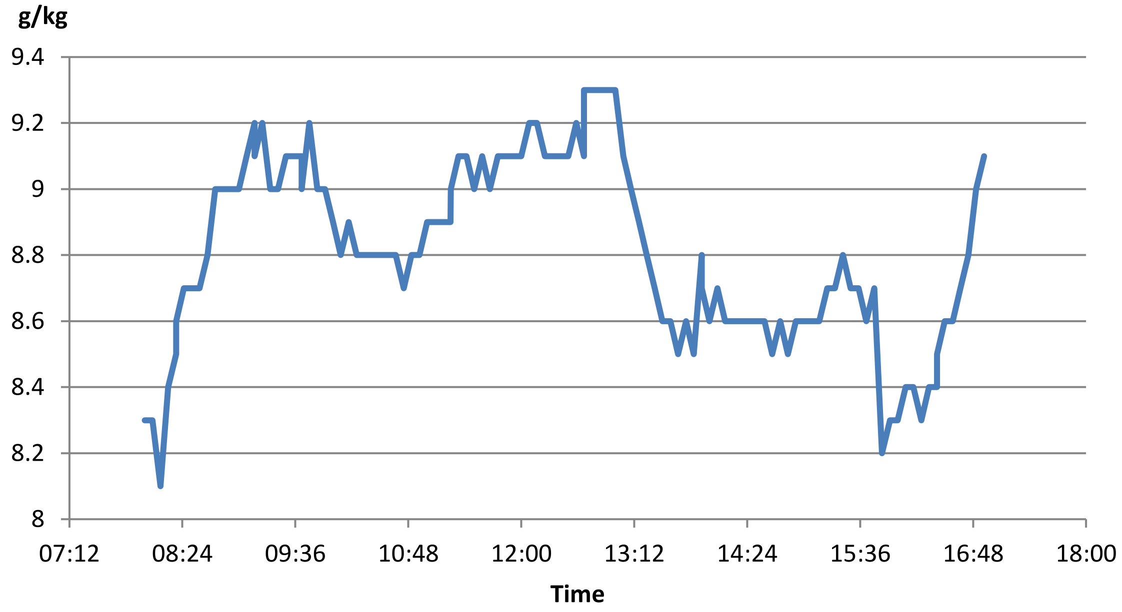

FIGURE 10. Absolute humidity on Tuesday the 24.5.2016

Absolute humidity fluctuated all day. It started to increase in the morning, when workers came to work and then changed all day, depending on their activity.

Table 12 shows CO_2 concentration results during the time, when CO_2 concentration were monitored.

TABLE 12. CO_2 concentration results

	Max. value	Min. value	Average value
CO_2 concentration, ppm	471	340	398

Maximum value was reached at 19.05.2016 (Thursday) at 17:25. Minimum value was reached at 21.05.2016 (Saturday) at 17:05. Average value of CO_2 concentration was 398 ppm at the time of measurements.

Figure 11 shows which values of CO_2 concentration were monitored most often.

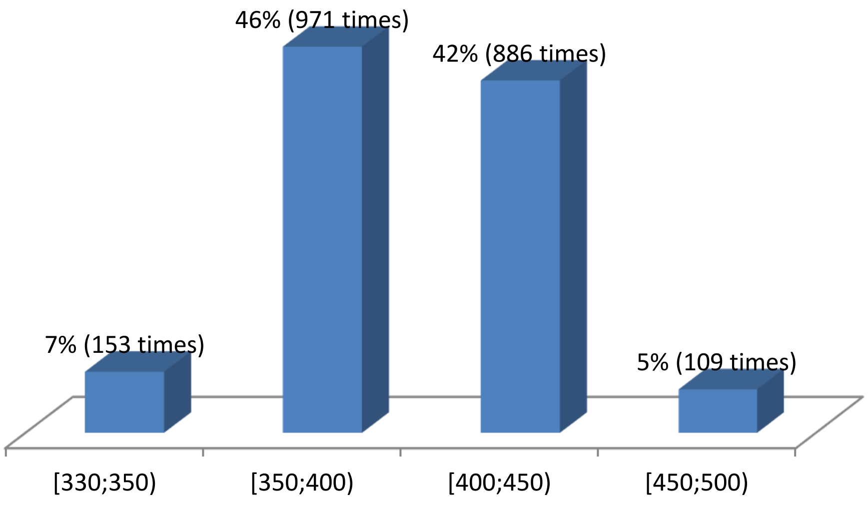

FIGURE 11. Percentage of CO_2 measurement values, which belong in particular group of values. Total number of samples was 2119

Looking at the figure, we can see that mostly of the time, CO_2 values were from 350ppm to 450ppm. 88% of total measured values belong to this group of value. CO_2 was measured all day and all night, so we could say that 12% of total measured values, which are little far away from normal CO_2 concentration value (350ppm-450ppm) group, were taken at the time, when mechanical ventilation systems were not working altogether. To see how CO_2 concentration changed during the time of measurements we need to look at figure 12.

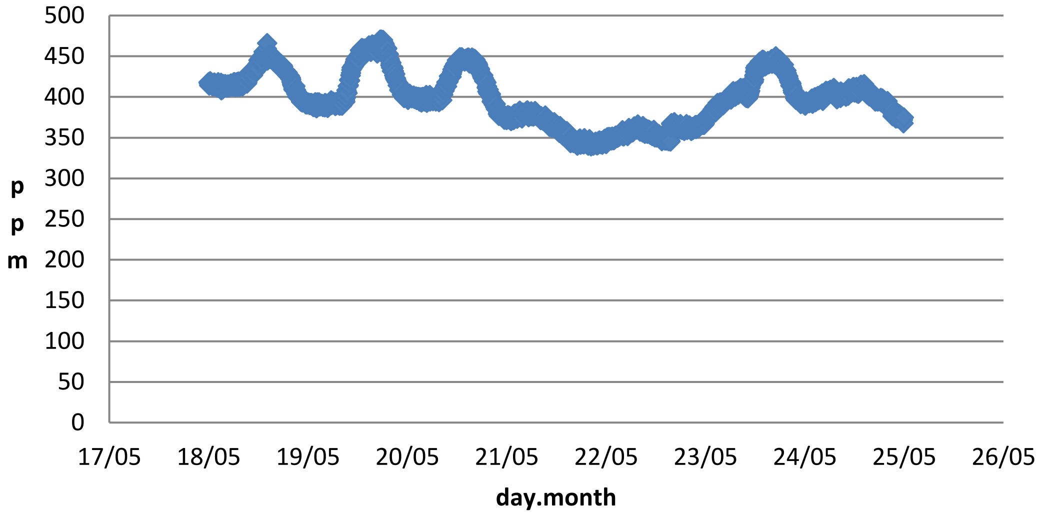

FIGURE 12. CO_2 concentration values at the time of measurements

Looking at the figure 12 we can see, that CO_2 concentration was fluctuating with the same pattern each day, except for 21.05 and 22.05, because it was weekend, and no workers were in the office. To see how CO_2 concentration changed in one working day we need to look at figure 13.

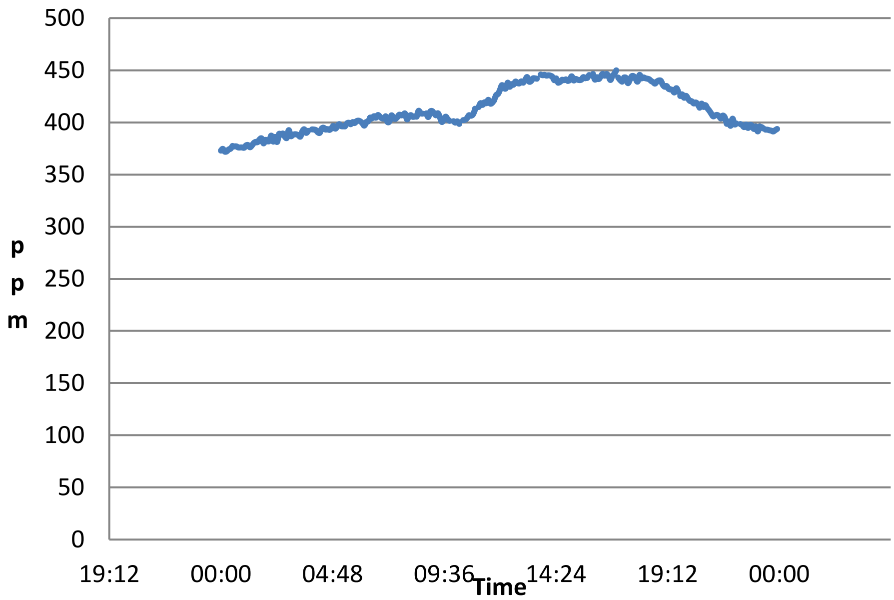

FIGURE 13. CO_2 concentration on Monday the 23.5.2016

Looking at the figure we can see, that CO_2 started more rapidly increase in the morning, when people came to work and settled in. CO_2 started to more decrease at the end of working day, when workers started to leave the office.

6 INVESTIGATION OF OFFICE IN FINLAND

6.1 Measurement setup

A cellular type of office was selected for measurements. This type of office is the same type of office as Lithuanian office. Office is located in Mikkeli, Finland. It is located near the centre of a town. Building was built and founded in the year of 1992 and the technical systems have not been renovated. Office is located in Mikkeli University of Applied Sciences. Ventilation system is constant air volume (CAV), mechanical supply and exhaust ventilation. This office is heated with district heating system. Measurements were taken with data loggers. Air temperature, CO_2 concentration and humidity were measured starting from 16.11.2016 15.20 till 23.11.2016 15.20 for seven days. Sampling interval during the measurements was 5 minutes. Amount of workers in this office is 19. On these days, on working time, two persons were working in the studied office room. Both workers were able to control their office indoor climate with doors, and with windows and with thermostats on the radiators.

Air can also be exchanged between rooms through open doors and corridor in this office. Office was located in the second floor of the building. The room, where indoor climate parameters were monitored, had one external wall, two internal walls, and one internal wall with doors and small window next to a door. The other worker was male and the other worker was female. Measurements were taken at 1.1 m height. Workers were doing the office work, which can be explained like this- this work requires modest physical tension while sitting, standing or walking. This work they were doing requires 1,2 met. People were wearing regular work clothes, of clo value 0,7.

Office building consists of two floors. The second floor had fifteen rooms. Room Nr.4 has about 15 m^2 of floor area and it was the room where indoor climate parameters were monitored. Figure 14 shows 2nd floor office plan. It has seven rooms, where people are working (Nr. 2, Nr.3, Nr.4, Nr.5, Nr.6, Nr.7, Nr.8). Nr.1 room is break room. Nr. 11 and Nr. 12 are WCs. Nr.10 is copying room. Nr.13 and Nr.14 are conference rooms. Nr.9 is wardrobe. Nr.15 is storage room.

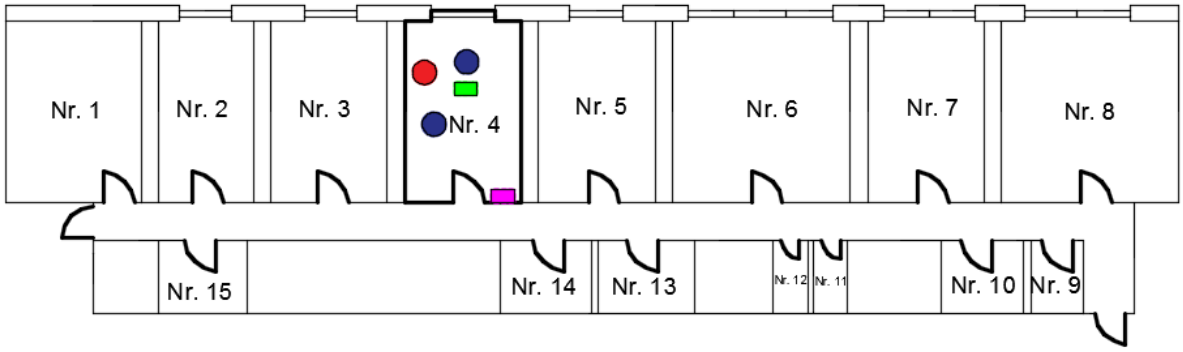

FIGURE 14. 2nd floor office plan

Blue circles shows place in the office, where workers were working. Red circle shows place in the office, where monitoring device was placed. Green rectangle shows place, where supply air device is located (on the ceiling). Purple rectangle shows place, where extract air device is located (on the wall).

Table 13 shows how long each worker occupied room when indoor climate parameters were monitored.

TABLE 13. Time spent by each worker in the room

Day of the week	1 worker	2 worker
Wednesday (16.11.2016)	3 hours	2 hours
Thursday (17.11.2016)	4 hours	6 hours
Friday (18.11.2016)	4 hours	6 hours
Saturday (19.11.2016)	4 hours	4 hours
Sunday (20.11.2016)	4 hours	0 hours
Monday (21.11.2016)	3 hours	5 hours
Tuesday (22.11.2016)	3 hours	5 hours
Wednesday (23.11.2016)	0 hours	6 hours

Figure 15 shows room, where indoor climate parameters were monitored. Two workers were working in this room during the time, when measurements were taken.

FIGURE 15. Room where indoor climate parameters were monitored

Figure 16 shows device used for monitoring CO_2 concentration air temperature and relative humidity.

FIGURE 16. Data logger Rotronic CP 11 for measuring the temperature, humidity and CO_2 concentration

Using this device, air temperature, CO_2 concentration and relative humidity was measured. Sampling time was 5 minutes. Duration of the measurements was one week. Data logger was which was used was Rotronic CP 11. Measurements were taken at 1.1 m height.

6.2 Measurement results

Table 14 shows air temperature results during the time, when air temperature was monitored. Minimum outside air temperature value during the time of measurements was 0^{o}C and maximum air temperature value during the time of measurements was 6^{o}C.

TABLE 14. Air temperature results

	Max. value	**Min. value**	**Average value**
Air temperature, ^{o}C	24	21.8	22.5

Maximum value was reached at 16.11.2016 (Wednesday) at 16:14. Minimum value was reached at 19.11.2016 (Saturday) at 09:30. Average value of air temperature was 22.5^{o}C at the time of measurements. To see how air temperature changed during the time of measurements we need to look at figure 17.

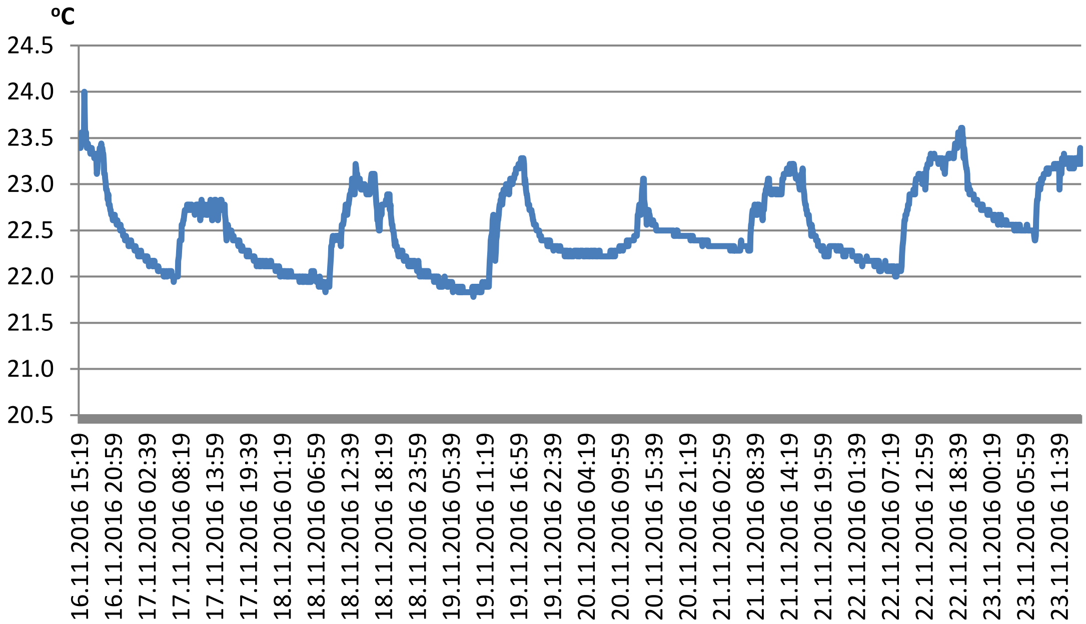

FIGURE 17. Air temperature values at the time of measurements

Looking at the figure we can see, that air temperature was fluctuating with the same pattern during all days. To see how air temperature changed in one working day we need to look at figure 18.

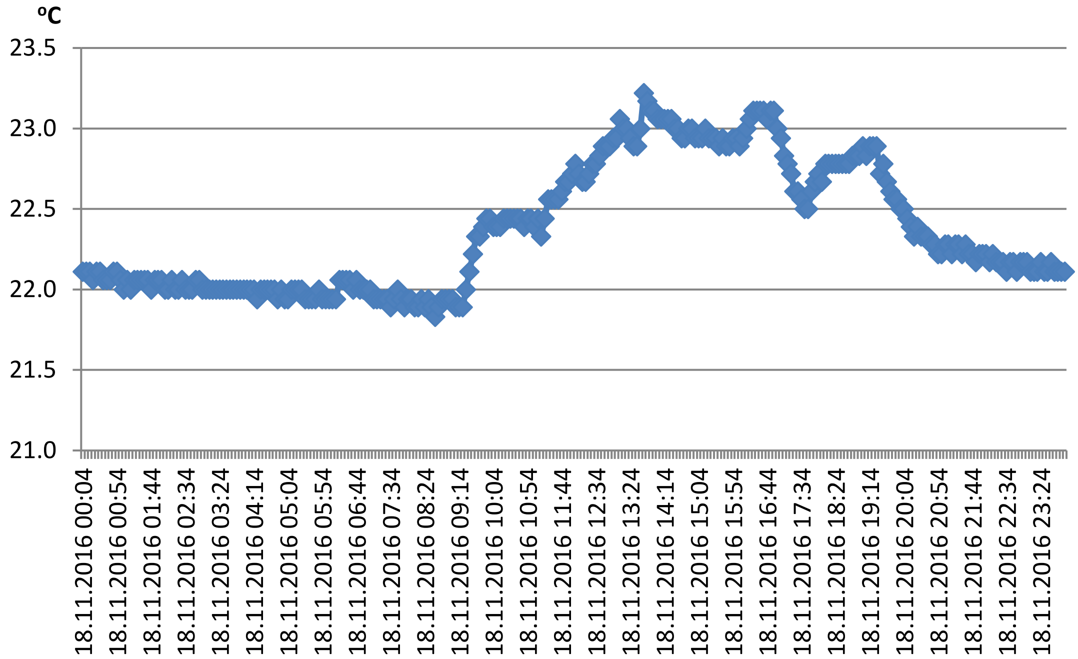

FIGURE 18. Air temperature on Friday the 18.11.2016

In the night, temperature was not changing, but in the morning, workers came to office, and air temperature started to increase. In the evening, it started to decrease. Table 15 shows humidity results during the time, when humidity was monitored. Minimum outside relative humidity value during the time of measurements was 93 % and maximum relative humidity value during the time of measurements was 98 %.

TABLE 15. Relative and absolute humidity results

	Max. value	**Min. value**	**Average value**
Relative humidity, %	32	21	25
Absolute humidity, g/kg	5,6	3,6	4,3

Maximum value of RH was reached at 22.11.2016 (Tuesday) at 11:09. Minimum value was reached at 16.11.2016 (Wednesday) at 17:49. Average value of relative humidity was 25 % at the time of measurements. Maximum value of AH was reached at 22.11.2016 (Tuesday) at 11:09. Minimum value was reached at 17.11.2016

(Thursday) at 02:15. Average value of absolute humidity was 4,3 g/kg at the time of measurements. To see how relative humidity changed in during time of measurements we need to look at figure 19.

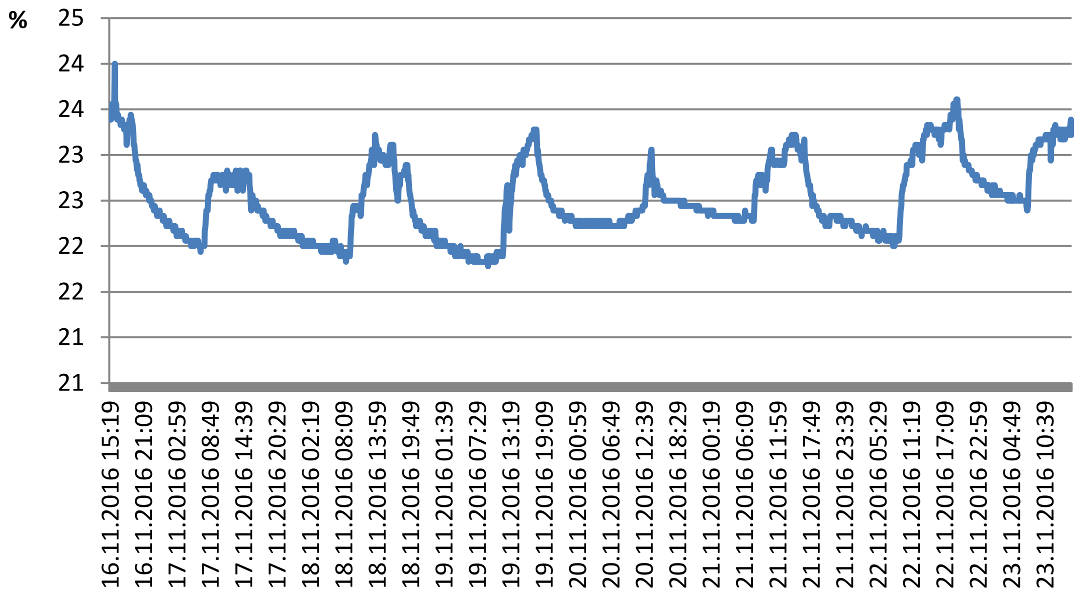

FIGURE 18. Relative humidity values at the time of measurements

Relative humidity fluctuated all week the same way. It started to increase in the morning, when workers came to work and then changed all day, depending on their activity. In the evening, it started to decrease. But changes were very small. To see how relative humidity changed in one working day we need to look at figure 20.

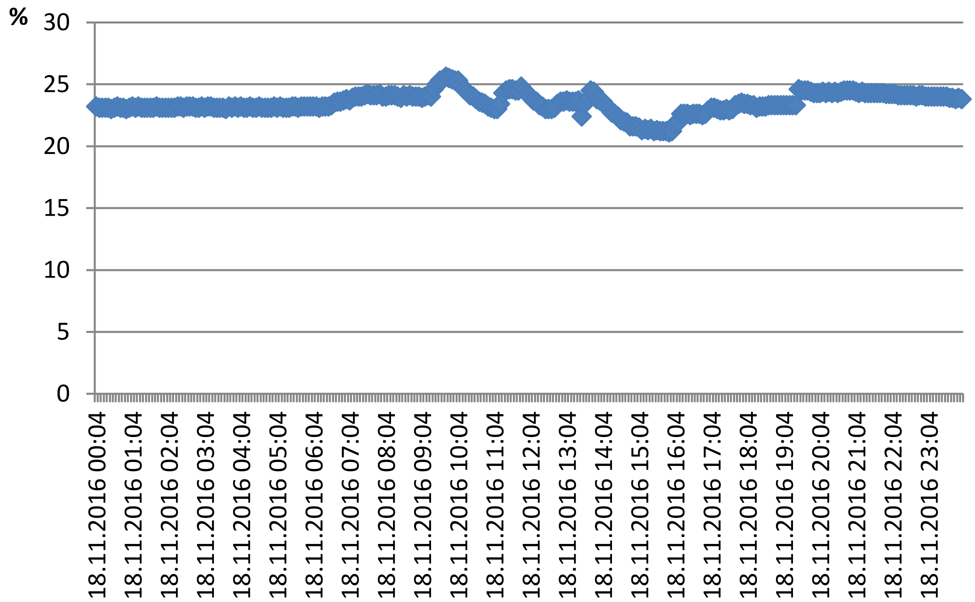

FIGURE 19. Relative humidity on Friday the 18.11.2016

Relative humidity changed only, when people occupied the office, but changes were insignificant. To see how absolute humidity changed all week when it was measured, we need to look at figure 21.

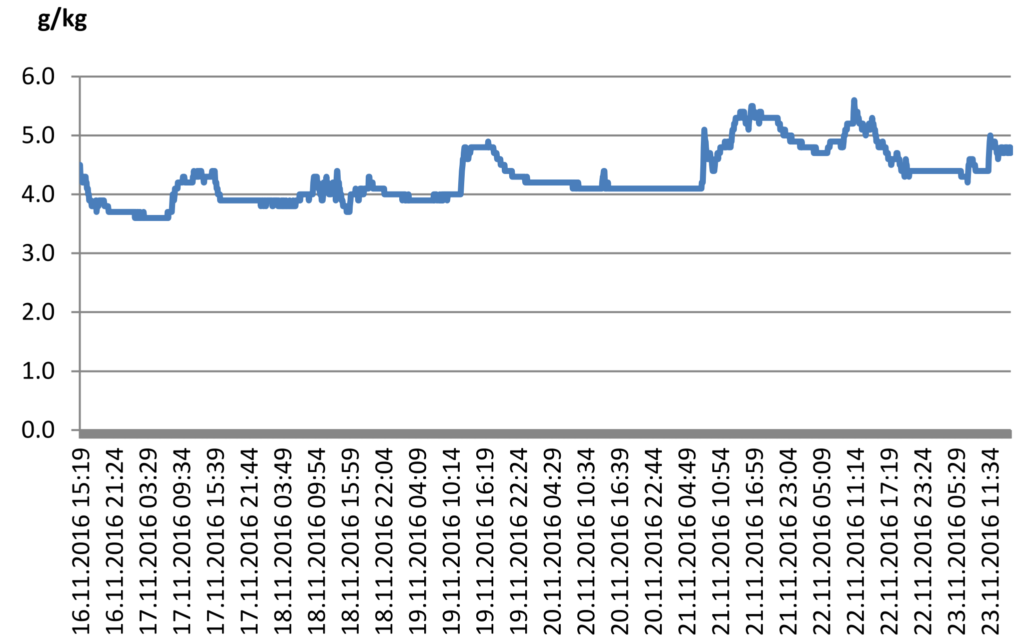

FIGURE 20. Absolute humidity values at the time of measurements

To see how absolute humidity changed in one working day, we need to look at figure 22.

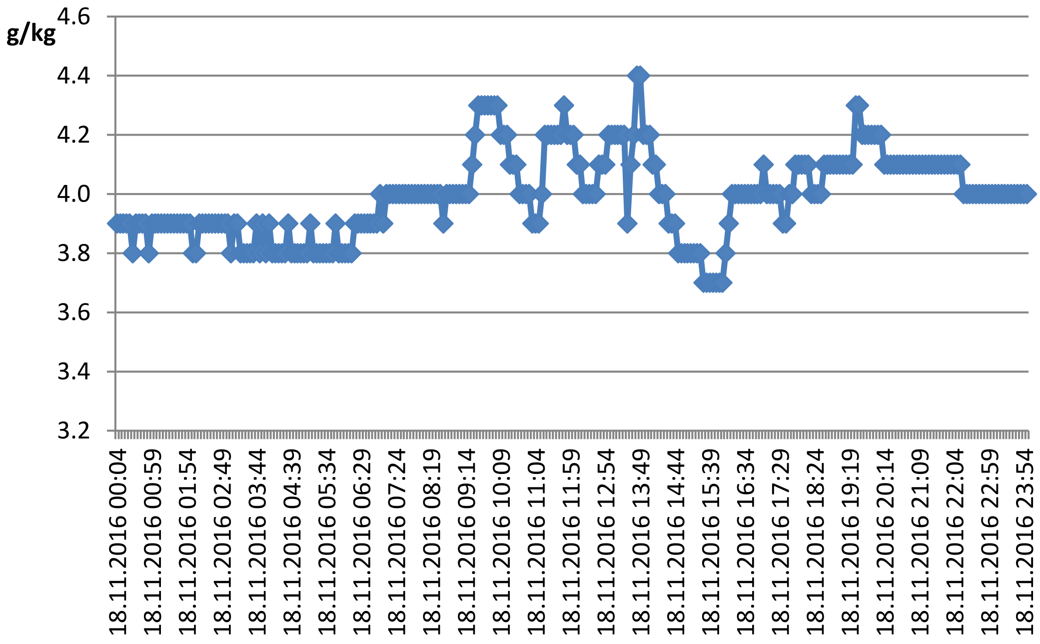

FIGURE 21. Absolute humidity on Friday the 18.11.2016

Absolute humidity fluctuated all day. It started to increase in the morning, when workers came to work and then changed all day, depending on their activity. But these changes were insignificant.

To see air flow rates in the room, we need to look at table 16.

TABLE 16. Designed and measured air flow values of Nr.4 room

	Supply	**Extract**
Designed air flow value, l/s	20	-20
Measured air flow value l/s	24	-19

Air flow were measured by professional company on 30.9.2016 using TSI VelociCalc-9565. Supply air device is CBEa-125 and extract air device is KSO-125.

Table 17 shows CO_2 concentration results during the time, when CO_2 concentration was monitored.

TABLE 17. CO_2 concentration results

	Max. value	**Min. value**	**Average value**
CO_2 concentration, ppm	897	411	501

Maximum value was reached at 16.11.2016 (Wednesday) at 15:20. Minimum value was reached at 18.11.2016 (Friday) at 03:25. Average value of CO_2 concentration was 501 ppm at the time of measurements.

Figure 23 shows which values of CO_2 concentration were monitored most often.

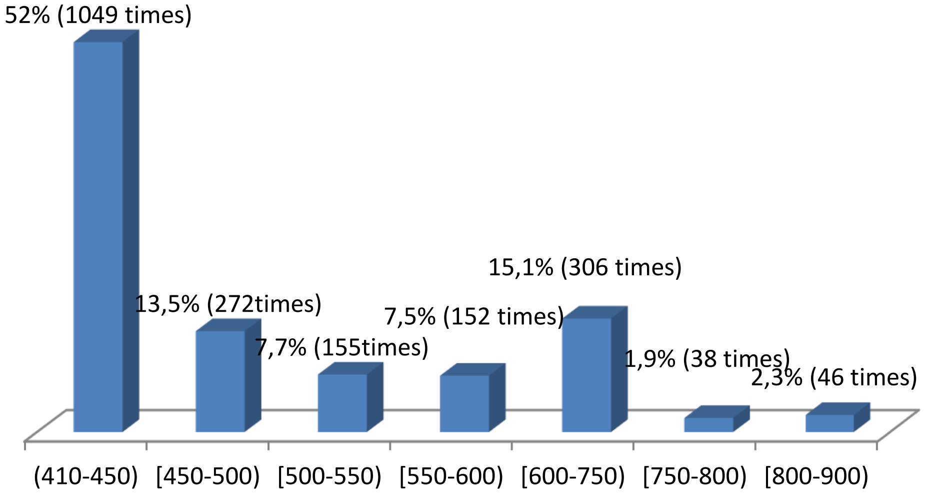

FIGURE 23. Percentage of CO_2 measurement values, which belong in particular group of values. Total number of samples was 2018

Looking at the figure, we can see that mostly of the time, CO_2 values were from 410ppm to 450ppm. 52% of total measured values belong to this group of value. About 96% time of measurements, CO_2 value were lower than 750 ppm. To see how CO_2 concentration changed during the time of measurements we need to look at figure 24.

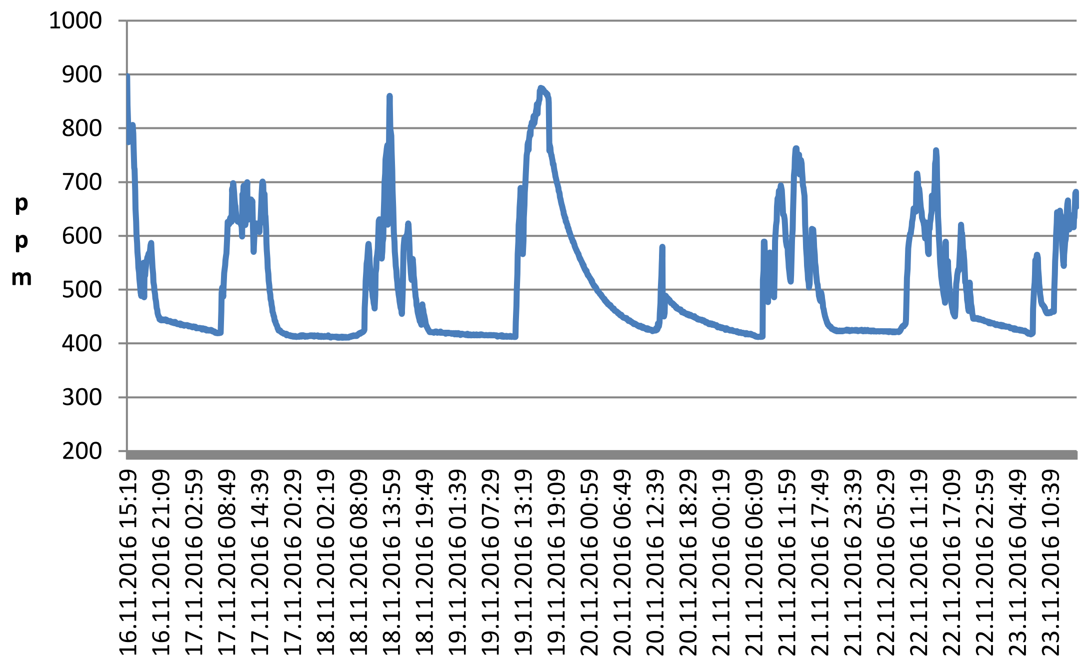

FIGURE 22. CO_2 concentration values at the time of measurements

Looking at the figure 24 we can see, that CO_2 concentration was fluctuating with the same pattern during all days (in the morning CO_2 concentration started to increase and in the evening it started to decrease), except for 20.11.2016, because it was Sunday, and both workers spent the least amount of time in the room. To see how CO_2 concentration changed in one working day we need to look at figure 25.

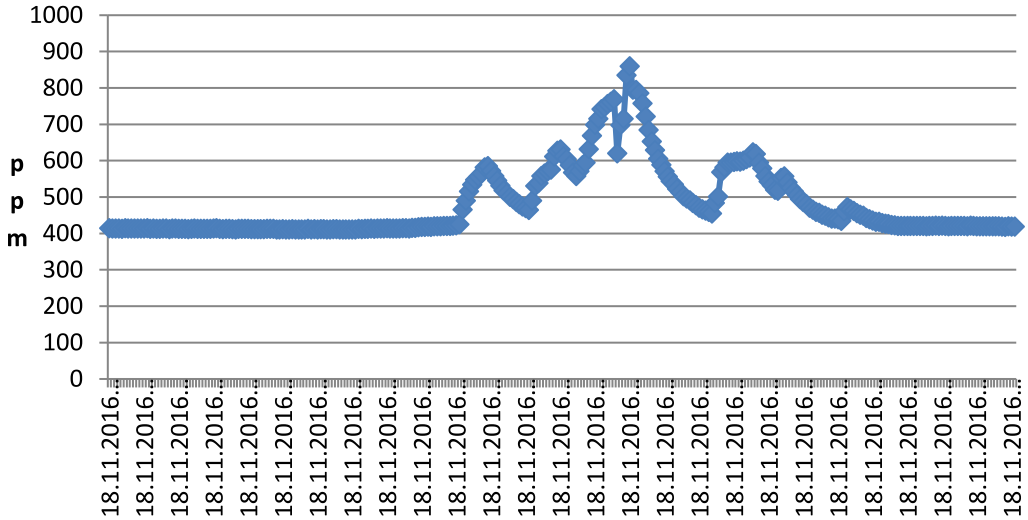

FIGURE 25. CO_2 concentration on Friday the 18.11.2016

Looking at the figure we can see, that CO_2 started more rapidly increase in the morning, when people came to work and settled in. CO_2 started to more decrease at the end of working day, when workers started to leave the office.

7 ANALYSIS

For Lithuanian office, average indoor air temperature during the time of measurements was 22.4^{o}C. Maximum value was 23.2^{o}C and minimum value was 20.6^{o}C. According to regulations (TABLE 3 page 19) air temperature had to be between 22-24^{o}C. Therefore, air temperature requirements were not met 15 % of the time because air temperature was lower than 22^{o}C. Air temperature was measured starting from 18.05.2016 00.00 till 25.05.2016 00.00 for seven days.

For Lithuanian office, average indoor relative humidity during the time of measurements was 51%. Maximum value was 54% and minimum value was 48%. According to regulations, (TABLE 4 page 20) relative humidity had to be between 40-60%. Therefore, relative humidity requirements were met 100% of the time. Indoor relative humidity was measured starting from 24.05.2016 08.00 till 24.05.2016 17.00 for one working day.

For Lithuanian office, average indoor CO_2 concentration during the time of measurements was 398 ppm. Maximum value was 471 ppm and minimum value was 340 ppm. According to 3.4 (page 21), CO_2 concentration had to be less than 1000 ppm. Therefore, CO_2 concentration requirements were met 100% of the time. CO_2 concentration was measured starting from 18.05.2016 00.00 till 25.05.2016 00.00 for seven days.

For Finnish office, average indoor air temperature during the time of measurements was 22.5^{o}C. Maximum value was 24^{o}C and minimum value was 21.8^{o}C. According to D2, (page 21) the indoor temperature design value had to be between 20-22^{o}C. Therefore, air temperature requirements were met 15% of the time because air temperature was higher than 22^{o}C. According to classification of indoor environment (TABLE 6 page 22) air temperature had to be between 20-23^{o}C to meet the requirements of S1 category. Therefore, air temperature requirements of S1 category were not met 16% of the time because air temperature was higher than 23^{o}C. Persons could adjust the indoor temperature with the help of the radiator valves. Air temperature was measured starting from 16.11.2016 15.20 till 23.11.2016 15.20 for seven days.

For Finnish office, average indoor relative humidity during the time of measurements was 25%. Maximum value was 32% and minimum value was 21%. According to 4.2 (page 23) relative humidity had to be more than 25% and less than 60% to meet the requirements. Therefore, relative humidity requirements were not met 60% of the time because relative humidity indoors was lower than 25%. Indoor relative humidity was measured starting from 16.11.2016 15.20 till 23.11.2016 15.20 for seven days.

For Finnish office, designed air flow value for supply and extract devices was 20 l/s. Measured air flow value for supply and extract devices was 24 l/s and 19 l/s. According to regulations, (TABLE 7 page 23) air flow for supply had to be 1,5l/s for 1m^2 of floor area. Room floor area was 15m^2. 24l/s divide by 15m^2 = 1.6l/s for 1m^2 of floor area. Therefore, supply air flow in this room was 1.6l/s for 1m^2 of floor area. According to it, deviation from requirements was only 7%.

For Finnish office, average indoor CO_2 concentration during the time of measurements was 501 ppm. Maximum value was 897 ppm and minimum value was 411 ppm. According to regulations, (TABLE 8 page 23) CO_2 concentration had to be less than 750 ppm to meet S1 category requirements. It had to be 750-900ppm to meet S2 category requirements. 96% of time CO_2 concentration was lower than 750ppm and met S1 category requirements. 4% of time CO_2 concentration was between 750-900ppm and met S2 category requirements. According to D2, (page 24) requirements of CO_2 concentration were met 100% of the time because. CO_2 concentration was measured starting from 16.11.2016 15.20 till 23.11.2016 15.20 for seven days.

The biggest differences between Lithuanian and Finnish Regulations and Guidelines are for relative humidity. Lithuanian requirements have strict values for relative humidity according to period of the year and according to work category. Finnish main regulations D2 /16/ tell that ”the humidity of indoor air shall not be harmfully high on a continual basis, nor shall humidity be allowed to concentrate on structures or on their surfaces or in the ventilation system in such a way that it will cause moisture damage, growth of microbes or micro-organisms or any other health hazards /16 p.10.” Finnish voluntary regulations are not strict with relative humidity, as it says that it has to be more than 25% for S1 category (but not more than 60%). S2 and S3 categories do not have requirements for relative humidity.

Air temperature requirements are almost the same. Lithuanian requirements are depending on work category and period of the year and have strict value. Finnish main regulations D2 /16/ tell that requirements of air temperature are depending on period of the year and have strict value. Finnish voluntary about air temperature are depending on outside temperature and have three different categories S1, S2, S3 for it.

CO_2 concentration in Lithuanian requirements don't have strict value, as it is said only that it can't have a negative effect on a person and can't reach more than 1000 ppm. Requirements for CO_2 concentration in Finnish main regulations D2 have a strict value. Finnish voluntary regulations have three categories (S1, S2, S3) for CO_2 concentration and has strict values.

Air flow rate values set in main regulations and guidelines are almost the same, as for Lithuanian it is 1 l/s for 1m^2 of floor area, and for Finnish it is 1.5 l/s for 1m^2 of floor area.

The biggest difference between measured indoor climate parameters in Lithuanian and Finnish office was humidity. In Lithuanian office, relative humidity was about 50% all the time. In Finnish office, relative humidity was about 25%. Measurements were taken at different time of the year. Outside air humidity is important factor and it was different when measurements were done in Lithuania and Finland. Furthermore, CO_2 concentration average value was a little higher in Finnish office than in Lithuanian office (501ppm to 398ppm). Air temperature values were almost the same in Lithuanian and Finnish offices.

8 DISCUSSION

This study was designed to measure indoor climate parameters (air temperature, relative humidity, air flow rates and CO_2 concentration) in two similar offices, one located in Lithuania and another in Finland, to see if they meet Lithuanian or Finnish regulations and guidelines. Another purpose of this study was to analyse the requirements and to see what the main differences between them are.

The main results showed that for Lithuanian office requirements were met for most of the time. Specifically, air temperature requirements were met 85% of the time, relative humidity requirements were met 100% of the time and CO_2 concentration requirements were met 100% of the time.

The main results showed that for Finnish office requirements were met for most of the time. Specifically, air temperature requirements were met 15% of the time, relative humidity requirements were met 40% of the time, CO_2 concentration requirements were met 100% of the time and deviation from air flow requirements was only 7%. Furthermore, indoor air classification (voluntary) was also used to describe indoor climate requirements. Less important results, but still worth mentioning, that air temperature requirements of S1 category were met 84% of the time and CO_2 concentration requirements of S1 category were met 96% of the time.

Lithuanian and Finnish requirements are quite the same, all differences and similarities are mentioned in paragraph 8 (page 43-44). The main conclusion of this study is that most of the time indoor climate parameters in Lithuanian and in Finnish offices met the requirements. It means that both offices were built accoring to the rules and all heating and ventilation systems are working good enough to ensure comfortable workplace.

BIBLIOGRAPHY

1. Yousef Al Horr, Arif M., Kaushkin A., Mazroei A., Katafygiotou M., Elsarrag E. Occupant productivity and office indoor environment quality: a review of the literature. Building and Environment 105, 369-389, 2016.

2. Dusan Licina, Melikov A., Sekhar C., Wai Tham K. Air temperature investigation in microenvironment around a human body. Building and Environment 92, 39-47, 2015.

3. Kunli Yang, Wan J.W., Zhang W.J., Zhang J.L. A new method of determination of indoor temperature and relative humidity with consideration of human thermal comfort. Building and Environment 44, 411-417, 2009.

4. The Commtech Group. Achieving the desired indoor climate. Denmark. 2007.

5. Mercola. Effects of low humidity on health. http://articles.mercola.com/sites/articles/archive/2014/01/13/low-humidity-health-effects.aspx. Updated 18.10.2016. Referred 18.10.2016.

6. Achoo allergy. The effects of humidity on the human body. http://www.achooallergy.com/learning/the-effects-of-humidity-on-the-human-body/. Updated 18.10.2016. Referred 18.10.2016.

7. Environmental Protection Agency. Fundamentals of Indoor Air Quality in Buildings. https://www.epa.gov/indoor-air-quality-iaq/fundamentals-indoor-air-quality-buildings. Updated 31.10.2016. Referred 31.10.2016.

8. Building Science Corporation. BSD-014: Air Flow Control in Buildings. https://buildingscience.com/documents/digests/bsd-014-air-flow-control-in-buildings. Updated 02.11.2016. Referred 02.11.2016.

9. Edoardo Moreci, Ciulla G., Lo Brano V. Annual heating energy requirements of office buildings in a European climate. Sustainable Cities and Society 20, 81-95, 2016.

10. Chron. The importance of an office layout. http://work.chron.com/importance-office-layout-15838.html. Updated 11.11.2016. Referred 11.11.2016.

11. WiseStep. Advantages and disadvantages of Cellular office layout. http://content.wisestep.com/advantages-disadvantages-cellular-office-layout/. Updated 9.11.2016. Referred 9.11.2016.

12. HN 69:2003 Šiluminis komfortas ir pakankama šiluminė aplinka darbo patalpose. Parametrų norminės vertės ir matavimo reikalavimai.

HN 69:2003 Thermal comfort and adequate thermal environment in workplaces. Normative values of parameters and measurement requirements. Lithuanian regulations and guidelines.
13. HN 23:2011 Cheminių medžiagų profesinio poveikio ribiniai dydžiai. Matavimo ir poveiko vertinimo bendrieji reikalavimai.
HN 23:2011 Occupational exposure limit values. Measurement and impact assessment general requirements. Lithuanian regulations and guidelines.
14. STR 2.09.02:2005 Šildymas, vėdinimas ir oro kondicionavimas.
STR 2.09.02:2005 Heating, ventilation and air conditioning. Lithuanian regulations and guidelines.
15. LVI 05-10440 en Classification of indoor environment 2008. Finnish society of indoor quality and climate.
16. D2 Indoor Climate and Ventilation of buildings 2003. Ministry of Environment.