THERMAL COMFORT AND INDOOR AIR QUALITY

Melek ÖZDAMAR*,
Filiz UMAROĞULLARI**
Trakya University Faculty of Architecture, Edırne, Turkey
*melekozdamar@trakya.edu.tr
**filizu@trakya.edu.tr

ABSTRACT

People spend a large part of their time in indoor environments. Living, working and etc. spaces mostly consist of enclosed volumes; therefore comfort expectations for enclosed spaces are increasingly gaining importance. Expectations of comfort in living spaces are becoming increasingly important. The comfort parameters of the interior environment, which are used in the efficient execution of the work function, play a decisive role. It is stated in the studies that the outdoor air is mostly more polluted than the indoor air. This condition emerges as an important environmental health problem. For this purpose, the importance of thermal comfort and indoor air quality is emphasized firstly in this study. The importance ofindoor air quality is described by a literature review related to comfort and air quality. In the study, factors affecting the thermal comfort conditions and indoor air quality are described. Environmental pollutants types and their impact on human health are mentioned.

Keywords: Thermal Comfort, Indoor Air Quality, Pollutants, Health Effects

INTRODUCTION

Human being's transition from the outdoor environment to the enclosed spaces bases itself in early ages. Afraid of the outdoors, humans found indoors to be safer for them. Even today, 80-90 percent of humans spent most of their time in enclosed spaces. The spaces we live, work, have fun and etc. are all enclosed spaces hence, the comfort in an enclosed space gains importance. The indoor comfort problem is not only valid for residential buildings, more problems are encountered in structures such as offices, health and education buildings which are not controlled. The air of these enclosed spaces could become polluted by indoor and outdoor pollutants. Various studies emphasized on the causes of physiological and psychological effects of pollutants on humans when the pollutants exceed a certain level. In international studies, it is shown that substances, related to the indoor air quality (IAQ), which threaten the human health, are handled with the experimental studies and the subject is analyzed in different aspects. The negative effects of the air pollution on human health, the indoor air quality, its affecting parameters and effects are examined in this section.

In their studies, Leung and his friends researched the indoor air quality control and management in hospital buildings (Michael, 2006).

Working on the content of educational buildings, Sanders (Sanders, 2008) aimed to found a basis about IAQ for the 30 schools he selected. While Hreha (Hreha, 2007) analyzed the exam results of students, Miller etal. (Miller,Facciola, Toohey,Zhai, 2008) and Torres (Torres, 2008) examined the PM concentrations and leakage from inside to outside environment in primary school classrooms. Besides primary school Miller et al.(Miller,Facciola, Toohey,Zhai, 2008) also carried out studies on an office building. On the other hand, Destaillats et.al (Destaillats, Fisk, Apte, 2008) assessed the indoor air quality and ventilation of the classrooms. Also, Kuş (Kuş,2007), Kocahakimoğlu (Kocahakimoğlu,Turan,Özeren,Sofuoğlu, Sofuoğlu,2009), Aslan et.al (Aslan, Sofuoğlu, İnal,Odabaşı, Sofuoğlu, 2009), Berberoğlu (Berberoğlu andMotör, 2011) and Keskin et.al (KeskinandEkmekcioğlu, 2011) researched the indoor air quality, causes of air pollution, the effects on health and the effects of traffic load on indoor PM levels of educational facilities.

Shan (Shan, 2008), Sing (Sing, 2007) and Senitkova (Senitkova, 2013), examined the indoor comfort conditions in office structures. While, Shan (Shan, 2008)formed a protocol for the assessment of indoor air quality in air-conditioned offices, Senitkova (Senitkova, 2013) investigated the effects of finishing materials on the ambient air of workspaces. Sing (Sing, 2007), on the other hand, aimed to form a protocol by handling office and public structures together. Yıldırım (Yıldırım, 2008), also, examined the effects of thermal control and volume control of educational structures and workspaces on health and learning performances of students. Teceret al. (Teçer, Ilten, Seliçi, 2013) researched the indoor and outdoor PM concentration on working and residential structures. Akal (Akal, 2013) emphasize upon the indoor air pollution and its negative effects on the workers.

Rim (Rim, 2009), examined the PM exposure level, the sources of pollutants and their relation with activities in commercial and residential structures. Li(Li, 2012) focused on smoking room and residential structures, and researched the effects of exposure to very small particles in enclosed environments. Sharmin et al. (Sharmin, Gül, Li, Ganev, Nikolaidis, Al-Hussein,2014)tracked down the energy consumption, thermal performance and indoor air quality of buildings in cold weather regions, through an apartment building example.

Ohet all.(Oh, Nam, Yun, Kim, Ynag, Sohn, (2014) and his friends researched the indoor air quality of children care centers and the properties of particulate matter types. Berberoğlu (Berberoğlu andMotör, 2011) evaluated the indoor air quality of textile-apparel companiesfor increasing the production efficiency of the operation.Atmaca & Yiğit (Atmaca and Yiğit, 2009), also, investigated the air quality and pollutant types through modelling the environments of classroom, laboratory, atelier, light rail metro and city busses in correspondence with his analyses.

1. THERMAL COMFORT CONDITIONS AND ITS PARAMETERS

In accordance with the purposes of usage, certain comfort condition features, which are indicators of user's satisfaction in an environment, should be met on account of health and efficiency in a living space. Although a relative notion, some general conditions are expected to be maintained in the environment in accordance with the characteristics of users. The comfort conditions in an enclosed environment are affected by thermal comfort, indoor air quality, and visual and auditory comfort parameters. Thermal comfort conditions consist of factors, such as, relative humidity, air flow rateand radiant temperature; visual comfort conditions consist of light, lighting, color, view, while, auditory comfort conditions consist of factors such as sound and noise. This sectionwas focused on one of the most effective factors on environmental conditions, which is the thermal comfort.

A heat balance should be established between a person and his surroundings for the said individual to continue to live a comfortable life. Thermal comfort is about senses and feelings. Therefore, heat balance and comfort conditions are different notions. ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) defines it as 'the condition of mind which expresses satisfaction with the surrounding environment the occupants'. Thermal balance is required for thermal comfort but it is not necessary. For example, a person in thermal comfort zone might not feel himself in thermal balance. Since, the thermal comfort, mainly, is one's state of feeling happy in an environment; it might differ from person to person. Because the thermal comfort is connected to many parameters, such as, human dimensions, age, sex, nutrition, form of the body, subcutaneous fat, height and weight, activity, clothing and personal differences, there are no exact limits (Atmaca andYiğit, 2009; Kaynaklı and Yiğit, 2003; BaumanandWebster,2001; Sözen, 2001; Sekhar, 2016).

In general, parameters that are affective in thermal comfort could be categorized as personal and environmental parameters. While, ambient temperature, ambient relative humidity , ambient air speed and average radiant temperature are named as environmental parameters; personal parameters consists of the person's metabolic activity level and clothing. Below, environmental parameters are examined in detail (Atmaca andYiğit, 2009; Kaynaklı and Yiğit, 2003; BaumanandWebster,2001; Sözen, 2001; Sekhar, 2016).Determined by different institutions, limit values for thermal comfort parameters are given in Table 1 (Ceylan, 2011; Uğuz, Işık, Aydoğan, 2013).

1.1. AIR TEMPERATURE

Human body exchanges heat through heat conduction mechanisms for establishing thermal balance. The metabolic heat produced by the body is removed through, 30% convection , %40 radiation, %20 evaporation and %10 respiration (Ceylan, 2011). As to the term temperature, it consists of dry-bulb temperature values that have been measured and recorded in the shade by meteorology stations. Body temperature is kept between 36-37°C so that the organs are not damaged and functionproperly. Body temperature differs according to the hour of the measurement, age, sex or any other personal factors. Body temperature of a new born baby is much higher than an adult's. The body temperature of a person measured in the morning and evening can be different. There are also differences between situations whether the person is naked or clothed. Even according to the activities in the environment temperature could be perceived differently. A person who sits in an office and a person who is constantly in motion could perceive temperature values differently. Similarly, women like heat more than men. Indoor air could be perceived differently in relation to heat. In low temperatures the air is perceived as clean. While the temperature differences between 1-3°C is not being noticed, if the difference increases, heat cramps, contractions, and heat exhaustion occurs in the body; in advanced levels of temperature differences it even leads to death (Ceylan, 2011; Atmaca and Yiğit; 2005; Toksoy, 1993; Öngel and Mergen, 2009).

The average radiance temperatures of wall, floor, ceiling and coating material surfaces in the built environment affect the ambient temperature. The warm or cold colorings of building materials affect people's perception. The presence of warm surfaces and the components exposed to high solar radiation affect the average radiance temperatures. The temperature difference between two surfaces should not exceed 5°C in a certain environment. The maximum temperature difference between the indoor air and the surfaces should be 3°C. It should not be forgotten that the body temperature rises with the increasing average radiance temperature (Ceylan, 2011; Atmaca and Yiğit; 2005).

1.2. RELATIVE HUMIDITY

Humidity defined as the water vapor in air and other gasses. There are three type of humidity; absolute humidity, relative humidity and specific humidity. Certain amount of humidity should be present in the air in terms of health and comfort of human beings. Relative humidity is the one that has an effect on humans and other living beings. Relative humidity is the ratio of humidity in the air to the saturated humidity. The necessary amount of water vapor to saturate the air with humidity changes in relation to the ambient temperature. There is a reverse relationship between temperature and relative humidity, when temperature increases the relative humidity decreases. Indoor humidity constantly affected by the outside humidity (URL1; Akyazı, Usta, Akpınar, 2011).

Parameters that affect the indoor relative humidity are; number of users, the type of activity, characteristics of the space, personal factors and temperature and etc. The water vapor caused by the breathing and sweating of the people in the environment affects the relative humidity (Ceylan, 2011). The amount of humidity in an environment should be between 40-60% in terms of human health and productivity. Low values of humidity causes dryness in respiratory tracts, skin, eye and hair in people. Together with dryness harmful substances enter in the body faster and the amount of water vapor in the air decreases. Also, low levels of humidity in an environment create static electricity problems. It decreases the electrical qualities of building materials. High humidity levels make it difficult for individuals to sustain their thermal balance while with clothing it causes dampness on the surface of the body. In high humidity reproduction of microorganisms is accelerated. Condensation occurs on the equipment and due to the condensation deformationscome about on the surface of building elements (Atmaca and Yiğit, 2009; Ceylan, 2011; Cilingiroğulu, 2010; Arıcı and Seçilmiş, 2005). Also, an appropriate humidity level affects the work efficiency and product quality as well as contributes to energy consumption savings (URL1).

'Ambient temperature' which affects the thermal comfort, is important for indoor air quality. In general temperature is tolerant in 22°C (20-24°C) ± 1°C. The change in this value is depended on the outdoor temperatures in summer or winter seasons. It is necessary for environments to ensure certain intended comfort conditions for human beings. Necessary limit values for these conditions are given in the standards. Any increases or decreases in the predetermined limit values of these factors, negatively affects the individuals, but also decreases work efficiency and quality (Ceylan, 2011). In Figure 1, According to ASHRAE comfort interval is given in relation to temperature and humidity in summer and winter seasons (Kuş, 2007).

1.3. AIR FLOW RATE

One of the environmental factors that affect indoor air quality is the 'air flow rate'. Air flow rate is the value of an air movement in a certain direction measured in unit of time. Ambient air flow rate, however, is the average of many readings taken from the environment and is expressed in units of m/sec (Arıcı and Seçilmiş, 2005; Spengler, McCarthy, Samet, 2001). The indoor air flow rate is affected by, specifically in an enclosed volume, the location of air inlets and outlets, the location and size of the windows, climatic properties, type of activity, the level of activity, number of users, if it exits the location of the ventilation in the environment, its power, angle and the amount of air it provides, relative humidity and temperature in the environment. Air flow is determined by air velocity and the amount of ventilation (Ceylan, 2011; Yakut and Yakut, 2013).

While low air speeds are defined as airless, in high speeds it is felt as windy and uncomfortable. The necessary limit values of air flow rates for an environment to obtain comfort conditions are determined by standards. According to ASHRAE, in order for an environment to obtain comfort conditions the air speed must be 0, 15 m/sec. This value changes by summer and winter seasons.While 0,1 m/sec air is not perceived by people, 0,2 m/sec air makes people generally content. On the other hand, in 0,35 – 0,50 m/sec users feel the environment as uncomfortable. The standards are given as to the ambient air flow rate not to exceed 0,8 m/sec. 1,5 m/sec causes discomfort by having a maddening effect on the user (Ceylan, 2011; Öngel and Mergen, 2009).

Ambient air speed affects the user's thermal comfort. As the air speed increases, the water on the body surface evaporates more and the person starts to get cold. As the increased air speed reduces the available still air mass around the person by dispersing it, chilling will increase. While this situation is beneficial in summer, it is felt as uncomfortableness in the winter. Therefore, the ambient air flow rate should be kept between specified standard values. During the design process or during usage, the air should be given in low air speeds and homogeneously for user's comfort (Ceylan, 2011; Öngel and Mergen, 2009; Fanger, 2002). In Figure 2, percentage of user dissatisfaction at different air flow rates is given (Ceylan, 2011).

Parameters as, temperature, relative humidity and air flow rate are objective parameters. During the formation of comfort intervals, evaluation is made according to the satisfaction of users in the environment. However, satisfaction of users differ person to person, in relation to different characteristics, such as, age, sex, getting used to the air, subcutaneous fat, health conditions, dietary patterns and etc. These are defined as personal parameters and it is a state in which the users in comfort, which is according to ASHRAE Standard 55 should be 90% and to ISO 7730 Standard should be 80%, are in satisfactory condition in a given space.

Personal parameters are categorized as clothing insulation value and activity level. A piece of clothing directly affects the heat transfer between the body and the environment and supports the heat flow. Also, it protects the humidity balance of the body. Clothes decrease the loss of heat and exhibit resistance to the transfer of heat energy. Heat insulation value of clothes is affected by fiber, thread and weaving patterns, fabric thickness and its components. In literature, there are many scientific studies done with test models (mannequins) in test rooms for measuring the thermal insulation values of clothes (Atmaca and Yiğit, 2005; Öngel and Mergen, 2009; Marmaralı, Dönmez Kretzschmar,Özdil,GülsevinOğlakcıoğlu, 2006).Clothing insulation value unit is signified as 'clo'. Dressing condition differs between summer and winter and together with relation to the type of activity and thermal comfort conditions. While in summer it is 0,5clo, in winter it is accepted to be 1 clo. A naked person is 0 clo and a light weighted clothing is between 0,2-0,3 clo. Polar wear register as 3 clo.

Another parameter that determines comfort is bodily activities. Metabolic energy production during resting period is signified as 'met'. It is determined as 1 met=58,2 W/m². According to the activity, the met value changes. A grown person's heat transfer area is 1,8 m² and he produces average of 106 W energy. The amount of energy production rises in uncomfortable environments. Activity speed, heart rate and produced metabolic rate affect the energy production of the metabolism (Yiğit and Atmaca, 2007). Furthermore, as a result of heavy activities, depending on age, sex, personal or psychological conditions,along with the increasing of body temperature sweating occurs which acts as a way of thermal balance control (Öngel and Mergen, 2009; Marmaralı, Dönmez Kretzschmar,Özdil,GülsevinOğlakcıoğlu, 2006). The necessary environmental conditions for thermal comfort and activities that are done whilst sitting are $M=70\ W/m^2=1,2$ met in ISO 7730, also clothing insulation in summer is given as 0,5 clo and in winter conditions it is 1 clo. The level of activity and clothing insulation value differ depending on the temperature and relative humidity. In 24°C temperature, clothing resistance for 1 met activity level is 0,75clo, while for 2 met level activity level it is 0,31 clo. Therefore, for comfort conditions, the ambient temperature should be kept low and high thermal resistance clothing should be worn. For an individual with 1 met metabolic activity, the relative humidity required to be 0,50, whilst the clothing insulation resistance is 0,625 clo. When the relative humidity is 0,80, clothing insulation is 0,75 clo. It has been observed that for metabolic activities, that are 1,6 met or over, humidity is an agent(Kaynaklı and Yiğit, 2003; Atmaca and Yiğit, 2005).

The neutral thermal zone where thermal comfort is provided when a person in middle age and weight quietly lie down is 35 kcal/ hm^2. If in a sitting position, as a result of slightly flexing of some muscles the metabolic speed rises to 50 kcal/hm^2. In standing position it is 60 kcal/hm^2 and in case of roaming quietly throughout the room it, again, rises to 100 kcal/hm^2. According to the calculations, when a person changes his/her position from lying down to a sitting position, his/her body temperature rises 0,51 °C in one hour time. In the case of standing it increases 0,85 °C per hour (Öngel and Mergen, 2009).

1.4. ELECTRO-CLIMATIC FORMATIONS

The electrical formations that occur in the air are called "electro-climate". Electro-climate includes natural and artificial electrical and magnetic fields. Electromagnetic formations are one of the important elements, affecting air quality in terms of atmospheric conditions. Throughout their lives, all living organisms are affected by electric, magnetic, and electromagnetic fields in nature. There is a balance between the existing electro-climatic formations and living beings. Nevertheless, due to the unconscious use of today's technology, this balance is distorted. The product variety and the increase in electricity consumption bring about electro-climatic pollution. A dense and artificial formation, which does not exist in nature, comes about. In the large cities, having transformers and residents together due to the irregular urbanization, overhead power lines, base stations, and so on can be considered as the examples of emission.Synthetic carpets, petroleum based coating materials, plastic structural elements, plumbing elements, lighting elements, and electrically operated hardware and equipments are the sources of electro-climatic pollution originating from within the structure (Korur, Oğuzalp, Korkmaz, 2011).

Electro-climatic pollution has negative impacts on users, especially elderly and children. In the living organisms that are exposed to pollution, the absorbed energy causes body to warm up, and this leads to the change of the electric currents in some of the organs. Its effect on biological systems causes different health problems. Studies on electrochemical pollution usually concentrate on cells and cancer. The human body resists low-level electro-climatic pollution for a certain period of time, but when there is a long-term exposure, the body loses resistance and health problems arise. Being exposed to high levels of pollution, even for the first time, may induce health problems including sleep disorder, fatigue, and headache. A long-term exposure can even give rise to intractable diseases such as cancer and birth injury. It does not only damage body physically, but it also affects the hormones and behavior in a psychological sense. Potential discomforts vary by the severity of the electro-climatic pollution exposure, the duration of the exposure, and the personal factors (Ceylan, 2011, Korur, Oğuzalp, Korkmaz, 2011; Charles, 2003).

Ambient temperature and relative humidity also affect the electrical field. With the rising humidity value, the effect of the electrical field is increasing. In addition, high levels of moisture affects the electrical properties of equipment and hardware, preventing them from functioning properly (Ceylan, 2011). As the dimensions of electro-climatic pollution cannot be ignored, necessary precautions must be taken. The required electrical and magnetic systems should be located far from settlement areas having residential units, offices, schools, and hospitals. If it is not possible to locate them far from the buildings, a masking system should be installed on the buildings' exterior walls. Since the green-field around the buildings will also serve as a living shield, afforestation should be done. Care must be taken to ensure that the structural elements used during the building construction are electro-conductive. Lightning arresters must be used to protect high-rise buildings, high chimneys, and air conditioners from lightning. Ground wire should be connected especially for the roof, ceiling, and floor systems. Pollution originating from the interior equipment can be reduced by remote positioning of the source, shortening the cables, closing the source when not in use, and using less electricity-emitting appliances (Korur, Oğuzalp, Korkmaz, 2011).

2. THERMAL COMFORT INDEX

The suitability of the temperature and humidity of an environment may not be sufficient for the users to feel comfortable. Thermal comfort is not only related to the physical environment, but it is also related to the feelings, emotions, and decisions of people. In such circumstances, a great number of thermal comfort indices have been developed in order to analyze indoor comfort conditions and to design ventilation systems. Only a few of these have been used to evaluate the satisfactory comfort range that must be achieved by the existing environmental conditions. The most common and understandable are Fanger's comfort equations (1972) “Predicted Mean Vote” (PMV) and “Predicted Percentage of Dissatisfied” (PPD) (Charles, 2003).

In 1970s, throughout the studies, which were developed according to the results of the laboratory and climate room studies, participants dressed in standardized clothes and completed standardized activities were exposed to different thermal environments (Fanger, 2002). This model relies on the extensive experiments that were conducted on more than a thousand people, who were exposed to well-controlled environments. Participants evaluated the environmental conditions with the generated scale. This scale offers a general comfort equation that achieves a combination by evaluating environmental variables such as air temperature, air humidity, radiant temperature, and air flow rate, as well as personal parameters such as activity level and insulation value of clothing. Equation is based on the assumption that when a person is exposed to a constant thermal environment for a long time at a constant metabolic rate, s/he can maintain the heat balance of the body by equalizing the heat produced and the heat distributed (Fanger, 2002). By correlating four basic environmental variables and two user variables, Fanger used the average thermal sensation, which defines users' senses of warmth or coolness on a standard scale and expresses users’ psychophysical bodily-scale subjective responses (Atmaca and Yiğit, 2009; Atmaca and Koçak, 2013).

PMV is called as the predicted mean vote or average heat sensitivity index. The predicted mean vote is a measure used to express the comfort of the environment, assuming that the heat transfer between the environment and the users' bodies is stable. In other words, it is the average prediction of the response, in seven different ways, of the human being to the conditions of thermal comfort. By this means, it is possible to see which comfort conditions are considered to be more appropriate by the users (Sekhar, 2016; Ceylan, 2011; Uğuz, Işık, Aydoğan, 2013; Atmaca and Yiğit, 2005; Toksoy, 1993; Ye, Yang, Chen, Li, 2003; Wei, Li, Lin, Sun, 2010; Hoof, 2008).

In an environment where the number of people is high, the response grades and environmental conditions of the users are estimated between the ranges of ±3 (hot / warm / slightly warm / neutral / slightly cool / cool / cold) with the aid of this scale (Atmaca and Yiğit, 2009). In Figure 3, it is schematized along with the inputs for PMV (Atmaca and Yiğit, 2009; ;Ceylan, 2011; Uğuz, Işık, Aydoğan, 2013; Atmaca and Yiğit, 2005; Toksoy, 1993). In the ASHRAE Standard 55, a condition for an interval $-0.5 < PMV < +0.5$ was set for an environment (Sekhar, 2016; Ceylan, 2011; Uğuz, Işık, Aydoğan, 2013; Atmaca and Yiğit, 2005; Fanger, 2002).

According to the Fanger law, at least 5% of the users in an environment do not feel thermally comfortable. Depending on their personal differences, users perceive the environment differently either. Percentage of users who do not find the environment comfortable is defined as PPD. PPD is considered as the percentage of thermal dissatisfaction. Although at least 5% of the users in an environment are not satisfied, a dissatisfaction limit of up to 10% is allowed for this environment (Uğuz, Işık, Aydoğan, 2013; Fanger, 2002; Kosonenaand Tan, 2004; HumphreysandNicol, 2002; Jang, Koh, Moon, 2007; Van Hoof, Mazej, Hensen, 2010; Ekici, 2013).

In Figure 4, the studies, investigating the PMV-PPD relationship, of some researchers are shown in a single graph. A psychometric chart, showing optimal comfort and efficiency loss lines between the range of 5% and 15% when compared to the ASHREA comfort zone, is given in Figure 5(Kosonenaand Tan, 2004).

3. INDOOR AIR QUALITY AND ITS EFFECTS ON HUMAN HEALTH

The importance of air breathed in for vital activities is quite huge. According to ventilation standard released by ASHRAE in 1999, **acceptable indoor air quality** is defined as the air in which the ratio of harmful substances do not exceed the limit values and with which the majority (at least 80%) of the people exposed are satisfied with this situation. In order to provide the desired conditions in standards, the required limit values are given.

Humans, by their nature, are dependent on air. During his/her entire life, a person consumes 400-500 million liters of air. Since air is a compulsory and top priority requirement, the quality of air is important both indoors and outdoors. Along with the oil and energy crisis that emerged in the 1970s, the concepts of the IHK and HBS have come to the fore. Studies on the decrease of the productivity of people living and working in unhealthy conditions emphasize the importance of the topic. The rate of harmful gas is also increasing rapidly due to the diffusion of the gasescoming from the artificial environment. In unhealthy weather conditions, physical and psychological discomfort can be seen in people.

Indoor air quality has a great importance in ensuring the comfort conditions that are suitable for people. When it is considered that people spend most of their time indoors, they interact with pollutants mostly indoors either. Pollutants can be classified in several forms such as particulate or gas, toxic or non-toxic, organic or inorganic, solid, liquid or gas and according to the particle size (Atmaca and Yiğit; 2009).

Some pollutants may originate basically from the outside, but they can also originate from the indoor materials, hardware, furniture, cigarettes, activity, chemical products used, and the building itself. Outdoor air pollutants can be classified as biological pollutants, UOB, sulfur oxides, ozone, lead compounds caused mostly by motor vehicles, hydrocarbons and benzene, nitrogen oxides, carbon constituents, and radon. The pollutants originating from the building interior are listed as building components and chemicals released from the materials used, pollutants resulting from human and machine activities, gases leaking from the outside, and biological pollutants such as fungi, mold, house dust, pets, and pests (Yurtseven, 2007; Kurutaş,2009; Tatlı, 2011).Indoor air pollutants are examined in three categories as biological pollutants, gases and chemicals, and particles and fibers.

Biological pollutants are composed of allergens such as microbiological factors, virus, bacteria, mite, mold, algae, fungus, pollen, and sports and micro organic particles are called “bio aerosol”. Pollutants from house dust, pets, and insects are also included in this category. These organisms are dangerous and fast-spreading. The effect of these pollutants is understood too late. They can be seen both in indoor air and in outdoor air. They can spread from the existing vegetation around the built environment, wet building elements, openings, living things, activities, air conditioning system components, moisture holders, water collection channels, drainage troughs, channels, and filters (Kuş, 2007; Ceylan, 2011).

Gas and chemical pollutants are air pollutants in the form of gas and vapor under normal temperature and pressure. The most important gas pollutants can be listed as UOB, PVC, CO, CO_2, ozone, sulfur oxides, nitrogen oxides, radon, formaldehyde, pesticides, organic gases, and cigarette smoke. These pollutants can be found in the spaces which are inadequately ventilated and where indoor air circulation is low, air conditioning system is used, and materials releasing chemicals are used. They diffuse to indoor spaces through ventilation, cigarette smoke, soil-contacting parts of the building parts, construction materials, and coating materials (Kuş, 2007; Yurtseven, 2007). The pollutants should not exceed certain limit values in order not to threaten human health.

The category of **particles and fibers** consists of lead, dust and particles, and fibers of various building materials such as asbestos [68]. **Fiber** is the filamentous structure forming the materials. Combining natural and artificial fibers with binding materials in order to manufacture composite materials has recently become widespread in the construction industry. Materials used in heat insulation such as glass wool, stone wool, and ceramic wool are fibrous materials. The carpets used as coating materials also have fibers. The fibrous materials used in the structure release fibers over time. The fibers can also spread during the construction phase or during the modifications such as cutting or sanding (Alpteken, 2007). **Particulate matter** (PM) is the mixture of small particles and droplets such as solid and liquid acids, organic chemicals, metals, earth, dust, smoke, and soot, which are suspended in air. Particulates are also called as 'Aerosol' (Atmaca and Yiğit, 2009). The micron (μ) unit is used to measure the size of the particles (1 millimeter = 1000 microns). Particles vary in number, diameter, shape, content, water solubility, density, health effects, and sources of formation. According to their weights, some move in the atmosphere while others settle rapidly. It is usually seen that particles are arranged according to their size. While particles having a diameter smaller than 0.5 μm move in the air through diffusion, particles with a diameter greater than 0.5 μm settle [54]. Particles larger than 50 μm can be seen with the naked eye and particles smaller than 0.005 μm can only be observed with electron microscope.

Dust is composed of 100 μm small particles that can be suspended in the air. Particles between 10-20 μm are considered as coarse dust. Dust, which is formed from natural means or from living and building activities, is a pollution that adversely affects human, plant, and animal health (Atmaca and Yiğit, 2009; Ceylan, 2011; Alptekin, 2007). Smoke refers to the carbon containing particles smaller than 1 μm, which release from the incomplete combustion. Zinc, ammonia, and sulphated compounds found in smoke are harmful to human health. Soot consists of particles smaller than 0.5 μm that are held together with tar during incomplete combustion of carbonaceous compounds. Fly ash is the name of the ashes of 1-200 μm in size, which contain the gases of the solid fuels burning in the combustion(Atmaca and Yiğit, 2009).

The health effects of air pollution are very complex. Air pollution is an environmental pollution that constantly affects the society throughout the life cycle and that is often exposed unwittingly. In order to understand the effects of air pollution on human health, identification of the source, the way of exposure to pollutants, and the interaction of the pollutants with their surrounding environment should be examined. In the human body, nose and lungs are primary organs that are exposed to air pollution. Depending on the characteristics of the pollutants and personal factors, the body systems, especially the respiratory system, and various parts are affected.

The size of the effect depends on the diameter of the pollutants as well as on the individual factors. As the particulate size decreases, the adverse effect on health increases. While PMs with a diameter greater than 10 microns are trapped in the mouth and nose, small particles with a diameter of 10 microns can pass through the mouth and nose to the respiratory system. Small particulates of 2-3 microns in diameter pass through the lungs and stick to the alveoli. Those smaller than 0.1 micron, called fine particles, can hold on to the alveoli and stay longer than the other ones (Yurtseven, 2007; SağlıkBakanlığı, 2012; Sun, Wang, Zhang, Ma, Hou, Kong, 2015).

Discomforts that can be seen in people exposed to dirty air can be listed as dry mouth and dry nose, fever, tremor, muscle pain andmuscle twitching, headache, nausea, allergy symptoms, dermatitis, coughing, phlegm, chest tightness, cold, bronchitis, asthma, legionnaires' disease, Pontiac fever, and lung cancer.

The impacts of environmental air pollution on health have been proven in the literature via examination on a large scale with many experimental and epidemiological approaches. Controlled exposure of living organisms to pollutants, long-term and short-term effects of the pollutants, possible diseases, personal sensitivities and exposure levels have been addressed in the studies (Can, 2015). Standards provide the amount of clean air required for human comfort, the limits of air pollutant concentrations, and exposure times that can be tolerated in response to a number of criteria such as the function, type, and size of the environment as well as the number of people, activity of people, and sensitivity of people. Table 2 lists the types of pollutants, sources of the pollutants, health effects, and control methods to remove them (Ceylan, 2011; Yurtseven, 2007, SağlıkBakanlığı, 2012; Can, 2015; URL 3).

CONCLUSION

Today, people spend 80-90 percent of their lives in enclosed spaces. Living, working and etc. spaces mostly consist of enclosed volumes; therefore comfort expectations for enclosed spaces are increasingly gaining importance. Thermal insulation technologies which are realized on the one hand to ensure thermal comfort conditions and on the other for aims of energy preservation, increased the impermeability of buildings. Due to this fact, the problem of increased indoor air pollution over time is emerged. It is stated in the studies that the outdoor air is mostly more polluted than the indoor air. When the level of pollutants in an enclosed space exceeds a certain level, it causes negative physiological and psychological effects on a human being. This condition emerges as an important environmental health problem.

A comfort balance should be established between a person and his surroundings in an enclosed space for that person to continue to live a comfortable life. Depending on the purpose of usage in a space, comfort conditions, which are signs of user satisfaction in an environment, should establish necessary properties for the health and productivity of users in a said environment. Although a relative notion, some general conditions are expected to be maintained in an environment in accordance with the expectations of users. For this aim, in this study, among the most affective bioclimatic parameters which affects the relation between environment - building- people in indoor spaces, and especially, the structure and user comfort; the thermal comfort conditions and indoor air quality are evaluated. Information about the PPD and PMV thermal comfort indexes, which analyze the environmental conditions and also explain the reactions of users, were given.

In enclosed spaces, indoor pollutants are results of building materials, human activities and interior fittings. Ambient pollutants were discussed as biological, gas and chemicals, and particulate and fibers. The sources of pollutants in an enclosed space, their levels and the exposure time of users to these pollutants are important. On this topic, the legal regulations differ between countries. In this study, conditions expected in an environment according to the standards established by certain international institutes have been given. With the aid of tables, sources of pollutants and their control methods have been explained; and information about the effects of pollutants over human health and productivity have been given.

REFERANCES

Aslan, G., Sofuoğlu, A., İnal, F., Odabaşı, M., Sofuoğlu, S.C. (2009). İlköğretim Okullarında Bina- İçi Hava Uçucu Organik Madde Derişimleri: Derslikler ile Anasınıflarının Karşılaştırılması. IX. Ulusal Tesisat Mühendisleri Kongresi ve Sergisi/TESKON, İzmir, Sayfa No:683-690, Mayıs.

Akal, D. (2013). İç Ortam Hava Kirliliği ve Çalışanlara Olumsuz Etkileri. ÇSBG/Çalışma Dünyası Dergisi, Cilt No:1, Sayı No:1 Sayfa No:112-119, Temmuz-Eylül.

Atmaca, İ. and Yiğit, A. (2009). Isıl Konfor ile İlgili Mevcut Standartlar ve Konfor Parametrelerinin Çeşitli Modeller ile İncelenmesi. IX. Ulusal Tesisat Mühendisliği Kongresi, İzmir, Sayfa No: 543-555, Mayıs.

Atmaca, İ. and Yiğit, A. (2005). İklimlendirilen Ortamlar İçin lsıl Konforun Geçici Rejim Enerji Dengesi Modeli ile Değerlendirilmesi. Tesisat Mühendisliği Dergisi, Sayı No:88, Sayfa No:61-71, Temmuz-Ağustos.

Akyazı, Ö., Usta, A., Akpınar, A.S. (2011). Kapalı Ortam Sıcaklık ve Nem Denetiminin Farklı Bulanık Üyelik Fonksiyonları Kullanılarak Gerçekleştirilmesi. 6th International Advanced Technologies Symposium (IATS'11), Elazığ, Sayfa No:16-18, Mayıs.

Arıcı, M. and Seçilmiş, M. (2005). Kapalı Yüzme Havuzlarının Nem Kontrolu ve Ekonomik Olarak İklimlendirilmesi. VII. Ulusal Tesisat Mühendisliği Kongresi, İzmir, Cilt No:1, Sayfa No:477-492, Kasım.

Atmaca, İ. and Koçak, S. (2013). İşletmelerde Farklı Metabolik Aktivite Düzeylerinde Çalışanlar İçin Isıl Konfor Bölgelerinin Tespiti. Mühendis ve Makine, Cilt No:54, Sayı No:638, Sayfa No:26-32, Mart.

Alptekin, O. (2007). Binalarda İç Hava Kalitesi Toz Partiküllerinin İç Mekân Hava Kalitesi Üzerindeki Etkilerinin İncelenmesi. Gazi Üniversitesi Fen Bilimleri Enstitüsü, Ankara, Yüksek Lisans Tezi, Şubat.

Berberoğlu, U. andMotör, D. (2011). Edirne'de Bir Dokuma-Konfeksiyon İşletmesinde İç Ortam Hava Kalitesinin Değerlendirilmesi–2010. X. Ulusal Tesisat Mühendisleri Kongresi ve Sergisi/TESKON, İzmir, Sayfa No:1793-1798, Nisan.

Bauman, F. And Webster, T. (2001). Outlook for Underfloor Air Distribution. ASHRAE Journal, Volume: 43(6), Pp. :18-27, June (2001).

Can, E., Üzmez, Ö., Döğeroğlu, T., Gaga, E.O. (2015). Indoor Air Quality Assessment in Painting and Printmaking Department of A Fine Arts Faculty Building. AtmosphericPollution Research Volum:6/6, Page: 1035-1045, November

Ceylan, A. (2011). İklimlendirme Sistemlerinin Yapı İçi Hava Niteliği Üzerindeki Olumsuz Etkileri. Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, İstanbul.

Charles, K.E. (2003). Fanger'sThermal Comfort and Draught Models. Institute for Research in Construction, National Research Council of Canada, IRC Research Report RR-162, Ottawa, Canada, 10 October. / http://irc.nrc-cnrc.gc.ca/ircpubs (Last Access Date:28.05.2017).

Çilingiroğlu, S. (2010). İç Hava Kalitesi, TMMOB Makine Mühendisleri Odası, Sayfa No:23-42. http://www.mmo.org.tr/resimler/dosya_ekler/7f2a4ea3bedd425_ek.pdf?dergi=966 (Last Access Date:08.04.2016).

Destaillats, H.,Fisk, W.H., Apte, M.G. (2008). AreVentilationFiltersDegradingIndoorAir QualityIn California Classrooms?. Environmental Energy Technologies Division Indoor Environment Department, Lawrence Berkeley National Laboratory, Berkeley, CEC-500-2009-054, October.

Ekici, C. (2013). PMV Metodu Ile Isıl Konfor Ölçümü ve Hesaplanması. VIII. Ulusal Ölçümbilim Kongresi, Gebze-Kocaeli, Sayfa No:1-5, 26-28 Eylül.

Fanger, P.O. and Toftum, J. (2002). Extension of The PMV Model toNon-Air-Conditioned Buildings in WarmClimates. Energyand Buildings, Volume:34, Issue:6, Pages 533–536, July.

Hreha, D.M. (2007). TheInfluence of Indoor Air Quality (IAQ) on Student Test Performance. Seton Hall University Dissertationsand Theses (ETDs), PhD Thesis, pp. 162.

Humphreys, M.A. andNicol, J.F. (2002). TheValidity of ISO-PMV For Predicting Comfort Votes in Every-Day Thermal Environments Oxford Centre For Sustainable Development. Oxford Brookes University, Energy and Buildings, Volume 34,Issue 6, Pages 667-684, July. Pages: 33–44.

Hoof, J.V. (2008). FortyYears Of Fangers Model Of Thermal Comfort: Comfort For All?. Indoor Air, Singapore.

Kosonena, R. and Tan, F. (2004). Assessment Of Productivity Loss İn Air-Conditioned Buildings Using PMV İndex. EnergyandBuildings, Volume:36, Pages: 987–993.

Jang, M.S., Koh, C.D., Moon, I.S. (2007). Review of Thermal Comfort Design Based on PMV/ PPD in Cabins of Korean Maritime Patrol Vessels. Building And Environment, Volume: 42, Pages: 55–61.

Kaynaklı, Ö. and Yiğit, A. (2003). İnsan Vücudu İçin Isı Dengesi ve Isıl Konfor Şartları. DEÜ Mühendislik Fakültesi Fen ve Mühendislik Dergisi, Cilt No:5, Sayı No:2, Sayfa No:9-17, Mayıs.

Kuş, M. (2007). Şanlıurfa İlindeki Yükseköğretim Kurumları Dersliklerinde İç Hava Kalitesinin İncelenmesi ve Modellenmesi. Balıkesir Üniversitesi Fen Bilimleri Enstitüsü Makine Mühendisliği Anabilim Dalı, Doktora Tezi, Eylül.

Kocahakimoğlu, C., Turan, D., Özeren, F., Sofuoğlu, A., Sofuoğlu, S.C. (2009). İlköğretim Okullarında Binan İçi Hava Ozon Derişimleri. IX. Ulusal Tesisat Mühendisleri Kongresi ve Sergisi/TESKON, İzmir, Sayfa No:697-703, Mayıs.

Keskin, S.S. andEkmekcioğlu, D. (2011). Okul Binalarında İç Ortam Havası Pm Kütle Konsantrasyonlarına Trafik Yükünün Etkileri. X. Ulusal Tesisat Mühendisleri Kongresi ve Sergisi/TESKON, İzmir, Sayfa No:1737-1747, Nisan.

Kurutaş, B. (2009). Bir Metal Endüstrisindeki Çalışma Ortamlarının İç Hava Kalitesinin Belirlenmesi. İstanbul Üniversitesi Fen Bilimleri Enstitüsü, Çevre Mühendisliği Anabilim Dalı, İstanbul, Yüksek Lisans Tezi, Şubat.

Korur, S.,Oğuzalp, E.H., Korkmaz, S.Z. (2011). Yapı Biyolojisi ve Elektroiklimsel Kirlilik. e- Journal of New World Sciences Academy, Volume:6, Number:4, pp:882-899.

Li, W.C. (2012). A Study of UltrafineParticleExposure in IndoorEnvironments. The Hong Kong University of Science and Technology Department of Mechanical Engineering, PhD Thesis, May

Michael, L. andA.H.S. Chan,A.H.S. (2006). Control and Management of Hospital İndoor Air Quality. Medical Science Monitor Journal, Volume:12(3), SR17-23.

Miller, S.L.,Facciola, N., Toohey, D., Zhai, J. (2008). Identification, Classificationand Correlation of Ultrafine Indoor Airborne Particulate Matterwith Outdoor Values. Department of Mechanical Engineering, University of Colorado, ASHRAE Research Project 1281-RP Final Report, March.

Marmaralı, A., Dönmez Kretzschmar, S., Özdil, N., GülsevinOğlakcıoğlu, N. (2006). Giysilerde Isıl Konforu Etkileyen Parametreler. Tekstil ve Konfeksiyon Dergisi, Sayı No:4, Sayfa No:241-246, Ekim-Aralık.

Oh, H., Nam, I., Yun, H., Kim, J., Yang, J., Sohn, J. (2014). Characterization of IndoorAirQuality andEfficiency of AirPurifier in ChildcareCentersKorea. Buildingand Environment Journal, Sayı No: 82, Sayfa No: 203-2014 Ağustos (2014).

Öngel, K. and Mergen, H. (2009). Isıl Konfor Parametrelerinin İnsan Vücudundaki Etkilerine Yönelik Literatür Taraması. S.D.Ü. Tıp Fakültesi Dergisi, Sayı No: 16(1), Sayfa No: 21-25.

Rim, D. (2009). Evaluation of Human Exposure to Indoor Airborne Pollutants: Transport and Fate of Particulate and Gaseous Pollutants. The University of Texas at Austin, PhDThesis, May.

Sanders, M.D. (2008). Assessment of Indoor Aır Qualıty in Texas Elementary Schools. The University of Texas at Austin, PhDThesis, December.

Shan, H.P. (2008). An İndoor Air Quality Monitoringand Assessment Protocol forAir- ConditionedOffices in Subtropical Climates. The Hong Kong Polytechnic Universtiy Department of Building Services Engineering, PhDThesis, November.

Sing, W.C. (2007). A New Engineering Approach for İndoor Air Quality Management in Buılding. The Hong Kong Polytechnic University Department of Building Services Engineering, PhD Thesis, December.

Senitkova, I. (2013). Impact of Indoor Surface Material on Perceived Air Quality. Materials Science and Engineering Journal, Sayı No:36, Sayfa No:1-61, Ocak.

Sharmin, T., Gül, M., Li, X., Ganev, V., Nikolaidis, I., Al-Hussein, M. (2014). Monitoring Building Energy Consumption. Thermal Performance and Indoor Air Quality in Cold Climate Region, Sustainable Cities and Society Journal, Sayı No:13, Sayfa No:54-68 Nisan.

Sözen, M. (2001). Yapı Kabuğunda Isı ve Ses Yönünden Denetim-Konfor İlişkisi. YTÜ Mimarlık Fakültesi Yapı Fiziği Bilim Dalı, Tesisat Mühendisliği, Şubat.

Sekhar, S.C. (2016). Thermal Comfort in Air-Conditioned Buildings in Hot and Humid Climates – WhyAreWe Not Getting it Right?.IndoorAir, Volume:26, Issue:1, Page:138-152, February.

Spengler, J.D.,McCarthy, J.F., Samet, J.M. (2001). IndoorAirQualityHandbook. New York, United States, Jan.

Sağlık Bakanlığı. Türk Toraks Derneği. (2012). Hava Kalitesi ve Sağlık. Anıl Matbaacılık, Türkiye Kronik Hava Yolu Hastalıklarını Önleme ve Kontrol Programı, Ankara.

Sun, Y.,Wang, P., Zhang, Q., Ma, H., Hou, J., Kong, X. (2015). Indoor Air Pollutionand Human Perception in Public Buildings in Tianjin. China, ProcediaEngineering Voluma:121, Page: 552-557, July.

Toksoy, M. (1993). Isıl Konfor. I. Ulusal Tesisat Mühendisliği Kongresi Bildiriler Kitabı, İzmir, Cilt No:1, Sayfa No:591-640 Nisan.

Tatlı, E. (2011). Indoor Aır Qualıty Assessment: Bıologıcal, Gasesand Partıculate Matter Pollutıon Indıcators. Fatih Üniversitesi Çevre Mühendisliği, İstanbul, Yüksek Lisans Tezi, Februrary.

Teçer, L.H.,İlten, N., Seliçi, A.T. (2013). Balıkesir İl Merkezinde Konutlarda İç/Dış Ortam Partikül Madde Konsantrasyonlarının Değerlendirilmesi. Hava Kirliliği Araştırma Dergisi, Cilt No:2 Sayı No:3, Sayfa No:74-102, Temmuz.

Torres, L.R. (2008). Determınacıon de Materıal PartıculadoFıno en Escuelas Publıcas Elementales del Dıstrıto de CAGUAS II. Universidad de PuertoRico, Tesis de Maestría, Diciembre.

Uğuz, S., Işık, A.H., Aydoğan, Ö. (2013). Yaşam Alanlarında Isıl Konfora Bağlı Enerji Verimliliği Uygulamaları. III. Elektrik Tesisat Ulusal Kongresi Kapsamında Güç ve Enerji Sistemleri Sempozyumu, İzmir, Kasım.

Van Hoof, J.,Mazej, M., Hensen, J.L.M. (2010). Thermal Comfort: Research And Practice. Frontiers in Bioscience, 15(2), pp. 765-788, January

Yıldırım, S.T. (2008). Eğitim Yapılarında Isı ve Ses Konforu Sorunlarını Değerlendirilmesi. İzolasyon Dünyası Dergisi, Sayı No:72, Sayfa No:70-74, Temmuz-Ağustos.

Yakut, Selbaş, R., Yakut, G. (2013). Ofis Ortamında İklimlendirmenin Çalışanlara Etkisi. S.D.Ü. Sosyal Bilimler Enstitüsü Dergisi, Büro Yönetimi Özel Sayısı, Sayı No:1, Sayfa No: 97-106.

Yurtseven, E. (2007). İki Farklı Coğrafi Bölgedeki İlköğretim Okullarında İç Ortam Havasının İnsan Sağlığına Etkileri Yönünden Değerlendirilmesi. İstanbul Üniversitesi Sağlık Bilimleri Enstitüsü, Halk Sağlığı Anabilim Dalı, Doktora Tezi, İstanbul.

Yiğit, A. and Atmaca, İ. (2007). Dünya'da ve Türkiye'de Isıl Konfor Çalışmaları. VIII. Ulusal Tesisat Mühendisliği Kongresi Sempozyum Bildirisi, İzmir, Sayfa No:305-315, Ekim.

Ye, G.,Yang, C., Chen, Y., Li, Y. (2003). A New ApproachForMeasuringPredictedMeanVote (PMV) AndStandardEffectiveTemperature (SET). Buildingand Environment, Valume: 38,

Wei, S.,Li, M., Lin, W., Sun, Y. (2010). Parametric studies and evaluations of indoor thermal environment in wet seasonusing a field survey and PMV–PPD method. Energy and Buildings, Volume:42, Pages:799–806.

(URL 1
http://www.jumo.ae/attachments/JUMO/attachmentdownload?id=8265&filename=t90.7000tr.pdf (Last Access Date:7.4.2017).

(URL 2) http://www.erengezgin.net/_xcelik/mimarligin_biyolojik_sorunlari.html (Last Access Date:08.04.2017).

(URL 3)
http://webcache.googleusercontent.com/search?q=cache:bpe1DZ1zBeoJ:www.bionano.com.tr/kapali-ortamdaki-hava+&cd=1&hl=tr&ct=clnk&gl=tr(Last Access Date:08.04.2017).

FigureList

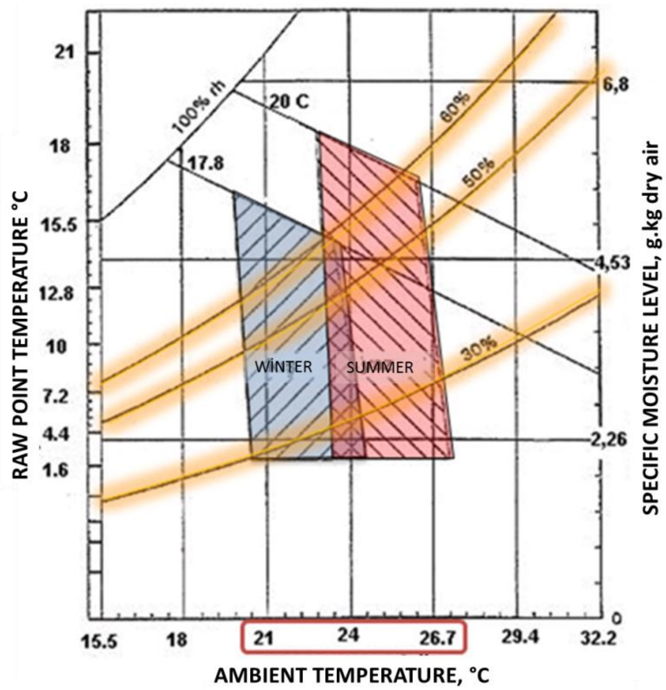

Figure 1. Comfort areas in summer and winter according to ASHRAE (Kuş, 2007; Atmaca and Yiğit, 2009; Spengler, McCarthy, Samet, 2001)

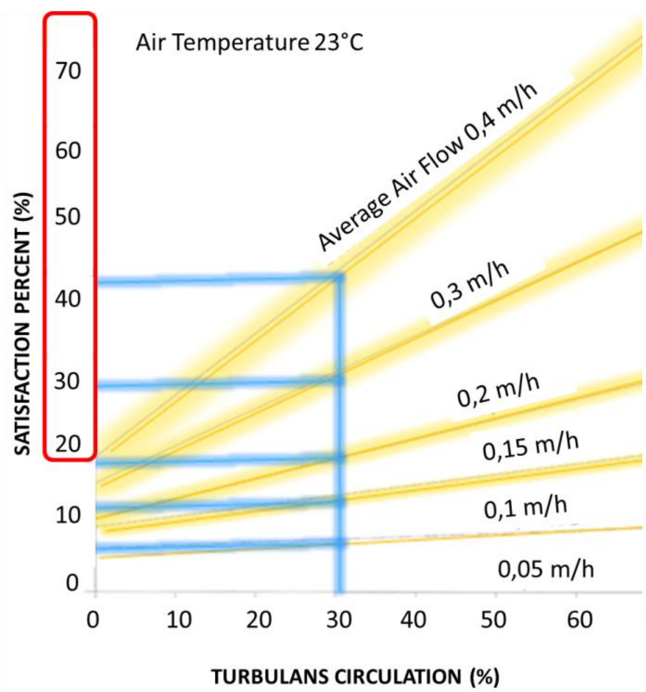

Figure 2. Percentage of discontent people at different air speeds and levels of turbulence (Ceylan, 2011)

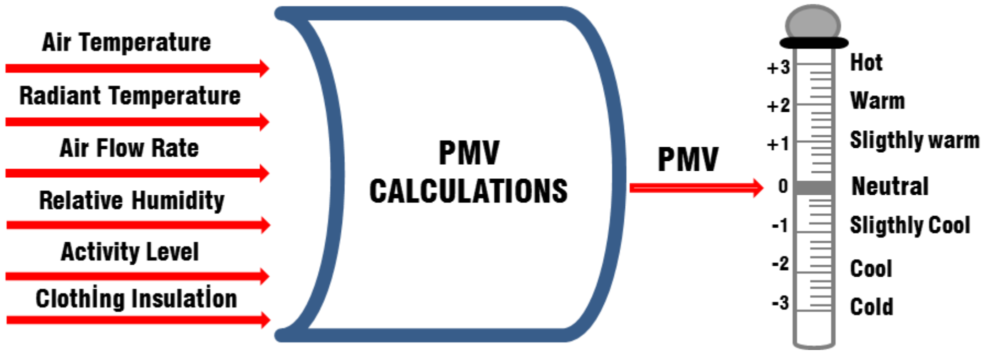

Figure 3. Inputs required for PMV and commentaries on thermal sensation (Sekhar, 2016; Ceylan, 2011; Uğuz, Işık, Aydoğan, 2013; Atmaca and Yiğit, 2005; Toksoy, 1993; Fanger, 2002)

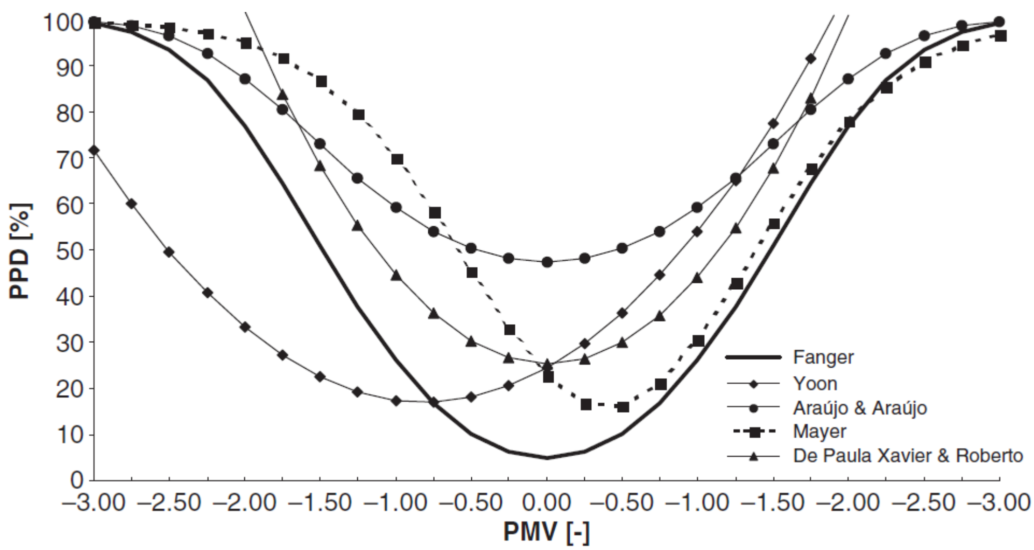

Figure 4. The studies investigating the PMV-PPD relationship (Hoof, 2008; Kosonena and Tan, 2004)

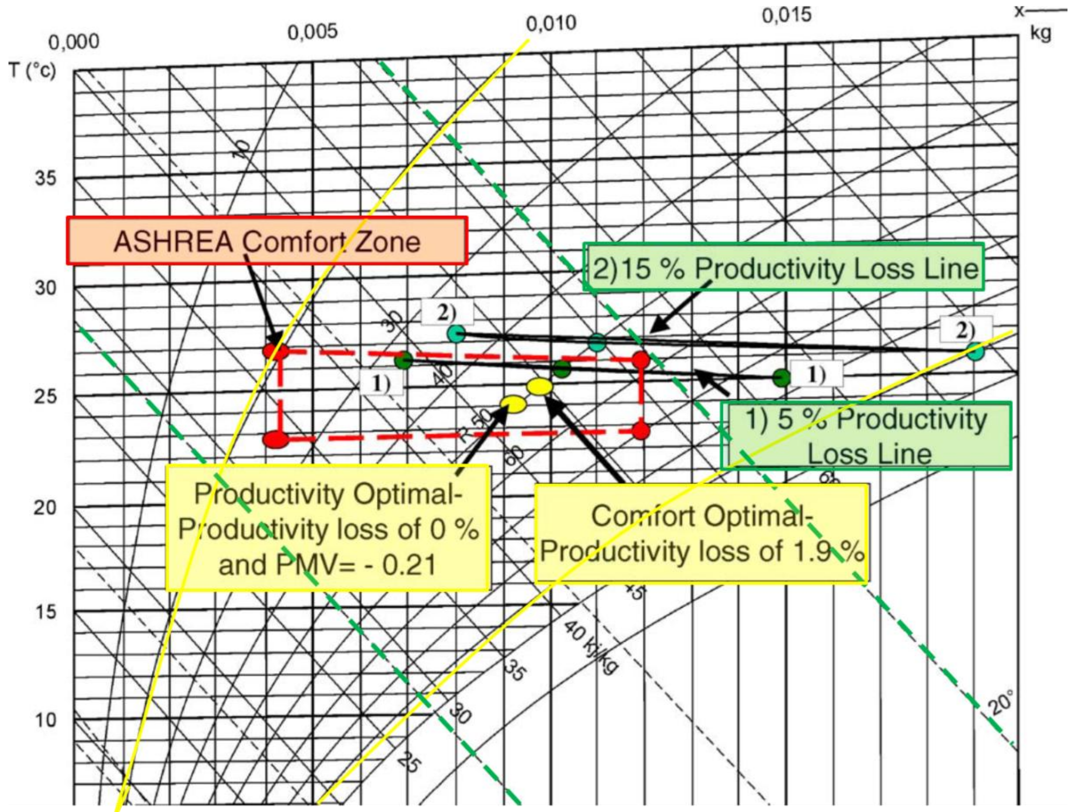

Figure 5. A psychometric chart showing the relationship between ASHRAE comfort zone and productivity loss (Kosonena and Tan, 2004)

Table List

Table 1. Limit values for thermal comfort parameters determined by different institutions (Ceylan, 2011; Uğuz, Işık, Aydoğan, 2013).

Parameters	Institution	Winter Comfort Range	Summer Comfort Range
Air Temperature	CIBSE	19°C - 23°C range	< 27°C
	ASHRAE Standard 55	20°C - 23,6°C range	22,8 °C - 26,1°C
	DIN (1946)	20°C - 26°C range	
Relative Humidity	ASHRAE Standard 55 (1982)	%30 (20,2°C-24,4°C)	%30 (23,3°C-26,7°C)
		%40 (20,2°C-24,2°C)	%40 (23,1°C-26,4°C)
		%50 (20,2°C-23,6°C)	%50 (20,2°C-26,1°C)
		%60 (20,0°C-23,3°C)	%60 (20,2°C-25,6°C)
	ASHRAE Standard 55 (1992) DIN (1946)	%30-65 range	%20-60 range
	ASHRAE 62 (1989 and 2001)	%30-60 range	
	ASHRAE Standard 90.1 (2004)	%55-85 range	
	ISO (1994)	%30-70 range	
Air Flow Rate	ASHRAE Standard 55 ISO Standard 7730	<30 Fpm (0,15 m/sn)	>50 Fpm (0,25m/sn)
	WHO	0,25 M/Sn (0,8 ft/S)	

Table 2. Types of pollutants, sources of formation, their effects on health and control methods for removal (Ceylan, 2011; SağlıkBaknlığı, 2012; URL 3)

Pollutant types	Sources	Effects on Health	Control Methods
Asbestos	Non-combustible, thermal and acoustic insulation materials, cement production, automotive brakes,old, damaged or degraded insulation materials	Asbestosis, lung cancer, mesothelioma	-Materials containing asbestos should be removed even if they are not damaged -Trained and qualified persons should be employed for control measures in asbestos mixtures and cleaning
Carbon monoxide(CO)	Gas stoves, wood stoves, fireplaces, cigarette smoke, exhaust fumes of motorized vehicles, kerosene and gas surface heaters, chimneys and ovens	Headache, dizziness, nausea, lost of consciousness, fatigue, cardiovascular diseases, chest pains, decrease in vision, imbalance, death	-Regular control of gas-powered devices - A fan should be provided to allow gas to flow out in gas stoves -Stove or fireplace chimney should be kept open -Central heating systems should be audited annually -Leaks should be repaired - The vehicle engines should not be left running in enclosed spaces

Carbon dioxide(CO	Gas stoves, wood stoves, fireplaces, cigarette smoke, motorized vehicles	Headache, loss of appetite, eye, nose and throat infections, upper respiratory tract infection	- Heaters , stoves and fireplaces should be kept under control -Clean air chimneys should be designed, chimney cleaning should be done regularly -Settings for gas-powered devices must be made
Cigarette Smoke	Smoking cigarettes, pipes and cigars	Respiratory system diseases, lung cancer, eye, nose and throat irritation, headache, heart diseases, asthma	-There should be no smoking inside the building -No smoking around children and babies -Ventilation should be increased in an area if and when smoking could not be prevented inside the building -Windows and ventilation fans should be opened
Nitrogen dioxide	Combustion sources, vehicle exhausts, kerosene heaters, gas heaters without an outlet, cigarette smoke	Eye, nose and throat irritation, nausea, slowing down of lung functions, tendency towards upper respiratory tract infection	- Settings for gas-powered devices must be made and ventilation fans should be used -Heaters with outlets must be used -Care must be given to clean chimneys -Specialists should be employed to clean, maintain and control the central heating system
Ozone (O_3)	Photocopiers, printers, high voltage lines and transformers, electrostatic air cleaners, outdoor air	Eye, nose and throat irritation, slowing down of lung functions, death, deterioration in respiratory functions, hypersensitivity of airway	-Sources should be identified. -Exhaust fumes of motorized vehicles in traffic should be cautioned -Gases leaked from residential and industrial areas should be controlled
Radon	Radon containing building products, groundwater, degradation of radioactive materials, building materials, well water	Lung cancer, diseases related to lymph and red blood cells (no immediate effect)	-Building should be tested for radon - Ratio should be fixed to 4 pCi/L -Building products with high radioactivity should not be used in constructions - Structure should be insulated, especially parts that are in contact with earth
Volatile Organic Compounds (VOC)	Cigarettes, air-fresheners, paints, varnishes, solvents, wood preservatives, aerosol sprayers, cleaners, disinfectants, moth removers, stored petroleum products, automotive products	Sleep, memory loss, sneezing, skin redness, respiratory difficulties, itchy eyes, nose, and throat, liver and kidney failure, damage to the central nervous system	-Paint, solvent, and more of the same products should be used in accordance with the directives of the manufacturer -When the products are used, plenty of fresh air should be provided - Unused or underutilized products should be removed immediately from the environment - Children and pets should be kept away from the places where these products are used -These products should not be mixed unless it is stated on the labels
Sulphur Dioxide	Fossil fuels, thermal power plants, burning coal, petroleum	Chest tightness, panting, narrowing of the respiratory tract	- Combustion sources should be reduced indoors - Industries should be located away from the city centers -The use of alternative energy sources should be increased
Pesticides	Sprays, chemicals in outdoor applications, insecticides, termites and disinfectants, products used in the fields and gardens	Itchy eyes, nose, and throat, damage to the central nervous system and kidneys, increase in risk of being cancer	-They should be used in accordance with the instructions -They should always be mixed and diluted outside the room -They should be used in recommended amounts -Ventilation should be provided -Unnecessary pesticides should not be stored in a closed environment -Clothes should be separately ventilated

Formaldehyde	Pressed wood products, furniture, insulation materials, cigarette smoke, combustion products	Itchy eyes, nose, and throat, coughing, fatigue, rash, allergic diseases, cancer, short-term memory loss, anxiety	- A kind of pressed wood containing phenol resin instead of urea should be used - Air conditioner and moisture holder should be used in order to dehumidify and to keep the ambient temperature normal - The environment should be ventilated when new sources releasing formaldehyde enter
Benzene	Paints, varnishes, carpets, treated wood, artificial wood, adhesives, insulation materials, office equipment, cigarettes	Death, drowsiness, dizziness, cardiac arrhythmia, negative effects on bone marrow and blood production	-Instead of using building materials that emit benzene, alternatives should be used -Benzene containing building elements that are deformed should be renovated -Less emitting materials should be used -The environment should be ventilated regularly
Lead	Lead-based paint, contaminated soil, dust, table water	Coma, death, damage to the central nervous system and kidneys, weakening the mental and body development	-Lead-based paint should not be used -Lead should not be covered with sand and should not be burned -Specialists should be hired to remove lead paint -Lead powders should not be given to the building - Organic lead in fuel should be forbidden -Use of lead in waste incinerators and lead-acid battery manufacturers should be reduced
Biological materials	Humid walls and ceilings, carpets, furniture, unserviced dehumidifiers, air conditioners, pets, ducts of conditioning system, humidifiers, insulation materials, grills	Itchy eyes, nose, and throat, dizziness, fever, flu, asthma, tremor, fatigue, respiratory disorders, nausea, cough, allergic diseases, legionnaires' disease, Pontiac fever	-Bathroom and kitchen fans and fan-out of the laundry dryer should be exhausted outside - Refrigerant vapors and ultrasonic humidifiers should be washed with fresh water every day - Air conditioners and moisture holders should be emptied frequently -Filter cleaning and maintenance of the air conditioning devices should be done regularly -Dust collecting coating materials should not be used