IOP Conf. Series: Materials Science and Engineering **245** (2017) 042068 doi:10.1088/1757-899X/245/4/042068

# Particulate Matter Mass Concentration in Residential Prefabricated Buildings Related to Temperature and Moisture

**Michal Kraus [1], Ingrid Juhásová Šenitková [1]**

[1] Institute of Technology and Business in České Budějovice, Department of Civil Engineering, Okružní 517/10, 370 01 České Budějovice, Czech Republic

info@krausmichal.cz

**Abstract**. Building environmental audit and the assessment of indoor air quality (IAQ) in typical residential buildings is necessary process to ensure users' health and well-being. The paper deals with the concentrations on indoor dust particles ($PM_{10}$) in the context of hygrothermal microclimate in indoor environment. The indoor temperature, relative humidity and air movement are basic significant factors determining the $PM_{10}$ concentration [μg/m$^3$]. The experimental measurements in this contribution represent the impact of indoor physical parameters on the concentration of particulate matter mass concentration. The occurrence of dust particles is typical for the almost two-thirds of interiors of the buildings. Other parameters indoor environment, such as air change rate, volume of the room, roughness and porosity of the building material surfaces, static electricity, light ions and others, were set constant and they are not taken into account in this study. The mass concentration of $PM_{10}$ is measured during summer season in apartment of residential prefabricated building. The values of global temperature [°C] and relative humidity of indoor air [%] are also monitored. The quantity of particulate mass matter is determined gravimetrically by weighing according to CSN EN 12 341 (2014). The obtained results show that the temperature difference of the internal environment does not have a significant effect on the concentration $PM_{10}$. Vice versa, the difference of relative humidity exhibits a difference of the concentration of dust particles. Higher levels of indoor particulates are observed for low values of relative humidity. The decreasing of relative air humidity about 10% caused 10μg/m$^3$ of $PM_{10}$ concentration increasing. The hygienic limit value of $PM_{10}$ concentration is not exceeded at any point of experimental measurement.

## 1. Introduction

Many concerns about indoor air quality (IAQ) have been raised by those people who spend their most time in work or life within a close indoor environment. Some problems concerning IAQ, i.e., CO2 concentration, emissions of volatile organic compounds (VOCs) and bacterium, are usually paid more attention [1, 2]. However, aerosols or inhalable indoor particulate matters are sometimes ignored. In the industrialized part of the world, we spend approximately 65% of our lives in our homes [3, 4]. Hereby we are subjected to various indoor-generated airborne particles as well as to background particles originating from outdoors.

Indoor air quality (IAQ) is closely associated with the Sick Building Syndrome (SBS). Respiratory diseases such as bronchia asthma and respiratory inflammation may be caused when human are exposed to particulate matters for a long time in a building. Indoor environmental quality significantly affects not only the health of individuals, but also their performance and psychological well-being. Today, more than 80% of the building users feel Sick Building Syndrome [5, 6]. Sick Building Syndrome is defined as a set of sub-clinical symptoms without identified causes. Common symptoms of Sick Building Syndrome include mucous membrane and skin irritation, dry eyes, dry nose, dry throat, headache, fatigue, memory decline, nonspecific hypersensitive reaction, sensory discomfort from odors, insomnia, allergies and asthma [7, 8].

It is necessary to note that the hygiene requirements for indoor environments are superior to energy savings. Indoor air quality is defined as a set of physical, chemical and biological factors. Dust (solid aerosols) and liquid aerosols create aerosol microclimate, which significantly affects the quality of the indoor environment. It is necessary to pay attention to dust particles as part of air aerosol in the context of indoor air quality. Particulate matter $PM_{10}$ are small solid particles of diameter less than 10 mm, which are able to move freely in the atmosphere. These particles are formed naturally (volcanoes, fires, erosion) or through anthropogenic activity. Anthropogenic sources include the burning of fossil fuels such as transportation, energy and the other heavy industries. Significant source, so called secondary dust, is already swirling of dust deposits (mining, transport, construction). The indoor concentrations of particulate matter are influenced by external climate conditions. House dust is a complex of solid particles of different sizes. Larger particles quickly settle on the surfaces of the internal environment. Smaller particles are floating in the indoor air for long time. The size, composition and shape of the particles varies continuously. Airborne particles $PM_{10}$ are formed from complex constituents such as carbon (soot), sulphates, metals and inorganic salts. Carcinogenic components, such as arsenic, cadmium, chromium, nickel, lead, and others, can bind to dust particles. The source of frequent diseases are the particles of biological origin, such as fungi, bacteria, mites, particles from the fur and feathers of pets, flakes of human skin and hair, textile particles and pollen.

Airborne concentration of particulate matter in indoor environment are commonly referred to as home dust. Extended exposure to high concentrations of particulate matter in indoor environment have adverse health effects on human health. Health problems caused by high concentrations of $PM_{10}$ are described in many studies [9, 10]. Excessive inhalation of dust particles can cause asthma, lung disease, miscarriages, growth defects, diabetes, high blood pressure, heart disease or cancer and premature death. The concentration of dust particles in the indoor environment is normally is around 50 $\mu g/m^3$. According to the applicable hygienic limits, the hourly concentration of $PM_{10}$ should not exceed 150 $\mu g/m^3$ in the internal environment of buildings under standard conditions.

For naturally ventilated buildings summarized indoor/outdoor ratios (I/O) for $PM_{10}$ and $PM_{2.5}$ (particulate matter smaller than 10 μm and 2.5 μm, respectively) from 0.5 to 0.98 and 0.54 to 1.08, respectively, in the absence of indoor sources [11]. However, when indoor sources were present, I/O ratios for $PM_{10}$ and $PM_{2.5}$ ranged from 1.14 to 3.91 and 1 to 2.4, respectively, which stress the significance of indoor source contributions [12]. According to the International Agency for Research on Cancer (IARC), the particulate matter components of air are classified as carcinogenic [13]. Influence of solid particles on human health depends mainly on the size. The smaller the particles are, the more dangerous are. Place of establishment is dependent on particle size. Dust particles larger than 10 μm are normally deposited on the nasal mucosa. These particles do not represent a serious health threat. Particles smaller than 10 μm are able to penetrate into the lower respiratory tract. These particles are able to settle on the bronchi. Very dangerous are particulate matter $PM_{2.5}$ and $PM_1$, which are able to settle in the lungs and air sacs. Nanoparticles can penetrate to the bloodstream.

## 2. Research methodology

The experimental measurement was carried out during summer season. The tested room is located in the apartment on the second floor of prefabricated panel building. The volume of air in the room is approximately 65 $m^3$. The value of air change rate is 0.5 $h^{-1}$. The furniture was cleared out before the actual measurement and the room was properly cleaned. The windows and the doors are closed during the experimental measurement.

Experiment measurement is performed according to the CSN EN 12 341 (2014) [14]. Quantity of $PM_{10}$ is determined by pumping air through the filter analysed. The quantity of captured aerosol is determined gravimetrically by weighing. The sample are collected on nitrocellulose filter (Synpor) with pore size 0.8 μm and with diameter of 35 mm. The sample are analysed by VPS 2000 (Envitech) with constant airflow. The airflow is recorded before and after each sampling period. The measuring device is placed in the middle of the room. The sampling equipment is at the height of 1 050 mm from the floor. This height is typical for breathing zone of sitting persons. The nitrocellulose filters are kept in desiccators at a constant temperature and relative humidity (RH=50%) for 24 hours before sampling. The filters are again kept in desiccators for 24 hours after sampling. The filters are weighed before and after sampling. The particulate matter mass concentration of $PM_{10}$ is determined by gravimetric method on the base of difference of measured weights. Morphology, the origin and composition of the dust particles is not the subject of this study.

The values of globe air temperature [°C] and relative humidity of indoor air [%] are changed during the experimental measurement. The values of globe temperature are ranged from 18 – 32 °C with the deviation of ± 1.0 °C and the range of relative humidity is in the interval from 25 to 60% with the deviation ± 5.0 °C. Other parameters of indoor environment such as the air change rate, roughness and porosity of the building material surfaces, speed of particles deposition, and volume of the room, indoor static electricity and number of light ions are constant.

## 3. Results and discussions

The relationship between particulate matter mass concentration ($PM_{10}$) and relative humidity of indoor air is presented in figure 1. It is clear that there is a correlation between the relative humidity of the internal environment and $PM_{10}$ concentrations. The lower the relative humidity of indoor air is, the higher of $PM_{10}$ concentration is. The correlation can be expressed by a polynomial equation ($y = 0.0039x^2 - 1.3901x + 84.307$) with the reliability coefficient of 97.74%. The mean value of $PM_{10}$ concentration is 42.4 μg/m$^3$. The maximum concentration of $PM_{10}$ (48.1 μg/m$^3$) is noted for the value of relative humidity of 25.4%. The lowest value of $PM_{10}$ concentration (18.6 μg/m$^3$) by value of relative humidity 59.0%.

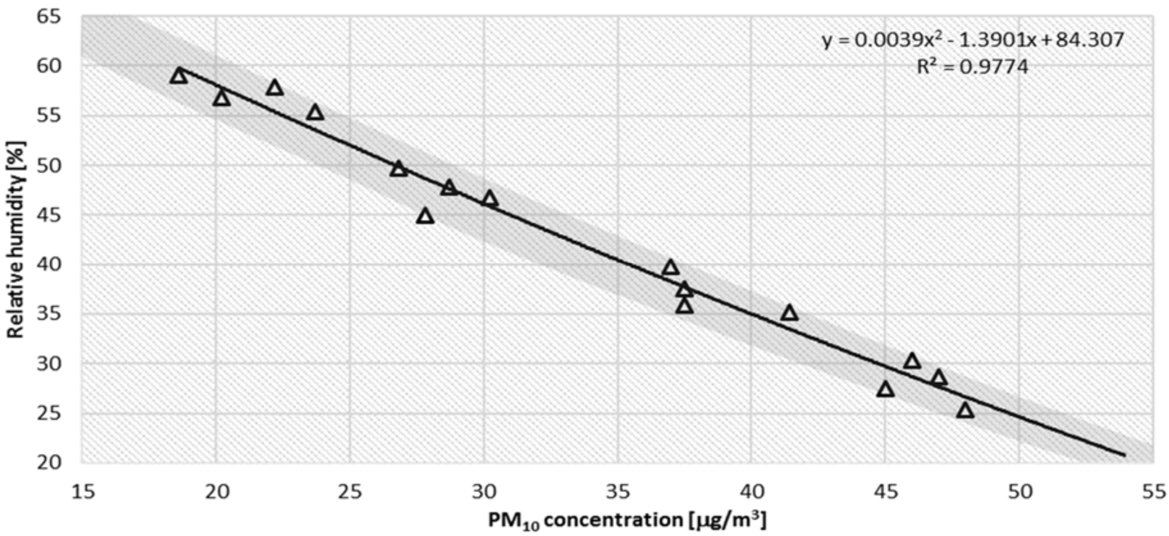


**Figure 1**. Relative humidity influence on indoor PM10 concentrations

Figure 2 illustrates the relationship between the concentration of $PM_{10}$ concentration [μg/m$^3$] and indoor air globe temperature. The results are divided into four categories according to relative humidity of indoor air. A total range of relative humidity from 25% to 55% represents a typical relative humidity in the indoor environment of residential prefabricated buildings. Linear trend lines are constructed for all groups of relative humidity with determination of reliability coefficients $R^2$. The lower the relative humidity is, the lower of dispersion of obtained values of particulate matter mass concentration is. The concentration suspended particulate matter can be estimated with reliability of 74.81% in the humidity range from 25 to 30%. In contrast, concentrations of $PM_{10}$ in the humidity range of 55-60% can only be determined with 32% reliability.

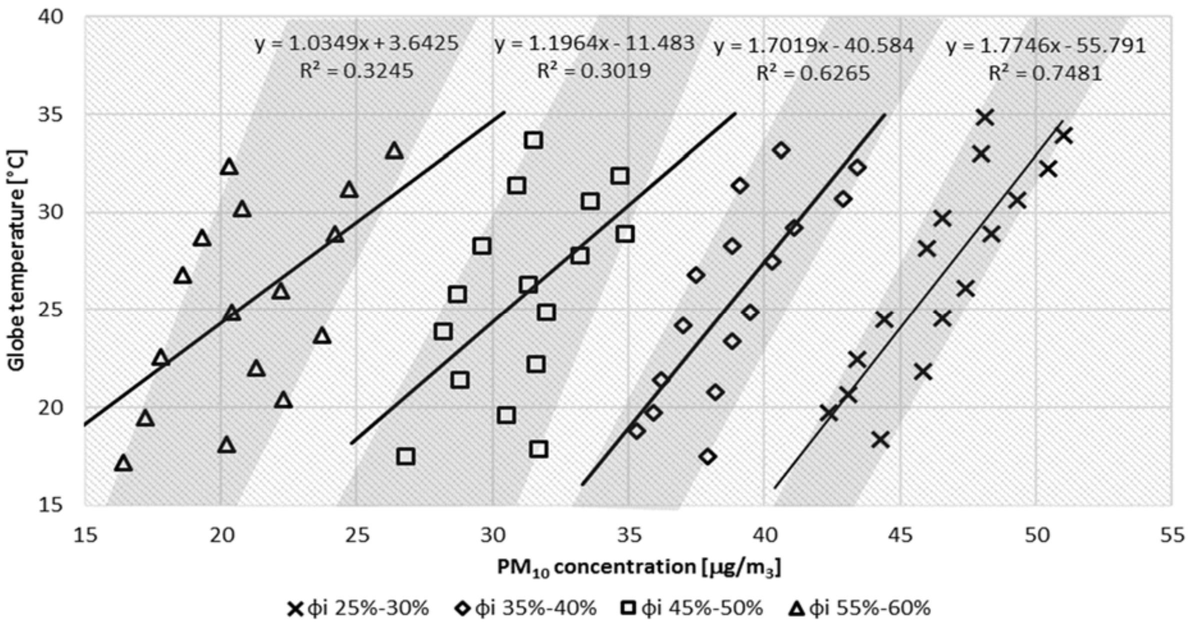


**Figure 2**. Globe temperature influence on indoor PM10 concentrations

## 4. Conclusion

Indoor air quality and comfort of users is one of the fundamental pillars of sustainable construction. The buildings design should respect to a complex system of internal environment with respect to predicted individual indoor pollutant occurrence.

This study described $PM_{10}$ occurrence related to indoor globe temperature in the indoors of residential buildings with suspected indoor air problems. The results of experimental measurements show that the hygrothermal microclimate of indoor environment has a significant effect on the concentration of dust particles. Based on the presented results, it can be determined that the decreasing of relative air humidity about 10% causes the increasing of $PM_{10}$ concentration approximately about 10 μg/m$^3$. On the contrary, the indoor air temperature does not have significant influence on particulate matter mass concentration. The data regarding the particle concentrations can be used to evaluate the general indoor air quality level in Czech residential buildings. Clearly, higher levels of airborne particles may indicate an indoor air problem, abnormal particle sources, and a need for additional investigations.

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