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Idoor Air Quality with Particular Reference to Carbon Monoxide in the Room – A Pilot Study

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ABSTRACT

Cigarette smoking are the most important reasons for increased carbon monoxide (CO) level in exhaled air. During the experiment, the CO level in indoor air in room was measured. Outdoor air quality data including atmospheric CO concentration, obtained from the own measured and data from the weather platform "freemeteo". The measurements were carried out with the following variants: outside air, a room ventilated without people, nonsmokers, smokers and non-smoking people, smokers entering the room after smoking cigarettes, smokers who smoke in the room. As proven by measurements, carbon monoxide carried in the lungs by smokers has low concentrations and should not threaten the health of non-smoking users of rooms. The maximum concentration of carbon monoxide in the room was 1.4 ppm. In the external air, the average concentration of carbon monoxide was exactly as much as reported in the literature – 0.3 ppm.

Keywords: air pollution, carbon monoxide, smoking cigarettes, air quality.

INTRODUCTION

The toxic gas polluting the air is carbon monoxide (CO). This gas is one of the most common reason for human intoxication in the house, in the enclosed spaces (Bleeker, 2015; Blumenthal, 2001). The sources of carbon monoxide are: cigarette smoke, street gas, gas furnaces, wood stoves, incomplete combustion of fossil fuels, mining industry and power plants (Awada et al., 2022; Maga et al., 2017). The carbon monoxide is odorless, tasteless and colorless, therefore it is very difficult to sense it. He is a by-product of incomplete combustion. It can be produced indoors as a result of combustion processes among others in natural gas appliances (Austin and Mejia, 2017; Mullen et al., 2016) or as a result of other human activities such as cigarette smoking (Konstantopoulou et al., 2014; Schober et al., 2019; Smilin et al., 2013). In a room with natural ventilation the concentration of carbon monoxide in the indoor air usually does not exceed 30 ppm (Fazlzadeh et al., 2015; Lee and Kim, 2021). The concentration of carbon monoxide in the indoor air depends on the concentration of carbon monoxide in the outside air (if there are no additional sources in the room). Both concentrations are very similar to each other (Zhong et al., 2013). Recommended limits of concentrations of carbon monoxide in indoor air present in Table 1.

Atmospheric air does not contain carbon monoxide. However, if people (in a closed room) are breathing for a long period of time air with low concentration of carbon monoxide, they are exposed to health problems. First of all, diseases related to cardiovascular, nervous, respiratory, digestive and immune systems are intensifying (European Environment Agency, 2011; Hallit et al., 2019). Effect of carbon monoxide on people present in Table 2. Maga et al. (2017) investigated

Table 1. Recommended limits of concentration of carbon monoxide in indoor air

Recommended CO concentration (ppm)	Authority
≥ 9	ASHRAE, 2016; U.S. EPA, 2013 Ambient air (8 h)
≥ 28	WHO, 2010 Ambient air (1 h)
≥ 35	ASHRAE, 2016; NIOSH, 2012 Ambient air (1 h)
≥ 50	OSHA, 2012

Table 2. How the concentration of carbon monoxide affects the human body

Concentration of carbon monoxide (CO) ppm	Symptoms of poisoning
35	The maximum CO concentration allowed by the World Health Organization when staying in the room for up to 8 hours.
200	Light headache, nausea, general fatigue, dizziness after about 3 hours.
400	Dizziness and severe pain after about 2 hours, life threatening after 3 hours.
800	Increased nausea, pain and dizziness, vomiting, coma after 45 minutes, death after 2-3 hours.
1500	Very strong nausea, vomiting, pain and dizziness, coma after 10-15 minutes, death within 1 hour.
12000	Fainting after 2-3 inhalations, death after a few minutes.

the concentration of carbon monoxide in the air exhaled by various people. They investigated smokers, passive smokers and non-smokers. The results of the study suggest that cigarette smoking affects the higher level of exhaled carbon monoxide. Carbon monoxide, which is a product of people who smoke cigarettes, may also have external sources (Asif et al., 2019; Gupta, 2019). In many restaurants you can only smoke cigarettes outside. Carbon monoxide can penetrate the rooms through leaks in window and door joinery. Then people who live there are passive smokers (Konstantopoulou et al., 2014). In Iran (Fazlzadeh et al., 2015; Heydari et al., 2019) tests the concentration of carbon monoxide in indoor and outdoor air the coffee shop. Their results are alarming. Inside in the cafe, the concentration of carbon monoxide was in the range of 6.1 to 112.4 ppm. This is significantly above the permissible CO concentration value in the standards (Table 1). However, the average carbon monoxide concentration in the outdoor air was 2.7 ppm (it varied between 1 and 6 ppm).

Currently, 12% of Poles say that their homes smoke tobacco without restrictions – throughout the home. 7% declare that tobacco is smoked in their homes only in designated closed rooms. In 20% of houses, tobacco is only smoked outside – for example on a balcony / terrace. The percentage of smokers in Poland in the years 2009–2017 is shown in Figure 1. This means that in Poland, every fourth adult smokes cigarettes, that is in Poland, 7 563.12 thousand people smoke (Demographic

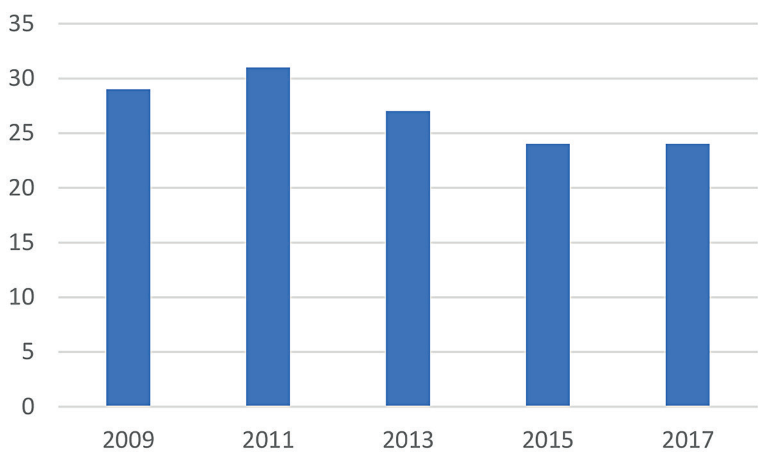

Fig. 1. Percentage of smokers in Poland in 2009–2017

Yearbook of Poland, 2018; Trząsalska et al., 2013). In the research group, almost 50% of people were smokers. The data was presented for Poland, because the experiment was conducted in Poland, and in each country there is a different approach to smoking cigarettes and therefore it is not possible to represent the entire EU on a single graph. Figure 2 presents the percentage of people exposed to second-hand smoke in the health care system in 2009–2017 (Demographic Yearbook of Poland, 2018). Whereas Figure 3 presents the percentage of people exposed to second-hand smoke in catering premises for the same period (Demographic Yearbook of Poland, 2018). Health services have been chosen, because we go to health and eating places and most of us, even smokers, want to be without smoke in these places. The aim of the article is to show that carbon monoxide introduced into the room by smokers (in the lungs) is not important for non-smokers.

MATERIAL AND METHODS

Experimental research was carried out in Bialystok, north-eastern Poland. Although it is a city with 300,000 inhabitants (medium city), the outside air is clean. The city is surrounded by forests, and within its borders there is a lot of greenery. The industry is natural (wood, furniture, textile) and equipped with modern filters. External air pollution in the form of so-called smog was not reported (Dutta and Roy, 2021; web-1).

The room in which the experiment was conducted is usually a non-smoking room, just like the rooms next to it. Measurements lasted 2.5 hours. They were performed in a ventilated room in the morning. Each measurement was made 6 times. People were their declared smoking status (smokers and non-smokers). A cigarette smoker was defined as a person who smokes average of 5 cigarettes a day for at least last 3 years (Maga et al., 2017). In the room and outside the

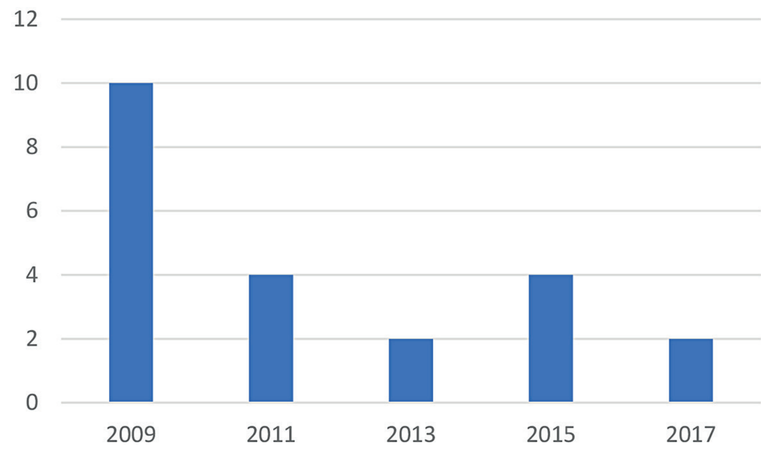

Fig. 2. Percentage of people exposed to second-hand smoke in healthcare in 2009–2017

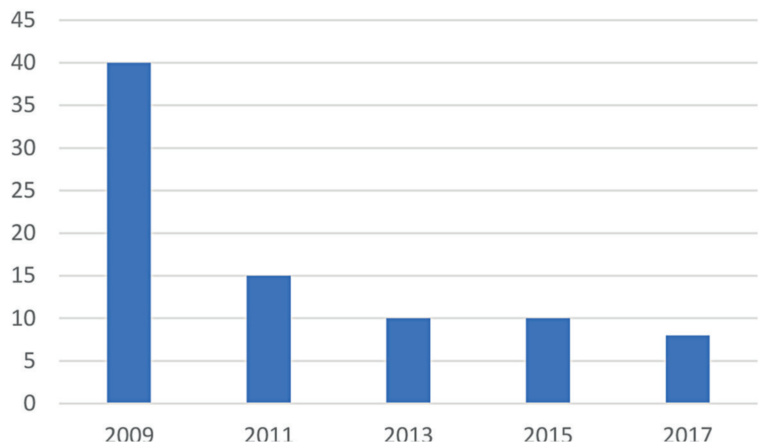

Fig. 3. Percentage of people exposed to second-hand smoke in dining outlets in the years 2009–2017

temperature, relative humidity, concentration of carbon dioxide and carbon monoxide and atmospheric pressure were measured. The last parameter was not analyzed, the measurement only served to record normal conditions. Each measurement was made with two Testo 435 recorders with IAQ probe and a carbon monoxide probe. Probes located 1 m above the floor. The unit result presented in the chart is the average of 10 measurements, each measurement is a sample of 30 seconds. The room volume was measured with a DLE 70 rangefinder. Devices with probes are shown in Figure 4. The specificity of the device is presented in Table 3. The measurements were carried out with the following variants:

- Outside air,
- A room ventilated without people,
- Nonsmokers,
- Smokers and non-smoking people,
- Smokers entering the room after smoking cigarettes.
- Smokers who smoke in the room (for the purpose of the experiment, non-smokers were asked to leave the room, and smokers were asked to smoke). Nonsmokers were asked out of the experimental room, because there was no point in making them uncomfortable.

Conditions in which measurements were carried out are presented in Table 4.

Fig. 4. Measuring instrument with probe air quality and probe carbon monoxide

Table 3. Description of measuring equipment

Using spot	Measuring items	Measuring range	Resolution	Accuracy
Testo 435-4 and probe air quality				
Outdoor	Temperature	–20 to +50 °C	0.1°C	±0.3 °C
	Humidity	+2 to +98% RH	0.1% RH	±2% RH
	Carbon dioxide concentration	+0 to +5000 ppm CO_2	50 ppm CO_2	±2% ppm CO_2
	Atmospheric pressure	+600 to +1150 hPa	0.5 hPa	±5 hPa
Indoor	Temperature	0 and +50 °C	0.1°C	±0.3 °C
	Humidity	+10 to +98% RH	0.1% RH	±1% RH
	Carbon dioxide concentration	+0 to +5000 ppm CO_2	50 ppm CO_2	±2% ppm CO_2
Testo 435-4 and probe carbon monoxide				
Outdoor and indoor	Carbon monoxide	0 to +500 ppm	5 ppm CO	± 5% ppm CO
Bosch DLE 70				
Indoor	Distance	0 to +70 m	0.0001 m	± 1.5%

Table 4. The room characteristics

Year of construction	1990
Year thermo-modernization	2015
Scope of thermo-modernization	full
Windows	triple-pane
Modernization of ventilation system	yes
Size of the room	222 m^3/ 73.5 m^2
Total window area	32.35 m^2
Ratio of window area to the area of the room	0.44
Heat transfer coefficient U	1.5
The number of people in the room	15 to 17
The fulfillment of peace by people	26% to 31%
The area of the room relative to one human	0.204 to 0.231
The volume of the room relative to one human	0.068 to 0.086

RESULTS

The results of the measurements are presented in Figures 5–8. The series number corresponds to the measurement variant (1–6). Figure 5 presents temperature in all series of measurements in indoor and outdoor, Figure 6 presents humidity, Figure 7 presents carbon dioxide concentration and Figure 8 presents carbon monoxide concentration. Atmospheric pressure of the measurements was in the range 997 to 1008 hPa. Temperature indoor in all series of measurements was in the range of 21.6 to 24 °C (Fig. 5).

Outdoors temperature in the series 1 is from 3.1 to 5.2 °C and relative humidity, in also series 1, is from 72% to 84%.

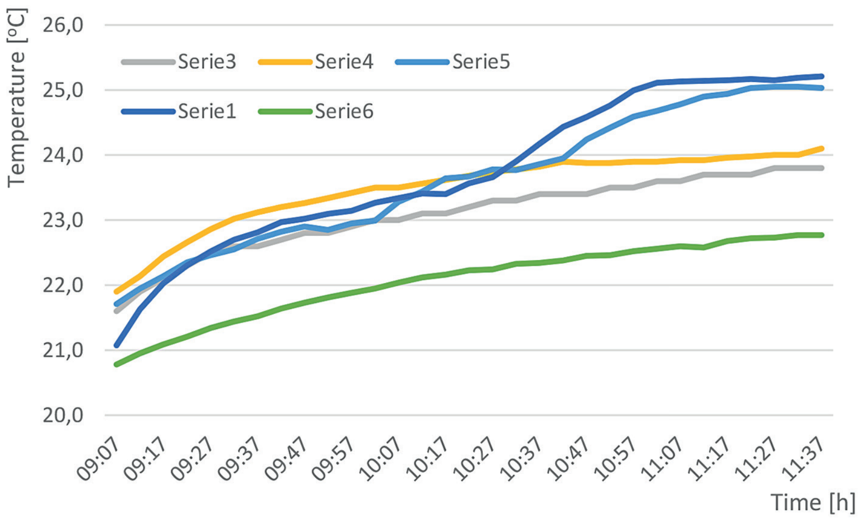

Fig. 5. Temperature in all series of measurements indoors

DISCUSSION

The temperature rise took place during measurements, so it should be assumed that it was an increase in the internal air temperature from people in the room (Bergel and Młyńska, 2021). This indicates insufficient ventilation, not overheating. The relative humidity during all measurement series was below the recommended values (ASHRAE, 2016; PN-EN 13779; WHO, 2010) in the range of 40 to 60% (Figure 6). This means that the air is dry (Staszowska, 2022). It may cause drying of mucous membranes, eg throat, nose or eyes. It may cause irritation of the above mucous membranes and, as a consequence, health problems (Awada et al., 2022; Benson et al., 2017). After about 40 min to 60 min, carbon dioxide exceeded the recommended by standards (ASHRAE, 2016; PN-EN 13779; WHO, 2010) 1000 ppm (Figure 7). It is surprising that the room was filled only 26% to 31% during measurement. This also indicates insufficient ventilation.

The carbon monoxide in the 1–5 measurement series was a maximum of 1.4 ppm when the persons participating in the experiment came to the room immediately after smoking the cigarettes. These people occupied 15% of the room. The CO concentration of this value was maintained for 3 minutes. Assuming that the concentration of CO spreads linearly and all people in the room would enter after smoking cigarettes, the maximum instantaneous CO concentration would be around 9 ppm, which is below all standards (ASHRAE, 2016; PN-EN 13779; WHO, 2010), the more so because it is instantaneous, below 5 min. The value of CO concentration in the outside air was maximum 0.51 ppm and it is below

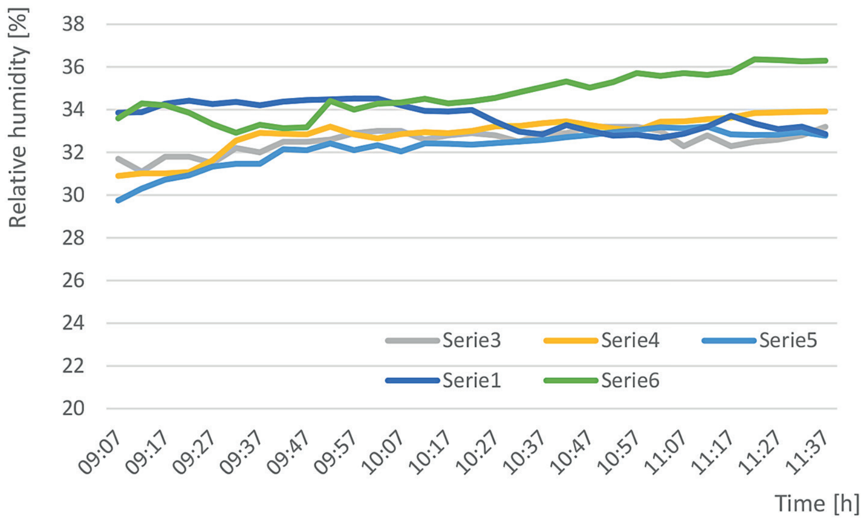

Fig. 6. Relative humidity in all series of measurements indoors

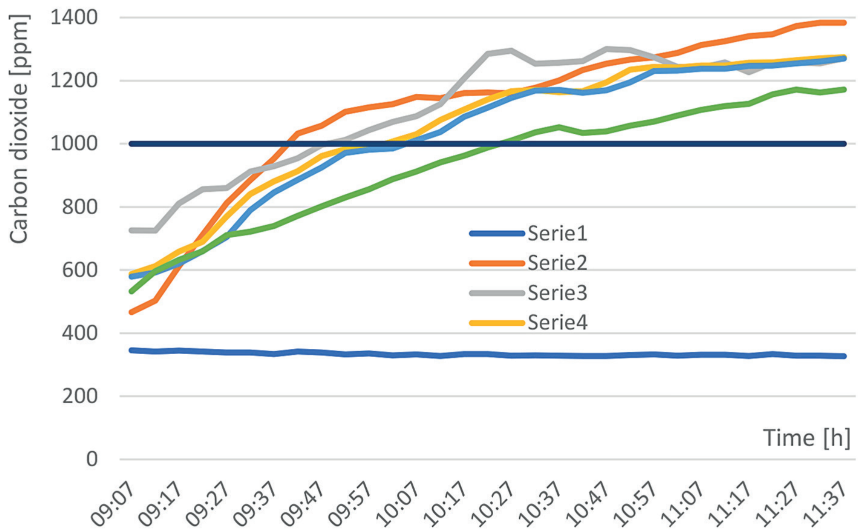

Fig. 7. Carbon dioxide concentration in all series of measurements indoors and outdoors

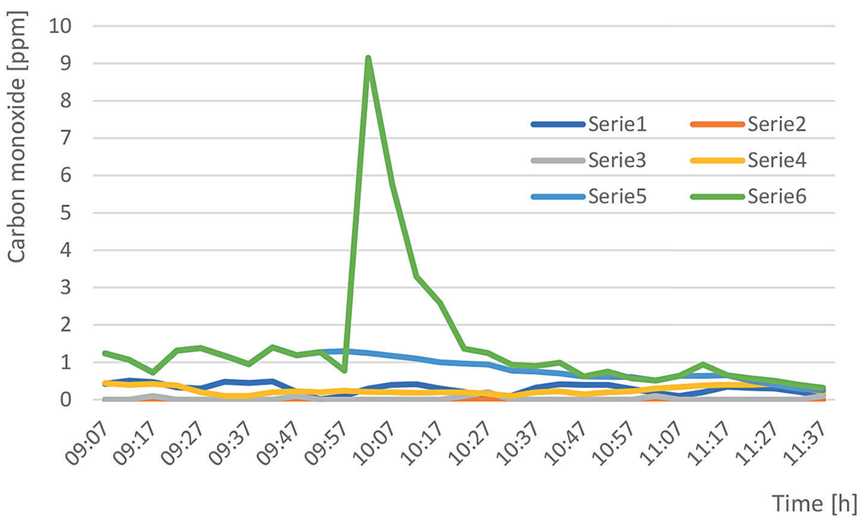

Fig. 8. Carbon monoxide concentration in all series of measurements indoors and outdoors

the accuracy of the measuring instrument. You could take CO concentration in the outside air at level 0 if it were not for the fact that this value is the average of 5 meters. This low concentration of CO in the outdoor air consists of air pollution from cars and incomplete combustion of fossil fuels and biomass, mainly due to activities involving naturally occurring events such as forest fires (Duncan et al., 2007). One should also mention natural chemical reactions, or CO production by microorganisms, but these are very small amounts of CO. In total, CO production is estimated at 0.3 ppm (Cowan et al., 2018). Exactly this value was obtained from own measurements (Fig. 8).

The harmfulness of cigarette smoking has been discussed in many publications (Bleeker, 2015; Blumenthal, 2001; Maga et al., 2017). The authors, however, ignore the fact of "unconscious" bringing carbon monoxide into rooms. Carbon monoxide, which is in the lungs of smokers. As proven by these short studies, carbon monoxide in the lungs of smokers does not reach significant values. In all measuring runs, when the cigarettes could not be smoked, the maximum CO concentration was 1.4 ppm. As proven by measurements, carbon monoxide "carried" in the lungs by smokers has low concentrations in the room and its value is lower than the most stringent standards and regulations regarding the concentration of this gas (ASHRAE, 2016; PN-EN 13779; WHO, 2010). The measured value of CO concentration should not endanger the health and lives of non-smokers in rooms with no smoking. Non-smokers can only complain about the wrong smell. Perceiving aroma is an individual matter, and it can't be measured with a meter. Not all non-smokers are bothered by cigarette smoke. Rarely do smokers complain about the smell of cigarettes.

During the implementation of the series 6, only 13 smokers remained in the room. Everyone lit cigarettes and stayed in one place of the room near the measuring probes. The concentration of carbon monoxide at the climax was 9.15 ppm. After 5 minutes, this concentration decreased to 5.76 ppm and after a further 5 minutes to 3.3 ppm. The process of complete ventilation of the carbon monoxide room took about 20 minutes. The smell of cigarettes still roiled in the room where the experiment was being carried out. CO concentration should be considered as maximum, temporary. Only ASHRAE standards; U.S. EPA give the value of 9 ppm as the recommended value. There is no question of momentary values. The value of 9 ppm should not be exceeded if a person is exposed to exposure for 8 hours (Fazlzadeh et al., 2015).

CONCLUSIONS

The results of measurements allowed to analyze carbon monoxide from the smokers in the room. There is a need for further more detailed analysis in selected rooms where it is acceptable to smoke cigarettes and to estimate the effect of CO concentration on people. Keep in mind the non-smokers who work or stay in rooms where you can smoke. As proven by measurements, carbon monoxide "carried" in the lungs by smokers has low concentrations and should not threaten the health of non-smoking users of rooms with a prohibition on smoking cigarettes. You can only complain about the wrong smell, which is difficult to measure. In addition, the smell sensation is an individual matter.

Carbon monoxide is not the only harmful waste when smoking cigarettes, so it is necessary to conduct more comprehensive studies in rooms with the possibility of smoking cigarettes and to precisely determine what harmful substances are transferred in the lungs of smokers.

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