Indoor Air Quality in an Auto Repair Shop: A Case Study [†]

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Abstract: The aim of the paper was to conduct an indoor air quality (IAQ) assessment in an auto repair shop, measuring CO₂ and CO concentrations. Carbon monoxide and carbon dioxide concentrations were measured for a week. Two Testo 435-4 gauges were located at head height of an adult person (ca. 170 cm above the floor) in a room. The CO₂ concentration was measured with an IAQ probe, which measures dew point temperature, psychrometer temperature and absolute pressure in indoor air. The second gauge was connected to a CO probe. Measurements were taken every 5 min and were averaged across an hour. Uncertainties were estimated using square-root combinations of fixed errors and random errors at a 0.05 level of statistical significance. The measurements were conducted from 17 November to 23 November 2018. The following graphs were plotted for carbon dioxide and carbon monoxide: hourly averaged concentration and 8 h averaged concentration. The results were discussed and compared to Polish, foreign and international standards and recommendations. It was found that the auto shop was in danger of negligence according to Polish law as well as nonfulfillment of healthy recommendations. An exhaust extraction system should be installed.

Keywords: indoor air quality; IAQ; carbon monoxide concentration; carbon dioxide concentration; auto repair shop

1. Introduction

Hundreds of people in Europe are killed per year by carbon monoxide. CO is generated by malfunctioning boilers or it infiltrates from garages. In generally, it is a product of incomplete combustion [1]. Moreover, a problem also exists in the garages wherein the concentration CO is not taken into consideration. The CO mole fraction exceedance was measured in a multi-car garage by Gładyszewska-Fiedoruk and Nieciecki [2], which inspired the authors of this paper to investigate this problem in other motorisation areas.

Carbon monoxide binds with haemoglobin to form carboxyhaemoglobin (COHb), which reduces the amount of oxygen supplied by the blood. As a consequence, people suffer from tissue hypoxia at low exposure levels. At higher concentrations, carbon monoxide significantly decreases oxygen consumption by the brain, the heart, exercising skeletal muscle and developing foetuses (cf. World Health Organization WHO [3]). Non-smokers in certain jobs can have long-term COHb concentrations up to 5%, while COHb content in heavy cigarette smokers can be up to 10%. Non-smokers, the foetuses of non-smoking pregnant women and people with coronary artery disease should be protected in such way that the COHb level of 2.5% is not exceeded (cf. WHO [3]). This

guideline can be met if a certain the CO concentration with respect to time is not exceeded. The comparison among WHO [3], USA [4], German [5] and Polish [6] recommendations is presented in the full text

Nieciecki and Gładyszewska-Fiedoruk [7] reported the human body's reactions to particular CO₂ concentration values in the air. Below is listed the volume percentages and human organism reactions that may appear in different job conditions, selected from the work of Nieciecki and Gładyszewska-Fiedoruk [7]:

- 0.15%—sense of impure air and sense of stuffiness;
- 0.2%—weakened individuals that suffer from respiratory diseases may cough or sometimes suffer from syncope;
- 1%—breath frequency is increased;
- 1.5%—mild metabolic stress appears after a longer time of respiration; this is the maximal tolerated concentration in submarines and space ships.

The volume percentage of 0.15% means 0.0015 m³ of CO₂ or 1.5 dm³ in 1 m³ of air.

The European Garage Equipment Association (EGEA) warns that harmful exhaust is emitted from even modern combustion engines. It publishes the following general recommendations [8]:

- Exposure to vehicle exhaust emissions indoors should be avoided whenever possible;
- If safety cannot be guaranteed, the workspace should be equipped with an exhaust extraction system to protect the workers against hazardous substances;
- Exhaust emissions should be captured at source, which means directly at the exhaust tailpipe. The exhaust nozzle or funnel should be designed so that 100% of the exhaust emissions can be captured;
- Exhaust extraction systems should work at vacuum gage pressure;
- The extraction volume should be at least 25% above the maximum emitted exhaust volume;
- The extraction system specification should accommodate the largest engine in use at the workplace.

The EGEA [8] recommends different extraction volume flow rates depending on engine volume and the type of service:

- 450 m³/h is needed for cars with up to 4 litre engines that are being serviced;
- 900 m³/h is needed for cars with up to 4 litre engines when exhaust tests are carried out;
- 1000 m³/h is needed for trucks with up to 16 litre engines that are being serviced;
- 1800 m³/h is needed for trucks with up to 16 litre engines when exhaust tests are carried out.

Ventilating or air conditioning systems are controlled by the value of indoor temperature or relative humidity. Although carbon dioxide is considered a pollutant and its gains are taken in consideration in air balance, its concentration is not controlled in ventilation systems (cf., e.g., [9]).

Carbon monoxide is much more harmful substance by far. However, there is no set concentration limit of this poisonous substance in ventilation system controllers. The general aim of the paper is to facilitate a change in attitude towards this issue, so that the concentrations carbon oxides, especially carbon monoxide, would be the desired values determined by the controllers of a ventilation system in any place where exhaust fumes are emitted. The particular goal is to convince each auto repair shop owner that ventilation system installation is a necessity.

2. Materials and Methods

The measurements were conducted in a three-place auto repair shop with a staff of four people. The building is located in a county town in the northeast part of Poland. It was constructed with perforated brick and insulated with Styrofoam. The shop is not ventilated with a stack effect nor with mechanical ventilation. The only form of ventilation is infiltration through the relatively large and unsealed doors. The window frames are made with Polyvinyl chloride (PVC).

This one-week experiment is a part of an experiment series that was conducted in different seasons in one location. It was conducted in autumn, November 2018, which was during the heating season. For this reason, the garage door was opened only when a car was being driven in or out. A probe for carbon monoxide concentration measurement and another probe for carbon dioxide content measurement were placed 170 cm above the floor.

The maximum 8 h average was calculated from moving averages, calculated every hour from eight 1 h averages over a 24 h period

3. The Results

The recommended CO₂ level (1000 ppm) was exceeded on 17 November for 3 h (from 11:00 to 13:00) with the maximal value at 2578.1 mg/m³. A greater concentration was recorded on 19 November for 2 h (8:00 and 9:00) at the maximal level of 2982.5 mg/m³. On 20–23 November, there were sporadically occurring 1 h CO₂ exceedances, whose concentration values reached up to 3264.4 mg/m³.

In the case of carbon monoxide, the maximal measured value was 480.88 mg/m³ on 22 November at 9:32.

The short-term exposure limit, according to WHO recommendations [3], (100 mg/m³ per 15 min) was exceeded twice. The first exceedance lasted 50 min on 22 November, between 8:57 and 9:47, with an average value of 212.07 mg/m³, the fifteen-minute means changes from 117.45 mg/m³ to 402.91 mg/m³. The second time the limit was exceeded occurred 10 h later, i.e., between 19:22 and 19:42, with an average value of 112.04 mg/m³. The Polish regulation was exceeded the first time, coinciding with the first exceedance of the WHO recommendations. In the second case, the exceedance lasted 15 min from 19:27 to 19:42 at 119.02 mg/m³.

The 30 min exposure limit (60 mg/m³ in WHO recommendations [3]) was exceeded six times. The first exceedance occurred on 19 November and lasted from 17:57 to 18:27 at 64 mg/m³. The second case took place on 20 November from 18:17 to 19:42 at 68.88 mg/m³. The third one was measured on 21 November between 15:57 and 16:27 at 62.77 mg/m³. The last three non-fulfilments were on 22 November, between 8:47 and 10:52 at 142.03 mg/m³; between 11:12 and 11:42 at 64.03 mg/m³; and between 19:07 and 20:02 at 79.88 mg/m³.

The 1 h exposure was greater than WHO recommendations (30 mg/m³) in eight long-term periods. The first time occurred on 17 Nov between 10:37 and 11:52 at 31.53 mg/m³. This was followed by Sunday, 18 November, which was a day off work. The second period started on 19 November at 17:02 and ended at 19:52 with an average concentration of 44.22 mg/m³. The three consecutive exceedances were recorded on the next day between 8:57 and 11:27 at 30.75 mg/m³; between 14:02 and 15:37 at 35.07 mg/m³; and between 17:42 and 21:22 at 51.80 mg/m³. The CO concentration was above the limit on 21 November between 14:52 and 17:42 at 45.04 mg/m³. The last two times the WHO recommendation was broken were on 22 November, between 8:17 and 12:22 at 92.74 mg/m³ and between 17:37 and 20:52 at 51.34 mg/m³. On November 23, no exceedance was recorded.

There was no exceedance in terms of the time-weighted average CO₂ concentration. However, the time-weighted average CO concentration was too high in four consecutive days from 20 to 23 November.

4. Conclusions

The results of the measurements lead to the conclusion that working in this garage can threaten employees' health. The lack of any ventilation is not acceptable, and results in the nonfulfillment of WHO [3] recommendations on numerous occasions. What is worse, the regulations of the Ministry of Economy and Labour [10] were breached on four constitutive weekdays. Such situations originate from the lack of fulfilment of the guidelines of the European Garage Equipment Association [8].

So as to improve work conditions and save workers from exposure to poisonous carbon monoxide, the installation of an exhaust extraction system that satisfies EGEA indications is recommended.

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References

1. Environment and Quality of Life. *Guidelines for Ventilation Requirements in Buildings*; Report No. 11; Commission of the European Communities Directorate General Information Market and Innovation Batiment Jean Monnet: Luxembourg, 1992.
2. Gładyszewska-Fiedoruk, K.; Nieciecki, M. Indoor air quality I a multi—Car garage. In Proceedings of the International Scientific Conference on Environmental and Climate Technologies (CONNECT 2015), Riga, Latvia, 14–16 October 2015.
3. *Air Quality Guidelines for Europe*, Second ed.; European Series 91; WHO Regional Office for Europe Copenhagen: København, Denmark, 2000. Available online: http://www.euro.who.int/__data/assets/pdf_file/0005/74732/E71922.pdf (accessed on 12 March 2019).
4. ASHRAE Standard 62.1-2016, Ventilation for Acceptable Indoor Air Quality. Available online: https://ashrae.iwrapper.com/ViewOnline/Standard_62.1-2016 (accessed on 16 July 2018).
5. Deutsche Forschungsgemeinschaft, List of MAK and BAT Values 2017, Maximum Concentrations and Biological Tolerance Values at the Workplace. Available online: <https://onlinelibrary.wiley.com/doi/pdf/10.1002/9783527812127.oth> (accessed on 16 July 2018).
6. Regulation of the Minister of Labour and Social Policy (Republic of Poland) of 29 November 2002 on Maximum Permissible Concentration and Intensity of Agents Harmful to Health in the Working Environment (Dz. U. [Journal of Laws] of 2002, 217, Item 1833). Available online: <http://dziennikustaw.gov.pl/du/2002/1833/D2002217183301.pdf> (accessed on 12 July 2018).
7. Nieciecki, M.; Gładyszewska-Fiedoruk, K. A Pilot Study of Air in the Garage. Part 1. Introduction, COW 2012, 43, 300–305.
8. Guidelines for the Reduction of Exposure to Hazardous Vehicle Exhaust Emissions, European Garage Equipment Association. Available online: <https://www.egea-association.eu/wp-content/uploads/guidelines-vehicle-emissions-egea-2011.pdf> (accessed on 17 July 2018).
9. Gładyszewska-Fiedoruk, K. Correlations of air humidity and carbon dioxide concentration in the kindergarten. *Energy Build.* **2013**, *62*, 45–50.
10. Regulation of Minister of Economy and Labour (Republic of Poland) of 10 October 2005 to Amend the Regulation on Maximum Permissible Concentration and Intensity of Agents Harmful to Health in the Working Environment (Dz.U. 2005 nr 212 poz. 1769). Available online: <http://dziennikustaw.gov.pl/du/2005/1769/D2005212176901.pdf> (accessed on 13 July 2018).