DETERMINATION OF VOLATILE ORGANIC COMPOUNDS IN THE BUILDING OF PRINTING COMPANY

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ABSTRACT

The man spends at work 40 hours per week in average. Therefore, the working environment should also satisfy requirements to indoor environmental quality. However, it is difficult for some workplaces. Measurements were carried out in the building of printing company during normal operation hours. Strong odour always prevails in this building because of the presence of printing inks and other chemicals. This odour can cause discomfort and thus reduce performance of workers. It is also known that odour can be caused by volatile organic compounds (VOCs). These compounds are usual gaseous pollutants in indoor air and they are known to have negative effect on human health. Problem with VOCs is that they may be released from many different sources in indoors or outdoors. Concentrations of total volatile organic compound (TVOC), which represent sum of all VOCs in the indoor air, were measured with photoionization detector with UV lamp. Simultaneously, relative humidity and air temperature was determined with data logger. The results were compared with recommended values for indoor air. In addition, questionnaire survey was carried out in order to determine the subjective perception of the indoor environmental quality by employees. The aim of this study was to determine actual information about levels of VOCs in buildings in eastern Slovakia. The results showed that parameters of air temperature and relative humidity were in accordance with recommended values for work environment in heating season. Despite this fact, employees perceived moderate heat during their work. On the other hand, TVOC concentrations reached relatively high levels (2596.5 μg/m^3) and significantly fluctuated with time. The most occurring "sick building syndrome" (SBS) symptoms were fatigue, headache, dizziness, memory impairment and difficulty in concentration between employees. Employees rated their working environment as more acceptable than unacceptable and quite tolerable despite their complaints in questionnaires.

Keywords: indoor environmental quality, working environment, volatile organic compounds, printing company

1. Introduction

Printing is a chemical-intensive industry, where workers are being generally exposed to many dangerous chemicals (Occupational Safety and Health Branch, 2004). The printing industry can be categorized by the type of printing press used, such as the lithography (offset), letterpress, (roto) gravure, flexography and silk screen (Novick *et al*., 2013). The chemical vapor composition emitted by the printing activity depends on the printing process, type of ink, and paper substrate. Prepress operations typically involve photo processing chemicals and solutions. Press operations include use of inks and cleaning solvents. Post press operations can use large amounts of adhesives, depending on the finishing work required (Caselli *et al*., 2009). Several studies of indoor environment were carried out in this type of industry. For example, study of Leung *et al*. (2005) showed that short-term personal exposure to total volatile organic compounds (TVOC) was exceedingly high when a print worker carried out ink roller cleaning procedures. Since the early 1980s the printing industry has made effort to reduce the exposure to organic solvents. However, recent studies indicate that exposure to these

substances is still present (Svendsen and Rognes, 2000). Indoor air quality and thermal comfort are two important aspects of indoor environmental quality that receive considerable attention (Huizenga *et al*., 2006) and these aspects have direct impact on health, performance and well-being of building occupants. Considering that people spend at work most of their time, it is necessary to pay attention to the IEQ also at those places. Therefore this study deals with these aspects in printing company.

2. Materials and methods

Measurement was carried out in the printing company focused on offset printing during normal operation. The building was built approximately in 1970s. It is a steel hall while parts of the walls with windows are built of brick. Partitions are created from gypsum boards. The whole building is thermally insulated with glass wool. This building has central heating with own heat source (gas caldron). The hall consists of several parts, but the measurement was performed only in one part with floor area of 608.5 m^2 (Figure 1). In this space there were aluminium windows, epoxy flooring, two printing machines, two machines for paper cutting, two creasing and folding machines, two binding machines, laminating machine, ten desks from particleboard, ten upholstered chairs, approximately 150 wooden pallets, and eleven open canisters with printing inks with weight of 25 kg. In addition, there were several tons of different types of paper and cardboard, sealed canisters with printing inks and cleaning chemicals. Seven employees worked in company at time of measurement.

Figure 1: Studied space

Concentrations of total volatile organic compounds (TVOC) were determined with ppbRAE 3000, which is photoionization detector with UV lamp. This device has measuring range from 1 ppb to 10,000 ppm, three-second response time and specified accuracy (isobutylene) from 10 to 2000 ppm: ±3% at calibration point. Two-point field calibration of zero and standard reference gases were carried out two days before measurement. Indoor air temperature and relative humidity were measured using data logger TESTO 175-H2. This monitor has measuring range from 0 to +100% RH and from -20 to +70°C. Specified accuracy is ±3% RH and ±0.5°C. Measurement lasted eight hours and started at 8:00 a.m. Measuring devices were placed approximately in the centre of the studied space at the height of 1.1 m. Besides the technical measurements, the employees completed questionnaires focused on their subjective assessment of the indoor environment quality. The building was heating during measurement and air condition unit was not working due to failure.

3. Results

3.1. Technical measurement

Mean outdoor temperature was 4°C during measurement in the printing company. Indoor air temperature ranged from 16.5°C to 19.8°C with mean value of 19.4°C. The permissible temperature for this type of work is 15-24°C in the cold season of the year but optimum is 18-21°C. Optimum temperature of 18°C was measured approximately at 9:00 a.m. and with increasing time was rising. Relative humidity ranged from 30.3% to 36.7% with mean value of 31.2%. The permissible relative humidity is 30-70%. According this recommendation measured

relative humidity was quite low but in the standard. TVOC concentrations ranged from 1897 µg/m^3 to 3742 µg/m^3 with standard deviation of 467.88 µg/m^3. Mean TVOC concentration was 2596.5 µg/m^3. The limit value for TVOC concentrations is not introduced in Slovak legislation. According to Mølhave (1990), TVOC concentration < 200 µg/m^3 has no effects on health or comfort. The concentrations of TVOC in the range of 200-3000 µg/m^3 cause irritation and possible discomfort. The concentrations of TVOC in the range of 3000 – 25,000 µg/m^3 cause irritation, discomfort and possible headache. Measured TVOC concentrations ranged from possible discomfort to discomfort area and exposure to these levels could cause health problems. Figure 2 shows the course of TVOC concentrations during eight hours. As can be seen, concentrations fluctuated significantly and had rising tendency approximately from fifth hour. Fluctuations of TVOC levels can be explained by work on certain machines that caused turbulence of indoor air.

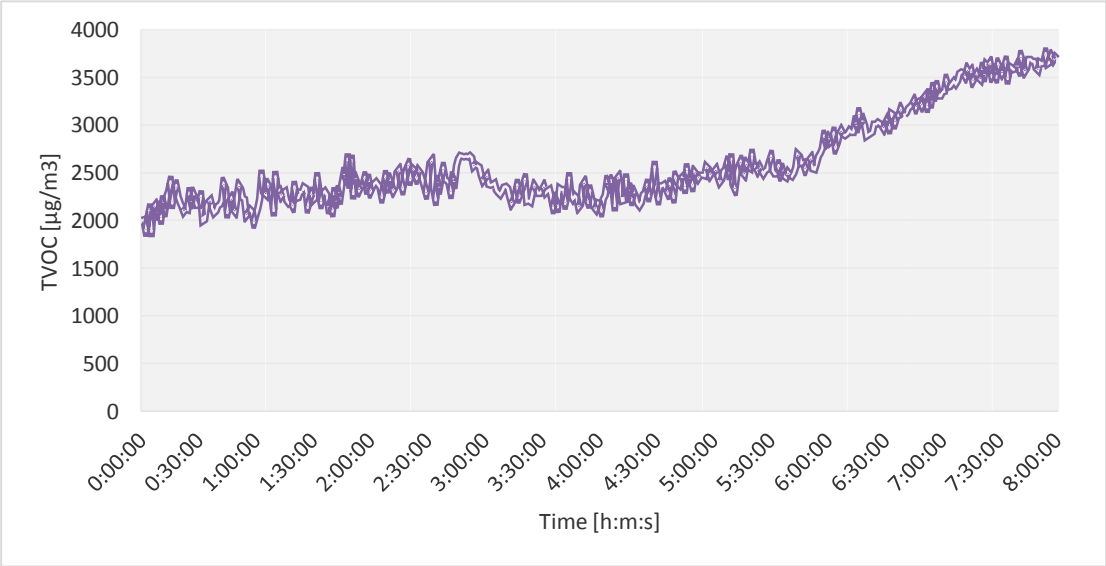

Figure 2: The course of TVOC concentrations

3.2. Questionnaires

Questionnaire survey (developed on the basis of the literature review) was carried out for the purpose of evaluation the influence of indoor environmental parameters on employees. Different types of evaluation scales were used in questionnaires. There were used scales of sensation evaluation (0 comfort, 1 slight discomfort, 2 discomfort, 3 great discomfort), self-evaluation of productivity (3 greatly increases, 2 increases, 1 slightly increases, 0 neutral, -1 slightly decreases, -2 decreases, -3 greatly decreases) and overall evaluation (more acceptable than unacceptable, more unacceptable than acceptable; 0 very well tolerable, 1 well tolerable, 2 quite tolerable, 3 hardly tolerable, 4 intolerable) for indoor environmental parameters (Budaiova *et al*., 2014).

Questionnaires were completed by 5 male and 2 female employees. The average age of these employees was 46 years. Six of them are working in the company more than 3 years. All employees working 40 hours per week as technical workers in studied part of hall. Three of them are smokers. Results showed that indoor air temperature, smell, noise level and lighting level caused discomfort and indoor air humidity level caused slight discomfort to these employees. But it should be noted that noise level and lighting level were not measured for this study. They considered the odor level as strong and indoor temperature as moderate heat at their workplace. At the end, employees rated the indoor environment as more acceptable than unacceptable and quite tolerable.

Employees were advised that they should only select those symptoms that they think are caused by their working environment in the case of SBS symptoms. Figure 3 shows results from

part of questionnaires about SBS symptoms. The most occurring symptoms were fatigue, headache, dizziness, memory impairment and difficulty in concentration. Dry or itchy skin, blocked nose, sneezing, cough, watering of the eyes were other symptoms which were marked multiple times.

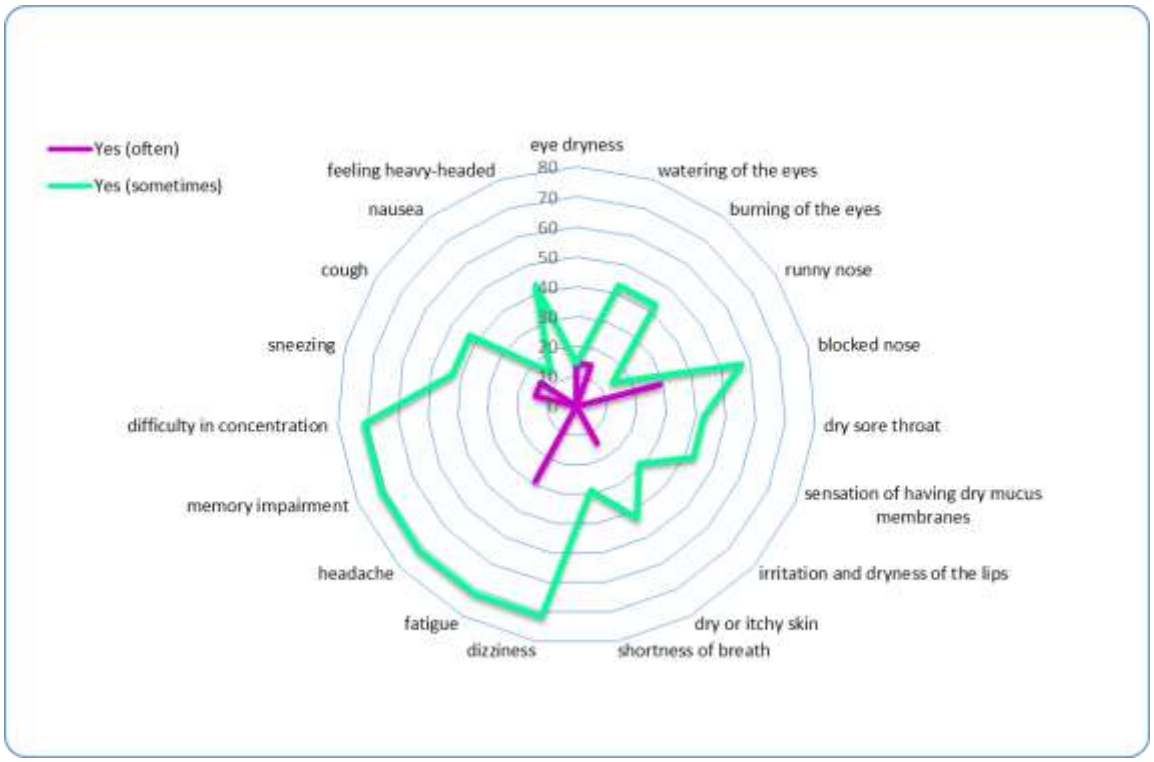

Figure 3: SBS symptoms

4. Conclusions

Subjective evaluation of indoor environment quality showed that employees felt moderate heat and strong odor during their work. On the other hand, technical measurement and comparison with Slovak legislation showed that air temperature was surprisingly low and from 9 a.m. in accordance with requirements for optimal value of air temperature. Relative humidity was also in accordance with Slovak legislation for work environment. Employees had some SBS symptoms and some of these symptoms are linked with exposure to VOCs. Also technical measurements showed that in studied part of the printing company were high levels of TVOC concentrations, which can cause various health effects. These high levels of TVOC concentrations may be reduced by repairing of air conditioning unit or at least increasing ventilation rates, by closing canisters with printing inks and by storing of materials and chemicals that are not necessary to operate outside the workspaces. Quantitative analysis of VOCs using electronic nose was also carried out in this company and further work will be focused on evaluation of the results from it.

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REFERENCES

1. Occupational Safety and Health Branch, Labour Department (2004), URL: http://www.labour.gov.hk/eng/public/os/C/GN_Printing.pdf

2. Novick R.M., Keenan J.J., Gross S.A. and Paustenbach D.J. (2013), An analysis of historical exposures of pressmen to airborne benzene (1938-2006), Ann. Occup. Hyg., **57/6**, 705-716.
3. Caselli M., de Gennaro G., Saracino M.R. and Tutino M. (2009), Indoor contaminants from newspaper: VOCs emissions in newspaper stands, Environ. Res., **109/2**, 149-157.
4. Leung M.K., Liu C.H. and Chan A.H.S. (2005), Occupational exposure to volatile organic compounds and mitigation by push-pull local exhaust ventilation in printing plants, J. Occup. Health, **47/6**, 540-547.
5. Svendsen K. and Rognes K.S. (2000), Exposure to organic solvents in the offset printing industry in Norway, Ann. Occup. Hyg., **44/2**, 119-124.
6. Huizenga C., Abbaszadeh S., Zagreus L. and Arens E.A. (2006), Air quality and thermal comfort in office buildings: results of a large indoor environmental quality survey, Proceedings of Healthy Buildings 2006, Lisbon, Vol. III, 393-397.
7. Mølhave L. (1990), Volatile organic compounds, indoor air quality and health, Proceedings of the 5th International Conference on Indoor Air Quality and Climate, July 29 – August 3, Toronto, Canada, 15-33.
8. Budaiova Z., Vilcekova S. and Kapalo P. (2014), Indoor environmental quality and productivity in open space office, Civil engineering 2014, Proceedings of the second international conference for PhD students in civil engineering and architecture, December 10-13 2014, Cluj-Napoca, Romania, 496-502.