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Level and Formation Peculiarities of Chemical and Physical Pollution in the Workplaces

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The use of computers, printers, copiers, other electronic equipment and technological processes increases indoor air pollution. Traditional collection of previous home and office air pollutants as sulphur dioxide, carbon monoxide, dust and alike is enriched with other pollutants as ozone, volatile organic compounds, noise, ultraviolet radiation. The growing use of office equipment in combination with health concerns and limited evidence whether and how this equipment can emit harmful chemicals demand systematic research into pollutant emissions from office equipment.

The measurements were carried out in the workplaces (in welding and copying premises) to estimate noise pollution, the level of ozone and aerosol number concentrations, the microclimate parameters (temperature, relative humidity). The sound level in the copying premises increased up to 75 dBA and mostly simultaneously varied with the aerosol particles and ozone concentration. During the copying machine non-working hours the ozone concentration varied about 4 μg m^{-3}, and the aerosol number concentration was up to $40 \cdot 10^6$ m^{-3}. When copying was performed the ozone concentration increased from 1 up to 270 μg m^{-3} and the aerosol number concentration exceeded $(10–315) \cdot 10^6$ m^{-3}. The results have shown that ozone concentration in a welding room can increase up to 1850 μg m^{-3} and UVB radiation intensity up to 1.78 mW cm^{-2}. It is established that the correlation coefficient between these parameters was 0.99 during the analyzed period. No increase in the thermal and noise pollution above the limited level associated with copying has been determined

Keywords: *noise, temperature, relative humidity, pollution level, ozone concentration, aerosol number concentration, workplace*.

1. Introduction

Ambient air pollution is recognized as an important problem, both nationally and worldwide. The outdoor air pollution has been observed since the industrial revolution and only later indoor pollution has become another major concern. High chemical and physical pollution level is traced in many workplaces. People can be exposed to very high levels of pollution for 3–7 hours daily over many years (Engle et al. 1997), because some activities can lead to indoor air pollutant levels up to 1000 times higher than outdoor levels (Hetes et al. 1995). Computers, printers, copiers and other electronic equipment are a common part of the home and office environment nowadays. Determination of the contribution from any one type of equipment to indoor air pollution is a complex matter (Wolkof 1999). Mounting application of office equipment can lead to an increase in physical and chemical pollution. Human exposure to potentially harmful pollutants emitted from the office equipment has not been systematically evaluated and currently it is not well realized. Office equipment is found to be a source of ozone, particulates, volatile organic compounds (VOCs) and semivolatile organic compounds (Carslaw&Wolkoff 2006). It can also be the source of physical pollution, such as sound, smell, thermal pollution and radioactive radiation.

Concentration of indoor pollutant depends not only on its indoor emission rate, but also on the rate at which it is being transported from outdoors to indoors, and the rates at which it is scavenged by indoor surfaces, consumed by indoor chemistry and removed by ventilation or filtration (Weschler 2009).

The outdoor ozone concentration in Lithuanian conditions is not high (Girgždienė 2007), and the level of 120 μg m^{-3} is observed only less than 10% of time per year. According to the Directive 2008/50/EC such level in the atmospheric air is not dangerous for human health. Nowadays there are different requirements for the air in the workplaces. According to the Lithuanian hygiene standard HN 23:2007 the threshold of ozone concentration in the workplace air should not exceed 200 μg m^{-3} during work hours.

Laser printers and photocopiers generate ozone in varying amounts (Lee et al. 2001, Leovic et al. 1998). Toner and paper dust from printing devices become airborne resulting in the generation of respiratory particles, including ultrafine aerosol particles (Wensing et al. 2006).

Ozone is being formed during the copying process when a photoreceptor and paper are inserted or discharged, and also when UV lamp operates during photocopying (Black&Worthan 1999). Mostly, indoor air concentration of ozone varies between 1 and 100 μg m^{-3} (Kephalopoulos et al. 2007). The emission rates from photocopiers are much higher than from printers (Destaillats et al. 2008). Even low levels of ozone emitted by printers and copiers can combine with the other commonly present indoor VOCs, triggering the formation of harmful secondary pollutants and ultrafine aerosol particles (Destaillats et al. 2006a, Destaillats et al. 2006b, Singer et al. 2006). Ultrafine particles (<100 nm) predominated in every case: the measured particle numbers were in the range $(50-34300)\cdot10^6$ m^{-3} for particles >7 nm, but significantly lower $(6-3.800)\cdot10^6$ m^{-3} for particles >100 nm (Destaillats et al. 2008). Ozone may react with unsaturated VOCs to produce a number of relatively reactive compounds. Some of these products may have low odour or airway irritation thresholds (Weschler&Shields 1997, Wolkoff et al. 1997).

Today welders use highly technical welding processes that can create dangerous conditions in their workplace. Welding fume is a mixture of very fine particles and gases (Lyttle 1998). Most of the common welding fume components include ozone, carbon monoxide, nitric oxide, phosphide and phosgene. Welding can be a major source of ultraviolet radiation, intense visible light and some infrared irradiation. Ozone is produced by reaction between UV light from the arc and oxygen in the air; it is especially intensively generated during arcing and then it quickly decays on the arc extinction (Ojima&Shibata 2000). During the gas shielded arc welding, approximately a half of all the ozone generated is formed within a 100−150 mm radius from the arc, outside the gas shield in the proximate zone (Jenkins et al. 1981). The radiation in wavelengths 175−242 mm are more penetrating, but less efficient in ozone production. The radiation of the shorter waves, namely, from 290 up to 320 nm, is called UVB, it damages the main nucleus of human life – desoxyribonucleic acid (DNA) (Diffey 1987).

As it is mentioned above, in addition to chemical pollution the physical pollution, as noise, vibration, non-ionizing radiation, temperature and relative humidity, odour can simultaneously exist in workplaces. Noise is becoming a major public health problem. Bothering and long-term noise even not exceeding the established standards may be the reason for physical and mental adverse health effects. The permissible sound level in a workplace is 85 dBA during 8 work hours. When the intensity of sound is 70 decibels, human performance decreases by 3.8 %, when 80 decibels − by 5.2 % and when 90 decibels – by 12.2 %.

The use of much equipment can simultaneously increase the air temperature in work premises. Temperature, humidity, ventilation and lighting are major determinants of comfort in the workplace. The World Health Organization recommends 24 ^{o}C as the maximum temperature for working in comfort. Low levels of humidity can exacerbate respiratory and skin conditions for workers. There may also be a build up of static electricity in dry air resulting in electrostatic shocks. Comfortable conditions are created by varying relative humidity between 40 and 70%.

Recent evidence suggests that increased contact with office equipment leads to higher doses and tissue levels of these pollutants. Office workers have frequently reported specific symptoms including eye, airway, and throat irritation, and more general symptoms of headache, fatigue, and nausea (Wolkof 1999). It is known (Mendell et al. 2002, Wolkoff et al. 2006) that ozone and particulates have been associated with occupational symptoms such as eye, nose or throat irritation, headache and fatigue. Noisy environment has a significant effect on humans: they may experience ear ache and increased irritability as well as fatigue. Long-term intensive noise may cause diminished hearing or deafness.

The research object and goal: to study the level and formation peculiarities of some chemical and physical pollution in the workplaces.

2. Research methods

Ozone and aerosol particles concentration, UVB radiation, noise, ambient temperature and relative humidity have been measured in the work premises containing the ozone emission sources, i.e. copying and welding machines.

Ozone concentration was measured with commercial ozone analyzer $O_3$41M. Limits of the concentration with this analyzer were 0–2000 μg m^{-3}

and sensitivity – 1 μg m^{-3}. The air was sucked through a Teflon tube at a flow rate of 1.6 l min^{-1}.

Ozone and aerosol particles concentrations, parameters of microclimate in the room were measured continuously by averaging 5 minutes data. An analogue signal was converted into digital by converter ADC-16.

Aerosol counter AZ-5 was used both for measuring the number concentration of D > 0.4 μm aerosol particles and for estimation of the spectrum of particles in the premises.

The measurements of UVB radiation intensity have been carried out by radiometer PMA 2200. The sensor's sensitivity is 50 mWcm^{-2}; the error of this device does not exceed 3 %.

DrDAQ data logger with the installed temperature, relative humidity and noise detectors was applied in order to ascertain microclimate parameters. Measurements of these parameters were carried out at the height of 1.70 m, i.e., at the height of the operator's breathing and hearing zone.

3. Research results

The variations of main measured parameters during five working days are presented in Fig. 1. In the workplaces the sound level lower than 55 dBA is considered to be safe, therefore it was accepted as a background level in the room. Such level was monitored in the premises when copying was not performed in the daytime and during the night hours. The data analysis proved that copying was the main source of the noise in the room. The sound level began to grow when operators switched on the equipment and copying procedures started, and when copying was stopped the sound level dropped rapidly to that of the background. During the experiment in the copying premises the sound level increased up to 75 dBA. Such level is permissible in accordance with the requirements of the hygiene standard. It was noted that sound level variation was observed simultaneously with the aerosol particles and ozone concentration change (Fig. 1), whereas the data analysis showed that increased ozone and aerosol particles level (Fig. 1) was a result of the work process. During the working hours the ozone concentration in the office premises varied from 2 up to 270 μg m^{-3}, while the aerosol number concentration exceeded (10–315)·10^6 m^{-3} The ozone night concentration in the office premises varied about 4 μg m^{-3}, and during non-working hours the aerosol number concentration was up to 40·10^6 m^{-3}.

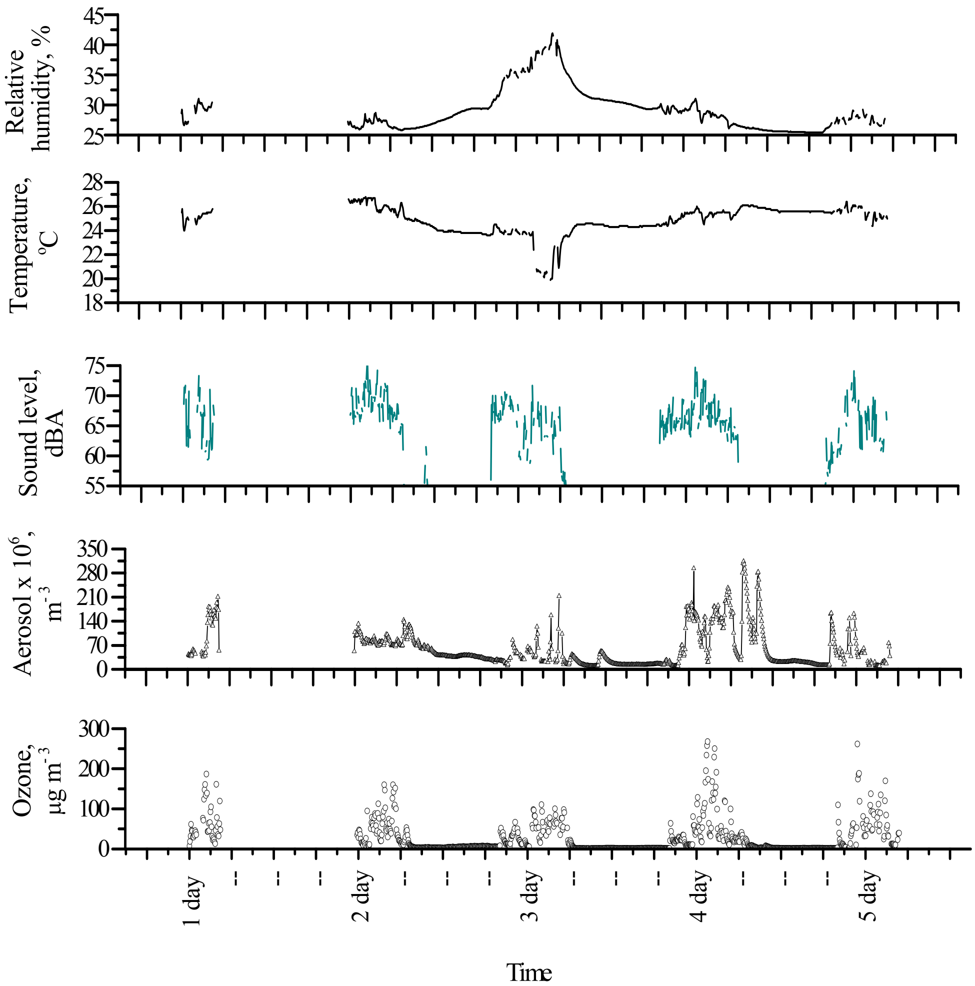

Fig. 1. Variation of the sound level, ozone and aerosol particles concentrations, temperature and relative humidity in the workroom

Analysis of the ozone concentration and the sound level during a workday showed that their variation characters were similar, only a decrease or increase in the ozone concentration was with the time lag of some minutes. This is due to the operation characteristics of an ozone analyzer which shows the concentration that has been observed approximately two minute ago.

The temperature and relative humidity can be attributed to the group of the main parameters describing the microclimate in the workroom. They are the factors which have a significant effect on human comfort conditions. In terms of human physiology the neutral temperature is 21 ºC. During the cold period of a year, when the experiment was performed, relative humidity should be 40–60 % and the temperature should be in the range of 18–23 ^{o}C in the working premises. During the experiment, the temperature varied from 20 to 27 ºC, and the relative humidity varied from 25 to 42 % (Fig.1). The results have shown that the temperature and relative humidity are practically not related to the working process; only insignificant changes of these parameters have been observed within 24 hours which can be linked with the operation. It should be noted that relative humidity in the premises was low, and its increase was measured on the third day when the window was open and the airflow from outdoors was observed. During the working hours both the temperature and relative humidity varied within the narrow limits. The results have shown that the relative humidity was lower than the value recommended for working premises, while the temperature was within the permissible limits and its value exceeded these limits only one day.

Another situation was established while analyzing the indoor air pollution by ozone and aerosol particles. The obtained data have shown that the level of sound, ozone and aerosol number concentrations depends on the intensity of copying. The average values of ozone, aerosol number concentration and the sound level in the room depending on the intensity of copying are presented in Fig. 2.

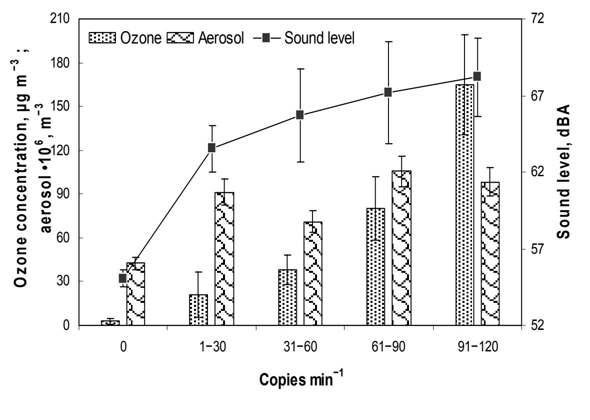

Fig. 2. Sound level, ozone and aerosol number concentration during different copying intensities

The maximum ozone concentration, i.e. 165 μg m^{-3}, was measured when the copying intensity was 91–120 copies per minute. Aerosol number concentration also increased in the premises with the growing copying intensity. Only in case of automatic copying, when the intensity was maximal (91–120 copies per minute) and pages were not changed manually, the aerosol number concentration decreased in comparison to the intensity (61−90 copies per minute).

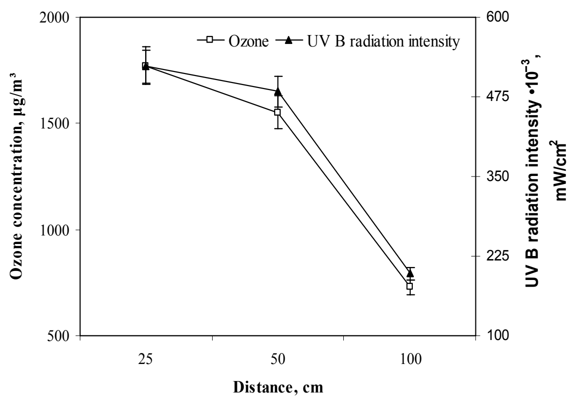

Fig 3. Changes of ozone concentration and UVB intensity

Studies of the variation of pollutants have been carried out in the welding premises. Ozone emission from a welding machine and intensity of UV radiation were measured at different distances from the electrode (0.25, 0.5 and 1 m) (Fig. 3.).

Ozone concentration and UV radiation intensity were unevenly distributed in the welding room. When no welding operations were performed, ozone concentration was close to 0 μg m^{-3}. The highest concentration was detected at a distance of 25 cm from the electrode, it was 1850±20 μg m^{-3}; and the most intensive UVB radiation was 0.6±0.018 Mw cm^{-2} (Valuntaitė et al. 2008). It was established that the correlation coefficient between ozone concentration and UVB radiation intensity was 0.99 during the analyzed period.

4. Conclusions

1. Ozone and aerosol number concentrations, sound level and UVB radiation in the workplaces (copying and welding rooms) are closely related to the intensity of work processes.
2. No increase in thermal and noise pollution above the limited level associated with the copying has been established.
3. The ozone concentration in the workplaces has exceeded the limit (200 μg m^{-3}) value specified in HN 23:2007 by 1 % and 40 % of working hours during the copying and welding, respectively.

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Fizinės ir cheminės taršos lygis ir susidarymo ypatumai darbo patalpose

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Patalpose naudojimasis kompiuteriais, kopijavimo mašinomis ir kitais elektros prietaisais, taip pat kai kurie technologiniai procesai didina patalpų oro taršą. Namuose ir įstaigose gausu oro teršalų: sieros dioksido, anglies monoksido, dulkių, taip pat ozono, lakiųjų organinių junginių, triukšmo, ultravioletinės spinduliuotės. Dėl didėjančio naudojimosi biuro įranga ir galimo jos poveikio sveikatai, taip pat dėl to, kad trūksta įrodymų, ar ši įranga gali išskirti žalingus cheminius junginius, reikalingi sistemingi teršalų emisijos nuo biuro įrangos tyrimai.

Tyrimai atlikti suvirinimo ir kopijavimo darbo patalpose vertinant fizinę (triukšmą) ir cheminę taršą (ozono koncentraciją, aerozolio dalelių kiekį) ir mikroklimatines sąlygas (temperatūrą, santykinį oro drėgnį). Atliekant tyrimą, triukšmo lygis kopijavimo patalpoje kito iki 75 dBA. Reikia pažymėti, kad jo lygis kito dažniausiai kartu su aerozolio dalelių ir ozono koncentracijomis, t. y. kai veikdavo kopijavimo aparatas. Kopijavimo aparatų ne darbo metu ozono koncentracija biuro patalpoje svyravo ~4 µg m^{-3}, o aerozolio dalelių ne darbo metu rasta iki $40 \cdot 10^6$ m^{-3}. Darbo metu ozono koncentracija biuro patalpoje kito nuo 1 iki 270 µg m^{-3}, o aerozolio dalelių – $(10–315) \cdot 10^6$ m^{-3}. Tyrimai parodė, kad suvirinimo patalpoje ozono koncentracija gali siekti 1850 µg m^{-3}, o UVB spinduliuotės intensyvumas − 1,78 mW cm^{-2}. Tiriamuoju laikotarpiu tarp ozono koncentracijos ir UVB spinduliuotės intensyvumo nustatytas koreliacijos koeficientas 0,99. Su kopijavimo aparatu susijusio terminės taršos ar santykinio oro drėgnio padidėjimo nenustatyta.