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NON-INDUSTRIAL INDOOR AIR QUALITY AND DEVELOPMENT OF BASIC METHODS FOR THE OCCUPATIONAL RISK ASSESSMENT

Summary of Doctoral Thesis
Speciality – Occupational and Environmental Medicine

Riga, 2012

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Doctoral thesis were elaborated in Riga Stradiņš University (RSU) Institute of Occupational Safety and Environmental Health, Laboratory of Hygiene and Occupational Diseases, RSU Laboratory of Biochemistry, RSU Institute of Anatomy and Anthropology, RSU Laboratory of Experimental animals, University of Latvia (LU) Laboratory of Bioanalytical methods and LU Faculty of Biology, Department of Molecular Biology.

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The doctoral thesis is available at the library and home page (www.rsu.lv) of Riga Stradiņš University.

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Council secretary: *Dr. habil. med.*, Professor **Līga Aberberga-Augškalne**

CONTENT

1. TOPICALITY OF THE PROBLEM

The work characteristics, technology and tools are constantly changing, especially in countries such as Latvia, where since the early nineties the occupational environment is developing. Number of employees in offices and other non-industrial work places (public and commercial institutions) are increaseing.

Indoor air quality is an important public health factor what influence persons' health and well-being. Indoor air quality is closely related to the environmental air problems. The focuse of particular attention in Latvia is individual chemical compounds monitoring in urban areas (Rules of Cabinet of Ministers determine allowable values of chemicals for outdoor air air quality). There is also focus on the industrial working environment - air quality in the workplace, but very few indoor air quality parameters are evaluated and studied in non-industrial workplaces of Latvia.

There are focused on non-industrial work environment (mostly - in offices) and are evaluated ergonomic risk factors (work computer), the lighting in the workplace, microclimate indicators, and in rare cases, when copying is measured ozone and nitrogen dioxide in Latvia. It should be noted that non-industrial indoor air pollution could cause many different risk factors, which are not well evaluated and analyzed. Therefore does not identify key issues and priorities of non-industrial work environment in Latvia.

Indoor air quality is characterized by physical (microclimate: air temperature, relative humidity, noise, lighting, etc.), chemical (dust, inorganic compounds: formaldehyde, carbon dioxide, organic compounds, etc.) and biological (dust mites, molds, etc.) pollutants. Much attention in the world is given to a very fine dust particles (PM_{10}, $PM_{2.5}$ and $PM_{0.1}$, where the PM - *Particular matter* - particulates with a diameter of 10 mm, 2.5 mm and 0.1 mm or 100 nm - nanoparticles) in ambient and occupational environment. Dust particles, especially nanoparticles, are identified as one of the emerging risk factors of occupational environment. Because the particles are finer and there many of them in the air their active surface area is greater. It is important to note the importance of the chemical composition of dust particles [*Maynard et al., 2003, Maynard et al., 2005*]. From the environmental point of view the identification of risk factors in offices and similar type of jobs are very much uncertain and will not consider the aspects related to the new office equipment, technology and air-conditioning equipment. The new chemical pollutants in indoor air are different types of nanoparticles such as carbon, etc. chemical compound nanoparticles, polybrominated diphenyl ethers used as flame retardants in printing plants, phthalates, volatile organic compounds released from detergents, synthetic building and decoration materials, and the use of personal hygiene products [*Andersson et al., 1998, Schecter et al., 2005, Wolkoff, Wikins et al., 2006, Morawska, He, et al. 2007*].

The literature referrs that the major health problems for office workers and other non-industrial workplace representatives are fatigue, headache, dizziness, dry skin, irritation of mucous membrane, cough, watery eyes, allergic rashes, colds, etc. [*Wolkoff, Nojgaard et al. 2006*]. Noting the dust particle health effects, epidemiological studies have found correlation between environmental contamination with dust particles (PM10, PM2, 5) and an increased incidence of acute lung and heart - cardiovascular diseases and exacerbation of chronic diseases, the immune reduction of organism, promotion of atherosclerosis development and of the role of other diseases development [*Cormier et al., 2006, Wolkoff, Nojgaard et al., 2006*]. However, dust particles are not enough investigated, including adverse effects of nanoparticles in non-industrial environment and the health of workers, quality of life, work capacity and productivity.

There are little research in the world on nanoparticle exposure in the occupational environment and the information is controversial about the nanoparticles health effects related with nanoparticles chemical composition, structure, and induced effects. Very small size (1-100 nm) due to its ability to penetrate from the respiratory tract into the bloodstream and cells, and cause significant health problems. Open is the question of the toxicity of nanoparticles and correlation with particle properties. The assessment of harmful effects caused by the nanoparticles are used markers of inflammation and allergies, but there is lack of comprehensive information about nanoparticle effects on different biological processes (oxidative stress, cancer etiology, DNA damage) [*Oberdörster et al., 2005, Maynard et al., 2005, Cormier et al., 2006*]. The studies of nanoparticle toxicity are very topical with development of technology (especially nanotechnology) and the production of materials.

It should be noted that non-industrial workplace indoor air quality is characterized by lower pollution levels compared with the industrial occupational environment. The urgent problem of industrial hygiene is the risks of different pollutants influence with different levels of exposure to the employees' health. Therefore is necessary research and common aproach is necessary for assessing the potential risks in non-industrial workplaces and correct acceptable values setting in Latvia.

There are not sufficiently updated risk factors for non-industrial work environment, the lack of information and specific guidelines for non-industrial indoor air quality assessment used by environmental experts, employers, workers and society as a whole in Latvia.

Objective of the Thesis

- To assess indicators of the non-industrial workplace indoor air quality and their evaluation methods
- To establish the basic methods for evaluation of the non-industrial indoor air quality and employeers health.

Tasks of the Thesis

- To collect information on non-industrial indoor air quality indicators and evaluation methods, and select the most important quality indicators and methods for non-industrial indoor air quality assessment.
- To collect information on non-industrial work environments present nanoparticles toxicity, mechanisms of action and potential biomarkers to select the most appropriate health indicators that could be used in preventative medicine.
- To perform experimental evaluation of potential effects on the body caused by the office equipment (printers, copiers) pollution to determine very small dust particles (nanoparticles) transport in the body, the precipitation of certain organs and the body's response.
- To provide survey among office employees and to analyze the relationship between employees' health complaints and indoor air pollution levels in offices.
- The establishemnet of complex basic methodes in non-industrial indoor air quality risk assessment and impact on the health assessment.
- To prepare a draft proposal for non-industrial indoor air quality performance standards values based on studies and experience of other countries.

Hypothesis of the Thesis

- Dust particles (including nanoparticles) leads to a higher indoor air pollution in the non-industrial occupational environment (offices).
- Fine dust particles (also nanoparticles) deposition in the organs of laboratory animals (rats) and cause the functional disorders.
- Polluted indoor air in offices cause a negative impact on office workers' health.

Scientific Novelty of the Thesis

1. Qualitatively and quantitatively identified occupational risk factors related to the widely used office equipment and technologies:
   - ✓ nanoparticles (carbon and other chemical compounds),
   - ✓ defined particle size, number, surface area is essential indicators to assess nanoparticle toxicity.
2. Complex indoor air quality evaluation is done for the first time in Lativa and correlations of indoor air quality measurements with employees' complaints in non-industrial workplaces of Latvia are performed.
3. Objective experimental studies *in vivo* and *in vitro* identified effects of office indoor air pollution on the body confirming the potential risk to human health.

Practical Significance of the Thesis

1. Most important indicators of indoor air quality in non-industrial occupational environments (offices) were identified with reference to their evaluation methods and complex occupational risk assessments of the basic principles/criteria in thesis were developed.
2. Thesis is the basis for indoor air quality guidelines and the establishment in Latvian including the requirements for the evaluation procedures, determinable standards and values. Acceptable values (OEL – occupational exposure limit) were developed for air quality indicators of the industrial work environment, but they do not apply to non-industrial environments (office and administrative work) in Latvia, because the work charectization and equipment vary considerably. The indoor air quality indicators can be adapted for housing, schools and other public spaces.
3. Thesis provides the key principles and indicators for assessing the interactions between health and indoor air quality.

Volume and Structure of Doctoral Thesis

Doctoral paper is written in Latvian language. It consists of 8 parts: Introduction, Literature review, Materials and Methods, Results, Discussion, Conclusions and Practical Recommendations, Bibliography. Doctoral Thesis is 162 pages long, including 86 tables and 75 figures. Bibliography consists of 161 references. Doctoral paper has 10 appendices. There are 7 publications in connection with the topic of doctoral thesis.

2. MATERIALS AND METHODS

General description of the study: there are summarized prospective cohort study data (cohort - the office staff), as well as animal and cell experiment data in thesis. The study was conducted using indoor air measurements, survey and experimental data.

The quantitative data (measurement) description of study: the measurement of non-industrial work environment were carried out from December 2009 to September 2011 in Riga, Acone, Salaspils and Kegums in different types of offices (banks, public and private offices), which deals with the preparation of documents, intensive use of electronic media, as well as customer service: virtual (e-mail, telephone) and on-site (customer service centers, etc.).

The selection of offices were based to availability - on a voluntary basis, it means that the procedure of measurements were carried out in coordination with responsible persons acceptance. During the study, measurements were carried out in 10 offices and copy shop.

Financial and technical reasons prohibited to include a greater number of offices around all Latvia reagions. During selection of offices following factors were taken into account: location of office space (areas of heavy traffic, industrial activities), copying / printing activities in the premises (a copy machines and /or printers), office type (open-plan office and /or close offices) ventilation system (yes/no mechanical ventilation), room characteristics (furniture, flooring, wall/ceiling finishes, cleaning schedule). Indoor air quality measurements were performed at workplaces in offices. A total of 14 offices were carried out chemical measurements in the indoor air, but 24 premises were taken microclimate (relative humidity, air temperature, air flow rate) measurements.

During study measurements of the following parameters were carried out: air temperature, relative air humidity, air velocity, carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), volatile organic compounds (VOC's), aldehydes, the dust particle number and surface area.

2.1. The assessment methods of dust particles

The concentration of dust particle surface area in the premises was determined using the equipment "AeroTrak 9000" (nanoparticles size: 10 - 1000 nm), while the particle count concentration was determined using equipment "P-Trak ultrafine Particle Counter" Model 8525 (particle size: 20 - 1000 nm). Particle surface area was determined in two fractions: TB-traheobronhial (particle size <1000 nm) and A-alveolar (particle size

<250 nm). All data were analyzed using specific programm tools for statistic and data imaging. Normative values for dust particles/nanoparticles concentration evaluation by number and surface area is not yet established, but according to the foreign experts and laboratories (Germany, France, Finland) experience, the results are compared with the background data (area without investigational activities, a room on weekends, outdoor air pollution). In study, the comparison was made with the "cleanest or reference room."

2.2. The assessment description of chemicals

During the study were identified 19 different groups of volatile organic compounds (VOC), aldehydes (formaldehyde, acetaldehyde, propilaldehyde, butilaldehyde and benzilaldehyde), alkanes (hexane, propane, ethane, and methane), aromatic hydrocarbons (toluene, xylenes, and ethylbenzene), alcohols (ethanol, isopropanol), ketones (acetone), esters (ethyl acetate, butyl acetate, dibutyl phthalate). Overall the following indoor air chemicals were detected: NO_2 (number of measurements, n = 61), SO_2 (n = 58), O_3 (n = 55), acetaldehyde (n = 55), formaldehyde (n = 55), propilaldehyde (n = 55), butilaldehyde (n = 49), benzaldehyde (n= 52), methane (n = 30), ethane (n = 42), propane (n = 41), ethanol (n = 37), acetone (n = 45), izopraponals (n = 53), hexane (n = 6), ethyl acetate (n = 43), butyl acetate (n = 22), toluene (n = 53), hydrocarbons (total of carbon (C)) (n = 56), ethylbenzene (n = 24), xylenes (n = 21), dibutyl phthalate (was identified and fixed in the copier/printer powder dust, n = 9).

Chemical measurements were carried out according to the following principle: the employee's work (on/near the table) and at the copier or printer. Measurements were made the each day per room - over the day. Each measuring point, in accordance with legislation, were taken three parallel air samples, except for CO_2 and microclimate measurements where the measurement points were selected depending on the area of premises (5 to 25 measurement points), the results were added together and averaged.

2.3. The assessment methods of volatile organic compounds

Working environment of air samples taken in the breathing zone of employees working in offices throughout the day with individual air-sampling devices "Gilian LFS - 113DC", the carbon tubes "ORBO TM - 32". Copier generated dust samples were collected from the surface of the copier (400 cm^2) with medical cotton swabs. The prepared sample analysis was performed by gas chromatography “VARIAN 3800” with an automatic sample injection system" CP8200 ", the analytical signal was obtained with a flame ionization detector (FID) and gas chromatography" Agilent 6890N "with masspectral analyzer" Waters Micromass. "

The reference values of air quality are used to detect possible effects of pollutants on the organism: World Health Organization (WHO) guidelines for indoor or outdoor air quality regulations and the Latvian Cabinet of Ministers Regulation Nr.1290 "Regulations on Air Quality" (adopted 11/03/2009). Those chemical substances which are not indicated by the first two documents are evaluated by the standard of the Russian Federation (ЃH2.1.6.1338-03), where are set the maximum concentration values for the atmospheric air.

Evaluation method of aldehydes: the environmental air samples were taken in the breathing zone of offices' workers with individual air-sampling devices Giliar, with aldehyde sorption cartridges Sep-Pak DNPH-Silica Cartidges and the reagent saturated glass fiber filters. Chromatographic analysis of aldehydes was carried out in high efficiency liquid chromatography (HPLC), Waters Alliance 2695 with an automatic sample injection system, the instructions of the method (NIOSH: 2018 and ISO 17735:2009).

2.4. The assessment methods of inorganic gases (NO_2, SO_2, O_3)

Inorganic gases in the office air pollution were took the through the analyte solution with absorbent for each gase. The determination of nitrogen dioxide (NO_2) (Method MN 1-5, Nr.1638, page 60), sulfur dioxide (SO_2) (BS:EN 1231) and ozone (O_3) (Method T-049-V) were done in indoor air. The absorbing solution air samples were analyzed using a spectrophotometer Varian Cary 50. Carbon dioxide (CO_2) was estimated using the "Test 400" probe. The measurements sampling and testing were performed in accordance with standards BS EN 689:2004 L "Workplace air and startegy of measuring" and BS EN 482:2006 A" Workplace atmospheres. General requirements for chemical measurement." The obtained results were compared with Nr.1290 the Cabinet of Ministers "Regulations on Air Quality" (03.11.2009.) and "Indoor Air Quality in Office Buildings: a Technical Guide", 93-EHD-166, Canada, 2003.

2.5. The assessment methods of indoor air quality

Indoor air (microclimate) parameters were done 0.6 m above the floor using the "Test 400" probe measurements taken every hour over the work shift, according to standart BS EN ISO 7726:2004 L and Testo guidelines. The measurement results were compared with the Cabinet of Ministers rules No. 359 "Labour protection in the workplace" in accordance with Annex 1, Table I, the category (light load job tasks), the requirement of microclimate: 1) the cold period of year: from +19.0 to +25.0 (air temperature (° C)), 30-70 (relative humidity (%)), 0.05 to 0.15 (air velocity (m / s)), 2) the warm period of year: from +20.0 to +28.0 (air temperature (° C)), 30 – 70 (relative humidity (%)), 0.05 to 0.15 (air velocity (m/s)).

2.6. The assessment and statistical methods of chemicals and microclimate

The one of the most popular methods for chemical evaluation was applied in study, it is the determination of chemicals exposure index (EI), in accordance with the rules No. 325 "Labour protection in contact with chemicals in the workplace", where is described (in 17. point) calculation of the exposure index: dividing the chemical concentration (occupational exposure levels) in the workplace air with the occupational exposure limit (TWA). This principle was applied to evaluate indoor air quality results and the recommended value of chemicals, for examples, the CO_2 (carbon dioxide) concentration was found 3200 mg/m^3 in room, but the recommended indoor value for CO_2 - 1830 mg/m^3, then EI = 3200/1830 = 1.8. In order to characterize the indoor air quality results were determined following exposure index levels: low exposure index (EI <0.5), medium exposure index ($EI \leq 0.5 \leq 0.75$), high exposure index (0.75 <EI <1), very high exposure index ($EI \geq 1$).

If the actual concentration of indoor air is greater than one, then it is probable that these substance concentrations can cause adverse effects on employee health. The doctoral thesis is considered that increased risk of adverse effects to the health of workers exist when the EI is high or very high.

The data was analysed by Microsoft Excel and SPSS for Windows 19.0 version to use statistical methods. The results of measurement for further processing of statistical data were recorded in both Excel and SPSS for Windows 19.0 program. The results was verify achieved against a normal (Gaussian) distribution using Kolmogorov - Smirnov test (KS test). As the indoor air measurements did not obey the normal distribution, the results were statistically processed using parametric methods for data processing. The descriptive statistics analysis was used (arithmetic and geometric mean, median and dispersion (standard deviation) values) in thesis. The results comparison was done using parametric method: Mann - Whitney (Mann-Whitney U test) test. The relationship between chemical evaluation and health complains was analysed with the Pearson's correlation (r^2).

2.7. Methodology of survey

RSU Ethics Commission gave permission to carry out surveys and experiments.

The survay was realised from December 2009 to May 2011 among office workers on a basis of voluntary and availability. Before survey office staff were informed that participation in survey is voluntary and all data will be used only for research purposes. The survey was anonymous and was completed manually. The office workers from offices in Riga also from Jelgava, Salaspils Acone, and Kegums participated in the survey. The study included 12 companies with 48 offices (rooms). Total 1221 questionnaires were distributed, but only 895 questionnaires were completed and it is representing 73.3%.

The subjective health assessment of office employees was based on the questionnaire what developed in Sweden (Örebro-MM40) for indoor air quality assessment. This questionnaire was translated and adapted in Latvian.

The questionnaire consists of 37 (a sub-part question) mainly closed questions on the following topics: part I. General information: the identity of the respondents (gender, age, education, employment sector, occupation, smoking habits, etc.) Part II. Job Description: information on length of job experience, jobs and facilities characteristics, frequency of use of office equipment, etc.; Part III. Health and wellness description: details of the approved medical diagnoses, the presence of symptoms etc.; Part IV. Work environment characteristics: data about air temperature, humidity, flow, presence of the chemicals, ventilation systems, etc.

All completed questionnaires were coded and entered into established matrix of SPSS for Windows 20.0 program. The main descriptive statistics of survey results were calculated: arithmetic mean, standard deviation, minimum and maximum values (measurements), the median, moda. For the purpose of statistical data processing, for the survey responses such as "never," "sometimes," "often" were given a numerical values (coding), respectively, one, two, and three.

Chi-square test (χ^2) was used to determine whether the results are in accordance with the normal distribution or not, and to test the statistical characteristics of the two independent of each other. For significantly different results were considered to be those with the significance level was less than 0.05 ($p < 0.05$).

Pearson's correlation (r^2) was used to determine the relationship between positive health complaints and responses to specific work environment factors.

Odds ratio with 95% confidence interval (Odds ratio with 95% Confidence Interval (CI)) was used to calculate what the employees likely to get health problems if they are or not exposed to occupational risk factors and exposure to other activities. Odds ratio calculated based on the influences of the work environment and symptom /complaint surveillance. Office workers were grouped according to occupational exposure factors, dividing them into two groups, for example, and exposed and unexposed workers too low humidity in offices. Employees were also divided into 2 groups according to health complaints/symptoms: observed or not observed specific health complaints. To create this group, was recoding data, where the answer, for example, "has not been observed in recent times" - there is no exposure, and the answers "1-3 days in the last month", "1-3 days per week last month", and "every or almost every day per last month" - it is considered as exposure. Health complaints/symptoms were re-coded, where the answer "never" meant that the health claim is not observed, but the answers "occasionally" and "often" meant that the office staff observed health complaints/symptoms. For odds ratio calculation using SPSS for Windows 20.0 program.

Multinominal logistic regression (MNLR) - used in cases where there are several independent variables that can affect the dependent variables and need these variables weighted with each others. Using multinominal logistic regression is possible to find a more reliable variable dependence on independent variables. The significant independent variables affecting by the dependent variables are considered, all variables with the significance level less than 0.05 ($p < 0.05$). Odds ratio (OR) was obtained using multinominal logistic regression which shows how the increases or decreases the chances. The reference value for regression was used respondents who have not observed health complaints. MNLR calculation was done using SPSS for Windows 20.0 program.

2.8. Methodology of animal experiment

The study was carried out in conformity with international OECD (OECD - Organisation for Economic Co-operation and Development; Consider Animal Welfare in the Development of Test Guidelines) guidelines and good laboratory practice, as well as the Cabinet of Ministers rules No. 450 (01.02.2002.) „The order of animals use, trade and killing for experimental and scientific purposes" (02.01.2002.) No. 58 "The rules of laboartory methods for the characteristics of chemicals and chemical products in the physical, chemical, toxicological or ecotoxicological properties" (17.01.2006.). The study was received permission from the Ethics Commission of Food and Veterinary Service (Nr.19/11.03.2010.).

The study was conducted using the white rats of "Wistar" populations. The white rats were selected as most appropriate to evaluate all body's response of the office pollution. Total were used 25 adult white rats - males. Animals were divided into 2 groups: control group - 10 animals, the experimental group - 15 animals. Animals were kept in special cages – 10 rats per 1 cage.

The experiment was carried out under real indoor air conditions in office premise – the cages of the experimental group of animals were placed in copy shop (copying, printing, working with paper and computer). The cages were placed close to copying, printing equipment 8 hours per day 5 days a week (modeling the environmental exposure); during weekends, animals were moved to an area with low background levels. Every day the copy number of pages was listed (average: 3000 to 5000 pages per day). The room were not equipped with a ventilation system – just opening windows and doors did ventilation. Specific pollution was not generated. Exposure levels in the experimental area (copy shop) were as follows: dust particle surface area of alveolar fraction - 42.4 $\mu m^2/cm^3$ (range: 25.3 to 109.6 $\mu m^2/cm^3$), dust particles surface area of traheobronhial fraction - 12.6 $\mu m^2/cm^3$ (range: 8.7 to 22.6 $\mu m^2/cm^3$), volatile organic compounds - 0.9 mg/m^3 (average), formaldehyde (average) - 0.5 mg/m^3, ozone (average) - 0, 93 mg/m^3, NOx (average) - 0.12 mg/m^3, SO_2 (average) - 0.24 mg/m^3.

Control group of animals was held in a separate room without office equipment and common background level. Exposure levels of experimental control animal in space was as follows: dust particle surface area of alveolar fraction (average) - 12.5 $\mu m^2/cm^3$ (range: 5.3 to 19.6 $\mu m^2/cm^3$), dust particles surface area of the traheobronhial fraction (average) - 9.6 $\mu m^2/cm^3$ (range: 8.7 to 12.6 $\mu m^2/cm^3$), the volatile organic compunds level (average) - 0.1 mg/m^3, formaldehyde (average) - 0.05 mg/m^3 ozone (average) - 0.06 mg/m^3, NOx (average) - 0.04 mg/m^3, SO_2 (average) - 0.08 mg/m^3.

Duration of experiment - 28 days.

Every day was regularly assessed clinical and physiological changes - animal behavior, appearance, and food and water consumption.

Animal body weight was determined before the experiment and after every 7 days.

The blood tests of experimental animals were taken in the begining of the study and in the end of exposure and after that in the next day animals were euthanised by dislocation in halothane anesthesia.

At the end of the experiment, following tests were carried out:

- Analysis of bronchoalveolar surfactant (the qualitative and quantitative changes in lung and upper respiratory tract cells).

- The clinical analysis of blood (red cells and white blood cell count, hemoglobin, white blood cell counts). Haematological analyzer „Pentre 120" assessed hematologic parameters.

- Biochemical parameters (C-reactive protein (determined by the equipment "INTEGRA 400 +"), cytokines IL-1, TNF-a factor (analysed by ELISA kits).

- Oxidative stress factors (superoxiddismutase (SOD), malondialdehyde (MDA), glutathione (GSH), lipid hydroperoxide (LOOH).

- Assessment of indicators of immune system (T, B cell analysis, assessment of circulating immune complex, immuno-competent relative weight ratio of organs (thymus and spleen).

From euthanised, animals were taken:

- Immuno-competent organs (thymus and spleen), weighted and determined the relative weight ratio.

- Histopathological examination of nasal, tracheal, bronchial tisues (cytokines, IL, TNFa, anti-microbial peptide defensin-2, cell apoptosis).

The results of animal experimental was carried out using Microsoft Excel software, determining the average value, standard error, t - test of Student ($p<0.05$) and nonparametric data analysis test – Mann-Whitney test ($p <0.05$). The data were statistically processed using Microsoft Windows Excel and SPSS for Windows 20.0 program.

2.9. Methodology of cell experiment

Preparation of dust particles for experiment: dust samples were collected from the office equipment (printers/copiers) and in the physiological solution were prepared dust particle material for experiment.

Peripheral mononuclear blood cell isolation: blood samples (16 ml) were taken from three "practically healthy" people. Peripheral mononuclear blood cells were isolated from blood samples using Ficoll gradient and centrifugation the obtained sample material.

Nanoparticles produced by office equipment through the lungs penetrating into the blood, was modeled impact of two indoor air concentrations of dust particles on peripheral mononuclear blood cells.

Experiment with dust particles and peripheral mononuclear blood cells: Six field plates with 0.5 million cells and 2 ml of media (RPMI + 10% FBS): two field plates - control (no dust particles), two - the largest concentration of dust particles (0.05 mg/ml) and two - the smallest dust particle concentration (0.03 mg/ml). All 6 field plate with the experimental material was incubated at 37 °C and 5% CO_2, and after 72h the cells were unrealized using TRIzol, isolated RNA and derived complementary DNA, and with semi qualitative method determined polymerase chain reaction, to determining the interleukin 6 (IL-6) expressions in 1.5% agarose gel electrophoresis and treated by ethidium bromide solution.

Visualizing of dust particles in cells: cells were “painted” with different colors (MitoTracker Red CMXRos (mitochondrial staining), Alexa Fluor 488 phalloidin (cells’ actin staining) and Confocal microscope were used to visualize the structure of cells.

3. RESULTS

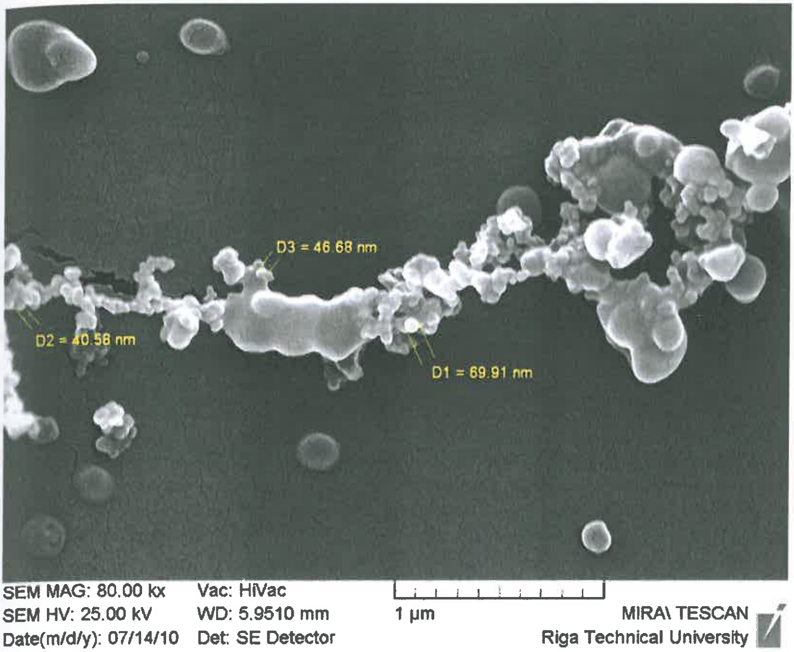
Potential impact of office equipment pollution (nanoparticles and chemicals) on the workers' health was evaluated. The following indoor air quality indicators: dust particles, including nanoparticle, chemicals – volatile organic compounds (aldehydes, hydrocarbons, etc.), inorganic gases (nitrogen dioxide, sulfur dioxide, carbon dioxide, and ozone), microclimate parameters (relative humidity, air temperature, air velocity) were evaluated in the indoor air of offices.

3.1. The results of indoor air quality

3.1.1. The results of dust particles surface area and count measurements

The picture of scanning electron microscope (see Picture 3.1.1.1.) shows the particle size emitted by office equipment (printers). The particle size ranges from 40.58 nm - 69.91 nm, nanoparticles also form agglomerates. Two representative indicators assessed particle pollution in the work environment: surface area and particle count.

The result of nanoparticle surface area measurements shows that alveolar fraction particles were found in range from 10.0 to 204.4 $\mu m^2/cm^3$ and traheobronhial faction particles in range from 2.5 to 25.0 $\mu m^2/cm^3$ in the office premises. The highest average value concentration of alveolar fraction dust particles was found to be 55.5 $\mu m^2/cm^3$ in premises with active copying and printing proceses, and with a carpet on floor. The individual measurements of environmental pollution (the peak) the particle surface area, reaching 93 $\mu m^2/cm^3$.



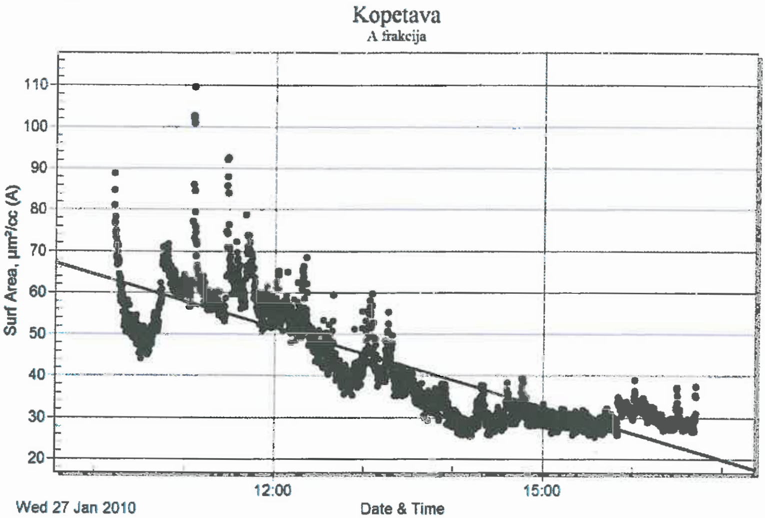
3.1.1.1. Picture. Laserprinters distributed dust particles (D1, D2, D3) sizes in nanometers (nm)

The highest mean concentration of traheobronhial faction was found to be 15.2 $\mu m^2/cm^3$ in premises with no windows and ventilation system not working. The counts of nanoparticle concentration also were evaluated in offices in range: from 3 140 to 30 000 particles/cm^3, where the average count of dust particle concentration was in range from 1 880 to 14 756 particles/cm^3.

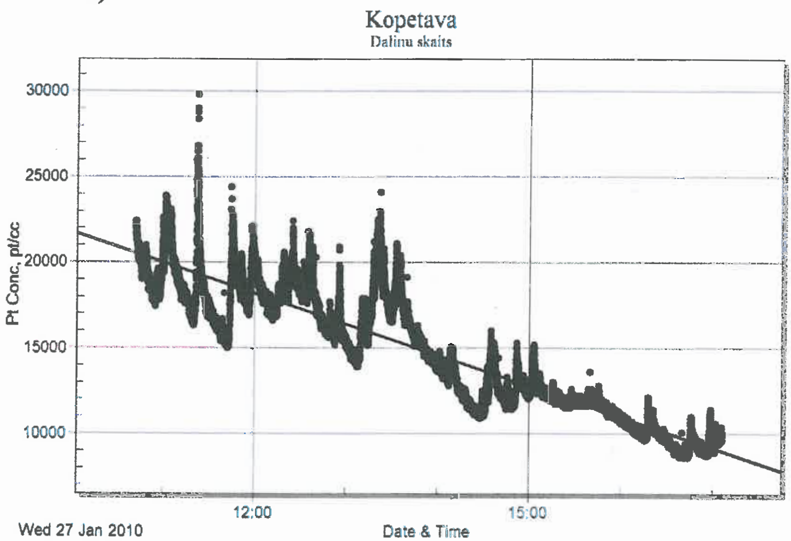
The results of indoor air quality indicate exposure to airborne nanoparticles, depending on the printing and copying activity in offices, office location, area characteristics, as well as the status of ventilation system.

The collected data shows the link between the surface area of alveolar fraction dust particles and count concentrations of dust particles in the measurements of whole day, it shows the peak (maximum) concentration at the same time (see Picture 3.1.1.2. a and 3.1.1.2.b).

a)



b)



b)

Pictures 3.1.1.2 a and 3.1.1.2 b. The relationship between the alveolar fraction of dust particle surface area concentration in copy shop and count of the dust particle concentration simultaneously during the measurement period

3.1.2. The results of volatile organic compound measurements

The results of aldehyde measurement: there were identified five types of aldehydes: acetaldehyde, formaldehyde, propilaldehyde, butilaldehyde, benzaldehyde in the office premises. The highest concentrations were detected for acetaldehyde and formaldehyde.

Since the highest concentrations were found for formaldehyde and acetaldehyde, and they are the most common pollutants in indoor air, therefore detailed data analysis will be performed only for these two compounds.

Looking to concentrations of acetaldehyde and formaldehyde in rooms that have ventilation and do not have it, a statistically significant ($p<0.05$) higher concentrations were observed in offices without ventilation (see Table 3.1.2.1). Formaldehyde concentrations were more than 2 times higher than acetaldehyde. The higher concentrations of formaldehyde and acetaldehyde were found in areas where is low copying and printing activity ($p <0.05$).

3.1.2.1. Table

The aldehyde measurements in office premises according to ventilation

Chemicals	Ventilation	C average, mg/m^3	SDEV, mg/m^3
Acetaldehyde concentrations in the offices	with	0,048	0,019
	without	0,117	0,142
Formaldehyde concentrations in the offices	with	0,101	0,041
	without	0,238	0,218

Looking to carpet areas and the presence of acetaldehyde and formaldehyde concentrations in the indoor air, the slightly higher concentrations of acetaldehyde were in premises with carpets, and formaldehyde - in premises without carpets.

The concentrations of **diisocyanates** in premises were found below the reference values, but the probability of exposure to isocyanates is a risk to health, because it presence the simultaneous with various pollutants into the indoor air of offices.

The measurements of volatile organic compounds (VOC) (total 882 gas chromatographic analysis) were made in office premises and were identified following chemicals: methane, ethane, propane, methanol, acetone, hexane, ethyl acetate, butyl acetate, toluene, total of hydrocarbons (by C), ethylbenzene, xylenes, dibutyl phthalate, polychlorinated biphenyls and polybrominated diphenyl ethers, etc. The thesis covers the most significant results of chemicals - compounds which are identified in most of the workplaces and their concentrations were high (exposure index exceeded 0.75 – EI >0.75 (see Table 3.1.2.2).

3.1.2.2. Table

The Chemical Exposure Index (EI) for indoor air pollutants in offices

Chemicals	Low exposure index (EI< 0,5)	Medium exposure index (0,5≤ EI ≤0,75)	High exposure index (0,75<EI<1)	Very high exposure index (EI ≥ 1)
CO_2	-	33,3 % (N=8)	8,3% (N=2)	18,3% (N=14)
NO_2	61,9% (N=13)	9,5 % (N=2)	19,0% (N=4)	9,5% (N=2)
SO_2	76,2% (N=16)	9,5% (N=2)	-	14,3% (N=3)
O_3	37,5% (N=13)	-	-	62,5% (N=5)
Formaldehyde	8,6% (N=5)	20,7% (N=11)	10,3% (N=6)	60,3% (N=33)
Acetaldehyde	-	-	-	100% (N=58)
Propilaldehyde	17,2% (N=10)	24,1% (N=14)	19% (N=11)	39,7% (N=23)
Butilaldehyde	61,2 (N=30)	16,3% (N=8)	2% (N=11)	20,4% (N=10)
Benzoaldehyde	92,3% (N=48)	1,9% (N=1)	-	5,8% (N=3)
Ethanol	100% (N=37)	-	-	-
Ethyl acetate	16,3% (N=7)	11,6% (N=5)	14% (N=6)	58% (N=25)
Butyl acetate	100% (N=22)	-	-	-
Toluene	96,4% (N=54)	3,6% (N=2)	-	-
Hydrocarbons (total by C)	61% (N=36)	25,4% (N=15)	5,1% (N=3)	8,5% (N=5)

The result shows that ethanol, butyl acetate, toluene concentration is relatively low, but the totals of ethyl acetate and hydrocarbon concentrations are higher.

Comparing the concentrations of organic compounds between premises with ventilation and witout, there was no statistically significant differences; concentrations were generally similar in both cases.

There was a slight trend (p>0.05), that the higher concentrations of hydrocarbons, toluene and ethyl acetate are in premises with ventilation system. In the premises where are carpets were found statistically significant differences between concentrations of toluene and hydrocarbon (p<0.05) (see Table 3.1.2.3.).

The organic compounds associated with copying and printing activities in the premises and it is indicates by the following trends (p>0.05): concentrations of ethanol, butyl acetate, hydrocarbons were the slightly higher in rooms with lower copying/printing activities, but concentrations of toluene and ethyl acetate were slightly higher in rooms with active copy/print activities.

3.1.2.3. Table

The results of volatile organic compounds in office premises according to type of flooring

Noteiktais rādītājs	Grīdas seguma veids biroja telpās	Vidējā vērtība, mg/m³	Standartnovirze, mg/m³
Etanola vidējā koncentrācija birojos	without carpets	0,023	0,021
	with carpets	0,178	0,243
Etilacetāta vidējā koncentrācija birojos	without carpets	0,147	0,132
	with carpets	0,162	0,093
Butilacetāta vidējā koncentrācija birojos	without carpets	0,003	0,001
	with carpets	0,003	0,002
Toluola vidējā koncentrācija birojos*	without carpets	0,009	0,008
	with carpets	0,034	0,039
Ogļūdeņraži (summāri) vidējā koncentrācija birojos*	without carpets	0,085	0,050
	with carpets	0,164	0,098

**statistical significant $p<0.05$*

3.1.3. The results of nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) measurements

The NO_2 (n=61) and SO_2 (n=58) was measured in the office premises, because they are popular outdoor indicators for environment monitoring, as well as NO_2 is associated with copying and printing activities in premises. The NO_2 concentrations were in range from 0.002 to 0.055 mg/m^3 (the average value was 0.02 ± 0.01 mg/m^3). However, the concentration of SO_2 was from 0.01 to 0.23 mg/m^3 (average value was 0.06 ± 0.004 mg/m^3).

Looking to NO_2 and SO_2 concentrations in premises with and without ventilation, it shows a trend ($p>0.05$) that the higher concentrations of NO_2 was in premises with ventilation, and the concentration levels of SO_2 was higher ($p> 0.05$) in the premises without ventilation.

By contrast, a statistically significant ($p<0.05$) the higer concentrations of NO_2 were in premises with high printing/copying activities.

3.1.4. The results of ozone (O_3) measurements

The measurements of ozone concentration (n=55) were made at the offics in the morning and afternoon. The highest ozone concentration were found in the afternoon (evening) - 0.27 mg/m^3.

The highest ozone concentration in both the morning and afternoon was observed in the offices without ventilation.

Ozone concentrations were strongly increased in the afternoon ($p<0.05$) compared with morning levels ($p<0.05$).

Looking at the ozone concentration in relation to copying activities, it shows that in the morning and afternoon ozone concentrations have a tendency ($p> 0.05$) increasing in premises with active copying / printing.

The ozone exposure index in office premises in 62.5% of case was very high, but only 37.5% - low (see Table 3.1.2.2).

3.1.5. The results of ozone carbon dioxide (CO_2) measurements

Average concentrations of carbon dioxide indicates that the concentration levels vary widely, ranging from 995.3 to 5349.7 mg/m^3 in the office premises, and highly visible dynamics of CO_2 during the day - the concentration were increasing in the afternoon, reaching a maximum value of 6442.0 mg/m^3.

The analysis of CO_2 concentrations shows, that concentrations exceed recommended values (1000 ppm or 1830 mg/m^3), at the morning in 50% of measurements, at the afternoon - 62.5%, at the evening - 58.3%.

There was a slight tendency that premises without ventilation system have a higher CO_2 levels.

Overall, looking at office premises with ventilation system there also was found high CO_2 concentration, especially at lunchtime. While the office premises without ventilation system, clearly shows an increase of CO_2 concentrations in the afternoon compared with morning.

The analysis of CO_2 exposure indices that the very high EI was found in 77.8% of premises with ventilation, medium EI - 22.2%, but in the premises without ventilation CO_2 EI was found very high in 46.7% cases, high - 13.3 % and the medium - 40%.

3.1.6. The results of microclimate measurements

Microclimate measurements were performed in the morning, noon and afternoon, to identify dynamics of air humidity, temperature and air velocity during the day, and taking into account the type of office and activities characteristics. Looking at the distribution of average humidity, below acceptable standards (<30%) humidity was found 55.6% of cases in the morning, below 30% humidity was found 52.9% in noon, but in the evening - 70.6% in the office premises. Looking at the results of measurements of humidity with ventilation and without, a trend ($p>0.05$), the relative humidity in the morning, noon, afternoon and evening, the total humidity was higher in the premises without ventilation system.

There was a statistically significant difference ($p<0.05$) between the activity of copying and air humidity, the more copying/printing the documents, the lower relative humidity in office premises.

The air temperature at the office premises, in general were above +20°C. The results of measurement showed a trend ($p>0.05$), that air temperature in the morning, noon, afternoon and day generally were the higher in premises with ventilation.

The air temperature was a trend ($p>0.05$) to increase in the office premises with more active document printing and/or copying during the day. The results of air velocity ranging from 0.01 to 0.02 m/s, while the highest air flow was only 0.04 m/s. The air velocity 0 m/s (non-airflow at all) was found 17.6% of cases in the morning in offices, noon - 11.8% and in the afternoon - 6.2%. Since the airflow varies very narrow range 0 – 0.04 m/s, therefore air velocity analysis with and without ventilation, as well as printing/copying activity not viewed at all.

3.2. The results of chemical compounds in office dusts

The copier dust extract were conducted by gas chromatography with flame ionization detector and were identified more than 250 chromatographic peaks, which means that approximately the same amount of various chemicals present in dust samples. When the copier dust extract were analysed by masspectral analysis there were detected phthalates, various oxygen-containing compounds that might arise during the cautery copier powder, or photo-chemical reactions, as well as polychlorinated biphenyls and polybrominated diphenyl ethers.

The study shows that office workers exposed to chemical exposure risk not consist only from the inhalation of VOC vapors, but also trought the entering the dust adsorbed substances into body.

3.3. The results of office workers survey

The 1221 office workers were include in the survey, but 895 respondents of them agreed to complete a questionnaire anonymously, respondance of survey was 73.3%.

From all respondents, 86% (N = 774) were women, while only 14% (N = 121) - male. Most respondents were in age group 25 - 34 years (29%, N = 259), 23% (N = 206) - the age group 45-54 years and over 55 years - 20.7% (N = 185), but respondents in age groups: younger than 25 years - 10.9% (N = 97) and from 34 to 44 years - 16.4% (N = 147).

Length of service for most workers (53.6%, N = 469) were from 2 months to 20 years, but there were also employees who work more than

40 years (6.9%, N = 60). The length of service among employees ranged from 0.2 to 47 years, average: 13.2 ± 11.8 years. Turn to the question: "How long working in this building? Office workers said that from 0.2 to 26.0 years. The most interesting that employees have mentioned that they are working 9 - 56 hours at the week, the analysis of the average working hours per day, shows average 40.3 ± 5.7 hours per day.

The most of office workers (79%, N = 705) have noted that they are non-smokers, 8% (N = 70) are ex-smokers, but only 13% (N = 120) - smokers. The 33.3% (N = 303) workers - do not need vision correction, 58.2% (N = 521) - need to use glasses, 4.6% (N = 41) - need to wear contact lenses, and 2 % (N = 18) - used for both glasses and contact lenses.

The most respondents (55.6%, N = 439) work in the premises together with 2-3 other wokers, 22.6% (N = 178) work in offices together with 4-7 employees, but 21.8% (N = 172) of respondents work in premises were are 8 or more employees. It should be noted that the open-plan office premises (no partition 20.4%, N = 182 and with partitions of 11.4%, N = 102) number of employees was significantly higher than 8, so-called up to 35 employees!

The office area was observed and it varied from 2.0 to 1800.0 m^2 (they may have offices all over the house perimeter.

Looking at the question of the premises flooring, which may play a role in influencing of indoor air quality, it was found that the majority of respondents working in rooms without carpet flooring (71.4%, N = 638), 2.9% (N = 26) space is semi-carpet flooring and 25.7% (N = 230) were carpets.

The 59.6% of the respondents noted that the facilities are clean ("very clean" - 8.1%, or "acceptable clean" - 51.5%), while 40.5% - noted that premises are "a little dirty or dusty" and "very dirty or dusty."

Looking to overall workers satisfaction with the workplace, then most of the notes as a job pretty easy - 57.0% and 5.4% - a very inconvenient.

Evaluating the changes in the premises during last 3 months, for example, 4.7% (N = 41) of respondents said they have moisture on the walls, ceilings, the windows, 1.4% (N = 12) of respondents working in rooms where is a newly painted wall or a new wall layer, 1.2% (N = 11) of respondents has new furniture in premises.

Analyzing the use of office equipment or office work activity was carried out, that most of office workers - 69% (57.6%, N = 502, 11.4%, N = 99) used laser printers several times a day, or at least one time per day. Copiers respondents used slightly less - 57.3% (42.3%, N = 373 and 15.0%, N = 132) than laser printers. Fax several times a day, or at least one time per day 19.6% (9.8%, N = 84 and 6.4%, N = 55) respondents, but more than 54.1% (N = 465) respondents do not used fax not at all. The adhesives, proofreaders, erasers, etc. chemical-containing products office workers used many times a day or at least 1 time per day in 60.0% (26.3%, N = 231 and 23.7%, N = 208) cases.

In the analysis, which is associated with a medical diagnosis of disease, most office workers diagnosed nasal / frontal cavity infections 22.5% (N = 192), 11.7% (N = 100) - an allergy to dusts, 11,5% (N = 98) - an allergy to chemicals, 9.9% (N = 85) - migraine, 9.5% (N = 81) - allergy to medicines, etc. diseases.

Analyzing complaints about health, it is evident that, overall, most of workers complain of tired or tense eyes ("occasionally" - 52.5% (N = 451), "often" - 33.5% (N = 288)), neck fatigue ("occasionally" - 46.9% (N = 395), "often" - 24.2% (N = 204)), headache ("occasionally" - 56.0% (N = 469), "often" - 13.3% (N = 111)), pain or stiffness in the back ("occasionally" - 47.2% (N = 401), "often" - 18.4% (N = 156)) , constant fatigue, weakness or drowsiness ("occasionally" - 50.0% (N = 420), "often" - 15.4% (N = 129)), etc.

Looking at the complaints about health, more than half the office workers were characteristic symptoms: tired or strained eyes, neck fatigue, headache, pain or stiffness in the back, constant fatigue, weakness or drowsiness, etc. However, it should be noted that at least one-third (over 30%) office workers also were enhanced by symptoms such as dry skin, sore and dry throat, sneezing, shortness of breath, etc.

Overall, 83.1% (N = 649) of office workers noted that the health symptoms/complaints have transitory nature, but 16.9% (N = 132) - the symptoms are constant - persistent.

The 78.7% (N = 653) of office workers had not noticed high air velocity during last month, but 45.6% (N = 382) workers were not observed too low airflow. In addition, each day 32.9% (N = 275) of respondents were observed too low airflow in offices and only 8.3% (N = 69) - too high airflow.

The high temperatures in workplace were not observed in 59.5% (N = 496) of respondents, but low temperature - 70.9% (N = 582), each day 18.4% (N = 153) of respondents had seen increased temperature, and 9.3% (N = 76) - reduced temperature.

The high air humidity not observed in 98.3% (N = 795) of respondents, but only 1% (N = 8) notes every day. By contrast, 42.7% (N = 362) of the office workers noted that dry air were observed, but 39.9% (N = 338) - it should be observed daily.

The most of respondents not observd cigarette smoke smell - 92% (N = 746) and the chemical smell - 91.8% (N = 751), but the smell of cigarettes observed every day were observed - 3.3% (N = 27), but chemical aroma - 1.7% (N = 14) of respondents.

The 65.1% (N = 579) of respondents said, that there is no ventilation system in the premises, but 34.9% (N = 311) - the ventilation system is in workplaces. In addition, 31.1% (N = 275) of employees in office premises are air-conditioned, but 68.9% (N = 609) - premises do not have air conditioning. In turn, air humidifiers are not in 91.3% (N = 793) of employees, but is - 8.7% (N = 76). The most of the workers assess their work environment in range of 6 to 8 points; most of them appreciate with 7 points (25.5%), 8 points (20%) and 6 points (16.9%).

3.3.1. The results of survey: occupational risk factors and health

Odds ratio analysis indicates to disturbances for office workers to exposed and non-exposed by occupational environment. The results are focused to such factors as conditions of work environmental in premises (airflow, humidity, temperature, chemical smell), the working area profile (floor type, presence of ventilation), as well as office equipment and tools use and relation of these factors to health complaints/symptoms.

Too low air flow creates the higher odds (p <0.05) for office workers to get the following health problems: dry, itchy or irritated eyes (OR = 2.2, 95% CI 1.6 to 2.9), dry skin (OR = 2.2, 95% CI 1.8 to 3.3), sneezing (OR = 2.2, 95% CI 1.6 to 2.9), constant fatigue, exhaustion and sleepiness (OR = 2.1 95 % CI 1.6 to 2.8), runny or stuffy nose (OR = 2.2, 95% CI 1.7 to 2.9), headache (OR = 2.0 95% CI 1.5 to 2.7).

Too high temperatures cause the higher odds (p <0.05) for office workers to complain for dry, itchy and irritated eyes (OR = 2.2, 95% CI 1.6 to 3.0), sneezing (OR = 1.5, 95% CI 0.8 to 1.5), dry skin (OR = 1.7 (1.3 to 2.4), runny or stuffy nose (OR = 1.7, 95% CI 1.3 to 2.3), etc.

Too dry air (low air humidity) caused the higer odds (p <0.05) for office workers to complain for following health symptoms: dry skin (OR = 3.4, 95% CI 2.6 to 4.6), sneezing (OR = 1.9; 95% CI 1.5 - 2.6), runny or stuffy nose (OR = 1.8, 95% CI (1,4 - 2.4), breathlessness (OR = 2.4, 95% CI (1 , from 6 to 3.8), difficulty remembering things or concentrating (OR = 1.7, 95% CI 1.3 - 2.3), constant fatigue, weakness or sleepiness (OR = 2.2, 95% CI 1.6 to 3.0), dry, itchy or irritated eyes (OR = 2.5, 95% CI 1.9 to 3.3), sore and dry throat (OR = 1.7, 95 % CI 1.3 - 2.3).

The observed **chemical odor** causes a greater chance (p <0.05) for office workers get very specific health problems: nausea or feeling sick (OR = 2.6, 95% CI 1.5 - 4.5), dizziness (oR = 2.0, 95% CI 1.2 to 3.4), sneezing (OR = 2.1, 95% CI 1.2 to 3.8), runny or stuffy nose (OR = 2.6, 95 % CI 1,5 - 4,7), cough (OR = 1.9, 95% CI 1.1 to 3.3), constant fatigue, weakness or sleepiness (OR = 2.2, 95% CI 1.2 to 4.3), sore and dry throat (OR = 2.6, 95% CI 1,5 - 4.6).

The observed **other types of odor** creates the higher chance (p <0.05) for office workers to get the following specific health disorders: headache (OR = 1.9, 95% CI 1.3 - 2.7), constant fatigue, weakness or sleepiness (OR 2.8, 95% CI 1.9 to 4.0), trouble remembering things or concentrating (OR = 2.1, 95% CI 1, 5 - two, 9), etc.

The **copiers use** gives a slightly higher chance (p <0.05) for office workers to get the following specific health disorders: cough (OR = 1.36, 95%

CI 1.02 to 1.82), runny or stuffy nose (OR = 1, 35, 95% CI 1.1 to 1.80), sore and dry throat (OR = 1.34, 95% CI 1.00 to 1.80).

The **laser printers** use gives the higest odds ($p<0.05$) for office workers to get specific health problems: headaches (OR = 1.57, 95% CI 1.13 to 2.20), constant fatigue, weakness or drowsiness (OR = 1.59, 95% CI 1.15 to 2.19), sore and dry throat (OR = 1.41, 95% CI 1.02 to 2.40).

The **office stationery supplies** (glue, proofreaders, erasers, markers, etc.) **use** give a slightly higher chance ($p <0.05$) for office workers to get specific health problems: headaches (OR = 1.68, 95% CI 1.25 - 2, 27), cough (OR = 1.56, 95% CI 1.17 to 2.07), sore and dry throat (OR = 1.36, 95% CI 1.03 - 1, 81), dizziness (OR = 1.41, 95% CI 1.02 - 1.95), nausea or feeling sick (OR = 1.57, 95% CI 1.08 to 2.28).

The **lack of ventilation** in premises creates the higer odds ($p <0.05$) for office workers to get following health complain: dry, itchy or irritated eyes (OR = 1.92, 95% CI 1.38 to 2.68), headache (OR = 1.42, 95% CI 1.03 to 1.96), tense or tired eyes (OR = 1.56, 95% CI 1.01 to 2.42), dry skin (OR = 1.57; 95% CI 1.17 to 2.10).

The **carpet flooring existence** in the office premises creates a better chance ($p <0.05$) for office workers to get following health complains: dry, itchy or irritated eyes (OR = 1.92, 95% CI 1.38 to 2.68), constant fatigue or sleepiness (OR = 1.54, 95% CI 1.10 to 2.15), runny, stuffy nose (OR = 1.40, 95% CI 1.03 to 1.92), tired or irritated eyes (OR = 1.80, 95% CI 1.10 to 2.93), sneezing (OR = 1.48, 95% CI 1.07 to 2.03), dry skin (OR = 1.73, 95% CI 1.26 to 2.37).

3.3.2. The results of multinominal logistic regression

The multivariate analysis (**multinominal logistic regression**) was done to find interactions between the office indoor air quality factors, office equipment use and their effects on employee health. Looking to this analysis, statistically significant were found following results: <u>sore, dry throat</u> if there is low air humidity in offices' premises (OR = 1.52, 95% CI 1.07 to 2.15), smell of chemicals in the indoor air (OR = 2.56, 95% CI 1.36 to 4.81). The <u>dry skin</u> more likely to occur if the indoor air is dry (OR = 2.53, 95% CI 1.77 to 3.62), but <u>runny or stuffy nose</u> between the office staff was observed, if in the premises are low air speed (OR = 1.64, 95% CI 1.14 to 2.36) and workers can feel the smell of chemicals (OR = 2.53, 95% CI 1.30 to 4.95). The <u>constant fatigue, weakness or sleepiness between</u> office workers' more likely was obtained if there is unpleasant smell in the office premises (OR = 2.29, 95% CI 1, 52 to 3.46) and among women (OR = 2.20, 95% CI 1.34 to 3.63), Besides between the staff is the better chance of getting <u>cough</u>, if in the office premises is odours of glue, eraser and other chemical products (OR = 1.47, 95% CI 1.06

to 2.04) and too much airflow (OR = 1.69, 95% CI 1.14 to 2.52). The office workers more likely to get a headache, if in premises are unpleasant smell (OR = 1.54, 95% CI 1.02 to 2.33) and between women (OR = 3.36, 95% CI 2.02 to 5.61), too. The better chance to observe dizziness is, if in the office premises is chemical odour (OR = 1.93, 95% CI 1.03 to 3.63), but nausea or feeling sick stomach more likely to observe between office staff, if they felt odour of glue, eraser and other chemical products (OR = 1.62, 95% CI 1.06 to 2.50), the strong chemical odour (OR = 2.51, 95% CI 1.29 to 4.90) and the stuffy air (OR = 1.57, 95% CI 1.04 to 2.63) in the office premises. The more likely occur sneezing between office workers', if in the office premises is low air temperature (OR = 1.47, 95% CI 1.00 to 2.14) and low air velocity (OR = 1.61, 95% CI 1.11 to 2.33).

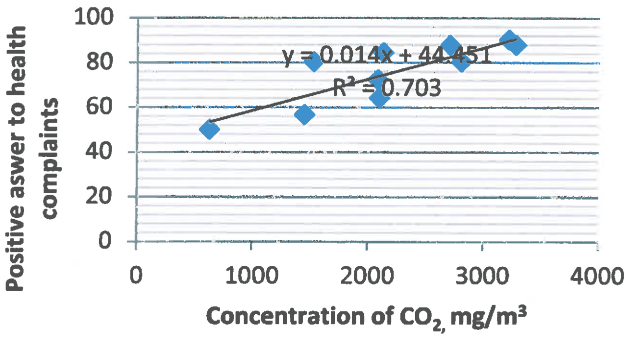
Multivariate analysis shows also other data of office workers' health problems, such as pain or stiffness in the back, tired and overstrained eyes, sensitivity, irritability or nervousness, neck fatigue, depressed mood. The results indicated that these health complaints mainly are influenced by gender and age, as well as ergonomic, psychosocial risk factors in the work and at home, too.

3.4. The results of correlations between measurements and health complains

Analyzing the relationship between (total) concentrations of hydrocarbons and office workers' positive responses of survey about the difficulties to remember and/or concentrating, there was a strong correlation (r^2=0.76) between actual measurements and survey data. Similarly, such a strong correlation was found between the formaldehyde concentrations and the difficulty to remember and/or concentrating (r^2=0.59). In addition, it was also found a strong correlation between the increasing of formaldehyde concentrations and headache (r^2=0.76). Looking at the relationship between total aldehyde exposure index increasing and the difficulty to remember and/or concentrating, there was also a very strong correlation (r^2=0.89). However, the correlation between exposure index of volatile organic compounds (solvents, hydrocarbons) and complaints about health, were found correlation between the shortness of breath and exposure index of organic solvent concentrations (r^2=0.57).

Analyzing the relationship between ozone concentrations and the positive survey responses for sore, dry throat, there was a very strong correlation (r^2=0.99) between measurements and survey data. Analyzing the relationship between measurement results of indoor air temperature and the positive responses of survey, there were a strong correlation between dizziness (r^2=0.85) and nausea (r^2=0.75) and air temperature.

Analyzing the relationship between carbon dioxide concentrations and difficulties to concentrate or concentrating (r^2=0.59), it was found a close correlation. The relationship between carbon dioxide concentrations and fatigue, exhaustion and sleepiness (r^2=0.53) shows close correlation. Looking at the correlation between carbon dioxide concentrations and headaches (r^2=0.70) (see Picture 3.4.1) and sneezing (r^2=0.48) was found a close relationship.



3.4.1. Picture. Correlation between carbon dioxide concentrations in the offices and headaches.

Looking at the relationship between dust particles and measurement of health complaints, it appears that there were the correlations between the cough and the alveolar fraction (r^2=0.33), as well as shortness of breath and traheobronhial fraction (r^2=0.36).

3.5. The results of animal and cells experiments

The experiment with white "Wistar" rats in the office-type premise (copy shop) was implemented to evaluate influence of indoor air pollution caused by office equipment on the respiratory system of experimental animals, ie, inflammation, decreasing of immunity. The experiment was carried out in real working environment, where the experimental animals were exposed to passive inhalation exposure method.

Experimental animal physiological assessment: During 28-day study period, animals were observed (appearance and behavior). During the study, both groups of animals were smooth hair, shiny, ears and easy pink nose, and clean body. All prepared food was eaten during 3-4 hours. The body weight increased in both animal groups (control and experimental) during the experiment. Comparing the data in the experimental group, body weight at the end of study was statistically significantly lower than the control group.

Analysis of bronchoalveolar lavage: at the end of the experiment was taken the lavage from upper respiratory tract and lung. Bronheoalveolar liquid contains surfactant and different cells. The epithelial cells, lymphocytes, neutrophils, macrophages, as well as the estimated number of cells were detected in bronchoalveolar lavage.The cell changes was found in the upper respiratory tract in experimental group of animals, i.e., there were significantly increased ($p < 0.05$) total cell count, neutrophil and lymphocyte counts. The macrophages were found in the upper respiratory tract.

Analysis of lung lavage showed statistically significant decreasing of number of neutrophils, other cells quantitative changes wereobserved, also tendency reducing the total number of cells, macrophages and increaseing the numbers of lymphocytes and epithelial cells.

Blood clinical finding: blood clinical picture showed that red blood cell count, hemoglobin, hematocrit in both groups of animals were not significantly changed throughout the study. The experimental group had increased white blood cell count, but since white rats have relatively large fluctuations in physiology, the difference was not statistically significant.

Biochemical indicators: the C-reactive protein and TNF-α (Tumor Nekrosius factor alpha) were statistically significantly increased in animals of experimental group compared with the control group.

Oxidative stress factors: superoxidedismutase (SOD), malondial-dehyde (MDA), glutathione (GSH), lipid hydroperoxide (LOOH). Such oxidative stress indicators as SOD and GSH were found statistically significantly higher levels in experimental animals.

Evaluation of immunity indicators: evaluation of immune system was carried out by T and B cell analysis, evaluation of circulating immune complex, the relative weight ratio of immunocompetent organs (spleen and thymus). The relative numbers of T and B lymphocytes in experimental group were not different comparing with control group. The relative number of D cells in experimental groups was statistically significant ($p < 0.05$) higher compared with the control group. The relative number of L cells in the experimental groups was statistically significant ($p < 0.05$) lower. The circulating immune complex in rat blood serum in the experimental group was statistically significantly higher ($p < 0.05$) compared with controls. The absolute number of leukocytes and lymphocytes in experimental groups and control animals did not differ statistically significant.

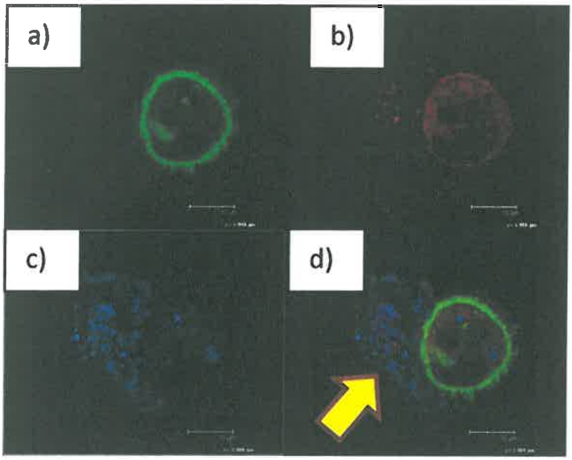
Evaluation of the relative organ weight of experimental animal: during the authopsy of experimental animals had taken the parenchymal organs of rats for macroscopic examination. Differences were found between control and experimental animals in internal organs - the consistence of liver in the all groups of animals were normal, with no apparent abnormalities, dark reddish brown in color. The heart, lungs, spleen were with no visible abnormalities.

Immunocompetent organs - relative weight rates of spleen and thymus in both control and experimental groups' animals did not differ.

The histopathological examination of nasal, tracheal, bronchial mucosa: In general, the main tracheal tissue changes in experimental animals were found: the inflammatory infiltration, tissue edema, hyperplasia of tracheal epithelial basal cell, secondary nodules and hialin cartilage degeneration. The lymphocyte and macrophage infiltration were observed in both groups. The tracheal tissue inflammatory cytokines in the tissues of experimental animals showed a tendency to increase IL1-containing structures, but the downward trend of IL6 and TNF-α. Defensin expressed at equally high level between bouth animal groups.

The main changes in the lungs of experimental animals were found inflammatory cell infiltration, some of which were focal, but one animal show pneumonia scene, found vascular repletion, focal and/or diffuse location of lymphatic nodules, and finally - vascular sclerosis, and focal emphysema. The IL1 and defensin-containing cells increased in the lungs of experimental animals, while IL6 and TNF-α-containing cells varied. The apoptotic cells in the lungs of experimental animals increased, but were not found statistically significant difference from control animals.

Evalution of dust particles in peripheral mononuclear blood cells (PMBC): the dust particles were determined using confocal microscopic method.



3.5.1. Picture. Image of Confocal microscopy: a) green – cells' actin; b) red/orange – mitohondria; c) blue – dust particles; d)cell fragmentation process (yellow arrow)

Dust particles were detected in peripheral mononuclear blood cells and on the surface of them. The smallest detectable size was 0.1 µm. The mitochondria were located mainly around the cell nucleus. The particles were mostly localized diffuse in the cells. In addition, the exsocitoses was obtained (fragmentation, scrapped the damaged cell sectors of the cell), because cells' mitochondria were visible outside the cell (see Picture 3.5.1), which shows adverse effects of particles to mononuclear cell function and subsequent cell necrosis. The cellular actin covering the particles surface. There is the possibility that the particles are localized in the mitochondria.

The expression of interleukin (IL-6) depending on the experiment simulated concentrations: IL - 6 is one of the first markers to indicate active inflammatory process in the cells, as well as it has a major role in macrophages production. The experimental results show, that expression of IL6 was observed at the lhigest particle exposure (0.05 mg/ml) than at the lowest exposure (0.03 mg/ml).

3.6. The recommended values for indoor air quality in Latvia

The indoor air quality indicators are: microclimate (temperature, humidity, air velocity), CO_2 (indicator of "fresh" air), NO_2, ozone, volatile organic compounds (including aldehydes), the dust particles (including nanoparticles) surface area and count.

There is identified the basic detection and evaluation principles of particles' surface area and count in the non-industrial workplaces based on study. The main principle is based to comparing measurements of non-industrial workplace with relatively "clean room" or the reference premises. The study gives the recommended values of nanoparticles surface area and count; these are based on the overall situation in the Latvian offices.

The doctoral thesis analyzed the results of well-being of employees in offices and the results of measurement, and indicated that the indoor air pollution of offices is poor and cause discomfort and health complaints for workers. Therefore, it is necessary to introduce indoor air quality and their recommended values in legislation of Latvia.

The discussion with competent specialists about radon and H_2S exposure actuality in the non-industrial indoor air of Latvia is necessary. As well as the need to review the recommended values of microclimate, i.e., review the Cabinet of Ministers Rules No 359 and coordinate these values with ISO 7730:2005 following values.

4. DISCUSSION

The research data of the working environment in offices indicate that the surface area and count of dust particle, concentrations of volatile organic compounds and inorganic gases leads to the higher level of indoor air pollution in offices.

For the first time the environmental assessment was conducted for the purposes of **dust particle surface area** evaluation of indoor air: alveolar fraction (<250 nm, i.e., from 10 - 250 nm) and traheobronhial fraction (<1000 nm, i.e., from 250 - 1000 nm). The results indicated that the highest concentration in offices was up 9.3 times (alveolar fraction) and 16.7 times (traheobronhiālai fraction) higer as in the "cleanest or reference" premise. By contrast, the **count concentration of dust particle** in polluted office's premise was 7.9 times higher than in the "cleanest or reference" premise.

There was observed correlation between the concentration of alveolar fraction surface area and concentration of particle count in the office premises, i.e., during simultaneous measurements of two parameters, the maximum values were obtained at the same time and exposure dynamics were similar.

The research data indicated the increasing of dust particles' pollution depending on the copy/print intensity, spatial characteristics, office location, the status of ventilation systems, carpets.

It should be noted that there is not regulations for evaluation of dust particles' count and surface area in Latvia and abroad. In addition, the dust particle surface area measurements of non-industrial work environment have not been published. Therefore, based on the measurements, the following recommended values in Latvia could be used: the lower recommended value for **count of dust particles** – 2000 particles/cm^3, but the upper recmmended values for count of dust particles – 10 000 particles/cm^3; the lower recommended value for **alveolar fraction** surface area - 6.0 $\mu m^2/cm^3$, but the upper recommended value for alveolar fraction surface area - 25 $\mu m^2/cm^3$; the lower recommended value for **traheobronhial fraction** of dust particles - 1.5 $\mu m^2/cm^3$, but the upper recommended value for traheobronhial fraction surface area - 15.0 $\mu m^2/cm^3$.

The complex evaluation of chemical was also done in indoor air quality of offices. In Latvia the first time has identified 19 different groups of **volatile organic compounds** (VOC) compounds in offices: formaldehyde, acetal-dehyde, propilaldehyde, butilaldehyde, benzilaldehyde, methane, ethane, propane, hexane, acetone, ethanol, isopropanol, ethyl acetate, butyl acetate, toluene, ethylbenzene, xylenes, dibutyl phthalate, hydrocarbons (total by C). This type of compounds in different indoor air also were indicated by other researchers [Carslaw, 2009; Wolkoff, 2005 and 2006, Bernstein, 2007]. *Bernstein et al.* found that office furniture is essential for formaldehyde, acetaldehyde, butilaldehyde, cyclohexanone, butyl acetate expression, and many of cleaning products release formaldehyde, acetaldehyde, isopropanol, limonene, isopentane, dichlorobenzene pollution, and emissions of aromatic compounds (styrene, xylenes, benzene, ethylbenzene) from office equipment (measurements done in special chambers) [*Bernstein, 2007*]. The chemical indoor air pollution from the office supplies use (glue, varnish, proofreaders, markers, etc.), use of household chemicals (cleaning products, office equipment cleaning products, air fresheners, etc.) and employees' personal care products (perfumes, deodorants, cosmetics, etc.) also is significant [Schecter et al., 2005, Wolkoff, Wikins et al., 2006, Andersson, K., 1998, Morawska, He, 2007].

The dust produced by office equipment the consist of different chemicals also persistent pollutant, particularly diphenyl ethers dividing, which is used as a flame-retardants. Similar researches on analyses of existing chemicals in office dust also indicate the presence of persistent pollutants [Fromme, 2009; Harrad, 2008, Rudel, 2003].

The volatile organic compounds results showed the high levels presence of formaldehyde (exposure index (EI) > 0.75) in 70.6% cases, the level of ethyl acetate – in 72.1% cases, hydrocarbons (total by C) level – in 13.6 % cases, etc. volatile compounds in smaller concentrations.

There was found relations the concentrations of **aldehydes** (mainly formaldehydes) with the lack of ventilation in offices, as well as carpet presence in premises, but in premises with other types of flooring.

It should be noted that work was obtained statistically significant results that toluene and hydrocarbons (total) concentrations were higher in premises with carpets. While in the premises with an active copy and print activities was a trend that toluene, ethyl acetate, ethanol, butyl acetate and hydrocarbons (total) were slightly higher concentrations. There was also observed a slight trend ($p > 0.05$) that hydrocarbons, toluene and ethyl benzene concentrations were slightly higher in premises with ventilation system.

The organic compounds sources in the indoor air mainly are from the materials, furniture, office equipment and machinery, personnel hygiene products, premises and office equipment cleaning products, also from environmental pollution [*Kotzia, 2005, Wolkoff, 2006; Bernstein, 2007*]. I should also mention the fact that hardware running heats, so it heats the surface on which laptop is located, therefore increasing indoor air pollutants, for example, aldehydes and other volatile organic compound concentrations.

In the all premises were found a poor ventilation (air speed <0.05 m/s), thus the chemical levels are not significantly different if the data were analyzed by ventilation status, copying/printing activities and carpet areas.

Note that the one-direction effects of chemicals (chemical irritants) and cumulative concentration can lead increased risk of office workers health disorders.

Also important is the fact that in the premises were bad organization of ventilation systems and the average air temperature was above +20 °C, what promotes the evaporation and accumulation of chemicals in premises, thus ensuring long-term chemical exposure and increasing the potential adverse effects on office workers' health.

The complex assessment of **inorganic gases** (nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3) and carbon dioxide (CO_2) are not done, therefore during the our reserch the inorganic gas were evaluatied to determine the detection efficiency of these gases in the non-industrial work environment in the future, too.

NO_2 and SO_2 concentration in the offices mainly related to environmental pollution, so it polluted indoor air of offices through the ventilation system and open windows and doors. SO_2 concentrations were the higher in premsies without ventilation, because there was "fersh air" taken in by opening windows, doors. In turn, NO_2 concentration was statistically significantly higher in premises with active document printing and copying proceses. The higest SO_2 and NO_2 concentrations were found in the premises, what were located closer to the streets with heavy traffic. In view of the study and the literature data NO_2 is more important than indoor pollutant SO_2 [*Kotzia, 2009*].

The sources of **ozone** in offices are ambient air and human activities in the premises (copying, air ionization etc.). The O_3 in 62.5% of cases exceeds the acceptable values (EI> 1) in offices. In addition, the ozone concentrations increased during the day (the higest at the afternoon) were observed in the premises without ventilation ($p < 0.05$) and high printing and copying activities. During the day nitrogen dioxide and ozone concentrations increased, and it could be explained by active and ineffectiveness of the ventilation systems, therefore not provide sufficient air circulation in the premises. In a similar study, NO_2, SO_2, O_3 air pollutants have been tested in Finland, where was found that outdoor air pollution affect indoor air quality [*Koponen, 2000*].

Carbon dioxide (CO_2) measurement data indicated that more than half of measurements the recommended value was exceeded in the morning. There were tendency increasing of CO_2 concenrtrations during the morning, lunch and afternoon (evening) in the premises without ventilation. Overall CO_2 results show that the ventilation system does not provide sufficient "fresh air" supply in the premises, because the ventilation system is irregular and with air recirculation. Other studies indicate that health symptoms associated with CO_2 are headaches, fatigue, difficulty concentrating, shortness of breath and nausea, and it is due to increasing of CO_2 (decresaing of oxigen) concentration during the day in premises. The reasons of high CO2 levels are the number of people and unbalanced ventilation systems in premises [*Kinshella, 2001, Lindgren, 2009, Scheff, 2000; Woodcock, 2000*].

Microclimate (relative humidity, air temperature, air velocity) play a significant role in increased indoor air pollution and causing workers' discomfort/health problems.

The air humidity data showed that the humidity is the lowest in the open-plant-type premises, but the highest maximum humidity value was found in the afternoon (evening) in the premises without ventilation system. Comparing the air temperature with the acceptable values, the results did not exceed values for the cold period of year, but the workers subjectively noted that the indoor air temperature around +25.0° C is too high and might cause discomfort. Temperature results indicate that during the measurement period (winter and spring) temperature was above +24 °C in office premises, so it could be problem in summer. Air velocity measurements indicated that 100% of all premises, it is sufficient and indicate the problems with wrong organization of ventilation system and it does not provides comfort conditions for employees, creating a body heating or cooling.

All three microclimate indicators should be evaluated together, because the study was found the correlations between them, i.e., low humidity, mostly associated with high air temperature and a reduced air velocity in the offices. Based on the measurement of experience and all results of our study obtained, the all microclimate and chemical measurements should be monitoring during all day, preferably by using automatic data recording devices to evaluate peak values and to analyze the causal factors and interactions.

The **health analysis** of office workers' health complaints (odds ratio - odds ratio) showed the influence of environmental conditions to adverse effects on employees' well-being and health. Odds ratio analysis assessed the health status between the workers groups (exposed and unexposed to risk factors in the offices). For each occupational risk factor was identified the specific health complaints, which was also discussed and analyzed in depth.

The most significant health problems that might be closely related to the environmental conditions are as follows:

- Low air velocity can cause dry, itchy or irritated eyes (OR=2.2), dry skin (OR =2.2), sneezing (OR=2.2), constant fatigue, weakness and sleepiness (OR =2.1), runny or stuffy nose (OR=2.2), headaches (OR=2.0).
- High air temperature can cause such health problems as dry, itchy and irritated eyes (OR=2.2), sneezing (OR=1.5), dry skin (OR=1.7), runny or stuffy nose (OR=1.7).
- Low air humidity associated with dry skin (OR=3.4), dry, itchy or irritated eyes (OR=2.5), sore and dry throat (OR=1.7), as and sneezing (OR=1.9), runny or stuffy nose (OR=1.8), breathlessness (OR=2.4), constant fatigue, weakness or sleepiness (OR=2.2).

- “Chemical odor” can cause office workers to specific health problems: nausea or feeling sick (OR=2.6), dizziness (OR=2.0), sneezing (OR=2.1), runny or stuffy nose (OR=2.6), cough (OR=1.9), constant fatigue, weakness or sleepiness (OR=2.2), sore and dry throat (OR=2.6).
- “Other types of smell (stuffy air may contain sweat, cosmetics, kitchen, perfume components, etc.), give rise to increased opportunities for getting a headache (OR=1.9), dizziness (OR=1.6), sneezing (OR=1.7), cough (OR =1.7), constant fatigue, weakness or sleepiness (OR=2.8), sore and dry throat (OR=1.5), and difficulties remember or concentrating (OR=2.1). The high CO_2 concentrations in the premises play a role in the development of these health symptoms, as it was indicated by measurements, as well as by analysis of correlation between CO_2 measurement and health complaints.
- Copier use activity cause the higher odds ratio for getting cough (OR = 1.4), runny or stuffy nose (OR=1.4), sore and dry throat (OR=1.3).
- Laser printers use activity gives a little higher odds ratio for getting headache (OR=1.6), constant fatigue, weakness or sleepiness (OR=1.6), sore and dry throat (OR=1.4).
- Office supplies use (glue, proofreaders, erasers, markers, etc.) a slightly increased odds ratio of headache (OR=1.7), cough (OR=1.6), sore and dry throat (OR=1.4), dizziness (OR=1.4), nausea or feeling sick (OR=1.6). The correctors, glue, markers, mostly have been adapted for ease use, i.e, to dry faster and have better quality (longer lasting, stronger, etc.) and associated with production of different chemical composition in the indoor air, because quickly drying chemicals more evaporate in the air, thus causing a greater concentration of this substance in indoor air.
- Lack of ventilation creates higher odds ratio for getting dry, itchy or irritated eyes (OR = 1.9), headache (OR = 1.4), tired or strained eyes (OR = 1.6), dry skin (OR = 1.6).
- Carpet flooring in offices leads to higher odds ratio of getting dry, itchy or irritated eyes (OR=1.9), runny, blocked nose (OR=1.4), sneezing (OR=1.5), dry skin (OR=1.7). Carpet flooring can accumulate dusts, as well as for carpets cleaning often are used specific cleaning products what may contain chemical compounds and cause adverse effects on workers' health [*Bønløkke et al., 2006*].

The copiers and laser printers use in the office premises is still studied, but the new risk factor in the work environment is identified - nanoparticles what released as the result of copying and printing activities. These dust nanoparticles can be hazardous to the health because they are very small and long-term may be in the indoor air, especially in the cause of poor ventilation systems in the premises. Therefore, office workers may be exposed to prolonged exposure of nanoparticle. The nanoparticles can be transported deep into the breathing system (alveoli) and can enter the bloodstream. In addition, the nanoparticles of toner powders contain of different chemical compounds what are added to ensure print quality, durability etc. The copying and printing proceses create the high temperature, so that promotes organic compounds evaporation and dust particles increasing in the indoor air. The heated plastic and rubber parts of copier and laser printers can promote evaporation of different chemical compounds in the indoor air. Consequently, the levels of chemical pollution caused by copying and printing processes can significantly increase [*Brown, 1999, Schecter et al., 2005, Morawska, He, 2007*].

The copying and printing procese are realised in office premises near the workplaces, therefore copiers and laserprinters generally contributes poor indoor air quality in the office premises. The copying and printing activities also influence the development of headaches, drowsiness and fatigue, coughing, sneezing, itchy eyes and other irritations. The "good practice" in the offices is the localisation of copiers and laser priinters as far as possible away from wokstations into special place with additional ventilation; it is also as promotion activities for non-stop seating, resting eyes, back and neck.

The survey shows that more office workers used laser printers (57.6%) than copiers (42.3%), it is seen also in the odds ratio (OR) results for laser printers users, they have slightly more likely to get sore and dry throat. However, copiers use a slightly increased chance of getting typical health problems caused by dust particles - cough and runny or stuffy nose. This is explained by the fact based on measured data, that copying machines in the air emit much higher concentration of small dust particles than laser printers in the office premises [*Morawska et al., 2007*]. During the study were identified that laser printers distributed nanoparticles in the typical size from 40 to 60 nm in the indoor air of offices.

The findings indicate that in the all offices' premises was found low airflow, indicating an inefficient ventilation system and cause "fresh air" defecite in the office premises, and produce high levels of chemicals in the indoor air, such as carbon dioxide, which can cause fatigue, headaches. Other chemical substances (dust particles, aldehydes, hydrocarbons, etc.) also can cause various health problems connected with the skin and mucous membrane irritation (sore throat, coughing, sneezing etc.). In addition, elevated temperature and dry air may increase another risk factor adversely affecting to the health of workers, resulting in dry mucous membranes, reducing the body's defenses and promoting the development of specific health symptoms.

Of course, it is conceivable that part of the observed health symptoms are caused by employees' psychological aspects, such as "poor ventilation and

I feeling bad", but in the doctoral thesis, psychosocial factors were uncontrolled and have esstemated in future.

The multivariate analysis indicated that low air humidity (dry air) cause increasing of dry skin health complaints among office workers' (OR = 2.53), shortness of breath (OR = 2.06), dry, itchy or irritated eyes (OR = 1.65), and dry irritated throat (OR = 1.52). The low air velocity cause the running or blocked nose (OR = 1.64), sneezing (OR = 1.61), and dry skin (OR = 1.49), but high air speed - cough (OR = 1.69) and headache (OR = 1.67). While in the office premises with high air temperatures, there have been a better chance to observe dry eye (OR = 1.60) and the constant fatigue, weakness, sleepiness (OR = 1.51), but in the premises with low air temperature - sneezing (OR = 1.47). Evaluating of office premises where observed the chemical smell, the data indicate that workers have runny or blocked nose (OR = 2.53), and dry irritated throat (OR = 2.56), nausea (OR = 2.52) and dizziness (OR = 1.93). In the office premises where employees observed chemical odour (correctors, adhesives, etc.), they have the better chance to get nausea (1.62) and cough (OR = 1.47). While in the office premises where is evidence of stuffy air, the between staff are health complaints such as persistent fatigue, weakness, and sleepiness (OR = 2.29), nausea (OR = 1.57), and headache (OR = 1.54). It should be noted that health complaints are associated with office workers on gender and age, too.

Overall, the data indicate not only the indoor air quality problems, but also the general problems of work organization in the offices, work on a computer, over the years it exacerbate eye problems, as well as employees' neck and back problems caused by ergonomic risk factors.

The **analysis of the correlations** between the measurement of environment and the health complaints indicated that there is close correlation between the hydrocarbon and aldehyde concentrations and such specific health symptoms: difficulty remembering and/or concentration and headaches. These health complaints have been directly linked with findings of chemicals' pollution levels in the indoor air, as volatile organic compounds affect the central nervous system (CNS) activity, it may leads to problems with the ability to concentrate and remember, of course, also headaches, because long-term exposure, although at relatively low concentrations, but different chemical "cocktail" may cause CNS irritation. Conversely, airflow and humidity showed no significant correlations, and the small number of measurements, as well as the results of the low airflow cases could explain it. In addition, the close relationship between elevated temperature and dizziness and nausea could be explained by the body overheating effects, particularly expressed in the summer season in the premises with poor ventilation, as well as influences of others factors (chemical exposure, low humidity and high CO_2 concentration). The CO_2 is one of the typical indicators what show possible higher concentration of chemicals in the premises. There was found a close correlation between CO_2

levels and such health symptoms as the ability to concentrate, fatigue, headaches and sneezing.

The concentrations of dust particles and health complaints such as cough, shortness of breath, etc., can be more closely correlated, if there were more of measurement database and targeted identification of health symptoms. The existence of any health complaints increased discomfort to workers, and affect the productivity and quality, as well as the motivation to work. In general, the relationship between indoor air quality indicators and health complaints demonstrate the existing of relationship. Of course, for evaluation that is more objective would be required additional measurement, survey data, as well as medical examination (functional tests).

The experiments were made with the animals and blood cells to evaluate office equipment and environmental conditions impact on the potential health workers. The **animal experiment** was provided at the office with copying, printing, working with computers and papers activities, therefore air can be contaminated with paper dust, very fine carbon particles (nanoparticles), ozone, etc. In this study was found that the presence of experimental animals in the office premise with intensive copying (~ 3000 pages/day), printing, works with the PC and papers during 28 days, affects the functional state of rats' body, The experimental result was found that at the end of the experiment body weight decreased in the experimental group animals compared with controls. In the upper respiratory tract were observed cell proliferation, increasing both the total number of epithelial cells and neutrophils (granular leukocytes), also lymphocyte count. Conversely, the study found a reduction the number of neutrophils in lung tissue; it also could affect the functional changes of immune system. The decreasing of macrophages in the upper airway could be indicative for phagocytic function collapse [*Töpfer G, 1990, Vander, 1990*].

Inflammatory cytokines IL-1, TNF-α produced by activated macrophages, and they are perceived as early inflammatory mediators, in a given experiment, were observed the evolution of inflammatory process. In addition, increasinf of C-reactive protein indicates the evolution of inflammatory process. The increasing of superoxiddismutase and reduced glutathione levels maybe considered as an indication of oxidative stress increase, which is offset, because the other antioxidant enzyme activities were not increased. In other studies are found a direct correlation between the amount of free radicals and inflammatory processes [Makay B, 2009].

Immuno-competent cells changes can be related with body defenses against the antigen, in this case to the office indoor air pollutants. T and B lymphocytes belong to the regulatory cells of immunity. The increasing of these cells indicates the mobilization of the immune system. D lymphocytes are considered the T and B cell precursors and the increasing of these cells shown the activation of T and B cells and immune stimulation.

The circulating immune complex is antigen-antibody compound, which was increased in this study. It can be increased in case of inflammatory processes in the body and it is considered as reaction of immune system response [*Bier, 1981*].

The pollution of office work environment causes such changes as: hyperplasia of tracheal epithelial basal cell, inflammatory cell infiltration and vascular plethora in lungs indicate severe inflammation-induced changes in the lungs, followed by vascular sclerosis and emphysema. The decreasing of lymphatic nodules in the trachea and the lungs were evaluated as immune exhaustion/decompensation.

IL1 expressing structures tended to increase in respiratory organs after the regular exposure (28 days) of inhaled office indoor air pollutants. IL6 and TNFα decreased steadily in the tracheal tissues, but varied in the lung affected by inflammation. The main expression of these imflamatory mediators was from focal inflammatory infiltrate cells around the secondary nodules.

Defensin antimicrobial peptide very well secreted in the respiratory system in general, but in case of expressed inflammatory process was observed the tendency to increase.

Programmed cell deaths (apoptosis) were more observed in the lungs affected by inflammation (no statistically significant difference). It shows a lot of plaque apoptotic alveolocites and inflammatory cell localization. The changes observed during the research show a countervailable inflammatory process of the experimental animals, what were exposed to the passive exposure of office pollution during 28 days. The measurements of indoor air quality indicates the high pollutants levels in the premises, where was placed the animals of experimental group, and that may lead the negative impact to animals health, including adverse effects of nanoparticles on experimental animal respiratory tissue, statistically significant increasing of inflammatory parameters (C-reactive protein and TNFα level) and statistically significant increasing of some oxidative stress indicators (superoxiddismutase and glutathione).

The analyses of **peripheral mononuclear blood cells experiment** was done by dust particle and cells stuctures visualization. The results showed that the particles were found on and into the cells, it was assumed that part of the cell has been exhaust during cell fragmentation process, which might indicate a possible functional disorder of cells, because mitochondria were excreted outside of the the cells with damaged cell fragments. In addition, the particles are mostly localized diffuse in the cell, what could adversely affect cell function.

The experiment was observed that the highest concentration of particles resulted in higher expression of IL6, which generally would indicate a body's response and pro-inflammation proceses - acute inflammation. In further to assess the cellular response to irritants would require the additional research: IL1, TNFα, and try several exposure scenarios.

In general, all research data indicate that there are different work environment factors in non-industrial work environment (office), what may cause increased risk of health complaints development for office staff. In addition, experimental results point to an existing of the adverse effects on animal tissues, and cellular functions caused by polluted indoor air quality.

The revision of indoor air quality guidelines let me conclude that there are not acceptable values for indoor air qality in non-industrial workplaces in Latvia. However, for many exsting indoor pollutants: VOCs, formaldehyde, microorganisms, CO_2, are established only occupational exposure limits in Latvia, but they are not correctly apply for the non-industrial work environments, because the non-industrial work environment and equipment is not suitable for works with chemicals. The reccomended values of indoor air pollutants should be implemented in the legislation of Latvia and it is necessary to develop guidelines for indoor air quality assessment.

5. CONCLUSIONS

- The most important indicators of the indoor air in non-industrial (office) environment, based on literature and measurements data, are air humidity, air temperature, air velocity, CO_2, NO_2, O_3, formaldehyde, hydrocarbons (total of C), ethyl acetate, and the dust particles' count and surface area of alveolar fraction.
- The indoor air analyses in offices indicate that office workers are exposed daily to many chemicals (also dust particles and nanoparticles) of different exposure levels, and almost all of these chemicals are irritants with one-direction effect on the body.
- The copier/printer toner dust consists of a wide range of chemical compounds (polychlorinated biphenyls, phthalates, etc.) which may influence the disorders development of the respiratory system for office employees.
- Indoor air quality can be negatively affected by inadequate ventilation system organization, the copy/print activity in the work environment, also soft flooring in the office premises.
- The using of daily monitoring principle (not express detection methods for chemicals) for non-industrial indoor air sampling is suitable.
- The correlation between the concentrations of chemicals in the work environment and difficulty in remembering and concentrating,

headaches, sore or dry throat exists, and in cases of high air temperature and dizziness and nausea the correlations exists.

- The highest odd ratio of health complaints for exposed office workers were obtained following: dry skin (OR=3.4) and dry and itchy eyes (OR=2.5) in case of reduced humidity; nausea or feeling sick (OR = 2.6) and sore, dry throat (OR = 2.6) in case of chemicals exposure; sneezing (OR = 2.2) in case of low airflow etc.
- Multivariate analysis indicates that the office workers' health complaints related to office indoor air quality indicators (air velocity, humidity, chemical pollution).
- In vivo study were found that the passive pollution exposure from office equipment indicated development of inflammatory process, because increased levels of C-reactive protein and TNF-α, oxidative stress indicators, and observed changes among immune-competent cells, what all together increase defensive of the body.
- The trachea and lung tissue histological analysis of experimental animals also points to signs of inflammation (decline of lymphoid nodules, reduction of IL6, IL1, and TNFα, defensin expression, basal cell hyperplasia, and apoptotic cells) compared to control animals.
- The peripheral mononuclear blood cells after exposure to dust particles showed cells fragmentation, during which cells were, eliminated mitochondria with damaged segments from the cells, but IL6 expression was higer in the case of higher dust particles concentration.

The draft of quidlines and methods for assessment of indoor air quality indicators is prepeared.

The confirmation of hypothesis

1. Hipothesis: "Dust particles (including nanoparticles) leads to a higher indoor air pollution in the non-industrial occupational environment (offices)" is confirmed, because the measurements of dust particle surface area and count showed that dust particle pollution levels were several times higher compared with the reference or cleanest premise.

2. Hipothesis: “Fine dust particles (also nanoparticles) deposition in the organs of laboratory animals (rats) and cause the functional disorders"is confirmed partly, because the nanoparticles were not visualized in rats’ lung, liver, spleen tissues, but histochemical and biochemical investigations pointed to the changes in the experimental animals group.

3. Hipothesis "Polluted indoor air in offices cause a negative impact on office workers' health" is confirmed, because results of measurements indicated poor indoor air quality in offices and increased odds ratio for office workers' health complaints.

6. PRACTICAL RECOMMENDATIONS

The recommended values for indoor air quality indicators

- Identify the following indoor air quality indicators as the most important air microclimate (humidity, temperature, air velocity), CO_2, NO_2, O_3, formaldehyde, hydrocarbons (total of C) dust particle count and alveolar surface area fractions, and they must be considered during the assessment of occuaptional risk factors in the non-industrial work environment.
- Review and implement the recommended values for the following indicators:
  - the relative humidity in range from 40 to 60%;
  - the temperature during the warm period of year (the average temperature outside the premises + 10 °C or more) + 24.5 ± 1 ° C and during the cold period of year (the average temperature outside the premises + 10 °C or less) +22.0±1 °C;
  - the air flow during the warm period of 0.12 m/s and during the cold period of 0.1 m/s;
  - the lower recommended value for CO_2 - 800 ppm and the upper recommended value for CO_2 - 1000 ppm;
  - for all aldehydes - 0.1 mg/m^3;
  - for hydrocarbons (total by C) - 0.3 mg/m^3;
  - for count of dust - the lowest recommended value – 2000 $particles/m^3$, but the upper - 10000 $particles/cm^3$;
  - for alveolar fraction of dust particles: the lower recommended value - 6.0 $\mu m^2/cm^3$, while the upper - 25 $\mu m^2/cm^3$;
  - Traheobronhial fraction of dust particles: the lower recommended value - 1.5 $\mu m^2/cm^3$, while the upper - 15.0 $\mu m^2/cm^3$.
- Implement the guidelines for the assessment of non-industrial indoor air quality and recommended values in legislation of Latvia.

Recommendations for measuring and sampling

- The inventory of teritory, buildings and facilities (building age, ventilation, cleaning, etc.) before measurements using a special questionnaire.

- Identify the objective of indoor air quality assessment (first time or repeated workplace risk assessment, or the employees' complaints etc.) to identify main indicators and prepare evaluation scheme.
- The methods choise based to monitoring mode - measurements over the day.
- Survey (also ergonomic risk, psychosocial, etc.) use as an additional tool for the environmental, occupational and health problem identification.
- The description of all activities in buildings rooms during the measurement period to correct interpretation of measurement results.
- Measuring principle (based to workplace or premise assessment) and the measurement location depending on the aim of measurement.

Recommendations for health promotion

- The placement of office equipment as far as possilbe from workpalces, the best in a separate room with an effective ventilation system.
- The organization of adequate ventilation system according to season, building / room characteristics, and job placement requirements.
- The choose building materials as much as possible safe for the environment and people.
- The planning of air humidification in the indoor environment.
- The complex assessment and prevention of risk factors (including ergonomic, psihosocial, etc.).
- Health promotion activities (health insurance, sports facilities, etc.).

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