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Improvement of Work Environment through Modelling the Prevention of Health Risks Focusing on Indoor Pollutants

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Declaration: Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology, has not been presented for any academic degree.

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Töökeskkonna parendamine tööruumi siseõhu saasteainete poolt põhjustatud terviseriskide hindamise kaudu

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LIST OF ORIGINAL PUBLICATIONS:

1. **A.Traumann**, P.Tint, O.Järvik, V.Oja. Determination of volatile hazardous components from shale fuel oil during handling. *Materials Science*, 2014, 7 pp., accepted **ETIS 1.1**
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3. **A.Traumann,** P.Tint, V.Tuulik. Indoor air quality in educational institutions in Estonia. *Environmental Engineering and Management Journal,* 2012, Vol.11, No.1, 207-214*,* **ETIS 1.1**
4. P. Tint, **A.Traumann**. Health risk assessment in atrium-type buildings. *International Journal of Energy and Environment, 2012,* Vol.6, Issue 4, 389-396*,* **ETIS 1.2**
5. **A.Traumann**, K.Reinhold, P.Tint. The model for assessment of health risks of dust connected with wood manufacturing in Estonia. *Agronomy Research*, 2013, Vol 11, No.2, 471-478, **ETIS 1.2**
6. **A.Traumann,** P.Tint, K.Reinhold. Qualitative and quantitative determination of chemicals and dust in the air of the work environment. *Proceedings of the 8th International Conference on Environmental Engineering,* May 22-23, Vilnius, 2014, Vilnius Gediminas University, 10 pp., accepted **ETIS 3.1**
7. **A.Traumann,** P.Tint, M.Kritsevskaja, D.Klauson. Air quality as an important indicator for ergonomic offices and school premises*. Agronomy Research*, 2014, Vol 12, No.2, 11 pp., accepted **ETIS 1.2**

The author’s contribution to the publications:

Article I. In *Article I* the author took part in the experimental work and in the interpretation of the survey results.

Article II. In *Article II* the author participated in conducting the experimental part (GC-MS) and the determination of chemical vapors in the work environment air (with the Dräger method) and in the review of the scientific literature and legislative documents for writing the paper.

Article III. In *Article* III the author developed the scheme for the assessment of comfort classes in office rooms and performed measurements of occupational risk factors. The author analyzed and interpreted the survey results.

Article IV. In *Article* IV the author carried out the measurements of the hazardous factors in the atrium-type office rooms. In addition, the author participated in the analysis.

Article V. In *Article* V the author participated in data collection (carried out the measurements of dust in the wood processing industry) as well as in writing the article.

Article VI. The author participated in the measurements of chemicals in the air, in the development of the model for HRA levels for chemicals and dust in the industrial rooms and in writing the paper.

Article VII. In *Article* VII the author carried out measurements, analyzed and interpreted the results and worked out the model for HRA in office rooms.

INTRODUCTION

The hazards in the work and living environment are diverse and constantly changing as new technologies are created and new wastes are formed. The current work is devoted to the hazards management in the work environment (mainly chemicals and dust) and in office room air (carbon dioxide and dust). The aim is to manage the new risks caused by the advanced technologies, products and premises in manufacturing enterprises in Estonia.

The technologies and products are changing very quickly, therefore the occupational health personnel and the employers need new models for risk assessment, particularly for chemical hazards; scientists from different countries are looking for updated risk assessment (RA) models (Petrescu et al., 2011; Simanovska et al., 2008; Bake et al., 2010; Broding et al., 2007; Raymond et al., 1991; Schecter et al., 2005; Sudmalis, 2013; Silei, 2008; Martinzone, 2011).

To determine chemicals in the work environment is complicated, as they emerge in complexes, and during the manufacturing or handling at different temperatures, new unknown vapors can appear in the air of the work environment (WE), new unknown vapors that are not predicted by the safety cards can appear (Principal, 2008; Evolutionary, 2002). One of the objects of the current research is shale fuel oil. Presently, the Estonian government is investing to the investigation of shale oil manufactured from oil shale. It is used as a fuel in boilers and in industrial furnaces, and has good prospects as a car fuel. As compared to similar petroleum-based fuels, it is characterized by low viscosity and low sulphur content (Kilk et al., 2010; Oja, 2007). The shale fuel oil has a specific smell that can cause health problems to the workers during handling (Traumann et al., 2013).

Thorough investigations of the chemicals in the workrooms in the current work became possible with the availability of the portable device FTIR/FT-NIR for measurements of chemicals. Until now, the measurements of chemicals in the work environment were feasible when the chemical was known beforehand. Then the air sample was taken from the work environment to the retrieval device and transported to the chromatograph in the testing laboratory. However, the uncertainty of the measurements increased as a result of these supplementary activities. Another possibility to measure the chemicals in the air of the WE was provided by the portable Dräger express method.

FTIR/FT-NIR device enables qualitative determination of about 5000 substances and quantitative determination of 435 different chemicals. Therefore it is very useful and indispensable in the future surveillance of the work environment air in the Estonian chemicals manufacturing industry.

In the study (Reinhold et al., 2006, 2008, 2009a, 2009b) at TUT possibilities of RA of occupational health hazards in small and medium-sized enterprises were described. The investigation of dust in the outdoor environment in Estonia (Orru et al., 2010) has shown that dust is the reason for an average decrease of the life expectancy at birth per resident of the capital of Estonia by

0.63 years. In the polluted city centres, the average decrease in the life-expectancy may reach over one year. In 2000, Estonia took the 1st-2nd place (with Latvia) in the number of workers (4.5-4.6% of population) exposed to the wood dust (Kauppinen et al., 2006). New technologies like production of souvenirs and wooden bathtubs bring new hazards connected with the wood type used (juniper, mahogany) (Reinhold et al., 2013). The wood processing industry is continuously one of the main processing industries in Estonia and in the EU, which gives exposure to chemicals and dusts (Baran & Trul, 2007; Innos et al., 2000; Imbus, 2002).

Office rooms exist in any industrial, business or social premises. New buildings (e.g. atrium-type) look impressive, but cause health problems or inconvenience for the workers at least after moving in (Seduikyte & Paukstys, 2008). In the office rooms, the hazards are of different types: not sufficient natural lighting in the atrium-type buildings in the rooms towards the atrium; too high concentration of CO_2 if there are more workers than allowed placed in the room (<10m^3 per person); strong smells from the carpets or wall coverings; draught from the ventilation devices; too high temperature in summer in glazed buildings (if the windows are not openable), and too cold in winter in protruding sockets' workrooms. The ergonomic and psychosocial hazards and problems (Brauer & Mikkelson, S., 2010; Lahtinen et al., 2002; Tint et al., 2012, 2014) can also arise in the office rooms. Therefore, the management of occupational health hazards is complicated and needs new approaches to the safety culture at enterprises (Järvis & Tint, 2007; Järvis, 2013).

Identification of the research problem

People are continuously exposed to different chemical hazards in everyday work and during the leisure time. In Estonian industries, the workers are exposed to different chemicals, like petroleum products, nitric and lead compounds, benzene and its derivates, manganese, nickel, phenols etc. and to different types of aerosols (organic dust, welding aerosols, oil-shale dust, mineral fibres, dust abrasive materials, etc.). The vapor pressure of chemicals in the air mainly depends on the air temperature and relative humidity. The content of chemicals and dust in the air of the environment depends on the industrial technological processes or handling of chemicals (Reinhold et al., 2008, 2009a). The number of occupational diseases is a specific indicator of the influence of existing hazards and risk factors in the environment air. Exposure to chemicals may initiate various occupational diseases, such as skin diseases, airway and lung diseases, neurological diseases, or noise induced hearing loss.

Aims of the study

The aim of the thesis was to contribute to the improvement of the work environment in enterprises, focusing on the air pollutants, such as dust and chemicals, by:

- collecting and critically analyzing the data from the working environment in Estonian organizations (*Articles II- VII*)
- developing of the model for the determination of health risk levels in the case of chemicals and dust in industrial rooms (*Articles V, VI*)
- modelling the determinant of comfort classes in office rooms (*Articles III, IV*)
- conducting the experimental determination of vaporization properties and volatile hazardous components of shale fuel oil (*Articles I, II*)
- grinding fineness and forming during polishing dust particles (*Articles V, VI*).

Research method

Several research methods and information sources have been used in the current study. The main research methods were on-site observations, measurements of occupational hazards and evaluation of the health risks.
Measurements based on standard methods are as follows:

- EVS-EN 15251:2007 "Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics" (for indoor climate, lighting and acoustics)
- EVS-EN 1231:1999 "Workplace atmospheres- Short term detector tube measurement systems- Requirements and test methods" (for chemicals)
- EVS-EN 689:1999 "Workplace atmospheres – guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy" (for chemicals)
- EVS-EN 12464-1:2011 "Light and lighting- Lighting of work places- Part 1: Indoor work places" (for lighting)
- EVS 891:2008 "Measurement and evaluation of electrical lighting in working places" (for lighting)
- EVS-EN ISO 10882-2:2001 "Health and safety in welding and allied processes – Sampling of airborne particles and gases in the operator's breathing zone – Part 2: Sampling of gases" (for dust) etc.

All equipment used for the measurements met the requirements set in the standards cited above and calibrated as required by Estonian Metrology Act (2004). EVS-EN 15251:2007 etc. recommend the following measuring devices for the measurements in the work environment: TESTO 435-2, Delta OHM lightmeter HD 2302.0, TES 1358, Dräger-Accuro Detection Pump. To determine organic compounds, gas chromatography mass spectrometry (GS-MS) with headspace sampling was used. FTIR/FT-NIR spectrometer Interspec 301-X with open optical path was used for the determination of chemical vapors in the air. The dust was measured with Haz-Dust EPAM 5000. For laser granulometry Fritsch Particle Sizer "Analysette22" was applied and particle distribution was investigated under the microscope Axioskop. The commercial vapor pressure tester ERAVAP, thermogravimetric analyzer (TGA) and gel permeation chromatography (GPC) were used to observe physical properties of shale fuel oil.

Thesis contribution

The doctoral thesis provides an original contribution both at the theoretical and practical level as follows:

- The study increased understanding of the vaporization properties of shale fuel oil (SFO) in relation to inhalation exposure (*Article I, II*).
- The exposure limits for hard and soft wood dust particles (*Articles V, VI*).
- The study provides important empirical evidence on the working conditions in Estonian industries and educational institutions and the main occupational hazards with a special focus on chemical hazards. The dissertation provides an assessment of occupational hazards (chemical, physical, physiological), indicating some important safety flaws. The author proposes several recommendations for the improvement of the occupational health and safety (OHS) situation (*Articles II- IV, VII)*.
- An important contribution of the study is the innovative conceptual model developed for the determination of health risk levels in the case of (benzene, toluene, xylene, phenol) and dust in industrial rooms (*Articles V, VI*).
- The study provides conceptual clarification of the determination of comfort categories in office rooms and industries, taking into account the microclimate indicators, including carbon dioxide concentration and dust, and ergonomic risks for computer workers (*Articles IV, VII*).
- The study contributes to the methodology of the determination and evaluation of chemicals and dust in the air of the WE by applying quantitative and qualitative approaches (*Article VI*).

Structure of the study

The current study consists of seven scientific articles, each addressing the subject under study from a different point of view. The current thesis is divided into three main chapters. Chapter 1 presents the theoretical framework for the study. The materials and methods used in this research are described in detail in Chapter 2. Chapter 3 presents the main results and applications, followed by a summary and discussion of the main conclusions of the seven articles presented.

Overview of the approval of research results

All the results from the current study have been published and presented by the authors at international scientific conferences and doctoral seminars (**PhD colloquia**), following the acceptance of peer-reviewed submitted abstracts.

- The presentation "Improvement of work environment through modelling the prevention of health risks focusing on indoor pollutants" on the FMDK conference in Tartu, 05.03.2014 and in doctoral seminar in Tallinn, 23.04.2014.
- The results of *Articles I and II* were presented by the author at the 4th International Scientific Conference on Biosystems Engineering, in Tartu, 2013.
- The results of *Articles III and IV* were presented by the author at the 8th IASME/WSEAS International Conference on Energy, Environment, Ecosystems & Sustainable Development (EEESD'12), 2012.
- The results of *Article V* were presented by the author at the 4th International Conference on Biosystems Engineering, in Tartu, 2013.
- The introduction of the developed model for HRA levels for chemicals and dust was presented at the 8th Scientific Conference on Environmental Engineering, in Vilnius, 2014 (*Article VI*).
- The results of *Article VII* were presented by the author at the 5th International Conference on Biosystems Engineering, in Tartu ,2014.

ABBREVIATION

OHS – occupational health and safety
RA – risk assessment
PM – particulate matter, dust particles
HRA – health risk assessment
HRL – health risk level
IC- indoor climate
PPE – personal protective equipment
OEL – occupational exposure limit (8 hours)
STL – short term exposure limit (15 minutes)
SFO – shale fuel oil
WE – work environment
U – uncertainty of measurements
IDLH – immediately dangerous to life or health concentration
TIC – total ions chromatogram
SIM – selective ions monitoring

1. THEORETICAL FRAMEWORK

1.1. Air pollution with chemicals and PM: influence on health

The continuous exposure of humans to multi-component mixtures of chemicals is derived from the following causes (Backhaus et al., 2010). Companies are using simultaneously large numbers of different compounds that can enter the environment from various sources and by different pathways. The complexity of degradation products has to be added to the parent compound exposure. Only some chemicals are used directly in the form of chemical compounds. Most chemicals are the compounds of various drugs (such as stabilizers, agents, ingredients, surfactants, preservatives, etc.). Chemical mixtures are directly emitted into the environment by industrial waste, sewage treatment plants, dumps, agricultural and urban areas. Mixtures might be more toxic than the individual components (Kortenkamp, 2007; Chemical, 2003). Interesting results of inhalable and total aerosol were obtained by Werner et al. in 1996. Studies were conducted to investigate workers' exposures to "total" aerosol and "inhalable" aerosol. The results from several hundred sample pairs taken in parallel showed that the level of exposure based on inhalable aerosol consistently exceeds that of "total" aerosol (from 1.2 to 3 times), tending to be greater for workplaces where the aerosol is expected to be coarser. Such results may be used to assess the impact on industry of new limit values based on inhalable aerosol. The cumulative properties of substances are described by Wilkinson (2000) and the influence on the endocrine system by Khandan et al. (2013).

Before 1985, OSHA regulated wood dust exposure limit as high as 15 mg/m^3 (Centre, 2014). Nowadays in some countries, there are different OELs for soft wood dust and hard wood dust (Kauppinen et al., 2006). However, the distribution of particles is not mentioned. Wood dust has irritant, fibrogenic, allergic, toxic, and carcinogenic influence on the body, depending on the physical-chemical properties of the dust (structure, shape, amount, solidity, liquidity, explosiveness), concentration in the air of the work environment and duration of impact (Vanadziens et al., 2010; Kauppinen et al., 2000). Diseases caused by wood dust most frequently affect respiratory organs, eyes, and skin (Peterson & Shaurette, 2013). Perry et al. (2009) have analyzed dust hazards.

Air pollution has been considered a hazard to human health (EU, 2008; Evolutionary, 2002; Air, 2000; Valavanidis et al., 2008). The dust and aerosol particles are considered a different type of environmental pollutants, which can cause lung cancer and cardiopulmonary diseases. Several epidemiological studies have shown an exposure-response relationship between short-term (mortality, hospitalization) and long-term or cumulative effects on health (lung cancer, cardiovascular and cardiopulmonary diseases, etc.). Several investigators have pointed to the size of the airborne particles and their surface area to determine the potential to induce an inflammatory lesion of other biological effects. The fine and ultrafine particles have stronger effects as they may penetrate into the airways of the respiratory tract and can reach the alveoli where approximately half of the particles are retained in the lung parenchyma. Composition of PM varies greatly and depends on many factors. Studies indicate that the smaller the size of PM, the higher is the toxicity via oxidative stress and inflammation. Some studies have shown that organic compounds to be extracted (with mutagenic and cytotoxic properties) contribute to the cytotoxicity by a variety of mechanisms. Connections between the chemical compounds and the toxicity of particles tend to be the strongest of fine and ultrafine particle size fractions (Kondej & Sosnovski, 2010; Sosnovski & Podgorski, 1999; Prasauskas et al., 2012; Harper et al., 2002). Work-related asthma is the most common occupational respiratory disaster in the industrial countries. The wood dust exposure may increase the risk of work-related asthma (Perez-Rios et al., 2010).

1.2. Risk assessment in the air of the work environment. A flexible risk assessment method

Organic solvents (such as toluene, styrene) have usually a neurotoxic effect; some of them might be carcinogenic (Whysner, 2000, 2003). The prevention of chronic neurological occupational diseases is possible in their early detection and exact diagnoses in the early stage of functional disorders. Only then it is feasible to rehabilitate the workers' health and work ability largely. The nervous system is one of the most sensitive systems of the organism that dynamically reacts to various exogenous factors (Bake et al., 2010). The syndromes are characterized in three stages (Table 2, blue): hypersthenic, hyposthenic and organic psychosyndrome (Tuulik, 1996).

The chemical exposure limits in Estonia give two different numbers: 8-hour mean concentration (OEL) in the air of the work environment and 15-minute momentary limit (STL). The norms also identify three levels of hazardousness of the chemical: harmful, toxic, and very toxic (Resolution, 2007).

The assessment of occupational risks in Estonia began in 1998, when the European regulation ”Guidance on risk assessment at work” (Guidance, 1996) became accessible. This guidance is tightly connected with the British Standard (BS) 8800 (two versions, the first in 1996 (BS 8800, 1996), the second in 2004 (BS 8800, 2004), where the five-stage risk assessment (RA) method is presented. However, it did not bind the employer in the determination of the risk level strongly with the exposure limits. This scheme advises the manager to choose the risk level corresponding to the acceptable one that is lower than the tolerable and lower than needed by the exposure limits. Such approach requires awareness, willingness and financial possibilities of the manager.

According to BS 8800:2004, three harm levels (slight harm, moderate harm, extreme harm) on health are determined. Five risk categories are identified (very low, low, medium, high, and very high risk). In addition, risk tolerability is evaluated as: acceptable, tolerable, or unacceptable. The very low risk is considered acceptable, very high risk unacceptable; while the other risks between acceptable and unacceptable (low, medium, high risk) require reduction to acceptable or tolerable level, whereas acceptable is a smaller risk than tolerable (Table 1) (Reinhold, 2009c).

Table 1. Risk levels (based on BS 8800:2004)

Severity of harm → Likelihood of harm ↓	Slight harm Nuisance and irritation (e.g. headaches); temporary ill health leading to discomfort (e.g. diarrhea)	Moderate harm Dermatitis, asthma, partial hearing loss, musculoskeletal disorders, ill-health leading to permanent mild disability	Extreme harm Acute fatal diseases; severe life shortening diseases; permanent substantial disability
Very unlikely Experienced at least once every six months by an individual	Very low risk-Acceptable	Very low risk-Acceptable	High risk-Tolerable*
Unlikely Experienced once every five years by an individual	Very low risk-Acceptable	Medium risk-Tolerable*	Very high risk-Unacceptable
Likely Experienced once during the working lifetime of an individual	Low risk-Acceptable*	High risk-Tolerable*	Very high risk-Unacceptable
Very likely Less than 1% probability of experiencing it during working hours	Low risk-Tolerable*	Very high risk-Unacceptable	Very high risk-Unacceptable

* Risks that should be reduced as low as acceptable or tolerable level

The existing RA models (on the basis of BS 8800) contain the need to determine the probability of the occurrence and the severity of the consequences of the influence of hazardous factors on a worker (Reinhold et al., 2008). It is complicated to determine the probabilities. Therefore, it is commonly used in the case of major accidents. The need for setting the correlations between the exposure and the stages of occupational diseases considering both the exposure time and exposure limits is very obvious. A Finnish study (Rantanen, 2001) has proposed a scheme for risk level determination for the hazards originating from chemicals considering exposure limits and considering the exposure time by the Estonian authors (Tint et al., 2004). The results are presented in Table 2 (Rantanen, 2001- italic); (Tint et al., 2004- blue).

Table 2. Determination of risk level in the case of hazardous chemicals in the air of the work environment (based on Rantanen, 2001; Tint et al., 2004)

Consequences → Probability ↓	Slightly harmful Hyperstenic syndrome (increased number of errors in the psychological tests, mild level of asthenia, irregular speed of mental activity, deficient ability to concentrate) ***Slightly harmful*** uncomfortable, irritative feeling, overcoming illnesses R20, 31, 36, 37, 38[2]	Harmful Hypostenic syndrome (decreased ability to concentrate, moderate asthenia, decreased speed of mental activity, prolonged reaction time) ***Harmful*** *burning, skin diseases, long-lasting severe damages, stable slight disturbances* *R23, 24, 25, 33, 34, 40, 43, 48, 62, 63*	Extremely harmful Organic psycho-syndrome (clearly prolonged reaction, expressed asthenia, memory disorders of organic type, lowered visual-constructive ability) ***Extremely harmful*** *poisonings, occupational cancer, asthma, stable severe damages, illnesses dangerous to health* *R26, 27, 35, 39, 41, 42, 45, 49, 60,61, 65*
Low, duration of exposure <5 years *Highly unlikely severe damage from <10% of the limits (OEL[1]), other 10–50% of the limits*	trivial risk no risk reduction measures needed	tolerable risk follow-up of risks	moderate risk risk reduction measures needed
Medium duration of exposure 5-10 years *Unlikely Severe damage from 10-50% of the limits; other 50-100% of the limits*	tolerable risk follow-up of risks	moderate risk risk reduction measures needed	substantial risk risk reduction measures inevitable
High duration of exposure >10 years Likely severe damage from 50-100% of the limits, other over limits	moderate risk risk reduction measures needed	substantial risk risk reduction measures inevitable	intolerable risk risk reduction measures to be implemented at once

[1] OEL – Occupational Exposure limit (8-hour exposure)
[2]The risk phrases have been replaced with hazard statements in the new legislation of chemicals

Table 2 contains two factors: probability (likelihood) of the occurrence and consequences if the harm from a particular hazard is realized. The percentage of exposure limit (<10%, 10-50%, 50-100%) is taken as the probability (Rantanen, 2001; Pääkkönen & Rantanen, 1999). Exposure limits are usually expressed as time-weighted, whole-shift concentrations and where necessary, short-term peak concentrations. However, in many cases (e.g., exposure to neurotoxic hazards) also the exposure time to the chemical has to be considered at low concentrations, not exceeding the limits. The neurotoxic substances can react on the nervous system during long-term exposure to chemicals at low concentrations (Table 2, blue, (Tuulik, 1996)).

Two different possibilities to determine the health risk level have been proposed. One of them takes into account the exposure level and the other exposure time. They both are too difficult to employers to realise and incomprehensible for occupational health doctors to identify risk levels and to prevent necessities. Therefore, a flexible RA method (1.3) was worked out in Tallinn University of Technology.

The flexible RA method is based on a two-step model (Fig. 1) that could be enlarged into a five- to six-level model. The two-level model has one boundary line (red on the colored scheme), which is a stable and largely spread number such as a norm or a standard (OEL). The no/yes principle is used or corresponds to the norms/does not correspond to the norms or justified/unjustified risk. The model also suits small enterprises and to those with a simpler combination of hazards or with rather inexperienced personnel (also in work safety).

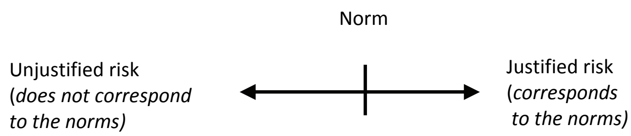


Figure 1. Two-step model (based on Reinhold, 2009c)

On the basis of the flexible RA method, a five-step model (presented by Reinhold & Tint in 2009b) has been derived to connect the occupational health diseases (3 levels) and the risk levels of dust in the work environment. However, deeper understanding of different exposure concentrations to chemical hazards and the potential health impairments are required to properly evaluate the health risk level and to manage the occupational risks. Despite multiple attempts to connect data from RA and ME of the employees, a challenge remains to combine a qualitative exposure characterization (based on the use of technical data available in the working environment) and the quantification of workplace measurement results (Kuhlbusch & Fissan, 2006; Nasterlack et al., 2008), as well as limited empirical evidence based research conducted in this area (Donaldson et al., 2005; Duffin et al., 2002).

1.3. Health risk assessment in the office rooms

Air temperature is one of the most important parameters of indoor climate and it has a significant effect on workability. But in many non-industrial buildings, thermal conditions are not well-controlled due to insufficient heating or cooling capacity, large thermal zones, improper control or operation of the heating, non-proper ventilation and air conditioning equipment surveillance as well as other factors (Valancius &d Jurelionis, 2013).

The indoor climate quality in industrial buildings is related to the employees' wellbeing, including job satisfaction, motivation and productivity (Kõiv et al., 2009; Skyberg, K. et al., 2003; Mergi et al., 2007; Statova, 2006). In the new European Standard EN 15251:2007 set for indoor climate (IC), the quality of work environment is associated with the comfort classes, including the basic microclimate indicators such as air temperature, humidity, velocity of the air, carbon dioxide concentration and also noise and lighting in offices. Prevention of rising carbon dioxide concentrations across the borders (out of more than 800 ppm as CO_2 concentration) and the new approaches for the ventilation of the rooms to improve the indoor air quality are addressed in (Hajek & Olej, 2011).

The interviews and questionnaires to find out the opinion of workers on the indoor air conditions serve as a good additional source for introducing the best improvements in the WE in the offices, particularly at computer-equipped work-places (Lahtinen et al., 2002; Tint et al., 2014). In the interviews, workers were very critical of the process of solving the indoor air problem (Lahtinen et al., 2002). The study supported the hypothesis that psychosocial factors play a significant role in indoor air problems.

The models for RA in office rooms have to consider all possible hazards: inappropriate microclimate, insufficient electrical lighting or shortage of natural lighting, insufficient ventilation, noise from the street or ventilation or old-fashioned computer-equipment, static posture of computer workers, eye and skin problems connected both with too dry indoor climate, and the use of computers (Seduikyte & Paukstus, 2008; Valancius & Jurelionis, 2013; Rutman et al., 2005; Martinzone, 2012; Koistiainen et al., 2012; Abanto et al., 2004). The researchers looking for new possibilities to improve the employees' health have emphasized the difficulty of the problem (Schneider et al., 2003; ISIAQ-CIB, 2004). The Estonian legislation (Resolution, 2003) provides for the medical examinations for the computer-workers once in three years. In the current work, this figure is taken as a basis in the process of establishing the frequency of the medical examinations in office rooms.

1.4. The model of categories comfort based on EVS-EN 15251

The present standard identifies parameters to be used for monitoring and displaying of the indoor environment in non-residential buildings. Different categories of criteria depend on the type of occupants and national differences, type of climate and type of buildings.

The categories used in the standard EVS-EN 15251 are as follows: I- high level expectations, recommended for spaces occupied by very sensitive and fragile persons with special requirements like handicapped, sick, very young and elderly persons; II- normal level of expectations that should be used for new buildings and renovations; III- acceptable, moderate level that should be used for new buildings and renovations; IV- values outside the criteria for the above categories. The last category should only be accepted for a limited part of the year.

Classification of the indoor environment can be based on the design criteria for each parameter (considering ISO 7730:2005), calculations or measurements over a time period (week, month or even year) of relevant parameters like room temperature, ventilation rates, humidity, and CO_2 concentrations.

It is possible to design for different categories of indoor air quality, which will influence the required ventilation rates. The different categories of air quality can be expressed in different ways (combination of ventilation for people and building components, ventilation per m^2 floor area, ventilation per person or according to required CO_2 level). In buildings where the people are main pollutants, the ventilation rates (per person or per m^2) can be derived using measurements of CO_2. In the case of CO_2 – controlled ventilation, the CO_2 concentration should not exceed the design values. Recommended values for the excess of CO_2 concentration above outdoors CO_2 concentration in non-residential buildings are given in the HRA model in Fig. 4. The ventilation rates for air quality are independent of the season. They depend on occupancy, activities indoors (smoking, cleaning, washing, etc.), processes (like copiers in offices, chemicals in school buildings, etc.) and emissions from materials as well as furniture. In the design and operation, the main sources of pollutants should be identified and eliminated or decreased by any feasible means. The remaining pollution is then dealt by the local exhausts and ventilation. In the current work, the concentration of CO_2 is used to determine the comfort class of the workroom.

The four-stage RA model suits for offices and schools to guarantee the comfort of people there. According to EVS-EN 15251, the hazards determining the category of comfort in the office room are: the temperature and humidity of the air, ventilation rate of the room, the concentration of carbon dioxide, lighting of the rooms, particularly in the modern buildings. We propose that the model could also be used in industrial rooms and for the assessment of chemicals and dust.

The current study concentrates on the influence of modern technologies (shale fuel oil handling, wood processing industry, etc.) on human health.

These manufacturing or handling processes involved create new hazards in the work and outdoor environments. It is complicated to determine chemicals evaporated into the work environment as the portable equipment has to be used and the chemical phase is usually mixed from different chemicals. Furthermore, it is unknown in advance which chemicals have to be dealt with. The problem with wood dust is that new wood types are used (juniper, mahogany) and new technologies and areas of manufacturing (like souvenir preparation, wooden baths) are created according to the market demands.

Despite the conceptual and empirical justification, researchers have not consistently included concepts of comfort classes to investigate the non-industrial rooms in enterprises or in the buildings for other work activities. The current research attempts to fill this gap and apply EVS-EN 15251 both in non-industrial and industrial rooms in the manufacturing.

1.5. Rationale for occupational medical examination

Procedure for Medical Health Examination of Workers (Resolution, 2003) sets the hazardous conditions when medical examinations (ME) are needed.
The evidence-based pre-employment ME is recommended (Pachman, 2009; Hulshof et al., 1999).

According to the relevant Estonian legislation, health examination includes both pre-employment (for new employees) and periodical examinations (at least, once every 3 years). The document is based on The Occupational Health and Safety Act (1999) and on the Council Directive 89/391/EEC (1989) on the introduction of measures to encourage improvements in the safety and health of workers at work. The health monitoring (Health, 2013; Schilling, 1986; Guidelines, 2014) contains interviews with employees on occupational hazards, present and previous health disturbances and if needed, biological exposure monitoring (measurements and assessment of the levels of chemicals and metabolites in the body tissues and fluids). ME must be performed under the supervision of occupational health specialists (occupational health physicians). On the basis of the risk assessment at the workplace and the health state of the employees, the frequency of examination is determined by the occupational health physicians (Wesdock & Sokas, 2000; Guidance, 2004; Doctors, 2004), based on the nature of the risk, the amount of exposure and the personal characteristics of the employees.

According to Nasterlack et al. (2008), the decision to conduct a targeted occupational ME requires: knowledge about the exposure to an occupational health hazard and specific health effects caused by such an exposure, the availability of tests and specificity to detect such health effects in an early, preferably reversible or treatable stage as well as establishment of a sufficient degree of the causal relation between the exposure and the health effect.

The current study focuses on the risk assessment that includes identification of hazards, estimation of the risk from each hazard and evaluation of the risk in order to determine the health risk levels in the case of chemicals (benzene (Whysner, 2000), toluene, xylene, phenol) and dust in industrial rooms and which can support the evaluation of the employees' health as well as the assessment of the frequency for ME (see *Articles V, VI*)

2. MATERIAL AND METHODS

2.1. Material

In this thesis, work-related data and information were collected from various types of workplaces in Estonia. The present study provides an in-depth analysis of vaporization properties of shale fuel oil in relation to inhalation exposure and of the work environment based on the data of measurements of occupational hazards and RA performed in manufacturing enterprises, office rooms and educational institutions.

Table 3 presents the description of the enterprises selected for the study and the main occupational hazards measured.

Table 3. The enterprises and offices studied and characterization of the hazardous factors

Production activity	Number of enterprises investigated	Number of workers	The parameters investigated
Welding in metal manufacturing	10	50-200	dust, chemicals: CrO_3 , Mn, H_2S, styrene
Wood souvenir making	2	10-25	dust, noise, lighting, microclimate
Wood processing	10	10-50	dust, microclimate
Glass wool manufacturing	1	30	dust
Shale fuel oil handling	2	5-10	benzene, toluene, o-xylene, phenol
Textile manufacturing	5	30-70	dust, microclimate
Plastics (rubber) manufacturing	2	100-200	mercaptane, dust
Opened car washing centres	1	no permanent workers	ethylene
Car painting centres	2	10-20	ethyl acetate, m-xylene
Office rooms	20	1-10 people in one room; total 400	microclimate, lighting, noise, CO_2

2.2. Methods and measuring equipment

In order to collect work-related information, 35 enterprises and 20 office rooms were surveyed for the investigation. The examined physical, physiological and chemical hazards were selected considering the most common and obvious occupational hazards present in the industrial sector in Estonia. Important determinants of work-related exposure were identified, verified and evaluated. Tasks and jobs were also classified on the basis of raw materials, products, and the tools used by the employees.

To determine hazards in the work environment, the following standards as the measurement methods were used: EN 15251:2007 "Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics"; EVS-EN ISO 7726: 2003 "Ergonomics of the thermal environments – Instruments for measuring physical quantities"; ENS-EN 12464-1:2011 "Light and lighting- Lighting of work places- Part 1: Indoor work places"; EVS 891:2008 "Measurement and evaluation of electrical lighting in working places"; ISO 9612:2009 "Acoustics – Determination of occupational noise exposure – Engineering method"; EVS-EN 1231:1999 "Workplace atmospheres- Short term detector tube measurement systems- Requirements and test methods"; EVS-EN 689:1999 "Workplace atmospheres – guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy"; EVS-EN ISO 10882-2:2001 "Health and safety in welding and allied processes – Sampling of airborne particles and gases in the operator's breathing zone – Part 2: Sampling of gases".

To measure the parameters of indoor climate, the device TESTO 435-2 (air temperature, relative humidity, air velocity, carbon dioxide) was used in four points of the workroom (eight if the surface area was over 100 m^2), at a level of 1.0 metres (sitting position of the worker) or 1.5 metres (standing position of the worker). Readings were recorded for each measurement and the average was calculated. The doors and the windows of the rooms were closed for at least one hour before the measurements. TESTO 435-2 enables also the measurements of CO_2.

Measurements of lighting the workplaces and the screen were performed using a Delta OHM lightmeter HD 2302.0 (ranges from 5-1900 lx). Lighting was measured on the worktable, on the screen and on the keyboard of the computer at the local workplaces (normally at a height of 0.80 m above floor level). The arithmetic mean was presented. To exclude the natural light, the measurements were carried out with the windows covered with blinds.

Noise was measured as an equivalent continuous A-weighted sound pressure level L_{eq}(A), using the hand-held Type II Sound Level Meter TES 1358.

For the measurements of chemicals, the portable FTIR/FT-NIR spectrometer Interspec 301-X with open optical path was used to determine chemical vapors in the air. Thermo Scientific Nicolet IR100 is the real-time process analyzer that enables quantitative determination of 435 different chemicals in the air of the work environment. The overall wavelength range is from 7000 to 400 cm^{-1} (IR). Infrared spectrometers measure the spectrum of light (colors) which is absorbed, emitted or reflected from the test material. The vaporization properties of shale fuel oil depend on such fuel oil characteristics as phenolic OH content, number of average molecular weight and molecular weight distribution. An infrared spectroscope (FTIR) with an attenuated total reflection (ATR, ZnSe crystal) system was used to characterize fuel oil functional groups and specifically to evaluate qualitatively the phenolic OH content. For quantification, a correlation was used that relates to the area of the 3600 - 3100 cm-1 region to the phenolic OH group content of shale oil fractions. Unpleasant odor of shale fuel oil might also be caused by phenols. Unfortunately, we were unable to determine the number of the phenol quantitatively, because it is not included in the analyzer database of substances.

Dräger-Accuro Gas Detection Pump is the device of the express method to determine the gaseous components in the work environment air. We can use different indicator tubes for the parallel determination of chemicals that have been detected by the FTIR. Comparison of the results improves the accuracy of the results obtained by the spectrometer. The express method helps to determine substances in the air qualitatively.

The Haz-Dust EPAM 5000 device with real-time dust monitoring was used to measure dust concentration by time. The Haz-Dust uses the principle of near-forward light scattering of an infrared radiation to immediately and continuously measure the concentration of airborne dust particles in mg/m^3. Particle size range is 0.1 – 10 μm. Particles in sizes >10 μm will be kept in the upper respiratory tract and do not threaten the workers lungs (Peterson and Schaurette, 2013).

Estonian factories use dust of two types: softwood and hardwood. Soft woods (pine, spruce, juniper) are considered to be coniferous species of wood and hardwoods (birch, alder, mahogany) are deciduous species of wood. The dust of both types of wood have a different distribution of particles depending on the handling process (polishing or grinding etc.).

The fine dust is present in the furniture industry. Our aim was to study the distribution of particles connected with sandpapers used in different manufacturing methods. The grit sizes (in micrometres) of the sandpapers used in the furniture industry are P240, P180, P 120 and P80. Paper P80 is intended for phasing, P120 for removing varnish or paint from the wood, P180 and P240 are mostly used in the furniture industry for sanding.

Fritsch Particle Sizer "Analysette 22" was used to determine the wood dust particles derived with different sandpapers. A wood dust dispersed at an adequate concentration in the water is passed through the beam of a monochromatic light source, which is a laser. The measurement of size distributions of particles in any two-phase system is based on the standard ISO

13320. The standard is applicable to particle sizes ranging from approximately 0.1 µm to 3 mm.

The polarization microscope Axioskop gave the 10,000 multiple magnification of wood dust particles (Fig. 5, *Article VII*). The microscope focused on the examination of crystalline structures. Using the highest Carl Zeiss standards, the shape and size of the dust particle was determined (from 0.74 to 15.71µm in the case of juniper dust; the mean 6.25 µm (SD 5.7)). The distribution for two different wood dusts (juniper and alder) grained by sandpaper P120 was examined.

The current study composed of seven scientific articles addresses each subject under study from a different point of view. Table 4 summarizes the research design in terms of the objectives, methodology and the data used in the publications.

The data for this study were acquired from different sources (See Fig. 2). To develop the health risk assessment (HRA) model, studies were conducted in different industries (shale fuel oil handling, wood and metal processing industries) in order to control the quality of the indoor air and working conditions in the work environment (see *Articles I, II, V, VI),* including office rooms and spaces in educational organizations (*see Articles III, IV, VII*).

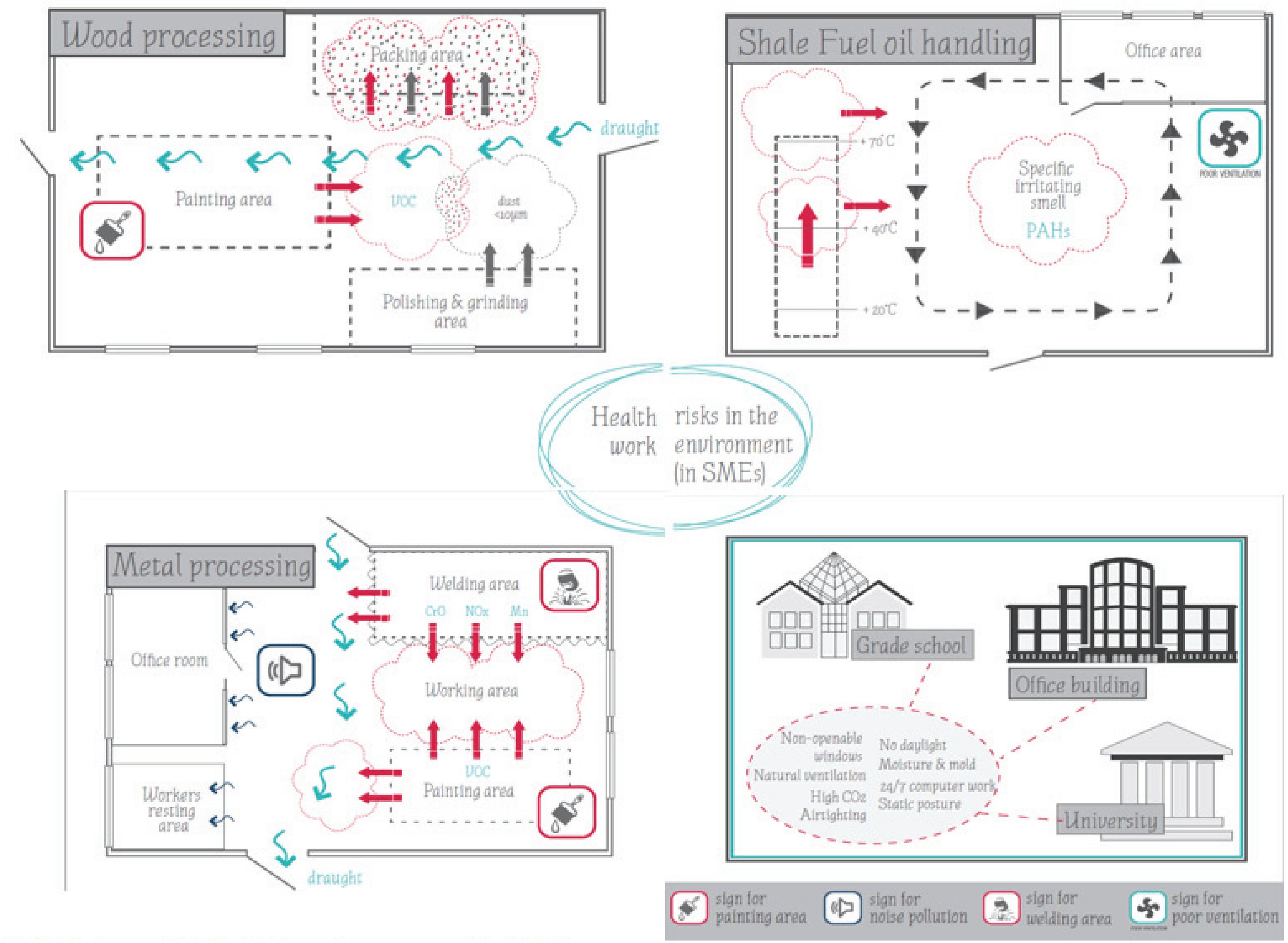
Table 4. Summary of the original papers (composed by the author)

Original papers	Objective	Methodology and data	Conclusions and contribution
I Determination of vaporization properties and volatile hazardous components relevant to kukersite oil shale derived fuel oil handling	To investigate vaporization properties of shale fuel oil (SFO) in relation to inhalation exposure	To characterize the volatility of the fuel ERAVAP (commercial vapor pressure tester) was used. Thermogravimetric analyzer (TGA) was applied to determine SFO vaporization rates at different temperatures as a function of time. Gas chromatography mass spectrometry (GC-MS) with headspace sampling was used to determine the organic compounds contained in SFO. An infrared spectroscope (FTIR) was applied to characterize fuel oil functional groups and specifically to evaluate quantitatively the phenolic OH content. Gel permeation chromatography (GPC) was used to measure the molecular weight distribution and average molecular weights	Increased understanding of the vaporization of shale fuel oil (SFO) at different temperatures. The contribution is: the use of TGA to estimate the changes in vapor pressure during vaporization at different temperatures. The uniqueness of this study is that hazardous substances, such as benzene, toluene, xylene and phenolic compounds in the vapor phase of shale fuel oil, were monitored using headspace analysis coupled with selective ion monitoring (SIM) and confirmed by the NIST Mass Spectral library and retention times of standard compounds.
II Why is education in environmental safety so important?	To use SFO in boilers and industrial furnaces as cars fuel in the future and to determine the toxicity and concentration of hazardous gaseous components in the work area during handling of SFO.	The chromatography of gases and Dräger Express method for the determination of the content of hazardous gases in the work environment during handling of SFO were used	Knowledge on the comparison of the concentration of the hazardous components in the gaseous phase between SFO and petroleum-based fuel oil is provided. The concentrations in the gaseous phase of the petroleum-based fuel oil were higher than during the handling of shale fuel oil at temperatures 40-60^0. Both gaseous phases contained phenol and benzene. Benzene is classified as the carcinogenic compound and its concentration was over the limits. Among the other determined compounds, toluene has a mutagenic effect.

III Indoor air quality in educational institutions in Estonia	To examine the working conditions and possible occupational hazards in the selected educational institutions and to provide recommendations for the improvement	Observation, flexible risk assessment method, measurements of occupational hazards: lighting, air, velocity, air humidity and concentration of CO_2 with the equipment calibrated and methods accredited by the Estonian Accreditation Board. Measuring devices: TESTO 435-2, HD 2302.0. Methods: EVS-EN ISO 7726, EVS-EN 15251, EVS-EN 12464-1	Providing knowledge on the working conditions in the educational institutions and measuring control risks Increased understanding of the ways for safety measure of the main hazards Several recommendations for the improvement of the safety situation are presented.
IV Health risk assessment in atrium-type buildings	To investigate the air in the workrooms of the new type of buildings: atrium	Standards ISO 7726; EN 12464-1; EVS 891, ISO 9612; WCB method 1159, EVS-EN 1231 were used. The measurement equipment: TESTO 435-2, HD 2302.0, noise level metre Type II Sound level Meter (TES 1358)	Providing knowledge on the working conditions, in particular the quality of the air in the new type of buildings: atrium-type and measuring control risks, evaluation of the comfort category.
V The model for the assessment of health risks of dust connected with wood manufacturing in Estonia	To explore the working conditions in the wood processing industry using the new technologies	Measuring device Haz Dust EPAM 5000 was used. The size of the particles was measured with Axiolam ICs 3. For risk assessment BS8800 standard was used. EVS-EN 15251 was used for other measurements in the work environment	Increased understanding of the size of particles in soft wood and hard wood dust Developing an innovative conceptual model for the health risk assessment for wood dust in the wood-processing industry

VI Qualitative and quantitative determination of chemicals and dust in the air of the work environment	To work out a new four-stage health risk assessment model with fixed boundary lines between the health risk levels for chemicals and dust in the workplace air	FTIR/FT-NIR spectrometer Interspec 301-X with open optical path was used for the determination of chemical vapors in the air. Thermo Scientific Nicolet IR 100 is the real-time process analyzer of chemicals in the air. Dräger-Accuro Gas Detection method was also used. The measurement of dust was carried out with Haz-Dust EPAM 5000. Fritsch Particle Sizer ”Analysette 22“ was used to determine the wood dusts derived with different sandpapers that come from the polishing machines in the new technologies	Developing a new four-stage health risk assessment model for chemicals and dust that connects the concentration of the chemical or dust in the air, the exposure time with the frequency of medical examination Contributing to the methodology for the determination of the chemicals in the workplace air qualitatively and quantitatively
VII Air quality in the school and university facilities and possibilities of improvement	To measure the content of CO_2 in the old and new buildings, the improvement of ventilation and to work out the new 4-stage health risk assessment method in the case of carbon dioxide in the air	Measurement equipment: TESTO 435-2; the measuring methods: EVS-EN 1231, EVS-EN 15251, EVS-EN ISO 7726, EVS -EN 13779. The comparison of the concentration of CO_2 in old (2005) and new (2013) buildings	Increased understanding of the changes occurring in the concentration of CO_2 in old (2005) and new (2013) buildings were compared. Developing an innovative conceptual model for the 4-stage health risk assessment (HRA) in the case of carbon dioxide in the air and for physiological risks. The connections between the risk levels in offices connected with the medical examinations of employees.

Figure 2. Health risks in the work environment in (SMEs)



3. RESULTS AND DISCUSSION

The results of measurements of microclimate, dust and chemicals in the enterprises (presented in Table 3) are presented in Table 5. Occupational comfort depends also on the main indicators of the microclimate: air temperature and relative humidity (*Article VI*). For example, higher humidity and lower temperatures will reduce the spread of dust or a chemical in the workroom. Working with chemicals, stronger draught regulation of ventilation is usually applied, which will cause excessive dry air in the work environment. Dry air may irritates eyes, nose and will increase the negative combined effect with chemical vapors.

3.1. Development of the health risk assessment (HRA) model for industrial rooms

The health risk assessment model for industrial rooms (see Fig. 3) has been worked out, based on the model presented by Reinhold et al. (2006), previous empirical research, literature review and on the relevant legislation and standards. The suggested criteria for risk levels of occupational hazards (dust and some chemicals) and possible health complaints were obtained from scientific literature and relative legislation. The focal points in the model are boundary lines between the four health risk levels. The model proposed takes into account the interrelationships between exposure to occupational hazards (the measurements in the work environment), analysis on the basis of the relevant legislation requirements and occupational exposure limits, determination of risk levels with connection it to the possible health complaints. Thus, the author suggests that the proposed HRA model can be used as a tool for assessment and evalution the health risk levels and for the preventive measures (risk management), for instance, as a basis for choosing the appropriate personal protective equipment as well as the frequencies of workers' health examination.

To connect the risk levels and the health complaints, on the basis of the original papers presented in the thesis (*Article I, II, V, VI*) a large number of occupational hazards are investigated in Estonian enterprises. The air temperature, humidity, carbon dioxide and dust are mostly presented for office rooms (*Article III, IV, VII*). The results show a variety of indoor conditions in the office rooms in Estonia. New and renovated buildings have better work conditions than the old ones (*Article III)*. The design solution (e.g. atrium-type) reveal new hazards like tightness in the rooms, non-sufficient fresh air; no natural lighting in offices, high carbon dioxide concentration, etc. (*Article IV*). New ventilation solutions and both natural and mechanical ventilation means give the best results. Risk assessment of Estonian workrooms in enterprises, offices and educational buildings show that the best results in the work environment ergonomics are achieved if the rooms and workplaces are designed considering the health conditions for workers who will stay there during long working hours.

Table 5. The results of measurement of microclimate, dust and chemicals in the enterprises and the nearest areas

Measurement point	**Mean air temperature ^{0}C /relative humidity, %** U=0.6/ 2.0 *cold season-hot season	**Measured value**	**The result/OEL**	**Health risk level (Fig.3)**
Wood factory	*19/38.5- 25/44	dust	0.09/ 2 mg/m^3	1st
Office-rooms (2) Room for copies In the library Offices, closed to the atrium Outside the office house (in town)	*21.0/30.2-24.0/41.2 *24.0/30.1-25.0/40.2 *22.5/35.0-23.0/40.1 *20.0/25.4-24.0/41.4 -	dust dust dust dust dust	0.012-0.014/ 0.050 mg/m^3 0.02/ 0.050 mg/m^3 0.012/ 0.050 mg/m^3 0.012/ 0.050 mg/m^3 0.005/ 0.050 mg/m^3	1st 2nd 1st 1st 1st
Welding in metal industry	*15.5/35.0-20.0/45.0	CrO_3 O_3 Phenol Styrene H_2S dust: swirling welding	<0.1±0.05/ 2 mg/m^3 <0.05±0.0075/ 1 ppm <1±0.15/ 4 ppm <10±0.15/20 ppm <0.2±0.02/5 ppm 0.049-0.25/ 5 mg/m^3 0.038-0.497/5 mg/m^3	2nd 1st 1st 1st 1st 1st 1st
Glass-wool manufacturing	*20.5/37.0-24.2/39.8	dust	3.7-20.0/ 10 mg/m^3 (overall dust)	4th
Textile manufacturing	*22.0/45.0-24.1/50.5	dust	0,083 –0.52/ 5 mg/m^3 (inhalable dust)	1st
Shale fuel oil handling, gaseous phase	*14.0/54.0-23.5/53.0	Benzene Toluene o-Xylene Phenol	3.2/ 1.5 mg/m^3 23.0/192 mg/m^3 35.0 /200 mg/m^3 34.0/ 8 mg/m^3	3rd 1st 1st 4th
Rubber manufacturing	*20.0/34.7-22.8/37.1	Methyl mercaptan	15/ 1.0 ppm	4th
Opened car washing centers	-	Ethylene	6.6 ppm/ safe, not listed	1st
Car painting	*22.2/45.0-23.6/45.0	m-Xylene Ethyl acetate	11,8 / 50 ppm 17,6/ 150 ppm	1st 1st

Occupational exposure limits (OEL) are set in order to protect the health of the workers in the working environment. The limits are the concentrations of hazardous substances in the air, averaged over a specified period of time, referred to as a time-weighted average (8-hour workdays and 40 hours per week). The limits are given in two types: as a long-term exposure limit (OEL) for 8 hours' exposure and the short-term exposure limit (STL) for 15 minutes. The last is settled for substances having a strong smell (like NH_3 or ethyl acetate etc.). During a long-term period, it is assumed, that a variety of substances cannot cause any health disorders during 8-hour workdays and 40 hours per week. The STLs are set to help prevent effects such as eye or throat irritation, which may occur caused by exposure to the chemical during a few minutes (Workplace, 2009; EH 40/2005, 2011).

The model also proposed to link the health risk levels (HRLs) with the frequency of medical examinations (ME) for workers in hazardous conditions. The Estonian regulation of the Ministry of Social Affairs "Procedure for health examination of workers" (Resolution, 2003) defines the health surveillance as follows: employee's health begins with the initial ME within the first month of the work activities and thereafter by the intervals indicated by the occupational physician, but not less than once every three years and for workers under 18 not less than once every two years. These demands are taken into account in the proposed HRA model (see Fig. 3, noted bold).

Some effects and illnesses caused by exposure to a complex of substances in the workplace may appear immediately or soon after the exposure, or they may take many years to appear (in the model Table 2, blue), which has to be taken into account in the total assessment.

The boundary lines in the model (Fig 3) are as follows:

B1- the hazardous exposure to the worker begins: the boundary concentration value for chemicals is 10-50% of OEL or odors threshold; the exposure time is 8 hours for those who are not allergic to the substances present in the work environment. The latter have to undergo the consultation with medical specialists on the possibilities of continuing the work in this environment.

B2- the boundary line for the 2nd health risk level. The concentration of substances is equal to OEL (Resolution, 2001). The summation in the case of mixture has to be taken into account (equation 1, *Article VI*). The exposure time is 8 hours per day with compulsory use of personal protective equipment (PPE).

B3- the boundary line for the 3rd health risk level. The concentration of a substance is equal to the short-time level (STL). The PPE is compulsory and the exposure time is 15 minutes per day.

B4- the boundary line for the 4th health risk level. The concentration of the chemical is 10% over the short-time level (STL), exposure time under 15 minutes and PPE (totally separating gas masks) is compulsory. The 4th health risk level is allowed only during changes like during the introduction of the new technology etc. These actions will hopefully manage to keep the workers' health.

The hazard statements are available on the labels of chemical packages and on the safety card of chemicals.

Awareness of the hazard statements and the HRA levels in the work environment would give a possibility for the occupational health personnel to foresee the possible negative health effects on the workers.

The results of the measurement of dust and chemicals, developed risk criteria and the health risk levels according to the HRA model are presented in Fig. 3.

Simultaneously to the HRA model, the hazard statements have to be followed for each health risk level (Regulation, 2007):

1nd HRL: H313, H335, H336
2nd HRL: H303, H305, H313, H316, H317, H333, H334, H 335, H336
3rd HRL: H302, H311, H312, H315, H320, H331, H332, H371, H372, H373
4th HRL: H 300, H 301, H304, H310, H314, H318, H319, H330, H340, H341, H342, H350, H351, H360, H362, H370.

RH < 20 or RH > 70	20< RH< 70	25< RH< 60	30< RH< 50	Relative Humidity (RH), %
7 - 10	*3 - 6*	*2*	*1*	*Wood dust, mg/m³*
10 - 20	*5 - 10*	*1 - 5*	*0.05 - 1*	*Dust, mg/m³*
-	*-*	*1.0*	*0.5*	*Thiols (mercaptan), ppm*
330	*300*	*150*	*75*	*Ethyl acetate, ppm*
110	*100*	*50*	*25*	*Toluene, ppm*
3.3	*3.0*	*0.5*	*0.05*	*Benzene, ppm*
55	*50*	*20*	*10*	*Styrene, ppm*
4.4	*4.0*	*2.0*	*1.0*	*Phenol, ppm*
110	*100*	*50*	*25*	*Xylene, ppm*
83	*75*	*50*	*25*	*Butanol, ppm*

4th health risk level (HRL)	3rd health risk level (HRL)	2nd health risk level (HRL)	1st health risk level (HRL)	**Variables**
*B4: c =10% over STL *Exposure time: less than 15 min*	B3: c = STL *Exposure time: 15 min*	B2: c = OEL *Exposure time: 8 hours*	B1: c = 10-50% of OEL or odor threshold *Exposure time: 8 hours*	
ME** twice a year	***ME** once a year***	***ME**once in 3 years***	***ME** once in 3 years***	

*B4, B3, B2, B1 are boundary lines between the health risk levels (1-4).

Figure 3. Determination of health risk levels of dust and chemicals in industrial activities

The harmful effect of some chemicals or dust begins at the concentration which the person (worker) feels as smell (the odor threshold, B1), or if the chemical has no smell, then at 50% of the concentration which is established as OEL for 8 working hours per day by the regulations of the Estonian Republic, allowed in production space. For some (carcinogenic) substances, like benzene, the 50% of OEL is too high (dangerous), then B1 in the model (Fig.3.) is taken lower: 10% of OEL. In the HRA model (Fig.3) the occupational limit value B2 is marked as OEL (operation permitted for 8 hours per day). In this case, the 2nd risk level begins. As said above, the working time with this concentration of the chemical in the air is 8 hours. The 3rd risk level begins with the chemical's concentration B3 which is equal to the Estonian legislation's 15-minute limit. Operation with this concentration is allowed 15 minutes. The 4th risk level begins with the chemical concentration of 10% over the 15-minute limit (B4). Run time in these conditions is less than 15 minutes (4th level of risk). Higher chemical concentration in the work environment are not allowed. Longer work with the concentration B4 is allowed if the collective protective means (firstly) and separating from the polluted environment PPE are used. The tendency is to the protective solutions towards lower concentrations of chemicals in the work environment (more closed equipment). The boundary lines between the risk levels in the case of dusts are taken from the scientific literature, measurements in industrial premises, feeling of dust odor and from the long experience of the workers working in dusty environments.

The HRA model (Fig. 3) sets very clear limits of chemicals that employers can allow in the workrooms during the workday and during short use (15 minutes). If the chemical is carcinogenic, then the limits are very strict (*Article VI)*.

3.2. Development of the health risk assessment model for office rooms

The proposed HRA model for indoor climate was also tested in the office rooms in order to assess the adequacy of the suggested risk criteria and the method (see *Article VII*).

Table 6 shows the results of measurements in the work environment of offices shown in *Article 4 and 7*. In winter time the humidity of the air is too low. By the norms (EVS-EN 15251:2007), relative humidity of 40-60% is required for the worker to feel comfort. The level of carbon dioxide ~1000 ppm is felt by the workers as poor microclimate.

The lighting of workplaces equipped with computers is usually good, in the frames of norms (300-500 lx), but sometimes info technologists prefer working in dark (without electrical lighting). However, this situation must be avoided. Some of the atrium-type buildings have openable windows in office-rooms (*Article 4, Fig.4*); in the others the windows are unopenable (*Article 4, Fig.2,*). If the windows are unopenable, then the concentration of carbon dioxide is higher (*Article 7*), but dust concentration is lower. Otherwise, the concentration of carbon dioxide could be lowered with the opening of windows, but in the same time, the outdoor air might contain more dust than the indoor air.

Table 6. Results of measurements indoors in offices (*Article 4, 7)*

Room type	**T, ^{0}C Cold/warm season U=0.6^{0}C**	**R, % Cold/warm season U=2.0%**	**L, lx U=10.4%**	**CO_2, ppm U=10%**	**Dust, mg/m^3 U=10%**
Office 1, (*Article 7, Fig.1)*	20-22/ 28-30	22-23/ 35-65	495-890	537-998	0.030
Office 2, (*Article 7, Fig.2)*	20-22/ 24-28	15-25/ 35-75	200-250	500-750	0.020
Office 3, (*Article 7, Fig.3)*	18-22/ 20-24	20-30/ 40-74	350-600	350-1200	0.015
Office 4, (*Article 7, Fig.4)*	17-20/ 22-28	15-30/ 40-70	690-1209	478-1152	0.011
Office 5, *(Article 4, Fig.2)* room closed to atrium*	21-22.5/ 23-26	24-26/ 48-53	457-847	585-935	0.017
Office 6, *(Article 4, Fig.2) room closed to outdoors**	20-23/ 23-32	24-25/ 44-62	300-915	462-744	0.011
Office 7, *(Article 4, Fig. 4 room closed to atrium*	21-23/ 24-27	24-33/ 35-48	433-1160	541-897	0.015
Office 8, (*Article 4, Fig.4); room closed to outdoors*	11-21/ 21-32	14-33/ 41-49	690-1209	478-1152	0.011 0.099 in the smoking room

*U - the uncertainty of measurements; T - temperature of the air; R - relative humidity; L - lighting; CO_2 - concentration of carbon dioxide in the air; Dust - dust concentration in the air; * - unopenable windows*

The proposed HRA model used for the office rooms is presented in Fig. 4. The work conditions, such as lighting of workplaces, ventilation, concentration of carbon dioxide, relative humidity of the air and room temperature; the dust concentration in office rooms, are classified. The ergonomic conditions are very closely connected with the room air quality, the necessity of ME depending on the ergonomic situation in the workplace is also shown in Fig. 4. The limits for carbon dioxide for four comfort classes are based on EVS-EN 15251:2007. The dust limit concentrations are determined based on the relevant Estonian regulations (Resolution, 2011), the measurements of dust, “feeling of dust” and visually perceived cleanliness of the air (Schneider, 2008 a, b) are taken into account in the HRA of office rooms.

< 100 RH< 20 or RH >70 T <19 or T >27	< 300 20<RH<70 19 – 27	300 – 500 25<RH<60 20 – 26	500 – 600 30<RH<50 21 - 23.5	Lighting, lx Humidity (RH), % Temperature of air (T), °C
v < 4	4 ≤ v <7	7≤ v ≤10	v > 10	Ventilation, (v) l/s per person
> 800	***≤ 800***	***≥ 500***	***350-500***	***CO_2, ppm (over the outdoor level)***
0.09 – 0.1	***0.06 -0.09***	***≥0.05***	***0.01 – 0.05***	***Dust, mg/m³***
Over 8 hours/day	8 hours/day	6 hours/day	4 hours/day	Work with computers
Old chairs, static posture, no natural lighting	The standard workplace for everybody, static posture	The desires of workers have been taken into account in some points (the chair)	The workers have designed the workplace themselves	Workplace ergonomics

4th health risk level	3rd health risk level	2nd health risk level	1st health risk level	**Variables**
ME** once-twice a year	***ME** once a year***	***ME**once in 2-3 years***	***ME** once in 3 years***	

**Medical examinations (*ME*)

Figure 4. The health risk levels for different hazardous factors in office rooms for administrative and research personnel

The comfort at workplaces is also determined with ergonomic indicators, like workplace design, the time spent at the computer per workday. The frequency of medical examinations (ME) is determined by the investigation results of computer-equipped workplaces (Tint et al., 2014). According to the Resolution of the Ministry of Social Affairs No.74 of 24 April 2003 on the procedure for health examination of workers (Resolution, 2003), the industrial workers and computer-workers are required to undergo the medical examination once in 2-3 years according to the decision of the occupational health doctor. According to the HRA model (Fig. 4), in the 3rd comfort class, the health examinations are recommended once a year and in the 4th comfort class, once-twice a year. If three or more hazards are over the norms in the 4th risk level, then the ME is recommended in the hot and in the cold season (twice a year). Currently, the decision is made by the occupational health doctors. The medical examinations are paid by the employers. From the viewpoint of the worker, the best result would be received if part of the costs for medical service of working people are compensated by the state. The close co-operation between the employers and occupational health personnel is needed.

The thesis contributes new insight by presenting a model of the HRA, which served as the possibility for risk assessment and can support to assess occupational hazards, to evaluate possible health outcomes as well as to link the health risk levels the frequency of the medical examinations.

The current model can be seen as an effective tool for assessment warning signals of safety what should be changes and allows in-depth studying the occupational hazards and, thus, can assist in the promotion safety in the enterprises and prevention occupational disease and accidents.

3.3. Hazardous gaseous components in the work area during handling of shale fuel oil and the hard and soft wood dust particles

The main emphasis in the investigation (*Articles I, II, V, VII,*) was placed on the chemicals and dust in the shale fuel oil handling and other manufacturing technologies, i.e. on their measurement, hazardousness to the workers, consideration of the EU and Estonian legislation in the field of OHS, to work out the HRA models for industrial and office rooms. The air environment in chemicals handling contains a large variety of chemicals. Focus in the articles is on the determination of hazardousness of chemicals to the human nervous system, to the skin, and to the internal organs.

Fig. 5 presents GC/MS based headspace analysis of shale fuel oil (*Article 1*). The dotted line presents total ions chromatogram (TIC) of shale fuel oil indicating that a wide range of compounds vaporizes from the shale fuel oil. The figure shows the GC-MS spectra of the vapor phase which is in equilibrium with the liquid fuel oil at 40°C (corresponds to the shale fuel oil vapor pressure at 1.13 kPa) (*Article 1*). Results were compared to a library of mass spectra and selective ions monitoring (SIM) of specific target compounds with known retention times. The ions peak of phenol appears to be very low, but there is reason to believe that phenol vaporizes under these conditions from the kukersite oil shale derived fuel oil (*Article 1).* This study also shows that than higher the ambient temperature is than more potentially harmful compounds evaporate.

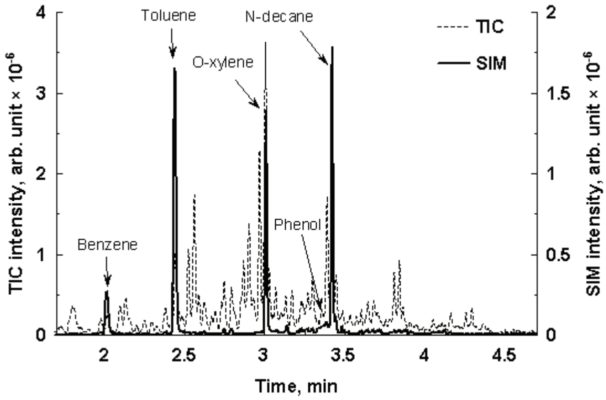


Figure 5. Mass-spectrum from headspace analysis of the shale fuel oil vapor phase at 40°C (*Article 1*)

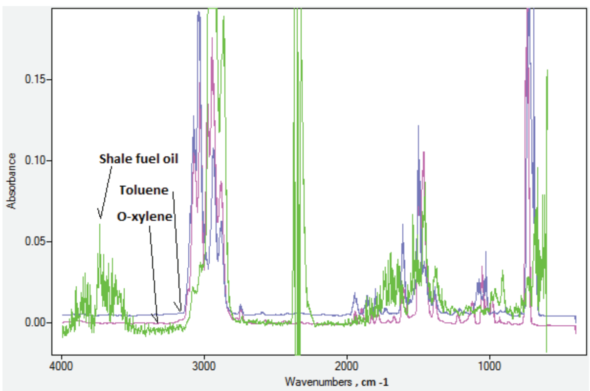


Figure 6. Determination of toluene and o-xylene with FTIR (*Article 6*)

Data characterizing the vapors identified during handling of shale fuel oil are presented in Table 7. The unpleasant smell of shale fuel is very strong and easily spreads throughout the work environment. Although the smell is bothersome, it does not provide a good measure of the exposure to hazardous chemicals. There is a wide variability in human sensitivity to feel the odor of specific compounds, including detection of the concentrations in the range of parts per million.

From the investigated gases, benzene is carcinogenic, toluene influences the central nervous system, benzene and toluene have also influence on unborn babies and may cause mutagenic effects. Xylene and phenols have effect on skin and if swallowed.

Table 7. Measurement results, odor thresholds, exposure limits, lethal concentrations and hazard statements of investigated chemicals evaporating from shale fuel oil

Hydrocarbon	Concentration of chemical in the air, ppm Dräger/FTIR	Hazard statements	Odor threshold, ppm	Exposure limit OEL, ppm	IDLH, ppm
Benzene (cyclohexa-1,3,5-triene)	1.0/n.i.	H225, H304, H315, H319, H340, H350	4.68	0.5	500
Toluene (Methylbenzene)	6.0/10.0	H315, H304, H373, H361	1.60	50	500
o-Xylene (1,2-Dimethylbenzene)	40.0/2.7	H332, H315	0.05	50	900
Phenol (Hydroxybenzene)	20.0/n.i.	H311, H301	0.04	2	250

n.i. - not identified

The concentration of o-xylene measured by Dräger methodic (compared with FTIR/FT) was higher because toluene was also indicated. There was no soft-wear for determination quantitatively the phenols with FTIR/FT device. So both the Dräger express method and the FTIR/FT device are very useful to determine chemicals vapors in the workroom during their handling. The results of measurement by the infrared spectroscope are presented in Fig.6. The analysis of the vapor phase of shale fuel oil composition revealed the presence of several hazardous compounds, including toluene, xylene, phenol and carcinogenic benzene, even at room temperatures.

The general ventilation works by diluting the air contaminants or vapors through pushing air to and from the workplace. This system can use natural air movement from open vents (windows, doors), or from a mechanical air-moving device. It is recommended only for substances with low toxicity. Because of this it can to disperse contaminants in the air, instead of removing them.

The ventilation productivity L for hazardous chemicals in the air is determined as follows (Angelstok, 2006):

$$L = \frac{G \times 10^6}{(Cw - Co)} \quad (1)$$

where L – the ventilation productivity, m^3/h

G – the amount of the polluting substances in the air of the work environment, kg/h

C_w – the concentration of the polluting substances in the air, mg/m^3

C_0 – the concentration of the pollutant in the outdoor air, mg/m^3.

The amount of the polluting substances ***G*** evaporating into the air of the work environment from the technology equipment is calculated considering the volume of the equipment, the factors of tightness and reserve of the devices, the relation between the vapour pressure in the apparatus and the air pressure in the work-room; the density of the vapors of hazardous substances evaporating from the equipment, the vapor pressure of the volatile components etc., depending on the process.

The coefficient of the ventilation multiplicity ***K*** is calculated as ***L/V***, where ***V*** is the volume of the workroom.

Dilution ("general") ventilation is forbidden in the case of highly toxic chemicals, only (local) exhaust ventilation is permitted (Resolution, 2007; Air, 2009). The exhaust ventilation multiplicity in each particular case is possible to calculate by the equations given in "Basis of ventilation" (Angelstok, 2006).

Wood (soft and hard) and metal dust are influencing the pulmonary organs *(Article V, VI*). It is essential to follow the legislative acts on chemical and dust concentration in industrial and office rooms. The exposure limits for dust in industrial rooms and offices are different. Therefore, it is very important to separate the industrial and office rooms and protect the office rooms from high-level dust amounts entering. Sometimes (depending on the season, wind speed and frequency of road transport) the outdoor fresh air is polluted more with dust (but less with carbon dioxide) than the mechanically ventilated indoor air. The personal protective devices have to be used in industrial rooms. The dust particle distribution has to be determined in every special case separately, but the results of the current study address the differences in the particle size of soft and hard wood dust.

The highest dust concentration measured in wood industry, was 4.27 mg/m^3. In the glass wool industry it is up to 20 mg/m^3. The health risk level is the 4^{th} in this case. The exposure limit for all inhalable dust in Estonia is 5 mg/m^3 (Resolution, 2001), although for wood dust it is 2 mg/m^3. The effective measures for workers' health protection are: effective local exhaust ventilation by all woodworking machines; automated machines; rooms should be cleaned every day, particularly the workplaces with vacuum; ventilation should be balanced by the intake of fresh air. The magnification on 10,000 times showed that the particles of wood dust are round rather sharp (*Article 6).* The conditions in the wood processing industry in Estonia have been improved compared with the period 1968-1995. Concentration of dust has decreased after the implementation of the compressed air at manual machines, work at fully automatic or semi-automatic machines, vacuum cleaning of machines, exhaust ventilation functioning, and regular daily cleaning of workrooms. From the investigated different Estonian softwood types juniper has the strong smell, but it is used only in small amounts for making souvenirs. The disparity of particles` shape between different type of woods was not observed. The shape is mostly round rather than fibrous (see *Article VI*, Fig. 5). Therefore, the toxicity of dusts is identified only by the type of wood. The distribution of particle size is smaller in softwoods` dust, therefore they are more hazardous for workers. Because of this, the occupational exposure limit (OEL) for dusts is justified to be the same both for soft- and hardwoods (2 mg/m^3) regarding to the Estonian legislation (Resolution, 2001).

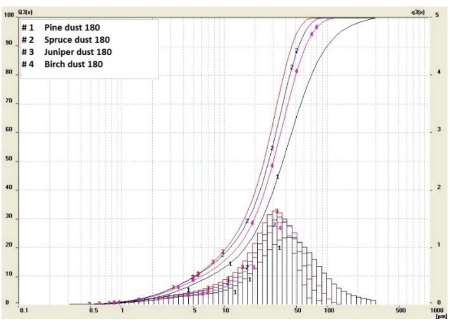


Figure 7. Dust particles distribution from grinding of different woods with 180 grit sandpaper (*Article VI*)

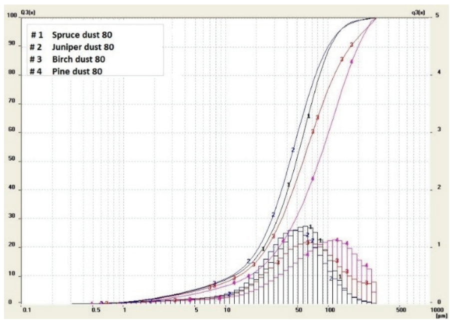


Figure 8. Dust particles distribution from phasing of different woods with 80 grit sandpaper (*Article VI*)

Fig. 7 and 8 show dust concentrations of pine wood and juniper after manual sanding of both woods (changes in sandpaper grit). The difference between the concentration of dust in the air using sandpaper P80 and P180 is insubstantial. The dust concentrations in the workrooms during testing were between 14 – 20 mg/m^3 (*Article VI*).

3.4. Modelling the categories of comfort in office-rooms situated in industrial and non-industrial premises

The categories of comfort as a term is presented in EVS-EN 15251 and as priority, for office-rooms (*Article III, IV*). To settle comfortable working conditions in industrial rooms is the topic of future research, but there are always office-rooms inside the enterprise buildings, where the comfortable conditions settled by the law for administrative workers have to guaranteed. In Fig.10 the inside office-room without direct natural lighting is presented. The ventilation of the room is lacking.

Figure 9. Inside office-room without ventilation and natural lighting

Figure 10. A new classroom in the university building

The modelling of risk categories and the boundary lines between the risk levels in office-rooms in the current investigation began from the settling of categories of comfort (also named as comfort classes). Here the hazards measurement results, the influence of these hazards on the human body and the legislative acts were taken into consideration (*Article III, IV)*.

The modelling of risk categories in office-rooms (Fig.4) contains more hazards than it is settled by the EVS-EN 15251 (from air temperature to ergonomic design of workplaces). The HRA model in offices (Fig.4) could be used in preliminary education for employers and employees to work out personal health care means for every office worker and workplace, particularly equipped with computer. As the risk analyses carried out by the author of the thesis in Estonian offices have shown, the peculiarities of the work have to be taken into account.

The comfort-classes in office-rooms are determined in the *Articles 3 and 4*. The investigations gave the conclusion that the workrooms in the old educational and office buildings and partly in atrium-type buildings belong to the 3^{th} to 4^{th} category of comfort (*Article 3, 4*).

Article 3 is concentrating on the educational buildings: the old and new classrooms were investigated. As a conclusion, it is recommended to use the supplementary heating system when the air temperature in the rooms is below $19\ ^{0}$ C in winter time; the window blinds and efficient ventilation from spring to autumn time; to use the modern equipment for raising the humidity of the air in the rooms (particularly in winter). The results of the investigation (*Article 3*) showed that the ergonomic design of computer workplaces is very important. In this field, the most demanding issue is the direction of the light related to the computers and covering of windows with blinds if necessary (Fig. 11). The ergonomics re-design of the existing workplaces is cost-effective considering the health of the younger generations (*Article 3*).

The ventilation of classrooms and offices could be organized naturally or mechanically (*Article 7)*. In the classrooms with natural ventilation (*Article 7, Fig.7*) the concentration of CO_2 is lowered from 1200-1800 ppm by the end of the classes until 550-750 ppm by opening the windows during the breaks. In mechanically ventilated classrooms the higher concentrations were measured in overcrowded classrooms (1067 ppm), but to balance the CO_2 concentration to the level 550 ppm takes only 15 minutes.

The concentration of carbon dioxide is often over 800 ppm that classifies the school classrooms as in renovated buildings as in small by the area office-rooms in the atrium-type buildings into the 4th comfort class (*Article 3, 4*). Better comfort-classes are obtained in the classrooms in the new atrium-type buildings, where good ventilation of rooms is organized. In these new rooms, the room temperature is usually followed in winter time (supplementary heating); in the rooms closed to the atrium in summer time (not direct sunlight) etc. The right ventilation and air conditioning of office-rooms gives the base for prevention of indoor air quality problems (*Article 4*). In big towns, where the car-transportation is highly used, the outdoor concentration of carbon dioxide is high (400-450 ppm) (*Article 4*) and the outdoor air is dusty. So both, the natural and mechanical ventilation means have to be scientifically planned for cleaning the workrooms (*Article VII*, Fig. 7). The temperature in the workrooms outside the atrium in summer is sometimes over 30 ^{0}C. Therefore solar-reflecting glazing materials for large wall-type windows are needed to accumulate the observable part of solar radiation.

4. CONCLUSIONS

The health risk assessment (HRA) model for the determination of health risk levels for chemicals and dust in the air of the industrial rooms was worked out. It takes into account the concentration of the chemical vapors in the air, the exposure time, the new legislation (hazards statements) and is connected with workers' medical examinations. The model is very appropriate for the employers of SMEs and occupational health personnel. The prevention of health disturbances caused by chemicals is more complicated than the diseases caused by dust. If a simple dust mask as PPE could commonly be used against dust, then with a complex of chemicals in the air of the WE, the 4th health risk level is easy to identify. Advanced measurement equipment helps caring employers to solve the existence of hazardous substances in the work environment air and choose the possibilities to diminish the concentration of substances or substitute them to less hazardous.

The model for the determination of comfort classes in office rooms was developed, taking into account the ergonomic risks for computer workers, the increasing work at computers (over the worktime, 8 hours). The workers are working at computers at home ahead. The design of workplaces (to guarantee the humid, clean (from excessive CO_2 and dust) air with comfort temperature and natural lighting) has to be based on the health and safety considerations.

It is necessary to reduce emissions of the air pollutants at workstations by improving technological processes and proper operation of general and local ventilation systems. During the handling of shale fuel oil, painting of cars and other activities, the PPE for the specific purpose has to be used (e.g., Organic & Inorganic Gases & Particulates -Painters Masks / Disposable & Re Usable Masks (BS EN 405:2001+A1:2009)).

Besides the shale fuel oil industry, another main processing industry in Estonia is the wood processing industry that constantly harms the health of workers. The connections between the grinding fineness and forming of dust particles during polishing were found. It was determined that soft wood particle distribution is larger compared with hard wood particles forming by grinding and therefore the exposure limit value for both types of wood dusts is justified in Estonian legislation.

The results obtained can be used to verify the criteria for the assessment of occupational exposure, including the size of wood particles in the wood dust fractions in the work environment. It is reasonable to take into consideration precaution measures in the improvement process of wood manufacturing workplaces as the following preventive measures: staff must not sweep wood dust or use the gun of air compressor; staff training on using machines and local ventilation systems; visual inspection of ventilation ducts to ensure they are free from blockages and identify any broken/damaged ducts for repair; wood dust cleared up using a vacuum cleaner with HEPA filter, combination of wetting and vacuuming to reduce the dust being generated; warning signs displayed while specific machines are in use.

The health risk assessment model for office rooms connects the main parameters of the indoor air (air temperature, humidity, velocity, and concentration of carbon dioxide) with the frequency of the medical examinations. Also, the levels of workplace ergonomics are incorporated into the model. The conclusions on the ergonomics are based on the investigation in the *Articles III, IV and VII*. In the case of office rooms, the comfort classes were addressed considering the standard EVS-EN 15251.

The frequency of medical examinations is also included into the HRA model. The criteria for risk levels of occupational hazards and possible health complaints were obtained from scientific literature, standards and regulative norms.

4.1. Thesis contribution

This section summarizes the contribution made to the knowledge provided by the thesis. The present dissertation is innovative in several respects. The original contribution of the dissertation in both theoretical and practical terms lies in the following:

Theoretical and practical contributions

The main contribution of the study is the innovative conceptual model of risk assessment for the determination of health risk levels for chemicals (ethyl acetate, styrene, thiols, benzene, toluene, xylene, phenol, and butanol) and dust in industrial rooms. The model of health risk assessment, which served as the basis for using the relationship between the exposure concentration to chemical hazards and the potential health impairments for the evaluation of the health risk level, can support an evaluation of the employees' health as well as assessment of the frequency for medical examinations. In addition, this model can be seen as an effective tool for diagnosing the occupational diseases in the early stage.

The dissertation contributes important empirical evidence on how Estonian industrial enterprises and educational institutions address occupational health and safety and explores the main challenges in this field. The dissertation provides an assessment of occupational hazards (chemical, physical, and physiological), indicating some important safety flaws and drawing attention to contextual variables in the development of safety measures and the practical means for improving the working conditions.

In addition, the present dissertation provides proposals on the modelling of the categories of comfort in office rooms and industries, taking into account the microclimate indicators, including carbon dioxide concentration, dust and ergonomic risks for computer workers.

The present dissertation sheds new light onto the existing understanding of the toxicity and concentration of hazardous gaseous components in the work area during handling of shale fuel oil and the exposure limits for hard and soft wood dust particles.

4.2. Implications

The practical concern of this thesis is to improve working conditions in Estonia with a special focus on industries (shale fuel oil handling and wood processing) and educational institutions. The thesis identifies commonalities in the need to improve the working conditions and awareness of the employees and employers about occupational hazards and risk assessment.

Analysis and evaluation of work-related factors have potential use in manufacturing enterprises for a better harmonization of work content, health, occupational hygiene and safety. The dissertation provides recommendations how to change or modify workplace situations, and to implement a correct (locally adjustable) safety measure to improve working conditions and to reduce work-related diseases.

The thesis suggests several possible approaches for managing chemical, physical and physiological risks, which can be used by senior managers, particularly in manufacturing (small and medium-sized enterprises), safety managers and occupational health professionals.

The study proposed a model of health risk assessment as an effective tool to determine health risk levels in the case of chemicals and dust in industrial rooms, to evaluate the employees' health and to diagnose the occupational diseases as well as the frequency of medical examinations.

The findings from the current dissertation are also important from a practical standpoint in the working environment, because the thesis attempts to contribute the author's own views and suggestions of how to improve the working conditions.

The results from the thesis study are essential for the management in manufacturing enterprises, safety and chemistry researchers who perform studies in such enterprises as well as for lecturers, students, OHS professionals, and safety managers at the enterprises.

4.3. Study limitations and future research

This study has some limitations to be addressed.
First, there are methodological limitations. The use of a flexible health risk assessment (HRA) method is suitable for the materials processing enterprises or handling of chemicals in some stages, but cannot be applied for chemical plants where a number of several other factors should be taken into account at the risks to safety and health of the workers and to the environment.

In addition, a limited number of the investigated enterprises and educational institutions may represent a small sample. Thus, further research with a larger number of enterprises and wider spectrum of the occupational hazards (particular, chemicals) must be conducted.

This study was not designed for the results to be generalized to other Estonian enterprises. However, the results are likely to have applications for the other educational institutions and manufacturing enterprises operating in Estonia. It is essential to mention here that all the data in the current study have been gathered from a single country, Estonia. That could pose some limitations to the generalizability of the results.

Despite these limitations, this study revealed findings that have both theoretical and practical significance.

Future research

Future studies can concentrate on different chemicals to be examined and validated and the proposed model of health risk assessment can be implemented in manufacturing enterprises, particularly in SMEs. Future research is needed to evaluate employers' and employees' attitudes and level of awareness towards safety.

In addition, future research will need to clarify the lifetime course of air pollution effects with full control of potential confounders (e.g., prospective cohort studies), examine the relevance of cumulative exposures, disentangle effects of multiple pollutants, and investigate other factors that may modify air pollution health effects, and identify pathophysiologic links between air pollution and occupational health hazards for the employees.

The main method for cleaning the indoor air from the pollutants (dust particles or liquid vapors) is ventilation. The ventilation rates and operational parameters are determined by the relevant legislations and standards. Nevertheless, there are a complex liquid vapors in the air of the work environment, which are constituted during manufacturing or handling of chemicals containing primary products (for instance, in shale fuel oil or rubber handling), where unpleasant and troublesome smell will not disappear even with the adequate ventilation. Thus, future research is needed to evaluate whether possible interventions, such as additional ventilation or air filtration, new technologies, air pollution control systems (like, fume extraction system, gas scrubbing system or dust extraction and collection system) and new, more closed equipment for handling the chemicals, is necessary, effective and useful.

Based on the thesis study, the author emphasizes that air pollution needs to be eliminated and reduced, indoor air quality and health indicators need to be monitored; this will enable employers and the relevant authorities to be aware of the trends and consequences of indoor air pollution, so they can determine how to ameliorate the situation.

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ABSTRACT

Improvement of work environment through modelling the prevention of health risks focusing on indoor pollutants

The indoor air quality is an important health risk factor that influences also a person's well-being. Indoor air problems are closely connected with outdoor air problems and *vice versa*. Indoor air quality is characterized by physical, chemical and biological pollutants. The number of people in office rooms (public and commercial institutions) is increasing, at the same time, industrial workers' employers also face new unknown risks, particularly the difficulty to measure chemical hazards and dust in the industrial work rooms. In the current study, new solutions for risk assessment have been worked out considering the new legislation, standards, measurement possibilities and changes in the production technologies and work-life.

The work environment air is multi-complex, containing hundreds of different chemical vapors, not presented on the Safety cards. They might be caused by the temperature rise in the work environment or during the production, manufacturing or handling (for example, shale fuel oil). Until now, the only database on the air contaminants is the Safety cards (not given if the product is patented) and the measurements are possible only if the chemical is known before the measurements.

The main aim of the current doctoral thesis is to enhance the understanding of the improvement of the work environment in enterprises, focusing on the air pollutants such as dust and chemicals.

Measurements were based on the standards EVS-EN ISO 7726, EVS-EN 12464-1, EVS 891, ISO 9612, EVS-EN 15251 etc., using the main measuring devices of the work environment TESTO 435-2, HD 2302.0, TES 1358, and Dräger-Accuro Detection Pump. Gas chromatography mass spectrometry (GS-MS) with headspace sampling was used to determine the organic compounds. FTIR/FT- Interspec 301-X with open optical path was used to determine chemical vapors in the air. The measurement of dust was carried out with Haz-Dust EPAM NIR spectrometer 5000. For laser granulometry the Fritsch Particle Sizer "Analysette22" was used and particle distribution was investigated under the microscope Axioskop. The commercial vapor pressure tester ERAVAP, thermogravimetric analyzer (TGA) and gel permeation chromatography (GPC) were used to observe physical properties of shale fuel oil.

The findings of the current research allow a set of conclusions and recommendations to be made.

In the research process, new and original results were obtained, which enable the improvement of the working conditions in the manufacturing enteprises and educational institutions.

The results of the investigation are:

1. The model for the determination of health risk levels in the case of chemicals and dust in the industrial room was developed. It takes into account the concentration of the chemical vapors in the air (the data from shale fuel oil handling and the wood processing industry are used); the exposure time, the new legislation (hazards statements) and is connected with employees' medical examinations.
2. The model was developed to determine the comfort classes in office-rooms, taking into account the microclimate indicators, including carbon dioxide concentration and dust; ergonomic risks for computer workers, the increasing work with computers (over the worktime, 8 hours). The workers are working with computers at home ahead. The design of workplaces (to guarantee the humid, clean (from excessive CO_2 or dust) air with comfort temperature and natural lighting) must be based on health and safety considerations.
3. The shale fuel oil industry and the wood processing industry are the main processing industries in Estonia that constantly harm the health of workers. The investigations of the contamination of the indoor air during handling of shale fuel oil showed that in addition to the irritable chemicals, carcinogens (benzene) might be present. In the investigations of the wood processing industry, the connections between the grinding fineness and forming during polishing dust particles are reported. It has been determined that the distribution of soft wood particles is larger than the hard wood particles. In addition, conifer dust is stickier due to its resin content. Therefore, the exposure limit value for both types of wood dusts is justified in Estonian legislation.

The dissertation provides recommendations how to improve the health and safety situation at the enterprise level.

The present thesis is innovative in several respects. An original contribution in both theoretical and practical terms lies in the following:
The main contribution of the study is the developed innovative conceptual model of risk assessment for the determination of health risk levels in the case of chemicals (benzene, toluene, xylene, phenol on the basis of the shale fuel oil investigation results) and dust in industrial rooms. The model of health risk assessment, which served as the basis for using the relationship between the exposure concentration to chemical hazards and the potential health impairments for the evaluation of the health risk level, can support an evaluation of the employees' health as well as the assessment of the frequency for medical examinations. In addition, this model can be seen as an effective tool for diagnosing the occupational diseases in the early stage.

The dissertation contributes important empirical evidence on how Estonian industrial enterprises and educational institutions address occupational health and safety and explores the main challenges in this field. The dissertation provides an assessment of occupational hazards (chemical, physical, physiological), indicating some important safety flaws and drawing attention to contextual variables in the development of safety measures and the practical means for improving the working conditions.

In addition, the present dissertation provides proposals on modelling the categories of comfort in office rooms and industries, taking into account the microclimate indicators, including carbon dioxide concentration and dust; ergonomic risks for computer workers.

The present dissertation sheds new light onto the existing understanding of the toxicity and concentration of hazardous gaseous components in the work area during handling of shale fuel oil and the exposure limits for hard and soft wood dust particles.

KOKKUVÕTE

Töö iseloom Eestis ja töövahendid muutuvad pidevalt vastavalt majanduslikele ja kaubanduslikele vajadustele. Siseõhu kvaliteet on oluline töötaja tervist ja heaolu mõjutav tegur. Siseõhu probleemid on tihedalt seotud välisõhu probleemidega ja vastupidi. Siseõhu kvaliteedi määrab füüsikaliste, keemiliste ja bioloogiliste ohutegurite osatähtsus ruumi õhus. Inimeste arv, kes töötavad arvutiga (kontoritöö), kasvab, samal ajal seisavad tööandjad silmitsi ka uute tehnoloogiatega kaasnevate uute tundmatute terviseriskidega. Eriti suuri probleeme on Eestis kemikaalide ja tolmu määramisega tööruumi õhus, kus ainsaks teabeallikaks on ohutuskaardid, mille koostamisel on aga kasutatud tundmatu tasemega uuringuid (sh töötlemise käigus võivad näiteks plastmassi või kummi toorained; põlevkiviõli jne keemiliselt laguneda ja saastada tööruumi õhku identifitseerimata keemiliste ainetega). Samas muutuvad õigusaktid, standardid ohtlike ainete määramiseks, aga paranevad ainete kvalitatiivse ja kvantitatiivse määramise võimalused.

Töökeskkonna õhk on multi-kompleksne, mis sisaldab sadu erinevaid kemikaale, palju erinevaid orgaanilisi ühendeid, kui tootmisprotsess on nende töötlemisega seotud. Õhku eralduvate keemiliste ainete ohutuse andmed peaksid olema esitatud ohutuskaartidel. Kuid nagu eespool öeldud, ei ole ohutuskaardid täiuslikud, sest tootmisprotsessis või käitlemisel võivad erinevatel temperatuuridel eralduda uued, ohutuskaardil mitte kirja pandud keemilised ained. Kui lähteained on uudsed, siis võib ka patentide võtmise vajadus takistada kogu teabe avaldamist ohutuskaardil.

Mõõtmiste valdkonnas kasutatakse kemikaalide määramiseks õhus siiani üldiselt kas kromatograafiat või Dräger-ekspressmeetodit. Kumbki ei ole piisavalt täpne ja kemikaalikoguse määramine õhus on võimalik ainult siis, kui kemikaal on ette teada.

Kaasaskantavad spektromeetrial põhinevad mõõteriistad võimaldavad avastada töökeskkonnas suurt hulka keemilisi ühendeid (FTIR/FT-NIR: 5000 kvalitatiivselt ja 435 kvantitatiivselt). See on eriti abiks, kui tootmises kasutatakse orgaanilisi aineid ja tootmis- ning töötlemistemperatuurid on laias vahemikus (20 - 600 ja enam ^0C). Näiteks põlevkiviõlide käitlemisel on uuritud tööruumi õhu saastatust kemikaalidega kolmel temperatuuril: 20, 40, 70 ^0C.

Et hinnata nende erinevate kemikaalide segude mõju töötaja tervisele, tuleb nii tööandjale kui ka töötajale ja töötervishoiuarstidele luua ja kättesaadavaks teha lihtsad riski hindamise skeemid, mis arvestavad kehtivaid õigusakte (piirnorme ja ekspositsiooniaega).

Uuringud näitavad, et kõva puidu tolmuosakesed on inimesele ohtlikud ja kopsu sattudes kinnituvad sinna pikemaks ajaks, seetõttu on haiguse kulg pikaajaline. Erinevates maades on arutusel (USA), et kõva ja pehme puidu piirnorm peaks olema erinev.

Töös väidetakse, et pehme ja kõva puidu tolmu osakesed ei ole ühesuguse jaotusega, pehme puidu osakesed on laiema tolmuosakeste jaotusega ja seetõttu ei ole põhjendatud piirnormi vähendamine pehmete tolmuosakeste suunas.

Ametiruumide õhk on saastunud süsinikdioksiidiga, talvel on keskküttega tööruumi õhk liiga kuiv, uut tüüpi (aatrium) majades ei ole piisavalt loomulikku valgust, samuti ei ole soojendus- ja jahutussüsteemide (ka kliimaseadmete) relaksatsiooniaeg piisav.

Töös väidetakse, et kui tervise ja ohutusenõudeid (sh ergonoomika) on arvesse võetud hoonete projekteerimisstaadiumis, siis on võimalik põhilisi siseõhu kahjulikke mõjusid töötaja tervisele ja mugavustundele vältida. Seejuures on vajalik ka praegusest intensiivsem ventilatsiooni ja konditsioneerimisseadmete järelevalve koos töötajate tervise monitooringuga. Kontakti loomine tööandja ja töötervishoiu-alase järelevalve vahel võimaldab vähendada tööst põhjustatud haigusi, aga ka kutsehaigusi, mis on juba suurem tervisekahjustus kui nimetatu.

Mõõtmised põhinevad standarditel EVS-EN ISO 7726, EVS-EN 12464-1, EVS 891, ISO 9612, EVS-EN 15251 jt. Mõõtmistel kasutatud seadmed: TESTO 435-2, HD 2302.0, TES 1358, Dräger-Accuro Detection pump; gaaskromatograafiline mass-spektromeeter (GS-MS). Keemiliste ainete määramiseks õhus kasutati FTIR/FT-NIR spektromeetrit Interspec 301-X avatud optilise proovivõtu seadmega. Tolmu mõõtmiseks kasutati Dust EPAM 5000; tolmuosakeste jaotuse, suuruse ja kuju määramiseks kasutati seadmeid Fritsch Particle Sizer "Analysette 22" ja mikroskoopi Axioskop. Põlevkiviõli omaduste uurimisel olid veel kasutusel aururõhu tester ERAVAP termogravimeetrilise analüsaator (TGA) ja geelkromatograafiline seade GPS.

Töö tulemused:

1. Kemikaalide ja tolmuga seotud terviseriski taseme määramise mudeli välja töötamine, kasutades antud uurimistöös kogutud andmeid ja kehtivat seadusandust ning kemikaalide toksikoloogilisi riskianalüüse. Mudel sobib eriti väikeste ja keskmise suurusega ettevõtete tööandjale ja töötervishoiuarstile. Mudeli aluseks on põlevkiviõli käitlemisel ja puidu töötlemisel saadud andmed.
2. On välja töötatud kontoriruumide mugavusklasside määramise mudel, võttes arvesse ka arvutiga töötamise ergonoomilisi terviseriske. Peamine rõhk mudelis on pööratud tolmu ja süsinikdioksiidi tasemete (kontsentratsioonide) seostele võimalike tervisekahjustustega. Töö arvutiga võib kesta rohkem kui ametlik tööaeg lubab (8 tundi) ja erinevates tingimustes. Vajalik ka töötajate koolitus terviseriskide osas. Töökohtade projekteerimine peab põhinema ergonoomilistel kaalutlustel.
3. Peamised tööstusharud, mida on uuritud, on põlevkivi töötlemine ja puidutöötlemine. Mõlemad tekitavad tervisprobleeme. Põlevkiviõli käitlemisel on uuritud lenduvate aromaatsete ühendite sisaldust tööruumi õhu. Tööruumi õhu uurimisel selgus, et peale ärritavate ainete leidub ka kantserogeenseid aineid, nagu benseen. Puidutöötlemisega seotult on läbi viidud pehme ja kõva puidu osakeste tervisekahjustuse määra uuring, mille põhjal võib väita, et pehme

puidu osakesed on küll laiema spektriga, kuid kleepuvad kokku, mistõttu suuri erinevusi tervisemõjude seisukohalt pehme ja kõva puidu osakeste vahel ei ole, kui need ei ole kantserogeensed. Kõva ja pehme puidutolmu erinevate piirnormide kehtestamine ei ole põhjendatud.

Väitekiri annab soovitusi, kuidas parandada töötervishoiu ja -ohutuse olukorda ettevõtte tasandil.

Käesolev töö on uuenduslik mitmes mõttes.

Töö teoreetiline ja praktiline panus seisneb järgmises:

Peamine uuringu panus on uuendusliku teoreetilise riskianalüüsi mudeli välja töötamine terviseriski tasemete määramiseks kemikaalide (benseen, tolueen, ksüleen, fenool; põlevkivi käitlemise eksperimentaalse uuringu baasil) ja tööstustolmu puhul. Mudel terviseriski hindamiseks, mille aluseks on keemiliste ohuteguritega kokkupuute aja (ekspositsiooniaja) ja võimalike terviseriskide vahelise seose hindamine, samuti et hinnata vajadust tervisekontrolli sageduse osas. Lisaks kujutab see mudel tõhusat vahendit kutsehaiguste varajaseks diagnoosimiseks.

Väitekiri toob välja olulisi empiirilisi tõendeid selle kohta, kuidas Eesti tööstusettevõtetes ja haridusasutustes tegeldakse töötervishoiu ja tööohutusega ning lahatakse peamisi probleeme selles valdkonnas. Väitekiri annab hinnangu töökeskkonna ohuteguritele (keemilised, füüsikalised, füsioloogilised) Eestis, mis näitab mõningaid olulisi turvalisuse vigu ja mõtestab lahti ohutusmeetmete ja praktiliste vahendite arengusuundi, et parandada töötajate töötingimusi.

Lisaks tuuakse käesolevas väitekirjas ettepanekud mugavuskategooriate määramiseks ühiskondlike hoonete ja toomisettevõtete kontoriruumidele, võttes arvesse mikrokliima näitajaid, kaasa arvatud süsinikdioksiidi kontsentratsiooni ja tolmu; samuti ergonoomilised soovitusi arvutiga töötajatele.

Doktoritöö heidab uut valgust olemasolevatele arusaamadele toksilisusele ja ohtlike gaasiliste komponentide osas töökeskkonnas ja põlevkiviõli käitlemisel ning kokkupuute piirmääradele nii kemikaalide kui ka puidutolmu osas.

APPENDIX 1

Article 1

A.Traumann, P.Tint, O.Järvik, V.Oja
Determination of volatile hazardous components from shale fuel oil during handling.
Materials Science (Medžiagotyra), 2014, 7 pp., accepted

Kaunas University of Technology

APPENDIX 2

Article 2

A.Traumann, V.Siirak, P.Tint
Why is education in environmental safety so important?
Environmental Engineering and Management Journal, 2012,
Vol.11, No.11, 2065-2072.

Gheorghe Asachi Technical University of IASI

APPENDIX 3

Article 3

A.Traumann, P.Tint, V.Tuulik
Indoor air quality in educational institutions in Estonia.
Environmental Engineering and Management Journal, 2012, Vol.11, No.1, 207-214.

Gheorghe Asachi Technical University of IASI

APPENDIX 4

Article 4

P. Tint, **A.Traumann**

Health risk assessment in atrium-type buildings. *International Journal of Energy and Environment, 2012,* Vol.6, Issue 4, 389-396.

WSEAS,

World Scientific and Engineering Academy and Society

APPENDIX 5

Article 5

A.Traumann, K.Reinhold, P.Tint
The model for assessment of health risks of dust connected with wood manufacturing in Estonia.
Agronomy Research, 2013, Vol 11, No.2, 471-478.

Estonian Agricultural University

APPENDIX 6

Article 6

A.Traumann, P.Tint, K.Reinhold
Qualitative and quantitative determination of chemicals and dust in the air of the work environment.
Proceedings of the 8th International Conference on Environmental Engineering, May 22-23, Vilnius, 2014, Vilnius Gediminas University, 10 pp.,
accepted

Vilnius Gediminas Technical University

APPENDIX 7

Article 7

A.Traumann, P.Tint, M.Kritsevskaja, D.Klauson
Air quality as an important indicator for ergonomic offices and school premises.
Agronomy Research, 2014, Vol 12, No.2, 11 pp., accepted

Estonian Agricultural University

APPENDIX 8

CURRICULUM VITAE

1. Personal data

Name	Ada Traumann
Date of place of birth	7 March 1970, Estonia

2. Contacts

Address	Kastolatsi tee 3, Otepää, Valga County
Phone	5126591
E-mail address	Ada.Traumann@ttu.ee

3. Education

Educational institution	Graduation year	Education (field of study/degree)
Tallinn University of Technology	2010…	Chemical engineering, PhD
Tallinn Polytechnic Institute	1988 – 1994	Technology of sewing products

4. Language competence/skills (fluent, average, basic skills)

Language	Level
Estonian	Fluent
English	Average
Russian	Average
Finnish	Basic

5. Special courses

Period	Educational or other organisation
February 2013	Nordic Institute for Advanced Training in Occupational Health (NIVA), Finland. Course: Roadmap to World Class Safety - New Approaches in Safety Research (Part II)
October 2012	Nordic Institute for Advanced Training in Occupational Health (NIVA), Norway. Course: ”Indoor air quality, health, comfort and productivity – the use of energy in buildings and building dampness“

May 2012	Nordic Institute for Advanced Training in Occupational Health (NIVA), Lithuania. Course: Roadmap to World Class Safety - New Approaches in Safety Research (Part 1)
October 2010	Eurotox Education Committee, Greece, Crete. Course: Basic Toxicology Course

6. Professional employment

Period	Organisation	Position
2010…	Tallinn University of Technology	Lector
2007 – 2008	Uptown Polska Sp.z.o.o	Manager
2006 – 2007	Baltika Ltd	Buyer
1994 – 2006	Zik-Zak OÜ	Production Manager
1994 – 1994	Estonian National Emergency Office	Laboratory

7. Research activity, including honours and thesis supervised

Field of research:
1. Biosciences and Environment, 1.9. Research into Substances Hazardous to the Environment, T270 Environmental technology, pollution control (Health and safety in work environment).

Current grants & projects:
"Workability and social inclusion"
"Chemical Engineering Aspects in Environmental Risk Assessment"
Additional information: Theme: Chemical hazards assessment in the handling of oil-shale oil (reg. nr. 11003re) 01.02.2011 - 31.12.2015.

Thesis supervised:
Katre Mähküll, MSc student's thesis on "Risk Analysis of Company AGN", Tallinn University of Technology

Published papers (selected):
1. Traumann, A., Tint, P., Järvik, O., Oja, V. 2013. Determination of volatile components from shale fuel oil during handling. B.Robu, C.Teodosiu (Eds.). *Integration Challenges for Sustainability. 7th International Conference on Environmental Engineering and Management. ICEEM07*. IASI, Romania: "Gheoghe Asachi" Technical University of IASI, Politehnicum Publishing House, 33-34.

2. Reinhold, K., Traumann, A., Tint, P. 2013. 2013. Environmental impact on human health of dust and chemicals from modern technologies. B. Robu, C. Teodosiu (Eds.). *Integration Challenges for Sustainability. 7th International Conference on Environmental Engineering and Management. ICEEM07.* IASI, Romania: "Gheorhe Asachi" Technical University of IASI, Politehnicum Publishing House, 57-58.

3. Traumann, A., Tint, P., Järvik, O., Oja, V. 2013. Management of health hazards during shale oil handling. *Agronomy Research*, 11(2), 479 - 486.

4. Traumann, A., Reinhold, K., Tint, P. 2013. The model for assessment of health risks of dust connected with wood manufacturing in Estonia. *Agronomy Research*, 11(2), 471 - 478.

5. Traumann, A., Tint, P., Reinhold, K. 2012. Work environment hazards during shale fuel oil handling. Riga: *Safety of Technogenic Environment*, 3(15), 50 - 55.

6. Traumann, A., Siirak, V., Tint, P. 2012. Why is education in environmental safety so important? *Environmental Engineering and Management Journal,* 11(11), 2065 - 2072.

7. Traumann, A., Reinhold, K. 2012. The health risk assessment in the work environment of shale oil production and handling. *In: Abstracts of the 62nd Conference of Chemical Engineering: 62nd Conference of Chemical Engineering, Vancouver, BC, Oct.14-17, 2012. Canadian Society for Chemical Engineering.* Canadian Soc Chemical Engineering, 2012, 1 p.

8. Tint, P., Traumann, A. 2012. Health risk assessment in atrium-type buildings. *International Journal of Energy and Environment*, 6(4), 389 - 396.

9. Tint, P., Traumann, A. 2012. Ergonomics of office-rooms workplaces in glazed buildings in cold climate. R. A. Rodrigues Ramos, I. Straupe, T. Panagopoulos (Eds.). Recent Researches in Environment, Energy Systems and Sustainability. *Proceedings of the 8th WSEAS Int. Conf. on Energy, Environment, Ecosystems and Sustainable Development (EEESD'12)*. Portugal: WSEAS Press, 152 – 157.

10. Tint, P.; Traumann, A.; Pille, V.; Tuulik-Leisi, V.-R.; Tuulik, V. 2012. Computer users' health risks caused by the influence of inadequate indoor climate and monotonous work. *Agronomy Research*, 10(S1), 261 - 276.

11. Traumann, A., Tint, P., Tuulik, V. 2012. Indoor air quality in educational institutions in Estonia. *Environmental Engineering and Management Journal*, 11(1), 207 - 214.

12. Paas, Õ., Traumann, A., Tint, P. 2011. Chemical risk assessment in the air of the work environment. *In: Hazardsap 2011 presentations, on-line: Hazards AP IchemE, Asia Pasific Symposium, 27-29 Sept. 2011, Malaisia, Kuala Lumpur. IchemE, Institution of Chemical Engineers, UK.* IchemE, UK, on-line: Institution of Chemical Engineers, 2011, 4 pp.

13. Traumann, A., Tint, P. 2011. Chemical risk assessment in the air of the work environment in manufacturing. *In: Abstracts of posters of ECCE: 8th European Congress of Chemical Engineering, 2011, Berlin, 25-29.09. Dechema,* 2011, 1p.

14. Tint, P., Traumann, A., Tuulik, V. 2011. Indoor air quality in educational institutions in Estonia. *In: 6th International Conference on Environmental Engineering and management. Green Future. Abstract Book: ICEEM06, 1-4 September 2011, Balatonalmadi, Hungary. (Eds.) Carmen Teodosiu, Akos Redey, Brindusa Robu.* Iasi, Romania: Ecozone Publishing House, Iasi, "Gheorghe Asachi" Technical University, 2011, 71 - 72.

15.Tint, P., Traumann, A., Siirak, V. 2011. The Assessment of Major Accident Risks in Tallinn. Maria G. Ioannides (*Eds.*). Proceedings of the 6th International *Conference on Interdisciplinarity in Education ICIE11,* April 14.-16, 2011 Karabuk, Safranbolu, Turkey. Athens, Greece: National Technical University of Athens, 20 - 26.

16. Tint, P., Reinhold, K., Traumann, A. 2011. The improvement of indoor environment in computer-classes. D.Cygas, K.D.Froehner (Eds.). *Environmental Engineering. Environmental protection.* 8th Int.Conf.May 19-20, Vilnius. VGTU Press "Technika", 382 – 386.

ELULOOKIRJELDUS

1. Isikuandmed

Ees- ja perekonnanimi	Ada Traumann
Sünniaeg ja -koht	7. märts 1970, Kuressaare
Kodakondsus	Eesti

2. Kontaktandmed

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E-posti aadress	Ada.Traumann@ttu.ee

3. Hariduskäik

Õppeasutus (nimetus lõpetamise ajal)	Lõpetamise aeg	Haridus (eriala/kraad)
TTÜ keemiateaduskonna doktorantuur	2010…	Keemiatehnika, filosoofiadoktor
Tallinna Polütehniline Instituut	1988 – 1994	Õmblustoodete tehnoloogia / insener

4. Keelteoskus (alg-, kesk- või kõrgtase)

Keel	Tase
eesti	kõrg
inglise	kesk
vene	kesk
soome	alg

5. Täiendusõpe

Õppimise aeg	Täiendusõppe korraldaja nimetus
Veebruar 2013	Nordic Institute for Advanced Training in Occupational Health (NIVA), Soomes. Kursus: Roadmap to World Class Safety - New Approaches in Safety Research (Part II)
Oktoober 2012	Nordic Institute for Advanced Training in Occupational Health (NIVA), Norra. Kursus: „Indoor air quality, health, comfort and productivity - the use of energy in buildings

	and building dampness“
Mai 2012	Nordic Institute for Advanced Training in Occupational Health (NIVA), Leedu. Kursus: Roadmap to World Class Safety - New Approaches in Safety Research (Part1)
Oktoober 2010	Eurotox Education Committee , Kreeta. Kursus: Basic Toxicology Course

6. Teenistuskäik

Töötamise aeg	Tööandja nimetus	Ametikoht
Alates 2010	Tallinna Tehnikaülikool	Lektor
2007 - 2008	Uptown Polska Sp.z.o.o	Juhatuse liige
2006 - 2007	Baltika AS	Ostuspetsialist
1994 - 2006	Zik-Zak OÜ	Tootmisjuht
1994 - 1994	Eesti Vabariigi Riiklik Päästeamet	Laborant

7. Teadustegevus, sh tunnustused ja juhendatud lõputööd

Teadustöö teema: Põlevkiviõlide käitlemisel eralduvate aurude ja gaaside ohtlikkuse
hindamine (reg. nr. 11003re) 01.02.2011 – 31.12.2015

Teadustöö põhisuunad:
1. Bio- ja keskkonnateadused, 1.9. Keskkonnaohtlikke aineid käsitlevad uuringud, T270 Keskkonnatehnoloogia, reostuskontroll (Töökeskkond ja -ohutus)

Projektid:
Interreg projekt “Töövõime ja sotsiaalne kaasatus”
„Keemiatehnilised aspektid keskkonnariskide hindamisel”
Juhendatud lõputööd: üliõpilase Katre Mähküll`i magistritöö teemal “ Ettevõtte AGN riskianalüüs”, rõivatootmise eriala, Tallinna Tehnikaülikool

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Also, my sincere thanks are due to my family, friends and colleagues for all their support during my study period and creating the pleasant working atmosphere.

DISSERTATIONS DEFENDED AT TALLINN UNIVERSITY OF TECHNOLOGY ON *CHEMISTRY AND CHEMICAL ENGINEERING*

1. **Endel Piiroja**. Oxidation and Destruction of Polyethylene. 1993.

2. **Meili Rei**. Lihatehnoloogia teaduslikud alused. Fundamentals of Food Technology. 1995.

3. **Meeme Põldme**. Phase Transformations in Hydrothermal Sintering Processing of Phosphate Rock. 1995.

4. **Kaia Tõnsuaadu**. Thermophosphates from Kovdor and Siilinjärvi Apatites. 1995.

5. **Anu Hamburg**. The Influence of Food Processing and Storage on the N-Nitrosamines Formation and Content in Some Estonian Foodstuffs. 1995.

6. **Ruth Kuldvee**. Computerized Sampling in Ion Chromatography and in Capillary Electrophoresis. 1999.

7. **Külliki Varvas**. Enzymatic Oxidation of Arachidonic Acid in the Coral *Gersemia fruticosa*. 1999.

8. **Marina Kudrjašova**. Application of Factor Analysis to Thermochromatography and Promotion Studies. 2000.

9. **Viia Lepane**. Characterization of Aquatic Humic Substances by Size Exclusion Chromatography and Capillary Electrophoresis. 2001.

10. **Andres Trikkel**. Estonian Calcareous Rocks and Oil Shale Ash as Sorbents for SO_2. 2001.

11. **Marina Kritševskaja**. Photocatalytic Oxidation of Organic Pollutants in Aqueous and Gaseous Phases. 2003.

12. **Inna Kamenev**. Aerobic Bio-Oxidation with Ozonation in Recalcitrant Wastewater Treatment. 2003.

13. **Janek Reinik**. Methods for Purification of Xylidine-Polluted Water. 2003.

14. **Andres Krumme**. Crystallisation Behaviour of High Density Polyethylene Blends with Bimodal Molar Mass Distribution. 2003.

15. **Anna Goi**. Advanced Oxidation Processes for Water Purification and Soil Remediation. 2005.

16. **Pille Meier**. Influence of Aqueous Solutions of Organic Substances on Structure and Properties of Pinewood (*Pinus sylvestris*). 2007.

17. **Kristjan Kruusement**. Water Conversion of Oil Shales and Biomass. 2007.

18. **Niina Kulik**. The Application of Fenton-Based Processes for Wastewater and Soil Treatment. 2008.

19. **Raul Järviste**. The Study of the Changes of Diesel Fuel Properties a its Long Term Storage. 2008.

20. **Mai Uibu**. Abatement of CO_2 Emissions in Estonian Oil Shale-Based Power Production. 2008.

21. **Valeri Gorkunov**. Calcium-Aluminothermal Production of Niobium and Utilization of Wastes. 2008.

22. **Elina Portjanskaja**. Photocatalytic Oxidation of Natural Polymers in Aqueous Solutions. 2009.

23. **Karin Reinhold**. Workplace Assessment: Determination of Hazards Profile using a Flexible Risk Assessment Method. 2009.

24. **Natalja Savest**. Solvent Swelling of Estonian Oil Shales: Low Temperature Thermochemical Conversion Caused Changes in Swelling. 2010.

25. **Triin Märtson**. Methodology and Equipment for Optical Studies of Fast Crystallizing Polymers. 2010.

26. **Deniss Klauson**. Aqueous Photocatalytic Oxidation of Non-Biodegradable Pollutants. 2010.

27. **Oliver Järvik**. Intensification of Activated Sludge Process – the Impact of Ozone and Activated Carbon. 2011.

28. **Triinu Poltimäe**. Thermal Analysis of Crystallization Behaviour of Polyethylene Copolymers and Their Blends. 2011.

29. **Mariliis Sihtmäe**. (Eco)toxicological Information on REACH-Relevant Chemicals: Contribution of Alternative Methods to *in vivo* Approaches. 2011.

30. **Olga Velts**. Oil Shale Ash as a Source of Calcium for Calcium Carbonate: Process Feasibility, Mechanism and Modeling. 2011.

31. **Svetlana Jõks**. Gas-Phase Photocatalytic Oxidation of Organic Air Pollutants. 2012.

32. **Aleksandr Dulov**. Advanced Oxidation Processes for the Treatment of Water and Wastewater Contaminated with Refractory Organic Compounds. 2012.

33. **Aleksei Zaidentsal**. Investigation of Estonian Oil Shale Thermo-bituminization in Open and Closed System. 2012.