JOURNAL OF ENVIRONMENTAL ENGINEERING
AND LANDSCAPE MANAGEMENT
2009
17(2): 69–80

HAZARD PROFILE IN MANUFACTURING: DETERMINATION OF RISK LEVELS TOWARDS ENHANCING THE WORKPLACE SAFETY

Karin Reinhold[1], **Piia Tint**[2]
Dept of Work Environment and Safety, Tallinn University of Technology,
Kopli 101, 11712 Tallinn, Estonia
E-mail: [1]*Karin.Reinhold@tv.ttu.ee;* [2]*Piia.Tint@tv.ttu.ee*

Submitted 28 Aug. 2008; accepted 12 Dec. 2008

Abstract. This study focuses on occupational hazards and the determination of risk levels derived from them. Indoor climate, noise, and dust are examined. An approach with numerical criteria is offered to assess these occupational hazards in manufacturing using a simple/flexible risk assessment method. Practical examples and the results of measurements of occupational hazards in five industries (mechanical, printing, wood, plastic and clothing industries) in Estonia are presented. Noise, as the most obvious health hazard, is analysed in depth, and the risk for noise-induced hearing loss is estimated. The overall purpose of the paper is to draw attention to the importance of measurements of occupational hazards in industry and to act as a reminder of a number of issues of practical relevance to effective workplace risk assessment from which employees, employers, occupational hygienists and physicians as well as authorities can benefit today and in the future

Keywords: legal regulations for occupational safety and health, labour conditions, work environment, occupational hazards, risk assessment, risk levels.

1. Introduction

In the last decades several researchers identified and studied a wide range of occupational hazards (physical, chemical, biological, psycho-social and physiological) that may lead to accidents (Hollmann *et al.* 2001; Saari 1990; Salminen *et al.* 1993). Accidents often result in occupational injuries, which can harm the reputation of a company, decrease productivity and result in large costs (Sheu *et al.* 2000). Injured employees may suffer not only pain and discomfort, but also more serious problems – either a temporary or permanent disability, or even death.

Risk assessment acts as a fundamental key factor in the safety management process of choosing the measures for prevention and protection (risk management) in order to guarantee the safety and well-being of workers (Degan *et al.* 2003). The safety management process can be summarized as follows:

1. Hazard identification and hazard evaluation (dangerous event forecasting);
2. Identification of involved people;
3. Numerical estimation of damage risk (damage can be classified in two categories: the accident and the occupational illness caused by the activity).

Workplace risk assessment can be defined as a systematic procedure for analysing workplace components to identify and evaluate hazards and safety characteristics (Harms-Ringdahl 2001). It is crucial to be able to identify the main hazards present in a work environment at a source and evaluate their magnitude, nature and characteristics. This way, a safe workplace can be provided.

As in many countries, employers in Estonia are legally obliged to carry out systematic, documented workplace risk assessment, which sets a special requirement to the method used: it should be flexible enough to be applicable for a large variety of enterprises. Risk assessment, which should be based on the measurements of occupational hazards in workplaces, has to be conducted by employers using their own resources or by registered practitioners in occupational health (Occupational Health and Safety Act adopted in 1999). The new supplement to the Occupational Health and Safety Act (enforced from 1 March 2007) strengthens the requirements for measuring laboratories of occupational hazards. The laboratories have to be accredited by the Standard EVS-EN ISO/IEC 17025:2006.

Manufacturing (wood processing, furniture, printing, clothing, plastic, wood, chemical process industries) dominates in the industrial activities in Estonia. The production is mainly exported abroad (Finland, Sweden, Germany, USA, etc.), while Estonians (population of 1.4 million; work force of 0.5 million) use only a small part of the products. Most Estonian manufacturing companies are small and medium-sized enterprises.

This study attempts to provide a basis for the determination of risk levels of the main physical (indoor climate, noise) hazards and dust in the work environment of manufacturing and to implement the flexible risk assessment method by using the results of measurements in five industries (printing, clothing, wood, plastic and mechanical industries), and draws conclusions about the main hazards.

ISSN 1648–6897 print / ISSN 1822-4199 online
DOI: 10.3846/1648-6897.2009.17.69-80

2. Methods

The study includes the following activities:

1. To connect risk levels and health complaints, the simple/flexible risk assessment method that was worked out by the authors in 2002 (Fig. 1, Reinhold *et al.* 2006) is used. The method is based on a two-step model that could be enlarged to a six-step model, and uses (no/yes) or (corresponds to the norms/does not correspond to the norms) principle. In this study, a five-step simple/flexible risk assessment method is used. The motivation to use five risk levels is derived from BS 8800:2004 standard, which also recommends five risk levels and is therefore familiar and easy to understand for employers and occupational health and safety specialists.

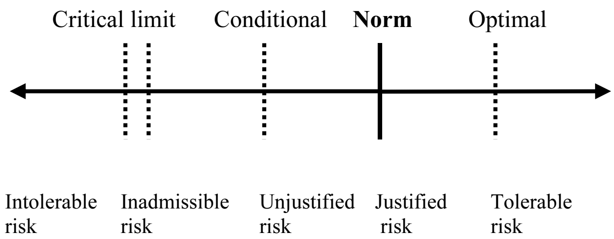

Fig. 1. Five-step simple/flexible risk assessment method

2. The criteria for risk levels of occupational hazards were obtained from regulative norms, standards, directives or scientific literature. Literature scan focused on the impact of the main occupational hazards on workers' health.

3. Eighteen case studies in companies of different industries were performed. Five case studies concerned the wood processing industry, five – the clothing industry, three – the printing and plastic industries each, and two case studies were carried out in mechanical industry. The idea was to cover some of the main industries in Estonia to be able to compare the results of measurements of occupational hazards in different industries, and to develop an analytical model as a basis for risk assessment at a workplace. For all the cases, the main occupational hazards were identified during the preparation visit to the factories. It was agreed beforehand, that some health hazards – indoor climate and noise – would be measured in all the cases. The office rooms of each factory were assessed separately. The details of the companies are shown in Table 3. The case studies were conducted in the time period of 2003–2008.

4. To perform the measurements of occupational hazards, standard methods were used:

- ISO 7726:1998 "Thermal environments – Instruments and methods for measuring physical quantities" (for indoor climate)
- ISO 9612:1997 "Acoustics – Guidance for the measurement and assessment of exposure to noise in a working environment" (for noise)
- WCB method 1150:1998 "Particulates (total) in air" (for dust)

3. Theoretical estimation of hazards using a simple/flexible risk assessment method

The examined physical hazards were selected considering the most common and obvious occupational hazards present in the industrial sector in Estonia. The authors have long-time experiences in solving complaints about indoor climate, dust, and noise in the working environment of different enterprises.

Next, a literature review and an analytical model based on the simple/flexible risk assessment method of the examined occupational hazards are presented.

3.1. Hazard: inconvenient microclimate

Exposure to high ambient temperatures while working in hot indoor climate or while working outdoors is a common occupational hazard. Workplace heat exposure, in addition to causing heat-related illness (such as heat stress, heat syncope, heat exhaustion, heat stroke, etc.), has been found to decrease productivity (Saari *et al.* 2006; Seppänen and Vuolle 2000) and to increase job-related accidents (Dukes-Dobos 1981).

Cold is a physical hazard that may affect workers both indoor and outdoor. The injuries may either be freezing or non-freezing. Non-freezing cold injuries include hypothermia, chilblains, pernio and trench/immersion foot, while freezing cold injuries cover, for instance, frostbites and forstnips (Evenson 2002). Additionally, cold stress can aggravate conditions caused by blood vessel abnormalities such as Raynaud's syndrome (Woodside and Kocurek 1997). The disturbances from an insufficient air movement at the workplace are fatigue, headache, breathing problems due to closed air in the workroom, disturbing smells as well as the decrease of cognitive abilities (Patterson *et al.* 1997).

The humidity of the air may influence the health and comfort of the worker as too dry air can cause local irritation of mucosa, eyes and skin. The overall symptoms are dizziness and headache. In the case of too humid air, the sensitiveness to the odours (gases, vapour) from the finishing materials will increase (Van Thriel *et al.* 2003).

According to the nature of work (technological requirements of production or technical reasons), the Estonian health protection norms on microclimate (Resolution ... 1996) divide the values of microclimate factors (air temperature, relative humidity, air velocity and thermal radiation intensity) into two categories: optimal microclimate parameters and permitted microclimate parameters. The minimal permitted air temperature in workrooms is 12 °C (in cold season the mean temperature of ambient air is below 10 °C), hard physical work (energy consumption exceeds 1050 kJ/h). The maximal permitted temperature is 28 °C (in warm season the mean temperature of ambient air exceeds 10 °C), light physical work (mainly performed in a sitting position, energy consumption is below 500 kJ/h). Both temperatures create conditions that may harm the human body if exposed for a long time. Therefore, these temperatures are permitted only at non-permanent workplaces and non-permanent working activities. Measures (e.g. availability of special rooms for warming-up in winter and intensive, but not on-blowing ventilation for cooling in summer; appropriate protective clothing, etc.) should be provided for particular industrial sectors like metal and glass works, construction work etc. By the norms, the optimal humidity of the air is 40–60%, while permitted humidity is up to 70%.

According to the classification of thermal comfort (EVS 839:2003), office rooms, living rooms, meeting rooms and other non-industrial rooms are divided into three types (A, B, C), where the most comfortable room is type A (Table 1). The permitted fluctuation of temperature of 0.5…3.0 °C (above or below 24.5 °C in summer and 22 °C in winter) is rather narrow – in practice, only new or renovated buildings with appropriate heating systems and thermoregulation are able to fulfil this requirement. The Estonian Standard EVS 839:2003 does not regulate temperature in industrial rooms.

Several studies indicate that high indoor temperatures reduce performance and productivity. Seppänen and Vuolle (2000) present a model on the average effect of temperature on performance, which shows that performance decreases by 2% per each degree over 25 °C and presents the link between a decrement in performance P (%) and high indoor temperature as follows:

$$P(\%) = 2x(Temp, °C) - 50. \tag{1}$$

This indicator is used here as a basis to connect the temperature rates with five risk levels.

The connections between the risk levels and stages of health complaints using the simple/flexible risk assessment method are shown in Fig. 2. Five different risk levels are distinguished, the numerical criteria are derived from regulations (Estonian indoor climate regulation), standards (ILO code of practice on ambient factors, EN 15251:2007, EVS 845-1:2004, EVS 839:2003, ISO 7726:1998) and scientific literature (Seppänen and Vuolle 2000; Witterseh *et al*. 2002).

3.2. Hazard: excessive noise

Occupational exposure to excessive noise is commonly encountered in a great variety of industrial processes (Baltrenas *et al*. 2007). Noise-induced hearing loss is often the cause of an occupational disease (Starck *et al.*

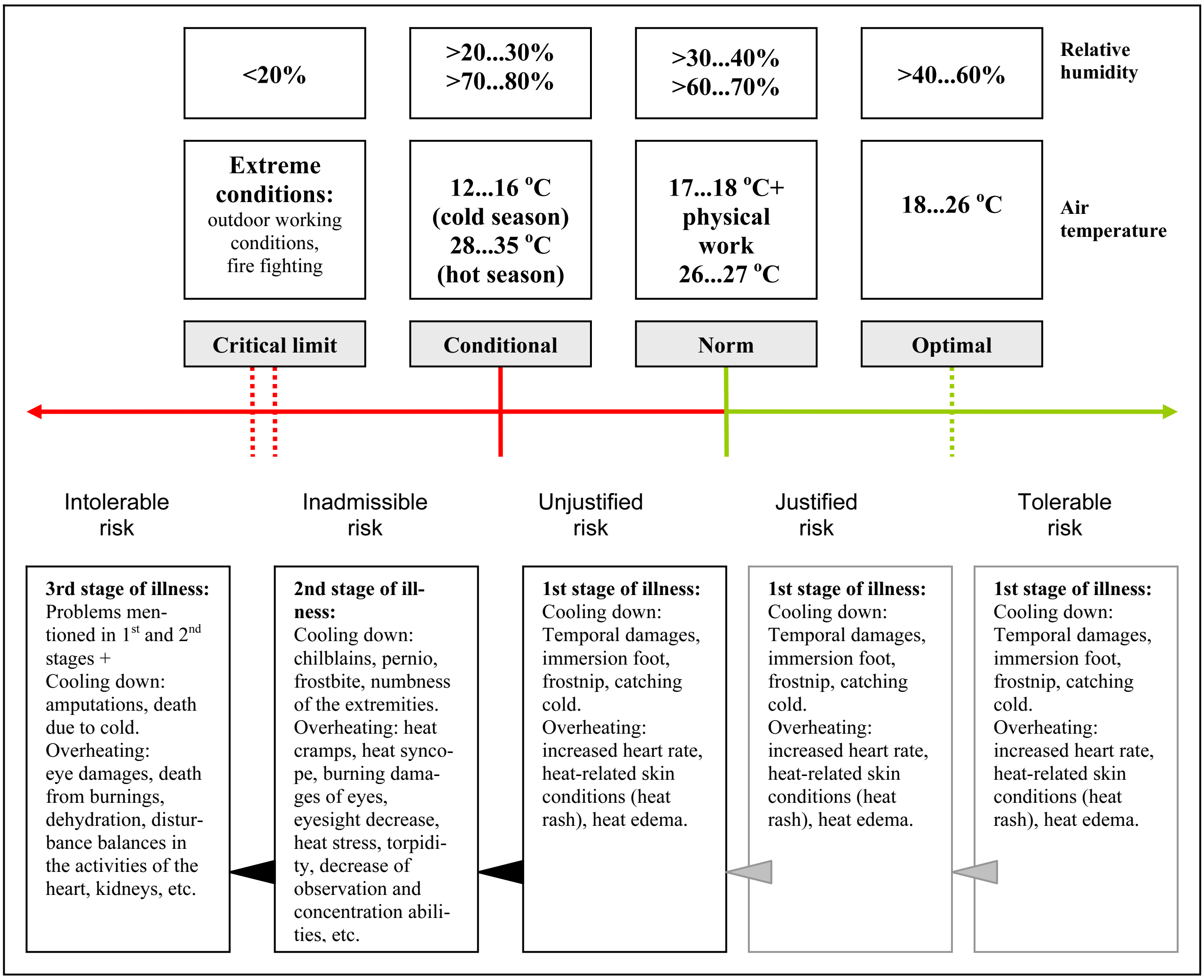

Fig. 2. Inconvenient indoor climate and risk criteria

Table 1. Comfortable indoor climate of office rooms (EVS 839:2003)

m^2 per person in the room	Room type	Air temperature, °C		Air velocity, m/s		Necessary ventilation, l/s per m^2
		In summer	In winter	In summer	In winter	
10	A	24.5±0.5	22.0±1.0	0.18	0.15	20
	B	24.5±1.5	22.0±2.0	0.22	0.18	14
	C	24.5±2.5	22.0±3.0	0.25	0.21	8

2004; Toppila 2000). But noise may cause harm in other ways as well: in industrial settings, it may contribute to cardiovascular disorders (faster pulse rate, increased blood pressure, coronary heart disease) (Dobbie 2002; Virkkunen *et al.* 2005; Woodside and Kocurek 1997), interact with dangerous substances to cause harm to the ear (Sliwinska-Kowalska *et al.* 2001), increase the risk of accidents by affecting spoken communication (Dobbie 2002), cause pregnancy complications while interacting with additional demands of shiftwork (Nurminen and Kurppa 1989) or have a negative impact upon job satisfaction (Nemecek and Grandjean 1973). Additionally, noise exposure has been found to be associated with self-reported fatigue (Carlestam *et al.* 1973).

Regulations limiting noise exposures of industrial workers have been instituted in many countries (Starck *et al.* 2004). In Estonia, the current threshold level value for 8-h noise exposure is 85 dB(A) (Resolution ... 2007a). To reduce noise levels, engineering control methods and administrative measures are used. If the engineering and administrative controls are not feasible or not in effect and a noise level less than 85 dB(A) is not achieved, personal hearing-protection devices should be offered to the workers. These devices are easily implemented due to low-cost methods of minimizing hearing loss from continuous exposure to high-intensity noise (Ivarsson 1997; Mohammadi 2008). Hearing damages from excessive noise are usually generated when noise exceeds permanently 85 dB(A) and the workers reject or misuse personal hearing protection. For effective noise-induced hearing loss prevention, it is important to reckon the spectral content of noise as the personal protective equipment is often designed according to the noise spectrum.

The connection between risk levels due to noise and stages of health complaints, determined using the simple/flexible risk assessment method, is presented in Table 2 and illustrated graphically in Fig. 3.

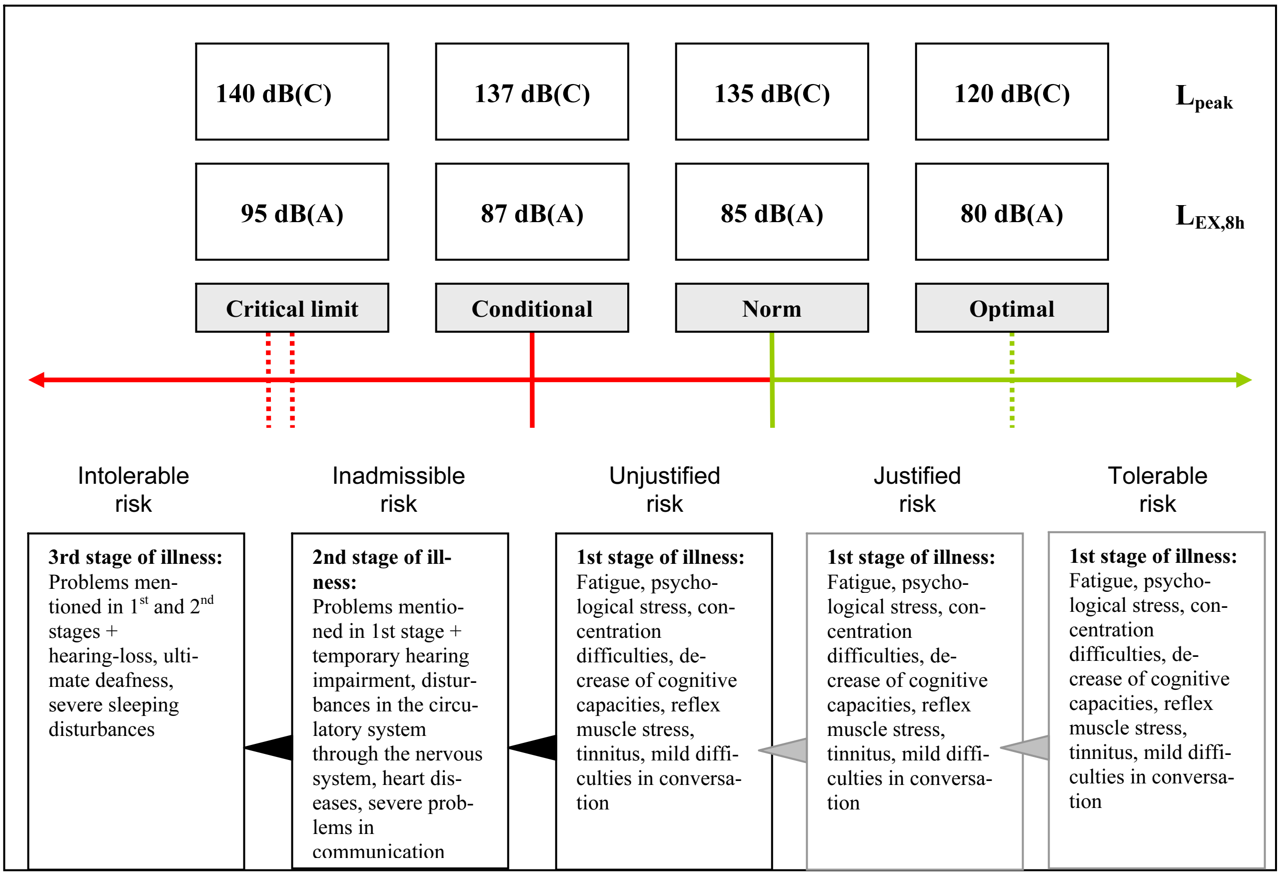

Fig. 3. Noise and risk criteria

Table 2. Noise: connection between risk levels and health complaints

Risk level numerically	Risk level	Criteria, dB(A)	Possible injuries to health
I	Tolerable risk	<80	Slight harm and complaints such as unpleasant feelings, mild difficulties for conversation, fatigue and psychological stress.
II	Justified risk	>80…85	Moderate harm such as that mentioned above + decrease of cognitive capacities, reflex muscles' stress, difficulties in conversation.
III	Unjusti-fied risk	>85…87	Severe harm such as temporary impairment of hearing, disturbances in the circulatory system through the nervous system, heart diseases, severe problems in communication, etc.
IV	Inadmissible risk	>87…95	Extreme harm such as hearing-loss, ultimate deafness, severe sleeping disturbances, etc.
V	Intolerable risk	>95	Rapid health impairments and excessive increase of the risk of accidents and occupational diseases. These noise levels should be avoided in any case.

Five different risk levels are distinguished, the numerical criteria were derived from regulations (Noise Directive 2001/10/EC (European Commission 2003), Estonian occupational noise regulation (Resolution … 2007a), calculations using standards on occupational noise (ISO 1999:1990 and ISO 9612:1997) and scientific publications (Atmaca *et al.* 2005; Eleftheriou 2002; Johnson 1991; Rachiotis *et al.* 2006; Toppila 2000; Powazka *et al*. 2002).

3.3. Hazard: dust

Wood dust poses a serious concern in Estonian manufacturing. The number of workers exposed to wood dust was 34,000 in Estonia in 1997 (Rjazanov *et al*. 2003). The distribution of wood-processing workers by the dust concentration in the air was: <0.5 mg/m^3: 8000 persons; 0.5–1 mg/m^3: 5000; 1–2 mg/m^3: 5000; 2–5 mg/m^3: 5000; >5 mg/m^3: 3000 (Kauppinen *et al.* 2006). The number of workers exposed to formaldehyde was 9000. The percentage of workers engaged in wood-processing of all industrial workers in Estonia was the highest in the EU (4.6%) (Rjazanov *et al.* 2003).

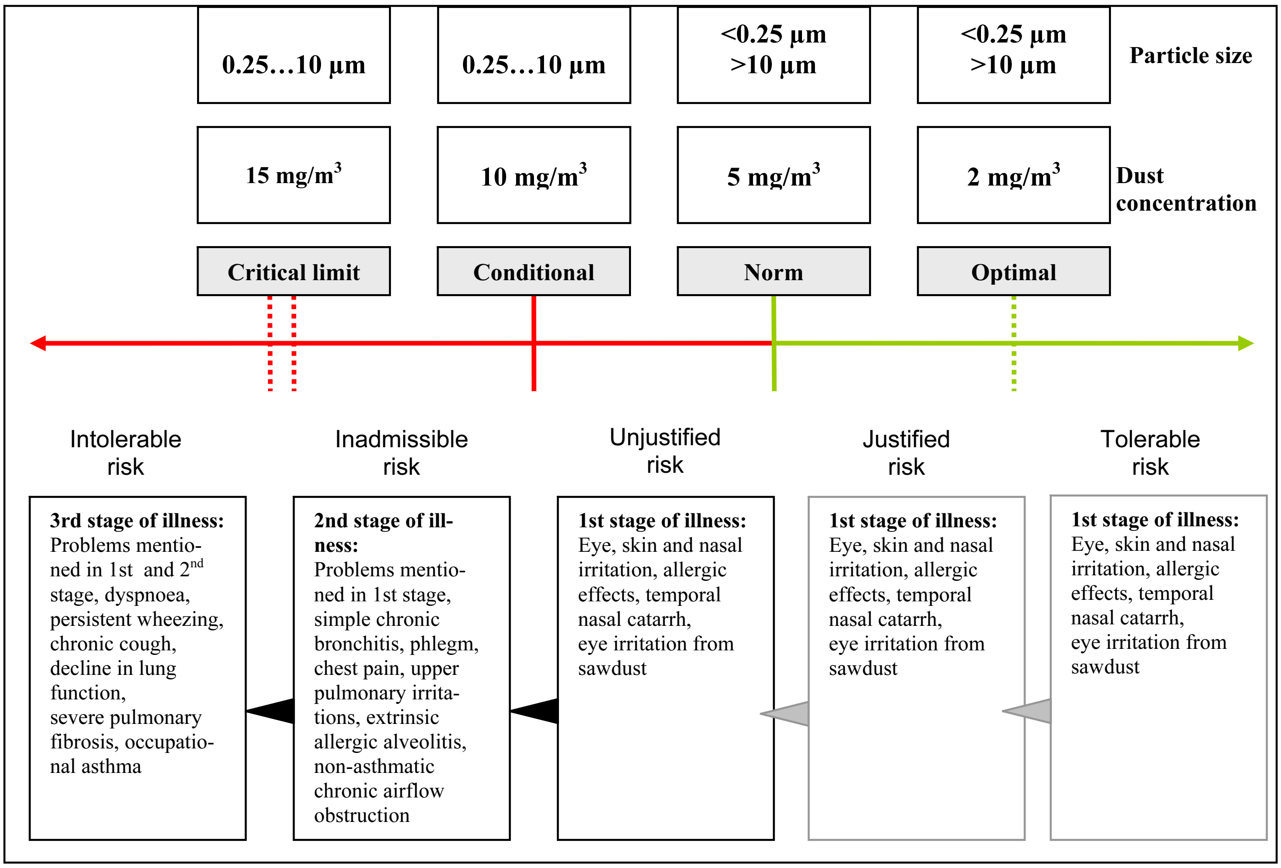

Fig. 4. Wood dust and risk criteria (does not apply to carcinogenic wood dust)

The risk assessment of dust exposure is based on the evaluation of the daily dose inhaled by workers. As the air flow inhaled by workers is constant (2.1 l/min) and knowing the time of exposure to dust for each worker, it is possible to calculate the air volume inhaled during the exposure period. The inhaled daily dose, considering the estimated concentration referred to eight hours, is expressed by the following formula (Degan *et al.* 2003):

$$\frac{V_{in}}{V_{st}} = \frac{X_c}{X_{st}}, \qquad (3)$$

where V_{in} is the inhaled volume by workers in each functional space, V_{st} – the standard volume (Nm^3), X_c – the partial dose and X_{st} – the dust concentration referred to the functional space.

Considering the data from scientific literature (Bardana 2003; Gustaffson *et al.* 2007; Jacobsen *et al.* 2008; Shamssain 1992; Stenton 2004), international standards (EN 481:1993; EN ISO 10882-1:2001) and Estonian norms for occupational dust in the work environment air (Resolution… 2007b) and using the simple/flexible risk assessment method, the connection between risk levels and health complaints due to wood dust is determined as shown in Fig. 4. Particle size and dust concentration in the work environment air were considered to be the basic variables determining the risk levels.

4. Analysis of health hazards

The data on companies investigated are given in Table 3. The analysis of the measurements of dust is also given in Table 3. All the investigated companies were assessed as small and medium-sized enterprises. In each company, the management attitude towards health and safety was assessed on the basis of the interest in the results of the research, the supportive actions to provide adequate information and details about the company and its investments into health and safety and the appreciation of workers' health through available protection, benefits, technical and administrative solutions present in the company and further efforts to enhance workplace safety. The awareness and supportive actions of the company management concerning occupational health and safety were assessed either as stimulating/supportive, neutral or impeding/negative.

4.1. Results of measurements of indoor climate

The indoor air parameters (room temperature and relative air humidity) were measured at 4 points of the workroom (8 if the surface area was over 100 m^2), at a level of 1.0 metres (sitting position) or 1.5 metres (standing position). Triplicate readings were recorded for each measurement and the average was presented. Before sampling, the doors between the rooms in the departments were closed

Table 3. Summary of the investigated companies

Industry	Companies	Number of workers	Awareness of company management	Dust, mg/m^3, U* = 0.3 mg/m^3
Wood processing	5	25…200	+ (2 cases), ± (2 cases), – (1 case)	2.0…10.0 (wood dust)
Clothing industry	5	120…225	+ (4 cases), ± (1 case)	0.4…1.0 (textile dust)
Printing industry	3	24…140	+ (2 cases), – (1 case)	1.2…4.4 (paper dust)
Mechanical industry	2	90…175	± (2 cases)	0.7…2.5(welding dust)
Plastic industry	3	25…180	+ (1 case), ± (2 cases)	2.05…6.04 (general dust)
Office rooms	18	15…100	+ (9 cases), ± (7 cases), – (2 cases)	n/m

Abbreviations: "+" – stimulating, supportive; "–" – impeding, negative; "±" – neutral, n.d. – not detected; n.m. – not measured, *U – uncertainty, k = 2

Table 4 presents the results of measurements of indoor climate and noise.

Table 4. Results of measurements of indoor climate and noise in manufacturing

Industry	Indoor air temperature, °C, U* = 0.6 °C		Indoor air humidity, %, U* = 2.0%		Air velocity, workplace, m/s, U* = 0.01 m/s	Noise level, dB(A), U* = 2.0 dB
	Cold season	Warm season	Cold season	Warm season		
Clothing	20.3…23.5	22.7…25.6	44.4…53.0	48.2…53.0	0.01…0.04	62.1…89.5
Printing	21.7…22.4	22.5…24.3	38.2…52.2	44.2…62.4	0.01…0.26	66.4…90.3
Wood	21.2…24.0	24.3…26.5	34.2…42.6	35.1…47.6	0.02…0.30	84.2…94.4
Mechanical	10.8…21.4	17.6…23.2	31.3…39.9	41.4…48.7	0.01…0.21	73.0…97.5
Plastic	14.0…22.4	18.6…25.5	26.1…40.7	36.5…45.7	0.02…0.07	61.1…83.8
Offices	18.7…23.0	22.4…26.7	32.6…47.9	39.5…54.6	0.01…0.17	46.7…62.4

for at least 1 hour and the doors to the corridors were closed all the time. The room temperature and relative air humidity were measured with electrical measuring instruments TESTO 615 and TESTO 625 and air velocity – with a termo-anemometer TESTO 415. The measurements of the room temperature were carried out twice in each factory – both in the cold and in the warm season.

In most investigated companies, the room temperature was at an acceptable level or very close to it. Some problems were encountered in the warm season in two companies of the clothing industry, two companies of the wood processing industry and one company of the plastic industry, where the temperature in departments was higher than optimal due to deficiencies in ventilation systems or their lack, however, it was still in the limits of permitted temperature. In the cold season, the temperature fell to a lower level than permitted in one of the mechanical companies due to deficiencies or lack of a heating system, opened doors and poor insulation of the industrial building.

Relative humidity posed a problem during the cold season when in some companies, the air dried due to a heating system and no conditioner system existed to balance the relative humidity of the air. A certain proportion of the employees complained about lippitude of eyes, skin xeric and dryness of mucus membranes, which may be caused by a low value of relative humidity during the cold season. However, no lower limit for relative humidity is fixed by Estonian regulations; any value below 70% is permitted. The values of air velocity were acceptable, except shortage of air during the warm summer days in rooms where the ventilation system was not regulated to produce higher air velocity values in the warm season than those in the cold season.

4.2. Results of measurements of occupational noise

As noise is the most obvious health hazard in the four different industries (mechanical, wood, printing and clothing) analysed in the current study, it is necessary to study the pattern of noise in depth to be able to implement appropriate risk control measures.

Noise, measured as equivalent continuous A-weighted sound pressure level (L_{eq}(A)), was evaluated under normal operating conditions using a hand-held Type II Sound Level Meter (TES 1358) following the standard method ISO 9612:1997. The measurement time interval varied depending on the type of noise exposure and was chosen so that all the significant variations of noise level at a workplace were measured and included. For some workplaces (especially in the mechanical industry) where noise occurred at a number of clearly distinguishable levels, the time interval was subdivided into sub-intervals, and the L_{eq}(A) was calculated using formula 4. Triplicate readings were recorded for each measurement (representing a certain machine working station) and the average was presented; additionally noise level analysis at various frequencies was conducted on the 1/3 octave band and linear (L) weighting mode.

To evaluate the health hazard and determine the risk level derived from noise, it is essential to assess the noise exposure level normalized to a nominal 8-h working day. The level, $L_{EX,8h}$, in decibels, is given by equation 4 (ISO 1997).

$$L_{EX,8h} = L_{Aeq.T_e} + 10\lg(\frac{T_e}{T_0}) \text{, dB,} \quad (4)$$

where $L_{Aeq,Te}$ stands for the equivalent continuous A-weighted sound pressure level over the effective time interval T; T_e and T_0 are the effective duration of the workday and the reference duration (8 h), respectively.

In many cases (e.g. in the clothing industry where a person works with the sewing machine the whole day, and a similar noise pattern is produced for all the procedures, 8 hours a day), T_e=T_0 and therefore, $L_{EX,8h}$ is numerically equal to $L_{Aeq,8h}$. In other cases, the noise produced by machines may occur only a part of the time or the worker's shift shorter than the reference duration (8 hours), and then formula 3 is applicable.

In the mechanical industry, where the time interval T was subdivided, the following formula was used to calculate the equivalent continuous A-weighted sound pressure level (ISO 9612:1997):

$$L_{Aeq,T} = 10\lg(\frac{1}{T}\sum_{i=1}^{m} T_i * 10^{L_{Aeq,Ti}/10}) \text{, dB,} \quad (5)$$

where $L_{Aeq,Ti}$ stands for the equivalent continuous A – weighted sound pressure level occurring over the time interval T, and m is the total number of sub-intervals of time.

It should be noted that T is equal to $\sum_{i=1}^{m} T_i$.

The results of noise measurements at various frequencies were used to identify specific frequencies with especially high intensity. These are useful to develop control measures and select appropriate ear protection. Moreover, it gives an indication about the noise levels for most hearing-damaging frequencies (0.5…2 kHz – the speech frequencies) which are the main concern in selecting the workers' hearing apparatus and serve as a basis in estimating numerically the risk of noise-induced hearing impairment/handicap if no risk control measures are applied or the worker misuses them.

The sound level meter was calibrated before each use to ensure accuracy.

The selected results of measurements are presented in Figs. 5–8 (four case studies in different industrial branches – one company in the mechanical, wood processing, clothing and printing industry each; selection of machines was based on the noisiest machines).

Compared to other studied industries, the noise levels in the clothing industry present the least concern as none exceeded 85 or 80 dB(A). Analyses of the measurements at various frequencies indicate that the noise level at work stations of machines have slightly different patterns, but all of them with the peak in the area of 500...2000 Hz.

According to the measurements, lower frequencies do not pose a concern in any of the studied industries. Knowing the prevailing damaging frequencies helps to decide which ear protection should be used. A hearing-protecting device can reduce the exposure significantly.

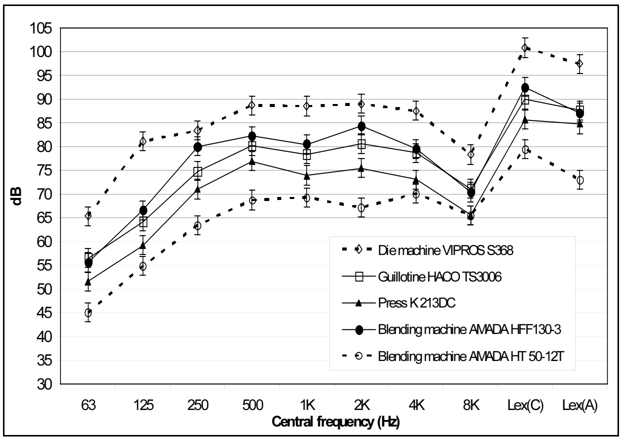

Fig. 5. Octave-band spectrum measurements and the values of 8-h time-weighted average exposure levels in the enterprise of mechanical industry

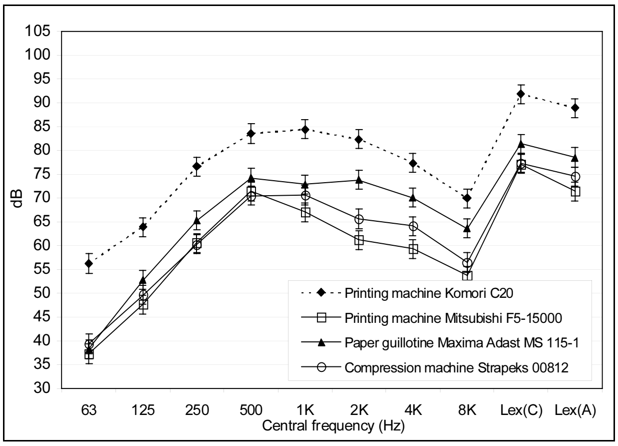

Fig. 7. Octave-band spectrum measurements and the values of 8-h time-weighted average exposure levels in the enterprise of printing industry

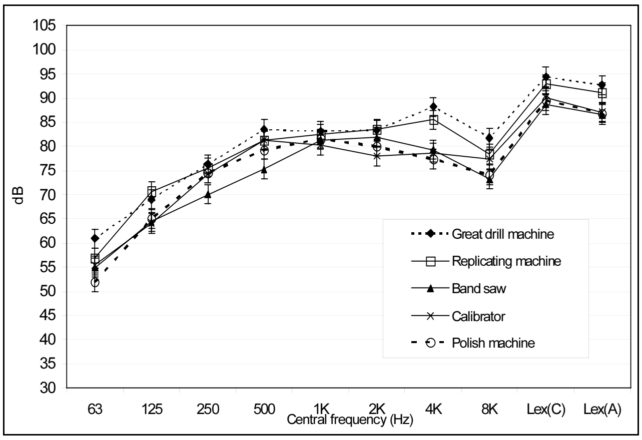

Fig. 6. Octave-band spectrum measurements and the values of 8-h time-weighted average exposure in the enterprise of wood industry

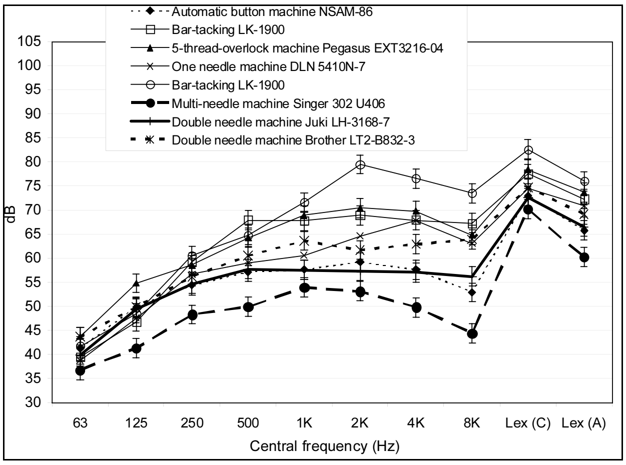

Fig. 8. Octave-band spectrum measurements and the values of 8-h time-weighted average exposure levels in the enterprise of clothing industry

The nominal attenuation, recommended by manufacturers, varies from 11 dB to 35 dB, depending on the hearing-protecting device and the frequency contents of noise (Toppila 2000). Several methods exist for estimating the amount of sound attenuation a hearing protector provides, among them the octave-band method, which gives the Noise Reduction Rate (NRR), is clearly the most common. Choosing suitable hearing-protecting devices, high-frequency protection should be emphasized in the studied cases.

For calculations of the risk of noise-induced hearing loss for male workers, a 25 year old man was taken as an example presuming he will work in the same noisy work environment for 15, 25 or 35 years (exposure to noise: 15, 25 and 35 years) without having any noise control measures. The two highest noise levels were obtained for calculations: 97.5 dB in the mechanical industry and 91.5 dB in the wood industry. For hearing handicap assessment, the frequency combinations of 1, 2 and 4 kHz were assumed. The risk calculation method proposed in ISO 1999:1990 (data base A), which uses three inputs (age, exposure to noise and gender) in the evaluation of noise-induced hearing loss, was used. The results are given in Fig. 9 (in an illustrative way).

Fig. 9 depicts the risk of handicap among people with noise exposure and non-noise exposed people. It should be noted that the risk of hearing handicap due to noise calculated by this method does not indicate the severity of the hearing handicap as such, but gives the fractile of a population whose hearing threshold level associated with age and noise exceeds the fence. At the fence level of 25 dB (hearing threshold level) (Sataloff, R., Sataloff, J. 2006; Starck *et al.* 2004), the risk of handicap due to noise exposure of 91.2 dB during 15 years of occupational life is insignificant, during 25 years the risk is 17.5% and in 35 years – 25.0%, while the noise exposure of 97.5 dB produces the risk of hearing handicap of 21.5%, 40.5% and 43.0%, respectively. The figure also illustrates that the risk of handicap due to noise exposure of 91.2 dB in 35 years has a similar pattern of the noise exposure of 97.5 dB in 25 years.

According to the proposed flexible risk assessment method (Fig. 4), the risk of noise exposure of 91.2 dB (Die machine Vipros) was determined as inadmissible risk (level IV) and of 97.5 dB (Great drill machine) – as intolerable risk (level V), which is in good conformity with the risk calculations according to ISO 1999:1990.

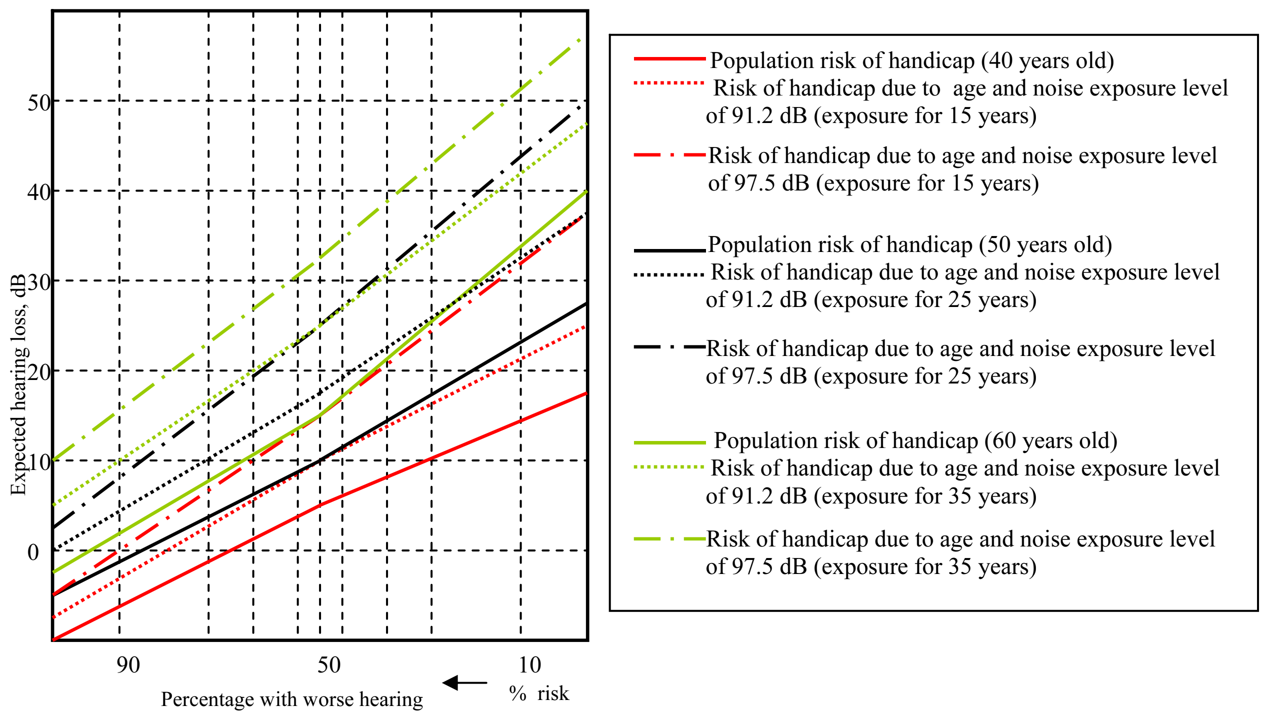

Fig. 9. Estimation of risk for noise-induced hearing loss at two noise levels – 91.2 dB and 97.5 dB – for 15, 25 and 35 years of exposure

4.3. Results of measurements of dust

Dust particulates were collected by drawing a measured volume of air through a pre-weighed PVC membrane filter; afterwards the particulate was weighed on the filter and the sample was quantified by taking the weight difference. Three parallel tests were used at each work station. The pump used for sampling was Universal Sampling Pump SKC 224-PCEX8. The sampling was conducted near the areas of machines or procedures producing potentially the highest amount of dust in the enterprise. Each sampling lasted for 60 minutes (following the standard EN 689:1995). According to the measurements, the concentration of wood dust in the Estonian wood processing industry varies from 2.0 to 10.0 mg/m^3. The processed wood types were mainly birch and juniper. The exposure limit for inhalable wood dust is 2.0 mg/m^3, but for all organic dust the exposure limit is 5.0 mg/m^3 (Resolution ... 2007b).

The presence of high concentrations of wood dust in the workplace air is a great concern because certain wood types are classified as carcinogens and need further investigation to develop suitable control measures. High levels of wood dust are considered as inadmissible risk according to the simple/flexible risk assessment method.

In the clothing and mechanical industries, dust does not present a hazard of high risk level since the values of dust are lower than the proposed limits; in the plastic industry, some departments were identified where the amount of total organic dust was higher than the proposed limit – the highest value measured was 6.04 mg/m^3 (the exposure limit is 5.0 mg/m^3). In one company of the printing industry, higher levels of paper dust were detected as well; but in this case study, a new wet-cleaning method was implemented immediately, and the further measurements showed that the levels of paper dust were lowered significantly.

5. Conclusions and discussion

Based on the study, the following conclusions can be drawn and remarks should be made:

1. A systemic approach to occupational safety is the key optimizing workplace safety in enterprises. A consistent method for assessing occupational hazards is recommended. The case studies show that the simple/flexible risk assessment method created by the authors is viable and applicable in the selected industries for assessing physical and chemical risks. The methodology can be used in any kind of company, but small and medium-sized companies are preferred. Large companies with higher capacities and resources seeking to enhance workplace safety might find a need to implement a more sophisticated and time-consuming approach.

2. Using the Estonian experiment, five or four risk levels to characterize risks in a working environment are sufficient and unsophisticated for the employer to understand and use. Triggers need to be in place, so people know how to conduct an effective risk assessment, who to involve and who to inform of the outcome. Preferably, risk assessment should be performed by a person with the necessary technical competence who has contextual knowledge of the workplace.

3. In the investigated Estonian enterprises, most of the hazards were under control. Noise is one of the main health hazards present in many industries. In the studied enterprises, the noise level exceeded the norms in several cases. The risk to experience noise-induced hearing loss

among workers who misuse the protective equipment is significant. The employers should attempt to find additional technical measures to lower the noise levels and encourage the workers to use the personal protective equipment properly.

4. New possibilities for the involvement of workers in the safety management in enterprises have to be considered by the top management of the enterprises. In many of the investigated enterprises, the management's attitude towards occupational health and safety was stimulating and supportive, and the management showed eagerness to enhance workplace safety. However, in several cases it was suggested that the employers should improve the dissemination of information to workers on safety matters, particularly on the accidents and incidents in the enterprise in order to remind them of the importance of following the safety measures for achieving a safe workplace. It is also essential to understand the occupational health and safety needs of an enterprise to allow sufficient freedom to enable workers to use the experience, judgement and skills they have acquired if necessary.

References

Atmaca, E.; Peker, I.; Altin, A. 2005. Industrial Noise and Its Effects on Humans, *Polish Journal of Environmental Studies* 14(6): 721–726.

Baltrėnas, P.; Butkus, D.; Nainys, V.; Grubliauskas, R.; Gudaitytė, J. 2007. Efficiency Evaluation of a Noise Barrier, *Journal of Environmental Engineering and Landscape Management* 15(3): 125–134.

Bardana, E. J. 2003. Occupational asthma and allergies, *Journal of Allergy and Clinical Immunology* 11(2): S530–S539.

Bridger, R. S. 2003. *Introduction to ergonomics*. 2nd Edition. London: Taylor&Francis.

Carlestam, G.; Karlsson., C.; Levi, L. 1973. Stress and disease in response to exposure to noise: a review, in *Proceedings of the Second International Congress on Noise as a Public Health Problem*. Report 550/9-73-008. Washington DC: EPA, 479–486.

Degan, G. A.; Lippiello, D.; Pinzari, M. 2003. Dust propagation: A method in risk analysis, in *The 3-rd Safety and Reliability International Conference KONBIN'03.* Monograph Series 3. Warszawa: Air Force Institute of Technology, 45–53.

Dobbie, R. A. 2002. *Noise. Physical and Biological Hazards of the Workplace*. Second Edition. Ed: Wald, P. H., Stave, G. New York: John Wiley & Sons, Inc.

Dukes-Dobos, F. N. 1981. Hazards of heat exposure: a review, *Scandinavian Journal of Work, Environment and Health* 7: 73–83.

Elefteriou, P. C. 2002. Industrial noise and its effects on human hearing, *Applied Acoustics* 63: 35–42.

European Commission. 2003. 2003/10/EC. Council directive on the minimum health and safety requirements regarding to the exposure of workers to the risks arising from physical factors (noise). Brussels: European Commission.

Evenson, E. T. 2002. *Cold Environments. Physical and Biological Hazards of the Workplace*. 2nd Edition. New York: John Wiley & Sons, Inc.

Gustaffson, T.; Dahlman-Höglund, A.; Nilsson, K.; Ström, K.; Tornling, G.; Toren, K. 2007. Occupational exposure and severe pulmonary fibrosis, *Respiratory Medicine* 101: 2207–2212.

Harms-Ringdahl, L. 2001. *Safety Analysis: Principles and Practice in Occupational Safety*. Second Edition. London: Taylor & Francis. 302 p.

Hollmann, S.; Heuer, H.; Schmidt, K.-H. 2001. Control at work: a generalized resource factor for the prevention of musculoskeletal symptoms? *Work & Stress* 15: 29–39.

Ivarsson, A.; Bennrup, S.; Toremalm, G. 1992. Models for studying the progression of hearing loss caused by noise, *Scandinavian Audilogy* 21: 79–86.

Jacobsen, G.; Schlünssen, V.; Schaumburg, I.; Taudorf, E.; Sigsgaard, T. 2008. Longitudinal lung function decline and wood dust exposure in the furniture industry, *European Respiratory Journal* 31: 334–342.

Johnson, D. 1991. Field studies: industrial exposures, *The Journal of the Acoustical Society of America* 90(1): 170–174.

Kauppinen, T.; Vincent, R.; Liukkonen, T. *et al.* 2006. Occupational exposure to inhalable wood dust in the member states of the european union, *Annals of Occupational Hygiene* 50(6): 549–561.

Mohammadi, G. 2008. Hearing conservation programs in selected metal fabrication industries, *Applied Acoustics* 69: 287–292.

Nemecek, J.; Grandjean, E. 1973. Results of an ergonomic investigation of large-space offices, *Human Factors* 15(2): 111–124.

Nurminen, T.; Kurppa, K. 1989. Occupational noise exposure and course of pregnancy, *Scandinavian Journal of Work and Environmental Health* 15: 117–124.

Patterson, M. J.; Taylor, N. A.; Amos, D. 1997. *Tests of cognitive, perceptual and sustained attention functions in hot environments. DSTO-TR-0650* [cited 8 August 2008]. Available from Internet: <http://hdl.handle.net/1947/4042>.

Powazka, E.; Pawlas, K.; Zahorska-Markiewicz, B.; Zejda, J. E. 2002. A cross-sectional study of occupational noise exposure and blood pressure in steelworkers, *Noise & Health* 5(17): 15–22.

Rachiotis, G.; Alexopoulos, C.; Drivas, S. 2006. Occupational exposure to noise, and hearing function among electro production workers, *Auris Nasus Larynx* 33: 381–385.

Reinhold, K.; Tint, P.; Kiivet, G. 2006. Risk assessment in textile and wood processing industry, *International Journal of Reliability, Quality and Safety Engineering* 13(2): 115–125.

Resolution of the Ministry of Social Affairs. 1996. No. 66 of , 28 December 1995 on the occupational health requirements for microclimate. *State Gazette in Estonia*, RTL 1996, 13, 98.

Resolution of the Estonian Government. 2007a. No. 108 of 12 April 2007 on the occupational health and safety requirements for noisy work environment, the occupational exposure limits for noise and measurement of noise level. *State Gazette in Estonia*, RTL 2007, 34, 214.

Resolution of the Estonian Government. 2007b. No. 223 of 23 October 2007 on the exposure limits of chemical agents in the work environment. *State Gazette in Estonia*, RTL 2007, 55, 369.

Rjazanov, V.; Kauppinen, T.; Veidebaum, T. 2003. Implementation of international information system on occupational exposure to carcinogens – CAREX in Estonia, *Meditsina truda I promõšlennaja ekoloogia* 2: 17–21.

Saari, J. 1990. On strategies and methods in company safety work: from informational to motivational strategies, *Journal of Occupational Accidents* 12: 107–118.

Saari, A.; Tissari, T.; Valkama, E.; Seppänen, O. 2006. The effect of a redesigned floor plan, occupant density and the quality of indoor climate on the cost of space, productivity and sick leave in an office building – A case study, *Building and Environment* 41: 1961–1972.

Salminen, S.; Saari, J.; Saarela, K.-L.; Rasanen, T. 1993. Organizational factors influencing serious occupational accidents, *Scandinavian Journal of Work, Environment and Health* 19: 257–352.

Shamssain, M. H. 1992. Pulmonary function and symptoms in workers exposed to wood dust, *Thorax* 47: 84–87.

Sataloff, R. T.; Sataloff, J. 2006. *Occupational hearing loss.* Third Ed. Boca Raton: Taylor & Francis.

Sheu, J.-J.; Hwang, J.-S.; Wang, J.-D. 2000. Diagnosis and momentary quantification of occupational injuries by indices related to human capital loss: analysis of a steel company as an illustration, *Accident Analysis and Prevention* 32: 435–443.

Seppänen, O.; Vuolle, M. 2000. Cost effectiveness of some remedial measures to control summer time temperatures in an office building, in *Health Buildings 2000, ISIAQ 6th International Conference, Espoo, Finland*, Vol. I: 665–670.

Sliwinska-Kowalska, M.; Zamyslowska-Szmytke, W.; Szymczak, W. *et al.* 2001. Hearing loss among workers exposed to moderate concentrations of solvents, *Scandinavian Journal of Work, Environment & Health* 27(5): 335–342.

Starck, J. P.; Toppila, E.; Pyykkö, I. 2004. *Industrial hearing loss* [online] [cited 24 July 2008]. Available from Internet: <http://www.kuulonhuoltoliitto.fi>.

Stenton, S. C. 2004. Occupational Airway Disease, *Medicine* 32(1): 83–85.

Toppila, E. 2000. *A systems approach to individual hearing conservation*. Academic dissertation. Helsinki.

Van Thriel, C.; Kiesswetter, E.; Blaszkewicz, M.; Golka, K.; Seeber, A. 2003. Neurobehavioral effects during experimental exposure to 1-octanol and isopropanol, *Scandinavian Journal of Work, Environment & Health* 29(2): 143–151.

Virkkunen, H.; Kauppinen T.; Tenkanen, I. 2005. Long-term effect of occupational noise on the risk of coronary heart disease, *Scandinavian Journal of Work, Environment & Health* 31(4): 291–299.

Witterseh, T.; Wyon, D. P.; Clausen, G. 2002. *The effects of moderate heat stress and open-plan office noise distraction on office work*. Indoor Air 2002. Abstracts.

Woodside, G.; Kocurek, K. 1997. *Environmental safety and health engineering.* New York: John Wiley & Sons, Inc.

PAVOJAI PRAMONĖJE. RIZIKOS LYGIO NUSTATYMAS IR DARBO VIETŲ SAUGUMO DIDINIMAS

K. Reinhold, P. Tint

Santrauka

Analizuojami profesiniai pavojai, kuriems gresiant būtina nustatyti rizikos lygį. Tirtas darbo aplinkos mikroklimatas, apšvieta, triukšmas ir dulkėtumo lygis. Profesiniams pavojams gamyboje įvertinti siūlomas paprastas ir lankstus rizikos vertinimo metodas, pagrįstas skaitiniais kriterijais. Pateikiami penkių Estijos pramonės šakų (mašinų apdirbimo, spaudos, medienos, plastmasės ir tekstilės) tyrimo šiuo požiūriu rezultatai ir praktiniai pavyzdžiai.

Kaip akivaizdžiausias pavojus sveikatai plačiai analizuojamas triukšmas, įvertinama klausos praradimo rizika. Straipsnio tikslas – atkreipti dėmesį, kaip svarbu pramonėje nustatyti profesinę riziką ir priminti apie kelis svarbius praktinius aspektus, kad darbo rizikos vertinimas būtų efektyvus ir padėtų darbuotojams, darbdaviams, darbo vietos higienos specialistams, gydytojams bei sprendimų priėmėjams.

Reikšminiai žodžiai: teisinis profesinio saugumo ir sveikatingumo reguliavimas, laboratorinės sąlygos, darbo aplinka, profesinė rizika, rizikos vertinimas, rizikos lygiai.

ПРОФЕССИОНАЛЬНАЯ ОПАСНОСТЬ. ОПРЕДЕЛЕНИЕ УРОВНЯ РИСКА И УВЕЛИЧЕНИЕ БЕЗОПАСНОСТИ РАБОЧИХ МЕСТ

К. Райнгольд, П. Тинт

Резюме

Проанализирована профессиональная опасность для здоровья людей, работающих на промышленных предприятиях, и определен уровень риска. Исследован микроклимат, освещение, уровень шума и пыльность на предприятиях. Для оценки профессионального риска для здоровья людей предложено применение простого (гибкого) метода, основанного на численных критериях. Исследованы пять отраслей промышленности Эстонии (машиностроительная, печатная, деревообрабатывающая, пластмассовая и текстильная), приведены результаты и практические примеры. Наиболее широко исследовано воздействие шума на здоровье людей, оценен риск потери слуха из-за шума. Целью статьи было обратить внимание на необходимость оценки профессионального риска на промышленных предприятиях, выявить несколько важных практических аспектов эффективной оценки риска и предложить их работникам, работодателям, специалистам по гигиене рабочих мест, врачам и специалистам, принимающим решения.

Ключевые слова: правовое регулирование профессиональной безопасности и здоровья, лабораторные условия, рабочая обстановка, профессиональный риск, оценка риска, уровни риска.

Karin REINHOLD. Master of Natural Sciences (Environmental Engineering, Chemical Faculty of Tallinn University of Technology) from 2003. PhD student in the Department of Environmental Engineering from 2004. Employment: Assist.

Prof. of Work Environment and Safety, Tallinn University of Technology (TTU) from 2002. Advanced training in toxicology in Uppsala University 2002–2003. Has taken part in several international conferences and projects in work safety and health. Publications: 34 research papers. Membership: Estonian Society of Toxicology. Research interests: risk assessment, investigations in work environment and measurements.

Piia TINT. PhD (Tehn., Leningrad Technological Institute of Lensoveta) from 1977. Chemical Engineer (TTU, 1970). Advanced training in the Nordic Institute of Occupational Health (NIVA, 13 courses). Employment: Prof., the Head of the Department of Work Environment and Safety (TTU, from 2000). Supervised dissertations: 5 Master theses, 3 PhD students. Has taken part in several international conferences and in 3 international and 2 national research projects. Member of Human Factors Society (Europe Chapter), Finnish Ergonomics Society). Publications: over 100 research papers, 7 books. Research interests: risk assessment, safety and economics.