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Original Article

Metal Workers: Exposure to Chemicals and Noise Caused by Using Incorrect Safety Measures

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Abstract

Background: This paper describes the common hazards in the metal industry – chemicals and noise. The aim of the study was to get an overview of risk levels of mentioned occupational hazards and examine the implementation of adequate safety measures.

Methods: Measurements of noise and chemicals were performed, self-reported exposure and usage of personal protective equipment from workers were used to assess the behavior of workers, semi-structured interviews were conducted to clarify employers' practices to provide workers with adequate personal protective equipment.

Results: The measurements of working environment in welders' workplaces showed that the main chemicals that reach workers' breathing zone are carbon monoxide, ozone, nitrous oxides, carbon dioxide, and metals (manganese, iron, chromium). The results of questionnaires and interviews revealed that 57% of employees provide and only 41% of welders use respiratory protectors against hazardous welding fumes. The results of noise measurements showed that many of the machines used in the metal industry produce high levels of noise. Those values were often above occupational exposure limits, but 35% of workers do not use any personal protective equipment. Workers reported several health problems connected with chemicals and noise.

Conclusion: Working conditions of the metal industry may impair workers' health considerably. Several safety measures can be implemented to protect metal workers' health against noise and hazardous welding fumes including noise screens, local ventilation, organizational measures (such as educational intervention, providing chemical material safety data sheets) and adequate personal protective equipment.

Keywords: Occupational hazards, Noise, Chemicals, Metal industry

Introduction

Working with metals is a common part of industry – various manufacturing processes and maintenance of production equipment involve metal work including welding and other activities such as polishing, cutting, die cutting etc. In Estonia, the metal industry covers 15.4% of all industrial enterprises (1). Employees performing metal work are exposed to a series of health risk factors, including chemical hazards (e.g. welding fumes) and occupational noise. In the enterprises, where safety culture is low, those hazards may still pose a high risk. Epidemiological studies have shown that a large number of welders experience some type of respiratory illness. Respiratory effects seen in full-time welders have included bronchitis, airway irritation, lung function changes, and a possible increase in the incidence of lung cancer (2). In Latvia, a study was performed where the author states that the average concentration of welding fumes in Latvian metal processing industries (2002-2009) was as high as 13.32 ± 33.73 mg/m^3. Compared to the control group, persons involved in welding had more frequently upper-respiratory tract and bronchial diseases, digestive tract disorders and rheumatic illnesses (3).

Occupational hearing loss has generally been associated with noise exposure, but there is a growing awareness that some industrial chemicals can have ototoxic effects as well (4, 5). One of those chemicals is carbon monoxide (CO) what can be found also in welding fumes. This combined effect can cause hearing loss in much lower noise levels than occupational exposure limits are (5). There is a general agreement that progression in hearing loss at frequencies of 500, 1000, 2000, and 3000 Hz of high levels of noise eventually will result in impaired hearing (6). Noise is also connected with other health problems concerning the extra-auditory, subjective and biological effects – such as sleep disturbances, hypertension, noise-induced annoyance (7), fatigue, lack of concentration. Errors in autonomic functions have also been reported (in cardiovascular, endocrine and digestive systems), as well as problems with growth and immune system (8).

The objectives of the study were to perform a quality assessment for welding and cutting workplaces; to find out the availability of safety measures against noise and hazardous chemicals; to determine the usage of those safety measures (including personal protective equipment) and to get an overview of health impairments the workers have experienced in the metal industry.

Materials and Methods

For sampling of welding fumes and determination of the concentration of chemicals in the working environment 2 test apparatus were used: 1) portable FTIR spectrometer 300-X with Tornado 10MTR gas cell (with volume of 2.6L) and SKC XR5000 sample pump; 2) Dräger indication tubes with Dräger accuro pump. Samples were taken from the workers' breathing zone, air was collected with a pump (the time varied according to the requirements of equipment used). The results had 10…25% of standard deviation (k =1, 95%), depending on the accuracy of a Dräger tube or FTIR spectrometer. Sound analyzer TES 1358 was used to measure the equivalent sound pressure level, the peak sound pressure level, and the noise frequency spectrum (1/3 octave band). The analyzer was held at a 1.55 m height from the floor, next to a working machine. Measurements with an A- and C-filter lasted for 2…10 minutes depending on a working cycle. The results had 1.0…2.5 dB of standard deviation (k =1, 95%). The results of chemicals and noise were analyzed using adequate software. Measurements were conducted in 10 different companies (named as company A…J).

Employees' habits to provide workers with adequate personal protective equipment (PPE) were clarified through semi-structured interviews. Workers' protection manners against noise and hazardous fumes were found out by using an anonymous questionnaire. Participants of the study were selected according to the principle of voluntary participation from 10 enterprises, 95 male workers in total. A questionnaire or an opportunity to use web-questionnaire was given to each metal worker. The questionnaire was compiled in two languages (Estonian and Russian) and comprised 25 questions that involved description of the work process, availability of different safety measures, actual usage of safety measures and health complaints. The mean age of the test subjects were 35.1 (SD: 7.1) years and the mean length of employment 6.6 years (maximum: 25 years; minimum: 1 year).

Results

The measurements of working environment in welders' workplaces showed that the main chemicals that reach workers' breathing zone are carbon monoxide (CO), ozone (O_3), nitrous oxides (NO_x), carbon dioxide (CO_2), and metals (manganese, iron, chromium). The results are presented in Table 1; metals were possible to detect only qualitatively. In some workplaces where the local ventilation was not installed or inefficient, the concentration of chemicals exceeded the occupational exposure levels, especially CO, O_3 and NO_x. Most probably, metals also exceeded norms in some cases as other similar studies have presented (3).

Table 1: Results of measurements of chemicals in workplace air, welders

Chemical detected	No of measurements (N)		C_{Max}, ppm	$C_{8\ hours}$, ppm	OEL, 8 hours exposure	OEL, 15 min exposure
	Total	Mismatch to OEL				
CO	42	8	40±6	3…40	35	100
O_3	13	4	0.7±0.6	<0.1…0.7	0.1	-
NO_x	17	3	2.5±0.3	0.5…2.5	NO: 2 NO_2: 25	NO: 5 NO_2: 50
CO_2	42	0	2405±360	844…2405	5000	-
Iron	18	n/a	n/a	+	3.5 mg/m^3	-
Manganese	18	n/a	n/a	+	0.2 mg/m^3	-
Chromium	18	n/a	n/a	+	2 mg/m^3	-

Abbreviations: C_{Max} – maximum measured value of a chemical in workplace air, $C_{8\ hours}$ – concentration of a chemical in workplace air, 8 hours exposure, OEL – Occupational Exposure Limit (EG, 2001), n/a – not applicable since metals were detected only qualitatively; + - metals were detected in workplace air, but not quantitatively.

In Company A, where only general ventilation was installed, the highest number of CO was detected as seen in Figure 1, the quantitative data is presented in Table 1. Figure 2 presents the photo of the same workplace where the IR spectrum of workplace air was taken as seen in Fig. 1. The concentration of CO=40 ppm exceeds Estonian norm (9), which is 35 ppm for 8 hours exposure.

Ozone concentrations at workplace air varied from 0.1 to 0.7 ppm; 4 measurements out of 13 exceeded the Estonian norm (9) of 0.1 ppm. The results of questionnaires showed that 64% of welding workplaces were equipped either with local exhaust ventilation or both local exhaust ventilation and mechanical general ventilation.

In 18% of workplaces only natural ventilation existed (e.g. possibility to open windows or doors of the shop-floor); in those workplaces some of the welders did not wear respiratory protection or had respirators which do not protect against welding fumes. The results of questionnaires and interviews also showed that 57% of employees provide and only 41% of welders use respiratory protectors against hazardous welding fumes. Concerning chemical safety data sheets (SDS), 91% of employers of companies where welding work is performed, confirmed the availability of the SDS, but interestingly only 6% of welders were aware of those documents. According to Estonian regulations (10), two action levels for noise exposure have been established.

With the daily noise exposure level (L_{EX}, 8 hours) of between 80 dB(A) and 85 dB(A) hearing protection should be made available to employees who ask for it.

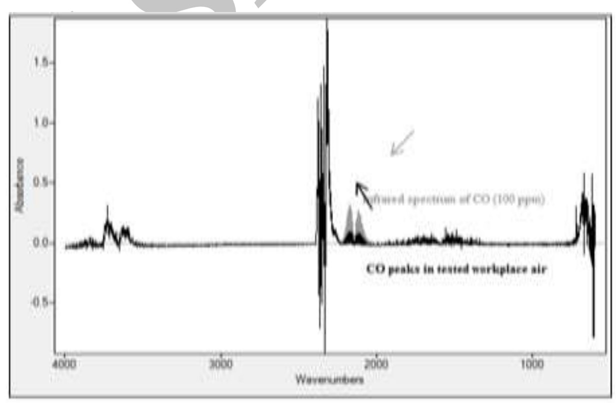

Fig. 1: IR spectrum of welding workplace air (Company A). High levels of CO are detected by using FTIR portable spectrometer

Fig. 2: Welder's workplace, Migatronic equipment (Company A)

L_{EX} (8 hours) over 85 dB(A) employees must wear the hearing protection provided and employers need to offer training on correct use. Additionally, a norm has been set to highest peak sound pressure level L_{Cpeak} (measured with 'C'-filer), which is 137 dB(C). The results of noise measurements (Table 2) showed that many of the machines used in the metal industry produce high levels of noise. Those values were often above OELs, especially when metal and welding work was performed in an open-planned department where all workers were exposed to noise produced by each equipment and procedure and no attempts to muffle noise was made. Automatic punch machines, depending on processed material and working task, produce the highest levels of noise: in company C, the daily noise exposure level L_{EX} was registered as high as 100.4±2.1 dB(A). While working with such high noise values without PPE, the daily working time with the punch press would be reduced to as little as 15 minutes. The results of the measurements showed that angle grinders produce noise above OEL as well – out of 32 measurements there were none which matched OEL. In welding workplaces, 28 measurements registered the daily noise exposure level L_{EX} higher than 85 dB(A), the highest in company D: 89.9±1.6 dB(A). Figure 3 presents a detailed noise frequency analysis of Company B.

The exposure levels normalized to a nominal 8 h working day varied from 84.1…95.0 dB(A). The machines involved in Company B were grinders, multi cutters and welding equipment. Angle grinders produce a significant amount of noise, depending on processed material and working task. The highest noise level was registered with angle grinder Hitachi Koki – 95.0 dB(A). In welding workplaces the noise varied from 82.8…86.9 dB(A). The octave band frequency analysis showed Hitatchi Koki angle grinders peak at first in 1600 Hz (depending on working tasks 85.2 and 86.8 dB(A)) and then again in higher frequencies such as 4000…5000 Hz (92.3…94.9 dBA)). In welding process, the prevalent frequencies are 1250…4000 Hz (67.1…68.4 dB(A)).

In the enterprise B, only one sort of earplugs was available – EAR 3M E-A-Rsoft "Yellow Neons". While choosing the hearing protection devices (HPD) no methods for calculating the effectiveness of hearing protection were implemented. During the interview with the working environment specialist, it turned out that the earplugs with the highest attenuation number were chosen to be sure they protect workers' hearing apparatus. No thought was given to the fact that too much reduction of the sound can have an effect of feeling of isolation that is risky, as employees may need to remove their PPE in order to communicate with colleagues or hear certain signals of dangerous equipment. Additionally, it has to be kept in mind that the effectiveness of hearing protection will always depend on human behavior. The results of questionnaires revealed that 35% of metal workers do not use hearing protection devices (Fig. 4).

Table 2: Results of noise measurements in metal industry

Equipment description at workplace	No of measurements (N) Total	Mismatch to OEL	L_{max}	L_{EX}, dB(A)	OEL	L_{Cpeak}	OEL
Welding equipment	45	28	102.9±2.2	81.3…89.9	85	81.9…90.7	137
Angle grinders	32	32	97.8±1.9	87.8…95.0	85	90.1…96.9	137
Oscillating multicutters	16	12	91.3±1.7	84.2…89.7	85	85.4…92.1	137
Automatic punch machines	7	4	101.6±2.5	78.2…100.4	85	79.2..108.1	137
Folder machines	6	0	79.9±1.5	71.1…76.7	85	71.2…80.0	137

Abbreviations: L_{EX} – measured daily noise exposure level, L_{max} – maximum noise exposure level measured, OEL – Occupational Exposure Limit (EG, 2007), L_{Cpeak} - peak sound pressure level, maximum value of the 'C'- frequency weighted instantaneous noise pressure level.

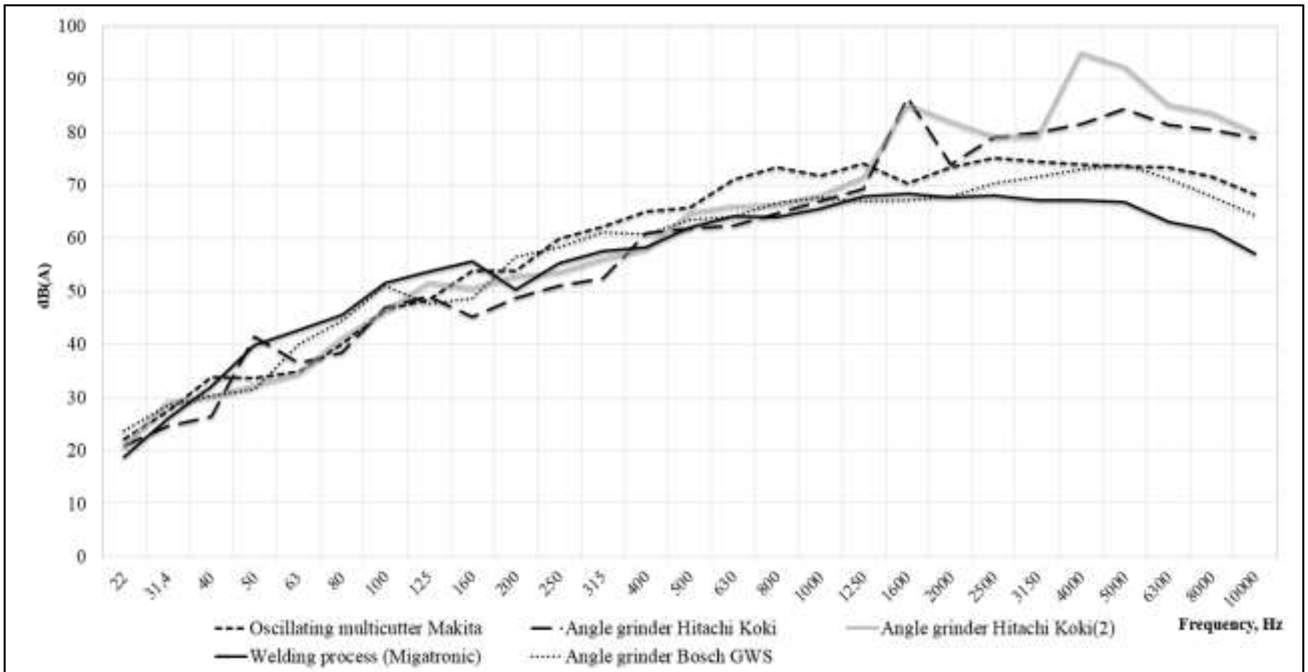

Fig. 3: Noise 1/3 octave band analysis in a metal industry (Company B)

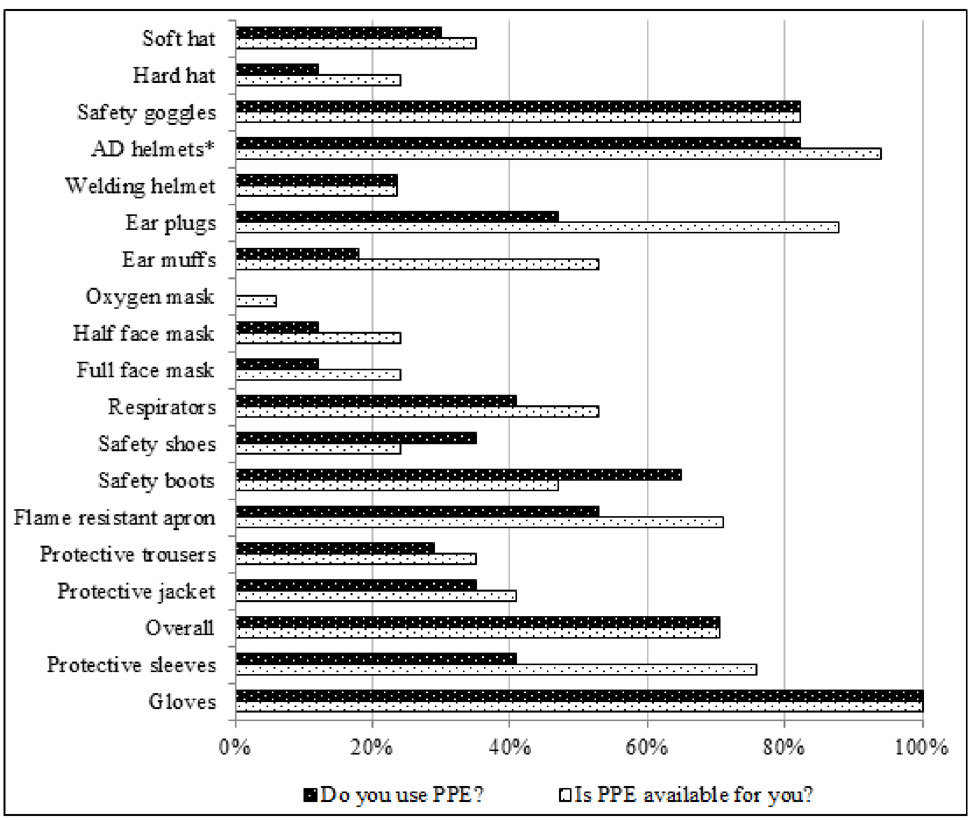

Fig. 4: Usage of PPE in metal industry (N=95, 10 companies), *AD helmets – auto-darkening helmets

Many of the welders have experienced ill-health what they think may be connected with the poor working conditions at welding workplaces - 24% of respondents claimed that they have experienced upper respiratory diseases or irritation, 77% of welders admitted that they have suffered eye irritation. Martinsone (3) demonstrates that men employed in welding work in comparison to the persons of control group have statistically significant more frequent chronic upper-respiratory tract and bronchial diseases, digestive tract and rheumatic diseases.

Concerning noise induced hearing impairment, the results of the current study revealed that 12% of workers had noted some kind of hearing loss, but no further questions were followed to find out in what stage the hearing loss was.

Several recommendations were given to the enterprises of the metal industry: 1) perform workplace risk assessment regularly, 2) perform the noise measurements and determine the concentration of welding fumes in the workplace air in systematic way; 3) install effective local ventilation system; 4) separate each work area with flexible noise barriers/shields; 5) arrange educational workshops to increase workers' knowledge about harmful effects of occupational hazards; 6) provide new generation welder masks; 7) provide ear muffs and ear plugs according to noise frequency.

Discussion

The study revealed that several hazardous chemicals were detected in welders' workplace air. Some of them exceeded OEL values. A study in Latvia (11) showed similar results: welding fumes exceeded OEL value in 55% of cases. In Canada (12), CO levels of welding workplaces were measured much lower than in Estonia - less than 5.0 ppm (at source). It is widely known that medium CO levels in workplace air cause decreased oxygen uptake and the resultant decreased work capacity (13). Additionally, carboxyhaemoglobin levels caused by breathing CO may produce decrements in neurobehavioural function (13). Higher levels of CO cause more severe health impairments - tissues of highly active oxygen metabolism, such as heart, brain, liver, kidney and muscle, may be particularly sensitive to carbon monoxide poisoning (13).

Even when metals (iron, manganese, chromium) were possible to detect only qualitatively in the current study, it is clear that those chemicals present a high risk for welders' health as well. Latvian study (11) showed that concentration of manganese exceeded occupational exposure limit (OEL) in 34% of cases. Manganese has toxic impact on nervous system, therefore being exposed to long-term increase doses serious neurological diseases might develop (14).

In the current study, ozone concentrations at workplace air varied from 0.1 to 0.7 ppm. It has been demonstrated in the studies that ozone-induced airway inflammation may be an important contributing factor to acute exacerbation of asthma and chronic bronchitis (15). Ozone concentrations at source in the Canadian study (12) ranged from 0.4 to 0.6 ppm, but were not detectable in the welders' breathing zone. However, ventilation upgrades in the workplace were required in most welding shops. Only 7% of the welders wore respiratory protection (12). In our study, the interviews and questionnaires revealed that more than half employers provide and 41% of welders use respiratory protectors against hazardous welding fumes. Similar findings have been reported by other researchers as well. In a study (16) workers generally reported low use of protective equipment. Use of PPE and controls during more than half of exposure time was reported by 35–72% of workers, depending on the hazard. The generally low reported use of PPE and controls suggests little social desirability bias in workers' responses. Kumar et al. (17) indicated in the study of Indian metal companies that welding workers were more aware of hazards (n=174, 83.3%) than safety measures implemented (n=134, 64.1%). Many of them had more than 5 years of experience in welding work (n=175, 83.7%), however, only 20% of them had institutional and safety training for doing the work.

The findings about excessive noise suggest that the noise levels in the metal industry were often over the regulative norm (85 dB(A)). Those findings are in line with other researches – a study in Latvia (12) showed that during measurements of welders' workplaces (N=703), noise exceeded OELs in 34% of cases. Noise measurements revealed that the welders' L_{EX} 8-hours levels ranged from 79 to 98 dB(A) (12). The noise exposure levels normalized to a nominal 8 h working day varied from 73.0 to 97.5 dB(A) in the metal industry (18).

Most machines in the metal industry produce high frequency noise, having peaks in 1250…4000 Hz, which is sensitive range of human hearing. Therefore it is even more important to protect workers against noise while picking up the most suitable HPD, which produces sufficient amount of attenuation. Risk for overprotection has to be carefully considered as many machines in the metal industry involve sharp and rotating parts, so it's crucial for the worker to hear safety signals and peers' warnings. Concerning actual usage of HPDs, 65% of metal workers reported they use hearing protection devices. Among the reasons why workers do not wear HPDs were interference with communication (70%), interference with job performance (46%) by making certain sounds from machinery undetectable (19). The study by Neitzel et al (16) in scrap metal recycling facility in USA showed that workers and observations underestimated noise exposures when compared to industrial hygiene measurements (19% of measurements exceeded the OEL of USA (90 dB(A) and 57% of measurements exceeded 85 dB(A)) .

Conclusions

Working conditions in the metal industry pose several high risks for workers' health. The results of the study showed that in many companies, noise and chemicals exceeded the occupational exposure limits. New approaches for development of workers' awareness of possible health effects and employees' willingness to enhance working conditions should be proposed. The employers should attempt to find additional technical measures to mitigate risk from chemicals and noise as well as to encourage the workers to use the PPE properly. An educational intervention with all production employees may contribute to a healthier performance at work.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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