Riga Stradins University

Inese Mārtiņsone

AIR POLLUTION OF WORK ENVIRONMENT OF WELDERS WITH METALS AND THEIR IMPACT TO EMPLOYEES HEALTH IN LATVIA

Speciality – Occupational and Environmental Medicine

Summary of doctoral thesis for obtainment of doctor's degree in medical sciences

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Rīga – 2011

EIROPAS SOCIĀLAIS FONDS

Doctoral thesis is elaborated in: Riga Stradins University agency Institute of Occupational Safety and Environmental Health, Laboratory of Hygiene and Occupational Diseases, Riga Stradins University Biochemistry Laboratory. Researches were performed within the period from 2002 to 2009.

Elaboration of the thesis was supported by ESF program „Support for Doctoral Students in Obtaining the Scientific Degree in Riga Stradins University", as well as within the framework of scientific project „Research of Exogenous and Endogenous Factors Endangering the Health of Latvian Residents" subproject RSU ZP08/03-2 „Impact of Metal and Stable Organic Pollutants on the Activity of Antioxidants for Employees in Certain Latvian Industrial Enterprises" of the Ministry of Education and Science of the Republic of Latvia as well as within the framework of study „Working Conditions and Risks in Latvia" in the national program „Labour Market Studies" co-financed by ESF.

Measurements performed by Riga Stradins University Institute of Occupational Safety and Environmental Health, Laboratory of Hygiene and Occupational Diseases in the work environment air of metal processing enterprises are used in the research.

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Presentation of the doctoral thesis will take place on May 30, 2011, at 15:00 p.m. on the open meeting of the Promotion Council of Theoretical Medicine disciplines of Riga Stradins University (RSU) in Riga, at Dzirciema Street 16, in the Hippocrates lecture-hall. The head of the Promotion Council of Medicine disciplines *Dr.habil. med,.* professor **Jānis Vētra.**

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Topicality of the Problem

Metals are widespread in nature. They are chemical elements of earth's crust and they participate in natural geochemical and biochemical processes. These natural as well as industrial and human-mediated processes influence the migration of chemical elements and also microelements in biosphere, their dispersion and concentration in soil, water, air, organism of plants, animals and human beings.

Working with metals makes an integral part of industry and nowadays one cannot imagine such manufacturing processes as metal processing, metallurgy and various manufacture auxiliary processes, for instance, maintenance of production equipments and work equipment without it. Latvia has mainly small and medium enterprises with nearly 2% employable residents involved in varied metalworking processes including welding and gas cutting (Martinsone & Skesters, 2009; Mārtiņsone *et al.*, 2010). In several countries employees involved only in welding and gas cutting processes amount to more than 1% of the employable residents (Hewitt, 1996; Antonini, 2003).

Employee who performs gas cutting and welding is subjected to series of harmful factors. Welding fume consisting of various metal salts and oxides is released in work environment air; the presence of substances having especially adverse human health effects – cadmium, nickel, chromium (VI) – is possible. As from laboratory experience, many of assessed welders' work places have no appropriate ventilation systems, employees use respirators which do not prevent inhaling the welding fume therefore it is possible for various occupational diseases to develop. Summing up scientific literature on the impact of metals contained in the welding fumes on welders' health, levels of metals in bio-environments and causes of their changes as well as possible health disorders, one must conclude that this problem is not sufficiently researched in Latvia. There are only fragmentary studies in Latvia on heavy metal pollution in the environment (moss, water, soil) and organism bio-environment (blood, urine, hair, nails and tissues) regarding unexposed and exposed population (Brūmelis, 1992; Ruža, 1994; Bake, 1998).

Metal concentrations in bio-environments of human organism are worldwide recognized environmental pollution indicator which reflects the level of environmental pollution, total amount of absorbed metals in organism and permits calculating the adverse effect on health caused by the environmental pollution. In the major part of world countries (Sweden, Denmark, Germany, Finland, Japan, USA, China, Poland, Estonia etc.) reference (average metal concentration in biological material for representative resident group) levels of microelements and most common toxic metals in bio-environments regarding unexposed and exposed population are set.

Latvia needs complex studies of trace and toxic element concentrations in population and organisms of employed in connection to the work environment. So far in Latvia correlations between levels of toxic metals and trace metals in organism, between concentrations of bound and free elements and level of damage caused to organism are little researched.

Data obtained in study will allow revealing correlations between metal pollution in work environment and employees' health as well as allow elaborating biological indicators for early occupational diseases diagnostics, organizing complex of preventive measures for health improvement. The obtained results can be compared to equal international studies performed in other countries and arrive at interstate comparable outlook.

Study results can be used as a basis for argumented planning of health improvement measures, education and improvement of life quality for employees in metal processing.

Objective of the Thesis

To research the pollution (welding fume, Mn, Cr) of work environment in processes of various welding types in Latvian enterprises, to determine metal (Mn, Cr, Zn, Cu, Cd) concentrations in bio-environments for those employees who are exposed in work environments, to assess probable impact on health condition and provide scientific substantiation for elaboration of preventive measures.

Tasks:

1. To gather worldwide published literature data on risk factors of work environment in welding works and their impact on health of employees, including development of occupational diseases.
2. To perform environment quality assessment according to Riga Stradins University Laboratory of Hygiene and Occupational Diseases' data base of air measurements in work environment.
3. To survey the employees involved in metal processing, to perform blood test for oxidative stress parameters.
4. To evaluate the probable impact of various factors (age, length of service, habits) on metal concentrations in blood of employees.
5. To determine connection between metal concentrations in bio-environments, changes in the activity of antioxidants for occupational exposed persons and unexposed persons.
6. To elaborate scientifically substantiated recommendations on preventive measures intended to improve welders' work environment and health and recommendations on supplements in normative acts in the field of work environment health.

Hypothesis of the Thesis

Monitoring of metal and biological exposure indices allows for an early assessment of probable work environment impact.

Scientific Novelty of the Thesis

For the first time in Latvia for welders involved in metal processing the biological indices were determined in blood and chemical factors of work environment influencing it were researched:

- hygienic measurements and analysis of biological samples made it possible to assess the impact of work conditions and habits on metal levels in organism, changes in homeostasis, oxidative stress markers and to define biological exposure index for manganese;
- disclosing of correlations between subjective health indices of those employed in welding and cumulative work time has allowed for substantiation of necessary preventive measures for reducing environmental impact on health of the employed welders.

Practical Significance of the Thesis

- Results of the paper make it possible for the work safety and occupational disease specialists to get acquainted with detailed analysis of chemical risk factors in welding works in order to perform workplace risk assessment more precisely and do the necessary additional examination of the work environment.
- Thesis presents an argumented application of subjective questionnaire of neurological symptoms Q16 for surveying the employed welders prior to compulsory health check in order to make the early diagnosis of probable health disorders.
- Elaboration of scientifically substantiated complex of preventive measures for improving the health and operational capacity of the employed welders, allowing for the efficiency assessment of preventive measures.

Volume and Structure of Doctoral Thesis

Doctoral paper is written in Latvian language. It consists of 8 parts: Introduction, Literature review, Materials and Methods, Results, Discussion, Conclusions and Practical Recommendations, Bibliography. Doctoral Thesisr is 148 pages long, including 21 tables and 27 illustrations. Bibliography consists of 206 references. Doctoral paper has 4 appendices. There are 20 publications in connection with the topic of doctoral thesis.

Materials and Methods

Air in the Work Environment. Data from Riga Stradins University (RSU) agency Institute of Occupational Safety and Environmental Health (previously, RSU Institute of Occupational and Environmental Health) about air quality in the work environment in 180 Latvian enterprises of various sizes where metal processing and metal cutting works are performed within the period 2002 to 2009 were used in the thesis.

In total 360 workplaces in these enterprises were surveyed with the following measurements:

1. Sampling of welding fume and determination of concentration (1073 samples);
2. Determination of manganese concentrations in the workplaces of employees (884 samples);
3. Determination of chromium concentrations in the workplaces of employees (650 samples).

ISO and LVS standard methods and modern measuring equipments (*Gillian* and *Buck*, USA individual air sampling pumps for sampling the welding fume in the respiratory zone of the employed, high-sensitivity scale *Kern*) were used in analysis of air samples. Concentrations of manganese and chromium were analyzed by means of Atomic absorption spectrophotometric method (AAS) using Varian AAS equipment with electro thermal sample distribution in graphite furnace and Zeeman background correction.

For estimation of health risk probability caused by the occupational exposure of chemical factor in the work environment the exposure index (EI) was used reflecting the occupational exposure level and simultaneously providing the information on probable influence of chemical substance. Exposure index for a certain substance is determined by relating the actual concentration of chemical substance in the work environment against occupational exposure limit value stipulated in the legislation. Occupational exposure limit value for welding fume is 4 mg/m^3, for manganese in welding fume (condensation fume) 0,1 mg/m^3 and for chromium (III) oxide after chromium 1 mg/m^3, they are integrated in the Regulation of the Cabinet of Ministers No. 325/2007 "Work Safety Requirements when Working with Chemical Substances" (adopted on 15.05.2007, published in *Latvijas Vēstnesis*, 18.05.2007). After assessing and describing the concentrations of chemical substances in the air of work environment, the exposure indices of chemical substances are subdivided in four groups/classes – low, medium, high and very high exposure level, respectively.

The first group with the index less or equal to 0.1 indicates of low probability of chemical substance influence. The second group ($0.1 \leq EI < 0.75$) indicates of medium probability of influence. 25 % mistake are allowed in chemical factor occupational exposure measurements therefore the third class EI can indicate that in certain measurements of work environment the occupational exposure limit value of the respective chemical substance is exceeded. The fourth group (EI ≥ 1) indicates of very high probability of influence, exposure in the air of work environment is larger than occupational exposure limit value. It poses a risk for the safety and health of employees and employer must immediately take measures for risk prevention.

Survey of Employees. Participants of study were selected according to the principle of voluntary participation from 20 Latvian enterprises in total, which cooperate with RSU agency Institute of Occupational Safety and Environmental Health and Occupational Disease Laboratory in the field of work environment air assessment. Survey was carried out by means of special questionnaire for the employees applying the guidelines recommended by World Health Organization and it included subjective questionnaire of neurological symptoms Q16. Survey was performed in the form of interview, surveying 254 persons in total. In the course of data collection and analysis respondents were divided into two groups:

1st group – employees who are in contact with metals and their compounds (97 persons - welders) in their work environment;

2nd group – employees who are not in contact with metals and their compounds (54 persons – electricians and 103 persons – office workers) in their work environment.

The age in exposed or welder group varied from 19 to 71 years with average age 41.3±14.1 years. Employees from various Latvian enterprises who are not in direct contact with metals or their compounds in the work process were included in the control group: age in electrician group varied from 23 to76 years with average age 47.6±11.0 years, age of office workers varied from 20 to 69 years with average age 39.2±12.6 years.

All persons involved in research were men employed in one shift.

Questionnaire consists of the following sections:

- General section (age, sex, occupation, length of service, habits);
- Questions about contact with chemical substances in work environment;
- Questions characterizing the health condition of the employed (data about previous or existing illnesses);
- Subjective questionnaire of neurological symptom assessment (Q16);
- Eating habits.

It was concluded in the course of obtaining results that during the work electricians are exposed to various organic compounds (solvents, mineral oil) the toxic influence of which affects the central nervous system. Due to this disturbing factor the section “health condition of the employed” and “Q16” in questionnaire were not used for electrician group in the joint data processing; exposed group (welders) were compared to the office workers in the respective age whose work process is not related to the use of various chemical substances.

Determination of Metals and Biochemical Parameters in Blood. The levels of metal and oxidative stress parameters in blood were determined for welders and electricians. Electricians and welders are employed in the same enterprises therefore the employees come from similar social environment. Electricians are not exposed to welding fume in their work process and their work is not related to various metal processing tasks under high temperatures. 148 blood samples (94 welders and 54 electricians) were taken in compliance with their voluntary consent. Blood samples were taken in the middle of working week (on Wednesday or Thursday) and in the end of the shift.

In order to determine metal concentrations blood samples were mineralized in closed system microwave oven (*MARS 5, CEM*). Metal concentrations were analyzed by means of atomic absorption spectrophotometric method (AAS) using Varian AAS equipment with electro thermal sample distribution in graphite furnace and Zeeman background correction at respective metal-specific wavelengths: Mn – 279.5 nm, Cr – 357.9 nm, Cu – 327.4 nm, Zn – 213.9 nm and Cd 228.8 nm.

Oxidative stress parameter analyses were performed in Riga Stradins University, Biochemistry Laboratory. Determination of the following indices were included in the biochemical test program: in blood – hemoglobin, Cu, Zn-superoxide dismutase (*Cu,Zn-SOD*), glutathione peroxidase (*GPx*), reduced glutathione (*GSH*); in erythrocytes – catalase (*CAT*); in plasma – total antioxidants (*TAS*).

Amount of hemoglobin in blood was determined by means of photometric standard method using “DIVIDENT” Ltd. (Latvia) testing system (kits) and spectrophotometer „*Cary 50*” *(„Varian”, Inc.*, Netherlands).

The amount of Cu, Zn-superoxide dismutase, glutathione peroxidase in blood and amount of total antioxidant in plasma were determined by means of clinical chemistry analyzer „*RX Daytona*” *(„Randox Lab.” Ltd.,* Great Britain) using standard testing systems of *Randox Laboratories Ltd. (Great Britain).*

Amount of catalase in erythrocytes and amount of reduced glutathione were determined by means of photometric method using spectrophotometer „Cary 50” *(„Varian”, Inc.*, Netherlands).

Statistical Result Processing was performed by using SPSS 16.0 computer program (company *SPSS Ltd., USA)* and Microsoft Excel and MedCalc 11.2.1 programs were used in separate cases. Generally recognized statistical methods (Teibe & Berķis, 2001; Paura & Arhipova, 2002; Teibe, 2007) were used in data statistical analysis. Consistency of acquired research results to normal (Gauss) division was examined by using Kolmogorov-

Smirnov test (*K-S test*), asymmetry and excess of results were also assessed. Since the measurements of work environment air, results of metal and biochemical analyses did not comply with normal distribution, nonparametric data procession methods were used for statistical processing of results. Corresponding statistical analysis was performed for each variable quantity – indices of central trends (arithmetic mean, median) and dispersion (standard deviation, 95% confidence interval) were found as well as quartiles calculated. For result comparison Odds Ratio (OR), Chi-square test, confidence interval (95%) methods of analysis were applied, as well as Mann-Whitney U test, linear regression, Spearman's rank correlation coefficient calculated.

Results

Work Environment Air. Riga Stradins University Institute of Occupational Safety and Environmental Health, Laboratory of Hygiene and Occupational Diseases Data base of measurements of the environmental risk factors including chemical substances was used in the assessment of work environment air quality. 1073 analyses of welding fume was performed by RSU Laboratory of Hygiene and Occupational Diseases in the period from 2002 to 2009; in 602 or 56.1% cases the concentration equals to or exceeds the occupational exposure limit value - 4 mg/m^3 (see Table 1)

Table 1. Number of measurements of welding fume distributed according to years and exposure indices

Exposure indices (EI)	Number of measurements per year								**Total**
	2002	2003	2004	2005	2006	2007	2008	2009	
low EI	0	0	0	3	3	0	8	3	**17 (1.6%)**
medium EI	42	69	39	48	12	37	61	43	**351 (32.7%)**
high EI	12	27	24	15	3	5	12	5	**103 (9.6%)**
very high EI	60	75	78	144	42	51	83	69	**602 (56.1%)**
Total	**114**	**171**	**141**	**210**	**60**	**93**	**164**	**120**	**1073**
Total, %	**10.6 %**	**15.9 %**	**13.1 %**	**19.6%**	**5.6 %**	**8.7 %**	**15.3 %**	**11.2 %**	**100%**

In laboratory measurements the concentrations of welding fume with a very high risk of influence showed the highest percentage in 2005 and 2996, 68.6% and 70.0% respectively. From 2002 to 2005 the increase of laboratory measurements is observed, respectively 114 measurements in 2002, 171 in 2003, 141 in 2004 and 210 in 2005 followed by a steep decrease of measurement episodes with 120 measurements in 2009 being close to the level of 2002.

Within the period from 2002 to 2009 the average (x ± SD) concentration of welding fume is 13.32 ± 33.73 mg/m^3 (95% TI 10.64 – 16.01); it means that occupational exposure limit value 4 mg/m^3, as set in the legislation of the Republic of Latvia, is exceeded more than 3 times. Since the concentrations of welding fume in the air of work environment fluctuate in very wide range, with maximum concentration reaching even 365.10 mg/m^3 in 2007, I used median as additional characterizing quantity. As shown in the Illustration 1, values of concentration medians for all years except 2003 exceed occupational exposure limit value for welding fume; since median is the average result in the series of figures where all pool results are arranged in the ascending sequence it is valid to assert that more than a half of annually performed laboratory measurements exceeds occupational exposure limit value.

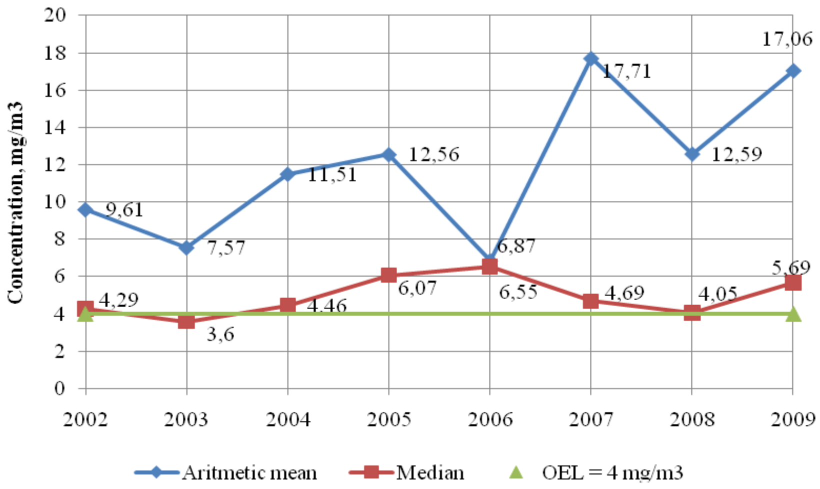

Illustration 1. Average concentration of welding fume and concentration median for work environment air distributed according to years

Out of 884 manganese analyses, performed by RSU Laboratory of Hygiene and Occupational Diseases from 2002 to 2009, in 350 or 39.6% cases the concentration of manganese equals to or exceeds the occupational exposure limit value 0.1 mg/m^3 (see Table 2).

The largest amount of manganese analyses is observed in 2003, making 162 analyses or 18.3% out of all laboratory analyses performed regarding manganese from the year of 2002 to 2009. The highest percentage of analyses in which the concentration of manganese does not comply with the occupational exposure limit value, was observed in 2009 with 54% exceeding occupational exposure limit value; number of analyses exceeding occupational

exposure limit value was relatively high also in 2008 and 2005, 48.6% and 47.1% respectively.
Analyzing the records of laboratory sampling and testing reports, high exposure indices are observed also in workplaces where no collective protective means are available or which are not properly equipped with adequate inflow-outflow ventilation.

Table 2. Number of manganese analyses in the work environment air distributed according to years and exposure indices

Exposure indices (EI)	Number of measurements per year								**Total**
	2002	2003	2004	2005	2006	2007	2008	2009	
low EI	12	18	45	42	9	25	18	27	**196 (22.2%)**
medium EI	45	84	33	33	27	27	36	11	**296 (33.5%)**
high EI	6	21	6	6	0	0	1	2	**42 (4.7%)**
very high EI	51	39	54	72	18	17	52	47	**350 (39.6%)**
Total	**114**	**162**	**138**	**153**	**54**	**69**	**107**	**87**	**884**
Total, %	**12.9%**	**18.3%**	**15.6%**	**17.3%**	**6.1%**	**7.8%**	**12.1%**	**9.8%**	**100%**

In the period from 2002 to 2009, RSU Laboratory of Hygiene and Occupational Diseases measured chromium concentration in the work environment air in 217 workplaces; 650 chromium analyses were performed in total, none of them exceeded occupational exposure limit value 1 mg/m^3 (see Table 3).

Table 3. Number of chromium analyses in the work environment air distributed according to years and exposure indices

Exposure indices (EI)	Number of measurements per year								**Total**
	2002	2003	2004	2005	2006	2007	2008	2009	
low EI	81 96.4%	123 78.8%	111 92.5%	96 91.4%	30 83.3%	54 100 %	65 95.6%	27 100 %	**587** **90.3%**
medium EI	3 3.6%	33 21.2%	9 7.5%	9 8.6%	6 16.7%	0	3 4.4%	0	**63** **9.7%**
high EI	-	-	-	-	-	-	-	-	**-**
very high EI	-	-	-	-	-	-	-	-	**-**
Total (%)	**84** 100%	**156** 100%	**120** 100%	**105** 100%	**36** 100%	**54** 100 %	**68** 100%	**27** 100 %	**650** **100%**
Mean concentr. of chromium, mg/m^3	0.03	0.09	0.06	0.02	0.07	0.01	0.02	0.01	

Looking at chromium exposure indices according to distribution in years, one can see that for the most part of analyses the exposure index in workplaces/ processes is low (EI < 0,1), only 9.7% or 63 analyses show average ($0,1 \leq EI < 0,75$) exposure index; it means that the concentration of chromium in work environment air does not cause serious threat to the health of employees. Average concentrations of chromium do not exceed 1/10 from the occupational exposure limit value – 1 mg/m^3 in any of years.

Since 2007 RSU Laboratory of Hygiene and Occupational Diseases operates a new data base version which helps acquiring more detailed information about the used types of welding. From 2007 to 2009, 127 different workplaces related to welding were surveyed and 377 work environment air samples were taken, 263 manganese and 149 chromium analyses performed. Percentage of welding types used in those workplaces is shown in Illustration 2.

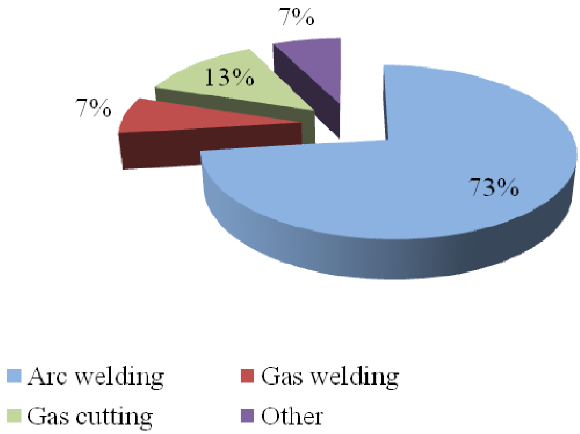

Illustration 2. Percentage of welding types used in workplaces according to laboratory survey

According to data from RSU Laboratory of Hygiene and Occupational Diseases, measurements of work environment air are most often performed during the arc welding, comprising 73% out of all laboratory measurements regarding welding fume from 2007 to 2009. Arc welding includes electric arc welding by means of electrode, semiautomatic welding, welding with wire and similar types. Gas welding includes semiautomatic gas shield welding. Gas cutting is mechanical partition of metal details by means of welding torch. Other types of welding are plasma arc welding, laser welding.

Concentrations of welding fume, manganese and chromium in the work environment air according to the used welding type are summarized in Table 4.

Table 4. Concentrations of welding fume, manganese and chromium in the work environment air according to the used welding type

Welding type	Indices	Number of analysis	Concentration in work place air, mg/m^3							
			$X_{vid.}$	SD	95% CI	Min	Max	Median	95% CI	IQR ($Q_3 - Q_1$)
Arc welding	Welding fume	275	12.70	28.05	9.37 – 16.03	0.003	231.26	4.10	3.69 – 4.84	1.81 – 9.78
	Manganese	194	1.01	3.66	0.49 – 1.53	< 0.001	32.60	0.08	0.04 – 0.13	0.012 – 0.42
	Chromium	119	0.005	0.007	0.004 – 0.006	< 0.001	0.033	0.003	0.002 – 0.003	0.001 – 0.005
Gas welding	Welding fume	27	24.00	41.96	7.40 – 40.60	0.44	141.35	7.00	4.91 – 16.46	2.83 – 22.78
	Manganese	18	0.77	1.49	0.03 – 1.52	0.001	5.49	0.24	0.002 – 0.39	0.002 – 0.40
	Chromium	6	0.006	0.002	0.004 – 0.008	0.003	0.008	0.006	0.003 – 0.008	0.005 – 0.007
Gas cutting	Welding fume	48	31.83	84.55	7.28 – 56.37	0.84	365.10	8.55	4.81 – 11.25	1.92 – 14.69
	Manganese	30	0.11	0.22	0.02 – 0.19	0.001	0.85	0.01	0.004 – 0.02	0.003 – 0.03
	Chromium	15	0.05	0.10	-0.004 – 0.109	0.002	0.250	0.004	0.002 – 0.005	0.002 – 0.005
Other types	Welding fume	27	3.42	4.44	1.66 – 5.18	0.28	16.22	1.10	0.69 – 2.11	0.54 – 5.33
	Manganese	21	0.05	0.08	0.01 – 0.08	0.001	0.24	0.006	0.001 – 0.04	0.001 – 0.06
	Chromium	9	0.002	0.001	0.001 – 0.003	< 0.001	0.003	0.002	0.001 – 0.003	0.001 – 0.003

$X_{vid.}$- mean concentration, mg/m^3; SD – standard deviation; CI – confidence interval, 95%; Min – min value; Max – max value; IQR ($Q_3 - Q_1$) – interquartile range

Metal levels and biochemical indices. Persons employed in metal processing are subjected to the impact of different work environment risk factors. One of the most important risk factors is various metal compounds in the air of work environment which enters organism through respiratory tract. Determination of metal levels and biochemical indices in the blood of employees might indicate of early work environment risk factor-induced changes in organism and so it is possible to assess the impact of work environment.

Five elements were used for determination – manganese, chromium, zinc, copper and cadmium. The first four elements are crucial in organism's metabolism nevertheless a probability states that the increased concentration of these elements in work environment can influence normal levels of metals in organism. Cadmium is not necessary for a human organism therefore it is possible that an increased concentration of this element in organism could mess up the balance of other elements.

Deposition of metals or insufficient level of them in organism cause changes in physically-chemical inner parameters of organism and in the course of time it might cause a disorder of main barrier organs and systems of organism protection system. In order for natural organism protection system to operate fully, organism needs a sufficient amount of antioxidants. Antioxidant enzymes, such as glutathione peroxidase (*GPx*), superoxide dismutase (SOD) and catalase (CAT), prevent heavy metal deposition in organism (Sharifian *et al.*, 2009).

Comparing the results of welder (exposed) group to the results of electrician (control) group, we can see that for **manganese (Mn)** concentration median in blood is 22.30 µg/l (95% CI 18.70 – 24.30), but for the electrician (control) group 16.50 µg/l (95% CI 14.99 – 18.14). Processing the obtained results by means of Mann - Whitney U test a statistically valid difference ($z=4.37$; $p < 0.001$) can be observed between groups, the level of Mn in blood for the exposed group is considerably higher.

Concentration median for **chromium (Cr)** in blood for the exposed group is 6.35 µg/l (95% CI 4.30 – 7.62) while for control group - 3.75 µg/l (95% CI 2.57 – 6.20). Even though the value of median for the exposed group is 1.7 times higher than for the control group, no statistically valid difference ($z = 1.84$; $p = 0.066$) was observed between the groups when processing the obtained results by means of Mann - Whitney U test.

Concentration median for **cadmium (Cd)** in blood for the exposed group is 1.06 µg/l (95% CI 0.48 – 2.53) while for control group - 0.60 µg/l (95% CI 0.28 – 1.25). Processing the obtained result by means of Mann-Whitney U test a statistically valid difference ($z = 2.99$; $p < 0.01$) can be observed, the level of cadmium for the exposed group is considerably higher. Being aware of the fact that welder group features more smokers than electrician group and that smokers have higher level of cadmium, a detailed analysis of impact of smoking and cadmium levels was performed.

Concentration median for **copper (Cu)** in blood for the exposed group is 0.71 mg/l (95% CI 0.66 – 0.75) while for control group – 0.99 mg/l (95% CI 0.86 – 1.11). Processing the obtained results by means of Mann - Whitney U test a statistically valid difference ($z = 4.23$; $p < 0.001$) can be observed between the groups. The level of Cu for the exposed group is considerably lower.

Concentration median for **zinc (Zn)** in blood for the exposed group is 6.90 mg/l (95% CI 6.51 – 7.39) while for control group – 6.20 mg/l (95% CI 5.82 – 6.60). Processing the obtained results by means of Mann - Whitney U test a statistically valid difference (= 3.78; $p < 0.001$) can be observed between the groups. The level of Zn for the exposed group is considerably higher.

Index characterizing the interaction of metals is **relation between copper and zinc (Zn:Cu)**. For the exposed group, Zn:Cu correlation median in blood is 9.47 (95% CI 8.70 – 10.69) while for control group – 5.64 (95% CI 4.28 – 7.75). Processing the obtained results by means of Mann - Whitney U test a statistically valid difference ($z = 5.62$; $p < 0.001$) can be observed between the groups. Increased Zn:Cu correlation is observed in the exposed group.

Correlation analysis does not confirm the alterations in manganese, chromium, copper and zinc depending on changes in age. Both in welder and electrician group along with increasing age, one can observe weak trend of cadmium decrease in blood, respectively ($r = -0.204$; $p=0.051$) and ($r = -0.254$; $p=0.072$). This weak trend shows that higher level of cadmium in both groups is observed among the younger participants of the study.

High metal concentrations in the work environment and long exposure time can encourage the increase or decrease of the level of various elements in organism bio-environments. Length of service is one of the indices characterizing exposure time. Correlations between the length of service and metal levels in blood was not found in any of groups involved in the study.

In order to assess the **impact of smoking**, metal levels were compared between smokers, former smokers and non-smokers in welder and electrician groups. Results are summarized in Table 5.

Table 5. Characteristic quantities of Mann – Whitney analysis comparing metal levels in blood for occupational exposed (welders) and unexposed (electricians) persons according to smoking habit

Element	Smoking habit	Group	N	Median (25‰ - 75‰)	z	p
Mn, µg/l	Non smokers	Electricians	22	16.70 (12.00 – 19.30)	2.87	0.0041
		Welders	20	20.95 (17.00 – 27.35)**		
Mn, µg/l	Ex smokers	Electricians	15	16.50 (14.55 – 20.45)	2.24	0.0253
		Welders	9	24.00 (19.28 – 37.25)*		
Mn, µg/l	Smokers	Electricians	16	16.29 (12.25 – 18.75)	2.44	0.0147
		Welders	50	21.95 (16.00 – 30.50)*		
Cr, µg/l	Non smokers	Electricians	21	2.50 (0.10 – 7.75)	2.28	0.0225
		Welders	18	7.75 (3.30 – 11.90)*		
Cr, µg/l	Ex smokers	Electricians	12	3.50 (2.00 – 7.95)	0.12	0.9076
		Welders	16	5.25 (2.00 – 7.25)		
Cr, µg/l	Smokers	Electricians	15	5.50 (3.28 – 12.10)	0.15	0.8802
		Welders	46	6.35 (3.00 – 9.70)		
Cd, µg/l	Non smokers	Electricians	23	0.30 (0.20 – 0.60)	0.95	0.3413
		Welders	21	0.30 (0.20 – 1.90)		
Cd, µg/l	Ex smokers	Electricians	13	0.63 (0.45 – 1.06)	1.15	0.2498
		Welders	17	0.60 (0.30 – 0.78)		
Cd, µg/l	Smokers	Electricians	14	1.40 (0.93 – 2.29)	1.02	0.3085
		Welders	54	1.60 (0.95 – 3.00)		

Statistically significant difference by Mann – Whitney test: * - $p < 0.05$; ** - $p < 0.01$; *** - $p < 0.001$

Table 5 (continued). Characteristic quantities of Mann – Whitney analysis comparing metal levels in blood for occupational exposed (welders) and unexposed (electricians) persons according to smoking habit

Element	Smoking habit	Group	N	Median (25‰ - 75‰)	z	p
Cu, mg/l	Non smokers	Electricians	23	1.00 (0.76 – 1.44)	2.58	0.0098
		Welders	20	0.72 (0.47 – 0.84)**		
Cu, mg/l	Ex smokers	Electricians	13	1.04 (0.81 – 1.31)	1.99	0.0468
		Welders	17	0.75 (0.62 – 0.94)*		
Cu, mg/l	Smokers	Electricians	15	0.87 (0.69 – 1.06)	1.95	0.0506
		Welders	55	0.69 (0.52 – 0.82)		
Zn, mg/l	Non smokers	Electricians	22	6.45 (5.60 – 6.90)	0.77	0.4441
		Welders	21	6.50 (5.65 – 8.80)		
Zn, mg/l	Ex smokers	Electricians	13	6.60 (5.60 – 7.05)	1.19	0.2330
		Welders	17	6.90 (5.75 – 7.65)		
Zn, mg/l	Smokers	Electricians	14	5.55 (4.80 – 6.30)	4.00	6.43e-05
		Welders	54	7.05 (6.20 – 8.00)***		
Zn : Cu	Non smokers	Electricians	21	6.16 (4.21 – 7.52)	3.20	0.0014
		Welders	20	8.99 (6.57 – 16.89)**		
Zn : Cu	Ex smokers	Electricians	12	5.23 (4.52 – 6.42)	3.16	0.0016
		Welders	17	8.75 (7.15 – 11.35)**		
Zn : Cu	Smokers	Electricians	12	6.69 (4.67 – 8.34)	3.47	0.0005
		Welders	54	9.72 (7.68 – 14.88)***		

Statistically significant difference by Mann – Whitney test: * - $p < 0.05$; ** - $p < 0.01$; *** - $p < 0.001$

Level of manganese in welder group has a higher statistical validity than that of electrician group. Comparing the level of manganese in welder and electrician groups (see Illustration 3) statistically valid differences between non-smokers (z=2.87; p<0.01), former smokers (z=2.24; p<0.05) and smokers (z=2.44; p<0.05) were found.

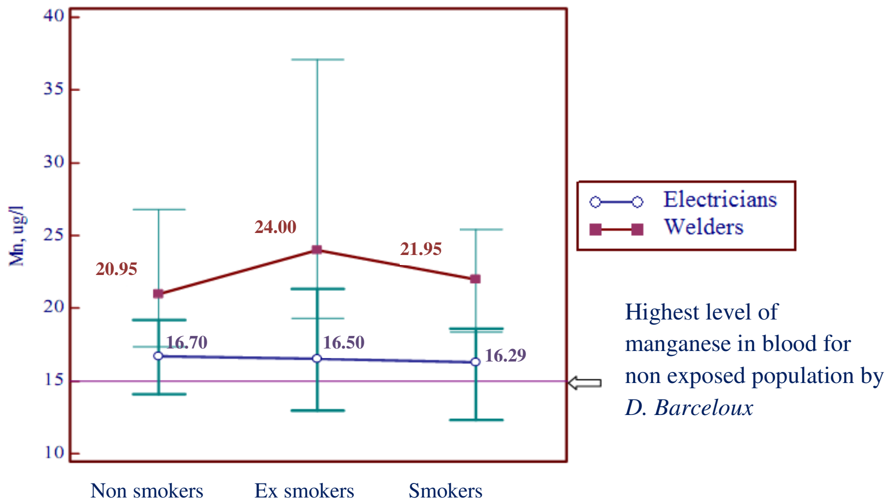

Illustration 3. Levels of manganese with 95% CI in blood of electricians and welders according to smoking habit.

Almost invariable level of manganese in electrician group similarly as in other authors' studies (Kristiansen *et al.*, 1997) testify the fact that smoking does not influence the level of manganese in blood.

Comparing the levels of copper medians between welder and electrician groups by means of Mann – Whitney U test, a statistically valid difference is found in results, see Illustration 4, for smokers (z=2.58; p<0.01) and former smokers (z=1.99; p<0.05) while differences between smokers have no statistical validity (z=1.95; p=0.051).

Level of copper in the blood of welders if compared to the recommendations in the literature (Wu, 2006) is lowered; the lowest level is observed among smoking welders.

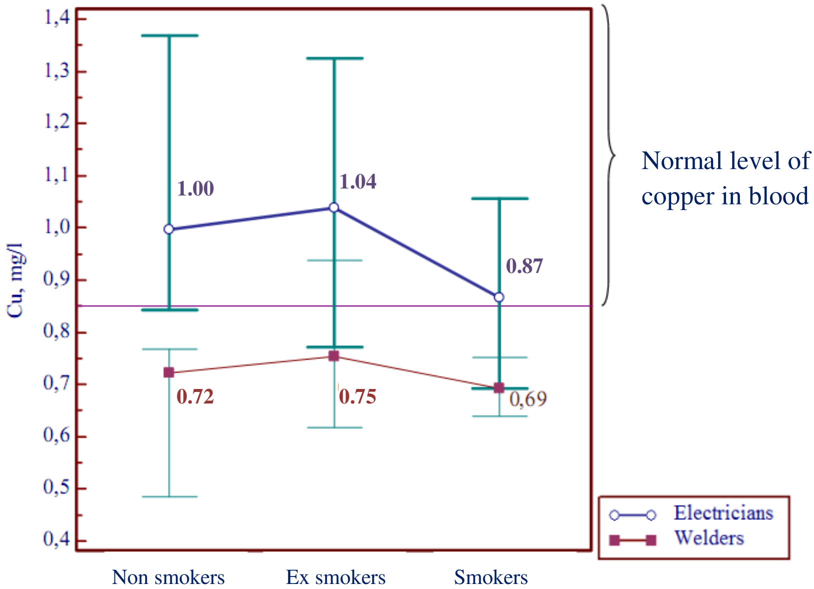

Illustration 4. Levels of copper with 95% CI in blood of electricians and welders according to smoking habit.

Weak (r = -0.265) and statistically significant ($p<0.05$) negative correlation between the levels of zinc and copper is found in blood of welders. It means that by increasing the level of zinc in blood, the level of copper decreases. According to the literature, zinc and copper can antagonistically influence each other's absorption volumes and metabolism (Telišman *et al.*, 2001).

Aggregating the obtained results in welder group and comparing them to the control group and reference levels indicated by other authors, increased levels of manganese, cadmium and zinc levels and decreased copper level in blood are observed. The most considerable source of cadmium pollution is smoking but changes in levels of other metals are associated with pollution in the work environment air.

In work environment welders are subjected to the influence of welding fume which has irritating, toxic, fibriogenic and probably has sensibilizing effect.

When welding fume enters into lungs it becomes the source of chronic irritation. Activation of macrophages and leucocytes is followed by phagocitosis thus causing the discharge of protease, inflammation agents and active oxygen radicals. Determination of Cu, Zn-superoxide dismutase, catalase, reduced glutathione and total level of antioxidants as well as determination of plasma hemiluminiscence (*HCL*) was performed in blood of welders and electricians. Obtained results are summarized in Table 6. Comparing the obtained results from both groups, none of found indices show statistically valid difference.

Table 6. Biochemical indices in blood of welders and electricians

Group	N	Indices	Median	IQR ($Q_3 - Q_1$)	95% CI
Welders	96	Cu, Zn - SOD, U/g Hb	1341.5	1161.0 – 1558.5	1276.3 – 1391.5
	96	CAT, k/g Hb	187.5	147.5 – 218.5	172.0 – 199.3
	97	GPx, U/L	6466.0	5510.3 – 7475.5	6036.0 – 6725.0
	97	Reduced glutathione, mg% (m g/dl)	40.4	36.8 – 46.0	38.7 – 41.0
	95	TAS, mmol/L	1.56	1.50 – 1.74	1.53 – 1.59
	70	H_{max} – amount of lipid peroxides, cond. unit	190.0	100.0 – 357.0	141.3 – 240.3
	38	S_{ox} – oxidation of plasma, cond. unit	517.2	255.0 – 722.0	415.9 – 655.5
	38	tg_{α} – oxidation speed, cond. unit	8.19	3.30 – 12.20	5.20 – 10.65
Electricians	54	Cu, Zn - SOD, U/g Hb	1279.0	1163.0 – 1404.0	1238.9 – 1354.78
	54	CAT, k/g Hb	179.0	155.0 – 209.0	165.0 – 191.7
	54	GPx, U/L	6215.0	5346.0 – 7348.0	5747.8 – 6777.4
	54	Reduced glutathione, mg% (m g/dl)	42.4	38.8 – 46.0	40.5 – 43.9
	53	TAS, mmol/L	1.58	1.47 – 1.72	1.53 – 1.65
	45	H_{max} – amount of lipid peroxides, cond. unit	228.0	92.3 – 323.8	125.7 – 275.8
	23	S_{ox} – oxidation of plasma, cond. unit	423.0	326.3 – 635.5	345.2 – 574.5
	21	tg_{α} – oxidation speed, cond. unit	5.90	4.46 – 9.63	4.72 – 8.83

By performing Spearman's rank correlation test, a positive weak (r=0.318), statistically valid ($p<0.001$) correlation was found between the amount of lipid peroxides and the level of manganese in the blood of welder group; it means that by increasing concentration of manganese the increase of "oxidative stress" is observed in organism. Negative weak (r=-0.310), statistically valid ($p<0.01$) correlation is obtained between the amount of lipid peroxides and the level of zinc in the blod of welder group. Negative weak (r=-

0.321), stastitically valid (p<0.001)) correlation is obtained between the amount of lipid peroxides and zinc-copper correlation in the blood of welder group. Such correlations are not observed in the electrician group.

Calculating the correlation of linear regression between the amount of lipid peroxides and level of manganese in blood of welder group (see Illustration 5), statistically valid ($p < 0.05$), positive regression was obtained, determination coefficient R^2=0.0766, regression equation Log(y) = 2.0229+0.009252x

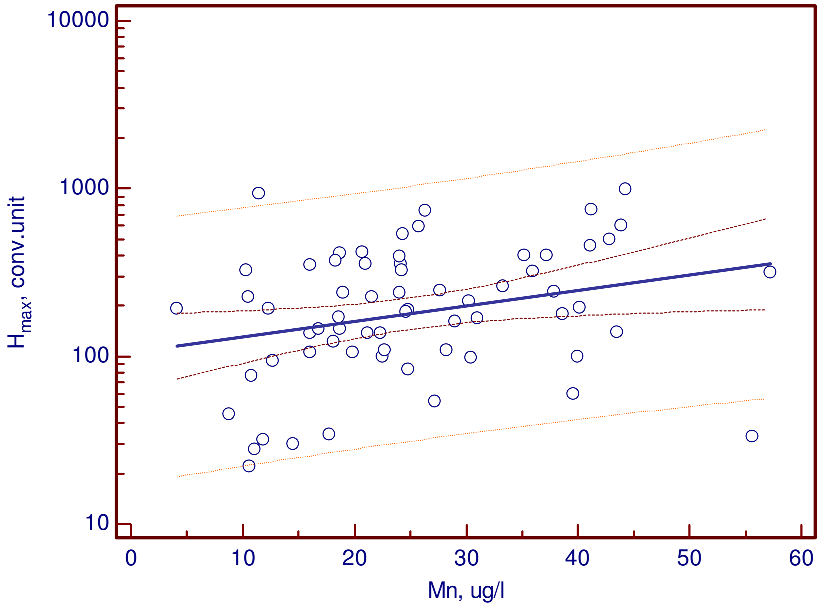

Illustration 5. Changes in the amount of lipid peroxide (H_{max}) depending on the changes of manganese level in blood of welder group.

Summing up the results of biochemical indices, statistically valid result differences were not obtained between the exposed and control group, however higher values of *SOD, CAT* and *GPx* medians are observed in welder group if compared to electrician group.

The indice of oxidative stress, namely, the amount of lipid peroxides in welder group has a positive correlation with levels of manganese and cadmium in blood. Thus we can conclude that metal compounds existing in the work environment has a considerable effect on causing "oxidative stress" for persons employed in welding processes.

Self-estimate of health condition of welders and office workers. There are increased concentrations of welding fume and manganese as surveyed in laboratory measurements in the workplaces, mainly work environment air, of welders in different Latvian enterprises. As we know, increased concentrations of welding fume and metals it contains can cause various diseases to welders.

Impact on respiratory system has been frequently researched and profoundly described in the literature sources; manganese compounds contained in the welding fume can cause welders nervous system disorders of various degrees.

Information from the questionnaires about welders' health condition show that the main health problems are: skeletal, muscle, connective tissues diseases, mainly pain in back 43.3%. 26.8% employees indicated that they suffer from digestive tract diseases (gastritis, stomach ulcer), 26.8% - sensory organ disorders (weakened hearing and sight), 25.8% has hypertension, 27.8% has chronic upper-respiratory tract and bronchial inflammation diseases, 5.2% had neurological disorders diagnosed. 48.5% have been involved in various accidents, mainly – bone fracture – 61.4%, concussion – 13.6% and eye injuries – 9.1%. 33.0% office workers indicated at skeletal, muscle, connective tissues diseases, mainly pain in back, 26.2% have hypertension, 18.4% have sensory organ diseases (changes in sight), 13.6% complain about chronic rhinitis and repeated inflammation of the upper-respiratory tract.

As shown in Table 7, those employed in welding work in comparison to the persons of control group have more frequent chronic upper-respiratory tract and bronchial diseases, digestive tract and rheumatic diseases; differences are statistically valid.

5.2% of surveyed from the welder group indicate peripheral nervous system disorders while these complaints are indicated by 1.9% from the office worker group; no statistically valid differences are found between the groups.

Welders in their work environment are exposed to manganese and laboratory analyses of work environment air show that in approximately 40% of performed measures exposure index is larger than 1 and it means that the occupational exposure limit value is exceeded. Manganese has toxic impact on nervous system therefore being exposed to long-term increase doses serious neurological diseases might develop.

Table 7. The main group of diseases for welders in comparison to the office workers according to the results of survey

Complaint	Groups			
	Welders (n=97)		Office workers (n=103)	
	Number.	%	Number	%
Skeletal, muscle, connective tissues diseases	42	43.3	34	33.0
Chronic upper-respiratory tract and bronchial inflammation diseases	27	27.8*	14	13.6
Sensory organ disorders (hearing and sight)	26	26.8	19	18.4
Digestive tract diseases	26	26.8**	8	7.8
Hypertension	25	25.8	27	26.2
Rheumatic diseases	14	14.4*	4	3.9
Allergic diseases	7	7.2	5	4.9
Peripheral nervous system disorders	5	5.2	2	1.9

Statistically significant difference between groups, * - $p < 0.05$; ** - $p < 0.01$

In order to assess the possible neurological impact of welding fume and manganese it contains, interview test was performed using the questionnaire with 16 questions (questionnaire for assessment of neurological symptoms) used in occupational diseases field (internationally validated). There is no limit value set for certain number of positive answers in examining the questionnaire according to which respondents could be divided into „ill" and „healthy" therefore positive answers median value was picked out as control point, similarly to the studies by Swedish researchers (Sjögren *et al.*, 1990); therefore those who have less than three positive answers are put in the "healthy" group while those who have three or more positive answers are included in the "group with endangered health". Table 8 shows the distribution of positive answers in welder and office workers groups.

Summing up the obtained results it has been observed that three or more positive answers in welder group was given by 34.9% of respondents while among office workers – 21.4% with a statistically valid difference between the groups (χ^2 = 9.92; $p < 0.01$). It must be noted that there were maximum 5 positive answers in one questionnaire in the office worker group while in welder group in similar proportions (from 3.1 to 4.1 %) five, six, seven and eight positive answers in one questionnaire was chosen. Maximum positive answers – 12 out of 16 possible – were found in one questionnaire filled out by welder.

Table 8. Distribution of positive (affirmative) answers in questionnaire Q16 between welder and office workers groups

Number of positive answers	Welders (n=97)		Office workers (n=103)	
	Number of questionnaire	%	Number of questionnaire	%
0 (Not)	31	32.0	38	36.9
1	16	16.5	24	23.3
2	16	16.5	19	18.4
3	10	10.3	16	15.5
4	8	8.2	5	4.9
5	3	3.1	1	1.0
6	4	4.1	-	-
7	3	3.1	-	-
8	4	4.1	-	-
9	1	1.0	-	-
10	-	-	-	-
11	-	-	-	-
12	1	1.0	-	-

Total number of exposure hours was calculated for each welder basing on the average length of working day and length of service. In order to calculate linear regression between the exposure time and number of symptom-positive answers those welders were selected who indicated in their Q 16 test three or more positive (affirmative) answers, 34 persons in total. Calculating the coherence of linear regression between the frequency of neurological symptoms indicated in the questionnaire and exposure time, a statistically valid ($p < 0.05$) positive trend was obtained with determination coefficient $R^2=0.1673$, regression equation $y=4.0792+0.00004721x$ (see Illustration 6).

Data analysis was processed by means of Spearman's rank correlation test and accordingly average ($r=0.446$) statistically valid ($p<0.01$) correlation was found between the frequency of positive answers and exposure time.

It means that for employees' group which has three and more positive answers to Q16 test, continuation of work without improving the work environment, new neurological symptoms might emerge and result in serious neurological diseases and disability.

Result analysis data of certain questions from Q16 questionnaire are summarized in Table 9

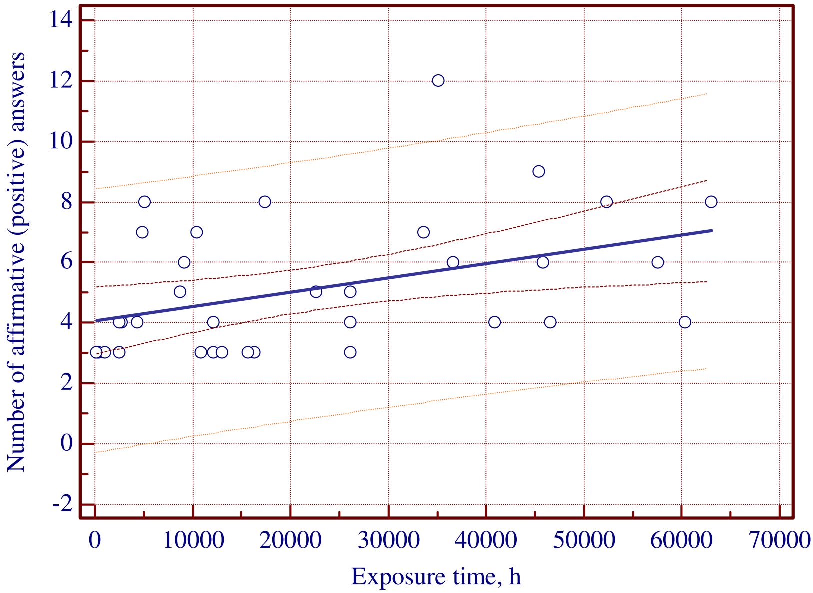

Illustration 6. Increase of affirmative (positive) answers to questions of Q16 test according to the number of working hours among welders

Comparing the frequency of positive answers in welder and control groups, statistically valid differences are observed in five questions: „ Do you often have a painful tingling in some part of your body?" (OR = 8.38; 95% TI = 1.86 – 37.76; p<0.05), „ Do you often feel irritated without any particular reason?" (OR = 4.26; 95% TI = 1.06 – 19.95; p<0.05), „ Do you have a short memory?" (OR = 8.14; 95% TI = 2.53 – 29.01; p<0.001), „ Do you generally find it hard to get the meaning from reading newspapers and books?" (OR = 9.17; 95% TI = 1.13 – 202.1; p<0.05), „ Do you often have to go back and check things you have done such as turned off the stove, locked the door, etc.?" (OR = 3.69; 95% TI = 1.47 – 9.57; p<0.01).

Total frequency of neurological symptoms for welder group has a higher statistical validity than to control group (OR = 1.91; 95% TI = 1.51 – 2.41; p<0.001). In comparison to the control group, welders complain more often about poor memory, problems with understanding a written message in journals and newspapers, nervousness without any obvious reason, problems with doing and undoing buttons.

Assessing the obtained results we conclude that this questionnaire can be used as neurological symptom screening tool before undergoing the compulsory health checks and more profound neurological assessment is necessary for persons with more than three positive answers.

Table 9. Frequency of neurological symptoms in welder and office worker groups

No.	Question	Welders (n=97)		Control group (n=103)		OR	95% CI	χ^2	p
		Yes	No	Yes	No				
1.	Are you abnormally tired?	19	78	15	88	1.43	0.64 – 3.20	0.57	0.449
2.	Do you have palpitations even when you don't exert yourself?	17	80	8	95	2.52	0.96 – 6.77	3.50	0.061
3.	Do you often have a painful tingling in some part of your body?	7	90	0	103	8.38	1.86 – 37.76	5.71	0.016
4.	Do you often feel irritated without any particular reason?	11	86	3	100	4.26	1.06 – 19.95	4.23	0.039
5.	Do you often feel depressed without any particular reason?	11	86	4	99	3.17	0.89 – 12.29	3.00	0.083
6.	Do you have problems with concentrating?	8	89	8	95	1.07	0.35 – 3.29	0.02	0.892
7.	Do you have a short memory?	24	73	4	99	8.14	2.53 – 29.01	16.36	<0.001
8.	Do you perspire without any particular reason?	10	87	11	92	0.96	0.36 – 2.58	0.02	0.884
9.	Do you have any problems with buttoning and unbuttoning?	4	93	0	103	8.11	1.13 – 58.51	2.50	0.115
10.	Do you generally find it hard to get the meaning from reading newspapers and books?	8	89	1	102	9.17	1.13 – 202.1	4.58	0.032
11.	Have your relatives told you that you have a short memory?	12	85	17	86	0.71	0.30 – 1.69	0.40	0.529
12.	Do you sometimes feel an oppression of your chest?	18	79	9	94	2.38	0.95 – 6.10	3.33	0.068
13.	Do you often have to make notes about what you must remember?	17	80	11	92	1.78	0.74 – 4.34	1.42	0.234
14.	Do you often have to go back and check things you have done such as turned off the stove, locked the door, etc.?	23	74	8	95	3.69	1.47 – 9.57	8.52	0.004
15.	Do you have a headache at least once a week?	24	73	28	75	0.88	0.45 – 1.74	0.05	0.816
16.	Are you less interested in sex than what you think is normal?	10	87	5	98	1.43	0.67 – 7.92	1.43	0.232

Abbreviations: OR – odds ratio; CI – confidence interval

Discussion

During the welding process welding fume, manganese, chromium and other metal compounds are released in the air of work environment, their concentrations in the air of work environment are regulated not only by the presence and use of means of collective protection or downtime during work, but also by type of metal alloy and welding method selected for its processing (Robinson, 1986; Guidotti *et al.*, 1992; Antonini, 2003; Antonini *et al.*, 2003b). The most popular welding methods are manual electric arc welding with electrode and gas metal arc welding (Kaļķis *et al.*, 2001). This fact is also testified by the information analysis performed in this paper basing on RSU Institute of Occupational Safety and Environmental Health, Laboratory of Hygiene and Occupational Diseases data base, because the measurements of work environment air are mainly performed during the manual electric arc welding (73% of measurements). In the study by Hewitt it was indicated that in case of stainless steel welding, the analyses of welding fume contain 18.9% potassium, 10.8% iron, 10.4% sodium, 6.2% manganese, 5.6% chromium, 4.9% silicium, 0.75% nickel and other elements (Hewitt, 1996). According to study results by *Antonini et al.* the composition of welding fume for steel with low carbon content is poorly soluble in water and contains 80.6% iron, 14.7% manganese, 2.75% silicium and 1.79% copper (Antonini *et al.*, 2009). Even though the composition of welding fume includes many metals, in Latvian enterprises during the welding process measurements of work environment air are performed mainly regarding the welding fume, manganese and chromium as the most typical toxic components. It is possible to perform the analysis of much wider spectrum of metals in the accredited laboratories; nevertheless enterprises do not demand to determine other metals in the air of work environment. The possible reason for this could be insufficient knowledge of work environment risk assessors about the chemical substances released during the welding process in the air of work environment and the probable risk for health of the employed as well as financial restrictions of enterprises.

Within the period from 2002 to 2009 RSU Laboratory of Hygiene and Occupational Diseases performed the measurements of welding fume concentration, determination of manganese and chromium in the work environment air in 360 workplaces. On average it makes 45 workplaces or welding positions per year. This number could be much larger if all welding workplaces were assessed in the enterprises where measurements of work environment air were performed.

From laboratory analyses, in 56.1% cases the concentration of welding fume equals to or exceeds occupational exposure limit value – 4 mg/m^3, regarding manganese in 39.6% cases the concentration equals to or exceeds occupational exposure limit value – 0.1 mg/m^3, and it is relatively high pollution index in the work environment air.

Performing the analysis of the probable influence of pollutants on employees' health, exposure index (EI) is used as characterizing indicator (Eglīte *et al.*, 2007; Martinsone & Skesters, 2009). The air quality of work environment in welders' workplaces can be estimated as critical in terms of influence probability, because exposure index of welding fume in 56.1% cases and exposure index of manganese in 39.6% cases is larger than 1 which means that very high influence probability of determined chemical substances on the health of the employed exists in these workplaces.

In the given situation it is important for laboratories when providing the test reports on the level of work environment pollution to enterprises to indicate not only the average concentration of pollutant in the work environment air, but also the exposure index that provides an information regarding pollution level, probable level of influence on employee's health and frequency of compulsory health checks to the representatives of enterprise and competent authorities.

Exposure index as a term, its calculation and application for determining the frequency of measurements is defined in the Regulation of the Cabinet of Ministers No. 325/2007 "Work Safety Requirements when Working with Chemical Substances" (adopted on 15.05.2007, published in *Latvijas Vēstnesis*, 18.05.2007), while Regulation of the Cabinet of Ministers No. 219/2009 "Procedure of Undergoing Compulsory Health Checks" (adopted on 10.03.2009, published in *Latvijas Vēstnesis*, 13.03.2009) stipulate the frequency of compulsory health checks depending on exposure index, however judging from the laboratory experience it could be said that series of competent specialists do not fully understand this quantity.

Therefore it would be necessary to organize campaigns on national level that would educate competent specialists, employers and also employees into issues of arrangement of work environment and to help arriving at the latest solutions in reduction of substances' exposure level.

Fluctuations of welding fume concentration interval in work environment air are very large – from 0.30 to 365.10 mg/m^3 with average concentration (x ± SD) 13.32 ± 33.73 mg/m^3 (95% CI 10.64 – 16.01). It means that the set occupational exposure limit value 4 mg/m^3 is exceeded more than 3 times. Manganese concentrations in work environment also varies in very wide range – from 0.001 to 18.06 mg/m^3, average concentration (x ± SD) 0.42 ± 1.60 mg/m^3 (95% CI 0,27 – 0,56), and it exceeds the set occupational exposure limit value 0.1 mg/m^3 more than 4 times.

From the performed measures regarding chromium (total) concentration in the air or work environment, in 90.3% cases results of analyses are less than 1/10 of occupational exposure limit value 1 mg/m^3 than set in legislation and there were no single instance when concentration in work environment would exceed occupational exposure limit value or would reach the critical value - ¾ from occupational exposure limit value. Nevertheless in this situation there is no place for optimism since as we know also Cr^{6+}

compounds are released in the work environment air during the welding process and they are more toxic than Cr^{3+} compounds. Occupational exposure limit value for Cr^{6+} compounds is 0.1 mg/m^3 and not being aware of the concentration of this chromium compound in the air of work environment we cannot state that there is no dangerousness of influence. Sample preparation process for atomic absorption spectrophotometric analysis in is different in determination method for Cr^{6+} in work environment air and it prevents determining such metals as Mn, Ni, Zn, Cu, etc. in the obtained sample solution. Therefore additional air samples are necessary for determination of these metals and so costs for laboratory services increase for enterprises.

It is important to note that very high concentrations of welding fume and manganese are not considered as striking values, but rather concentrations characterizing the real work environment situation because all measurements of work environment air are performed in real workplaces and corresponding standard methods are applied. According to Robinsons (1986), performing the electric arc welding with electrodes (*MMAW*) large fluctuations in the individual exposure indices can be observed in identical conditions if stance or welding position are changed (Robinson, 1986).

According to Antonini (2003) and Hewitt (1996), the most widely used type of welding in the world is electric welding (Hewitt, 1996; Antonini, 2003). Results obtained also in this study show that from all the surveyed workplaces electric welding was performed in 73% cases. It is important to note that types of welding differ not only in their technological solution, but each type of welding has its level of work environment air pollution and slightly different proportional composition of metals contained in welding fume. Guidotti et al. (1992) writes that each type of welding can be characterized by the volume of welding fume consumed per one minute during the welding process. If electrodes are used in electric arc welding this index varies between 300 to 800 mg/minute but in gas electric arc welding – from 200 to 500 mg/minute (Guidotti *et al.*, 1992). Even though it is indicated in literature that volume of welding fume consumed per one minute in case of electric arc welding with electrodes is larger than in case of gas electric arc welding, our results show that concentration median for welding fume in the welder's respiratory zone is 4.10 (95% CI 3.69 – 4.84) mg/m^3 while performing electric welding with electrode and 7.00 (95% CI 4.91 – 16.46) mg/m^3 when performing gas welding. It supports the necessity to do the real work environment air quality measurements in workplaces and by performing the risk assessment and analysis not to rely merely on descriptions of technological processes. In the practice of risk assessment, assessing more seemingly identical workplaces, measurements of work environment are performed only in one of workplaces. Yet, according to the information in bibliography sources (Robinson, 1986), the obtained results and individual observations even in identical workplaces exposure indices can be different when workers are replaced or change their working position. Recommendation to work safety specialists and work environment risk evaluators is to plan laboratory measurements so that the results of work environment air quality would be obtained gradually regarding all workplaces and positions instead of annual measurements in one and the same workplaces. Furthermore, in performing risk assessment to follow not only the name of the workplace, but also take into consideration the most frequently used welding method and materials in welding position. When assessing work environment risks one must schedule the laboratory measurements also in welders' workplaces which are located outside processing department, for instance, during the pipeline repair in basements or trenches. In most cases the inflow-outflow ventilation is not provided and exchange of natural air is difficult, the employees do not have individual protective means which ensure supply of fresh air.

Since the concentrations of welding fume and manganese in work environment air fluctuate in wide range and standard deviations of results are larger than the mean values, it is more precise to use the pool of median values together with interval of quartiles ($Q_3 - Q_1$) when drawing the group-describing statistics. In this study for current measurement pools the median for welding fume concentration in the work environment air is 4.46 mg/m^3 (1.95 – 9.87), minimum value is 0.29 mg/m^3 and maximum value is 365.10 mg/m^3 and median for manganese concentration in work environment air is 0.04 mg/m^3 (0.01 – 0.23), minimum value is 0.001 mg/m^3 and maximum value is 18.06 mg/m^3. As one can see, median values are much lower than the average values but irrespective of that it exceeds occupational exposure limit value 1.1 times for welding fume.

In studies performed so far in Latvia (Lūse, 1999; Mārtiņsone, 2006; Antoneviča, 2007; Eglīte *et al.*, 2007) the average values are used when analyzing the existing pollution of work environment air, nevertheless from the perspective of statistical theory it is more precisely to use median values and concentration intervals otherwise due to certain workplaces with poor showings the situation gets dramatic in whole industry.

Comparing the situation in workplaces which we had surveyed with information in foreign authors' publications, we can see that they experience wide range of concentration fluctuations. In study performed by Norwegian and Russian scientists in St. Petersburg, the geometric mean concentration of manganese in respiratory zone was 0.097 mg/m^3 and concentration interval varied from 0.003 to 4.620 mg/m^3 (Ellingsen *et al.*, 2006). Similar situation is observed in study by Park et al. for welders employed in the Bay Bridge repair works. Geometric mean concentration of manganese in respiratory zone was 0.14 ± 2.33 mg/m^3 and concentration interval varied from 0.03 to 0.67 mg/m^3 (Park *et al.*, 2006).

High concentrations of pollutants in welding work environment air can be observed not only in our enterprises, but elsewhere in the world and it is not always possible to adjust proper ventilation system to welders' workplace that would reduce the probable influence of harmful substances. Therefore, for instance, in Sweden, Germany, Denmark, the majority of welders perform their work in appropriate work clothes and the latest generation welder masks which are equipped with supply of fresh air and "chameleon" glass which automatically becomes dark once the welding has started.

From 2002 until 2005 a steep increase of laboratory measurements can be observed, and there is also a trend of very high exposure index of welding fume in the majority of surveyed workplaces/work processes: 52.6% in 2002 and 70.0% in 2006. Use of laboratory services and thus also the increase of measurement episodes was encouraged by series of legislative acts adopted since 2002 which regulate improving of work environment and risk prevention. High concentrations of welding fume in workplaces indicate of poor arrangement of work environment as well as high probability influence of welding fume and their components on the health of employees and ability of work safety specialists to notice the problematic workplaces in the enterprise when making the work environment risk assessment.

In order to assess the impact of chemical substances' exposure and possible health risks, the analysis of biological samples are used by determining the concentration of received substances in bio-environments (blood, saliva, hair, urine etc.) or discovering the functional changes caused by the substances. It is possible to assess the potential health risk by determining metal levels in blood for occupational exposed groups and comparing them to references levels (Lauwerys, 1991; Knudsen & Hansen, 2007; Baķe, 2008; Jēkabsone *et al.*, 2008; Klaassen, 2008).

Within the framework of study the measurements of manganese, chromium, copper and cadmium levels in blood for occupational exposed persons (welders) and occupational unexposed persons (electricians) were performed. Electricians and welders are employed in the same enterprises but the first are not subjected to the influence of welding fume and metals it contains, they have equal social environment and no differences in nourishment are observed. If compared to electrician group, the welder group shows higher level of manganese ($p<0.001$), cadmium ($p<0.01$) and zinc ($p<0.001$) in blood, while level of copper ($p<0.001$) in blood is significantly lower.

No significant impact of length of service and age on the levels of metals in blood for both groups was established during the analysis of study data.

In compliance with principles of chemical risk assessment, the allowable concentration of cadmium in blood (biological exposure index – BEI) for occupational exposed persons is 5 µg/l. The average concentration of cadmium for participants of research does not exceed the reference level in blood. Obtained results show that the concentration of cadmium in welder group is 1.06 µg/l (95% CI 0.72 – 1.54 µg/l) and 0.60 µg/l (95% CI 0.40 – 1.01 µg/l) for electrician group, statistically valid difference ($p<0.01$) is observed between both groups. Since there are more smokers in welder group consequently higher level of cadmium is observed in blood. Comparing both groups regarding the smoking habit, the level of cadmium in blood of former smokers and non-smokers does not differ while smoking welders have higher level of cadmium in blood than non-smoking electricians.

The established level of manganese in blood of persons exposed in work environment is 21.20 µg/l (95% CI 18.40 – 24.10) and it is with higher statistical validity (z=2,88; p<0,01) than that of the control group 17.00 µg/l (95% CI 15.63 – 19.00). Interval of manganese levels for exposed group varies from 2.70 µg/l to 57.20 µg/l while for unexposed group it varies from 1.80 µg/l to 31.60 µg/l. Comparing the obtained results with the works of other authors (Lauwerys, 1991; Barceloux, 1999) it must be concluded that the recommended levels of manganese in blood for unexposed population are lower than the levels found in our study for electrician (unexposed) group. Normal level of manganese in blood for unexposed persons, as indicated in the study of D. Barceloux, varies from 4 to 15 µg/l (Barceloux, 1999). R.Lauwerys in his turn recommends when assessing the manganese compound in occupational exposure risk to consider less than 10 µg/l as normal manganese level in blood while consider 10 µg/l concentration as biological exposure limit value (maximum allowed level) (Lauwerys, 1991). It must be noted that in study by M.Ā Baķe et al. (Bake, 1998) on metal levels in bio-environments in Latvia, the concentration of manganese for unexposed group (n = 295) was 15.60 ± 5.00 µg/l which is higher than in the studies of foreign authors and lower than the recommended biological exposure index for manganese in blood - 20 µg/l as recommended in Germany (DFG, 2003).

One of hypothetically probable causes of increased level of manganese for control (electrician) group if compared to the unexposed persons from other countries (USA, Denmark, Brazil, Italy) could be higher concentration of iron and accordingly manganese in natural water sources of Latvia. In order to refute or confirm this statement more profound examination of environmental impact on Latvian population is required.

No differences are observed in the levels of manganese for electrician group regarding the smoking habit. It means that smoking does not influence the level of manganese in blood. Similar results are obtained in study by Kristiansen et al. (Kristiansen *et al.*, 1997). Former smokers and smokers in welder group show higher level of manganese than non-smoking welders. One of possible explanations for observed slightly higher level of manganese in blood among smoking welders could be violation of hygiene requirements in workplace. It is possible that particles of welding fume reach the mouth when smoking with dirty hands and further they get in digestive tract and are absorbed into organism. The second version states that substances of cigarette smoke facilitate the increased absorption of manganese compounds through the respiratory tract creating synergy effect. Both versions are only conjectures requiring further research.

For welder group, median for copper (Cu) concentration in blood is 0.71 mg/l (95% CI 0.66 – 0.75) and 0.99 mg/l (95% CI 0.86 – 1.11) for electrician group. Processing the results by means of Mann-Whitney U test, statistically valid difference ($z = 4.23$; $p < 0.001$) is observed between groups. The level of copper in blood for unexposed population as found in study by Minoia et al. is 0.807 – 1.643 mg/l (Minoia *et al.*, 1990) is close to the level found in our study in blood of electricians. Level of copper in welder group, however, is significantly lower if compared to electrician group and what is written in literature source; it indicates of probable copper deficiency.

Results of study by Suliburska et al. verified statistically lower copper concentration in blood serum for smokers (Suliburska *et al.*, 2007). Also in our study lower copper concentrations in blood respectively for smoking welders (0.69 mg/l (95% CI 0.64 – 0.75 mg/l)) and smoking electricians (0.87 mg/l (95% CI 0.69 – 1.06 mg/l) is observed when determining the copper concentration in full blood for smokers of both groups. Although no statistically valid difference is observed in relating the obtained results of concentrations against the non-smokers or former smokers of the respective group nevertheless the obtained results confirm the probable influence of smoking on copper concentration in blood. It is important to note that even though copper concentration in blood for control (electrician) group smokers is lower than non-smokers and former smokers, yet it is not lower than reference level, while copper concentration in blood for welders – both non-smokers and former smokers and smokers – is lower than reference level that indicates at possible copper deficiency caused by pollution in work environment air. Since copper deficiency is seldom observed for people, additional research must be done, as indicated also in works of other authors (Hinks *et al.*, 1983; WHO, 1998a; Liu *et al.*, 2008) by determining the amount of copper in serum and urine and also the concentration of ceruloplasmin in blood and activity of copper-dependent ferments.

For exposed group, median for zinc (Zn) concentration in blood is 6.90 mg/l (95% CI 6.51 – 7.39), but for control group – 6.20 mg/l (95% CI 5.82 – 6.60). Processing the obtained results by means of Mann-Whitney U test a statistically valid difference ($z = 3.78$; $p < 0.001$) is observed between groups. Zinc level for the exposed group is considerably higher. In the study by Minoia et al. the found level of zinc in full blood for unexposed population is 6.340 ± 0.210 mg/l (interval: 4.076 – 7.594 mg/l) (Minoia *et al.*, 1990) which is close to the level in blood of electricians found in our study and also zinc level in the blood of welders falls within the interval of reference concentrations.

Zn/Cu correlation is pollution-sensitive index in organism, normally in hair and full blood it must be 6:1. In blood of electricians the correlation of Zn/Cu is close to the recommended, namely, 5.6:1 but in the blood of welders – 9.5:1. From the results described above, we can see that the level of zinc in organism stays in norm and we can conclude that the welders' organisms have reduced amount of copper. Zn and Cu are crucial elements for organism and their proper correlation is important for ensuring various biochemical processes. Along with changes in normal levels of metals in organism the health disorder risks increases (Telišman *et al.*, 2001; Pizent *et al.*, 2008).

It is indicated in literature sources that long-term zinc exposure with lower doses causes symptoms which are related to reduced copper intake from food, reduced amount of erythrocytes (Liu *et al.*, 2008). Unfortunately the results of our study cannot either deny or confirm this fact, because laboratory according to the request of employers measure zinc concentration in work environment air no more than few times a year. For solving this problem further new studies are necessary since welders use several welding methods and weld different metal alloys which can contain also zinc. Therefore hypothetically it is possible that in the work environment air they are subjected to long-term, low zinc doses.

Many variations are possible about interaction of metals and their mutual influence when basing only on determination of metals in full blood. In form of ions, metals can be very reactive and they can influence biological systems in very different ways. Nevertheless organism cells contain many ligands which bind metals. In order to evaluate if metal ion can bring about any toxic impact, it is necessary to determine not only the concentration of the very metal in bio-environments, but also the amount of respective ligand in cell. Toxic metals can arrive at many vital metal-aided cell functions by using the mutual similarity (valence, nucleus size, reactivity) with metals supporting life functions and inhibit them. It is obvious that the ingredients (various metal compounds) of welding fume existing in welders' work environment air have favoured the changes in metal levels existing in blood.

Welders in the work environment are subjected to the influence of metals and harmful gases contained in the welding fume. It is known that the primary impact on organism manifest as various respiratory diseases while question whether welding fume's impact through respiratory tract causes any oxidative mechanism damage in organism remains controversial. Determining Cu, Zn-superoxide dismutase (Cu,Zn-SOD), catalase (CAT), glutathione peroxidase (*GPx*), reduced glutathione and total level of antioxidants as well as plasma hemiluminiscence (HLC) in blood of welders and electricians, welder group showed higher Cu, Zn – SOD and CAT and GPx levels in blood, nevertheless in none of determined indices between groups a statistically valid difference was found. In Spearman's range correlation test a positive weak (r=0.318), statistically valid ($p<0.001$) correlation was found between the amount of lipid peroxide and level of manganese in blood for welder goup; it means that with the increased manganese concentration in organism, increase of the amount of lipid peroxide or "oxidative stres" can be observed. Such correlations are not observed in the electrician group.

In data analysis by means of Spearman's range correlation test a positive, averagely close (r=0.460), statistically valid ($p<0.001$) correlation was found between the amount of lipid peroxide and level of cadmium in blood in welder group, while in electrician group a negative, averagely close (r=-0.404), statistically valid ($p<0.01$) correlation was found between the amount of lipid peroxide and level of cadmium in blood. So, it is known that the main source of cadmium in organism is smoking and intake with food; for electrician group which are not subjected to the welding fume, amount of lipid peroxide reduces along with the increase of cadmium concentration in blood and probably the reduction of oxidative stress can be actively ensured by primary antioxidants already existing in organism. In welder group an averagely close correlation with cadmium and weak ($r=0.318$) statistically valid ($p<0.01$) correlation with manganese was found for the amount of lipid peroxide in organism. In organism of welders, between both metals weak ($r=0.245$) and statistically valid correlation ($p<0.05$) is also observed. It means that the oxidative stress for welders increase along with the amount of manganese and cadmium in organism. Elaborating more on this idea, I can put forward a hypothesis that probably the weding fume and smoking have synergetic influence.

These altered levels of metals in blood of welders and correlation between the level of manganese in blood and amount of lipid peroxide testifies the impact of work air pollution on the health of employed. It is important to remember that a considerable part of welding fume is formed by small disperse particles with size less than 100 nm, therefore they can easily enter the lower respiratory organs and are absorbed in organism as a consequence of phagocytosis. Since materials used for the welding contain also alkali metals (K, Na) and halogens (F, Cl), part of compounds which has formed during the process of welding is well soluble and it makes these small particles easier to absorb.

The monitoring of metal levels in welders' organism in our country is not a common practice even though Regulation of the Cabinet of Ministers No. 325/2007 "Work Safety Requirements when Working with Chemical Substances" (adopted on 15.05.2007, published in *Latvijas Vēstnesis*, 18.05.2007) stipulate the biological exposure indices for such metals as lead, chromium, cadmium. In my opinion it poses several problems, namely, there is no single understanding regarding the necessity of bio-monitoring; employers and employees are poorly informed about the possibilities to perform measurements of metals in bio-environments; there are fears of the unknown; correct interpretation of results obtained in bio-monitoring, because there are very many unexplained issues regarding the correlations of metals in organism in general and separately in each of the bio-environments.

Welding fume and metals contained in it can cause considerable health disorders: worsening of lung functions, cough, short breath, rhinitis, chronic bronchitis, asthma, pneumonia, siderosis, fibrosis, pneumoconiosis, lung carcinoma, central nervous system disorders, manganism, Parkinson's disease, cataract, erythrema, skin tumours, malignant melanoma. Besides the above mentioned diseases, welders are also subjected to eye irritation, skin itch, movement disorders and infertility, men have a reduced amount of spermatozoids (Eglīte, 2000; Antonini, 2003).

In the framework of study we surveyed welders and office workers (control group) regarding the existing or former diseases and obtained results show that persons involved in welding if compared to the control group, more frequently have chronic upper-respiratory tract and bronchial diseases, digestive tract disorders and rheumatic illnesses; differences are statistically valid.

According to the data from Latvian State Register of Occupational Disease Patients and register of persons exposed to radiation after Chernobyl NPP accident, mainly in Latvia such chronic occupational disease forms are found that has developed in a long-term. The most frequent pathology among occupational diseases for welders is chronic diseases of respiratory organs. According to yet unpublished registry data, the number of chronic obstructive pulmonary diseases and upper-respiratory organ chronic inflammatory diseases diagnosed in 2009 has doubled if compared to data from 2005. It is possible that disclosing of diseases were encouraged by the Regulation of the Cabinet of Ministers No. 219/2009 "Procedure of Undergoing Compulsory Health Checks" (adopted on 10.03.2009, published in *Latvijas Vēstnesis*, 13.03.2009) which requires in the framework of compulsory health checks the assessment of external respiratory system if there is a contact with welding fume in the work place.

Besides during the economic recession many people lose their jobs therefore welders who have become unemployed and show significant health problems address specialists to get an occupational disease diagnosis and receive compensation for the lost operational capacity thus slightly alleviating their social condition.

A separate occupational disease group consists of nervous system disorders caused by the welding fume. Within the period from 1993 to 2005, 26 toxic polyneuropathy cases and 11 encephalopathy cases were diagnosed for welders. It is difficult to compare the obtained results with other industries and foreign data because they are provided in absolute numbers. In 2009, 5 polyneuropathy cases and 3 encephalopathy cases were diagnosed, in comparison to the period from 1993 to 2005 when there were on average 2 polyneuropathy cases and 0.8 encephalopathy cases per year. The increase of diagnosed occupational diseases is obvious.

One aspect indicating of existence and increase of occupational diseases is high concentrations of welding fume and their ingredients in the air of work environment, however it must be admitted that employees become better informed about the risk factors in workplace and signs of occupational diseases; increasingly more employees receive the information about the possibilities to get financial aid in case of occupational disease. Number of occupational disease physicians has grown and so have the knowledge of physicians (for instance, the training course for occupational disease physicians were increased from 50 hours in 1998 to 550 hours in 2009).

Since 2009 Regulation of the Cabinet of Ministers No. 219/2009 "Procedure of Undergoing Compulsory Health Checks" (adopted on 10.03.2009, published in *Latvijas Vēstnesis*, 13.03.2009) has entered into force which stipulate the frequency of compulsory health checks depending on the risk factor and its exposure level in the workplace.

Welders in the work environment are exposed to manganese and laboratory analysis for work environment air quality show that in approximately 40% from performed measurements the exposure index is larger than 1 and it means that occupational disease limit value is exceeded.

Manganese toxicity impact nervous system therefore under long-term exposure to increased doses of manganese serious neurological diseases may develop. When undergoing compulsory health checks employee is not always honest with specialist and possibly does not speak of some early symptoms; this assumption could be supported by the large number of chronic diseases in Occupational Disease Registry. In Germany, Sweden, Denmark and other countries, prior to health check subjective questionnaires are filled in order to find out probable neurological symptoms; one of them is questionnaire for determining neurological symptoms Q16 (Sjögren *et al.*, 1990; Edling *et al.*, 1993; Chouanière *et al.*, 1997; Kiesswetter *et al.*, 1997; Lundberg *et al.*, 1997; Eglīte, 2000; Ihrig *et al.*, 2001). There is no limit value for the number of certain positive answers when examining the questionnaire after which respondents could be divided into "ill" and "healthy"; similarly to Sjögren et al., in the framework of our study we included those persons who provided three or more positive answers in the "group with endangered health condition" (Sjögren *et al.*, 1990). This questionnaire could be used for survey of employees before undergoing compulsory health check. Suitability of survey is supported by the fact that in the welder group three or more positive (confirmative) answers were observed for 34.9% respondents and 21.4% in control group with statistically valid difference ($\chi^2 = 9.92$; $p< 0.01$) among both groups and average (r=0.446) correlation was obtained also between the frequency of neurological symptoms and exposure time.

Total frequency of neurological symptoms for welder group has higher statistical validity than for control group (OR = 1.91; 95% CI = 1.51 – 2.41; $p<0.001$). Welders in comparison with control group complain more often about poor memory, problems with understanding the message written in journals and newspapers, agitation without any obvious reason, difficulties in doing and undoing buttons and among these symptoms there are statistically valid differences if compared to control group. There can be a discussion about the credibility of answers provided by the employees, but according to the remark from the group of American researchers (Bowler *et al.*, 2007a; Bowler *et al.*, 2007b) a relatively high prevalence is observed between the results of subjective survey and changes in health condition diagnosed during the check at neurologist. In study by Bowler et al. 90.9% out of 62 welders reported the presence of tremor while during the neurological check 72.7% were acknowledged to have light forms of disease but 27.3% - average or bad tremor; bradikinesia was mentioned by 72.7% while neurological diagnosis was set to 81.8%; 90.9% of welders indicated depression while in terms of medical diagnosis a light form was found to 18.2%, but average or heavy depression to 63.6% (81.8% in total).

Current legislation determines the frequency of compulsory health checks depending on the chemical substance exposure index at workplace, however, as noted by many researchers (Racette *et al.*, 2001; Park *et al.*, 2006; Bowler *et al.*, 2007a; Bowler *et al.*, 2007b; Ellingsen *et al.*, 2008; Flynn & Susi, 2009), the correlation of toxic manifestation of manganese and concentration of manganese in the work environment is not sufficiently researched and there is no interconnection between the received dose and diagnosed neurological changes.

According to the results of this study, we recommend to determine the level of manganese in blood when performing the compulsory health checks for welders if exposure index (EI) for welding fume and manganese in the air of the work environment air is larger than or equal to 0.75. The recommended biological exposure index is 15 µg/l.

Conclusions

1. Summing up the scientific literature about the impact of metals contained in the welding fume on the health of welders, more attention in foreign authors' work is paid to the probable impact of individual metals and mutual alterations and their causes are analyzed little.
2. Study summarizes wide information about the work environment air measurements in Latvian enterprises during the welding work which allows evaluating the situation in the work environment. Work conditions in places of work execution within the period of study can be estimated as critical.
3. Analyzing and gathering information within the framework of several enterprises or workplaces, it is more precise to use median values and concentration intervals instead of arithmetic mean values and their standard deviations for description of obtained results. Using average values in result presentations due to certain poorly arranged workplaces the situation in general is dramatized in the whole industry.
4. Concentrations of manganese, cadmium, zinc in blood of welders have higher statistical validity than for the electrician (control) group, while level of copper in blood is statistically lower. It must be noted that copper concentration is lower not only in comparison to the control group but also to the reference levels of other countries and indicates of probable clinical changes in organism. Results of study indicate of considerable impact of the work environment air on the mutual balance of metals existing in organism.
5. No significant age impact on manganese, chromium, copper and zinc levels in blood for welder and electrician groups were found in the study while trend to have higher level of cadmium in blood for younger participants having also larger number of smokers was established.
6. Statistically valid higher concentration of cadmium in blood for smoking welders and electricians was established if compared to non-smokers of these groups. Trend of reduced copper concentration in blood was observed for smokers in the electrician group while impact of smoking on copper level in welder group was not observed.
7. Copper concentration in blood of welders is clinically low; in order to find a cause for the reduced concentration in welder group additional research is necessary by determining copper concentration in cells and in ceruloplasmin serum.
8. It is possible that the welding fume exposition can cause synergistic effect of manganese and cadmium in organisms; it can be judged from

the weak (r=0.245) statistically valid ($p<0.05$) correlation between the level of manganese and cadmium in the blood of welders.

9. Welders have higher level of oxidative stress parameters in blood than electricians and they have chronic upper-respiratory tract diseases and bronchial diseases ($p<0.05$), digestive tract diseases ($p<0.01$) and rheumatic diseases ($p<0.05$) more often than the office workers.
10. Longer exposure time to welding fume (work hours) for welders increase the number of neurological symptoms (complaints); it is supported by the average (r=0.446), statistically valid ($p<0.01$) correlation.
11. Impact of welding fume and metals it contains in the work environment on the health of welders is demonstrated by statistically valid ($p<0.001$) higher total frequency of neurological symptoms (OR = 1.91; 95% CI 1.51 – 2.41) if compared to office workers.
12. Subjective questionnaire of neurological symptoms Q16 is suitable tool for the assessment of the impact of harmful chemical substances in work environment air, it can be used as aid for work environment risk assessors or in physician practice, preparing the documentation for the compulsory health checks.
13. It is possible to have an early assessment of work environment impact on organism of employee when using monitoring of metals and complex of biological indices.

Practical recommendations

In order to improve the work conditions and reduce the risk of occupational diseases development and also to encourage the diagnosis of occupational diseases early symptoms for persons involved in the welding work it is recommended to:

1. Introduce a comprehensive work condition control and monitoring system (equipment examination and maintenance, cleaning of ventilation systems and efficiency tests etc.)
2. Perform the work environment risk assessment on a regular basis, with a special emphasis on the most often used welding type or type of welding metal in each welding workplace or position. For manual electric arc welding it would be advisable to indicate the label of electrodes in use.
3. Determine the concentrations of welding fume and metals it contains in the work environment air. For instance, when welding stainless steel, it is advisable to determine manganese, chromium and nickel in the work environment air, but when welding steel with low carbon content – manganese and nickel, and in case of use of electrodes – the most important ingredients.
4. Ensure environment in compliance with the work safety requirements, with a special emphasis on reduction of concentrations of welding fume and manganese (by providing sufficiently effective airing). If necessary, to zone off the working place so that persons of other occupations, for instance, locksmiths or lathe operators who are often working alongside, are not subjected to the welding fume and metals it contains.
5. Introduce the latest generation individual protective means – welding masks with “chameleon” protective glass and fresh air supply option.
6. For the purpose of health monitoring of employees, to perform welders’ screening by using Q16 questionnaires before compulsory health checks so that the occupational disease physicians receive more information about the health condition of employee.
7. During the compulsory health checks for welders to determine the level of manganese in blood if welding fume and manganese exposure index (EI) in the work environment air is larger or equals to 0.75. Recommended biological exposure index is 15 µg/l.
8. Elaborate a body of lectures and seminars for education of employees and work safety specialists regarding the impact of chemical risk factor in the existing work environment during welding processes on health and possible measures of its reduction.

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TESTIMONIAL

Author of the study extends gratitude to all who were involved in the research, especially to:

1. The supervisor of my paper, docent Dr. med. Mārīte Ārija Baķe, for valuable advises in summarizing results and preparation of doctoral paper;
2. I extend my gratitude to the scientific advisor of the paper, Riga Stradins University, Head of Occupational and Environmental medicine Department, professor Dr. habil. med. Maija Eglīte for consultations and support in preparing doctoral paper;
3. I extend my gratitude to the scientific advisor of the paper, Riga Stradins University, Head of Biochemistry Laboratory, Associated Professor Dr. biol. Andrejs Šķesters for consultations and valuable advises in processing biochemical results;
4. I extend my gratitude to Riga Stradins University, Associated Professor of Occupational and Environmental Medicine Department Dr. chem. Jānis Dundurs for valuable advises and critical remarks in the preparation of doctoral paper;
5. I extend my gratitude to the administration of Riga Stradins University, Doctoral Programme Department for aid during doctoral studies, support and consultations as well as opportunity to receive ESF and RSU scientific degree applicant scholarship;
6. I extend my gratitude to the heads of all enterprises involved in my research, work safety specialists and employees for the interest, responsiveness and consent to participate in the project. Special gratitude to Maris Grūtups and Juris Kaņepe;
7. I extend my gratitude to the collective of Riga Stradins University Institute of Occupational Safety and Environmental Health Hygiene and Occupational Disease Laboratory and collective of Riga Stradins University Biochemistry Laboratory for understanding, cooperation and responsiveness. Special gratitude to Mairita Zellāne.
8. I extend my gratitude to my relatives and family, especially to my husband and children for tolerance, understanding and love.