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Prevention the impact of chemicals on the health of workers in fibreglass industry

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Abstract. Most of the chemicals make our everyday life easier and safer. However, there are a lot of new emerging risks connected with chemicals causing damage to people's health and environment. The results of the investigation: the chemical exposure index (EI) is between 0.16 to 25.98 (the last determined by the mould spray-up, outside of the protective masks). The air pollution index determined was between 16 to 760%. The ventilation rates for the remove of the volatiles from the workplace air are settled, the possibilities for substitution of hazardous chemicals to less hazardous are presented. When the concentration of a volatile is measured under the protective mask, which has a new filter, the tested substance concentration is lower that under the mask with an old filter, although the differences between these two were rather small. When the volatiles were measured under the protective mask, the concentrations of tested substances met the requirements.

Key words: chemicals' hazardousness, health risks, solvents, substitution.

INTRODUCTION

Increasing human consumption is accompanied by growing risk that the chemicals can cause to human health and the environment, so it is important that production and use of chemicals is managed with a proper responsibility (Latvian Free Trade Union, 2010).

To prevent the impact of chemicals on the health of workers, measures should be taken to reduce their concentration and exposure time in the work environment. On the other hand, the chemical can enter the lungs if it is in the dispersed state in the air. The source of the substance could be the equipment or device from where the chemical can be spread into the surrounding work environment. When chemicals are in the spread form in the work environment air, they may enter the employee's breathing area and from there get into his lungs (Samet & Spengler, 2003; Raaschou-Nielsen et al., 2013).

Factors of the working environment or working process, which adversely affect the body of workers and as a result of prolonged, intense exposure cause diseases, are called the harmful occupational factors (Latvian Association of Occupational Physicians, 2016).

Harmful occupational factors are commonly associated with:

- manufacturing process, technology and equipment (industrial dust, toxic chemical and radioactive substances, ionizing radiation, noise, vibration, high or low atmospheric pressure, increased or reduced temperature, electromagnetic radiation etc.);
- work process, its organization, intensity and duration (tension of nervous system, vision, hearing, voice, frequent repetitive movements, straining of certain group of muscles, prolonged forced body position etc. (Hakkola et al., 1997; Valavanidis et al., 2008).

Due to diversity and originality of occupational risk factors, their various combinations and effects on the body, a specific clinical structure of occupational diseases has formed. Polytrophic effect characteristics to the majority of harmful occupational factors result in the frequent formation of the visceral, neurological and other poly-syndrome abnormalities, which in specific combinations acquire a certain specificity (State of the Art Report, 2009). The aim of the study is to determine the influence of fiberglass particles on the workers' health in the Latvian companies and to compare the results with the other countries similar production areas air atmosphere.

The study objects in the company are the chemical risk factors, but the study subject is the reduction of chemical risk factors' effect on the workers' health at the fibreglass products manufacturing company.

THEORETICAL BASIS

Fiberglass production volumes in Europe continued a steady growth in 2015. Their output has reached 1,069 megatons, the highest level for eight years. This development is largely dependent on the economic trends in Europe in general. Fibreglass products are mainly used in transport and construction; therefore, the fiberglass products output volumes are dependent on the development trends in these industries. The last development in recent years in Europe, the output volumes of fibreglass products grow as well. The European fibreglass production is growing more slowly than generally in the world (Global, 2011).

Table 1 shows that the amount of fibreglass products annually manufactured in European countries is almost unchanged. The biggest changes have been observed in the Eastern Europe (where Latvia is also situated), which is associated with a higher number of countries here (Latvian Fiberglass, 2014; EUCIA, 2015).

The company is a fibreglass products manufacturing enterprise that started its activities in Latvia in 1996. Production is exported to Norway. The company annually produces up to 700 tons of fibreglass; in 2015 the output was 580 tons. The main raw materials are fibreglass fabric, resin, paint and hardener. The company has implemented the integrated quality management system – ISO 9001, ISO 14001 and OHSAS 18001. The company holds the B Category polluting activities permit. Fiberglass products are manufactured in three workshops of the company with use of three production technologies.

1) Manual technology: glass fibre and adhesives are applied on the product mould; the air is removed from the glass fibre by means of metal rollers. By means of manual lamination the company develops products where the product thickness and weight are

important, and which can be very well controlled when gluing the product with by manual lamination.

2) Vacuum technology: glass fibre is applied on the product mould at the required thickness, then the film is applied and the glue is sucked into the product by vacuum. This technology allows to obtain a very thin and lightweight, but durable product.

3) Spray-up plant by means of spraying technology produces roofs and engine covers of open-pit truck, ship safety equipment – accessory cabinets, life jackets storage boxes, battery boxes, fibreglass mini-golf courses, figures and leisure baths; water purification equipment. Spraying technology: glue together with glass fibre is applied by spraying with subsequent rolling and squeezing the air out of the glass fibre. This method speeds up the production laminating processes, but is not applicable to all types of products. In manufacture of certain products it is much more economical to use this spray-up method, since the manual gluing cannot provide such application rate as with the spray-up method.

Table 1. Fibreglass products in European countries (kilotons) (EUCIA, 2015)

	2012	2013	2014	2015
Great Britain, Ireland	134	140	146	150
Belgium, Netherlands, Luxembourg	43	42	43	44
Finland, Norway, Sweden, Denmark	44	44	42	39
Spain, Portugal	160	152	154	156
Italy	152	146	148	150
France	117	112	108	108
Germany	182	192	200	212
Austria, Switzerland	17	17	18	18
Eastern Europe (Poland, Czech Republic, Hungary, Macedonia, Latvia, Lithuania, Slovakia and Slovenia etc.)	161	175	184	192
Total, megatons:	1,010	1,020	1,043	1,069

Styrene emission at workplace changes depending on the production process (Stockton & Kuo, 1990). Manual technology and spray-up technologies are open type processes while vacuum technology is a process of closed moulds. Styrene emission into air in vacuum technology is only 2% compared to 94% in open mould technology. With vacuum technology, resin is introduced into the product under the film, therefore styrene does not evolve into the air (Kalkis, 2001).

Styrene emissions in Europe

When using unsaturated polyester resins, employees are potentially exposed to styrene effect. In all European countries the employer is responsible for the control of hazardous substances at the workplace and ensuring the observance of occupational exposure limits (OEL) established by competent national authorities. Table 2 provides an overview of styrene OEL across Europe. Styrene vapour concentration is shown in parts per million (ppm). Short term OEL is the maximum allowed value within a short period, usually 15 minutes. Some countries have high values, which may not be exceeded in any case.

Table 2. Overview of styrene occupational exposure limits in Europe (International Labour Organization, 2016)

State	OEL 8 h, part per million (ppm)	Short term OEL, part per million (ppm)
Belgium	50	100 (15 min)
Denmark	-	25*
Estonia	20	50
Finland	20	100 (15 min)
France	50	-
Germany	20	40 (30min)
Latvia	2,4	7
Lithuania	20	50
Netherlands	25	50 (15 min)
Norway	25	37.5 (15 min)
Poland	12	47
Sweden	20**	50 (15 min)
Switzerland	20	40 (4 x 10 min)
England	100***	250 (15 min)

As shown in Table 2, Latvian occupational exposure limit is the lowest in Europe, which is due to the fact that Latvian chemical industry is highly developed and this threshold is trying to limit the chemical industry. As shown, the highest occupational exposure limit value is in England, the reason being that chemical industry is not developed in this country. Value adopted in Europe when determining the styrene concentration in the air is parts per million – ppm. To convert mg m^{-3} into ppm, formula 1 is used:

$$\mathrm{PPM} = \frac{mg}{\mathrm{m}^3} \cdot \frac{\frac{g}{mol}}{L}, \tag{1}$$

where PPM – parts per million; g mol^{-1} – hazardous molar mass of substance; L – molar volume.

Air pollution index

Latvian University offers a simplified chemical risk assessment matrix based on the Air quality index (GPI) determination, taking into account the concentration of chemicals in working environment, *OEL* values, risk phrases, and determines the necessary preventive measures (Kalkis, 2001).

GPI is determined by formula:

$$\mathrm{GPI} = \frac{\left(\frac{c}{OEL}\right) \cdot t}{8} \cdot 100\% \tag{2}$$

where C – chemical concentration in working environment air (mg m^{-3} or ppm); *OEL* – occupational exposure limit for 8 workday hours (mg m^{-3} or ppm); t – time of workers' exposure to chemicals, *h*; GPI – value determining % concentration of chemicals in working environment air within time of workers' exposure to chemicals (Kalkis, 2001).

Chemical concentration measurements frequency is determined according to the chemical exposure index obtained by dividing the concentration of a chemical (occupational exposure concentration) in working environment air by the occupational exposure limit (*OEL*):

$$EI = \frac{C}{OEL}, \quad (3)$$

where EI – chemical exposure index; C – chemical concentration (occupational exposure concentration) in working environment air.

Substitution of chemicals for less hazardous substances

In order to reduce the workers' exposure of chemicals, it is necessary to consider whether the chemicals can be replaced with less harmful substances. One of the changes in the production process, which can provide the desired result, is substitution of a dangerous chemical for other, less hazardous (harmful). This particularly applies to consumables, such as solvents. Such possibilities are usually objected, referring that the potential substitutes usually do not exist, but if they do, then they are much more expensive. However, it should be tried to find any opportunity to replace hazardous chemicals with less hazardous ones (Hazardous, 2001; Oosterhuis, 2006).

Often these alternatives, less harmful chemicals, cannot be used throughout the process, but they can be used in some phases of the technological process (Bake et al., 2010; Tint et al., 2015; OSHA, 2016).

MATERIAL AND METHODS

The air quality assessing method was gas chromatography. As the measuring instrument for determination of styrene concentration in the air, gas chromatograph SHIMADZU 2010 was used. The air samples were taken with the syringe by the Pumped sampling method described in the ISO 16200-1:2001 'Workplace air quality – Sampling and analysis of volatile organic compounds by solvent desorption/gas chromatography – Part 1', method code 4.3 (ISO 16200-1:2001). The measurements errors range from 6.7 to 7.6%. The experiments were carried out in three (3) enterprises producing and manufacturing the fiberglass during different production procedures. The concentration of chemicals was measured under protective masks with filters; out of the protective masks, during gluing, colouring, spraying-up and packing. Measurements were made within the worker's breathing area outside and inside of the mask.

One of the methods for cleaning the workplace air is ventilation. Ventilation systems performance is characterized by the air exchange coefficient K, that is, the ratio between the discharged air amount and the ventilated space volume:

$$K = \frac{W}{V_t}, \quad (4)$$

where W – discharged air amount, $m^3 h^{-1}$; V_t – premise volume, m^3.

RESULTS

In this part the results of measurements of chemicals in the work environment, the substitution possibilities of the hazardous chemicals to less hazardous, the effectiveness of using the personal protective equipment and the ventilation of the rooms as one of the main means for cleaning the workplace air.

Table 3 shows air pollution indexes in production shops both under and outside the protective masks. Outside the protective masks at the workplace in all production shops in accordance with the chemical risk assessment matrix intolerable risk V (GPI – 200%) was established.

Table 3. Air pollution index at the enterprise (GPI)

No.	Production shop (PS), works performed	t, h	C, mg m^{-3}	GPI, %
1.	PS 1, mould gluing, under protective masks with filters	3 h	4.4	17%
2.	PS 1, mould gluing, out of protective masks	3 h	129.9	487%
3.	PS 2, mould gluing, under protective masks with filters	4 h	6.4	32%
4.	PS 2, mould gluing, out of protective masks	4 h	151.6	760%
5.	PS 3, mould colouring, under protective masks with filters	3 h	8.8	33%
6.	PS 3, mould colouring, out of protective masks	3 h	216.5	812%
7.	PS 3, mould spry-up, under protective masks with filters	3 h	7.7	29%
8.	PS 3, mould spry-up, out of protective masks	3 h	259.8	259.8
9.	PS 3, packing, out of protective masks	2 h	45.0	113

Respiratory protection half-mask air purifying respirators with organic vapour cartridges and particulate filter P100 were used. Necessary measures: work with chemicals should be stopped immediately until the fulfilment of necessary measures ensuring the prevention of air pollution is guaranteed.

Calculating the exposure index (Table 4), it is evident that the company's employees must be sent to mandatory periodic health checks annually as well as that the company should carry out periodic measurements every 16 weeks.

Table 4. Chemical exposure index (EI)

No.	Production shop (PS), works performed	t, h	C, mg m^{-3}	EI
1.	PS 1, mould gluing, under protective masks with filters	3 h	4.4	0.17
2.	PS 1, mould gluing, under protective masks with filters	3 h	4.2	0.16
3.	PS 2, mould gluing, under protective masks with filters	4 h	6.4	0.32
4.	PS 2, mould gluing, out of protective masks	4 h	151.6	7.60
5.	PS 3, mould colouring, under protective masks with filters	3 h	8.8	0.33
6.	PS 3, mould colouring, out of protective masks	3 h	216.5	8.12
7.	PS 3, mould spry-up, under protective masks with filters	3 h	7.7	0.29
8.	PS 3, mould spry-up, out of protective masks	3 h	259.8	25.98
9.	PS 3, packing, out of protective masks	2 h	45.0	1.13

The air quality measuring method was a gas chromatography. The measuring instruments of styrene concentration in air were the chromatography SHIMADZU 2010. The measurements errors range – 6.7–7.6%.

The concentratilons of tested substances, measured under the protective mask, meet the requirements. If an employee uses the protective mask with a new filter, the tested substance concentration is even lower than OEL.

Checking the styrene and acetone concentrations, it was found that the styrene concentration exceeds the occupational exposure limit value (making measurements within the worker's breathing area outside at the mask). When measuring under the protective mask, the concentrations of tested substances meet the requirements. In general at the enterprise, the styrene occupational exposure concentrations in the working environment outside the mask significantly exceed the allowable norm. The highest occupational exposure concentration is with the spray-up operator and painter as at these workplaces chemicals are applied by spraying.

The results on the substitution possibilities of chemicals are presented in Table 5.

According to Table 5, almost all solvents which the company could use for cleaning the tools are volatile and harmful to the health of workers. As a substitute for acetone, the company can use the acetone substitute 'GRP Multi Cleaner', which is not classified as a hazardous substance and is a solvent, less harmful to the environment and workers.

Table 5. Acetone substitutes (Safety Data Sheets: 'Solvent Acetone', 'Safety Data Sheet RS-2', 'Solvent Vaitsol', 'Solvent Turpentine', 'Solvent Solveks spirit', 'Solvent 646', 'Solvent 2290', 'Solvent 647', 'GRP Multi Cleaner')

No.	Name	Ingredients	Ingredient %	Boiling t°, C	H-sentences
1	Acetone			56.3	H36, H66, H67
2	Solvent RS-2				H10, H43, H65, H66, H67, H51/53
		White spirit	65	150–200	
		Solvent	30	140–200	
		Turpentine	5	162–174	
3	*Vaitsol* solvent				H10, H43, H65, H66, H67, H51/53
		White spirit	90–100	150–200	
		Turpentine	< 10	162–174	
4	Turpentine			162–174	H38, H43, H65
5	*Solvent* spirit				H20/21, H38
		Xylene	90–95	137–143	
		Acetone	5–10	55	
6	Solvent 646				H20/21, H38, H41
		Xylene	45–55	121–127	
		2-butoxyethanol	5–10	171	
		n-Butanol	5–15	118	
		Acetone	5–10	55	
		n-Buthylacetate	5–15	137–143	
		Ethanol	5–15	78	
7	Solvent 647				H20/21, H36/38, H66
		n-Butyl acetate	25–35	121–127	
		Ethyl acetate	20–25	70–95	
		n-Butanol	< 10	118	
		Xylene	40–45	137–143	
8	Solvent 2290				H10, H66, H67
		n-Butyl acetate	> = 99	124–128	
9	GRP Multi Cleaner			200–230	

'GRP Multi Cleaner' boiling point is 4 times higher than the boiling point of acetone. It means that this product is not volatile and will not vaporize and be present in the air of the workroom. Disadvantage of this substance is that it is oily and inconvenient for workers because after cleaning of tools they are slippery and it is not possible to work properly with them. Taking into consideration that 'GRP Multi Cleaner' is not a hazardous substance and does not vaporize the company needs to replace the existing solvent – acetone with 'GRP Multi Cleaner'.

The Styrene concentration measurements are presented in Table 6.

Table 6. Styrene concentration measurements

No.	Air sample taking place	Characteristic of production conditions	Measured substance	Concentration of OEC mg m^{-3} tests results	Concentration of OEC admit table norm mg m^{-3}
	Shop 1				
1	gluing in masks				
1.1.	gluing out of masks	measurements	Styrene	4.4 ± 0.5	10/30
	Shop 2				
2.	gluing in masks	gluing process	Styrene	129.9 ± 13.0	10/30
2.1.	gluing in masks	gluing process	Styrene	6.4 ± 0.6	10/30
2.2.	gluing out of masks	gluing process	Styrene	151.6 ± 15.2	10/30
3.	Shop 3				
3.1.	Painting in masks	Painting process	Styrene	8.8 ± 0.9	10/30
3.2.	Painting out of masks	Painting process	Styrene	216.5 ± 21.7	10/30
3.3.	Spraying – up in masks	Spraying – up process	Styrene	7.7 ± 0.8	10/30
3.4.	Spraying – up out of masks	Spraying – up process	Styrene	259.8 ± 26.08	10/30
3.5.	packing	Measurements performed only of masks out	Styrene	45.0 ± 4.5	10/30

The results show (see Table 6) that styrene concentration exceeds OEL when measurements are performed out of masks. The highest concentration of styrene is marked both in spraying – up and painting process. In order to reduce harmful usage of styrene it is advisable to substitute it by less poisonous substance, such as resin 'Aropol M60HTB' (styrene contains 37%; standard resin contains – 50% styrene) or 'Apolo M105TB' contains styrene 41%. These resins have low emission; nowadays enterprises have already substituted 50% of high styrene emission resin.

Ventilation improvements in production shops

The ventilation system in improve. As the conclusion from the previous analysis in all the production shops the air exchange and the existing ventilation system are not sufficient and need to be improved in order to the air exchange coefficient $K = 8.96\ h^{-1}$.

The worst situation is in the Production Shop No. 2. There is also the highest yearly output of products and manual technology is used. The best indicator, in its turn, is in the Production Shop No. 2 spray-up room, where the styrene concentration is found highest by the experiments. Ventilation air exchange coefficient is presented in Table7.

Table 7. Ventilation air exchange coefficient

Production place	Room's volume m^3	Local ventilation system with capacity m^3 h^{-1}	Air exchange coefficient h^{-1}	Air exchange coefficient required by the enterprise h^{-1}
Shop 1	2,300	10,000	10,000/2,300 = 4.35	20,603/2,300 = 8.96
Shop 2	5,300	10,000	10,000/5,300 = 1.89	47,480/5,300 = 8.96
Shop 3	1,700	10,000	10,000/1,700 = 5.88	15,220/1,700 = 8.96

DISCUSSION

The following improvement measures can be proposed:

1)Improvement of work equipment.

To reduce the concentration of styrene in production shops of the company, it is necessary to wider the use of the vacuum technology. At present time, the vacuum technology is only used for certain products, approximately only 10% of all manufactured products. Increasing the production by vacuum technology, the company will reduce the occupational exposure levels in the working environment. The analogous statements are given also by Hablanian, 1997).

In the vacuum technology, resin is sucked by vacuum, placing special tubes into the article and into a bucket with resin. The bucket is open, which means that the styrene from resin evaporates into the air. In order to reduce the concentration of styrene in the working environment, it is recommended to use buckets with lids. The company should substitute the existing buckets for buckets with holed lid, thus it is possible to reduce the concentration of styrene in the air (Vacuum, 2010).

2) Storage of personal protective equipment.

Personal protective equipment shall be provided with a special, dedicated for this purpose storage place, which must be clean and in working order. The EU legislation demands the same in the whole European workplace area (Regulation (EU) 2016/425; Council Directive 89/686/EEC).

3) Isolation of the work operations.

In certain cases when it is not possible, both, to reduce the concentration of a chemical and to shorten the exposure time, it is possible to try the method where the work operation, during which chemicals are released, is isolated. One of most effective and most common methods is isolation of such operations, which includes a potential pollution occurrence in a room separated from other premises. A separate room allows more efficiently and economically organize the preventive measures compared to the operations, carried out in common production areas. At the same time, it allows to reduce and limit the number of people who are or work in a given premise and are exposed to risk (Traumann at.al, 2014; OSHA, 2016). For example, isolation of spray-up equipment depending on dimensions of the workplace is suitable. Spray-up equipment will be located at the confining site and the worker producing the products will put his arms into special holes, which in total will be three pairs and each pair will be located at different height because three people work at this equipment and the height will be adjusted for each of them (Isolation, 2017).

Isolating the work process, it is possible to reduce the occupational exposure concentration in production shop since the exhaust ventilation place will be located in the confining site. As well, it is possible to reduce the number of workers exposed to styrene emissions.

4) Mandatory health checks.

Company production workshop workers are sent to mandatory health checks once a year, while office employees – every three years. Taking into consideration the mandatory health check results, the company needs to reduce the impact of harmful working environment factors on employees' health. The effectiveness of health checks is analysed by different authors and they usually give positive results (Si et al., 2014).

To reduce the impact of harmful working environment factors on employees' health, the company needs to replace the existing chemical substances with less harmful ones as well as to improve the efficiency of ventilation.

CONCLUSIONS

1.When using unsaturated polyester resins, workers are potentially exposed to styrene impact.

2.In all production shops of the company according to the chemical risk assessment matrix there is intolerable risk V level (GPI – 200%).

3.Calculation of the exposure index shows that the company employees must be sent to mandatory periodic health checks annually. As well as the periodic measurements shall be carried out by the company every 16 weeks.

4.Concentration checks of styrene and acetone in the working environment air show that styrene concentration exceeds the occupational exposure limit value when measuring within the worker's breathing zone outside the protective mask.

5.According to the air exchange coefficient calculations, the existing ventilation system of the company is not efficient enough and needs to be improved so that the air exchange coefficient would be 8.96 h^{-1}.

6.Can be changed to 'GRP multi cleaner', which is not volatile and is not a hazardous substance.

7.In order to reduce styrene concentration in production shops of the enterprise, it is necessary to wider the use of the vacuum technology. At present time, the vacuum technology is only used for certain products, approximately 10% of all manufactured products. Increasing the production by vacuum technology, the company will reduce the occupational exposure levels in the working environment.

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