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Occupational risk reduction by acetone substitution in particle board surface cleaning

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The Lithuanian wood industry covers three main sectors: wood processing, paper industry, and furniture production. The wood processing sector also includes the production of particle board. Technological developments have led to more intensive use of various additives – chemicals. To avoid the risks related to the impact of chemicals on human health and the environment, companies must comply with legal requirements and seek to replace the hazardous chemicals used in their processes. Substances must be replaced with less hazardous or harmless alternatives. In order to find out whether the options chosen are better, an assessment of the alternatives must be carried out. The present study includes the assessment of sustainability, targeted risk assessment for exposure of workers to chemicals, consumers, and the environment, and work risk assessments. The analysis of chemical products used in the production of particle board has shown that they contain ingredients with toxic, carcinogenic, and other properties hazardous to human health and the environment, and should therefore be substituted. After analysing the market for chemicals used in the wooden furniture industry, four potential alternative products were identified to one of the hazardous mixtures, and then the alternatives were assessed in terms of human health and environmental risks. The most suitable alternative was LPZ/II. Benefits of the proposed alternative for the company consist in the elimination of the mixture containing acetone and reduction of the risk to workers.

Keywords: chemical substitution, hazardous chemicals, wooden furniture industry, particle board

INTRODUCTION

The most commonly used adhesives for wood processing are urea – formaldehyde resin (UFR), phenol – formaldehyde resin (PFR), and melamine – formaldehyde resin (MFR) (Meyer, Hermanns, 2009). In addition to adhesives, the wooden furniture industry also uses cleaners that contain substances hazardous for humans and the environment, acetone being one of them.

Acetone is an organic solvent used in industry and the home. This material is found in varnishes, nail polish removers, glues, and other products. It is a colourless, clear, and highly volatile and

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flammable liquid. Acetone has the smell of aromatic fruit and a sharply sweet taste. This substance can be absorbed by inhalation, through the skin, and orally. After mild exposure to acetone, depression and vomiting may occur (Gwaltney-Brant, 2013). Acetone is classified as a highly flammable liquid and vapor that causes severe eye irritation and may induce drowsiness and dizziness. The staff working with acetone may experience eye irritation, burning of the mucous membranes of the nose and throat, and even erythema, i.e., reddening of the skin due to inflammation and dilation of superficial blood vessels in the skin. Also, exposure to acetone after inhalation or prolonged exposure to large amounts of the substance may cause corneal damage, nausea, headache, vomiting, agitation, chest tightness, and restlessness. In more severe cases of acetone poisoning, a coma, convulsions, respiratory failure, hyperglycemia, and renal and hepatic impairment may occur (Bradberry, 2007).

The risk is the likelihood of a harm arising from an exposure to a chemical substance under specific conditions. Risk assessment is the process of assessing that likelihood. The assessment shall be carried out according to an established system. In 1983, four distinct stages of risk assessment were identified: hazard identification, exposure assessment, dose-response assessment, and risk characterisation (Whittaker, 2015).

The wooden furniture industry uses chemicals that have properties hazardous for both human health and the natural environment. Some of these chemicals are volatile organic compounds that exhibit hazardous properties such as sensitisation, adverse effects on the nervous system, toxicity, mutagenicity, carcinogenicity, etc., and therefore are subject to strict occupational exposure limits in the European Union. Therefore, in order to ensure adequate protection of the human health and the environment, companies handling hazardous substances must anticipate and properly manage the risks posed by these substances. The search for alternatives to chemicals and the application of substitution are important steps in avoiding or reducing the risks involved. The substitution of hazardous chemicals in industrial production is a process that aims to reduce their use by finding alternatives that meet their technological needs and do not have such severe negative properties. The change requires considerable effort: when new materials are found, they need to be evaluated, tested, and even adapted to production processes.

This article analyses a wooden furniture industry company, which used a hazardous chemical mixture in its production process, namely, in cleaning of particle board, that contained acetone, and the possibility to refuse the use of this mixture by substituting it with less hazardous substances. The assessment of potential alternatives included the following key criteria: technological and economical suitability and reduced risk to human health and the environment. Only reduced risks to the human health and the environment will be discussed in the article.

METHODS

The study consisted of four stages. The first step identified the need for substitution in a company using chemicals. This was done by assessing the substances according to two criteria: the hazards and the risks to workers. After finding out the chemicals that needed to be replaced (LC 1/18 cleaner), the second step, which was a search for alternative chemicals, began. The search for and identification of the alternatives began with a literature review, a search in chemical substitution portals and databases such as ChemSec Marketplace (CHEMSEC MARKETPLACE, 2019). After finding out theoretically the possible alternatives to the substances used and to be replaced, the next step was an actual search for suppliers and a survey of alternative chemicals. After finding potential alternative chemical mixtures, in the third stage their evaluation was performed according to three methodologies; the alternatives found were compared with each other and with the currently used chemical. To compare different substances, safety data sheets and assessment tools were used: SubSelect (SubSelect, 2019), ECETOC TRA (ECETOC Targeted Risk Assessment, 2019), and COSHH (COSHH Essentials, 2019). The assessment was carried out in several stages: a sustainability assessment, a targeted risk assessment of the effects of chemicals on workers, consumers and the environment, and a workplace risk assessment. The final step was to assess the risk reduction potential and the difficulties involved in substituting chemicals.

Evaluation of alternatives by three methods

Assessment of the sustainability of alternatives. SubSelect, funded by the German Federal Environment Agency, is a tool to evaluate and compare the sustainability of chemicals/chemical mixtures by helping chemical manufacturers, distributors, and consumers to focus more on the sustainability aspects of their use of chemicals. Up to five different substances/mixtures can be compared with this tool. The comparison is based on the concentration of the substances in the mixture, toxicological information, physicochemical properties, information on the supplier, the greenhouse gas potential, and the consumption of resources to produce the substance. Chemicals are also automatically compared against lists of restricted substances. Using the SubSelect tool in this study, the alternatives found for chemical mixtures were compared with the chemical mixture already in use.

In the SubSelect tool, a colour and an estimate (numeric value) are assigned to each criterion and sub-criterion of the mixture.

For most sub-criteria, the colours are determined based on the evaluation of the substances in the mixture, and for some criteria the colours are determined for the mixture as a whole. The Subselect tool uses four different colours to represent the evaluation result:

- red – means ‘critical’. The substance/mixture is assessed as ‘poor’ according to the criterion. This colour means that it should be checked immediately if the substance/mixture can be replaced;
- yellow – an intermediate result. The substance/mixture is evaluated ‘average’. Yellow indicates critical properties but does not require immediate action for replacement.
- green – means ‘good’. The substance/mixture is ‘good’ and there is no need to substitute the substance/mixture according to these criteria;
- light blue – this colour can be assigned when a criterion is evaluated without sufficient information, no data has been entered, or it has been omitted. So, this colour means there is a lack of information.

Targeted risk assessment of the effects of chemicals on workers, consumers, and the environment. The ECETOC (European Centre for Ecotoxicology and Toxicology of Chemicals) Targeted Risk Assessment (TRA) tool was used to assess the change in the risks to workers' health and the environment as a result of the alternatives to the chemicals used. This tool was launched in 2004. The TRA consists of three separate models for assessing the risks to workers, consumers, and the environment (ECETOC, 2019).

Numerical values for risk assessment were taken from the ECHA database and safety data sheets.

Risks are described in terms of RCR (Risk characterisation ratio) for the aquatic environment (1):

$$RCR = PEC / PNEC \quad (1)$$

where PEC is the predicted environmental concentration; PNEC – predicted no effect concentration.

Risks are described in terms of RCR for humans (2):

$$RCR = \text{Exposure level} / DNEL \quad (2)$$

Where DNEL derived no effect level; dose or concentration of a substance below which no adverse effects on human health are expected. Different values are defined for acute and chronic toxicities and the three pathways inhalation, ingestion and skin contact as well as for workers and consumers.

The RCR (1, 2) ratio must be less than 1.0. If this is not the case and RCR > 1, risk management measures (RMM) must be taken.

The results assess the change in the risks for workers and the environment posed by the proposed alternatives compared to the mixture used. A decreased change is denoted by '–' and an increased change is denoted by '+'.

Workplace risk assessment. The risk assessment for the health of workers was carried out using the guidelines of the COSHH methodology. COSHH (Control of Substances Hazardous to Health Regulations) was first introduced in 1988. COSHH advice employers how to reduce the risks of hazardous chemicals in the workplace, thus protecting workers from illness in the workplace.

The COSHH Essentials report provides an overall risk assessment to identify appropriate risk control methods (COSHH Essentials, 2019). This report provides key tips for taking action to control exposure to hazardous chemicals in the workplace. When assessing the hazards of a product, it is not the classification of the product itself that is assessed, but the classifications of the hazardous substances it contains.

Calculations were performed to determine the amount of a substance consumed in the workplace per year. A mixture containing a substance was taken and its consumption was multiplied by the upper concentration limit (%) of the substance in the mixture. According to COSHH methodology (COSHH Essentials, 2019), the data on the annual consumption of the chemical mixture in the company determine whether the consumption quantity is small, medium, or large. Volatility information for the chemical mixtures used may be taken from the Safety Data Sheets (SDS). The temperature during the process should also be taken into account. It is sufficient to describe mixtures as low, medium, or high volatility.

By summarising the various factors in the workplace, the degree of risk is determined, according to which the risk control method will be applied (Table 1). With a higher degree of risk, stricter control methods are needed to protect workers in the workplace.

Table 1. **Determination of the control method by hazard group, amount of use, and volatility**

Quantity used	Low volatility	Medium volatility	High volatility
Hazard group A			
Low	1	1	1
Medium	1	1	2
High	1	1	2
Hazard group B			
Low	1	1	1
Medium	1	2	2
High	1	2	3
Hazard group C			
Low	1	2	2
Medium	2	3	3
High	2	4	4
Hazard group D			
Low	2	3	3
Medium	3	4	4
High	3	4	4
Hazard group E			
	4		

Note: 1 – low risk, 4 – very high risk. Source: COSHH Essentials, 2019.

RESULTS AND DISCUSSION

In this study, the mixture to be substituted was cleaner LC 1/18, and alternatives were found and evaluated. This cleaner contains acetone (CAS No. 67-64-1), which is classified by ECHA as:

- H225: Highly flammable liquid and vapor (Flammable liquids, Category 2);
- H319: Causes serious eye irritation (Eye irritant, Category 2);
- H336: May cause drowsiness or dizziness (Specific target organ toxicity, single exposure, Category 3).

The following potential alternative chemical mixtures without acetone were identified:

- Alternative 1: Technomelt Cleaner 103 (Determelt 3)
- Alternative 2: LPZ/II;
- Alternative 3: FT 400
- Alternative 4: Casco® Brutal Wipes

Assessment of the sustainability of the alternatives. The integration of information on chemical mixtures and their components (substances) from the Safety Data Sheets and the ECHA database into the SubSelect tool yielded the evaluation results. The colour of the mixture and its rank were assigned to each criterion and sub-criterion. The lower the score next to the colour code, the higher the consistency level of the mixture. The colour codes (Fig. 1) show that little information is available on the criteria 'Greenhouse Gas Emissions', 'Resource Consumption', and 'Responsibility in the Supply Chain'. Mixtures FT 400, LPZ/II, and the currently used cleaner LC 1/18 are included in the 'Material Mobility' criterion due to the hazardous impact/effect of its components. Casco Brutal Wipes is an alternative to Aquatic Hazards due to aquatic toxicity. None of the chemical mixtures are included in the 'List of priority substances' criterion, which shows that the substances in the proposed alternatives are not yet restricted by legal requirements as substances of very high concern.

It was determined that the hazard comparison with the SubSelect tool did not show a significant advantage of any of the alternatives over the mixture used.

Figure. Comparison of mixtures. Source: SubSelect, 2019

Targeted risk assessment of the effects of chemicals on workers, consumers, and the environment. No consumer exposure assessment was carried out as this was not relevant in the present case: the mixture was used exclusively in the workplace and would not reach consumers with the product. According to the ECETOC TRA methodology, two groups at risk from exposure to chemicals were identified: the workers and the environment. The risk is described as the ratio of the predicted environmental concentration to the predicted no-effect concentration and shall be less than 1.0. If RCR > 1.0, risk management measures must be taken. The results show that, due to the exposure of workers to the chemicals in it, the risks of Alternative 2 are acceptable as there is a reduced change compared to the mixture used. However, the effects of alternatives 1, 3, and 4 on the workers show an increase in the change compared to the mixture used. This is due to the hazardous components in these alternative mixtures that cause adverse effects to the workers through inhalation and skin contact: orange oils, 1-[1,3-bis (hydroxymethyl)-2,5-dioxoimidazolidin-4-yl]-1, 3-bis (hydroxymethyl) urea, (r)-p-mentha-1,8-diene. Environmental exposure – reduced change in risk of all alternative mixtures. However, the risk to the terrestrial environment of Alternative 3 and the risk to marine water of Alternative 4 is an increase compared to the mixture already in use. This increase is due to the aquatic toxic components in the mixtures, which cause long-term changes in (r)-p-mentha-1,8-diene. The increased change in the exposure of both workers and the environment to chemicals necessitates risk management measures.

The risk assessment with the help of ECETOC TRA showed that the risk from exposure of workers to the substance is reduced only for Alternative 2 (LPZ/II): long-term exposure by inhalation is reduced by 74% and exposure by skin contact by 53%. The environmental risks of almost all four alternatives are reduced, with the exception of the risks to the terrestrial environment of Alternative 3 and the risks to marine waters of Alternative 4 compared to the mixture used.

Workplace risk assessment. The risk of substances in the workplace was assessed according to the guidelines of the COSHH methodology (COSHH Essentials, 2019).

Due to the risk to the workers at the workplace, the COSHH methodology showed that only option 2 (LPZ/II) reduced the risk and that option 3 was not an inferior choice compared to the mixture used. All other mixtures presented a higher risk in the workplace and required stricter controls.

The degree of risk (Table 2) was determined according to the hazard groups of the

Table 2. **Comparison of alternatives with the mixture used according to hazard groups A, B, C**

Mixture used/ Alternative	Hazard group	Hazard group by chemical	Quantity used	Volatility	Degree of risk
Mixture used	A	Acetone	Medium	Hight	2
Alternative 1	C, S	White mineral oils (petroleum); orange oils	Medium	Medium	3
Alternative 2	A	Oil	Medium	Medium	1
Alternative 3	B, S	Butyl cellosolve; 1-methoxy-2-propanol, 1-propoxy-2-propanol	Medium	Medium	2
Alternative 4	C, S	1-[1,3-bis(hydroxymethyl)-2,5-dioxoimidazolidin-4-yl]-1,3 bis(hydroxymethyl)urea; (R)-p-mentha-1,8-diene	Medium	Medium	3

Note: The higher the degree of risk, the stricter the control approach for the protection of workers.

mixtures, the chemicals, the amount used, and the volatility.

The workplace risk assessment showed that only alternative 2 (LPZ/II) reduced the risk and that alternative 3 was not an inferior choice compared to the cleaner used. All other mixtures present a higher risk in the workplace and require stricter controls.

The substitution of chemicals faces a number of challenges: it is difficult to find suitable suppliers of alternative substances in terms of hazards; lack of knowledge of employees in determining the substances to be replaced and their hazards.

CONCLUSIONS

One of the most commonly used chemicals in the production of particle board and furniture is acetone. This substance is hazardous to workers as it causes severe eye irritation and drowsiness or dizziness. In order to reduce the risks of substances in products, priority is given to their substitution. Substitution of chemicals may be hampered by the technological processes of production, the cost of the alternative substance, or a mismatch between the physical and chemical properties of the product and the production technology. In such a situation, industry must take at least a minimum level of action to reduce risks to the health of workers at all stages of production. Based on the risk assessment performed in the study, the most suitable alternative for the furniture industry company was selected LPZ/II. Benefits of the proposed alternative substance for the company: the mixture containing acetone was eliminated and the risk to workers was reduced.

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PROFESINĖS RIZIKOS MAŽINIMAS NENAUDOJANT ACETONO MEDŽIO DROŽLIŲ PLOKŠČIŲ PAVIRŠIŲ VALYMUI

Santrauka

Lietuvos medienos pramonė apima tris pagrindinius sektorius – medienos perdirbimą, popieriaus pramonę ir baldų gamybą. Į medienos perdirbimo sektorių įeina ir medienos drožlių plokščių gamyba. Tobulėjant technologijoms, gamybos metu intensyviau naudojami įvairūs priedai – cheminės medžiagos. Siekdamos išvengti rizikos, susijusios su cheminių medžiagų poveikiu žmogaus sveikatai ir aplinkai, įmonės privalo vadovautis teisiniais reikalavimais ir atsisakyti savo veikloje naudojamų pavojingų cheminių medžiagų – jos turi būti keičiamos mažiau pavojingomis arba visai nekenksmingomis alternatyviomis medžiagomis. Renkantis alternatyvias medžiagas, būtina įvertinti jų darnumą, tikslinę riziką dėl cheminių medžiagų poveikio darbuotojams, vartotojams ir aplinkai. Analizė atskleidė, kad penkiuose gamybos procese naudojamuose cheminiuose mišiniuose yra medžiagų, pasižyminčių toksinėmis, kancerogeninėmis ir kitomis žmogaus sveikatai ir aplinkai pavojingomis savybėmis, todėl būtina jų atsisakyti. Iš baldų pramonėje naudojamų cheminių medžiagų buvo pasirinkti keturi alternatyvūs produktai, pakeisiantys vieną mišinį. Įvertinus pavojų žmogaus sveikatai ir aplinkai, pasirinkta tinkamiausia alternatyva – LPZ/II. Siūlomos alternatyvios medžiagos nauda: atsisakoma mišinio, turinčio acetono, sumažinama rizika darbuotojams.

Raktažodžiai: cheminių medžiagų pakeitimas, pavojingos cheminės medžiagos, medienos baldų pramonė, medžio drožlių plokštė