

SHORT THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PHD)

# **Workplace chemical exposures in closed spaces of transportation and storage**

by Szabolcs Lovas, MSc

Supervisor: Balázs Ádám, Ph.D.



UNIVERSITY OF DEBRECEN  
Doctoral School of Health Sciences

Debrecen, 2023

# **Workplace chemical exposures in closed spaces of transportation and storage**

By Szabolcs Lovas  
MSc in Public Health

Supervisor: Balázs Ádám, Ph.D.

Doctoral School of Health Sciences

University of Debrecen

Head of the **Defense Committee**: György Paragh, Ph.D., D.Sc.

Reviewers: Antal Tibold, Ph.D.  
Róbert László Kolozsvári, Ph.D.

Members of the Defense Committee: László Nagymajtényi, Ph.D., D.Sc.  
Károly Cseh, Ph.D., D.Sc.

The PhD Defense takes place at the Lecture Hall of the Department of Gynecology and Obstetrics, Faculty of Medicine, University of Debrecen, on the 1<sup>st</sup> March, 2023 at 12 pm.

## 1. INTRODUCTION

Global trade is essential for the economy, but it also involves risks in many areas, arising from the complexity of regulation, logistics, administration and rapidly evolving technology. The most advantageous way to transport goods across continents is to ship them in closed devices of transport (e.g. freight containers), which are handled and stored in logistics centres once they reach their destination country before being transported inland. In international transportation, it can often take weeks to months for the cargos stored in closed devices to reach their destination. During this time, several volatile organic compounds and chemicals used to fumigate containers can accumulate in the closed spaces, and directly expose the workers who open the equipment and handle the goods.

For a long time, methyl bromide was used for the chemical treatment of transport equipment, but this was gradually phased out due to its the ozone layer depleting effect. Today, the most commonly used fumigants for the treatment of sealed conveyances are magnesium phosphide, chloropicrin, hydrogen cyanide, sulfuryl fluoride, acetaldehyde and formaldehyde.

From an occupational health and safety perspective, an additional problem is that goods in closed spaces of transportation and storage can release volatile organic compounds, which may accumulate due to insufficient ventilation and expose employees working there. Volatile organic compounds detected in the closed spaces of transportation and storage include formaldehyde, benzene, toluene, xylene, styrene, vinyl chloride, ethylene oxide, acetone, methanol, ammonia, and methylene chloride.

The lack of awareness of exposure, the insufficient knowledge of fumigation practices of exporters, the presumed insufficiency of applied preventive measures, and the consequently inadequate chemical risk assessment pose significant challenges to occupational health and safety in every country, including Hungary. Investigation of chemical exposures in closed spaces of freight transportation and storage is essential to ensure the health and safety of workers in the sector.

## **2. LITERATURE REVIEW**

### **2.1. Chemical pollutants in closed spaces of transportation**

Goods are transported using closed devices of transportation that provide safe conditions for the raw materials and finished products from the harmful effects of environmental factors. Goods are transported between continents using cargo aircraft and ships. The most cost-effective way to transport goods between continents is by sea, with a significant proportion of goods moving from one part of the world to another in shipping containers. From an occupational health and safety perspective, these closed spaces can present several chemical hazards. The chemical pollutants that accumulate in them can pose workers handling containers and other closed transport equipment to significant health risks. A variety of chemical pollutants can be present in closed spaces of transportation, mainly biocides used in the chemical treatment of containers, volatile organic compounds released from goods, and diesel exhaust gases from combustion engines of vehicles.

In order to protect goods from various pests during transport by sea, fumigants are used to chemically treat the containers. Another objective is to prevent the spread of invasive species during intercontinental transportation of goods, the spread of which could cause significant environmental and economic damage on another continents. Containers and packaging materials are treated with heat or fumigants under the 2009 International Plant Protection Convention (IPPC) to prevent fungal decay and the spread of invasive species into the destination countries. As a result, both fumigators and workers loading and unloading goods can be exposed to significant occupational chemical exposures when they come into direct contact with these chemicals while working in closed spaces.

Fumigants used for the chemical treatment of closed transport devices include methyl bromide, chloropicrin, sulfuryl fluoride, magnesium phosphide, formaldehyde, hydrogen cyanide and acetaldehyde. Being toxic chemicals, their use is subject to authorisation and specific occupational health and safety measures.

Chemical exposure can also be caused by volatile organic compounds emitted by the transported goods and their packaging materials, which can accumulate in the interior of closed devices of transportation due to insufficient air exchange. Volatile organic compounds that have been detected in these closed spaces are formaldehyde, benzene, toluene, xylene, styrene, vinyl chloride, ethylene oxide, acetone, methanol, ammonia, and methylene chloride.

## **2.2. Chemical pollutants in closed spaces of warehousing**

The next stage in the logistics process is warehousing, where goods are stored in safe conditions in the warehouses of logistics companies before being transported inland. The various warehouses form closed spaces that can create ideal conditions for the accumulation of chemical pollutants due to insufficient ventilation. Warehouses vary in both design and size, and these factors determine how a warehouse is ventilated, whether quantitatively and qualitatively sufficient air exchange is provided, or artificial ventilation is required to remove pollutants from the work area.

When handling goods in warehouses, workers come into direct contact with the closed transport devices, opening and unloading them while handling goods in the warehouse. During these work processes, workers may be exposed to chemical pollutants accumulated in the closed spaces of transportation and storage, which may lead to the development of work-related health problems. Goods in warehouses may continue to emit volatile organic compounds during storage and the accumulated pollutants can significantly exceed the applicable occupational exposure limit values, going unnoticed.

The scientific literature on the presence of chemical pollutants in warehouses is rather limited. Research on this topic focuses mainly on occupational chemical exposures from the storage of dangerous goods, not considering exposures from the storage of non-dangerous goods.

The most common volatile organic compounds appearing as chemical pollutants in warehouses are benzene, toluene, styrene, xylene, vinyl chloride, acetone, formaldehyde, ethanol, methanol, and other volatile organic compounds depending on the chemical composition of the goods. After transportation, certain biocidal substances may also remain but in significantly reduced concentrations.

Occupational chemical exposure from diesel exhaust gasses can be a further problem in warehousing, given that some of the exhaust gases emitted by transport vehicles and diesel forklifts can enter and remain in the air of warehouses for long periods of time.

## **2.3. Potential health effects of chemical pollutants in closed spaces of transportation and storage**

Exposure to volatile organic compounds, fumigants, and components of diesel exhaust in closed spaces of transportation and storage poses several health risks.

One of the most commonly used fumigants is methyl bromide, which is highly toxic, can cause neurological disorders and lung damage, and has genotoxic and cytotoxic effects. The most common symptoms experienced on exposure are dry cough, dizziness, headache, hand tremors, vomiting, cramps, and other non-specific neurological symptoms. According to scientific studies, long-term exposure to methyl bromide was also associated with an increased risk of developing asthma and prostate cancer.

Phosphine is also a commonly used fumigant, exposure to which acutely causes nausea, vomiting, dyspnoea, chest tightness, abdominal cramps, low blood pressure and other cardiovascular symptoms shortly after the exposure. Phosphine gas poisoning has no specific antidote or treatment, and if significant amounts of the gas are inhaled, it can lead to death within hours due to multi-organ failure. Long-term exposure can result in inflammation of the nasal cavity and throat, damage to the central nervous system and liver.

Chloropicrin is typically inhaled and is mainly a respiratory toxin. Low-level exposure results in headache, shortness of breath, dizziness, nausea, vomiting, acute bronchitis, pulmonary oedema, irritation of the eyes and upper respiratory tract. Its cytotoxic effects are mainly exerted on the respiratory system and the retina. Inhalation in large quantities can also cause life-threatening conditions, as treatment is only symptomatic.

Sulfuryl fluoride, hydrogen cyanide, formaldehyde and methyl isocyanate are less well known but also in daily use and can have a number of adverse health effects. The most common symptoms experienced by workers using these fumigants are respiratory and eye irritation, headache, nausea and vomiting, dry cough, dizziness and general weakness, muscle twitches and, in more severe cases, pulmonary oedema, shortness of breath and consequent hypoxia. An increased risk of certain cancers (gastric, prostate, nasopharyngeal) has been observed in logistics workers chronically exposed to methyl bromide and formaldehyde.

Goods can emit several volatile organic compounds during transportation and storage, which can contribute significantly to the pollution of the working environment. The most common symptoms associated with volatile organic compounds are irritation of the eyes, nose and respiratory tract, dry cough, headache, nausea, allergic skin reactions, dyspnoea, fatigue, dizziness, visual disturbances, memory problems, weakness of arms and legs, hand tremors and coordination problems. These aspecific symptoms usually occur at low exposure levels and recover after exposure ceases. With increased long-term exposure, symptoms can worsen and persist, and asthma, chronic obstructive pulmonary disease (COPD), liver, kidney and central nervous system damage can develop. Some volatile organic compounds have been shown to

cause cancer (nasopharyngeal cancer caused by formaldehyde, haematological tumours by benzene, and lymphoma and leukaemia by ethylene oxide).

The health effects of certain components of diesel exhaust gases have been known for a relatively long time. Among the most common acute effects are irritation of the respiratory tract and eyes, headache, fatigue, nausea, vomiting and dyspnoea. Chronic effects often include coughing, impaired lung function, later asthma, COPD and other respiratory diseases may develop. Diesel exhaust is a proven human carcinogen (IARC 1).

## **2.4. Objectives**

The aim of our research was the complex assessment of occupational exposures, adverse health effects and preventive measures of chemical pollutants that can potentially accumulate in the workplace air of closed spaces of transportation and storage of non-dangerous goods.

Our research hypothesis is that workers who open closed transport devices and inspect, unload and store goods in warehouses are exposed to chemical pollutants accumulated in the air of the closed transport devices and warehouses, which can cause acute and chronic health effects. Preventive occupational health and safety measures in the practice of transportation and storage of non-dangerous goods are assumed to be not effective enough to protect workers' health at an adequate level, the legal regulation in this area is insufficient, and chemical exposures in these work environments often remain hidden from both employers and workers due to poor awareness.

In order to get a comprehensive picture of the problem under this study, the following tasks were planned to be completed during the research:

- a) to review the regulations and practices of handling goods in closed spaces of transportation and warehouses of logistics distribution centres in Hungary through a content analysis of relevant international and national occupational health and safety legislation,
- b) to assess the knowledge and attitudes of occupational health and safety professionals and managers responsible for goods handling and warehousing with experience in this field through semi-structured interviews, and
- c) to conduct a questionnaire survey of potentially exposed workers on their knowledge about exposures, experienced health effects, and preventive occupational health and safety measures applied in their daily work.

### **3. MATERIALS AND METHODS**

#### **3.1. Systematic search and content analysis of national and international legal documents on the control of chemical pollutants in closed spaces of transportation and storage**

##### *3.1.1. Systematic search in web-based legal databases*

We conducted a web-based systematic search of the EU and national occupational health and safety legislation on the handling of goods in closed transport devices and warehouses, using keyword searches in legal databases. The used databases were the European Union legislation database (EUR-Lex) and the National Legislation Repository. The keyword search string was structured as follows:

- (“Occupational Health and Safety”) AND (“Chemical Safety” OR “Transportation” OR “Container” OR “Phytosanitary”), and
- (“Munkaegészségügy”) ÉS (“Kémiai biztonság” VAGY “Áruszállítás” VAGY “Konténer” VAGY “Növényegészségügy”).

International legal documents were identified by reviewing the relevant literature on the subject, as well as the websites of the International Labour Organization, the International Maritime Organization, and the International Plant Protection Convention.

##### *3.1.2. Selection of legal documents identified by the systematic search*

In order to identify and analyse the content of relevant legal documents, the selection criterion for the legislative review was that the title and/or abstract/preamble of the legal document identified in the systematic search had to deal with an area of occupational health. Those legal documents that met the selection criterion of the first screening round had to meet an additional selection criterion during the full text screening, which was to deal with chemical exposure and/or its management/prevention in the work environment.

##### *3.1.3. Content analysis of the selected legal documents*

First, the hierarchical relationships between the legal documents that were identified in the systematic search and met the selection criteria were mapped. Then, the content of the included legal documents was analysed based on eight pre-defined yes/no type questions. The questions were as follows:



Does the selected legal document address

- a) occupational safety,
- b) chemical safety,
- c) transportation,
- d) phytosanitary measures,
- e) chemicals at the workplace,
- f) chemical exposure at the workplace,
- g) prevention of exposures caused by chemicals at the workplace; and
- h) prevention of chemical exposures in closed spaces of transportation and storage?

If a document received a yes answer to all assessment questions, it was subjected to a detailed content analysis to identify the measures in the document that directly addressed chemical pollutants in closed spaces of transportation and storage.

A content extract of the relevant paragraphs of the analysed documents was prepared using NVivo® 11 software, summarising the preventive occupational health and safety measures defined by law to protect the health of workers from chemical pollutants in closed spaces of transportation and storage.

### **3.2. Interview survey among occupational health and safety professionals and warehouse managers**

#### *3.2.1. Semi-structured interview template used in the study*

The chemical exposures during handling of goods in Hungary and the occupational health and safety practices of prevention were investigated by semi-structured face-to-face interviews to assess the knowledge and experiences of occupational health and safety professionals and managers responsible for goods handling and storage. The interview template included questions about the way goods are handled in transport devices and warehouses, knowledge of potential risk factors and perceived risks, and the estimated frequency of chemical exposures. The risks perceived by the workers, the symptoms and possible diagnoses of acute and chronic illnesses experienced by them, and the preventive occupational health and safety measures used were also identified in the survey. Respondents provided textual answers of five-item Likert scale rating to the interview questions.

The interview template has been adapted to the domestic conditions of transportation and storage. Subsequently, two pilot interviews were conducted to assess the comprehensibility of the interview template questions, their specificity, the average time required for the interview,

and the intervention points where the interviewer may need to provide additional information to the interviewee in order to get adequate answer to some questions.

### *3.2.2. Contacting Hungarian companies involved in the transportation and storage of non-dangerous goods*

The companies involved in the transportation and storage of non-dangerous goods located in Hungary were identified and contacted with the help of The Association of Hungarian Logistics Service Centres. We received a letter of support from the Association and a database containing the contact details of the companies relevant to the subject of the study.

The companies were contacted electronically. The email briefly explained the purpose and methodology of the research and asked the responsible managers of the companies to allow conducting interviews with employed occupational health and safety professionals and with persons responsible for goods handling and warehousing.

The size of the study population was determined using the methodology of data saturation, whereby interviews were completed until no further interviews were expected to yield any meaningful new information.

### *3.2.3. Semi-structured interviews with occupational health and safety professionals and warehouse managers*

Semi-structured interviews were conducted face-to-face at the companies' sites in a pre-arranged time. During the interviews, occupational health and safety professionals and warehouse managers gave insight into the day-to-day work at the company, the receipt and handling of goods, and other work processes involved in warehousing.

Interviews were conducted in a confidential manner, ensuring anonymity. During the interviews, the interviewees gave their verbal consent to the recording of the interviews. Where possible, audio record was made after obtaining verbal consent. The qualitative and quantitative information obtained from the interviews were analysed descriptively.

## **3.3. Questionnaire survey among workers at companies of transportation and storage**

### *3.3.1. Questionnaire used for data collection*

In the cross-sectional questionnaire survey, the study sample consisted of potentially exposed employees working in closed spaces of transportation and storage and office administrative workers not directly exposed.

A questionnaire previously used in studies in Australia and the United Arab Emirates ("*Occupational chemical exposure from transport containers questionnaire*", *OCETCON*) was adapted for the survey. The questionnaire collected the following information from the study sample:

- a) socio-demographic data,
- b) occupational history (previous jobs and occupations),
- c) knowledge and attitudes about chemical exposure at work,
- d) symptoms experienced in the last period,
- e) diagnosed medical conditions,
- f) preventive occupational health and safety measures in the workplace, and
- g) potential confounders (chemical exposure outside the workplace, smoking, alcohol consumption).

The English questionnaire was translated to Hungarian and back to English for comparison. The focus of the questionnaire was extended to the closed spaces of warehousing and standardised question blocks were added. The standardised questionnaires used for source were the Tobacco Questions for Survey (WHO), the AUDIT-C alcohol consumption survey and the European Health Interview Survey (EHIS).

In the pilot testing of the questionnaire, 12 employees (6 warehouse workers and 6 office workers) of a logistics company involved in transportation and storage of goods completed the questionnaire to assess the internal validity and to improve the clarity of the questions based on the comments of the respondents and on the coherence of the answers to the individual questions.

### 3.3.2. *Survey*

Questionnaires were distributed personally to all available employees of the participating companies who gave written consent.

The study population was defined according to the following criteria:

- 1) age between 18 and 65 years,
- 2) place of daily work is the logistics company where the questionnaire is completed,
- 3) the daily work of the exposed group takes place in closed spaces of transportation and storage,
- 4) the daily work of the non-exposed group does not take place in closed spaces of the transportation and storage,

- 5) voluntary completion of the questionnaire, written consent.

### 3.3.3. Statistical analysis

The collected data were recorded using Microsoft® Excel 2016 and statistically analysed using STATA® 12.0 software.

The main exposure variable used in the descriptive and inferential statistics, by which the exposed and non-exposed groups were compared, was based on the question *"Do you work in a closed space of transportation and storage during your work?"* If the answer was yes, the respondent was classified as exposed, otherwise as non-exposed.

Socio-demographic data, lifestyle factors, chemical exposures outside the workplace, diagnosed medical conditions and the prevalence of symptoms experienced in the past period were statistically analysed. Possible differences between the two study groups in univariate analyses were tested using chi-square tests for categorical and ordinal variables, and independent t-tests for continuous variables. Adjustment for potential confounders (gender, age, smoking, alcohol consumption, chemical exposure outside the workplace, time spent at the company, past or present work with chemicals, medication; in addition, previous head injury, coma, and concussion for the comparison of neurological symptoms) was performed using multivariate logistic regression. Significance was accepted at the 5% level ( $p < 0.05$ , 95% confidence interval (CI)).

In the analysis of the second part of the questionnaire, which was completed only by employees working in closed spaces of transportation and storage, the main explanatory variable was based on the question *"Have you received any specific training on safe working practices in closed spaces of transportation and storage?"*.

Differences between the two groups were assessed using multivariate logistic regression with adjustment for potential confounders (gender, age and years spent at the company) ( $p < 0.05$ , 95% CI).

### 3.3.4. Ethical permission

The study was approved by the Regional and Institutional Ethics Committee, University of Debrecen, Clinical Centre (UDCC REC/IEC, Identification number of ethical permission: DE RKEB/IKEB: 5065-2018 (17 September 2018)).

## **4. RESULTS**

### **4.1. International and national legislation on the control of chemical pollutants in closed spaces of transportation and storage**

The systematic search of web-based legal databases and legal documents published by international organisations resulted in 4.737 hits, of which 51 met the selection criteria. 16 legal documents and international recommendations received a "yes" answer to each of the eight pre-defined questions and were subject to detailed content analysis.

#### *4.1.1. International legal documents*

As a result of the systematic search, six documents relevant to the research topic were identified and content analysed. These recommendations discuss in detail the problem of chemical pollutants in confined spaces for the transport of goods and the related specific occupational health measures. They require workers handling chemically treated goods to be aware of the hazards of fumigation and that closed spaces of transportation carrying such goods must be clearly labelled to show that the goods have been chemically treated. Prior to unloading of the goods, the closed spaces must be ventilated (naturally or artificially) to ensure a safe working environment that does not present a health risk. The fact of ventilation must also be clearly indicated on the closed space of transportation, together with the date of ventilation. If the required occupational health measures have been taken, the closed space shall be labelled "gas-free", indicating that entering does not pose risk to the health of the workers.

The training of staff involved in the transportation of goods must include specific information on the risks of entering closed spaces. Workers shall be informed about the chemical pollutants that may be present in closed spaces and how to recognise them. According to the legal documents, a safety plan must be in place for international transportation, detailing whether chemical treatment has taken place, what kind of fumigant-treated goods are being transported, what safety measures are required to avoid exposure, who is authorised to inspect fumigant-treated closed spaces, and what preventive occupational health and safety measures are required before unloading goods from such closed spaces.

#### *4.1.2. European Union legal documents*

As a result of the systematic search of the European Union's legislative database, five EU legal documents relevant to the research topic were identified, and their content analysed. The legal documents cover chemical risk assessment for the segments of a work process, the provision of

adequate work equipment to protect the health and safety of workers, the adoption of appropriate hygiene and occupational health and safety measures, and the setting of occupational exposure limit values for some of the chemicals relevant to this research.

In line with international recommendations, chemically treated goods are classified as other shipments not falling into any of the main hazard categories but potentially dangerous to the environment and human health: 'Class 9 - Miscellaneous dangerous substances and articles'. Fumigated goods may be transported only in transport devices that can be closed in a way to minimise the release of fumigants into the environment and, before unloading, these closed spaces of transportation must be ventilated (by natural or artificial ventilation) to ensure that no fumigants in concentrations dangerous to human health remain.

#### *4.1.3. National legal documents*

The systematic search of the national legislative database identified five legal documents that were content analysed. The legal documents set out minimum occupational health and safety measures to avoid or reduce risks from exposure to hazardous substances and mixtures. They also set occupational air limits for several chemicals that may expose employees working in closed spaces of transportation and storage of non-dangerous goods. Chemicals that are relevant for this research and the exposure limits of which are regulated by law are acetone, ammonia, benzene, ethanol, n-butane, hydrogen cyanide, ethylene oxide, formaldehyde, phosphine, methyl bromide, n-pentane, carbon dioxide, carbon monoxide, styrene, toluene, and xylene.

An important measure in the national legislation relevant to this study is local or general ventilation of the working environment, which can significantly reduce the concentration of pollutants in the workplace. Other relevant measures of the national legal documents include protection against plant contaminants, official controls on certain goods at border posts, framework for Community action to achieve sustainable use of plant protection products, description of the obligations of importers of plant products (e.g., wood-based packaging materials) and description of other official procedures relevant for the transportation and storage of non-dangerous goods.

## **4.2. Knowledge, attitude, experience and practice in relation to chemical pollutants among occupational health and safety professionals and warehouse managers**

We contacted 35 logistics companies located in Hungary and 9 of them agreed to provide opportunity for personal interviews with their occupational health and safety professionals and warehouse managers at pre-arranged times. A total of 21 semi-structured interviews were conducted with 13 occupational health and safety professionals and 9 warehouse managers.

### *4.2.1. Work processes in logistics companies and knowledge of the relevant occupational health and safety legislation*

During the face-to-face interviews, the professionals gave a comprehensive overview of the daily operations at their companies and the workflow of goods handling and warehousing. Interviewees estimated that less than one per cent of the unopened transport devices arriving at logistics companies were labelled as chemically treated. In such cases, the opening of fumigated transport equipment is carried out with due care in open air and the ventilation time as required in the documentation is assured.

Professionals were aware of some occupational health and safety legislation on working in closed spaces of transportation and storage but did not know whether the mandatory legislation instructed the work in closed spaces in detail.

The interviewees were unanimous in their opinion that the mandatory EU and national occupational health and safety legislation and internal company guidelines adequately protect the safety and health of workers involved in handling goods and warehousing.

### *4.2.2. Occupational chemical exposures in closed spaces of transportation and storage*

The experts interviewed in the study agreed that the investigated issue may be an existing problem, but they believed the frequency of such exposures was generally rare. Chemical pollutants most frequently mentioned by the professionals during interviews were diesel exhaust gasses, carbon monoxide, particulate matter, and chemicals that workers may come into contact with due to the nature of the goods, e.g., components of paints, detergents, aerosols, lubricants and electrotechnical goods. Although some experts expressed concern about the phenomenon, they could not identify any chemical pollutants relevant to this research.

The warehouse managers agreed that the investigated occupational chemical exposures are not typical in these jobs, which they justified by the fact that they do not handle dangerous goods and therefore no chemical pollutants harmful to health were suspected in the working environment.

#### *4.2.3. Health effects of chemical pollutants and their presumed severity*

Occupational chemical exposures to pesticide residues and volatile organic compounds that may occur in closed spaces of transportation and storage were considered by the interviewees to be negligible to moderately harmful to workers' health. In practice, the most common symptoms reported by workers to occupational health and safety professionals were irritation of the upper respiratory tract and skin. These health effects were attributed to the presence of diesel exhaust fumes in closed spaces, dust pollution and the irritating effects of certain goods. Other occasional symptoms among workers that occupational health and safety professionals were aware of were headaches, weakness in the arms and legs, a general feeling of fatigue and hand tremors.

According to interviewees, workers reported little or no concern about their health in relation to occupational chemical exposures.

#### *4.2.4. Preventive occupational health and safety measures*

According to the responding professionals, the mandatory legislation, as well as internal work instructions and process regulations, adequately define the preventive occupational health and safety measures that need to be taken to ensure the health protection of workers working in closed spaces. If the goods transported have been subjected to chemical treatment in the past, they shall be treated in accordance with the relevant provisions in the documentation. According to experts, taking these measures is sufficient to minimise the risk of exposure to various pesticide residues. According to the experts, general and natural ventilation and frequent opening of warehouse doors ensure adequate air exchange to prevent the accumulation of these substances in closed spaces.

The most commonly used personal protective equipment is work clothing, safety shoes and gloves, and occasionally a dust mask for respiratory protection. The use of specific protective equipment to protect against the chemical exposures under investigation (e.g., specific respiratory protective equipment) was not common.



### **4.3. Knowledge, attitude, experience and practice of workers at logistics companies in relation to chemical pollutants**

The questionnaire was completed by 122 warehouse workers potentially exposed to the occupational chemical exposures and 136 office workers defined as a non-exposed group. The response rate was 73.9% among warehouse workers and 73.5% among office workers.

#### *4.3.1. Socio-demographic and lifestyle characteristics of the study population*

Most employees working in closed spaces of transportation and storage were male (92.6%), while the majority of office workers were female (79.4%). No significant difference in average age was observed between warehouse and office workers ( $41.2 \pm 0.93$  and  $38.1 \pm 0.89$  years). Workers in closed spaces significantly more likely consumed alcohol ( $p < 0.001$ ) compared to office workers, and significantly more likely have worked with chemicals ( $p = 0.002$ ).

#### *4.3.2. Diagnosed medical conditions and experienced symptoms among the participants*

No significant difference was identified between the two groups in terms of diagnosed medical conditions.

Among the investigated potentially work-related symptoms, feeling numbness or heaviness in the arms and legs (AOR = 3.99; 95% CI = 1.72-9.26) and dry cough (AOR = 2.32; 95% CI = 1.09-4.93) were significantly associated with working in closed spaces of transportation and storage after adjusting for confounders.

Forgetfulness (AOR = 0.40; 95% CI = 0.18-0.87), sleep disturbances (AOR = 0.36; 95% CI = 0.17-0.78) and feeling tired after waking up (AOR = 0.40; 95% CI = 0.20-0.79) were significantly more frequent among office workers in the multivariate analysis.

#### *4.3.3. Knowledge of and attitude towards chemical pollutants among warehouse workers*

Of the 122 warehouse workers surveyed, 79.5% worked in closed spaces of transportation and storage on a daily basis, while only 1.6% reported that they rarely worked in closed spaces. The majority of warehouse workers who completed the questionnaire (62.3%) had never heard of chemical pollutants in closed spaces of transportation and storage, while those who had knowledge of such occupational chemical exposures cited occupational safety and health training as the main source of information. 65.6% of the respondents said they did not know any pollutants, while 9.8% expressed detailed knowledge. 47.5% of the warehouse workers thought that they never work in an environment where chemical pollutants could be present, while 5.7% thought that these pollutants are often present in their work environment. The

exposure to chemical pollutants was considered unlikely by 39.3% of the respondents, likely by 8.2% and very likely by 9%.

Regarding the severity of the health effects of chemical pollutants, 21.3% of the warehouse workers thought that such chemical pollutants were not harmful to health, 27.1% deemed them moderately harmful while 8.2% extremely harmful.

38 (31.1%) warehouse workers had received specific occupational health and safety (OHS) training related to their work activities. The most common topics covered by such trainings were the selection and correct use of personal protective equipment (89.5%, 34 out of 38) and how to report contact with chemical pollutants (81.6%, 31 out of 38). However, only 36.8% (14 out of 38) of the participants reported that the specific OHS training informed them about chemical pollutants and their recognition.

Warehouse workers who had received specific occupational health and safety training were significantly more likely to have heard about chemical pollutants and their exposures in closed spaces of transportation and storage (AOR = 7.85; 95% CI = 3.20-19.27). These workers significantly more likely reported detailed knowledge of chemical pollutants potentially present in closed spaces (AOR = 8.18; 95% CI = 3.47-19.27). They estimated the presence of chemical pollutants in the work environment significantly more frequent (AOR = 2.67; 95% CI = 1.24-5.78). Health effects from chemical pollutants were also perceived significantly more serious by workers who had received specific training (AOR = 2.21; 95% CI = 1.06-4.63).

#### *4.3.4. Preventive occupational health and safety measures applied in closed spaces of transportation and storage*

The most frequently reported preventive occupational health and safety measures was the wearing of personal protective equipment (66.4%), followed by the natural ventilation of the working environment (31.9%). Other applied measures were to open closed transport equipment with due care (23.7%), to check the documentation of closed transport equipment (22.1%), to remove pollutants from the working environment using mechanical ventilation (10.6%) and to check the composition and quality of the air (4.9%). 18.8% of respondents (23) said that they did not take any preventive measures when working in the closed spaces of transportation and storage.

Workers who had previously heard about chemical pollutants potentially present in closed spaces of transportation and storage were significantly more likely to review documentation of closed transport devices (AOR = 2.96; 95% CI = 1.18-7.44) and to open closed transport

equipment with due caution (AOR = 3.04; 95% CI = 1.25-7.39). Warehouse workers who had received specific OHS training on chemical pollutants in closed spaces were significantly more likely to check the documentation of closed spaces (AOR = 5.49; 95% CI = 2.13-14.14), to open closed transport devices with due care (AOR = 7.16; 95% CI = 2.78-18.44), to remove pollutants with a blower or extractor (AOR = 8.90; 95% CI = 1.96-40.27) and the use natural ventilation to remove pollutants (AOR = 2.48; 95% CI = 1.03-5.96).

Among warehouse workers who received specific OHS training, some health effects, such as dry mouth or throat (AOR = 0.26; 95% CI = 0.10-0.64), throat irritation (AOR = 0.33; 95% CI = 0.14-0.81), dry cough (AOR = 0.43; 95% CI = 0.19-0.97) and diarrhoea (AOR = 0.38; 95% CI = 0.16-0.91), were significantly less frequent.

## **5. DISCUSSION**

### **5.1. International and national legislation on the control of chemical pollutants in closed spaces of transportation and storage**

The content analysis of the legal documents identified by the systematic search and included in the study revealed that while international recommendations address chemical exposures to biocidal substances during the transportation of non-dangerous goods, the EU and national legislation does not directly deal with the investigated problem. Chemical exposures during the storage of non-dangerous goods are not directly addressed in the identified international or national legal documents, only indirectly through the general management and prevention of occupational chemical exposures and by setting occupational exposure limit values for certain chemicals.

As regards the storage of non-dangerous goods, the legal documents identified and content analysed do not address the problem of exposure to chemical pollutants in closed spaces, and thus no preventive occupational health and safety measures tailored to such work activities could be identified. Although the binding regulations require complex risk assessment and evaluation, none of the selected and analysed legal documents specifically mention occupational exposures associated with chemical pollutants in the storage of non-dangerous goods.

## **5.2. Knowledge, attitude, experience and practice in relation to chemical pollutants among occupational health and safety professionals and warehouse managers**

As a result of the interviews, it can be concluded that occupational health and safety professionals and warehouse managers at the surveyed logistics companies considered the investigated problem basically negligible. With a few exceptions, they were not concerned that workers could be exposed to chemicals at the workplace. Most of the interviewees did not have knowledge about the presence of the concerned chemicals in the work environment, and consequently did not anticipate such risks in their daily work.

Respondents considered the severity of health effects caused by chemical pollutants to be moderate to negligible. The professionals' perception was that workers were not concerned about their health in relation to pollutants, which can be explained by the fact that occupational health and safety training barely addresses such exposures, consequently the workers are unaware of the potential risks.

## **5.3. Knowledge, attitude, experience and practice of workers at logistics companies in relation to chemical pollutants**

Among the surveyed workers at the logistics companies, symptoms potentially associated with chemical pollutants under investigation were relatively rare but not negligible. Given that there are no data on the presence and concentrations of chemical pollutants in the studied workplace environments, we could not establish a direct correlation, but statistically we could show that workers employed in closed spaces of warehousing experience significantly more frequent numbness or heaviness in the arms and legs and dry cough. Thus, in our study, we found irritation and fatigue to be correlated with the job, but failed to demonstrate the same with neurological effects, reported in other studies.

Knowledge of chemical pollutants is relatively rare or absent among workers who completed the questionnaire. Workers consider exposure to chemical pollutants in their daily work unlikely, but, contrary to the opinion of professionals, they have concerns about the health effects associated with them, which may be linked to their poor knowledge.

Among workers who completed specific OHS training on chemical pollutants of closed spaces of transportation and storage, more detailed knowledge, and application of a wider range of OHS measures could be observed. The frequency of exposures and the severity of their health effects were also estimated to be higher by them, who also showed significantly lower prevalence of diarrhoea, dryness of mouth or throat, throat irritation and dry cough.

Wearing personal protective equipment is the most commonly used occupational health and safety measure among workers, but this does not imply adequate respiratory protection, only the use of dust masks. Natural ventilation of closed spaces is also a common measure, but it is unlikely to be adequate in all cases to reduce pollutant concentrations sufficiently.

#### **5.4. Main findings of the study**

The new results of our studies confirmed our hypothesis that the Hungarian occupational health and safety legislation on chemical exposures in closed spaces of transportation and storage is incomplete, and that the legislation does not specify protection against potential chemical pollutants in the transportation and storage of non-dangerous goods.

A new finding is that the health and safety professionals responsible for warehouse workers are not sufficiently informed about the seriousness of the problem and, with few exceptions, consider its importance to be negligible. It should also be pointed out that fumigation as a process is now considered to have been phased out, so no fumigant residues are assumed to be present in the working environment.

Consistent with the research hypothesis is the finding that warehouse workers do not anticipate chemical risks, they only rarely use specific preventive measures in addition to mandatory generic measures, but that workers who have received specific OHS training are informed about chemical pollutants and are more likely to use appropriate preventive measures that provide adequate protection against pollutants.

A noteworthy new finding is that, despite the limitations of our research, we could find correlation between the working environment and certain health effects (dry cough, numbness or heaviness in the arms and legs) among warehouse workers.

Our study concluded that working in closed spaces of transportation and storage of non-dangerous goods requires the development of targeted occupational health and safety legislation that is based on scientific evidence and considers the chemical pollutants that can potentially accumulate in these spaces.

According to the results of the legal review and the interview survey, the relevant legislative environment in its current form is not suitable to address the examined problem in a meaningful way. The mandatory legislation applicable to work in closed spaces does not deal with exposures to chemical pollutants, and thus specific occupational health and safety measures defined at legislative level to prevent chemical exposures in closed spaces of transportation and storage of non-dangerous goods are not applied.

While there is published scientific literature on the effects of occupational exposure to fumigants while working in closed spaces of transportation and warehousing, there is relatively few data on how and to what extent long-term low-level chemical exposures to volatile organic compounds in specific work environments contribute to the development of certain health problems among workers. Further studies are required to quantitatively measure the presence of chemical pollutants and their concentrations in the workplace air.

Occupational health and safety professionals and those responsible for handling and storage of goods need to be informed to understand the risks of chemical pollutants associated with working in closed spaces. In order to ensure that the problem under consideration is reflected in occupational health and safety trainings, the results of foreign studies need to be applied to the Hungarian context, and further domestic investigations need to be carried out and their results communicated.

In addition to the natural ventilation currently used when working in closed spaces of warehouses, mechanical ventilation may also be necessary where, due to the volume of goods, some pollutants may exceed the applicable occupational exposure limit values, but evidence for such exposures needs the above-mentioned quantitative measurements. In addition, the expansion of the use of personal protective equipment, in particular respiratory protection, should be considered.

Workers working in closed spaces need to be provided with the necessary knowledge through OHS training, which will make them aware of potential risks, enable them to recognise pollutants by their properties and improve their compliance with OHS measures preventing from chemical pollutants.

At the moment, the significance of the investigated problem is considered negligible by both professionals and workers, which calls for further studies involving direct exposure measurements and long-term follow-up.

## **5.5. Strengths and limitations**

The systematic search of legislation at EU and national level provided the possibility to identify all relevant legal documents in comprehensive databases. The international legal documents were searched manually by reviewing websites and scientific research previous published on the subject. As a result of this limitation, it is possible that there are some international legal documents relevant to the topic of the study, which were not identified in the manual search.

In the semi-structured interview survey, the willingness to participate on the part of logistics companies was relatively low (9 out of 35 companies contacted provided the opportunity for interviews). As a result, selection bias may have occurred. It is possible that the knowledge of chemical pollutants among professionals at the surveyed logistics companies may be more detailed and compliance with occupational health and safety measures stricter than at companies where the survey could not be conducted. Another potential limitation of the interview survey is that participants had to give subjective answers to a number of questions. It is likely that they were trying to create a positive impression of the company they represented and thus over-reported the OHS measures in place at the company. The anonymous recording of the interviews served to mitigate this information bias.

The questionnaire survey of workers in closed spaces of transportation and storage was a cross-sectional study reflecting on a situation at a given moment in time, and therefore not suitable for establishing causal relationship between potential occupational chemical exposures and diagnosed medical conditions as well as health effects experienced by workers. Of the 35 logistics companies visited, we were able to conduct the questionnaire survey in seven, so the low participation of the companies may affect representativeness. It can be assumed that the occupational health and safety situation in the participating companies is generally better than the industry average. At the same time, all employees of the enrolled companies were invited to participate in the survey and the response rate was high. The questionnaires were self-reported, which limits the reliability of the information collected. The medical conditions and symptoms examined in the survey are multifactorial, and even after adjusting for confounders, there may remain confounding factors that could influence the results.

## **6. SUMMARY**

During the transportation and storage of non-dangerous goods, workers in closed spaces may be exposed to chemical pollutants, which are often hidden from employers and workers alike. Exposure can cause long-term health effects that could be prevented by the application of evidence-based occupational health and safety measures.

The objectives of our study were (1) to identify and analyse the content of international and national legislation applicable to the transportation and storage of non-hazardous goods, (2) to assess the knowledge and experience of those responsible for the safety and health of employees working in closed spaces with respect to chemical exposures, and (3) to examine the health

effects experienced by employees working in closed spaces as well as their knowledge, attitude and preventive practices related to chemical exposures.

The research was carried out by a systematic search and analysis of legislation, semi-structured interviews with occupational health and safety (OHS) professionals and warehouse managers, and by a questionnaire survey of workers at logistics companies to investigate the Hungarian context of the problem.

The analysis of the legislative environment showed that the EU and national legislation in their current form is not specific enough to adequately regulate the investigated problem. The interviewed professionals considered chemical exposures to be rare, their health effects to be negligible, and, in their experience, workers were not concerned about their health in relation to this problem. The questionnaire survey of workers revealed gaps in their knowledge about chemical exposures, demonstrated the association of respiratory irritation and fatigue with warehouse work, and pointed out the inadequate use of preventive OHS measures. Workers who had acquired specific knowledge about chemical exposures during their OHS training were found to use effective preventive measures more likely.

As a result of our investigation, it can be concluded that in order to ensure an adequate level of health protection for employees working in closed spaces of transportation and storage, the legislative environment should be more specific reflecting new scientific findings on chemical pollutants, this information should be incorporated in OHS training to increase awareness and enable workers to take effective preventive measures. Direct exposure measurements would be required to detect the presence and concentration of chemical pollutants in closed spaces, and long-term follow-up studies adapted to domestic conditions would be necessary to study potential health effects.



## 7. LIST OF PUBLICATIONS



UNIVERSITY of  
DEBRECEN

UNIVERSITY AND NATIONAL LIBRARY  
UNIVERSITY OF DEBRECEN

H-4002 Egyetem tér 1, Debrecen  
Phone: +3652/410-443, email: publikaciok@lib.unideb.hu

Registry number: DEENK/493/2022.PL  
Subject: PhD Publication List

Candidate: Szabolcs Lovas

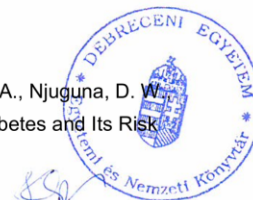
Doctoral School: Doctoral School of Health Sciences

### List of publications related to the dissertation

1. **Lovas, S.**, Varga, O., Loney, T., Ádám, B.: Chemical pollutants in closed environments of transportation and storage of non-dangerous goods - Insufficient legislation, low awareness, and poor practice in Hungary.  
*Int. J. Environ. Health Res.* 6, 1-18, 2022.  
DOI: <http://dx.doi.org/10.1080/09603123.2022.2035325>  
IF: 4.477 (2021)
2. **Lovas, S.**, Nagy, K., Sándor, J., Ádám, B.: Presumed Exposure to Chemical Pollutants and Experienced Health Impacts among Warehouse Workers at Logistics Companies: a Cross-Sectional Survey.  
*Int. J. Environ. Res. Public Health.* 18 (13), 1-14, 2021.  
DOI: <http://dx.doi.org/10.3390/ijerph18137052>  
IF: 4.614

### List of other publications

3. Mahrouseh, N., **Lovas, S.**, Njuguna, D. W., Nellamkuzhi, N. J., Soares, A. C. A., Sackey, W. E., Irawan, A. S., Varga, O.: How the European Union legislations are tackling the burden of diabetes mellitus: a legal surveillance study.  
*Front. Public Health.* 10, 1-12, 2022.  
DOI: <http://dx.doi.org/10.3389/fpubh.2022.1002265>  
IF: 6.461 (2021)
4. **Lovas, S.**, Mahrouseh, N., Bolaji, O. S., Nellamkuzhi, N. J., Soares, A. C. A., Njuguna, D. W., Varga, O.: Impact of Policies in Nutrition and Physical Activity on Diabetes and Its Risk Factors in the 28 Member States of the European Union.  
*Nutrients.* 13 (10), 1-17, 2021.  
DOI: <http://dx.doi.org/10.3390/nu13103439>  
IF: 6.706





5. Nagy, K., Duca, R. C., **Lovas, S.**, Creta, M., Scheepers, P. T. J., Godderis, L., Ádám, B.:  
Systematic review of comparative studies assessing the toxicity of pesticide active  
ingredients and their product formulations.  
*Environ. Res.* 181, 1-19, 2020.  
DOI: <http://dx.doi.org/10.1016/j.envres.2019.108926>  
IF: 6.498
6. Ádám, B., **Lovas, S.**, Ádány, R.: Use of Genomic Information in Health Impact Assessment is Yet  
to Come: a Systematic Review.  
*Int. J. Environ. Res. Public Health.* 17 (24), 1-13, 2020.  
DOI: <http://dx.doi.org/10.3390/ijerph17249417>  
IF: 3.39

**Total IF of journals (all publications): 32,146**

**Total IF of journals (publications related to the dissertation): 9,091**

The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on  
the basis of the Journal Citation Report (Impact Factor) database.

07 December, 2022



## Acknowledgements

I would like to thank my supervisor, Dr. Balázs Ádám, for taking on my thesis supervision and for his confidence in me during my doctoral studies. Over the years, he has provided me with knowledge and experience that have made me realise that working with him was one of the greatest opportunities of my life. His precise, accurate, detailed and always objective professional guidance has not only resulted in the completion of my doctoral dissertation, but has also made me a better professional thanks to the knowledge he has provided.

I would like to express my gratitude and appreciation to Prof. Dr. Róza Ádány, Prof. Dr. Margit Balázs and Prof. Dr. János Sándor for giving me the opportunity to carry out my research and for being there for me at times when I really needed the right guidance. Their knowledge and experience have had a significant impact on me not only in the academic world, but often in my personal life as well.

I am grateful to Prof. Dr. Karolina Kósa, who, as the Dean of the Faculty at the time, supported my doctoral studies and helped me to deal with the situation.

I would like to thank Prof. Dr. János Sándor, Dr. Károly Nagy, Dr. Edit Orsolya Varga and Dr. Tom Loney for their contribution to the preparation of the publications on which my thesis is based.

I would like to thank The Association of Hungarian Logistics Service Centres for their support during our research, the supportive attitude of the professionals who participated in our survey, and the employees who filled in our questionnaire for taking the time to complete the survey and share their experiences with us.

I am especially grateful to the staff of the European Agency for Safety and Health at Work (EU-OSHA), where I spent the last months of my thesis writing as a trainee in Bilbao, Spain, for their patience, understanding and support throughout my work and my doctoral thesis-related activities.

Last but not least, I would like to thank my family and friends for their support and patience during my doctoral studies, which was much needed, as well as my support and their always positive feedback.

The research was funded by the "Debrecen Venture Catapult Program" EFOP-3.6.1-16-2016-00022.