

Health risks and prevention practices during handling of fumigated containers in ports

Literature Review

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Executive Summary

▪ Background

Freight containers are widely used all over the world to transport goods. These freight containers are frequently fumigated with pesticides before shipping. Pest control is implemented to protect the cargo from being damaged by pests during the long transport time, and thereby to prevent the spread of unwanted organisms. This review is limited to pesticides used for fumigating containers. Chemicals that may be released from materials in the cargo are not included.

▪ Objective

The objective of this report is to provide a review of potential occupational safety and health (OSH)-related risks resulting from exposure to fumigated freight containers in ports, and to identify prevention gaps and suggest recommendations on how these risks can be minimised. To achieve this, the report describes relevant legislation, gives examples of preventive actions and strategies that are used, identifies health and safety risks, and includes final conclusions and recommendations.

▪ Methods

The project group at the Department of Occupational Medicine and the Norwegian Center for Maritime Medicine, at Haukeland University Hospital, Norway, was multidisciplinary, including one senior physician, occupational hygienists and a toxicologist. International legislation has been examined, and a comprehensive literature search has been conducted using recognised databases for scientific and biomedical publications, as well as Google Scholar to search for 'grey' literature such as reports, information leaflets, guidelines and newspaper articles. The information sought was related to pesticides used for fumigation, the frequency of fumigated containers arriving in European ports, health effects on exposed workers and guidelines for handling fumigated containers. The European Agency for Safety and Health at Work (EU-OSHA) provided information from various national bodies after a request from EU-OSHA to its focal point network. The Technical report by the Joint Research Centre (JRC), the European Commission's science and knowledge service, also provided information on occupational exposure to fumigants related to port containers. Information about methods and equipment for monitoring fumigants was collected from the various literature sources. In addition, a small and a large European port were visited to observe current practices.

▪ Results and recommendations

The main impressions obtained from the project are as follows:

- There are several indications that the fumigation problem is underestimated, probably because of a lack of systematic documentation of incidents of adverse health effects.
- It is a major problem that fumigated containers are almost never labelled, and that current practices when opening and unloading these containers do not follow safe procedures based on appropriate risk assessments.
- Recommendations and procedures for control measures, such as measurement technology/strategy, degasification/ventilation and personal protective equipment (PPE), should be developed for various scenarios.

The major findings and recommendations of the project are summarised under the three headings 'Present knowledge', 'Gaps in knowledge' and 'Recommendations', as shown below.

▪ Present knowledge

- A number of fumigants with significant acute and long-term health effects are used in transport containers, with methyl bromide (MeBr) and phosphine (PH₃) currently the main ones.

- The proportion of containers with a concentration of fumigants above the occupational exposure limit (OEL) varies considerably between studies. In eight of the nine available studies from 2002 to 2013, the OEL for phosphine was exceeded in 0.4-3.5 % of containers (and in 47.2 % of containers in one study), while MeBr was above its OEL in 0-21.1 % of containers. The variations were probably due to factors such as different procedures for selecting containers for measurement, number of containers measured, measuring equipment, content of containers and country of origin.
 - The available publications/reports on container screening using fumigants relate to larger ports before 2014, and might not be representative of the current situation.
 - There is no consistent distribution of pesticides between types of cargo, except for PH₃ in foodstuffs.
 - Fumigated containers are almost never appropriately labelled. Increased transport cost seems to be one of the major obstacles to correct labelling of fumigated containers.
 - Knowledge and awareness of the health risks among workers opening containers seem to be low, although employers are obliged to inform workers about all hazards in their work environment, and to provide adequate training in health and safety at work.
 - The workplaces are multicultural. The use of different languages among the workers is among the barriers to adequate training of workers.
 - Workers unloading containers might be exposed to fumigants if they open containers that have not been checked and declared gas free. Employees of authorities such as the food inspectorate or customs might also be exposed when opening containers for inspection.
 - So far there have been no reports of fatalities related to the opening of containers, but several reports describe adverse health effects in workers opening and unloading containers. Several representatives of research institutions and regulatory bodies suggest that many near-accidents and toxin-related incidents with serious outcomes are not reported.
 - Few countries seem to have detailed and adequate guidelines on how to handle freight containers that may have been fumigated, although various organisations and employers have made available guidelines/information sheets on good practices for safe handling.
 - Measurements/samples of fumigants are taken mainly using probes pushed through the rubber seals of container doors. These probes are connected to various monitoring instruments, and they indicate a potential peak exposure level for personnel opening the containers, rather than the average personal exposure measured in the breathing zone of the workers during unloading.
 - Current practice for degasification is scarcely documented, and containers are often left to ventilate naturally, even though this is documented not to be efficient.
 - Efficient methods for degasification by forced extract ventilation have been published, but it seems that few locations have access to such ventilation facilities.
 - Current container design is not optimal for degassing with extract ventilation, with only small openings in the corners.
 - Use of PPE is inconsistent and variable, and routines and guidelines on proper PPE are often lacking.
 - The decision on whether or not to use PPE seems to be left to workers, who may lack sufficient knowledge of the risk and level of protection needed.
- **Gaps in knowledge**
- Most containers arriving in Europe are not opened at ports. However, no information about the proportion of containers that are actually opened by the various groups of workers in European ports, in warehouses and by the end-user is available.
 - There are no accessible reports on detailed risk assessments, including assessments of actual personal exposure to fumigants for relevant groups such as dock workers, warehouse workers or customs officers.

- It is not apparent what should be considered the best indicators of fumigated containers when no labelling is present.
 - The number of incidents may be greatly underestimated, since input from representatives from both research institutions and national regulatory bodies suggests that many near-accidents and intoxications with serious outcomes are not reported in public forums.
 - The literature surveys add to this and illustrate one of the major challenges in this field, which is to provide adequate and sufficient documentation of incidents related to fumigated transport containers, including adverse health effects, clinical symptoms and exposure data, and to make these data publicly available in recognised sources.
 - Responsibility for the OSH training of workers opening containers needs clarification, especially when they are employed through a staffing agency.
 - Description of scenarios for when and which type of PPE should be used is lacking.
- **Recommendations**
- There should be systematic exposure/risk assessment among potentially exposed groups of workers, for various exposure scenarios.
 - There should be systematic surveillance of the prevalence of containers with fumigant residues arriving in European ports.
 - There should be assessment/modelling of personal exposure levels based on arrival concentrations of fumigants in containers, for various scenarios.
 - The best solution is that the exporter should remove fumigant residues after fumigation, degas and declare the container gas free before it is shipped.
 - Measures should be taken to enforce relevant regulations regarding labelling — containers that are not labelled in accordance with regulations should ideally be returned unopened and at the exporter's expense.
 - The lack of compliance with regulations on labelling indicates that more involvement of authorities is needed.
 - Two aspects of container fumigants have to be considered: first, the container should not have fumigant concentrations high enough to represent a risk of acute health effects when the container is opened; and, second, the container atmosphere should not contain fumigants at low concentrations that may impose long-term effects due to prolonged exposure during unloading. Accordingly, it is important that the measuring technology is sensitive enough to detect levels below those presenting any risk of long-term hazard.
 - The impression after review of the literature is that the two main fumigants currently used are MeBr and PH₃, and accordingly a standardised screening/monitoring procedure should be developed. The measuring technology should be able to identify at least MeBr and PH₃, with sufficient sensitivity to quantify levels at one-tenth of the OEL or lower.
 - Based on available data, the most efficient degasification method is forced extraction ventilation, which results in rapid washout of the fumigant. However, current container design makes safe and rapid air sampling and ventilation prior to opening the doors technically difficult.
 - Facilities for forced extract ventilation should be available at ports.
 - Containers should not be opened until risk assessment concludes that it is safe, for instance based on shipping documents or by approved measurement of the container atmosphere, if necessary after sufficient ventilation has been performed.
 - There should be systematic collection of new information on present practices of opening of containers, risk assessments and preventive measures from a representative sample of European ports.
 - Adequate training programmes, brochures, information sheets and guidelines should be developed for workers, in relevant languages.
 - Easily understandable information sheets should be made available, including information on what PPE to use for various scenarios.

- Risk communication systems should be in place for port companies, so that they can make plans to receive incoming fumigated containers.

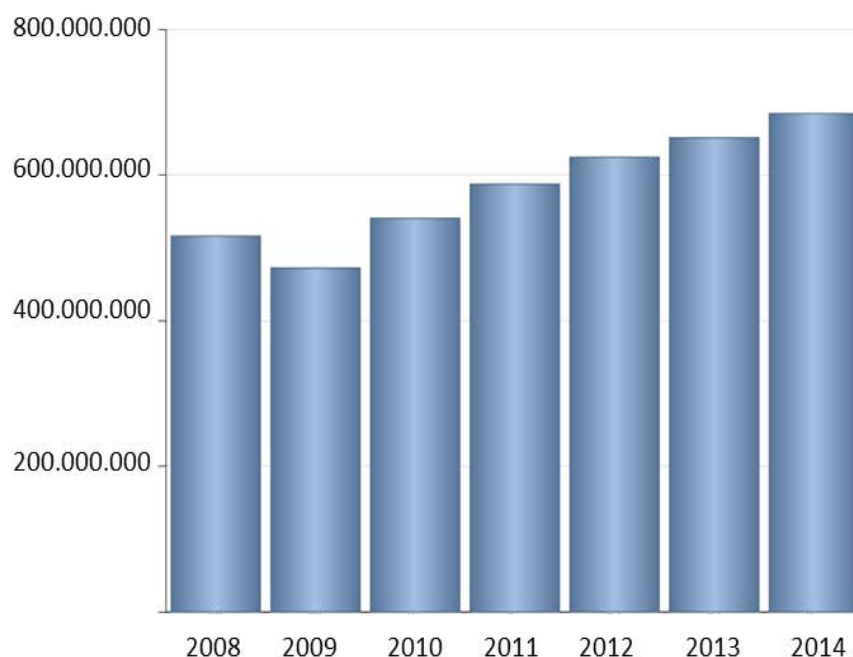
- **Priority should be given to the following recommendations:**
 - a) Measures should be taken to enforce relevant regulations regarding labelling. This is a collective problem that should be dealt with by national authorities, shippers, ship-owners, employee organisations and ports. A uniform approach in European ports is recommended to avoid competition at the expense of health and safety.
 - b) Containers should not be opened until risk assessment concludes that it is safe, for instance based on shipping documents or by approved measurement of the container atmosphere, if necessary after sufficient ventilation has been performed.
 - c) Develop a standardised screening/monitoring procedure that is able to identify at least MeBr and PH₃, with sufficient sensitivity to quantify levels at one-tenth of the OEL or lower.

1 Introduction

Freight containers are widely used all over the world to transport goods. More than 600 million container units are filled, shipped and stripped annually (Figure 1). These freight containers are frequently fumigated with pesticides before shipping. Pest control is implemented to protect the cargo from being damaged by pests during the long transport time, and thereby to prevent the spread of unwanted organisms. The objective of this report is to provide a review of potential health risks resulting from exposure to fumigated freight containers in ports, and to identify prevention gaps and suggest recommendations on how these risks can be minimised. To achieve this, the report describes relevant legislation, gives examples of preventive actions and strategies that are used, identifies health and safety risks, and includes final conclusions and recommendations. This review is based on information obtained by a literature search of scientific databases, as well as through general Internet searches, and also by visiting two European ports.

As indicated in the literature review, several papers on the subject do not clearly distinguish between chemicals used as pesticides (fumigants) and chemicals off-gassing from goods in transit. Chemicals released from the cargo represent another problem: they include a wide range of chemicals with various characteristics and health effects, and their presence may go undetected, since a complete chemical composition of the cargo is difficult to obtain. It is therefore emphasised that this review is limited to pesticides used for fumigating containers. However, some chemicals that may be released from materials in the cargo may also be used as fumigants, and these are included in the report. Formaldehyde is a typical example of the latter. Toluene, benzene and xylene are solvents, and are typical examples of chemicals that have been detected in containers but are not used as fumigants as they originate from the cargo. Such chemicals are not included in the present review.

Figure 1: Annual worldwide container port throughput in 20-foot equivalent units.



Source: United Nations Conference on Trade and Development,
<http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=13321>

2 Methods

The project was run by the Department of Occupational Medicine and the Norwegian Center for Maritime Medicine, at Haukeland University Hospital, Norway, from 15 December 2016 to 15 September 2017. The project group was multidisciplinary, including one senior physician, occupational hygienists and a toxicologist.

The project group met every second week during the first six months of the project, and every week during the last three months, to discuss the analysis and interpretation of collected information.

Five Skype meetings with the European Agency for Safety and Health at Work (EU-OSHA) were arranged to discuss progress during the project.

The project period was divided into four main stages:

1. overview of occupational safety and health (OSH) risks
 - a. kick-off meeting with EU-OSHA
 - b. literature search
 - c. working report submission after three months
2. collection of additional information
 - a. visits to two European ports
3. preparation of the delivery after six months
 - a. analysis of collected information
 - b. identification and description of gaps
 - c. preparation and submission of draft six-month delivery report, article and PowerPoint presentation
4. preparation of the final delivery.

To address container incidents and adverse health effects, search strings were developed for a literature search of relevant research databases (PubMed, Web of Science and Google Scholar). The strategy for search on relevant legislation and policy documents included searching for information in scientific and non-scientific publications, information papers, brochures, presentations, etc., as listed in the reference section (section 4.4). We also extracted information from EU-OSHA's focal point network and the Technical report by the Joint Research Centre (JRC).

Visits were undertaken to two European ports, one a representative large port and one a typical small port. These ports receive approximately 12 million and 90,000 containers per year, respectively. To prepare for the visits, we sent an information letter about the project to the selected ports. The letter explained what information we were looking for, and asked for permission to visit. EU-OSHA produced a supporting letter to attach to our request. In the large port we met representatives from a gas measurement station, a workers' representative, a customs officer and a victim of fumigant intoxication. In the small port we met representatives of the port management and dock workers. The aim of the visits was to verify and supplement the collected information on relevant preventive practices that had become available via the literature search and from the focal point network. The purpose was also to observe how the containers are handled and obtain indications of possible good practices. We prepared a checklist for these visits to collect reliable information from the invited bodies. Some main topics in the checklist were:

- how to identify health and safety risks;
- fumigation chemicals identified and labelling;
- monitoring technologies;
- degasification and ventilation technologies;
- personal protective equipment (PPE);
- communication bottlenecks in the transport chain;
- guidelines for safe procedures;
- groups of workers with potential exposure;
- information given to workers.

Deliverables for review in EU-OSHA before final submission were:

after three months:

- a draft interim report comprising a description of the methods and the initial findings;

after six months:

- a draft report including an overview of relevant literature on exposure and health effects, international policy and European legislation, an overview of preventive practices and a description of knowledge and prevention gaps;
- a draft PowerPoint presentation summarising the findings, conclusions and recommendations;
- a draft OSH Wiki article summarising the results;

after 8 months:

- a draft report, also including the recommendations.

The final report was delivered nine months after the start of the project.

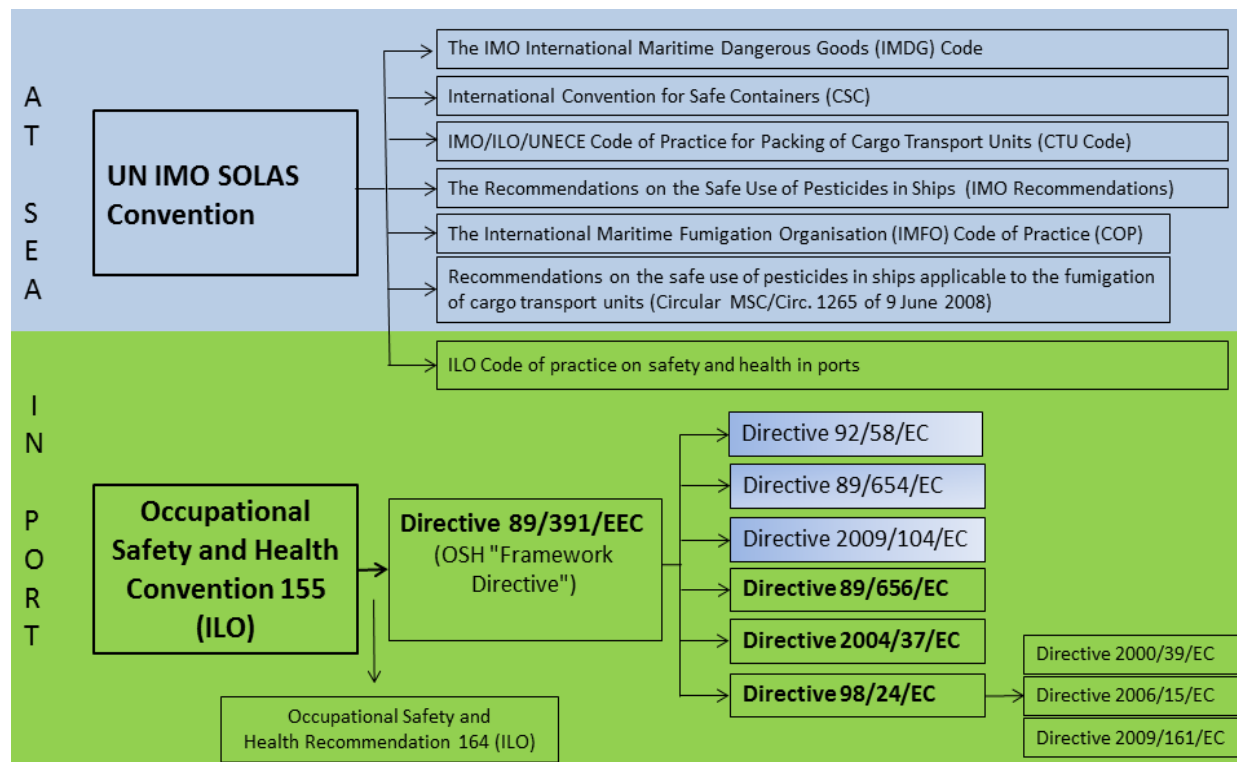
3 Relevant legislation and policy documents

There are several international regulatory instruments in place in respect of the regulation of safe handling of fumigated containers at the port/end-user, of which International Labour Organization (ILO) Convention 155 (Occupational Safety and Health Convention), Occupational Safety and Health Recommendation 164 and EU Directive 89/391/EEC are the most important framework instruments (Figure 2).

The ILO code of practice on safety and health in ports (ILO, 2016) relates to the stacking and handling of containers in container ports, but it also provides a set of recommendations on precautions that should be taken before entering a container that has not yet been confirmed safe, including placing no reliance on the absence of dangerous goods placards or fumigation warning signs, or on efficient ventilation. International Maritime Organization (IMO)/ILO/United Nations Economic Commission for Europe (UNECE) Code of Practice for Packing of Cargo Transport Units (CTU Code), a non-mandatory global code on safe packing and labelling of cargo transport units with the proper fumigation warning marks, also provides advice for other parties in the supply chain, including those involved in the unpacking of containers, those involved in the fumigation of containers and those testing containers for hazardous gases (IMO/ILO/UNECE, 2014).

In addition, the IMO instruments of the International Maritime Dangerous Goods Code (IMDG Code) and the International Convention for Safe Containers (CSC) might be appropriate targets for future efforts in respect of facilitating safe handling of containers (see below). Hence, while European Union (EU) regulations and various national actions are dominant in port or at the end-user, the IMO regulations and recommendations, including the CSC, are limited to the sea. To facilitate safe handling of fumigated containers at sea and in port/on land, joint effort from both organisations is needed.

Figure 2: Overview of the most relevant regulatory instruments in respect of regulation and facilitation of safe handling of fumigated containers at the port or end-user. Most countries have adopted their own national legislations, actions and recommendations in addition to the minimum standards



Handling of fumigated containers at the port and at the end-user is regulated by the Framework Directive on OSH (89/391/EEC) and Chemical Agents Directive (98/24/EC), which stipulate that a risk assessment must be carried out by the employer and, depending on the results that appropriate

measures must be taken before work starts. If applicable, this risk assessment has to include the safe entering of sea containers and safe handling of goods from such containers. However, compliance with present regulations has been reported to be low, partly because of companies' failure to adequately translate the regulations into operational management (Dutch Labour Inspectorate, 2008). A summary of EU regulations directly relevant for the enforcement and facilitation of safe handling of fumigated containers, including their aims and objectives, is given in Annex 1.

Some countries have implemented regulations specifically referring to the handling of fumigated containers, including Australia, Canada (Minister of Justice Canada, 2008) and the United States (United States Department of Labor, 2000).

The United States Regulation on Marine Terminals, Regulation No 1917 (United States Department of Labor, 2000), requires that:

- *Before cargo handling operations begin, the employer shall ascertain whether any hazardous cargo is to be handled and shall determine the nature of the hazard. The employer shall inform employees of the nature of any hazard and any special precautions to be taken to prevent employee exposure, and shall instruct employees to notify him of any leaks or spills. (§1917.22)*
- *When the employer is aware that a room, building, vehicle, railcar or other space contains or has contained a hazardous atmosphere, a designated and appropriately equipped person shall test the atmosphere before employee entry to determine whether a hazardous atmosphere exists (§1917.23)*
- *Tests to determine the atmospheric concentration of chemicals used to treat cargo shall be: 1) appropriate for the hazard involved and conducted by a designated person (§1917.25)*
- *Persons entering a space containing a hazardous atmosphere shall be instructed in the nature of the hazard, precautions to be taken, and the use of protective and emergency equipment. Standby observers, similarly equipped and instructed, shall continuously monitor the activity of employees within such space. (§1917.23 and 1917.25).*
- *Signs shall be clearly posted where fumigants, pesticides, or hazardous preservatives have created a hazardous atmosphere. These signs shall note the danger, identify specific chemical hazards, and give appropriate information and precautions including instructions for the emergency treatment of employees affected by any chemical in use.*

The Australian Customs and Border Protection Service requires testing for fumigants, and has established container examination facilities (CEFs). These are purpose-built, integrated examination facilities that house large X-ray systems and a range of other technologies to enable the rapid inspection and physical examination of selected sea cargo. Containers that are unloaded for physical examination are also tested for fumigants and are defumigated when required (ACBPS, 2011).

Canada has a specific regulation concerning fumigated cargo, but it is mainly restricted to activities on board the vessel or prior to being loaded (Minister of Justice Canada, 2008). However, the Canada Border Services Agency (CBSA) requires that all marine containers are tested for fumigants at the marine CEFs prior to offloading goods. Containers selected for a dockside, or pier, examination do not need to be tested for fumigants. The containers may be opened and visually inspected without the use of respiratory protection, as long as the border service officers do not enter the container (see CBSA, 2008).

Current container design limits the possibilities for conducting a proper risk assessment. At present, containers are closed, making it technically difficult to ventilate them prior to opening the doors, and to perform proper sampling of environmental concentrations of fumigants that might pose a risk to the workers opening the containers. Svedberg and Johanson (2013) have proposed that the container manufacturers provide preinstalled ventilation ports and internal sample lines that allow sampling of air in the front, middle and rear of the container. Hence, preliminary findings indicate that a revision of the CSC, which among other things sets international standards in the structural design of containers, appears to be an appropriate target for future efforts in respect of facilitating safe handling of containers both at sea and at the port/end-user (for example requirements in respect of mechanical ventilation of the container, holes for air sampling, etc.).

4 Health and safety risks related to fumigated containers at port

4.1 Overview of relevant fumigants and potential health effects

Fumigants used, some of their chemical properties and relevant occupational exposure limits are shown in Table 1. The table is not exhaustive; a few other compounds have also been used to a limited extent and will not be addressed here.

All of the compounds listed in Table 1 have significant toxic potentials, including both acute and long-term effects. As indicated below, the major fumigants used today include methyl bromide (MeBr) and phosphine (PH₃). In addition, ethylene oxide seems to be increasingly used. Formaldehyde may occur both as a fumigant and as an off-gassing product from cargo in containers, but is less frequently used as a fumigant pesticide in freight containers, as indicated below. Chloropicrin is used both as a fumigant and as an addition to other fumigants, for example MeBr, to increase awareness of the fumigant. A brief description of the toxicological characteristics of the major fumigants in use today is given below.

Table 1: Chemical properties of major fumigants and relevant occupational exposure limits (OELs)

Pesticide	CAS No	MW	Physical state ¹ ; boiling point (°C)	OEL (ppm) ²	IDLH, ppm ³	IARC group ⁴
Methyl bromide (MeBr)	74-83-9	94.94	Gas; 3.5	0.25	250	3
Phosphine	7803-51-2	34	Gas; -87.7	0.1	50	
Formaldehyde	50-00-0	30.03	Gas; -19.5	0.1	20	1
Chloropicrin	76-06-2	164.38	Liquid; 112	0.1	2	
1,2-Dichloroethane	107-06-2	98.96	Liquid; 83-84	1.7	–	2 B
Ethylene oxide	75-21-8	44.05	Gas/liquid; 10.7	0.5	–	1

¹At room temperature.

²Occupational exposure limit (OEL) in the Netherlands (ppm, parts per million).

³Immediately dangerous to life or health (IDLH) (United States National Institute for Occupational Safety and Health).

⁴Carcinogenicity classification by International Agency for Research on Cancer (IARC), Lyon, France.

–, data not available; CAS, Chemical Abstracts Service; MW, molecular weight.

Methyl bromide (MeBr) is a colourless gas at room temperature and is applied mainly in the gas phase. Workers may be exposed by inhalation or by the dermal route. It affects primarily the respiratory system and central nervous system (CNS), but gastrointestinal symptoms have also been reported. The CNS effects are considered to be the most serious and relevant for human risk assessment (Alexeeff and Kilgore, 1983; Klaassen, 2008; de Souza et al., 2013; Bulathsinghala and Shaw, 2014). MeBr may cause chronic effects such as speech impairment, lack of coordination, visual impairment and loss of memory (Alexeeff and Kilgore, 1983). Behavioural dysfunction and emotional changes may be significant and seem to be correlated with neurological alterations observed in the brain. Recovery from non-fatal intoxications seems to be slow, with frequent neurological and mental impairments (de Souza et al., 2013).

MeBr has not been shown to be carcinogenic to humans, according to the International Agency for Research on Cancer (IARC) (IARC, 1999). There are numerous examples of intoxications by MeBr related to fumigation of facilities other than freight containers, for example fumigation of museums (Yamano and Nakadate, 2006). Recently a link between the occurrence of motor neurone disease in port workers in New Zealand and the use of MeBr has been suggested (Bulathsinghala and Shaw, 2014).

MeBr has little odour at lower, but still toxic, concentrations and, consequently, humans may be exposed unknowingly. In contrast, chloropicrin has a pungent odour and is often added in low concentrations to MeBr formulations to act as a warning sign of potential harmful exposure.

Phosphine (PH₃) is a colourless gas with a garlic-like odour. It holds a unique position among the fumigant pesticides, since it is applied as a solid in the form of a metal phosphide, most often aluminium phosphide (AIP). The phosphide reacts with water vapour in the air and liberates phosphine gas, PH₃. The mechanism of action is still not elucidated, but the main harmful effects seem to be on the CNS, possibly inhibiting acetylcholine neurotransmission and mitochondrial energy metabolism, and leading to increased cellular oxidative stress. Typical symptoms in humans are respiratory effects that include pulmonary oedema, cardiac failure and hepatic failure (Nath et al., 2011; Sciuto et al., 2016). PH₃ is highly toxic, and health effects from inhalation may occur at levels as low as 5-10 parts per million (ppm) over several hours (Sciuto et al., 2016). Many studies of the acute effects of phosphine in humans are limited to accidental or intentional (suicide) ingestion of high doses of metal phosphide. Some studies have focused on inhalation among workers. There have been several fatalities after inhalation of high levels of PH₃, some of them related to fumigation of bulk cargo ships (Wilson, 1980; Lemoine et al., 2011; Lodde et al., 2015). Since the breakdown products of PH₃ are stable phosphorous oxides that enter normal cellular metabolism as phosphate (Nath et al., 2011), and since the inhibition of energy metabolism may be reversible, acute toxicity seems to be the major effect of PH₃ poisoning (Pepelko et al., 2004). Animal studies also indicate that lethality is the primary outcome, and that PH₃ does not accumulate in the body. Three human studies also indicate the lack of long-term effects after occupational exposure to up to 7 ppm PH₃ (Pepelko et al., 2004). Few studies of the long-term effects of PH₃ are available, but both neurological and respiratory chronic effects have been reported (Brautbar and Howard, 2002). Recently a case study showed long-term cardiac adverse effects in a seafarer after PH₃ exposure on board a bulk cargo ship (Szymczyk et al., 2017). Long-term effects have also been observed after repeated exposures to concentrations that do not trigger severe acute effects, as discussed below.

Formaldehyde is a nearly colourless gas with a pungent odour. It is used as a fumigant in several contexts, including in agricultural and industrial premises and veterinary clinics, as a preservative for consumer products such as laundry detergents and wallpaper adhesives, and as a component of the glue in wood-based structural panels. Today it is seldom used as a pesticide. Formaldehyde is irritating to eyes and skin, and may affect the respiratory system at concentrations as low as 0.1 ppm. At higher concentrations it may generate pulmonary oedema, inflammation and pneumonia (TOXNET, 2017). It is a known human carcinogen that causes cancer of the nasopharynx and leukaemia (IARC, 2012).

1,2-Dichloroethane is a clear, colourless liquid at room temperature with a boiling point of 83.5 °C. It has a pleasant, chloroform-like odour. It is an industrial solvent for oils and waxes and particularly for rubber. It has been used as a fumigant, but is increasingly replaced by other fumigants. It has low acute toxicity, but may have serious long-term effects. The major targets are the CNS, liver and kidneys. Signs of CNS effects may occur several hours after exposure and may be followed by hepatic and renal failure (TOXNET, 2017). There are indications that 1,2-dichloroethane is carcinogenic to animals, inducing neoplasms in several organs. The evidence for humans is limited and, accordingly, it is classified by the IARC in group 2B, possibly carcinogenic to humans (IARC, 1999).

Chloropicrin (trichloronitromethane) is a liquid at room temperature. The gas has an intensely irritating, pungent odour and has been widely used in warfare and as tear gas. It has a low odour threshold at 0.7 ppm and it is therefore often used as an additive to odourless fumigants such as MeBr, as a 'warning gas' (Oriel et al., 2009; TOXNET, 2017). Chloropicrin is also used as a broad-spectrum pesticide, although its use in fumigation of freight containers is limited compared with MeBr and PH₃ (TOXNET, 2017). The primary effects of chloropicrin are the irritating effects on eyes and the respiratory system; high concentrations also induce severe gastrointestinal effects (Oriel et al., 2009; TOXNET, 2017).

Ethylene oxide is a colourless gas at room temperature and highly reactive. It is used as a fumigant (disinfectant), particularly for health care products and heat-sensitive materials. According to the company that we visited in Rotterdam in April 2017, the use of ethylene oxide in fumigation of containers is increasing (see below). Because of its chemical structure, ethylene is highly reactive and reacts in particular with mucous membranes. Acute effects from inhalation of ethylene oxide are dominated by irritation of the respiratory system, in particular the nose and throat. In addition, high concentrations may cause CNS depression (TOXNET, 2017). With respect to long-term inhalation exposure, cancer is the most severe adverse effect, since ethylene oxide is considered a known human carcinogen that causes lymphatic, haematopoietic and breast cancers (IARC, 2012).

4.2 Groups of workers potentially exposed to fumigants

Several groups of workers are at risk of exposure to fumigants. The fumigators who carry out the fumigation are at high risk of being exposed to toxic concentrations of fumigants. However, the present report is focused on the potential exposure of personnel receiving and handling the containers at ports, and the fumigators will thus not be included.

Workers unloading containers by pallet trucks or by manual handling could be exposed if they open containers that have not been checked and declared gas free. According to information collected during a visit to a large European port (discussed in more detail below), the containers that arrive are not opened at the receiving point in the port, but are transported to larger warehouses/logistics companies, which open and unload many of the containers. Some of them are transported by truck directly to the final onshore destination. Thus, the workers at risk are those who open and unload the containers in the warehouses. If the containers are fumigated with high levels of pesticide, for example PH₃, the truck drivers may also be at risk in the event of fumigant leak, or if they open the containers at their destinations. Customs officers and food inspectors may also be exposed when containers are opened for inspection, but their risk of adverse exposure will be reduced if container opening is the responsibility of the staff of specialist companies.

Unloading of a container may take up to several hours, and the OELs normally used when assessing workers' personal exposure to chemicals, including fumigants, are based on time-weighted average (TWA) exposures over eight hours. Svedberg and Johanson (2013) used a tracer gas method to assess workers' exposure during stripping of containers. The average breathing zone and work zone concentrations during stripping of naturally ventilated 40-foot containers were 1-7 % of the arrival concentrations; however, peaks of up to 70 % were seen during opening. The authors conclude that, even if average exposures during stripping are significantly lower than arrival concentrations, they may still represent serious violations of OELs in high-risk containers.

A total of 131 short-term 'peak' personal exposure samples (20-30 seconds) from the workers' breathing zone were taken during the unloading or inspection of containers in Australia (Safe Work Australia, 2011). The two most common residual chemicals exceeding the Dutch OEL (maximum allowable concentration (MAC) value) were formaldehyde (21 %) and MeBr (21 %). In addition, 12 samples representing two- to three-hour TWA exposures were collected from 10 workers. The MAC value was exceeded for formaldehyde in only one of these 12 samples.

▪ Present knowledge on fumigants in containers

Peer-reviewed publications

There are only two peer-reviewed publications on screening of containers for toxic substances in ports. Both studies cover both fumigants and chemical off-gassing from goods, and the figures presented do not always distinguish between the two classes of compounds, illustrating the limitations of data on the issue. The first study was done in the Port of Hamburg in 2006 (Baur et al., 2010), where air samples from 2,113 containers were obtained using penetration probes that were pushed through the rubber seals of the container doors, collected in three minutes into Tedlar bags, and analysed using two mass spectrometry methods: selected-ion flow-tube mass spectrometry (SIFT-MS) and transportable gas-chromatograph mass spectrometry (GC/MS). Residual fumigants were detected in a total of 541 containers (26 %). The major fumigants detected were formaldehyde and MeBr, with concentrations exceeding the Dutch OELs in 31 % and 7 % of containers, respectively. PH₃, chloropicrin, ethylene oxide and 1,2-dichloroethane were also detected, but each in less than 2 % of the containers. The authors claim that 0.6 % of the containers had concentrations exceeding the levels classified as immediately dangerous to life or health (IDLH) (NIOSH, 2017), but it is difficult to see how the results can substantiate this claim.

The second published study on toxicants in shipping containers is from Sweden (Svedberg and Johanson, 2016). Six container ports and two inland distribution centres were included in the fieldwork, which was conducted in 2010 and 2013. Air samples were taken from 372 packed and 119 empty containers, through a flat nozzle tool led through the rubber seals between the container doors. Results from a pilot study in Gothenburg (Svedberg and Johanson, 2011) were integrated into this publication. An onsite photoionisation detector (PID) was used for non-specific analysis of volatile organic compounds (VOCs), while some selected volatile substances, including VOCs and inorganic gases,

were analysed in more detail using a Fourier-transformed infrared light (FTIR) instrument. Container air sampled in Tedlar bags was analysed by GC/MS to confirm the FTIR results and to detect substances for which the FTIR method has limited sensitivity or specificity. FTIR analysis showed that 30 of 249 containers (12 %) contained concentrations of fumigants and off-gassing substances above the eight-hour OELs, and close to 7 % were above the short-term exposure limits. The authors believed that all measurements, apart from a single instance of a confirmed fumigant, PH₃, at 3 ppm in a container listed as carrying rice bags, and possibly three instances of carbon dioxide, can be attributed to off-gassing substances. They discuss whether or not the low frequency of fumigants compared with the previous studies in Hamburg and Rotterdam could be explained partly by poorer detection limits using the FTIR methodology, and whether or not the phasing out of certain fumigants, such as MeBr, may have had some effect on fumigation trends between the studies.

▪ Reports

The Dutch National Institute for Public Health and the Environment (*Rijksinstituut voor Volksgezondheid en Milieu* (RIVM)) was one of the first institutions to look into the issue, and prepared several reports on the subject. In cooperation with the Dutch Inspectorate for Housing, Spatial Planning and the Environment, the RIVM inspected imported containers on a regular basis for a number of years, by taking samples of container air and analysing them for concentrations of fumigants and other harmful gases (de Groot, 2007). In a study in the Port of Rotterdam, 303 randomly selected containers were investigated (Knol-de Vos, 2002). Again the measurement probe was placed between the rubber seals on the container doors in order to measure the concentration of compounds inside the container. Air samples were collected in 2,4-dinitrophenylhydrazine cartridges for formaldehyde analysis and in Tedlar bags for analysis of MeBr, and unknown compounds using a GC/MS. Phosphine was analysed with an electrochemical cell. MeBr was detected in 19 containers, formaldehyde in 42 containers and PH₃ in 28 containers (Knol-de Vos, 2002). In 15 (5 %) of the containers, the concentrations of PH₃, MeBr and formaldehyde exceeded the Dutch eight-hour OEL.

In a report from 2007, the RIVM conducted a trend analysis based on air samples collected from 277 containers between 2003 and 2006 (de Groot, 2007). The method used to select containers for inspection had not changed over the years. MeBr was the compound found most frequently in these four years (in about 25 % of the analysed containers), but no clear trend was found. The percentage of containers containing 1,2-dichloroethane rose from 7 % to 33 % in the 2003-2006 period. PH₃ was detected in 8 % of the containers in 2006, and in these containers the MAC value of phosphine (140 micrograms per cubic metre (µg/m³)) was exceeded. In 2006, the atmosphere in almost a quarter of the inspected containers had several compounds that exceeded their respective MAC values. The percentage of containers with MeBr concentrations above the MAC value (1 milligram per cubic metre (mg/m³)) decreased to 11 % in 2006, after an initial increase to 20 % in 2004. The percentage of containers in which the MAC value (7 mg/m³) for 1,2-dichloroethane was exceeded shows a rising trend, from 0 % in 2003 to 9 % in 2006.

A large study was conducted on imported freight containers in Belgium and the Netherlands in 2010. The study included measurements from 42,888 containers (Luyts and Mück, 2011). In terms of location, 90 % of the containers were examined at main seaport locations, and rail and barge terminals, while the remainder were examined at the end-user location or at the customs scanning facilities. Highly sensitive measurement technology such as SIFT-MS showed that the fumigants most frequently found in concentrations above the OEL were PH₃ (0.9 %), MeBr (0.7 %), chloropicrin (0.2 %) and sulfuryl fluoride (0.05 %). The highest concentrations of PH₃ and MeBr were 368 ppm and 88 ppm, respectively.

A similar study was performed in 2011 in several European countries, including Austria, Belgium, Denmark, Germany, the Netherlands and Spain. A total of 123,349 containers were measured, using the same technology as the Luyts and Mück study. Containers with fumigant above OELs constituted 9.5 % of the total number of containers, and the major fumigants were 1,2-dichloroethane (3.8 %), formaldehyde (3.7 %), PH₃ (1.5 %) and MeBr (0.4 %). Again, one of the containers had a very level of PH₃, at 329 ppm (Mück and Stock, 2012).

A large Australian study was carried out between 2007 and 2008, examining approximately 15,000 freight containers in five ports along the coast of Australia. The results demonstrated that 17 % of the containers had fumigants at concentrations above their OEL. The dominant fumigants were formaldehyde (32 %), 1,2-dibromoethane (26 %), chloropicrin (18 %), MeBr (13 %) and ethylene oxide (5 %) (Frost, 2010).

In another Australian report, 76 containers arriving from overseas, mostly from China, were included for personal exposure sampling for about 20-30 seconds among those unloading the containers (Safe Work Australia, 2011). Six businesses were recruited from Melbourne and Brisbane, including one large retail outlet, three distribution centres, and two trucking and distribution centres. Analysis of personal grab samples from handling of 76 containers was conducted by using SIFT-MS. MeBr, PH₃ and chloropicrin were detected in 68.4 %, 32.9 % and 10.5 % of the samples, respectively. Of the 76 containers, 27 had fumigants at concentrations exceeding the corresponding OELs. The percentages of containers with levels exceeding the Dutch eight-hour MAC values were 18.4 %, 1.3 %, and 5.3 % for these three compounds. The containers with MeBr contained mostly wooden and metal furniture.

In Italy, marine chemists have since 2004 systematically analysed the air inside freight containers before opening for customs inspection or other purposes. Analysis of about 10,000 containers demonstrated that the major fumigants were MeBr, PH₃ and formaldehyde. Notably, 6 % of all containers had levels of fumigant exceeding the relevant IDLH. In total, 5,415 of the containers were contaminated with PH₃, 2,556 (47.2 %) of them had levels exceeding the OEL and 357 (6.6 %) had levels of more than 50 ppm (IDLH) (Tortarolo, 2011).

An overview of the occurrence of major fumigants in various studies is shown in Table 2.

During our visit to the large port, representatives from the gas measurement station stated that they check for/analyse fumigants and toxic gases from goods in about 60,000 containers per year. The station has contracts with several companies importing a variety of products, including electronics, children's toys, food products and medical equipment. Gas measurements are performed mainly because the customers are concerned about their reputation. The measurement station provides monthly statistics to the companies on the gases identified, their levels and the relevant goods. Approximately 90 % of the containers checked are acceptable, in that measurements show contamination levels below Dutch OELs. About 9 % are contaminated because of off-gassing from goods, while less than 1 % contain residual fumigants in concentrations above the relevant OELs. The station's database contains information about measurements from about 76,147 containers, and levels above the Dutch OEL were found for ethylene oxide (663 containers; 0.87 %), PH₃ (189; 0.25 %) and MeBr (125; 0.16 %). The most common country of origin of these containers was China, but the country of origin was unknown in the case of a large number of the containers (ethylene oxide: China 173, unknown country 477; PH₃: China 70, unknown 85; MeBr: China 45, unknown 59). Ethylene oxide was found mainly in containers with medical devices and products (532 containers), PH₃ in food and feed products (120 containers), and MeBr in decoration materials (45 containers). In comparison, toxic gases emitted from goods in concentrations above their respective OELs were found in 15,387 (20 %) containers.

Only a few containers per year are really high-risk containers with possibly fatal concentrations of fumigants; in most cases these contain foodstuffs fumigated with PH₃. It is often easy to verify the use of PH₃ for fumigation since small, empty bags or sachets that have been filled with solid PH₃ can be found in the container when it is opened. Often such bags or sachets contain residues of solid PH₃, and these residues are often thrown in a garbage bin, where they may release considerable amounts of highly toxic PH₃ gas. These residues should be taken care of, but the station personnel we interviewed claimed that there is only one company in Europe (in Denmark) that handles them properly. When PH₃ is detected in a container atmosphere, the container doors are opened by gas measurement station personnel wearing PPE, and solid PH₃ residues inside are removed. The doors are closed and the container degassed/ventilated until the fumigant is at safe levels.

The small port visited receives about five container ships per week. About 90,000 containers are received annually, of which about 20,000 come from foreign ports. Eighty per cent of containers are sent unopened to the customer, while the rest (20 %) are opened in the port by a workforce of 20 persons. There have never been measurements of fumigants or other toxicants in containers in this port.

Table 2: Major fumigants detected in freight containers in different studies

Study	Total no of containers	Percentage of containers with pesticide level > Dutch OEL (highest detected concentration in ppm)						
		Formaldehyde (H ₂ CO)	Methyl bromide (CH ₃ Br)	Phosphine (PH ₃)	Chloropicrin (CCl ₃ NO ₂)	1,2-Dichloroethane (ClCH ₂ CH ₂ Cl)	Ethylene oxide (H ₂ COCH ₂)	
Rotterdam, the Netherlands, 2002 ¹	303	1.3 (13.4)	3.4 (90)	2.0 (> 20)	n.d.	n.d.	n.d.	
The Netherlands, 2003-2006	277	n.d.	13.4	2.9	2.4	4.3	n.d.	
Australia, 2007-2008 ³	14,943	31.6	13.0	3.5	18.0	n.d. (*)	5.4	
Australia, 2012 ⁴	76	21.1 (2)	21.1 (4.4)	1.3 (0.15)	5.3 (1.6)	2.6 (9.6) (*)	0	
Hamburg, Germany, 2006 ⁵	2,113	30.9	7.1	0.9	1.3	1.3	0.9	
Italy, 2004-2010 ⁶	9,482	4.7	> 13.8 (1,380) ¹⁰	47.2 (680)	n.d.	n.d.	n.d.	
Belgium and the Netherlands, 2010 ⁷	42,888	2.6 (40)	0.7 (88)	0.9 (368)	0.2 (26)	2.7 (239)	n.d.	
Europe, 2011 ⁸	123,439	3.7 (38)	0.4	1.5 (329)	0.01 (26)	3.8 (152)	n.d.	
Sweden, 2013 ⁹	249	3.6 (2)	n.d.	0.4	n.d.	0.8 (30)	0.7 (1.7)	

Note: n.d., not determined.

*It should be noted that both the Australian studies found 1,2-dibromoethane in several containers; in particular, the larger study found that 26.1 % of the containers had 1,2-dibromoethane levels exceeding the OEL.

¹Knol-de Vos (2002). ²de Groot (2007). ³Frost (2010). ⁴Wagstaffe et al. (2012). ⁵Baur et al. (2010) ⁶Tortarolo (2011). ⁷Luyts and Mück (2011). ⁸Mück and Stock (2012). ⁹Svedberg and Johanson (2017).

¹⁰13.8 % > 1 ppm.

4.3 Health effects among workers at port

Adverse health incidents with fumigants used for pest control are reported frequently (Burgess et al., 2000; Sudakin, 2005, Oriol et al., 2009; Alavanja and Bonner, 2012). Many cases arise from the agricultural use of pesticides, in some cases affecting both applicators and people living in the neighbourhood (Lee et al., 2011). Some incidents occur in relation to fumigation of buildings, including both public structures and private homes (Yamano and Nakadate, 2006; Lemoine et al., 2011). In January 2014, fumigation with PH₃ of a private home in Jerusalem, Israel, by a professional exterminator resulted in the death of two children. Two other children were seriously harmed but survived (The Times of Israel, 2014).

Although adverse health effects after occupational exposure to pesticides seem to occur frequently, the documentation of these incidents is often insufficient, lacking traceable description of exposure with respect to site and time, well-documented exposure data, description of adverse health effects and clinical symptoms, and, not least, publication in recognised and traceable sources.

In particular, incidents related to the opening of transport containers or fumigant intoxications on bulk cargo ships are seldom reported in scientific journals or described in publicly available reports. For those that are reported, the sources are variable, but include a few scientific papers, conference presentations, newspaper articles and short notes published by organisations such as the Marine Accident Investigation Branch (MAIB).

To address container incidents and adverse health effects, a comprehensive literature survey was conducted using PubMed, Web of Science and Google Scholar. The Technical report by the Joint Research Centre (JRC), the European Commission's science and knowledge service, was also used.

PubMed: The search was conducted in February 2017 with the following search string in all fields: '(fumiga*NOT fumigatus) AND (occupational OR container*)'. The term 'fumigatus' was used to exclude all articles concerning the fungus *Aspergillus fumigatus*. The search returned 247 references and the oldest was from 1955. The papers were examined by title and abstract, and articles were excluded according to the following criteria:

- language not English, German or Scandinavian (Norwegian, Danish or Swedish);
- chemicals not used for elimination of microorganisms or pests;
- not pesticide in gaseous form;
- article concerned effect of pesticide against target organism, not humans;
- pesticide not related to freight containers;
- health effects/risks during the fumigation process only (that is, health risks against fumigators).

Using the exclusion criteria above, 19 relevant articles were found among the 247 returned from the search. A total of 13 papers were from the German research group headed by Professor Xaver Baur, but several of these are reviews with limited quantities of exposure measurement data and documented health effects related to fumigants.

Two papers from Germany reporting exposure incidents were found. Preisser and coworkers described 26 patients referred to a clinic in Germany with symptoms of pesticide intoxication after opening transport containers (Preisser et al., 2011). However, exposure data were not available and the majority of these patients were examined weeks or months after the incident, making it difficult to relate the symptoms directly to the presumed exposure. In addition, the compounds detected in several of the blood samples did not match the presumed exposure agent/fumigant.

Another paper described three cases of presumed intoxication by transport containers (Preisser et al., 2012). In two of the cases PH₃ was indicated as the fumigant, while in the third case ethylene dichloride was indicated. However, the paper lacked documentation of exposure data, and in two of the cases no information about where the incident took place was provided.

A recent paper presented case reports from a warehouse in Europe receiving and unloading containers. The paper lacks detail on where and when the incidents took place. MeBr and ethylene oxide were detected in the storage room five days after the workers showed signs of intoxication, but there were no measurements of the air in the containers before or immediately after opening. Furthermore, blood samples for biomonitoring for pesticide residues or metabolites did not allow for any firm interpretation (Kloth et al., 2014).

The PubMed search revealed only one paper with sufficient documentation of an intoxication case related to the opening of transport containers: two dock workers who opened a container in the Port of Rotterdam in 2006 were acutely intoxicated, and subsequent field analysis by the fire brigade confirmed the presence of MeBr as the likely causative agent, although the paper did not contain any data on MeBr levels (Breeman, 2009).

Web of Science: A similar search, with the same search string used in the PubMed search, retrieved 236 papers; the oldest was from 1974. A total of 133 of these papers were not included among those returned from the PubMed search. The titles and abstracts of these 133 papers were examined using the same exclusion criteria as above, resulting in only eight relevant papers. A closer examination of these eight papers revealed that only three included health effects related to exposure to pesticides. However, all three are meeting abstracts, and two of them (Spijkerboer et al., 2008; Scholtens et al., 2009) describe the same incident of two dock workers being poisoned by MeBr by opening a transport container. The abstracts did not contain any information about location and date, but the incident most probably occurred in the Netherlands, since the authors were from the National Institute for Health and the Environment in the Netherlands. Most likely the abstracts refer to the incident described by Breeman (2009).

The third abstract, by Hahn et al. (2012), describes a survey of German poison centres in December 2007 regarding intoxications from fumigated containers. The response showed 30 incidents between 2003 and 2007, which had affected 71 subjects; however, none of the incidents had caused serious health effects, but only moderate and mild symptoms.

Google Scholar: A search that included all the words 'fumiga container occupation freight', without the word 'fumigatus', and with a timeframe beginning in 2000, returned 329 hits. Using the same criteria as above, seven papers were identified that were not picked up by the searches on PubMed and Web of Science. The search was repeated by changing the search option to include all the words 'fumiga container occupation health' and at least one of the words 'freight ship', but without the words 'fumigatus soil fumigator'. This returned 273 hits, but only one new relevant paper. A third search was conducted with all the words 'fumiga container worker health' and at least one of the words 'freight ship', but without the words 'fumigatus soil fumigator'. The search returned 347 hits, but only one new relevant paper.

In total the Google search had returned nine relevant papers that were examined closely. Only one of these describes human health effects after presumed exposure to fumigants during the opening and unloading of transport containers. Clinical symptoms are described but there are no quantitative exposure data, making it difficult to relate the health effects to specific fumigant exposure (Preisser et al., 2009).

One of the other papers, from the 'Chemical Hazards and Poisons Report' from the Health Protection Agency in the United Kingdom (UK), included a reference to a previous report in the same series. This report contained a paper (Goodfellow et al., 2009) that described three incidents in the UK involving unloading containers fumigated with PH₃. In all three incidents it seemed that the fumigant was identified based on residual solid AIP. Two of the incidents occurred in Leeds in 2002, and one in Elland, West Yorkshire, in 2007. The paper did not, however, contain details of the medical outcomes of the workers affected.

From participation in a workshop in Berlin in 2014, regarding fumigants in transport containers, we had become aware of the Expertise Centre Environmental Medicine (ECEM) in Arnhem, the Netherlands. According to one of its managers, Dr Atie Verschoor, the centre has received several patients who had been intoxicated by opening transport containers. Since the PubMed and Web of Science searches had retrieved no articles from this clinic, Google was searched for 'Verschoor and health and containers'. That returned 36 hits, among them two relevant short reports describing patients referred to the ECEM presumably after intoxication by container fumigants (Verschoor et al., 2010, 2011). However, these reports lack substantial data on exposure conditions (time, concentrations), elapsed time to clinical examination, clinical symptoms and severity, etc.

The results from the searches above also provided the relevant literature for the review above regarding concentration and fumigant exposure levels at ports.

The literature survey conducted in the present report illustrates one of the main problems regarding possible adverse health effects related to the opening and unloading of freight containers in ports: lack of documentation. This is somewhat in contrast to the situation with fumigation on board bulk cargo ships, for which the documentation is also limited, but still much more extensive than for containers.

Several fatal incidents have even occurred, and these are well documented. Based on our knowledge it seems that there might also be a difference in the severity of outcomes of the two types of exposure: so far, there have been no reports of fatalities in relation to the opening of transport containers (Table 3), while fumigation of bulk cargo ships has led to several fatalities, including of stowaways (Table 4).

Table 3: Reported incidents/intoxications with fumigants in transport containers

Date	Location	Fumigant	No of subjects		Reference/source
			Affected	Fatalities	
November 2008	–	PH ₃	1	0	Case reports, (Preisser et al., 2012) (PubMed)
2008?	–	PH ₃ ?	1	0	
2006	Warehouse, Germany	1,2-Dichloroethane	2	0	
2006	Rotterdam	CH ₃ Br	2	0	Breeman (2009) (PubMed)
2008-2009	Rotterdam?	1,2-Dichloroethane	20	0	Verschoor et al. (2010) (Google)
		PH ₃	9	0	
		CO ₂	2	0	
		CH ₃ Br	2	0	
2007-2008?	The Netherlands?	CH ₃ Br	2	0	Spijkerboer et al. (2008) (Web of Science)
2003-2007	Germany	CH ₃ Br, PH ₃ 1,2-dichloroethane	71	0	Hahn et al. (2012)*

*It is unclear whether the affected subjects were workers opening and unloading containers only, or whether they also included fumigators.

A possible explanation may be that the exposure on a bulk cargo ship may be of considerably longer duration, and is more difficult to escape. In addition, the fumigants may be present in the living compartments on the ship, without this being recognised until the exposure has become fatal.

Table 4: Reported incidents/intoxications with fumigants on bulk cargo ships

Date	Location	Fumigant	No of subjects		Reference/source
			Affected	Fatalities	
September 1978	Bulk grain freighter, east coast Canada/USA	PH ₃	31 (1)	2 (1)	Wilson et al. (1980) (PubMed)
1988-1996	Danish bulk carriers	PH ₃	2	1 (2)	Hansen and Pedersen (2001) (PubMed)
		Unknown pesticide	4	3 (2)	

Date	Location	Fumigant	No of subjects		Reference/source
			Affected	Fatalities	
October 2007	General cargo ship, Russia-UK	PH ₃	1	1	MAIB (2008)
2010	General cargo ship, Latvia-Antwerp	PH ₃	2	1	
2010	Bulk carrier, east coast USA	PH ₃	16	0	
2009	General cargo ship, Lagos, Nigeria	PH ₃	6 ³⁾	1 ³⁾	
2000	Bulk carrier, west coast USA	PH ₃	12	0	Gard (2012)
1997	Geared bulker, Brazil-Ireland	PH ₃	5	0	
2008	Bulk carrier, France-Egypt	PH ₃	13	1	Lodde et al. (2015)
2015	Bulk cargo, Ivory Coast	PH ₃	> 3	0	Szymczyk et al. (2017)

¹Two children.

²Four stowaways.

³Six stowaways.

5 Present procedures and practices

Practices in opening containers at ports should be based on risk assessments that comprise hazard identification, exposure assessment and risk characterisation, followed by preventive measures. The employer is responsible for carrying out the risk assessment, for informing its employees about the risks and for establishing the appropriate preventive measures. This chapter describes these aspects firstly by providing examples of risk communication systems, risk assessments and procedures/guidelines for the safe handling of fumigated containers and, secondly, by providing examples of current practices in the areas of risk identification, monitoring equipment, degasification/ventilation and PPE.

5.1 Risk communication systems

There is limited communication on the potential health risks from fumigated containers as they pass along the transport chain, from the exporting country to ports in the importing country, including the risks to staff in logistics companies, customs officers and workers unloading containers. Ideally a global communication system with a common risk database should be established, comprising information on the risks of transporting not only fumigated containers, but also other hazardous chemicals and radioactive material.

According to the outcome of an interview with representatives of the measurement station at the large port we visited, cost is one of the major obstacles to labelling of fumigated containers. They claim that generally there is decreasing information about container content along the transport chain. Information about goods is often missing, but country of origin should be available from the shipping documents. Information needed from the exporter in the country of origin includes, among other things, what has been used for fumigation, the amount used and the humidity on departure.

The Dutch Labour Inspectorate has stated that businesses will have to become more active in coming to proper agreements with their suppliers abroad about whether or not containers are fumigated (Dutch Labour Inspectorate, 2008). It reports that some businesses have already made sound agreements with their foreign suppliers on this matter, and gives examples. When this is the case, the Dutch Labour Inspectorate can get by with taking only spot measurements to investigate the presence of hazardous substances in these containers.

An example of a dangerous goods communication system that is currently operating on a city level is the GEGIS dangerous goods information system in Hamburg (DAKOSY, n.d.). This system is made for the safety and monitoring of dangerous goods transport in the port, and provides the water police and fire brigade with an overview of dangerous goods movements to, from and within the port area (Figure 3). In accordance with applicable maritime safety regulations, companies involved in dangerous goods handling (terminals and carriers/brokers) must electronically report all dangerous goods movements to GEGIS.

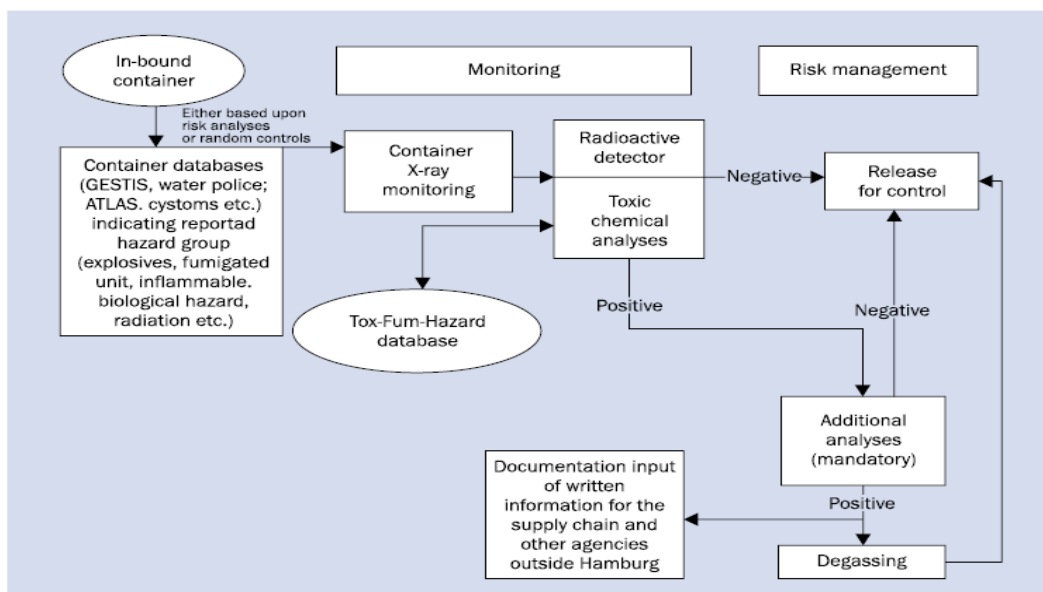
Figure 3: The dangerous goods information system GEGIS is operated by DAKOSY on behalf of the City of Hamburg (DAKOSY, https://www.gegis.net/index_english.html)



5.2 Risk assessment

According to Baur et al. (2014), the Hamburg Customs Model is implemented in the Port of Hamburg, and is a risk assessment system to protect the controlling bodies when handling fumigated containers, and can serve as an example of a system for preventive measures. Figure 4 shows that the system is connected to the GESTIS database (<http://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index-2.jsp>), an open information system on hazardous substances operated by German Social Accident Insurance. Figure 4 further indicates the procedure for monitoring/screening of hazards, degassing if necessary and final release of the container. If the screening detection is positive, additional mandatory analytical measurements are required. The transit container receipt has to indicate information about a possible chemical hazard, if present.

Figure 4: Preventive measures model monitoring system in the Port of Hamburg in 2010 (Baur et al., 2014)



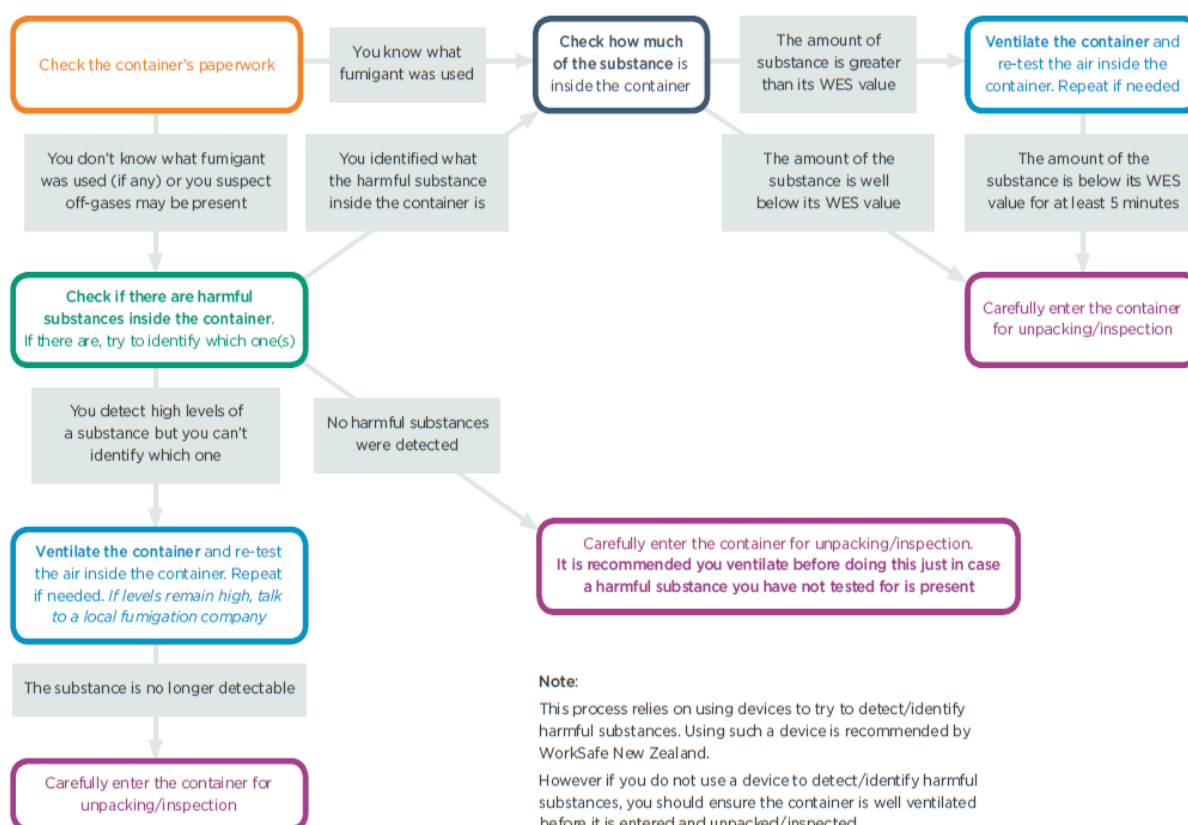
The Dutch Labour Inspectorate carried out inspections in 2008 at 405 companies that receive containers from abroad (Dutch Labour Inspectorate, 2008). The inspected companies received more than 75,000 containers during the inspection period. Only 62 (15 %) of them demonstrated proper compliance with the Working Conditions Act with regard to risks in entering spaces that may contain hazardous substances. A total of 343 (85 %) of the companies were not in full compliance with the law. The high percentage of enforcement procedures instituted (85 %) was due to the fact that companies knew the risks of fumigated containers but did not have a good idea of how to translate the working conditions regulations to their specific company situations.

5.3 Procedures and guidelines

In addition to the international and national regulations related to container handling, there are instructions/information sheets from organisations and employers on safe handling of containers.

One example of simple guidance on good practices was recently developed by WorkSafe New Zealand (WorkSafe New Zealand, 2017). Figure 5 illustrates the main procedures dealt with in this guide, topics that are described in more detail in sections 5.3 to 5.8 of the present document.

Figure 5: Good practice for safely entering shipping containers (WorkSafe New Zealand, 2017)



<https://worksafe.govt.nz/topic-and-industry/hazardous-substances/guidance/industry-guidance/inspecting-and-unpacking-containers-harmful-substances>

Examples of detailed procedures are summarised in sections 5.3.1 and 5.3.2:

'Technical Rules for Hazardous Substances (TRGS 512) "Fumigations"', Germany (BAuA, 2007) (https://www.baua.de/EN/Topics/Work-design/Hazardous-substances/_functions/Publications-search_Formular.html?nn=8710720);

'Safe handling of gasses in shipping containers', ABC system, the Netherlands (Gezond Transport, 2011) (<http://www.kgn-measurement.nl/Protocol%20gasses%20in%20import%20containers.pdf>).

Examples of short information sheets are:

- 'Managing risks of hazardous chemical exposure when unpacking shipping containers — information sheet' (Safe Work Australia, 2016a) (https://www.safeworkaustralia.gov.au/system/files/documents/1702/managing_risks_of_hazardous_chemical_exposure_when_unpacking_shipping_containers_information_sheet.pdf);
- 'Managing risks of methyl bromide exposure when unpacking shipping containers — information sheet' (Safe Work Australia, 2016b) available at: (https://www.safeworkaustralia.gov.au/system/files/documents/1703/managing_risks_of_methyl_bromide_exposure_when_unpacking_shipping_containers_information_sheet.pdf);
- 'Ventilation of fumigated freight containers with methyl bromide mixtures' (NT WorkSafe, 2015, Australia) (http://www.worksafe.nt.gov.au/Forms_and_Resources/ventilation-of-fumigated-freight-containers-with-methyl-bromide-mixtures.docx).

Examples of information cards/leaflets (see also section 5.3.3) are:

- 'Gases in containers. Be aware of the risk' (FNV (n.d.), the Netherlands) (<http://www.netwerkarbofnv.nl/werkgroep-gassen-containers>);
- 'Containergassen' (Gasmeetstation (n.d.), the Netherlands) (<http://www.gasmeetstation.nl/veiligheidswijzer/>);
- 'Sicherheit beim Umgang mit begasten Containern' (BG Verkehr (2011), Germany) Berufsgenossenschaft für Transport- und Verkehrswirtschaft, Hamburg, Germany (<https://www.bg-verkehr.de/medien/medienkatalog/flyer/sicherheit-beim-umgang-mit-begasten-containern>);
- 'Toxische gassen' (Sociale partners van de sector Transport en Logistiek (n.d.), Belgium) (www.toxischegassen.be).

5.3.1 'Technical Rules for Hazardous Substances (TRGS 512) "Fumigations" ' (BAuA, 2007)

In summary, this document, issued by the Federal Institute for Occupational Safety and Health (*Bundesanstalt für Arbeitsschutz und Arbeitsmedizin* (BAuA)) in Germany, states that a risk assessment is always necessary for the safe opening of containers. Measurements of pollutants with the container door closed are necessary to determine the risk potential. In the case of flows of goods of a known nature (countries of origin, contents, sender), measurements carried out on a random sampling basis may be sufficient. If unusual odours are perceived in the atmosphere of a transport unit, it is also to be assumed that contamination is present. This is to be characterised more precisely, for example by screening with multifunctional devices.

Contaminated transport units are to be ventilated until the measured concentrations are below the assessment criteria. If ventilation does not lead to a reduction in the pollutant concentration to below the corresponding assessment criteria because of the nature of the goods and packaging, the transport unit in question must be unloaded by personnel wearing suitable respiratory protection (full-face mask with a filter attachment) and the goods subjected to further forced ventilation by fans with the packaging open in suitable sheds, which must be secured against unauthorised entry, until the values fall below the assessment criteria. The TRGS procedures for safe opening of containers are detailed and demonstrate the complexity of developing and performing a safe procedure.

The TRGS includes detailed procedures on several aspects of container handling, which are briefly summarised below.

Identification of the risk potential

- The transport unit is assumed to be fumigated based on:
 - labelling;
 - relevant information or notes in the loading and freight documents;

- detection of a fumigant by measurement.

B) Indications that the transport unit has been fumigated:

- labelling has not been fully removed, or is illegible or otherwise unclear;
- the ventilation slits on the transport unit have been glued together or sealed;
- the freight has been packed and stored on wooden pallets, according to the attached documents;
- the results of measurements are unspecific;
- other suspicious facts.

Opening potentially fumigated transport units

Depending on whether the container is classified into A or B, procedures are described for measurements, safety distance, ventilation period, respiratory protective equipment, and visual inspection for fumigant residues (by introducing a probe).

Release of fumigated containers after opening and ventilation

A sufficiently long ventilation phase is necessary, with reventilation if the container is not unloaded in good time. Measurements to check whether or not fumigants are still present inside the unit may also be necessary.

Release of containers after measurements.

There is a release certificate for documentation — a release certificate loses its validity after 24 hours.

Personal protective equipment (PPE)

The type and nature of the PPE are to be established in the risk assessment.

Respiratory protection equipment for phosphorus hydride includes full-face masks with a filter of at least class B2.

5.3.2 'Safe handling of gases in shipping containers' (Gezond Transport, 2011)

The action plan includes a policy process and an operational process. The policy process indicates how a company can design a policy to deal safely with gases in containers. The operational process leads to the 'safe' opening and entering of containers. This strategy is based on a preliminary examination of the containers, placing them in one of the following categories, which determine the further processing of the container (flow):

- Category A: The shipping container contains hazardous gases. The gases in question and their expected concentration are known (controlled risk).
- Category B: It is not known if the shipping container contains hazardous gasses (undetermined risk).
- Category C: It is highly unlikely that the shipping container contains hazardous gases (negligible risk).

The action plan uses detailed flow charts for safe handling according to the three container categories (A, B and C), and refers to several information cards on different procedures.

The action plan consists of the following steps:

1. A company policy is drawn up — assignment of containers into category A, B or C.
2. Containers are reported.
3. A measurement survey is conducted, with different strategies for category A, B and C containers. Recommendations from measurements are directed at, among other things:
 - release of the shipping container, with or without conditions;

- ventilation/degassing of the container.

4. Measures are based on results from step 3.

5. Safe opening and entering of the containers may then be possible.

The company releases the container, and it may be opened and entered if:

- previous research shows the container is safe to enter (category C);
- the measurements indicate that the container can safely be opened and entered;
- the history and knowledge of the container flow corresponds with the measuring results.

6 Registration of collected data takes place.

6.1.1 Example of measurement strategy

As an example, one warehouse company in the Netherlands (Rotra Warehousing) has developed a procedure for classification of containers and measurement strategy, which is mainly in compliance with the action plan described below (Table 5). The containers are classified in three categories:

- Category A: These containers have definitely been fumigated, and we are aware of the type of gas that has been used. These containers will always be checked.
- Category B: It is uncertain if this container has been fumigated and if this container can be opened safely without any risks for the health of our employees. These containers will always be checked. It can happen that the supplier states that no gas has been used. However, gas measurements have not verified this.
- Category C: There is 100 % certainty that the container has not been fumigated. However, a random check will still be applicable.

The company's strategy for measurement of containers by category is summarised in Table 5.

Table 5: Summary of strategy for measurements by container category (Rotra Warehousing, n.d.)

Category A		Category B		Category C	
100 % of containers are always tested	The first two containers from each supplier are tested	Subsequently, 10 % of containers from these suppliers are checked at random	The first two containers from each supplier are tested	Subsequently, 5 % of containers from these suppliers are checked at random	

6.1.2 Examples of leaflets/information sheets/cards

Several organisations have made leaflets and information sheets about how to handle fumigated containers. Two examples are given in Figure 6 and Figure 7.

Figure 6: Example of information card



(Federatie Nederlandse Vakbeweging; <https://www.fnv.nl/contact/arbo-adviespunt/>)

Figure 7. Example of part of information leaflet

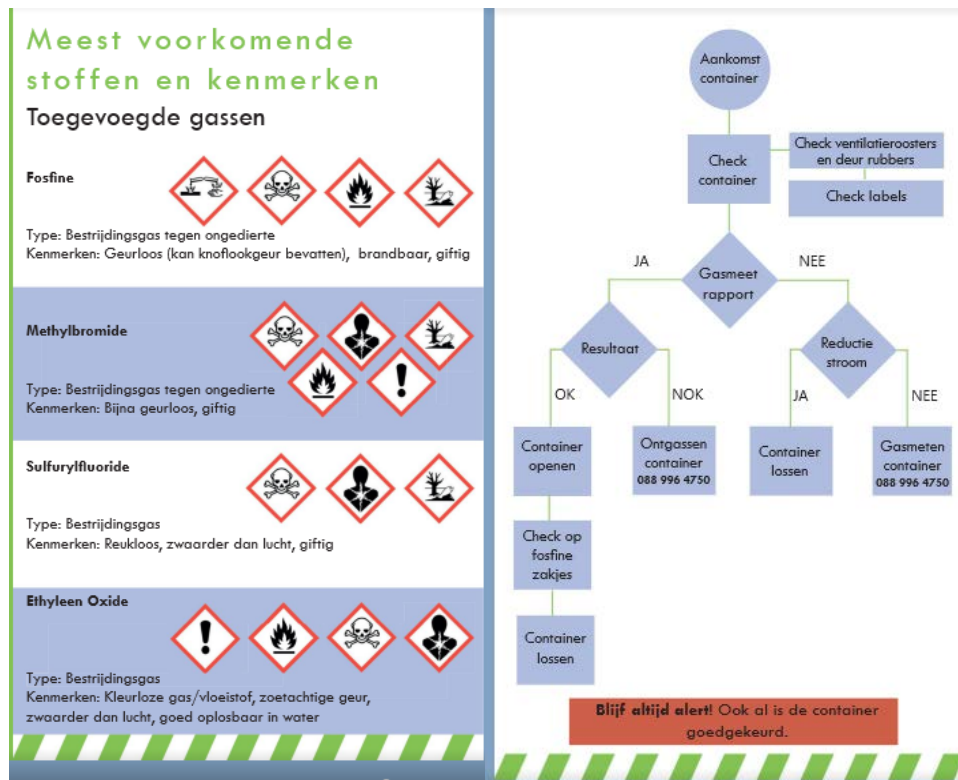


Figure 7. Example of part of information leaflet (Cont)

Productie gassen

1,2 Dichloorethaan



Type: Productiegas
Kenmerken: Zoete geur

Formaldehyde



Type: Productiegas
Kenmerken: Sterke onaangename geur, giftig

Alpha Pinene



Type: Productiegas
Kenmerken: Typerende dennengeur

Tolueen



Type: Productiegas
Kenmerken: Lijm geur

Ammoniak



Type: Productiegas
Kenmerken: Penetrante geur, zwaarder dan lucht, giftig

Overzicht stoffen

		GRENSWAARDE
Dichloromethane	CH ₂ Cl ₂	100 ppm
Hexane	C ₆ H ₁₄	20 ppm
n-Pentane	C ₅ H ₁₂	600 ppm
Alpha Pinene	C ₁₀ H ₁₆	25 ppm
Acetaldehyde	C ₂ H ₄ O	20 ppm
Methanol	CH ₃ OH	99 ppm
Oxygen	O ₂	19-22 %
Carbon dioxide	CO ₂	4900 ppm
Carbon monoxide	CO	25 ppm
Nitrogen dioxide	N ₂ O	0.2 ppm
LEL		10 %
Ammonia	NH ₃	19.8 ppm
Formaldehyde	CH ₂ O	0.12 ppm
Ethylene oxide	C ₂ H ₄ O	0.46 ppm
Benzene	C ₆ H ₆	1 ppm
Toluene	C ₆ H ₅ CH ₃	40 ppm
Methyl bromide	CH ₃ BR	0.25 ppm
1,2 - dichloroethane	C ₂ H ₄ Cl ₂	1.7 ppm
Chloropicrin	CCl ₃ NO ₂	0.1 ppm
Styrene	C ₈ H ₈	25 ppm
Phosphine	PH ₃	0.1 ppm
Sulfuryl fluoride	SO ₂ F ₂	2.5 ppm
Hydrogen cyanide	HCN	0.9 ppm
Carbon disulfide	CS ₂	4.9 ppm
Acetone	C ₃ H ₆ O	500 ppm

(<http://www.gasmeetstation.nl/veiligheidswijzer/>)

6.2 Identification of hazardous containers

Between 2002 and 2011, several scientific articles and reports described violations of the regulations concerning appropriate labelling, which stipulate that warning signs must accompany transportation documents, specifying the fumigation procedures for fumigated containers.

Knol-de Vos (2002) reported that, although MeBr or PH₃ was detected in 23 % of randomly selected containers in Rotterdam, only 3 of 303 containers had some kind of warning sticker, and none of them was accompanied by valid dangerous goods transport documentation.

In the study in Hamburg (Baur et al., 2010), only 3.6 % of the 2,113 containers examined carried any form of fumigation hazard warning; none of these warnings corresponded to those required by the IMDG Code, and they consisted mostly of fragments of old, presumably outdated, warnings.

None of the 101 randomly selected containers in Gothenburg were labelled (Svedberg and Johanson, 2011). The authors argued that lack of compliance with the labelling regulations raises serious concerns, as the warning sign is the first and perhaps the only message the worker receives that the container atmosphere could be hazardous.

In the Australian report, only one of the surveyed containers displayed any external notice that the contents had been fumigated, and in discussions with managers and workers it was revealed that no systematic assessment of containers took place prior to entry by workers (Safe Work Australia, 2011).

A Danish study concluded that, in practice, the measures applied to prevent harmful chemical exposures released from transport containers are based primarily on attempting to identify the containers that carry occupational health risks (Pedersen et al., 2014).

Authorities/labour inspection in some countries, such as the Netherlands and Germany, have focused on fumigated containers, as indicated by compliance reports and websites (Dutch Labour Inspectorate, 2008). However, based on feedback on an EU-OSHA survey in 2016, the involvement of authorities in most European countries seems to be weak on this topic.

The representatives from the gas measurement station whom we spoke to when we visited the large port stated that, in their experience, fumigated containers are never appropriately labelled, or that perhaps 1 in 1,000 containers are. In some cases the labelling and information from the manufacturer is misleading. For example, a container that contained shoes was not expected to contain PH₃, but measurements of the atmosphere inside the container indicated high concentrations of the fumigant. According to the measurement station, the attitude in the port of shipment may often be that 'we will fumigate this container with PH₃ because that is what we do with all the others', even if the contents do not indicate that it is required. Best practice would be for the exporter to remove phosphide residues after fumigation, degas and declare the container gas free before it is shipped.

6.3 Knowledge and awareness

The practice of handling containers was investigated in a qualitative study in Denmark based on semi-structured interviews with nine key informants, including managers and health and safety representatives of organisations that handle containers (Pedersen et al., 2014). The authors concluded that there was limited knowledge among managers, workers and even occupational health professions about the types of chemicals that can be released from containers. However, all the interviewees agreed on the existence of such exposures. MeBr was the only fumigant that all interviewed persons could quote. Some interviewees expressed their awareness about the occurrence of general industrial chemicals in containers but could not specify them. Workers unloading containers had very limited understanding of the risk posed to them from chemical exposure in transport containers. Because of the limited number of participants in that study, the authors argue that their findings could be generalised only to the Danish context, and with caution. The interviewed managers were aware of the existence of relevant international and national regulations but were typically not able to specify them (Pedersen et al., 2014). The interviewees were more familiar with the local instructions but these were reported to give insufficient guidance for several practical challenges in preventing chemical exposures during work with containers.

In Australia, informal discussions were held with five experienced managers and 15 workers (Safe Work Australia, 2011). In this study the numbers of workers who completed the surveys was again low, and the authors argued that the results should not be used to make generalisations for broader industry or

occupational groups. However, about 70 % of the workers had completed specific work health and safety training on unpacking shipping containers. None knew a large amount about the risks of fumes in containers, but 67 % knew a little. The most significant reason for not taking safety precautions was lack of training (33 %), followed by lack of awareness that the container atmosphere may contain chemical fumes (29 %). Thus, although most workers had received work health and safety training, there was still a large degree of uncertainty regarding the risks associated with fumigated containers and workers' ability to identify such containers.

Representatives from the gas measurement station we visited at the large port stated that many logistic companies/warehouses employ people from staffing agencies, including many workers from eastern Europe, in particular Poland. The high turnover of personnel makes it difficult to follow up employees with respect to possible health problems that might be associated with exposure to chemicals during container opening/unloading. Information on fumigation hazards for workers is generally very limited, but there are five or six relevant external training companies in the Netherlands. Some logistics/warehouse companies have made information cards. Their experience is that the ABC system from Gezond Transport is difficult to use since different items from different manufacturers are often placed in the same container. In addition, the knowledge that container chains/exporters/goods have previously been identified as risky/fumigated or safe is of little use for subsequent identification of hazardous containers since the situation changes over time.

In the small port we visited, the employer was aware of the possibility of fumigated containers, but did not provide any specific training on this topic for workers. The workers we met had many years of work experience in the port, but they were not aware of the possibility of fumigated containers.

The Annex of the German TRGS 512 (BAuA, 2007) describes the contents of training courses that provide knowledge on fumigation at various levels, including a 'Shortened course on expert knowledge for transport units' (Annex 1c) of at least 15 45-minute lectures, including an examination (Figure 8).

Figure 8: The contents of a training course on safe handling of fumigated containers (BAuA, 2007)

Annex 1c to TRGS 512	
Shortened course for the acquisition of expert knowledge in opening, ventilating and releasing transport containers under gas	
Requirement: First-aid course and suitability to wear respiratory protection equipment	
Subject and contents	Time
Statutory regulations: IMO Recommendations/Guidelines, Hazardous Substances Ordinance, TRGS 512 etc. e.g. Phytosanitary Ordinance, ISPM 15 and responsibility under criminal law	2 TU
Properties and mode of action of relevant fumigants: Bromomethane, phosphorus hydride, sulfuryl difluoride, hydrogen cyanide and other fumigants which may occur and are listed in GefStoffV	3 TU
Occupational safety - Risk assessment with allowance for ancillary risks such as other gases which may occur, e.g. formaldehyde, carbon dioxide, carbon monoxide and chloropicrin, phenolic substances, fungicides, insecticides, fungus spores, reduced oxygen concentrations and potentially explosive atmospheres - Regulations of the Berufsgenossenschaften	2 TU
Gas measurement methods Demonstration of different measurement processes for the relevant gases	2 TU
Personal protective measures with emphasis on respiratory protection equipment	2 TU
First aid for accidents involving poisoning Gas poisoning in general and peculiarities of certain gases	1 TU
Practical exercises: Container assessment, weak points, approach, technical handling and preparation of the release certificate	2 TU
Final written examination	1 TU
Total duration	15 TU

6.4 Monitoring equipment and procedures

First, it should be emphasised that chemical contamination of air is rarely due to the presence of a single chemical compound; rather it is due to a mixture of several chemicals. In principle, there are two methods to measure the content of the different compounds:

- 1) The first method seeks to determine the amount of each chemical compound in the mixture simultaneously. This can be done by spectroscopy, in which light is passed through a sample of air. Each chemical compound will absorb some of the light, with different compounds absorbing light of different wavelengths. Using sophisticated computer models, the quantities of different chemical compounds in the mixture can be estimated. Another method is to use high-energetic ultraviolet light to ionise molecules and then detect the electrical current that is generated.
- 2) In the second method, the different chemical compounds are separated from each other by a process termed chromatography, and then each single compound is detected and quantified. The most sensitive and reliable method for identification and quantification of most of the pesticide fumigants is by use of liquid chromatography (LC) or gas chromatography (GC) to separate the different compounds, and to then use mass spectrometry (MS) to identify and quantify each compound.

Examples of the first methods are FTIR and PID, both of which can be carried out using portable instruments that can be used for online monitoring. The advantages of these methods are that a reading is obtained in seconds and that they are easy to use in the field. The drawbacks are the limited specificity and limits of detection, which may be well above the OELs. As a consequence, a reading of such an instrument that indicates that a pesticide is not present may mean only that it is present in amounts below the detection limit, but well above the OEL. For example, an FTIR instrument recently used for examination of container air had a limit of detection (LOD) for PH₃ of 0.5 ppm, whereas the OEL of PH₃ is 0.1 ppm (Svedberg and Johanson, 2017). This study also used a PID that failed to detect hazardous levels of PH₃, chloroethanol and ethylene oxide, demonstrating the limitation of this type of instrument in screening containers for fumigant residues. According to the authors, a likely explanation was the simultaneous presence of 12 ppm isopentane.

Several other methods or instruments developed for field use and using electrochemical detectors (ECDs) are also available, but all these methods have the common feature of lacking separation of the chemical compounds before detection.

A more sophisticated example of a technology that does not separate the compounds before detection is SIFT-MS. The chemical compounds are ionised by a technique (soft ionisation) that creates fewer fragments than ordinary MS technology, and the ionised molecules can then be discriminated and quantified by the mass selective detector. The technology is suitable for detection and quantification of molecules in the low molecular weight range (10-200), for example some of the typical fumigants such PH₃ and MeBr. Syft Technologies Ltd, New Zealand, is the manufacturer of an instrument of this type that is intended mainly for laboratory use because of its size and weight, but which can be transported to external locations as well. It has high sensitivity, with limits of detection (LODs) in the parts per billion (ppb) to parts per trillion range (www.syft.com). Six of the studies cited above have used this kind of instrumentation; see, for example, Baur et al. (2010).

Even better results can be achieved using a method that separates the individual chemicals from each other before detection. The advantage of using a sophisticated method such as GC/MS is that it will in most cases give a precise identification of the chemicals present and a quantification of the compounds in amounts usually well below the OELs. The drawback of such a method is that the instrumentation is usually not suitable for working in the field; the analysis will be performed in a laboratory and will take from hours to 1 or 2 days to complete. However, some simpler GC/MS instruments are portable and may be transported to different locations. An example of the latter was used in the study in Hamburg in 2006 (Baur et al., 2010). Of the studies cited above, three used GC/MS, in all cases as a complementary method to other analytical techniques. In addition to the methods described under (1), different kinds of indicator or colorimetric tubes may also be used. Samples of air are drawn by a specific pump through a glass tube that is filled with a material that reacts chemically with the compound that is measured. The reaction generates a coloured product that can be seen through the glass wall of the tube. Scale marks on the tube wall indicate the concentration of the compound in the sample. The method is not accurate, but it may give some indication of the concentration present. In some cases interference from other compounds may impair the results. Dräger and Kitagawa are examples of manufacturers that market such indicator tubes for a number of chemical substances. Five of the nine studies cited above used colorimetric indicator tubes, most of them as a supplement to other methods.

Indicator tubes may be more sensitive than electronic devices for some substances, but may be subject to substantial reading errors. A report prepared on behalf of the United States Environmental Protection Agency (EPA) showed that when 28 grain elevator operators measured the level of PH₃ in samples with a defined concentration, some of the readings were significantly out of range. For example, a concentration of 0.4 ppm was read by one operator as 0.02 ppm (Danley et al., 2005).

A comparison between an ECD instrument and an indicator tube (Dräger) for the detection of PH₃ demonstrated that the ECD showed 0.13 ppm PH₃ while the indicator tube showed 0.05 ppm PH₃. Moreover, previous studies have shown that the lengthy sampling time required by the use of indicator tubes increased the time taken to respond to elevated PH₃ concentrations in warehouses (Thorn et al., 2002).

It is difficult to obtain an overview of procedures and monitoring equipment in routine use at ports. Most if not all of the literature that describes intoxications by fumigants or the presence of pesticides is based on research investigations, where the investigators have used different kinds of monitoring equipment (for some, rather sophisticated analytical instrumentation). For example, Baur et al. (2006) compared measurements of 153 containers taken by three different techniques: indicator tubes, SIFT mass spectrometry and GC/MS with thermal desorption (TDS-GC/MS). The last was used as the 'gold standard' because it detected all of the possible contaminants. The results demonstrated that indicator tubes identified MeBr in only 29 % of the containers in which it was detected using the gold standard, while the SIFT instrument detected MeBr in 40 % of containers found positive by TDS-GC/MS. Chloropicrin was detected in 19 of 153 containers by the gold standard method, while neither indicator tubes nor the SIFT detected any of these (Baur et al., 2006).

A study of 303 containers in the Port of Rotterdam compared the ability of indicator tubes, and of sampling in Tedlar bags followed by GC/MS analysis, to detect the presence of MeBr. MeBr was detected in 19 samples by GC/MS, and in 43 samples by indicator tubes. However, nine samples that tested positive by MeBr by GC/MS analysis were negative using indicator tubes (Knol-de Vos, 2002).

A comprehensive study of 2,113 containers in the Port of Hamburg in 2006 used both a SIFT instrument and a portable GC/MS system. According to the authors, the SIFT instrument can detect both PH₃ and MeBr, whereas GC/MS can detect a large number of VOCs but not PH₃ or hydrogen cyanide (HCN), and cannot distinguish between MeBr and sulfonyl difluoride (Baur et al., 2010).

These examples illustrate the importance of using appropriate and sensitive analytical equipment when detection of all possible fumigants in transport containers is required.

Our visit to a small port revealed no measurement of container atmosphere, nor any monitoring equipment. According to a Swedish report, in the Port of Gothenburg there is no systematic surveillance of container atmosphere, but in some instances the Swedish National Food Agency inspects containers carrying foodstuffs. On those occasions a pest control company is engaged to monitor the atmosphere prior to inspection by National Food Agency officers (Svedberg and Johanson, 2011).

In the well-documented case of intoxication by MeBr in Rotterdam in 2006, the analytical procedure or equipment used for determination of the fumigant is not specified, although the report states that the measurement was performed by the local fire department, which was equipped with monitoring instrument(s) for toxic chemicals (Breeman, 2009).

A survey of nine companies inspecting and unloading containers in Danish ports revealed that few of these had access to monitoring equipment and, furthermore, that the available equipment could detect only MeBr (Pedersen et al., 2014).

Our visit to the large port in April 2017 demonstrated the routine use of monitoring equipment for analysing container atmosphere. The port had a facility for measuring the gas/atmosphere inside the container (Figure 9) and a facility to ventilate containers that are contaminated with hazardous chemicals. The measuring facility consists of two identical 'stations' that introduce a sampling tube with a flat nozzle in between the sealing of the container doors, and use a pump to sample container atmosphere to three analytical instruments:

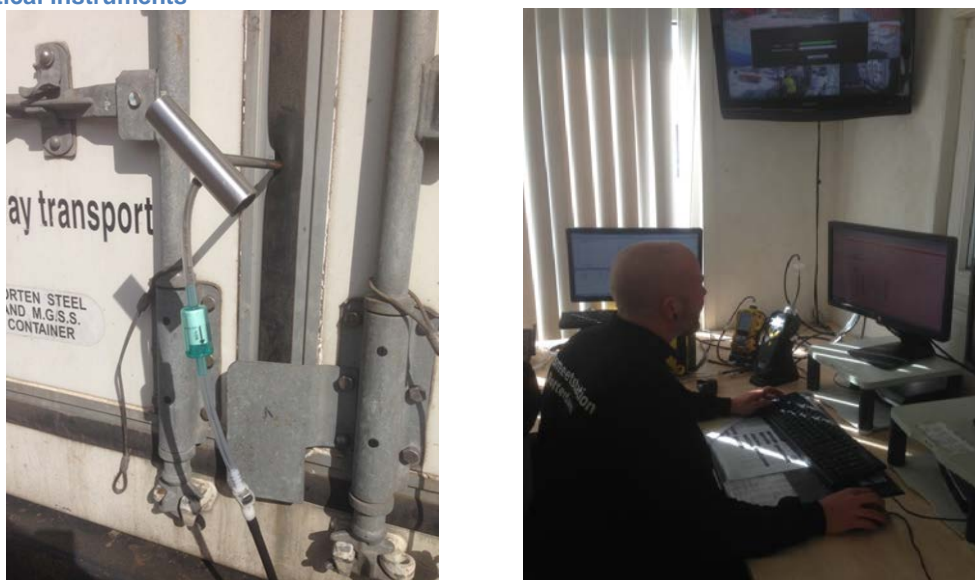
- hand-held device for determination of oxygen (O₂) level and lower explosive limit (LEL);
- hand-held PID for determination of VOCs;

- FTIR instrument for determination of carbon monoxide (CO), carbon dioxide (CO₂), high levels of PH₃ and a selection of other relevant gases such as toluene, 1,2-dichloroethane, formaldehyde, methanol and ethanol.

Low levels of PH₃ were detected by indicator tubes (Kitagawa, Dräger).

Instruments B and C are calibrated using isobutylene, on the assumption that the different VOCs are quantified as isobutylene equivalents.


Figure 9: Container air is pulled through the nozzle in between the sealing of the container doors via a tube to three analytical instruments



It is, however, uncertain if the methods and instruments in use have sufficient sensitivity. For example, indicator tubes were used for detection of PH₃, but the LOD of these was not shown. The gas measurement report stated that the measured values were below the OELs but without any indication of the LODs for the compounds listed. To our knowledge, the best indicator tube for detection of PH₃ has an LOD of 10 ppb, but this requires extra sample volume and the test may take up to 20 minutes to perform (Leesch, 1982; Dräger, 2011). If the sensitivity is not high enough, monitoring may protect workers from acute intoxications by PH₃ when unloading the container, but may not be protective against long-term effects due to low-dose exposure.

The results from all measurements at the gas measurement station are recorded and stored in a database by the company, including measured values of gas contaminants, country of origin, goods, etc. The most frequent fumigants detected were PH₃ (primarily in containers with foodstuffs), MeBr and, lately, ethylene oxide, in particular in containers with medical equipment. The station issues gas-free/safe container certificates for containers with gas levels lower than the relevant OEL (Figure 10). The customers are notified of the findings along with a recommendation of what to do, for example ventilation/degassing. Customers follow the recommendations almost all of the time. The measurement station prepares monthly reports to their customers, which provide an overview of the identified gases/export country/goods in their containers.

Figure 10: Example of a gas-free container certificate

GASMEETRAPPOR / GAS MEASURING CERTIFICATE		119917		
Containernummer / Container number: Lading / Cargo: Referentie / Reference: Opdrachtgever / Client: Locatie / Location: Meting / Measurement: Type meting / Type of measurement: Meetmethode / Method of measurement: Temperatuur / Temperature:	CAIU8176750 Lightmakers 161093 Gasmeetstation Rotterdam B.V. / Gasmeetstation Rotterdam B.V. GMS Eerste meting / First measurement vrije ruimte in container, gemeten vanaf buiten FTIR Ex/Ox/Tox 15,00 °C Datum / Date: 08-06-2016 Tijd / Time 07:15	Oude zegel / Old seal: Nieuw zegel / New seal:	532341K NVT	
Soort gas / Type of gas	Afkorting / Short	Grenswaarde / Limit value	Waarde / Concentration	Resultaat / Result
Ammoniak / Ammonia:	NH3	19,80 ppm	0 ppm	Ok
Benzeen / Benzene:	C6H6	1,00 ppm	0 ppm	Ok
Chloorpicrine / Chloropicrine:	CCL3NO2	0,10 ppm	0 ppm	Ok
1,2-Dichloorethaan / 1,2-DichloroEthane:	C2H4CL2	1,70 ppm	0 ppm	Ok
Formaldehyde / Formaldehyde:	H2CO	0,12 ppm	0 ppm	Ok
Waterstof cyanide / Hydrogen cyanide:	HCN	0,90 ppm	0 ppm	Ok
Methylbromide / Methylbromide:	CH3BR	0,25 ppm	0 ppm	Ok
Methylchloride / Chloro Methane:	CH3CL	25,00 ppm	0 ppm	Ok
Fosfine / Phosphine:	PH3	0,10 ppm	0 ppm	Ok
Styreen / Styrene:	C8H8	25,00 ppm	0 ppm	Ok
Tolueen / Toluene:	C7H8	40,00 ppm	0 ppm	Ok
Sulfuryldifluoride / Sulfuryldifluoride:	SO2F2	2,50 ppm	0 ppm	Ok
Kooldioxide / Carbon Dioxide:	CO2	4.900,00 ppm	434,23 ppm	Ok
Koolmonoxide / Carbon Monoxide:	CO	25,00 ppm	0 ppm	Ok
Zuurstof / Oxygen:	O2	20,90 %	20,90 %	Ok
Explosiemeting / Explosion:	LEL	10,00 %	0 %	Ok
Xyleen / Xylene:	C8H10	48,00 ppm	0 ppm	Ok
Voc / Voc:		100,00 ppm	3,80 ppm	Ok
Ethyleenoxide / Ethyleneoxyde	C2H4O	0,46 ppm	0 ppm	Ok
Isopetaan / Isopentane	CSH12	600,00 ppm	0 ppm	Ok
Gasmeetdeskundige / Measuring expert Deskundigheidsbewijs / Nr of certificate of expertise	T.S. Ruijgrok 220074.05064151 GEB: 22/03/1994			
Resultaat / Result	Geen waarde boven het limit / No value above limit			
Geen gevaarlijke concentraties gassen boven de vastgestelde grenswaarden (veilig te betreden) No toxic, obnoxious or flammable gasses at dangerous levels above TLV-limits (Safe to enter)				
Advies / Advice	Container lossen binnen 24u / discharge container within 24hrs			

De genoteerde waarden zijn slechts een weergave van de toestand op het moment van de meting. Aangezien gasconcentraties in een gesloten container kunnen fluctueren in de tijd aanvaardt Gasmeetstation Rotterdam geen aansprakelijkheid in het geval van veranderingen bij latere metingen. De opdrachtgever vrijwaart Gasmeetstation Rotterdam van alle mogelijke schade aan derden, die door de uitvoering van de opdracht kunnen zijn ontstaan.

Source: Gasmeetstation Nederland BV – www.gasmeetstation.nl

So far, we are aware of only a few national requirements for measuring the atmosphere of imported transport containers. According to a Swedish report (Svedberg and Johanson, 2013), the Australian Customs and Border Protection Service requires that container atmosphere be tested before staff are permitted to enter a container. Australian authorities have recently reorganised and it has not been possible to find these requirements on the official website of the Department of Immigration and Border Protection (<http://www.border.gov.au/>).

Canada is one of the few countries that has national requirements in this respect. The CBSA has issued the procedure 'Testing and ventilation of marine containers' (CBSA, 2008). Furthermore, to meet requirements the CBSA has issued a SIFT instrument to all of its CEFs, and has identified 10 hazardous fumigants and solvents to be measured before containers are unloaded. It is emphasised that this holds true only for containers that are to be examined at CEFs; containers that are examined dockside are not covered.

Another country with national regulations in this regard is Germany. In the document 'Technical Rules for Hazardous Substances (TRGS 512) "Fumigations"' (BAuA, 2007), issued by the Federal Ministry of Labour and Social Affairs (BMAS), available from the German focal point, comprehensive rules are

outlined for both fumigation processes and receiving and unloading transport containers. The document contains detailed instructions for identifying risky containers and quantified requirements for the release of containers for the unloading of goods. This includes the use of direct-display instruments or devices for measuring fumigants: indicator tubes, electrochemical cell-based systems or PIDs. Furthermore, limit values are specified for four fumigants: 1 ppm MeBr, 1.9 ppm HCN, 0.1 ppm PH₃ and 2.4 ppm sulfuryl fluoride (SO₂F₂). The measurements must comply with these limits before the container is released for unloading.

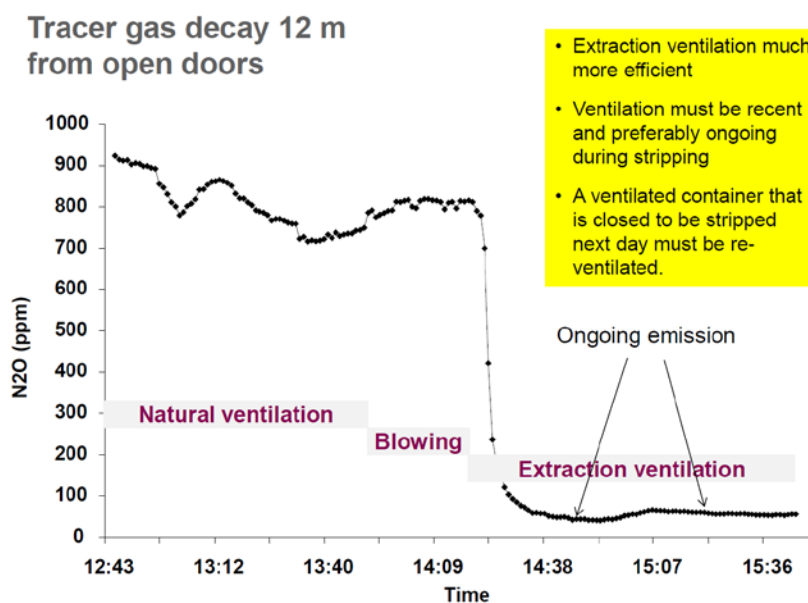
It is important to emphasise that the methods referred to above are only examples of technology that has been used. A comprehensive review of available methods and instrumentation for measuring the concentration of actual fumigants is a demanding task that is not within the frame of the present project. The choice of technology may be a compromise between sensitivity, accuracy, reproducibility and ease of use. It should be noted, however, that our limited knowledge of, and data relating to, fumigant residues in containers means that an important aspect is to collect such data using a robust technology suited to routine use. Standardisation of such technology will further improve the quality of the data obtained. Assuming full public accessibility of data, this will over time result in a valuable database that may form the basis of efficient actions to prevent exposure of workers to hazardous fumigants when opening and unloading transport containers.

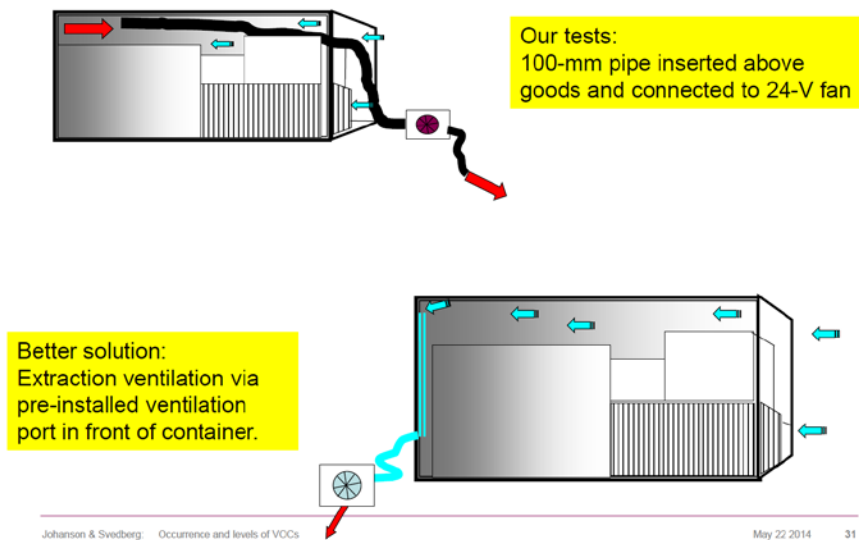
6.5 Degasification and ventilation technologies

The container should be efficiently ventilated when high concentrations of harmful substances have been detected or when measurements have not been taken. Containers normally have small openings in the top corners to provide limited natural ventilation.

Svedberg and Johanson (2013) evaluated various ventilation methods by tracer gas (nitric oxide), and reported that natural ventilation (open doors) and blowing ventilation (open doors, fan blowing air towards goods) had virtually no impact on gas levels in deep container air 12 metres from the doors (Figure 11). In contrast, forced extraction ventilation (fan sucking air via a tube inserted all the way into the container and fresh air entering via the doors) resulted in rapid washout of the gas. The authors concluded that, unfortunately, current container design makes safe and speedy sampling and ventilation prior to opening the doors technically difficult. Ventilation must preferably be ongoing during stripping, and a ventilated container that is closed to be stripped next day must be reventilated.

Figure 11: Effect of different types of container ventilation by using tracer gas as an indicator (Johanson and Svedberg)





Source: <https://www.eomsociety.org/images/PDF/Johanson%20Svedberg%20-%20Occurrence%20and%20levels%20of%20VOCs%20in%20containers%20arriving%20in%20Sweden%20including%20aspects%20on%20personal%20exposure%20ventilation%20and%20sampling%20position.pdf>

Braconnier and Keller (2015) studied three sets of container ventilation conditions, namely natural, mixed mode and forced ventilation, using tracer gas measurements and numerical airflow simulations. They took into account container size, degree of filling and type of load. The efficiency of natural ventilation, which seems to be the most commonly used method at present, was highly variable, depending on environmental conditions. The purging rate decreases when moving towards the rear end of the container. Use of a mechanically supplied or extracted airflow under mixed mode and forced ventilation conditions enables purging to be significantly accelerated. Mixed mode ventilation combines opening of the door with creating airflow towards the rear end of the container. Under mixed mode ventilation, extracting air from the end of the container furthest from the door ensures quicker purging than supplying fresh air to this area. Under forced ventilation, the container is closed and ventilated through orifices drilled through its walls or through a foam insert between the door leaves. Under forced ventilation, purging rate is proportional to the applied ventilation flow. Purging rate depends mainly on the location at which air is introduced, the most favourable position being above the container loading level.

In the Australian study (Safe Work Australia, 2011), the containers were often left to ventilate naturally. The authors concluded that, for those containers with known high levels of fumigants, natural ventilation may require supplementation with forced ventilation to reduce residual chemicals to acceptable concentrations for unloading. Industry representatives expressed concern that ventilation systems extracting fumigants from containers were not effective because levels of fumigants within containers simply rose again after ventilation ended and the containers were closed. Thus, it may be useful to set a time limit (for example two hours), after which unloading should be stopped and the container ventilated again.

The workers who performed stripping of containers in the Swedish study expressed that the containers frequently carried unpleasant odours that from time to time prevented stripping. Such containers were left to ventilate naturally before the workers re-entered them (Svedberg and Johanson, 2013)

The interviewed personnel in the Danish study reported that the main preventive measure to reduce chemical exposure is natural ventilation; active ventilation is not used in practice (Pedersen et al., 2014). The conditions of aeration were not consistently applied; the reported ventilation times varied between two and 48 hours, without any knowledge of whether or not this amount of time was sufficient.

In our visit to the large port we observed that degassing/ventilation of containers is performed in a dedicated area in the port, close to the measurement station (Figure 12). The station team uses a hose with a specially designed 'mouthpiece' that is inserted between the sealing of the doors of the container.

The hose is connected to a fan system that draws air out of the container. However, because opening of the mouthpiece is narrow, airflow through the hose is limited and it takes at least 12 hours to completely replace the air in a container. The containers may have between zero and four small openings to allow passive ventilation. In many cases, however, the openings are taped up on the inside.

When containers are considered unsafe based on low O₂ or high CO₂ or CO, but there is no indication of other gases above OEL, the container doors are opened for natural ventilation. Off-gassing of all other gases is performed by forced extraction ventilation. The time needed for degassing/ventilation will depend on several factors, including how the goods are stacked in the container, the filling grade of the container, the nature of the goods, the climatic conditions and the characteristics and concentration of the fumigant used. The fan system of the off-gassing station can accommodate up to 60 containers simultaneously. The air extracted from the containers passes through a filter of activated charcoal, which is assumed to remove all the contamination.

Ethylene oxide takes a long time to be removed — up to two weeks — because the gas penetrates the goods and sticks to it. The station team has therefore made four specially designed ‘trailer-trucks’ for degassing of ethylene oxide: the container is opened by workers using PPE, the goods are moved to the degassing trailer and then air is blown through the trailer until the ethylene oxide has been removed.

Figure 12: Example of degasification station



6.6 Personal protective equipment (PPE)

Fumigants can enter the body through inhalation and by absorption through the skin after dermal exposure. PPE includes respirators, gloves, suit, boots and safety goggles, and should always be considered as the last choice of preventive measures. PPE should be an option only when other preventive measures are not sufficient to reduce the concentration of fumigants below accepted concentrations. It is important to ensure that workers receive regular training and instruction on the procedures to be used, and on the maintenance and correct use of PPE.

The use of PPE is recommended if, for any reason, fumigated containers are opened and entered, for example when representatives of authorities such as a food inspectorate or customs open containers for inspection and no gas measurements have been taken beforehand. Another scenario when PPE is required is when PH₃ is detected by measurements. To obtain an efficient degassing of the container, the container doors should be opened, and any residues of PH₃ in solid form have to be removed from the container.

Risk assessments for the relevant exposure scenarios are necessary to determine when and which type of PPE should be used. The risk assessment should take into account the type of fumigant present, the concentration of the fumigant and the duration of the exposure. The respiratory protection must be sufficient to reduce exposure to levels below the OEL or another appropriate level. The term assigned

protection factor (APF) is used for the level of protection a respirator can be expected to provide if it is functioning properly and the user is wearing it correctly. The APF is highest for self-contained breathing apparatus (SCBA), an air-supplying respirator whose breathing air source is carried by the user. A supplied-air respirator (SAR) or airline respirator is an air-supplying respirator whose source of breathing air is not carried by the user. An air-purifying respirator is a respirator with an air-purifying filter, cartridge or canister that removes specific air contaminants by passing ambient air through the air-purifying element, and which generally has a lower APF than either SCBA or SAR.

The National Institute for Occupational Safety and Health (NIOSH) in the United States has published a strategy for selection of PPE (respirator, gloves and suit) to protect against PH₃ (NIOSH, 2015). This recommendation comprises four protection levels, dependent on the PH₃ concentration. The type of respiratory protection is selected according to the required APF, which reflects the measured or estimated fumigant concentration. The four levels of protection are, in order of decreasing protection needed for the workers, SCBA or SARs, air-purifying respirators (APRs) or powered air-purifying respirators (PAPRs); in some situations no respirator is needed.

One of the major producers (3M) of PPE states that it has traditionally recommended SARs if worker exposure to PH₃ is higher than the applicable OEL of 0.3 ppm (3M, 2013). The A1HgP3 cartridge filter may be used with half- and full-face masks to help reduce exposure to low ambient levels of PH₃ (for example up to 15 ppm TWA on a full-face mask, or 3 ppm TWA on a half-face mask). Service life is expected to be at least 40 hours in-use time for maximum concentrations of less than 60 ppm PH₃ and at a normal breathing rate. Cartridges must be discarded and replaced sooner if taste, smell or irritation is noted, or if the cartridge is physically damaged.

Chemical protective clothing (CPC) also needs to be selected according to risk assessments for exposure to the fumigants and the relevant scenarios. CPC such as gloves, suits and aprons is made of various materials, and the selection of appropriate types of material is based on:

- penetration:
 - whether or not the protective film could be damaged by cutting, burning, etc.;
- degradation:
 - whether or not the chemical dissolves/corrodes the material;
 - whether or not the material stiffens, swells, etc., if it comes in contact with the chemical;
- permeation:
 - the likelihood of diffusion of the chemical through the protective material;
 - breakthrough time and permeation rate.

CPC manufacturers have developed selection charts that indicate which material provides the best protection against permeation of a number of chemicals and classes of chemicals. For handling of fumigated containers, chemical-resistant gloves of butyl rubber are recommended.

Gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates that this is necessary. Taking into consideration the parameters specified by the glove manufacturer, it should be checked during use that the gloves have retained their protective properties. It should be noted that the time to breakthrough for any glove material may be different for different glove manufacturers.

In published articles and reports, the use of PPE during container stripping has been only briefly mentioned, and the types of protective mask or other PPE that have been used are not discussed. PPE should be used, and rescue strategies must be made available to individuals who need to enter unventilated containers with unknown hazards (Svedberg and Johansson, 2013). When the workers in Sweden experienced unpleasant odours, containers were left to ventilate naturally or, alternatively, the workers were instructed to wear respiratory equipment (Svedberg and Johanson, 2013).

In the Australian study, one-third of those surveyed reported use of PPE, but did not specify which kind of PPE they used (Safe Work Australia, 2011). Knol-de Vos (2002) noted that staff wore personal protective equipment when opening containers in Rotterdam. Pedersen et al. (2014) reported that, although masks are usually provided to workers in Denmark, they are mainly dust masks that do not prevent exposure to gaseous chemicals. The authors stated that the decision and choice of preventive measures to be used are in practice often left to the directly involved employees, and that the actions taken show considerable variation.

According to NT WorkSafe (2015), PPE for containers with MeBr mixtures could include, depending on the risk assessment:

- elbow-length chemical gloves;
- full coveralls;
- full-face mask equipped with:
 - multigas filters; or
 - an organic vapour cartridge filter, designed to cover MeBr and chloropicrin; or
 - mixed gas filters (filter type will depend upon the brand and type of full-face mask); or
 - self-contained breathing apparatus (SCBA).

During our visit to the large port we were informed that there is no provision of PPE for those at the measurement station, since they insert a nozzle inside the container for remote monitoring of gases, and do not open the doors. In the warehouse the workers have access to full-face masks with various filter cartridges. PPE is used when the end-user wants to open the container within a short time, even though the container has not been declared safe. Some end-users want workers to use PPE even when a container has been declared safe. We observed that workers in a warehouse emptying containers filled with guitar cases were wearing full-face masks.

A representative from customs told us during the port visits that officers will not be exposed to fumigants unless container trailers are stopped for inspection on roads (see below). A maximum of 1.2 % of all containers arriving in the port are inspected by customs, and there are four main scenarios:

1. Containers are checked at a customs checkpoint/warehouse in the port, including full X-ray scan of containers. For the last 10 to 12 years an external company has opened the container and unloaded the contents for inspection by customs. Customs officers are thus not exposed — they never open and unload containers.
2. The outer parts of container contents are subjected to scatter scanning with X-rays, primarily aiming to detect narcotics. In total, 100 containers are scanned consecutively. On average, 10 in every 100 containers are opened because customs officers suspect they contain narcotics. After measuring/controlling for O₂ and percentage LEL, the container doors are opened. The custom officers use full PPE, including chemical suits and SCBA, when opening these containers, and thus should not be exposed. When using dogs, gases are measured before the doors are opened and the dog enters the container.
3. When containers are inspected by customs at inland destinations, the customs officer demands a gas-safe/safe container certificate before opening. The external company that opens the containers is required to have certification for safe opening. Customs officers do not enter the container, and are not considered to be exposed.
4. Along roads, container trailers can be stopped, and it might be the case that the doors are opened by the customs officer, which implies a risk of exposure since customs officers do not normally use PPE. The customs officer we interviewed was not aware of any incidents intoxication occurring in this way, but could not exclude the possibility that such an event might have occurred but was not reported.

7 Conclusions and recommendations for policy and practice

The present project has addressed the potential health risk to workers when freight containers that are fumigated with pesticides are opened at ports or warehouses. International legislation has been examined, and a comprehensive literature search has been conducted, using recognised databases for scientific and biomedical publications, as well as Google Scholar, to search for 'grey' literature such as reports, information leaflets, guidelines and newspaper articles. The information sought was related to the kind of pesticides used for fumigation, the frequency of fumigated containers arriving in European ports, health effects on exposed workers and guidelines for handling fumigated containers. EU-OSHA Focal points provided information from various national bodies, in response to a request from EU-OSHA. Information about methods and equipment for monitoring fumigants was collected. In addition, one small and one large European port were visited to observe current practices.

The main impressions obtained from the project are as follows:

- There are several indications that the fumigation problem is underestimated, probably because of a lack of systematic documentation of incidents of adverse health effects;
- It is a major problem that fumigated containers are almost never labelled, and that current practices when opening and unloading these containers do not follow safe procedures based on appropriate risk assessments;
- Recommendations and procedures for control measures, such as measurement technology/strategy, degasification/ventilation and PPE, should be developed for various scenarios.

The major findings and recommendations of the project can be summarised under the three headlines 'Present knowledge', 'Gaps in knowledge' and 'Recommendations', as shown below.

Present knowledge

A number of fumigants with significant acute and long-term health effects are used in containers, with MeBr and (PH₃) currently the main ones.

The proportion of containers with concentration of fumigants above the OEL varies considerably between studies. In eight of the nine available studies from 2002 to 2013, the OEL for PH₃ was exceeded in 0.4-3.5 % of containers (and in 47.2 % of containers in one study), while MeBr was above its OEL in 0-21.1 % of the containers. The variations were probably due to factors such as different procedures for selecting containers for measurements, number of containers measured, measurement equipment, content of containers, country of origin.

- The available publications/reports on the container screening of fumigants relate to larger ports before 2014, and might not be representative of the current situation.
- There is no consistent distribution of pesticides between types of cargo, except for PH₃ in foodstuffs.
- Fumigated containers are almost never appropriately labelled. Increased transport cost seems to be one of the major obstacles to labelling of fumigated containers.
- Knowledge and awareness of the health risks among workers opening containers seem to be low, although employers are obliged to inform workers about all hazards in their work environment and to provide adequate training in health and safety at work.
- The workplaces are multicultural. The use of different languages among workers is among the barriers to adequate training.
- Workers unloading containers might be exposed to fumigants if they open containers that are not checked and declared gas free. Employees of authorities such as the food inspectorate or customs might also be exposed when opening containers for inspection.
- So far there have been no reports of fatalities related to the opening of containers, but several reports describe adverse health effects in workers opening and unloading containers. Several

representatives from research institutions and regulatory bodies suggest that many near-accidents and intoxications with serious outcomes are not reported.

- Few countries seem to have detailed and adequate guidelines of how to handle possibly fumigated freight containers, although various organisations and employers have made available guidelines/information sheets on good practices for safe handling.
- Measurements/samples of fumigants are taken mainly using probes pushed through the rubber seals of container doors and further connected to various monitoring instruments. They indicate a potential peak exposure level for personnel opening the containers, and not the average personal exposure measured in the breathing zone of the workers during unloading.
- Current practice for degasification is scarcely documented, and containers are often left to ventilate naturally even though this is documented not to be efficient.
- Efficient methods for degasification by forced extract ventilation have been published, but it seems that few locations have access to such ventilation facilities.
- Current container design is not optimal for degassing with extract ventilation, with only small openings in the corners.
- Use of PPE is inconsistent and variable, and routines and guidelines on proper use of PPE are often lacking.
- The decision on the use of PPE seems to be left to workers, who do not have sufficient knowledge on the risk and level of protection needed.

Gaps in knowledge

- Most containers arriving in Europe are not opened at ports. However, no information about the proportion of containers that are actually opened by the various groups of workers in European ports, in warehouses and at the end-user is available.
- There are no accessible reports on detailed risk assessments, including assessment of actual personal exposure to fumigants for relevant groups such as dock workers, warehouse workers or customs officers.
- It is not apparent what should be considered the best indicators of fumigated containers when no labelling is present.
- The number of incidents may be greatly underestimated, since input from representatives of both research institutions and national regulatory bodies suggests that many near-accidents and intoxications with serious outcomes are not reported in public.
- The literature surveys add to this and illustrate one of the major challenges in this field, which is to provide adequate and sufficient documentation of incidents related to fumigated transport containers, including adverse health effects, clinical symptoms and exposure data, and to make these data publicly available in recognised sources.
- Responsibility for the OSH training of workers opening containers needs clarification, especially when they are employed through a staffing agency.
- Description of scenarios for when and which type of PPE should be used is lacking.

Recommendations

- There should be a systematic exposure/risk assessment among potentially exposed groups of workers, for various exposure scenarios.
- There should be systematic surveillance of the prevalence of containers with fumigant residues arriving in European ports.
- There should be assessment/modelling of personal exposure levels based on arrival concentrations of fumigants in containers, for various scenarios.
- The best solution is that the exporter should remove fumigant residues after fumigation, degas and declare the container gas free before it is shipped.

- Measures should be taken to enforce relevant regulations regarding labelling — containers that are not labelled according to regulations should ideally be returned unopened, and at the exporter's expense.
- The lack of compliance with regulations on labelling indicates that more involvement of authorities is needed.
- Two aspects of container fumigants have to be considered; first, the container should not have fumigant concentrations high enough to represent a risk of acute health effects when the container is opened; and, second, the container atmosphere should not contain fumigants at low concentrations that may impose long-term effects due to prolonged exposure time during unloading. Accordingly, it is important that the measuring technology is sensitive enough to detect levels below those representing any possible long-term hazard.
- The impression after review of the literature is that the two main fumigants currently used are MeBr and PH₃, and accordingly a standardised screening/monitoring procedure should be developed. The measuring technology should be able to identify at least MeBr and PH₃, with sufficient sensitivity to quantify levels at one-tenth of the OEL or lower. Based on available data, the most efficient degasification method is forced extraction ventilation, which results in rapid washout of the fumigant. However, current container design makes safe and rapid air sampling and ventilation prior to opening the doors technically difficult.
- Facilities for forced extract ventilation should be available at ports.
- Containers should not be opened until the risk assessment concludes that it is safe, for instance based on shipping documents or by approved measurements of the container atmosphere, if necessary after sufficient ventilation has been performed.
- There should be systematic collection of new information on present practices of opening of containers, risk assessments and preventive measures from a representative sample of European ports.
- Adequate training programmes, brochures, information sheets and guidelines should be developed for workers, in relevant languages.
- Easily understandable information sheets should be available, including information on what PPE to use for various scenarios.
- Risk communication systems should be in place for port companies, so they can make plans to receive incoming fumigated containers.

Priority should be given to the following recommendations;

- Measures should be taken to enforce relevant regulations regarding labelling. This is a collective problem that should be dealt with by national authorities, shippers, ship-owners, employee organisations and ports. A uniform approach in European ports is recommended, to avoid competition at the expense of health and safety.
- Containers should not be opened until the risk assessment concludes that it is safe, for instance based on shipping documents or by approved measurements of the container atmosphere, if necessary after sufficient ventilation has been performed.
- A standardised screening/monitoring procedure for containers arriving at European ports should be developed; the measuring technology should be able to identify at least MeBr and PH₃, with sufficient sensitivity to quantify levels at one-tenth of the OEL or lower.

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9 Annex 1

9.1 Overview of legislation and regulatory instruments already in place in respect of the regulation and facilitation of safe handling of fumigated containers at the port or end-user in the European Union.

Objective	Contents
Directive 89/391/EEC on the introduction of measures to encourage improvements in the safety and health of workers at work ('Framework Directive')	
Aims to establish an equal level of safety and health for the benefit of all workers.	<p>Obliges employers to take appropriate preventive measures to make work safer and healthier.</p> <p>Introduces as a key element the principle of risk assessment and defines its main elements (for example hazard identification, worker participation, introduction of adequate measures with the priority of eliminating risk at source, documentation and periodical reassessment of workplace hazards).</p> <p>Obligation to put in place prevention measures implicitly stresses the importance of new forms of safety and health management as part of general management processes.</p>
Directive 98/24/EC on the protection of the health and safety of workers from the risks related to chemical agents at work	
Lays down minimum requirements for the protection of workers from risks to their safety and health arising, or likely to arise, from the effects of chemical agents that are present at the workplace or as a result of any work activity involving chemical agents.	<p>The employer must determine whether or not any hazardous chemical agents are present at the workplace and assess any risk to safety and health arising from their presence.</p> <p>In the case of activities involving exposure to several hazardous chemical agents, the risks must be assessed on the basis of the risk presented by all such chemical agents in combination.</p> <p>The employer must take the necessary preventive measures, and risks must be eliminated or reduced to a minimum following the hierarchy of prevention measures.</p> <p>The specific protection, prevention and monitoring measures listed below must be applied if the assessment carried out by the employer reveals a risk to the safety and health of workers.</p> <p>The employer must regularly measure chemical agents which may present a risk to workers' health, in relation to the occupational exposure limit values, and must immediately take steps to remedy the situation if exceeded.</p>

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The employer must establish procedures (action plans) which can be implemented in the event of an accident, incident or emergency related to the presence of hazardous chemical agents at the workplace.

The employer must inform workers:

- on emergency arrangements;
- on the results of the risk assessment;
- on the hazardous chemical agents present at the workplace, with access to safety data sheets;
- by training on the appropriate precautions and on the personal and collective protection measures that are to be taken.

The employer must ensure that the contents of containers and pipes and any hazard that they represent are clearly identifiable.

The employer must review the risk assessment made and the measures provided to eliminate or reduce these risks.

Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens or mutagens at work

Protection of workers against health and safety risks from exposure to carcinogens or mutagens at work.

The employer shall assess and manage the risk of exposure to carcinogens or mutagens. This process shall be renewed regularly, and data shall be supplied to authorities upon request. Special attention is given to taking account of all possible exposure routes (including the skin), and to persons at particular risk.

Workers' exposure must be prevented. If replacement is not possible, the employer shall use a closed technological system. The employer shall reduce the use of a carcinogen or mutagen by replacing it with substance not or less dangerous.

Where a closed system is not technically possible, the employer shall reduce exposure to minimum.

Exposure shall not exceed the limit value of a carcinogen.

Wherever a carcinogen or mutagen is used, the employer shall:

- limit the quantities of a carcinogen or mutagen at the place of work;
- keep as low as possible the number of workers exposed;
- design the work processes so as to minimise the substance release;
- evacuate carcinogens or mutagens at source, but respect the environment;

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- use appropriate measurement procedures (especially for early detection of abnormal exposures from an unforeseeable event or accident);
- apply suitable working procedures and methods;
- implement individual protection measures if collective protection measures are not enough;
- inform workers;
- demarcate risk areas and use adequate warning and safety signs;
- draw up emergency plans;
- use sealed and clearly and visibly labelled containers for storage, handling, transportation and waste disposal.

Employers shall inform the workers if abnormal exposure has happened.

If a temporary, planned higher exposure is unavoidable (for example maintenance), the employer shall consult workers/representatives on the measures to minimise exposure, and provide appropriate prevention, together with access control.

If there is a risk for workers, areas shall be made accessible solely to workers who, by reason of their work or duties, are required to enter them.

The employer shall provide appropriate hygienic conditions for workers free of charge:

- prohibition of eating/drinking/smoking in contamination risk areas;
- appropriate protective clothing;
- separate storage places for working/protective clothing and for street clothes;
- appropriate and adequate washing and toilet facilities;
- cleaned, checked and maintained protective equipment, stored in a well-defined place.

The employer shall also provide appropriate training on potential risks to health, precautions to prevent exposure, hygiene requirements, protective equipment, clothing and incidents.

Employers shall inform workers on objects containing carcinogens or mutagens, and label them clearly and legibly, together with warning and hazard signs. Employers shall inform workers and/or representatives on abnormal exposures as quickly as possible.

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Directive 89/656/EC on the minimum health and safety requirements for the use by workers of personal protective equipment at the workplace

This Directive lays down minimum requirements for personal protective equipment (PPE) used by workers at work.

Personal protective equipment must be used when the risks cannot be avoided or sufficiently limited by technical means of collective protection or procedures of work organisation.

All personal protective equipment must be appropriate for the risks involved.

Directive 2009/104/EC concerning the minimum safety and health requirements for the use of work equipment by workers at work

This Directive lays down minimum safety and health requirements for the use of work equipment by workers at work.

The employer shall take every measure to ensure the safety of the work equipment made available to workers. During the selection of the work equipment the employer shall pay attention to the specific working conditions which exist at the workplace, especially in relation to the safety and health of the workers. If risks cannot be fully eliminated during the operation of the work equipment, the employer shall take appropriate measures to minimise them. Furthermore, the work equipment should comply with relevant Community directives and/or the minimum requirements laid down in Annex I.

Throughout its working life, the employer shall keep the work equipment compliant by means of adequate maintenance. The employer shall ensure that the work equipment is installed correctly and is operating properly by inspection/testing of the work equipment (initial, after assembly, periodic and special) by competent persons. The results of inspections shall be recorded and kept.

If the use of work equipment is likely to involve a specific risk the employer shall ensure restricted access to its use, and allow any modification by expert personnel only. Ergonomics and occupational health aspects shall be taken fully into account by the employer.

The employer shall provide workers with adequate, comprehensible information (for example written instructions) on the work equipment, detailing the conditions of use, foreseeable abnormal situations, and any additional conclusion drawn from experience. Workers shall be made aware of dangers relevant to them. The employer shall ensure that workers receive adequate training, including risks and specific training on specific-risk equipment.

Directive 92/58/EC on the minimum requirements for the provision of safety and/or health signs at work

Lays down minimum requirements for the provision of safety and/or health sign at work.

Employers must provide or ensure that safety and/or health signs are in place where hazards cannot be avoided or reduced. Workers and their representatives must be informed of all the measures taken concerning health and safety signs at work and must be given suitable instruction about these signs. This covers the meaning of signs and the general and specific behaviour required.

* Only the content directly relevant for enforcement and facilitation of safe handling of fumigated containers is included in the table.

The European Agency for Safety and Health at Work (EU-OSHA) contributes to making Europe a safer, healthier and more productive place to work. The Agency researches, develops, and distributes reliable, balanced, and impartial safety and health information and organises pan-European awareness raising campaigns. Set up by the European Union in 1994 and based in Bilbao, Spain, the Agency brings together representatives from the European Commission, Member State governments, employers' and workers' organisations, as well as leading experts in each of the EU Member States and beyond.

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