

## HEALTH RISKS AND PREVENTION PRACTICES DURING HANDLING OF FUMIGATED CONTAINERS

### Introduction

Transport of goods by freight containers is used all over the world. More than 600 million container units are filled, shipped and stripped annually. The freight containers are frequently treated with chemicals that kill pests before shipping. Pest control is implemented to protect the cargo from being damaged by pests during the rather long transport time, and thereby to prevent the spread of unwanted organisms. The chemicals used are toxic not only to pests, but also to humans. The fumigants are usually applied in a gas form to the containers, a process termed fumigation. The major fumigants used today are methyl bromide (MeBr) and phosphine (PH<sub>3</sub>). When these containers arrive at the destination there may be residues of the fumigation chemicals that may represent a risk to the workers that open and unload the containers. Fumigated containers are seldom labelled with warnings that show that they are fumigated even if international regulations say so. Several incidents have been reported where workers have been exposed to such fumigant residues and experienced adverse health effects, some of them severe. Health personnel working at hospitals and clinics have reported about patients they have examined after what seem to be intoxications by fumigants. Still there is limited documentation that shows the extent and the severity of the problem, probably because several of the incidents are not publically reported.

Fumigants deliberately added to the containers should be distinguished from chemicals off-gassing from the goods in the cargo. Off-gassing from the cargo includes a wide range of chemicals with different characteristics and health effects. Toluene, benzene and xylene are solvents, and typical examples of chemicals that are detected in containers but are not used as fumigants as they originate from the cargo. However, some chemicals like formaldehyde may be released from materials in the cargo and might also be used as fumigants.

Some relevant questions on this topic:

- What do we know about the containers that arrive in European ports with respect to fumigant residues?
- What kind of fumigants is primarily used, and what are the health risks if workers are exposed to these fumigants?
- How should the containers be handled to minimize the risk of adverse health effects to the workers that open and unload it?

To address these questions the project has performed a survey of the literature, both scientific and non-scientific literature like reports and other publications. Furthermore, one large and one small European port have been visited. The purpose was to see how the containers are handled and get an impression of good practice.

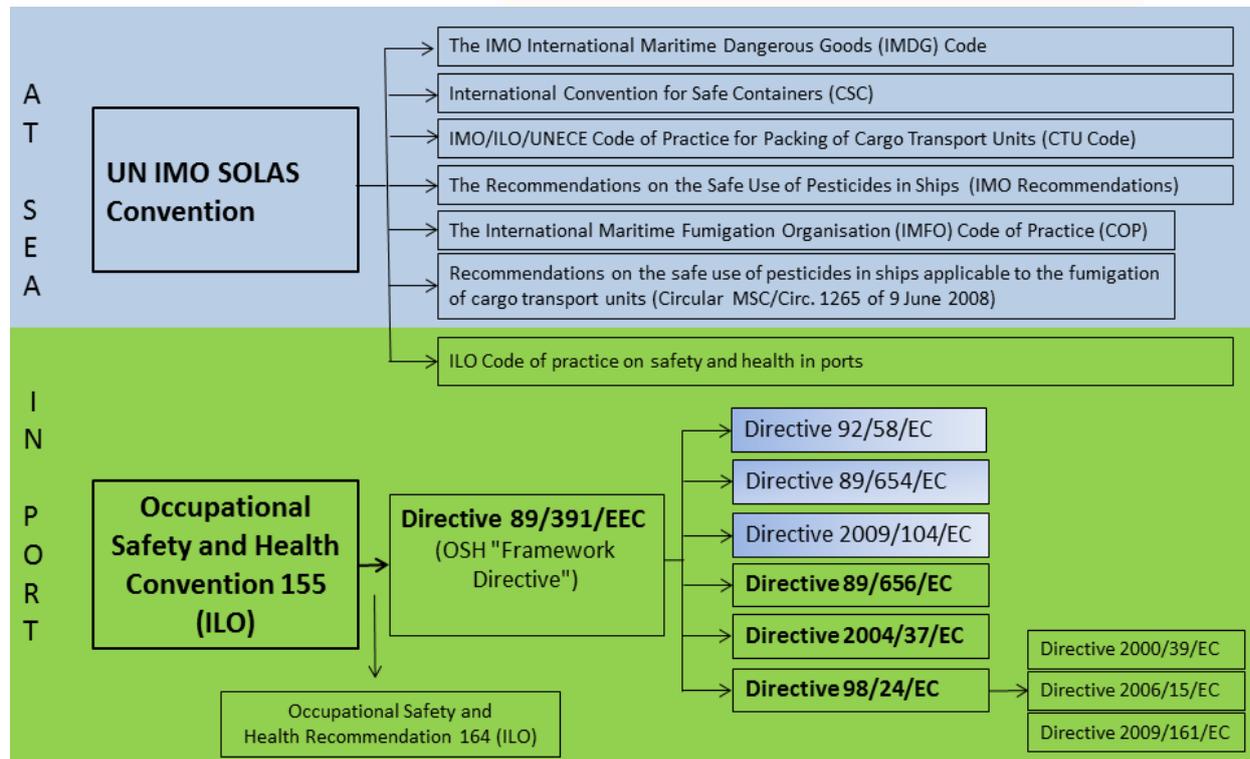
### Legislation, regulations and guidelines

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 the EU Directive 89/391/EEC are the most important framework instruments (Figure 1). 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 to facilitating safe handling of containers.

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. The IMDG Code covers issues such as packing, container transportation and stowage. Proper labelling of fumigated containers is mandatory.

Figure 1: International regulations and guidelines for handling of fumigated containers at sea and at ports.



Handling of fumigated containers at the port and at the end-user is regulated by the OSH “Framework Directive” (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 the work starts. If applicable, this risk assessment has to include the safe entering of sea containers and safe handling of goods from such containers.

## Relevant fumigants

The major fumigants used today are methyl bromide (MeBr) and phosphine (PH<sub>3</sub>). Formaldehyde may occur both as a fumigant and as an off-gassing product from the cargo in the container, but is less frequently used as a fumigant pesticide in freight containers. Chloropicrin is used both as a fumigant and as an addition to other fumigants, e.g. methyl bromide, to increase the awareness of the fumigant. Ethylene oxide seems to be increasingly used as a fumigant.

Methyl bromide is a colourless gas. It has little odour at low, but toxic concentrations and consequently humans may be exposed without knowing it. MeBr affects primarily the respiratory and central nervous system (CNS), and recovery from intoxications seems to be slow (de Souza et al., 2013).

Phosphine is a colourless gas with garlic-like odour, and is applied as solid phosphide that reacts with water vapour in the air and liberates highly toxic phosphine gas, PH<sub>3</sub>. There have been several fatalities

after inhalation of high levels of PH<sub>3</sub>, some of them related to fumigation of bulk cargo ships (Lemoine et al., 2011; Wilson 1980; Lodde et al., 2015). Food and feed products are the goods most often fumigated with phosphine. It is often easy to verify the use of phosphine for fumigation since small, empty bags or sachets that have been filled with solid phosphide can be found in the container by opening.

Formaldehyde is a nearly colourless gas with a pungent odour. Today it is seldom used as a pesticide. Formaldehyde is irritating to eyes and skin, and may affect the respiratory system at low concentrations, and it is classified as carcinogen.

Chloropicrin gas has an intensely irritating, pungent odour. It has a low odour threshold and it is therefore often used as additive to odourless fumigants such as methyl bromide as a "warning gas". It is less used for fumigation than methyl bromide and phosphine. The primary effects of chloropicrin are the irritating effects on eyes and the respiratory system, high concentrations also include severe gastrointestinal effects (TOXNET, 2017; Oriel et al., 2009).

Ethylene oxide is a highly reactive, colourless gas. The use of ethylene oxide in fumigation of containers seems to be increasing, e.g. in containers with **medical devices and products**. Acute effects from inhalation of ethylene oxide are dominated by irritation of the respiratory system, in particular nose and throat. It is also carcinogenic.

## Lack of labelling of fumigated containers

In 8 of the 9 available studies from 2002-2013 the Occupational Exposure Limit (OEL) for phosphine was exceeded in 0.4-3.5% of the containers (47.2% in one study), while MeBr was above its OEL in 0-21.1% of the containers. This variation is probably due to several factors such as different procedures for selecting containers for measurements, number of containers, measurement equipment, content of containers, country of origin, etc. There is no consistent distribution of pesticides between types of cargo - except phosphine in foodstuffs.

With very few exceptions the fumigated containers were not labelled or declared as chemically treated. Thus, these observations show that caution has to be taken when handling containers. Several reports have described violations of the regulations concerning appropriate labelling with warning signs accompanied with transportation documents specifying the fumigation procedures for fumigated containers.

## Who could be exposed to fumigants?

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. This could be workers in the port of arrival and in warehouses/logistic companies. If the containers are fumigated with high levels of pesticide, for example phosphine, the truck drivers may also be at risk in the event of fumigants leaking, or if they open the containers at their destinations. Customs officers and food inspectors may also be exposed when containers are opened for inspection.

Unloading of a container may take up to several hours, and the OELs normally used for personal exposure to chemicals, including fumigants, are based on time weighted average exposures over eight -hours. A study in Sweden indicated that the average personal exposure during stripping of naturally ventilated 40-foot containers were 1–7% of the arrival concentrations of fumigant in the container; however, peaks of up to 70% of the original concentration were seen during opening (Svedberg & Johanson, 2013). They conclude that even if average exposures during stripping are much lower than arrival concentrations, they may still represent serious violations of occupational exposure limits in high-risk containers.

So far there have been no reports of fatalities related to opening of transport containers, but several reports describe adverse health effects in workers opening and unloading containers. Several representatives from research institutions and national regulatory bodies suggest that a lot of near-

accidents and intoxications with serious outcomes are never reported. Thus, the actual number of incidents with adverse health effects is not known, - severe underreporting is indicated.

## Risk assessment

Practices in opening containers at the port should be based on risk assessments that comprise hazard identification, exposure assessment and, risk characterisation followed by preventive measures. The employer at the port is responsible for carrying out the risk assessment, for informing its employees about the risks and establish the appropriate preventive measures.

This risk assessment at the port is a challenging task since there is limited communication on the potential health risk from fumigated containers, including proper labelling, along the transport chain from the exporting country to ports in the importing country, including the risks to staff in the logistic companies, customs officers and workers unloading containers. Cost might be one of the major obstacles for proper labelling of fumigated containers. Ideally a global communication system with a risk database should be established.

## Procedures and guidelines for safe practices

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

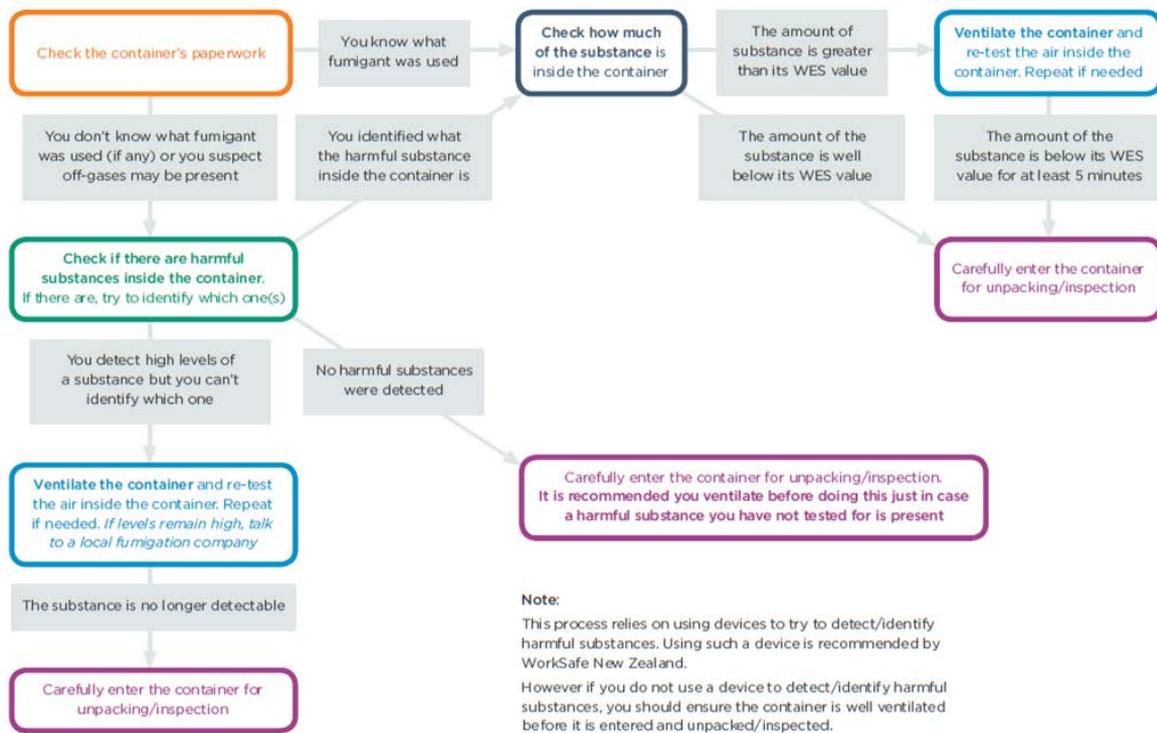
Some examples:

- The Technical Rules for Hazardous Substances“ on Fumigations (TRGS 512) (BAuA, Germany, 2007);; [https://www.baua.de/EN/Topics/Work-design/Hazardous-substances/\\_functions/Publications-search\\_Formular.html?nn=8710720](https://www.baua.de/EN/Topics/Work-design/Hazardous-substances/_functions/Publications-search_Formular.html?nn=8710720), download TRGS;
- Safe handling of gasses in shipping containers; ABC system, Gezond Transport the Netherlands (2011); <http://www.kgn-measurement.nl/Protocol%20gasses%20in%20import%20containers.pdf>
- WorkSafe New Zealand; Quick guide. Keeping Safe from Harmful Substances while Inspecting or Unpacking Containers (2017); <https://worksafe.govt.nz/topic-and-industry/hazardous-substances/guidance/industry-guidance/inspecting-and-unpacking-containers-harmful-substances>, see download «*Keeping-safe-from-harmful-substances.pdf*»

The German procedure (BAuA, 2007) is detailed, and states that a risk assessment is always necessary for the safe opening of containers. Measurements of pollutants with the container doors 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 characterized more precisely, for example by screening with multifunction devices.

Contaminated transport units are to be ventilated until the measured concentrations are below the assessment criteria. If ventilation does not reduce the pollutant concentration 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 class AB filter attachment) and the goods subjected to further forced ventilation by fans with the packaging open in suitable sheds secured against unauthorized entry, until the values fall below the assessment criteria.

Figure 2: from the Quick guide of WorkSafe New Zealand (2017) illustrates the main procedures for safe opening of containers, and is in line with the BAuA procedure from Germany (2007)



<https://worksafe.govt.nz/topic-and-industry/hazardous-substances/guidance/industry-guidance/inspecting-and-unpacking-containers-harmful-substances>, see download «*Keeping-safe-from-harmful-substances.pdf*»)

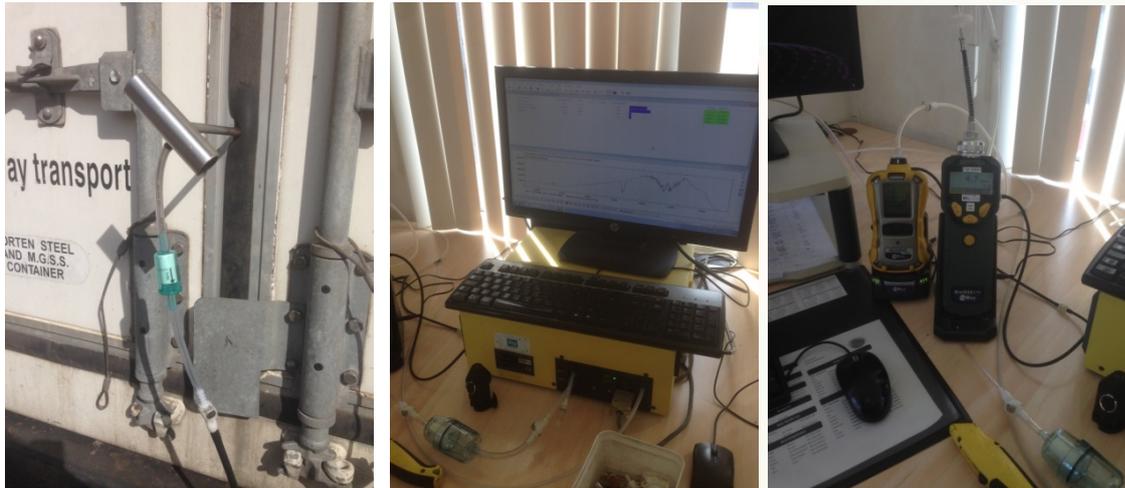
There are also several examples of available information cards/leaflets:

- Gases in containers. Be aware of the risk. (FNV, the Netherlands) [www.fnvgasincontainers.nl](http://www.fnvgasincontainers.nl)
- Containergassen.(Gasmeetstation, the Netherlands) <http://www.gasmeetstation.nl/veiligheidswijzer/>
- Sicherheit beim Umgang mit begasten Containern. (BG Verkehr, 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, Belgium). [www.toxischegassen.be](http://www.toxischegassen.be)

## Measurements of fumigants in containers

The measurements of fumigants are mainly taken using probes pushed through the rubber seals of the container doors, and further connected to monitoring instruments (Figure 3).

Figure 3: Container air is pulled through the nozzle in between the sealing of the container doors via a tube to monitoring instruments.



Chemical contamination of air in the container comprises a mixture of several chemicals. However, there is no standardized screening/monitoring instrumentation for containers. 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 different instrumentation such as Fourier transformed infrared light (FTIR) and photo ionisation detector (PID), methods that are available in portable instruments that can be used for online monitoring. The advantages of these methods are that a reading is obtained in seconds and that it is easy to use in the field. The drawbacks are the limited specificity and a limit of detection that may be well above the OELs.
- 2) In the second method the different chemical compounds are separated from each other by chromatography, and then each single compound is identified and quantified using mass spectrometry. The advantage of this method is a precise identification of the compounds and a limit of quantification that is very low, usually well below the OELs. The drawback is that the instrumentation is not suitable for working in the field; rather the analysis will be performed in a laboratory and will take from hours to 1-2 days to complete.

In addition different kind of adsorbent tubes may be used for specific chemicals. 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. In some cases interference from other compounds may impair the results.

A standardized screening/monitoring procedure for containers arriving at European harbours should be established including measurement technology and selection of fumigants, e.g. at least MeBr and PH<sub>3</sub> with sufficient sensitivity, at least 1/10 of the OEL.

A gas-free/safe container certificate should be issued for containers with gas levels < OEL (Figure 4). Otherwise when the concentrations are ≥ OEL, the containers should be ventilated before unloading.

Figure 4: Example of a gas-free certificate indicating safe concentrations after measurements.

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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.

## Degasification/ventilation of containers

The container should be efficiently ventilated when high concentrations of harmful substances have been detected or when measurements have not been carried out. Containers normally have small openings in the top corners to provide limited natural ventilation. However, if the container is fumigated these openings are often taped, frequently on the inside.

When unsafety of containers is based on low O<sub>2</sub> or high CO<sub>2</sub> or CO, - but with no indication of other gases above OEL, the container doors can be opened for natural ventilation. For all other gases the off-gassing should be performed by forced ventilation.

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 (Svedberg & Johanson, 2013; Braconnier & Keller, 2015). The time 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 what fumigant that is used and its concentration. In contrast, 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 meters from the doors. The authors concluded that the 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 re-ventilated.

Figure 5 shows a degasification station with a “mouthpiece” pushed in between the sealing of the doors. Due to small ventilation openings in the container and narrow opening of the mouthpiece it may take at least 12 hours to completely replace the container air using this method.

Figure 5. Example of a degasification station.



## Personal protective equipment

Fumigants can enter the body through inhalation and by absorption through the skin after dermal exposure. Personal protective equipment (PPE) includes respirators, gloves, suit, boots and safety goggles, and should always be considered as the last choice of preventive measures. Thus, 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 the maintenance and correct use of PPE.

The use of PPE is recommended if containers are opened and entered without prior risk assessment or ventilation, for example by inspection by the food inspectorate or customs. Another scenario when PPE is required is when phosphine is detected by measurements. To obtain an efficient degassing of the container the container doors should be opened, and any residues of solid phosphide should be removed from the container when degassing is initialised.

Risk assessments for the relevant exposure scenarios are necessary in order to determine when and which type of PPE should be used. The risk assessment should take into account the type of fumigant present, its concentration and the duration of the exposure. The respiratory protection must offer enough protection to reduce exposure to levels below the OEL or other 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) which means an air-supplying respirator for which the breathing air source is carried by the user. Supplied-air respirator (SAR) or airline respirator means an air-supplying respirator for which the source of breathing air is not carried by the user. Air-purifying respirator means 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 has generally less APF than the SCBA and SAR.

Chemical protective clothing also needs to be selected according to risk assessments for exposure to the respective fumigants and the relevant scenarios.

Easily understandable information sheets should be available including illustrations showing what PPE to use for different exposure scenarios.

## Conclusions

There are several indications that health risks related to opening and unloading fumigated freight containers are 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 the 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 different scenarios.

### **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 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.
- c) 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 PH<sub>3</sub>, with sufficient sensitivity to quantify levels at 1/10 of the OEL or lower.

## References

- Braconnier R, Keller F-X. (2015) Purging of Working Atmospheres Inside Freight Containers. *Ann. Occup. Hyg.*, **59**:641–654.
- de Souza, A., Narvencar, K. P. and Sindhoora, K.V. (2013) The neurological effects of methyl bromide intoxication. *J. Neurol. Sci.*, **335**(1-2): 36-41.
- Lemoine, T. J., Schoolman, K., Jackman, G. and Vernon, D. D. (2011) Unintentional fatal phosphine gas poisoning of a family. *Pediatr. Emerg. Care*, **27**(9): 869-871.
- Lodde, B., Lucas, D., et al. (2015) Acute phosphine poisoning on board a bulk carrier: analysis of factors leading to a fatal case. *J. Occup. Med. Toxicol.*, **10**: 10.
- Oriel, M., S. Edmiston, S. Beauvais, T. Barry and M. O'Malley. (2009) Illnesses associated with chloropicrin use in California agriculture, 1992-2003. *Rev. Environ. Contam. Toxicol.*, **200**: 1-31.
- Svedberg, U., Johanson, G. (2013) Work inside ocean freight containers--personal exposure to off-gassing chemicals. *Ann. Occup. Hyg.* **57**(9):1128-37.
- TOXNET. Toxicology Data Network, US National Library of Medicine, National Institute of Health, Health and Human Services. <https://toxnet.nlm.nih.gov/>
- Wilson, R., Lovejoy, F.H., Jaeger, R.J. and Landrigan, P.L. (1980) Acute phosphine poisoning aboard a grain freighter. Epidemiologic, clinical, and pathological findings. *JAMA*, **244**(2): 148-150.