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Health effects due to fumigated freight containers and goods: how to detect, how to act

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ABSTRACT

Headache, concentration and memory disorders, dizziness and nausea, skin irritation, respiratory distress, and muscle cramps — isolated or in various combinations — may be the result of acute or chronic intoxication by fumigants. The occurrence of these symptoms in workers who are engaged in the opening and unloading of containers, unpacking of imported goods, ventilating of containers, or working on bulk carriers are urgent indications of intoxication by fumigants or other toxic chemical residues in the transported goods. The severity of the disorder depends on the concentration and duration of exposure, distribution and release of the fumigant, its kinetics, the individual susceptibility of the person, as well as any simultaneous exposure to other toxic substances. Physical symptoms, acute and chronic health effects due to contact with fumigants, are complex and difficult to discover. In this article we explain how to identify the guiding symptoms and describe the appropriate diagnostic steps and the prevention of such events on cargo vessels as well as in the logistics and the handling of imported goods.

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Key words: fumigants, container turnover, occupational risk, health effects

INTRODUCTION

Global transportation of goods is linked with a serious problem: the spread of pests and degradation of goods. Therefore, measures of pest control are required by the Food and Agriculture Organisation of the United Nations (FAO) [1]. Due to these international regulations, fumigation of freight containers and cargo compartments has increased worldwide in the last nine years. The fumigants used (Table 1) can be absorbed by the transported goods and accumulate in the packaging materials or the products themselves, thereby be emitted later, e.g. after unloading from the container or during storage of the goods. Our investigation in 2006 confirmed that 15% of the containers unloaded in the Port of Hamburg had retained harmful concentrations of various fumigants and toxic chemicals. There were also fumigants found that were not allowed in European countries. Furthermore, the required labelling was lacking in nearly all cases [2–6]. This means that only in the Port of Hamburg, with a turnover of about 9 million per year in 2011, about 135,000 such potentially contaminated containers are trans-shipped and are mostly opened by employees of the logistic branch or custom officials, or wait to be directly forwarded to other destinations. The resulting health risks mainly concern entire container logistics, and warehouse and shop employees, and, ultimately, the toxins can end up in the homes of consumers (Table 2).

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Table 1. Frequently identified fumigants [5, 6] and their specifics

Fumigant	Boiling point	Properties
Ethylene dichloride (1,2-dichlorethane)	83 °C	Oily, colourless fluid, odour like chloroform, olfactory threshold: 3–6 ml/m^3
Methyl bromide (bromomethane)	4 °C	Colourless gas, odourless and purely gaseous
Phosphine (hydrogen phosphide)	–88 °C	Gas (aluminium phosphate = powder), smell of garlic and foul fish
Methylene chloride (dichloromethane)	39.8 °C	Colourless, hardly combustible fluid, sugary odour (like chloroform), fat-soluble, vapours heavier than air

Table 2. Exposed risk groups and typical exposures

Exposed persons	Circumstances	Case report No.	Comments
Professional fumigators	Gassing and degassing of vessels or containers	1	
Seamen (crew and persons on board)	Working on container ships or on bulk carriers, e.g. with fumigated grain, corn, or soya	2	Reasons are incorrect storage of fumigated containers or of fumigants, also leaks between cargo space and crew cabins
Customs officials Stevedores and dockworkers Logistics personnel	Opening, controlling, and unloading of import-container units	3	Despite knowledge of the hazards and protective measures, they can experience severe intoxications
Warehousemen	Unpacking of dunnage and imported goods from overseas, especially textiles	4	Often unskilled and/or agency labourers
Window dressers Vendors	Ironing unwashed clothes for the mannequins	5	Exposure due to evaporation of chemical residues by the heat
Persons in private households	As direct recipients of shipments from overseas	6	E.g. removals

RELATED HEALTH PROBLEMS

Acute occurrence of headache, dizziness and nausea, irritation of the skin and mucous membranes during or after potential exposure to fumigants are typical health problems in the practical handling of fumigated containers or goods. They may occur acutely with dramatic physical signs. With some delay, symptoms of shortness of breath, chest pain, concentration and memory problems, reduction in physical performance and stamina, as well as muscle cramps may occur. With chronic exposure, the symptoms are similar, but evolve gradually. Our investigations so far [7] do not allow a clear differentiation of symptoms and disorders with regards to duration of exposure (chronic or acute).

CASE REPORT 1

In November 2008 an employee of a shipping company performed a routine analysis of fumigant residues in 13 containers with peanuts arriving from Argentina, fumigated with phosphine. The first ambient measurements showed very high concentrations of phosphine (200 ppb), and subsequent measurements revealed 3.5 ppm. The employee continued to run tests on other containers in close vicinity but left the measure lancet in place between the rubber seals of the doors of the contaminated container. After about 2 h, headache, dizziness, vomiting, impaired concentration, and articulation problems forced him to leave his workplace. Two weeks later he complained about pain in his chest and in both flanks. Loss of appetite, as well as weight loss was associated over the next two weeks, with persisting neurological symptoms, especially lack of concentration, headaches, muscle cramps, and bronchial asthma.

CASE REPORT 2

In December 2010 in Canada 16 Chinese sailors became ill after phosphine gas leaked from cargo holds with grain into their living and working spaces. Later, experts discovered a leak in the ventilation system. They anchored on Lake Erie because too

few of the crew were healthy enough to safely bring it into port. The sailors were evacuated to hospital. They were vomiting, having difficulty in breathing and were suffering from fatigue. Five sailors not affected by the fumes remained aboard the ship [8].

CASE REPORT 3

A dockworker recurrently unloaded bags of guar gum out of containers from India. Guar gum is a fine ground powder made from guar beans, used as an industrial water-thickener. He stored the bags by hand in the container on pallets, which took about 40 min. After that, he transported the pallets with a forklift. Since November 2008, he noticed a number of 5 to 20 little sachets with a garlic odour labelled "aluminium phosphine" in the containers. Seven times he had unloaded these containers, and each time after 3–4 h he suffered headache, dizziness, nausea, diarrhoea, muscle cramps, and cough. Because of the latter, he went to a lung specialist. The physician detected an unspecific bronchial hyperresponsiveness even several weeks after exposure.

CASE REPORT 4

In summer 2006 in Westphalia (Germany) — far from the coast and harbour — two warehousemen were exposed to residues of fumigation agents for up to 4.5 h when unloading machine components from import containers. Shortly after, both men complained about headaches, nausea, and skin-irritations. They both showed persistent neurological symptoms with headache and lack of concentration, detectable in neuropsychological testing until the last examination in 2012. One of them also showed an unspecific bronchial hyperresponsiveness in methacholine challenge test up to that time. In samples taken from the dunnage in one of the containers, residues of ethylene dichloride were confirmed.

CASE REPORT 5

For several years up to 2008 a 41-year-old woman had dressed mannequins for fashion collections. The textiles were imported from the Far East. Her task was to unpack the clothes and to iron them before she decorated the mannequins. She noticed unpleasant-smelling fumes, then from 2005, additionally, irritation of the respiratory tract, and in 2007 shortness of breath at work. At this time an unspecific bronchial hyperresponsiveness was diagnosed. After she quit this job, the symptoms gradually declined.

CASE REPORT 6

After returning from Bolivia to Hamburg, an aid project staff member unpacked her moving boxes, which had been transported by ship. She complained immediately about headache, chest pain, and burning of the tongue. Two months later in May 2008 she reported about concentration disorders and headache, language disorders, emotional instability, and irritation of skin and respiratory tract. Residues of methylene chloride were confirmed in her blood and in samples of the household goods.

MEDICAL EXAMINATION IN CASES OF SUSPECTED GAS INTOXICATION

The recommendations given here are based on the experiences we collected from 2006 to 2010 when we examined about 60 patients sent to our outpatient clinic with presumed intoxication by fumigants [7]. We introduce here a standardised comprehensive diagnostic program for acute (up to one year after exposure) health problems due to intoxication with fumigants (Table 3).

SUSPICION OF INTOXICATION: IMMEDIATE MEASURES AND COLLECTING EVIDENCE

In case of any suspicion of intoxication, any work activities in the vicinity should be stopped immediately and the involved workers should be taken to safety — considering the self-protection. If the affected person complains particularly about difficulty in breathing, intense headache, or nausea, hospital admission is urgently required. The degree of intoxication depends on the fumigant concentration and time of exposure, the duration of the exposure, the individual susceptibility, the distribution volume and pharmacokinetics of the used substance, and the possible simultaneous presence of more than one toxic substance. In addition to first aid, collecting and documenting evidence is important, i.e. locking up the container, prompting air measurements, and collecting air samples (if possible also of freight samples) for analysis of fumigants and other toxic substances. It is therefore important to document exterior conditions like outdoor temperature and ventilation, and to search for signs and hints of declaration of fumigation on the container and/or in the shipping documents.

MEDICAL HISTORY

The patient's case history should reveal typical signs and symptoms. The acute symptoms are mentioned above. Persisting problems are often loss of

Table 3. Diagnostic steps in cases of suspected intoxication with fumigants

Instruments	Comments
General	
• Clinical and occupational case history (questionnaire) (see in detail ZfAM Questionnaire [17])	• Imperative, query of the above-mentioned conditions of exposure and health problems
• Physical examination	• Status, in particular lung auscultation, neurological examination
Biomonitoring	
• Headspace tubes ("vacuum") to test residual blood gases (methyl bromide, ethylene dichloride, methylene chloride (other halogenated fumigants), benzene, toluene, styrene, xylene)	• Evaporation of suspected fumigants from the blood, valid for only a few days after exposure; headspace tubes for blood sample are required
• Bromide and fluoride in serum and urine	• As supplementary information
• Haemoglobin adducts	• Less specific long-term parameter
• Other laboratory parameters	• Liver enzymes, creatinine, blood count; for exclusion of severe organic lesions
Pulmonary function diagnostics	
• Spirometry, body plethysmography (when available)	• Basic information
• Test of unspecific bronchial hyperresponsiveness	• Results often unexpectedly positive
• In case of restricted physical capacity: cardiopulmonary exercise testing	• Quantification, and differential diagnosis
Neurological and neuropsychological tests	
• Detailed neuropsychological tests (tests for speed of information processing, selective and divided attention, working memory)	• Significant, but laborious
Ambient monitoring	
• Analysis of air samples and environmental sampling	• I.e. evaporation of suspected fumigants

physical fitness and muscle cramps. The latter can be very painful and is difficult to counteract with the help of magnesium intake. A latency period of several hours up to several days until the onset of symptoms is possible [7, 9]. We also observed symptoms of the central nervous system such as concentration problems, memory disorders, psychological alterations like emotional instability, apathy, apprehensiveness, loss of consciousness, lack of concentration, hallucinations, altered perception with threat and delusions, impaired speech, impaired coordination, sensitivity distortion, sleep disorders, and loss of appetite and libido as well as diarrhoea.

PHYSICAL EXAMINATION

Basic examination should include lung auscultation with special attention to symptoms of bronchial obstruction or oedema like wheezing or crackles. Neurological examination should include tests of ataxia, sensibility, fine motor skills, and muscle strength.

BIOMONITORING AND CLINICAL CHEMISTRY

The detection of residues of fumigant metabolites, such as bromide (degradation product of methyl bromide) in blood and urine is possible until about two weeks after exposure, with a half-life of 12–16 days [10].

A more accurate method of detection of several fumigants (methyl bromide, ethylene dichloride, methyl chloride) is via a blood sample; for this purpose blood collection in gas-tight vacuum tube (headspace tube) is required, which remains meaningful only within a few days after exposure. Analysis is performed in the blood material as well as in air samples by gas chromatography–mass spectrometry [6, 11]. Also, the detection of haemoglobin adducts is now possible, which may confirm incorporation of fumigants even four months after exposure to halogenated hydrocarbon fumigants (i.e. methyl bromide). Due to the lack of reference ranges for exposure levels it is difficult to evaluate the levels of ethylene chloride at present, and the same goes for other fumigants after blood or urine measurement [12].

Routine laboratory parameters may be normal or show unspecific changes, but clinical chemistry should still be determined for differential diagnostic reasons, also to see if toxic exposure has taken place and if the detoxification system is working properly. All noted fumigants are hepato- and nephrotoxic at high concentrations [13, 14].

PULMONARY FUNCTION TESTS

Supplementary to spirometry and whole body plethysmography examination should include testing

of non-specific bronchial hyperresponsiveness when available (methacholine test). This method proved to be particularly sensitive in our study. The diagnosis of reactive airways dysfunction syndrome is closely associated with intoxication by phosphine and ethylene dichloride and less pronounced with methyl bromide [7, 15]. Corresponding to these findings, patients complain of respiratory irritation, cough, and chest tightness, sometimes persisting for months or even years. In patients with subjectively reduced performance, cardiopulmonary exercise testing should be performed to verify and differentiate the diagnosis. As methylene chlorides metabolize to carbon monoxide, elevated carboxy haemoglobin as high as 50% can be reported [14], with elimination kinetics 2–3 times longer as compared to carbon monoxide intoxication.

NEUROLOGICAL TESTS

Although many exposed patients report neurological problems, the available test procedures often reveal normal results. Reduced fine motor skills can be documented but usually at a level below significance. Also, tests of fluid and crystallised intelligence often show no clear deviations. In case of concentration problems, detailed neuropsychological testing should be given. Any neurological limitations were most clearly shown for divided attention span [16]. Table 3 gives a detailed and commented overview of the recommended instruments.

TREATMENT OPTIONS

First, ensure that contact and exposure are terminated, remove any persons from the danger zone and remove contaminated skin and mucous membranes. In situations where Occupational Exposure Limits may be exceeded, wear self-contained breathing apparatus with a facemask and all safety clothing (including gloves and boots); this applies equally to rescuers.

There is no specific therapy for patients with injuries caused by fumigation. Treatment of impaired organ function depends on the predominant symptoms and clinical findings. Severe intoxication requires intensive care monitoring, which may include treatment of pulmonary oedema, convulsions, and coma. In cases of asthmatic symptoms and bronchial hyperresponsiveness, medical treatment according to asthma guidelines is suggested. Persistent headache may require the consultation of a neurological clinic with an affiliated pain unit. In cases of reduced physical capacity, patients need rehabilitation and physical training. Depending on national regulations it may be necessary to give a report to the employer's accident insurance institution or state institution. When required, within the framework of tertiary prevention, the adaptation of the workplace to the physical fitness of the affected person, as well as reduction of daily work hours, should be provided. Financial compensation may be needed (for this purpose the early collection of evidence is very important).

PREVENTION

INDIVIDUAL PREVENTION

Potentially, all overseas shipments are treated with fumigants. Usually there are no warning signs of such treatment: no indication on the container or in the shipping documents for that matter. Therefore, education is essential for all employees and persons coming directly into contact with goods transported from overseas (consumer goods, foods, household goods, etc.). All these persons (Table 2) should be informed about the imperceptible dangers, detection methods, possible safety, and first aid measures. They should be aware of medical locations for appropriate diagnostics and care. An overview of typical symptoms and dangerous situations is shown in Table 4.

MEASUREMENTS FOR GLOBAL PREVENTION

As long as the FAO's regulations [1] are not fully complied with, for the protection of all employees, including the general public, several short- and medium-term measures are mandatory:

- Importers must insist on clear and correct labelling of the container and the fumigants used;
- Deliberate addition of a pungent smell to these mostly odourless gases would serve as a warning to this danger;
- Specific air analysis of imported containers and their contents have to be performed;
- For this purpose appropriate workflow organization, protection and training measures should be established;
- The ventilation of suspicious containers should be carried out with special suction-ventilation [20];
- Alternative methods of pest control should be further developed and established worldwide, such as those that rely on heat treatment of dunnage or oxygen-depleted air.

Fumigants escape into the atmosphere and deplete the stratospheric ozone layer.

Table 4. Fumigants, typical clinical findings, and aetiology of safety hazards

Fumigant	Clinical findings	Safety hazards
Ethylene dichloride	• Skin and mucous irritations • Nausea • Reactive airways dysfunction syndrome • In some cases long-term neuropsychological deficits	Not allowed in Europe, but may be used by non-European exporting countries (in such cases, fumigation often will not be displayed). High ambient temperature favours the outgassing. Typical risks: fumigants in the dunnage, unpacking of textiles. Due to lack of reference ranges that correlate with exposure levels it is not possible to assess the level of ethylene chloride to which the person had been exposed from blood or urine measurements [12]
Methyl bromide	• Skin and mucous irritations • Nearly constant headache and dizziness • Respiratory irritation, pulmonary oedema (sometimes delayed 4 to 5 days) [18] • Convulsions, coma, and death • Impaired sense of smell • Less acute symptoms than ethylene dichloride and phosphine in our investigations	Mostly used for fumigation of containers. Intoxication happens while opening containers, unloading, and unwrapping imported goods. Inspection of empty containers with wooden floors. Toxic when inhaled and to a lesser extent when absorbed through skin [10, 19]. Potent ozone-depleting gas
Phosphine	• In our findings almost always reactive airways dysfunction syndrome (with a latency period of 1–2 days) • Skin and mucous irritations are predominant • Neurological disorders (including headache) may also occur, their tendency is somewhat less distinct	Preferred fumigant for grain and food in containers or bulk carriers. Warning signs could be the remaining empty sachets of the aluminium phosphide
Methylene chloride	• Various symptoms • Respiratory irritation	E.g. ironing imported textiles or unpacking of moving boxes. Used as a solvent in the chemical industry [14]

CONCLUSIONS

Simple measures like fumigation are efficient to stop pests and degradation of goods but have a negative impact on the environment and health of persons who handle or receive these goods. Intoxications with fumigants are serious but preventable. Fumigation is highly dangerous for any living thing, no matter whether it is carried out with permitted or forbidden chemicals, whether appropriately labelled or not, whether listed in the shipping documents or not. As long as alternative methods of pest control are ignored or are not possible, the only way to cope with the situation is to educate and train all affected persons about the possible health hazards and to establish safety measures.

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