

Fumigation of cargo on board ships: the invisible killer

Following the tragedy of a seaman's death in his cabin on a vessel with a fumigated cargo on board, Gard News presents an analysis of similar cases.



Plastic tubes used for aluminium phosphide tablets, pulled out after discharge of the cargo holds.

It is extremely important to raise awareness of the dangers of in-transit fumigation of cargo. Fumigation of cargo by hydrogen phosphine gas is excellent for killing insects, but it also endangers the lives of crew members and shore-based personnel if not handled correctly.¹

Fumigation in general

A fumigant is a chemical which under certain conditions will enter a gaseous state and in sufficient concentration will be lethal to pest organisms. One important and useful property of fumigants is that in gas form they diffuse as separate molecules, thus enabling penetration into the material being fumigated and diffuse away afterwards. Aerosols and pesticides sprayed onto plants, etc., are not fumigants.

In the old days, the traditional shipboard fumigants against insects in cargo used to be hydrocyanide acid and mixtures of ethylene dichloride and carbon tetrachloride, but from the 1960s-70s these have been replaced by methyl bromide and hydrogen phosphide. Both are very dangerous if inhaled by humans. Methyl bromide depletes the ozone layer and has been banned in the western world since 2005. Hydrogen phosphide (PH₃) is commonly called "phosphine" and is now the most popular fumigant in use for disinfestation of dry plant products loaded in bulk. Successful use demands longer exposure periods than with methyl bromide – periods from four to five days to a fortnight or more – but that is not a problem due to

¹ The article "In-transit fumigation of bulk cargoes", which appeared in Gard News issue No. 173, cautions shipowners about the risks associated with in-transit fumigation and provides practical advice on how to minimise these risks and otherwise protect their legal position. It also includes a template LOI which represents a fair starting point for negotiations with charterers and, with appropriate amendments, may be used when a charterparty entitles charterers to request in-transit fumigation and also when the charterparty is silent but owners agree to the request nonetheless.

the long haul nature of maritime transportation. Phosphine is easy to handle by the fumigators, as it is manufactured in a solid formulation of either magnesium or aluminium phosphide. These solids, which often are in the shape of tablets, will react and break down in contact with water or in an atmosphere containing moisture. They will then release hydrogen phosphide, a gas efficient in the killing of insects in bulk cargo, like for instance grain. The most favourable conditions for complete release of phosphine from the tablets are in tropical and subtropical climates, where four to five days are sufficient. In temperatures below 15°C, or in a very dry atmosphere, much more time would be needed. If the tablets are only spread on top of the cargo, it will also take time for the gas to spread through the full depth of the cargo, although the gas is heavier than air. Tablets may therefore be placed in tubes penetrating the cargo depth and the gas spread by a fan or pushed into the cargo by probes, etc., to speed up the process.

Pure phosphine gas is odourless. The odour, often compared to the smell of garlic, carbide or decaying fish, is due to a contaminant, offering the advantage of serving as a warning to people. But it is important to know that the lack of odour does not guarantee that there is no dangerous gas. Odour may not be detected under all circumstances and the gassing may last much longer than the emission of the smell.

Most recent Gard case

Gard's most recent case of fumigation causing the death of a seaman happened on board a 30-year-old general cargo ship of 4,000 GT. The vessel loaded a full cargo of wheat in all three holds in Liepaja, Latvia, bound for Antwerp, at the end of 2010. In order to carry out fumigation of the cargo, six pieces of 10 mm diameter plastic tubes were hung from the hatch coamings to the tanktops of each hold before starting the loading. The tubes were of a type with small perforations, used in agriculture for draining wet fields. When the cargo had been loaded, aluminium phosphide tablets were spread on top and dropped into the tubes. Hatchcovers and ventilators to the cargo holds were closed, and plastic bags were placed around the coaming drains. In the accommodation, the main ventilation system was closed down, but people were allowed to use the extraction fans from their bathroom/WC. Outside doors were closed and people forbidden to go out on deck if not necessary for the operation of the vessel. Two gas masks with eight filters and one gas detection kit with 50 detection tubes were delivered to the vessel by the fumigators who advised that the cargo holds could be opened again after five days.

During passage of the Kiel Canal, the bosun needed to go to the forecabin and did so wearing a gas mask. He smelled a strange smell, and the captain ordered the space to be ventilated and then tested for phosphine gas using the detection kit supplied by the fumigators. Having passed the Kiel Canal, the test was negative. The crew members were not very familiar with the use of the kit, and the date limit of the detection tubes expired during the voyage.

Four days after the start of the fumigation, at the time of anchoring to wait for a berth, a seaman complained about feeling ill when being relieved from watch duty in the morning. Due to his eating habits it was believed that he had an indigestion or liver problem and he was sent to bed in his cabin and advised to drink water and take some charcoal tablets. He was very pale, had a slight temperature and was vomiting. The next day he felt better, had regained his normal skin colour and no doctor was therefore sent for. One day after that, the seaman, having spent 48 hours in his cabin, was found dead in his bed. Two days later the second officer also became sick, but recovered later. There was no odour of gas, but when tests were carried out, a high concentration of phosphine gas was detected in spaces within the accommodation.

The deceased seaman's cabin was on main deck level, in front of the accommodation and next to the captain's office. When the lining of the office was pulled down, a small corroded hole was found in the front bulkhead. That steel plate was the common boundary with the aft ventilator from the aft cargo hold. Corrosion within the ventilator over many years had made a small opening for the gas in the cargo hold to pass to the insulation of the accommodation walls. The extraction fans from the toilets created a slight under-pressure, sufficient to draw the gas, which escaped to the cabins wherever there was an opening. The sad truth is that the seaman would most probably have survived if he had not been told to rest in his cabin, and had instead been placed in fresh air.

Following the death of the seaman, there was of course an investigation, and the level of gas in the cargo holds was measured regularly, every day. The process should have been completed after five days, but it took a full month before the gassing stopped. The reason for the slow process must have been the dry weather and the temperature of -10°C at the time of loading. There must have been insufficient moisture in the cargo for the aluminium phosphide tablets to react faster. The small holes of the tubes arranged in the cargo holds may also have provided insufficient contact with the cargo. When pulling out the tubes, several aluminium phosphide tablets were found still intact. It was noted that the distinct odour, which should have made people aware of the presence of hydrogen phosphide gas, had already disappeared after three or four days. When the vessel was finally discharged, the cargo was placed into barges for further transportation on inland waterways. Workers informed that it was not uncommon to see aluminium phosphide tablets still being active in the transshipment of such cargo.

A similar case

This is not the first time that phosphine gas leaks from the cargo hold to the accommodation through corroded holes and causes the death of a seaman. In January 2008 the UK Marine Accident Investigation Branch (MAIB) reported on a very similar case to the above, and issued Accident Flyer 1/2008 to warn the shipping industry.²

The vessel loaded 2,500m³ of feed wheat in Kaliningrad, Russia, bound for Montrose in Scotland. After loading, tablets of aluminium phosphide were pushed into the wheat by a probe and the hatches were closed. The fumigator in charge briefed the chief officer about the dangers of phosphine gas and told him to alert the crew to its distinctive garlic smell. He handed over two gas masks, a gas detector pump and five detection tubes. It took the vessel four uneventful days to go through the Baltic and the Kiel Canal, but in the North Sea she encountered bad weather. To protect the cargo, the hatchcovers were sealed with expanding foam. Several crew members became seasick. One seaman had to give up on his Sunday lunch and retired to his cabin, where he was found dead the next morning. Another seaman had smelled a bad odour outside his next door cabin, but took it to be the smell of vomit due to sea-sickness.



Grain being unloaded from cargo hold. Three out of six vertical plastic tubes can be seen. The aluminium phosphide tablets were placed into these tubes after loading. The tubes had small holes, but contact between cargo and tablets was probably insufficient so it took a full month for the fumigation to be completed in this case.

This vessel was not covered by Gard. She was a 1977-built general cargo ship with two cargo holds and a crew of nine. The front of the accommodation extended the aft bulkhead of the aft cargo hold by 0.5 metres, so the deckplating in way was a boundary between the hold and the forward cabins on deck level. Arriving in port, tests revealed high concentrations of phosphine in the diseased seaman's cabin and the adjacent hospital compartment. At first no leakage path could be found by way of smoke testing, but when chipping rust scales off the underdeck plating, pin holes were found through the steel plating, which could lead the gas to the accommodation. It was assumed that the pounding of the ship in rough weather could have increased the pressure in the sealed cargo hold and thus pressed the gas into the deceased's cabin, although the holes were very tiny and the smoke test at the arrival port had failed. It is not known whether exhaust fans were used in the bathrooms, etc., but if so, that could also have been a contributing factor.

The fumigator had only used 10 minutes on board before loading started, which appears inadequate for a thorough pre-loading survey, although a superficial inspection of the corroded deck-plating would probably not have revealed the danger. Also, the test equipment for phosphine gas had not been used by the crew, and they seem not to have been suspecting a gas leak, attributing the symptoms of dizziness and vomiting to sea-sickness.

Lack of alertness

In 1997 a geared bulker had her holds inspected by officials of the Brazilian Ministry of Agriculture in Paranaguá. The empty vessel passed the inspection, but as insects were found in the cargo of soya bean meal, fumigation by phosphine was ordered by the authorities. As the vessel was then already loaded, all the aluminium phosphide tablets were placed on top of the

² The flyer can be found on the MAIB's website at www.maib.gov.uk.

cargo. The Master was told by the fumigators that the hatches had to remain closed for 10 days. On the second day after the fumigation had started, the vessel now being at sea bound for Ireland, a fitter working on deck felt ill, had convulsions and loss of feeling in his limbs. A further four crew members subsequently fell ill with similar symptoms. The vessel sought medical assistance by radio and headed for Rio de Janeiro, where health authorities came on board and five crew members were hospitalised. The health authorities refused the vessel leave to sail until it was proven that there were no further risks to the crew. Ventilating the cargo holds in the middle of the fumigation process involved the risk that pests might not be killed and the cargo become contaminated.

All the crew members recovered and the case became one of debating who should pay for the deviation and delay of the vessel. Vessel interests maintained that the fumigation firm had not carried out their duty to ensure the vessel was in a suitable condition to be fumigated, in other words, to ensure that there were no outlets for the gas from the cargo holds, while the fumigators blamed the vessel for not having closed cargo hold ventilators gas-tight. No testing equipment was delivered on board by the fumigators and no tests were carried out by the ship, as there was no gas-detecting equipment on board. But there had been a clear smell of gas and the crew had taped leaking hatchcovers. No instructions were apparently given by the fumigators and none were asked for. Both sides quoted the IMO Recommendations on the Safe Use of Pesticides at Sea, the opposition quoting that fumigation in transit "should only be carried out at the discretion of the master", placing responsibility upon him for the safety on board. In hindsight it appears that both sides had been negligent and should have been more alert and careful. The case illustrates how difficult it is for a Master or a charterer to avoid fumigation of a cargo once it is on board and authorities discover that it is contaminated by pests. Phosphine is heavier than air and is meant to be able to penetrate a cargo from top to bottom. It was believed that by placing all the tablets on top of the cargo, there might have been a substantial gas pressure in the headroom of each hold, in the early stages of the fumigation, allowing gas to escape.

A cargo of lumber

Fumigation is not only used for grain cargo, but also against insects in timber. In 2006, a 25,000 GT vessel covered by Gard loaded a cargo of sawn timber in Peru. Before passing the Panama Canal, the vessel anchored at Balboa to take bunkers and carry out fumigation of the cargo using aluminium phosphide, tablets which will produce phosphine gas after contact with moisture. Cargo holds were fumigated for 72 hours, and thereafter ventilated for 24. Thereafter, upon the vessel's berthing at Ponce, Puerto Rico, the fumigators collected the excess tablets from the cargo holds, but had a dispute with the captain about how to dispose of them. At one instance tablets were placed on the wet deck, where they caught fire. As it was raining, the tablets were collected in plastic bags, but the captain did not allow them to be disposed of in the vessel's incinerator, as was the wish of the fumigators. Instead, they placed them in a plastic container filled with water and detergent. Boiling and gassing resulted, before the contents were poured out overboard. There is such a "wet method" designed to deactivate excess material, but appropriate respiratory protection should be used and there are several precautions to observe. The two fumigators became ill and were taken to hospital where they recovered. It was observed that the fumigators had not used their gas masks and their gas detecting equipment while on board. In his report, the surveyor appointed to the case by Gard advised that the incident could have had much more serious consequences.

A full crew in danger

In 2000 an issue of the US Coast Guard News informed that a bulk carrier bound for Australia had to seek refuge at Coos Bay, Oregon due to the entire crew being affected by gas emitting from cargo hold No. 6. That hold contained soya bean meal, and was one of three holds fumigated to control insects at Port Angeles, Washington.

On the second day at sea, 12 of the 19-man crew started complaining about either headache, dizziness, nausea, breathing difficulties, vomiting or diarrhoea, leading the captain to suspect gas leakages from the fumigated holds. Tests carried out revealed that there was 0.5 ppm phosphine in the ship's office. The air conditioning was closed down and all doors and portholes were opened for natural ventilation. All crew members were moved to open air and subsequently recovered.

When a doctor and a fumigation specialist boarded the ship, they found phosphine gas to be leaking from the cargo holds. A leaking ventilator on deck was closed down, and tape, silicone and plastics were used on all openings from the cargo holds, including the drain pipes from the hatch-coamings. Particular attention was paid to lids on access hatches to cargo holds from under-deck passageways. These passageways were connected to the accommodation and non-tight seals may have been the main reason for the crew to be affected. Several of the dogs of the hatch lids were not in order. The surveyor appointed to the case was of the opinion that the firm carrying out the fumigation was wrong when it confirmed that all cargo holds were in good order to fumigate. Pre-voyage fumigation procedures required the vessel to be declared suitably designed and in order so as to allow for safe occupancy by the ship's crew throughout the duration of the fumigation. Otherwise the vessel should not be fumigated unless all crew members were removed from the vessel. The fumigators should have carried out a better inspection of all accesses to the cargo holds, but the vessels owner was also to blame for not having maintained hatch lids, seals and dogs in good order.



Ventilator opening in deck at the aft bulkhead of cargo hold No. 3. The steel bulkhead is the common boundary between the accommodation and the cargo hold ventilator.

Another crew being lucky

Just a few days before Christmas 2010 the entire crew of a bulker could have died on Lake Erie, when phosphine gas seeped into the accommodation. In this ship the leakages were not through corroded holes, as the vessel was only one year old, but through the ventilation system. This was not a Gard vessel, but the story reached the headlines.

The vessel had loaded a cargo of grain in Milwaukee and was on the way to Montreal when most of the crew became ill. Believing the cause to be phosphine from the fumigation of the cargo or food poisoning, the captain called for assistance. Officials at St Lawrence Seaway halted the vessel offshore and a rescue team from the fire department of Port Colborne went on board. They found that the crew quarters contained 1.5 ppm of phosphine gas, and that the sick crew members were lying down in their cabins, with all portholes closed due to the cold weather, inhaling the polluted air from the ventilation system. Investigators determined that the gas that escaped the cargo hold by a piping conduit had been drawn through a supposedly water and air-tight door and into the ventilator room, and from there circulating into the crew quarters by the ventilation system. The crew suffered from vomiting, diarrhoea, headaches and dizziness and several were unable to stand on their own. After stopping the ventilation system and opening all windows, 16 of the 21 crew members on board were evacuated and soon recovered in hospital. If the vessel had not been assisted by the rescue team, there could have been several casualties. According to the US Agency for Toxic Substances and Disease Registry (ATSDR), an eight-hour average respiratory exposure to phosphine gas should not exceed 0.3 ppm and a short-term exposure should not exceed 1 ppm.³

There is no antidote for phosphine poisoning. Treatment consists of support of respiratory and cardiovascular functions. In an emergency it is important to get the victims into fresh air!⁴

The death of a stowaway

Stowaways trying to flee a country may do so in desperation, but may not know the dangers to which they expose themselves – and certainly not when they hide in cargo holds under fumigation. Six stowaways were found on board a vessel in 2009, after leaving Lagos, Nigeria. The first one was found inside a cargo hatch, when a crew member heard him banging on the steel. Two more were found in another hold and two came out of the garbage bin. Those having been in the cargo holds were very weak and groggy, but recovered by resting in fresh air. The sixth was not so lucky; he was found on the upper platform of the ladder from a cargo hold entrance hatch. Revival was attempted, but unfortunately he was already dead. All were taken ashore in Abidjan, and the five were treated in hospital and recovered. The vessel was loaded with fumigated cocoa beans in bags after fumigation of the holds with aluminium phosphide. Cocoa is one of the goods regularly treated with phosphine.

³ Guidelines from US authorities such as the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) provide that worker exposure to phosphine must not exceed the 8-hour TWA of 0.3 ppm. TWA, the Time Weighted Average, is a term used in the specification of Occupational Exposure Limits (OEL). If a person should be exposed to phosphine gas for a full 24 hours, for instance while resting in a cabin polluted by the gas, the gas concentration should thus not exceed 0.1 ppm. European countries are stricter and follow the values of the European Commission's Scientific Committee for Occupational Exposure Limits (SCOEL), which for phosphine is 0.1 ppm for 8-hour TWA.

⁴ Those interested in the medical aspects of phosphine poisoning may wish to get further details of a 1980 case in which two children and 29 of the 31 crew members became ill on board a vessel carrying grain under fumigation. One of the children died. The gas escaped from the cargo hold through a cable box close to an accommodation ventilator. See The Journal of the American Medical Association (JAMA 244: 148-150, 1980).

This is only one of many cases of stowaways dying due to fumigation of cargo.

Flammability

Aluminium phosphide is not itself flammable, but in contact with water hydrogen phosphide gas will be created, which may ignite spontaneously in air. Ignition of high concentrates of hydrogen phosphide can result in a very energetic reaction, an explosion which may cause severe personal injury. To suffocate the flames, do not use water, but sand, carbon dioxide or dry extinguishing chemicals.

In 2008 the Australian Transport Safety Bureau (ATSB) issued a report on a vessel where the cargo was under fumigation and caught fire.⁵

IMO recommendations on the safe use of pesticides in ships

Considering the high toxicity of phosphide, as well as the ability of spontaneous ignition in contact with water or exposed to moisture- laden air, it is imperative to establish and follow a detailed and strict protocol whenever fumigation is to take place. The IMO first issued recommendations on the safe use of pesticides in ships in 1971, which have been revised several times since then by the Maritime Safety Committee. The latest revision can be found as Supplement to the IMDG Code 2010 Edition. There are guidelines both concerning fumigation of cargo holds and fumigation of cargo transport units. Governments are invited by the IMO to bring the recommendations to the attention of competent authorities, mariners, fumigators, fumigant and pesticide manufacturers and others concerned.

If fumigation of a vessel is to take place, the IMO recommendations are the most important guidelines of which mariners should be aware, and should be thoroughly read and followed to the letter. In addition, there may be flag and port state regulations, and not least the manufacturer's instruction in the use of the fumigant. The IMO documents list symptoms of inhalation of phosphine poisoning as "nausea, vomiting, headache, weakness, fainting, chest pain, cough, chest tightness and difficulty breathing". Those symptoms are for those likely to survive. For humans exposed to phosphine gas, death is certainly a possibility, depending on gas concentration and time of exposure.⁶

Observations from incidents

The following observations can be made based on the cases found on Gard's files:

- There are cases where the fumigation firm has not followed the IMO recommendations to the letter.
- There are cases where the information given by the fumigator is not complete or not correct, such as how many days the fumigation process will take. Temperature and humidity have to be considered.
- There are cases where inspections to establish a vessel's suitability for fumigation are very superficial and insufficient to



Aft bulkhead of cargo hold No. 3. The ventilator opening is in the corner, above the ladder. Access is difficult, as it is behind pipes under deck.

⁵ ATSB Marine occurrence investigation No. 250.

⁶ The US National Institute for Occupational Safety and Health (NIOSH) has established the immediate danger to life or health level (IDLH) of phosphine at 50 ppm.

ensure the safety of the crew.

- Some ships are unsuitable for fumigation of cargo due to age and/or lack of proper maintenance of steel boundaries between cargo hold and crew quarters.
- Captains do not always know the details of the IMO recommendations and do not always comply with them. There are cases where the captain appears to consider the fumigation of a cargo to be the business of the shipper and the fumigator, without fully realising his own authority and the responsibilities placed on him by the IMO recommendations.
- There are cases where inadequate test instruments are provided to the vessel, cases where the crew has inadequate knowledge of how to use the equipment, and cases where testing equipment is not used during in-transit fumigation. (Bellow-type test kits with glass tubes are well known on board tankers, but crew members of bulk vessels may not be so familiar in their usage. It is important that the tubes to be used correspond with the expected gas concentration and that the correct number of pumping movements of the bellow is used. Read the instructions! It should also be noted that the test tubes have a limited shelf life, especially if exposed to heat or sunlight. Nowadays there are electronic measuring instruments available, fitted with an alarm, for various gases, including phosphine. These will give permanent control of the gas concentrations in the air, while the bellow-type only tests the air at a given moment. There are also smaller instruments for personal protection. Often vessels under fumigation only have the bellow-type test kit on board, while shore-side inspectors are often equipped with electronic instruments.)
- The IMO recommendations require that the fumigator in charge should ensure that both gas detection and respiratory protection equipment carried on board is in good order.

In many cases such equipment is delivered by the firm carrying out the fumigation. "Respiratory protection" normally consists of one or two gas masks with a supply of filters. But crew members not used to operating in chambers containing gas should be very reluctant to enter them, and be aware that gas masks may leak. Not only do the filters need to be of the right type and replaced as necessary, but the full tightness of the mask may depend on size and shape of head, whether the person is bearded, etc. When entering a space with a gas mask, it is also imperative to ensure that there is enough oxygen in the air of that space. People who understand the dangers of phosphine gas are likely to prefer breathing apparatus with air bottles, where the overpressure in the air supply will hinder a gas leakage through the mask, if they have to enter a space with gas.

- There are cases of people with symptoms of phosphine poisoning who are thought to be suffering from sea-sickness or food poisoning. That may be because the master and crew have not fully understood the risks represented by carrying a cargo under fumigation, not paying sufficient attention to signs of danger.
- Apparently there are no class rules stopping a vessel from being constructed with a deck or bulkhead as a common boundary between the cargo hold and the crew accommodation. This is something that should be looked into by the international classification societies. The positioning of ventilators from cargo spaces and air intakes to the accommodation should also be considered in ships likely to carry cargo under fumigation. All penetrations through common bulkheads, like a small passage for an electric cable, can allow the penetration of gas if not made gas-tight.

Fumigation of containers

Cargo in containers may also be under fumigation. In 2008 three shore-side workers in Rotterdam fainted after opening the doors of a container shipped from the Far East. Hanging on the inside of one of the doors was a bag emitting phosphine gas. Apparently the bag was from a recent previous cargo which the workers had no knowledge of having been under fumigation. The three workers were taken to hospital and recovered fully.

The need to remove and handle remains of fumigation material is well illustrated by the following case, also from 2008. A Gard vessel discharged a 40-foot reefer container in Long Beach, containing 20 pallets of live ornamental plants. At the receiver's premises, the container was emptied and remained in storage for a month, until it was needed for another cargo. In preparation for the next cargo, the container was cleaned, and one worker found a thin-walled aluminium cylinder, similar to a cigar tube. It was open at one end and marked "30 tablets Aluminiumphosphide. Poison!" The worker sniffed at the open end and noted a grey powdery material inside. A second worker also handled the tube and sniffed at the open end. The terminal management was thereafter contacted and the two workers filed for compensation - in case of potential harm from exposure to the substance. No one was harmed, as the tube did not emit any phosphine gas, but the claim process involved surveyors, lawyers, doctors and a hazardous material firm.

In 2009 Gard had a case on board a container vessel sailing to Valparaiso from Callao in Peru. On the vessel's open deck were 28 containers under fumigation. Twelve hours after departure, the bosun noted a strong odour on deck, which he ignored at first. After some time he started sweating, vomiting and had a headache. Two other crew members felt the odour, but had no health complications. Access to the area was then restricted, and ventilation of the accommodation was shut down as a safety measure. Analysing the Stowage Plan and the Dangerous Goods Plan, the location of the containers under fumigation was identified. All containers were marked with labels announcing that they were under fumigation by aluminium phosphide and should not be entered. At the discharge port, health authorities examined the vessel, but the gassing was then over and as no abnormalities were found, the vessel was allowed to unload. The bosun was examined in hospital and found to have completely recovered with fresh air alone.

It is important that people on board container vessels are also informed of containers under fumigation and warned to observe the smell of gas and the symptoms of phosphine poisoning. But it is shore-based people who are most at risk, when involved in the opening and discharging of such containers. There is a new handbook available, "Don't get caught by surprise", which deals with toxic gases in containers and how to act safely.⁷

⁷ www.tgav.info.