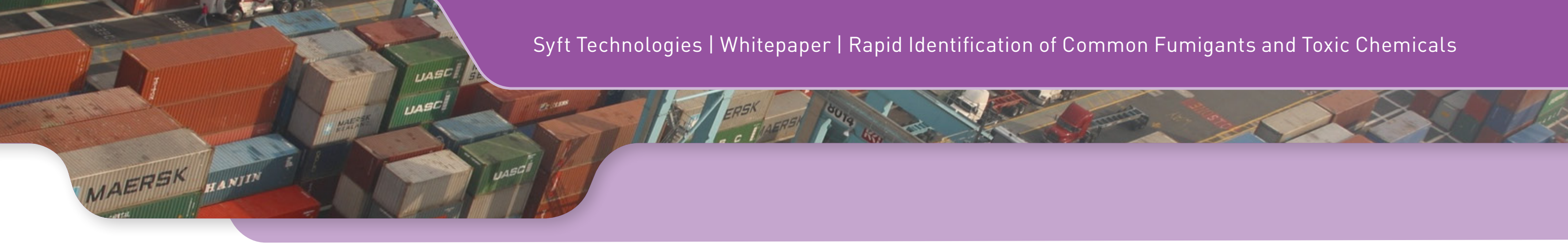

Rapid Identification and Quantification of Common Fumigants and Toxic Chemicals in the Shipping Industry

Frontline workers in the shipping and border security industries face constant danger from exposure to undocumented or incorrectly packaged or applied toxic compounds, such as fumigants and toxic industrial chemicals (TICs).

Until now, protecting workers from these dangers has been difficult because traditional detection technologies have proven too slow, inaccurate or uneconomic for fast-paced modern freight handling facilities.

SIFT-MS is the first technology proven capable of rapidly, simply and accurately detecting and quantifying a broad range of fumigants and TICs, without unnecessarily disrupting movements through freight-handling facilities. With an ability to identify compounds well below risk levels for long-term exposure, SIFT-MS is successfully protecting workers in the shipping and border security industries.

Introduction

Economic gains associated with globalization and increased international trade have multiplied the financial and ecological risks of biosecurity threats. In a world where international trade is worth trillions of dollars, no country can afford to ignore biosecurity threats and the potential for lost markets and crippled industries. To minimize these risks, most countries now demand that imported goods be fumigated, either at source or point of entry.

Another consequence of growing international trade and industrialization is the increasing trade and shipment of toxic industrial chemicals (TICs). With standards for and attitudes to these chemicals varying greatly between jurisdictions, frontline workers in the shipping and border security industries face exposure to very real, often undocumented, dangers.

Unfortunately, given the size and diversity of international trade, it has not proved possible to accurately track which fumigants and TICs are being used and shipped, what concentrations are being used and shipped, or what qualifications and experience those doing the fumigation or packaging have. A recently published study[1] involving analysis of over 2000 containers arriving in the Port of Hamburg over a 10-week period clearly illustrates this problem. Chronic reference exposure levels were exceeded in 70% of containers. Still more alarming was that 36% of the containers had concentrations over acute reference exposure levels.

This means safeguards are needed to protect the health of workers involved with loading, transport, inspection and unloading of imported goods, particularly shipping containers.

In this whitepaper we overview the common fumigants and volatile TICs, and compare commercially available detection technologies, including Selected Ion Flow Tube Mass Spectrometry (SIFT-MS).

Common Fumigants

A variety of fumigants are commonly used against biosecurity threats, some of which are listed in Table 1. The chemical and toxicities properties of these fumigants are very diverse.

Table 1 also lists time-weighted average (TWA) exposures given by the Australian Government's (http://www.safeworkaustralia.gov.au/swa/HealthSafety/HazardousSubstances/HSIS/). Note that acceptable exposure levels may differ from country to country. For example, in the United States exposure limits may be found in the National Institute for Occupational Safety and Health Pocket Guide to Chemical Hazards at http://www.cdc.gov/niosh/npg/.

When protecting workers from these toxic chemicals it is recommended that several fumigants be detected at much lower levels than those indicated (for example, ethylene dibromide and methyl bromide, which are known carcinogens, and ethylene oxide and formaldehyde, which are suspected carcinogens).

Table 1. Common fumigants, their uses and occupational exposure limits.

Fumigant name (synonyms) [CAS number[1]]	Examples of fumigant use	TWA[2]
Chloropicrin (trichloronitromethane) [76-06-2]	Soil; timber and timber products	0.1 ppm (0.67 mg/m^3)
Ethylene dibromide (1,2-dibromoethane) [106-93-4]	Soil; post-harvest for crops; citrus and tropical fruits; vegetables; beehives	0.5 ppm (3.9 mg/m^3)
Ethylene oxide (oxirane, 1-2-epoxyethane) [75-21-8]	Grains; dried fruits and nuts	1 ppm (1.8 mg/m^3)
Formaldehyde (methanal) [50-00-0]	Eggs (killing viruses and bacteria); most commonly present due to outgassing from manufactured goods	1 ppm (1.2 mg/m^3)
Hydrogen cyanide [74-90-8]	Fresh produce; structures; aircraft	10 ppm (11 mg/m^3)
Methyl bromide (bromomethane) [74-83-9]	Very widely used general fumigant, but especially for wood[3]	5 ppm (19 mg/m^3)
Phosphine [7803-51-2]	Grains; tobacco; dried fish and meats; fresh fruits; beverages	0.3 ppm (0.42 mg/m^3)
Sulfuryl fluoride (Vikane™) [2699-79-8]	Structures; timber and timber products; shipping containers	5 ppm (21 mg/mv)

1. 'CAS number' refers to the unique identifier assigned to a chemical compound by the American Chemical Society's Chemical Abstract Service (www.cas.org).
2. Time-weighted averages (TWAs) from the Australian Government's agency Safe Work Australia. Units are parts-per-million (ppm) by volume and milligrams per cubic meter (mg/m^3).
3. Food and Agriculture Organization of the United Nations (2002). "Guidelines for regulating wood packaging material in international trade", ISPM Pub. No. 15, FAO, Rome.

Common TICs

A vast range of compounds are produced in very large quantities by industry as end products or as building blocks to form other chemicals. Among these are many TICs, some of which are volatile and pose health risks to workers who are exposed to their vapors when they are transported. Table 2 lists some very common examples of volatile TICs.

Table 2. Common toxic industrial chemicals, their uses and occupational exposure limits.

TIC name (synonyms) [CAS number[1]]	Examples of TIC use	TWA[2]
Benzene [71-43-2]	Precursor for many industrial compounds	1 ppm (3.2 mg/m^3)
Toluene [108-88-3]	Solvent, synthetic precursor, fuel	50 ppm (191 mg/m^3)
Ethylbenzene [100-41-4]	Intermediate in synthesis of styrene	100 ppm (434 mg/m^3)
Xylene [1330-30-7; 95-47-6; 106-42-3; 108-38-3]	Solvent, cleaner, synthetic precursor	80 ppm (350 mg/m^3)
Styrene [100-42-5]	Synthesis of polystyrene, etc.	50 ppm (213 mg/m^3)
Mesitylene (1,3,5-trimethylbenzene) [98-82-8]	Solvent	25 ppm (125 mg/m^3)
1,3-Butadiene [106-99-0]	Manufacture of synthetic rubber	10 ppm (22 mg/m^3)
Ammonia [7664-41-7]	Fertilizers, synthesis, refrigeration	25 ppm (17 mg/m^3)
Phenol [108-95-2]	Synthesis of plastics, pharmaceuticals, etc.	1 ppm (4 mg/m^3)
Acetaldehyde (ethanal) [75-07-0]	Synthetic precursor	20 ppm (36 mg/m^3)
Dichloromethane (methylene chloride) [75-09-2]	Solvent, cleaner	50 ppm (174 mg/mv)
Chloroform (trichloromethane) [67-66-3]	Solvent, cleaner, anesthetic	2 ppm (10 mg/m^3)
1,1-Dichloroethane (vinylidene chloride) [75-35-4]	Synthetic precursor	5 ppm (20 mg/m^3)
Vinyl chloride (chloroethylene) [75-01-4]	Manufacture of PVC	5 ppm (13 mg/m^3)

1. 'CAS number' refers to the unique identifier assigned to a chemical compound by the American Chemical Society's Chemical Abstract Service (www.cas.org).
2. Time-weighted averages (TWAs) from the Australian Government's agency Safe Work Australia. Units are parts-per-million (ppm) by volume and milligrams per cubic meter (mg/m^3).

Detection Technologies

There are a number of commercially available technologies for fumigant detection, several of which are compared in Table 3. They range from the simplicity of compound-specific colorimetric tubes to the complexity of gas chromatography.

Table 3 indicates that SIFT-MS offers the most comprehensive fumigant detection solution, especially in situations where it is not known which fumigants have been used. Moreover, the high sensitivity of SIFT-MS provides added confidence that carcinogenic fumigants will be detected at levels much lower than formal TWAs, thus avoiding unnecessary exposure.

Table 3. A comparison of the characteristics of a variety of commercially available fumigant detection technologies.

Characteristic	Colorimetric Tubes[1]	Electronic Detectors[2]	GC Detection[3]	SIFT-MS
Breadth of analysis	One tube per fumigant tested	Limited to a few fumigants per detector	All fumigants, but this requires several analyses using different columns	All fumigants. Easily configured for detection of any additional volatile organic compounds
Specificity	Moderate	Low to moderate	High	High
Sensitivity	Moderate	Moderate	High	High
Accuracy	Moderate	High	High	High
Speed	Approx. 1 minute	Approx. 1 minute	> 15 minutes	< 1 minute[4]
Required user skill level	Low	Low	High	Low
Consumable costs per sample	High	Low	Moderate	Low
Maintenance	Low	Low to moderate	High	Moderate
Sample preparation	No	No	Yes	No

1. For example, Dräger and Kitagawa tubes.
2. Performance varies depending on the type of detector, so generalizations have been made. Detectors in this class include infrared sensors, electronic noses and photoionization detectors (PIDs).
3. Most often the detector is a mass spectrometer, but specific detectors may be used for certain compounds.For example, an electron capture detector (ECD) for halogenated compounds.
4. SIFT-MS offers real-time detection and quantification of fumigants. See references 2-4 for more information about SIFT-MS

Conclusion

A diverse range of fumigants and TICs with a diverse range of chemical properties occur at harmful levels with concerningly high frequency. Until now there has not been a technology that can rapidly, accurately and simultaneously detect this range of threats. SIFT-MS, however, provides rapid and accurate broad-spectrum fumigant and TIC screening, combined with simplicity of operation.

For the first time, SIFT-MS provides workers and businesses in the shipping, freight and border security industries with a reliable and safe fumigant and TIC detection system.

References

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