SAFE AND EFFECTIVE FUMIGATION PRACTICE

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What is fumigation?

**Fumigation** is a treatment with a chemical agent that reaches the commodity wholly or primarily in a *gaseous* state (ISPM No. 5 Glossary of phytosanitary terms, FAO, 1990; revised FAO, 1995)

**Fumigation** is the process of *application, exposure and dissipation* of a toxic chemical in its *gaseous* state with the purpose of control of target pests in the product and its enclosure (GAFTA 2012, Fumigation Rules 132)
# Fumigation And Fogging Difference

<table>
<thead>
<tr>
<th>Key Differences</th>
<th>Fogging</th>
<th>Fumigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties</td>
<td>Creates fog using a mixture of insecticide and a carrier.</td>
<td>Highly toxic gas acting at the molecular level.</td>
</tr>
<tr>
<td>Target pests</td>
<td>Reducing the adult flying insects population, especially mosquitoes</td>
<td>Control of Stored Product Insects at all life stages.</td>
</tr>
<tr>
<td>Service person</td>
<td>Trained pest control experts</td>
<td>Professional and licensed fumigators</td>
</tr>
<tr>
<td>Types</td>
<td>Thermal fogging:</td>
<td>Fumigants:</td>
</tr>
<tr>
<td></td>
<td>• Water-based fogging</td>
<td>• Phosphine gas, Methyl Bromide gas</td>
</tr>
<tr>
<td>Service area</td>
<td>Can be carried out in an open environment</td>
<td>Gas can only be released in enclosed and airtight space</td>
</tr>
<tr>
<td>Plant protection</td>
<td>Prolonged protective effect after application</td>
<td>During exposure time only. No protective effect after ventilation.</td>
</tr>
<tr>
<td>Health effects</td>
<td>Low risk of adverse health effects on people who are occasionally exposed to the fog.</td>
<td>Can cause death if proper safety checks are not done.</td>
</tr>
</tbody>
</table>
Why fumigate?

**IPPC - the International Plant Protection Convention**
- International cooperation in controlling pests of plants and plant products and in preventing their international spread, and especially their introduction into endangered areas.

**WTO - Sanitary and Phytosanitary Agreement (SPS)**
- Countries require the compliance of imported agricultural products with their national sanitary and phytosanitary regulations.
- The primary aim of these regulations is to protect human, animal or plant life or health from pests and diseases that may be brought in by imported agricultural products.
Parties to Fumigation

- REGULATORY AGENCIES
- THE CARRIER (THE KEEPER)
- THE FUMIGATOR
- THE TRADER
Best Fumigation Practice

1. **SANITARY**: the people inside and around the fumigation treatment area remain safe

2. **ENVIRONMENTAL**: the environment inside and around the fumigation treatment area is not harmed

3. **ECONOMICAL**: the product treated is not damaged in any way and the fumigation treatment procedure is cost effective

4. **PHYTOSANITARY**: all life stages of all target pests are controlled as a result of fumigation treatment
Fumigation Certification
3.3.2.1 Fumigation in transit should only be carried out at the discretion of the master.

**In-transit fumigation options:**

.1 fumigation in which treatment is intentionally continued in a sealed space during a voyage and in which no aeration has taken place before sailing; and

.2 in-port cargo fumigation where some aeration is carried out before sailing, but where a clearance certificate for the cargo hold(s) cannot be issued because of residual gas and the cargo hold(s) has been re-sealed before sailing.
Fumigation Certification

A. IN-PORT FUMIGATION
1. Fumigant application
2. Exposure period
3. Cargo degassing
4. Efficacy control
5. Certificate issuance

B. IN-TRANSIT FUMIGATION
1. Fumigant application
2. Certificate issuance
3. Exposure period
4. Cargo ventilation
5. ???
Lack of fumigation clearance risks:

- Poisoning
- Fire
- Pollution
- Damages
- Demurrage
- Penalties
Fumigation Clearance

1. Cargo Degassing (Sanitary)
2. Residues disposal (Environmental)
3. Efficacy control (Phytosanitary)
4. Certification (Clearance) (Economical)

IMO Recommendations:
5.1.1. Qualified operators only
5.1.2. Clearance certificate

IMFO Solution:
Port-to-Port Service
Fumigation Essentials
## Factors affecting fumigation efficacy

<table>
<thead>
<tr>
<th>FACTORS</th>
<th>CONTROLABILITY</th>
<th>EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target organism</td>
<td>Non - controllable</td>
<td>Hidden infestation, mites</td>
</tr>
<tr>
<td>Temperature</td>
<td>Non - controllable</td>
<td>Not effective &lt; +10°C</td>
</tr>
<tr>
<td>Moisture content</td>
<td>Non - controllable</td>
<td>Not effective &lt; 40%</td>
</tr>
<tr>
<td>Gas tightness</td>
<td>Controllable</td>
<td>Safety + Efficacy + Economy</td>
</tr>
<tr>
<td>Fumigant quality</td>
<td>Controllable</td>
<td>&quot;Cheaper&quot; does not mean &quot;better&quot;</td>
</tr>
<tr>
<td>Gas permeation</td>
<td>Controllable</td>
<td>Poor &gt; 12 m of product depth</td>
</tr>
</tbody>
</table>
Gas tightness

Gas-tightness is the key factor for the fumigation success!

- **Sanitary**: Preventing the people from being exposed to dangerous gas concentrations;
- **Ecological**: Preventing the non-target organisms from being exposed to dangerous gas concentrations;
- **Economical**: Preventing expensive products and materials waste;
- **Phytosanitary**: Maintaining the lethal concentration of fumigant during the time necessary to control the target pests.
Typical sources of gas leakage

- Access areas to holds: hatch covers, vents and forced draught systems, manholes and other openings. Particular attention should be paid to the condition of gaskets in all openings.

- Structural or other systems that may allow the fumigant to leak from one area to another, such as coffer dams, pumping systems, all weather tunnels, keel ducts, electrical conduit, smoke detection or fire extinguishing systems, bilges and bilge pumps, deck lockers, bulkheads and decks, refrigeration drain lines from galley, antenna wires from crew's quarters.
Typical sources of gas leakage

• The special attention should be given to cargo compartments bordering or connected with the ship's working or living quarters through pipelines, drains, etc.

• Any source of potential gas leakage should be effectively sealed before fumigant application
Gas Tightness Testing

KINDS OF TESTS

- Chalk test
- Light test
- Smoke test
- Hose test
- Ultrasonic test (?)
- Pressure test (!)

Instrumental test required by IMO (p. 3.3.2.4)
Fumigant Formulation

Tablet reaction

Phosphine gas

Hydrogen Phosphide (or phosphine) – PH$_3$ is released from metal phosphide fumigants in the presence of atmospheric moisture and moisture of the goods to be treated.

Chemical reactions of metal phosphides:

- Aluminium Phosphide: 
  \[ \text{AlP} + 3\text{H}_2\text{O} \rightarrow \text{Al(OH)}_3 + \text{PH}_3 \uparrow \]

- Magnesium Phosphide:
  \[ \text{Mg}_3\text{P}_2 + 6\text{H}_2\text{O} \rightarrow 3 \text{Mg(OH)}_2 + 2\text{PH}_3 \uparrow \]
Phosphine properties

<table>
<thead>
<tr>
<th>PH₃ in air</th>
<th>%</th>
<th>ppm</th>
<th>g/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 AlP tablet release</td>
<td>0.07</td>
<td>694.9</td>
<td>1</td>
</tr>
<tr>
<td>At 15°C, 760 mmHg</td>
<td>1.0</td>
<td>10 000</td>
<td>14.39</td>
</tr>
<tr>
<td>Lower Flammability Limit</td>
<td>1.6</td>
<td>16 000</td>
<td>23.0</td>
</tr>
<tr>
<td>Boiling point</td>
<td></td>
<td>−87.7 °C</td>
<td></td>
</tr>
<tr>
<td>Specific gravity</td>
<td></td>
<td>1.2</td>
<td></td>
</tr>
</tbody>
</table>
High moisture content fumigation

Rapid phosphine gas liberation in wet cargo conditions may result in explosion.
Improper fumigant application may result in highly active (dangerous) residues.
Prepack form

- The maximum concentration of Phosphine is reached in 24 - 36 hours depending on ambient temperature & humidity;
- Residue does not come in the direct contact with the commodities. The spent residue magnesium hydroxide (3Mg(OH)₂) remains in the moisture permeable membrane and is easily removed;
- Formulated without ammonium carbamate (NH₂COONH₄). It won’t release ammonia (2NH₃) during the fumigation
Cylindrized (liquified) Phosphine

VAPORPH$_3$OS:
- PH$_3$ – 100%

ECO$_2$FUME:
- CO$_2$ – 98%
- PH$_3$ – 2%
Exposure Time (Inland Fumigation)

Commodity Operations Fumigation Protocol (COFP), Fumigation Handbook, USDA

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Minimum Concentration</th>
<th>Minimum Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 15°C</td>
<td>&gt;300 ppm</td>
<td>*See note below</td>
</tr>
<tr>
<td>From 15°C to 20°C</td>
<td>300 ppm</td>
<td>144 hours</td>
</tr>
<tr>
<td>Above 20°C</td>
<td>300 ppm</td>
<td>96 hours</td>
</tr>
</tbody>
</table>

**NOTE:** Fumigation under storage temperatures below 15° C with phosphine gas is less effective than at higher temperatures; therefore, gas concentrations above 300 ppm should be maintained as long as possible past the minimum of 144 hours.
Temperatures During Voyage

Annual Weather Averages Near Odesa
Averages are for Odesa Airport, which is 6 kilometers from Odesa.
Based on weather reports collected during 1985–2015.

Annual Weather Averages Near Port Said
Averages are for Port Said Airport, which is 5 kilometers from Port Said.
Based on weather reports collected during 1985–2015.

All Year Climate & Weather Averages in Odesa
High Temp: 28 °C
Low Temp: -3 °C
Mean Temp: 11 °C
Precipitation: 14.1 mm
Humidity: 75%
Dew Point: 6 °C
Wind: 14 km/h
Pressure: 1017 mbar
Visibility: 10 km

All Year Climate & Weather Averages in Port Said
High Temp: 31 °C
Low Temp: 12 °C
Mean Temp: 22 °C
Precipitation: 0.4 mm
Humidity: 71%
Dew Point: 16 °C
Wind: 16 km/h
Pressure: 1014 mbar
Visibility: 10 km
Voyage Time

**Distance from Ukraine to Egypt**

- Odessa – Istanbul: 345 nm
- Istanbul – Alexandria: 720 nm
- **Total Distance:** 1065 nm
- @Speed: 10 knots
- **Voyage time:** 4D 10H
## Exposure Time (In-transit Fumigation)

**Fumigant Application Methods and Mandatory Minimum Exposure Time, Fumigation Handbook, USDA**

<table>
<thead>
<tr>
<th>Application Method and Minimum Dosage Rate Per 1 Cubic Meter of Cargo Hold</th>
<th>CARGO HOLD DEPTH IN METERS*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 6</td>
</tr>
<tr>
<td>SURFACE APPLICATION</td>
<td></td>
</tr>
<tr>
<td>metal phosphide - 1.6 g/m³</td>
<td>9</td>
</tr>
<tr>
<td>SUBSURFACE APPLICATION</td>
<td></td>
</tr>
<tr>
<td>metal phosphide - 1.6 g/m³</td>
<td>8</td>
</tr>
<tr>
<td>RECIRCULATION APPLICATION - I</td>
<td></td>
</tr>
<tr>
<td>metal phosphide - 1.2 g/m³</td>
<td>4</td>
</tr>
<tr>
<td>RECIRCULATION APPLICATION - II</td>
<td></td>
</tr>
<tr>
<td>aluminum phosphide pellets - 1.6 g/m³</td>
<td>3.5</td>
</tr>
<tr>
<td>magnesium phosphide pellets - 1.0 g/m³</td>
<td></td>
</tr>
</tbody>
</table>

* Cargo Hold Depth is the length from the bottom of the hold to the top of the coaming.

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* Exposition Time *(In-transit Fumigation)*

Fumigant Application Methods and Mandatory Minimum Exposure Time, Fumigation Handbook, USDA
Phosphine Penetration

Passive fumigation (No Recirculation System)

- **Phosphine** gas moves down through the grain mass very slowly by own gravity
- After 5 – 7 days some phosphine gas should reach 10-12 m at effective concentrations
- **Phosphine** gas very unlikely to reach 15 - 20 m at effective concentrations however long the voyage
- **Not recommended** for shipments over 10 000 mt or holds deeper 12 m.
Phosphine Penetration

Active fumigation (With Recirculation System)

- **Phosphine** gas is drawn from cargo surface to bottom of hold by electric blower through plastic piping
- **Phosphine** gas penetrates through cargo mass as re-circulation continues during voyage
- **Is recommended** for shipments over 10,000 mt or when grain or commodity is greater than 12 m in depth
Re-circulation system

Installation of plastic pipes for the re-circulation system before loading operations
Re-circulation system

Proper connection of electric fan to plastic piping and ships electricity is principal.
Fumigation Monitoring

Fumigation Safety & Efficacy Monitors
Safe Concentration Limits

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TLV-TWA</strong> – <em>Time Weighted Average</em> - for a normal eight-hour work-day or 40-hour work-week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effects.</td>
<td>0.3 ppm (0.4 mg/m³)</td>
</tr>
<tr>
<td><strong>TLV-STEL</strong> - <em>Short Term Exposure Limit</em> - the maximum concentration to which workers can be exposed for a period up to 15 minutes continuously</td>
<td>1.0 ppm</td>
</tr>
</tbody>
</table>
### 3.3.2.7 The ship should carry:

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>.1</td>
<td>gas-detection equipment and adequate fresh supplies of service items for the fumigant(s) concerned, together with instructions for its use and the occupational exposure limit values set by the flag State regulations for safe working conditions;</td>
</tr>
<tr>
<td>.2</td>
<td>instructions on disposal of residual fumigant material;</td>
</tr>
<tr>
<td>.3</td>
<td>at least four sets of adequate respiratory protective equipment and</td>
</tr>
<tr>
<td>.4</td>
<td>a copy of the latest version of the Medical First Aid Guide for Use in Accidents Involving Dangerous Goods (MFAG), including appropriate medicines and medical equipment.</td>
</tr>
</tbody>
</table>
## Effective Concentration

### Gas Detector Tube Specification Summary

**Phosphine (PH₃)**
- **TWA (TLV):** 0.3 ppm
- **STEL (TLV):** 1 ppm
- **Flammable Range:** NA

### Measurement Range
- 10,000-200,000 ppm-hours

### Sampling
- By diffusion

### Color Change
- Yellow → Black

### Shelf Life
- 2 years (preferred storage below 10°C (50°F))

### Active Reagent
- Gold

### Dose
- **ppm**
- **g/h/m³**
- **Total:** 180,000 ppm * h * m³ = 250.2 g/h/m³

### Average Concentration
- **ppm**
- **g**
- **Total:** 1,071 ppm = 1.49 g

### Conversion
- **1 ppm = 1.4 mg/m³**

**Exposure Time:** 168 H (7 D)

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Safe & Effective Concentration

Wireless phosphine sensors

- Easy to use, robust and accurate sensors in gas tight shells
- Gas concentration measured automatically in a given frequency
- The system is equipped with a sound and light alarm
- Reports to a gateway that uploads all data to the cloud
- Cognitive software is turning the data into graphs and keeps record
- A control center is informed in real time of any leakage 24/7
Current MRL values


<table>
<thead>
<tr>
<th>Code number</th>
<th>Groups and examples of individual products to which the MRLs apply (a)</th>
<th>Phosphane and phosphide salts (sum of phosphane and phosphane generators (relevant phosphide salts), determined and expressed as phosphane)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0500030</td>
<td>Maize/corn</td>
<td>0.7 mg / kg</td>
</tr>
<tr>
<td>0500090</td>
<td>Wheat</td>
<td>0.05 mg / kg</td>
</tr>
</tbody>
</table>
Notifications

RASFF - Food and Feed Safety Alerts - features an interactive searchable online database

<table>
<thead>
<tr>
<th>product category</th>
<th>date</th>
<th>notification type</th>
<th>notified by</th>
<th>countries concerned</th>
<th>subject</th>
<th>action taken</th>
<th>distribution status</th>
<th>risk decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>cereals and bakery products</td>
<td>04.04.2005</td>
<td>information</td>
<td>Italy</td>
<td>Argentina (O), Italy</td>
<td>yellow hybrid popcorn from Argentina incorrectly stored together with hazardous chemicals (Aluminium phosphide)</td>
<td>re-dispatch</td>
<td>no distribution</td>
<td>undecided</td>
</tr>
<tr>
<td>fruits and vegetables</td>
<td>22.10.2014</td>
<td>alert</td>
<td>United Kingdom</td>
<td>Austria (D), Belgium (D), Cyprus (D), Finland (D), France (D), Germany (D), Ghana (D), Ireland (D), Italy (D), Malta (D), Netherlands (D), Nigeria (D), Norway (D), Poland (D), Portugal (D), Sierra Leone (D), Spain (D), Sweden (D), Switzerland (D), Trinidad and Tobago (D), United Kingdom (D), United States (D), unknown origin (O)</td>
<td>risk of chemical contamination (aluminium phosphide) of brown beans from unknown origin</td>
<td>recall from consumers</td>
<td>distribution to other member countries</td>
<td>serious</td>
</tr>
<tr>
<td>fruits and vegetables</td>
<td>11.11.2014</td>
<td>information for attention</td>
<td>Ireland</td>
<td>Ireland (D), Nigeria (O)</td>
<td>risk of chemical contamination (aluminium phosphide) of brown beans from Nigeria</td>
<td>withdrawal from the market</td>
<td>distribution restricted to notifying country</td>
<td>serious</td>
</tr>
<tr>
<td>fruits and vegetables</td>
<td>30.01.2015</td>
<td>information for attention</td>
<td>Ireland, Commission Services, Ireland (D), Nigeria (O)</td>
<td>risk of chemical contamination (aluminium phosphide) of brown beans from Nigeria</td>
<td>recall from consumers</td>
<td>distribution restricted to notifying country</td>
<td>serious</td>
<td></td>
</tr>
</tbody>
</table>

RASFF Portal Search result: 4 notifications (on 10.01.2020)
Fumigation Code of Practice

“IF YOU ARE NOT MONITORING, YOU ARE NOT FUMIGATING”

- Created by the Phytosanitary Association of Ukraine (PAU) on the request of the Food and Agriculture Organization of the United Nations (FAO) with the support of the European Bank for Reconstruction and Development (EBDR)

- Provides practical recommendations for safe and effective fumigation of grains and grain products with phosphine during storage or transportation

- Used for certification of fumigation companies in Ukraine by PAU.
Fumigation Protocol for Egypt

- Compulsory instrumental check of cargo holds gas tightness (IMO MSC.1/Circ.1264, p. 3.3.2.4);
- The minimum effective fumigant dosage rate (3.0 g/m³ – for tested, 4.5 g/m³ – non-tested);
- Compulsory recirculation system use for commodity depth over 12 m;
- The minimum effective fumigant exposure time (5 days);
- Compulsory fumigation clearance procedure before discharging (Clearance/Gas-Free Certificate).
Thank You For Attention!

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