

Phosphine

Fumigation Management

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1. Introduction

Fumigants are insecticides in the form of gas. They kill adult insects that live on the outside of most grains and do away with the eggs, larvae and pupae that generally make their home inside the grain.

Fumigants must be used only in receptacles that do not allow the gas to escape. Remember that it is toxic and can kill humans as well as domestic animals in the same way as it does insects.

Nonetheless, phosphines are the least harmful fumigant. They are also the easiest to use. Phosphine tablets can be easily purchased at agrochemical product distributors and small village stores in all of Central America.

2. Description of Phosphine

Synonyms for phosphine include hydrogen phosphide and phosphorated hydrogen. Commercial names include Phostoxin, Gastion, Detia, Gas XT, Fumitoxin, quickphos, celphos, and others. Its ease of handling and effectiveness have made it the most important fumigant in the world.

Its formulation is solid and usually is concentrated in tablets weighing 3 grams each. Most cans contain 168 tablets or 6 tubes with 28 tablets each. It is indispensable that

these receptacles containing the tablets remain well closed when not in use. At present there are receptacles on the Central American market containing 3 tablets weighing 3 grams each. These are used for fumigation in storage facilities with a capacity for 1,360kg or less.

The tablets contain aluminum phosphide (AIP) covered with paraffin and mixed with ammonium carbonate ($\text{AIP} + 3\text{H}_2\text{O} = \text{PH}_3 + \text{Al}(\text{OH})_3$). This formula turns into gas only upon being removed from the receptacle and coming into contact with the humidity in the environment. The hydrogen phosphide (PH_3) being released is a very toxic gas. It is colorless and is the active ingredient that kills the insects in their various phases of development (egg, larva, pupa and adult). The fumigant penetrates the bodies of the insects through the stigmas as they breathe.

Carbon dioxide and ammonium are also released, thus reducing the danger of combustion when the phosphine emerges from the tablets. With their smell of carbide or garlic they also act as an alarm for the fumigator.

The dispersion of the gas takes place rapidly through the mass of the grains in the form of isolated molecules. For this reason, phosphine should be used only in an airtight setting, which is to say in well-sealed Postcosecha Metal Silos.

The liberation of gas reaches its maximum intensity approximately 4 hours after the tablets are put into the silo and ends 4 days afterwards. Nevertheless, a small amount of gas is liberated immediately and continuously from the moment the tablet is exposed to the air and thus to humidity.

The length of time during which the gas is freed, and therefore the toxicity of the fumigant to insects, depends upon a series of complex and interrelated factors, such as for example, the fact that at temperatures under 15°C, the reaction takes place very slowly. This influences the breathing rate of the insects and interferes in the absorption and dissemination of the gas through the mass of the grains. It is generally true that the liberation of the gas and its toxicity increase as the temperature rises.

The high content of humidity in the grains leads to a greater absorption of the fumigant, but reduces its distribution and penetration in the mass of the grains. The tablet will slowly decompose at a relative humidity of less than 40% or at an 8% to 10% equilibrium in the humidity contents of the grain.

Due to the reduced volume of air in the smaller grains (sesame, sorghum, etc.) it is more difficult to disseminate the fumigant than in the larger ones (maize, beans).

Other factors that affect the toxicity of the fumigant are related to factors such as the type of storage structure used, the construction materials employed and the time of exposure to fumigation.

Once all of the gas has been liberated from the tablet, a residual powder is left over. This will be mainly Aluminum (Al), which is hardly toxic at all for humans and insects.

Considering the environmental conditions that prevail in Central America, fumigation with phosphine will last 10 days, whereupon the residual powder should be buried.

3. Factors that influence fumigation

When applying phosphine there are many factors that play a role. The most important of these are the *airtightness* of the structure in which fumigation is to occur, the *dose* to be employed and the *time* during which the adequate concentration of gas and the grains must remain hermetically sealed.

3.1 Airtightness

Phosphine tablets are used to control infestation by insects of grains stored in airtight structures such as metal silos, barrels or brick silos, all of which can be sealed so that the gas cannot escape.

It is important to remember that this fumigant is volatile and active for a short period only. It can be easily distributed throughout the entire volume occupied by a particular storage system. However, if the structure is not completely airtight, some gas will necessarily escape and not all insects will be eliminated, thus leading to greater resistance on the part of the insects.

In case a load of bagged grains is to be fumigated, it is necessary to use a canvas or plastic cover in perfect conditions. Airtightness can be achieved by placing the plastic over all the bags of grains, leaving only a flap along the edges of the pile of bags. These flaps must then be properly sealed. This can be achieved by using sand, earth, or bags of sand (sand bag rings, etc.), which must be placed upon the plastic flaps to prevent the gas from escaping, thus creating the desired airtightness.

When fumigating small amounts of grains, plastic bags can be used to achieve airtightness. The grain to be fumigated is put into a sack and then placed into a plastic bag that must have no holes whatsoever. Finally the recommended dose of fumigant is added and the plastic bag is duly sealed.

If airtightness is not achieved, there will not be a toxic concentration of the fumigant for the length of time necessary. Thus not all insects will be exterminated. They may become resistant to phosphine and proceed to produce resistant progeny.

Achieving airtightness is perhaps the area in which fumigation encounters the greatest difficulties. Airtightness is not only important but also absolutely crucial.

3.2 Dose

The recommended doses are those found on the fumigant's label and these instructions must be followed carefully. However, the following recommendations may be followed for fumigating grains contained in *Postcosecha* Metal Silos.

Apply 1 tablet (3 grams) for every 225kg of the silo's total capacity (see Table 1, below).

Table 1. Amount of tablets to be used based on silo capacity.

Silo capacity (kg)	Amount of tablets used
180	1
225	1
360	2
800	4
1,360	6

It is important to point out that the tablets must not be broken up or allowed to come into contact with the naked skin. A whole number of tablets is always used, as is protection for the hands (gloves).

Because PH₃ acts as a gas it will have the tendency to occupy all of the available space in the storage structure. Thus the dose is calculated based on the total volume of the structure's storage capacity and not simply on the number of kg it contains at a given time. If we do not take into account the additional space beyond the amount of grains actually being stored, we will end up by using a smaller dose than is recommended. This is particularly true when fumigating grains contained in Metal Silos when these are not filled to capacity.

In general, when a product is fumigated in bulk it is recommended that the dose be calculated by the ton. When dealing with goods that have been packed hermetically using plastic, the dose can be calculated in relation to the volume occupied or based on the weight of the grains.

3.3 Time

The length of time during which the storage structure should remain hermetically sealed is 10 days. The liberation of the gas contained in the solid tablets depends upon the ambient temperature and relative humidity. In tropical settings this is usually not a very relevant limitation upon fumigation efforts.

Adult insects and larvae are eliminated rapidly. The eggs and pupae require a maximum exposure time to the fumigant of approximately 10 days. After the 10-day period the airtight structure can be opened and is allowed to ventilate for several hours so that the gas can escape. The grains are then ready for consumption or sale.

If the grains are stored for several months the lids must remain closed after the two-hour ventilation period. This prevents the insects to reinfest the grains from the outside.

When a pile of bags has been fumigated, it will be reinfested by flying insects almost immediately upon removal of the plastic cover. It is important to remember that Phosphine has no residual effect, and therefore does not protect grains from insects once the gas has escaped.

In the case of a *Postcosecha* Metal Silo the metal sheet used in its construction will prevent access or reinfestation by insects. Put otherwise, after fumigation the silo affords the stored grain only physical protection.

4. Fumigating a Metal Silo

4.1 Materials

The following materials should be available before beginning to fumigate:

- tablets of Phostoxín, Detia or Gastión;
- two rubber strips taken from a bicycle inner tube or adhesive tape; and
- grease, wax, soap or tallow.

(The amount of tablets to be purchased must be calculated based on the capacity by volume of the silo to be fumigated).

The tablets can be purchased at the branches or distributors dealing in agrochemical products. Often they can be found at the village store. They should be carefully stored to avoid deterioration. When the tablets are stored in an inappropriate fashion they will show signs of dust or emit a strong odor. When transporting the tablets they should be carried in hermetically sealed bottles to avoid leaks and the subsequent escape of the gas. If you are going to purchase a limited amount of tablets (say, less than a tube), take along a small bottle that can be sealed for transport purposes. Never transport an individual tablet in a paper envelope or in your pocket.

Under no circumstance should the tablets be transported or stored in plastic bags, matchboxes or wrapped in paper. Always avoid skin contact when applying the recommended doses.

Introduce the tablets into the silo directly from the tube or bottle in which they were transported. It must once again be stressed that the tablets must not be broken up. Use only a whole number of tablets.

4.2 Fumigation procedures

- Check if the silo is beneath a roof and set upon a platform. The grains inside the silo should have a humidity content of 14% or less.
- Check if all the necessary materials for fumigation are available.
- Place a rubber strip around the seed outlet of the silo. To make certain it is hermetically sealed, grease, molten wax, soap or tallow are spread along the edges of the rubber strip.
- The tablets are deposited through the intake throat of the silo, inside a maize husk or a piece of paper. These are placed upon the grains in the silo.

- Remember: the gas emanating from the tablets will distribute itself throughout the silo, and the dust or waste from the tablet can be removed after fumigation without coming into contact with the grains.
- After fumigation the leftover tablets are kept in hermetically sealed bottles.
- The lid to the silo intake throat is sealed with a rubber strip or adhesive tape or tallow. To ascertain that the seal is airtight use grease, wax, soap or tallow around the edges of the rubber strip or adhesive tape.
- After fumigating it is important to wash your hands with water and soap.
- Remember that during the process of fumigation you must not smoke, drink or eat.
- Check if there are any leaks 3 to 5 hours after fumigation and sealing has taken place. This is easy to do, since the gas has a pungent, garlic-like smell. If you smell the gas, the leak must be located so as to plug it up with grease or tallow. Continue to check for leaks on a daily basis.
- Leave the silo sealed for at least 10 days.
- Ten (10) days after fumigation the seals may be broken. Allow the grains to ventilate for a few hours. The grains are now ready for use.
- Remember: to avoid a reinfestation by the insects, the intake throat and seed outlet must be kept closed at all times.

Note that the grains can also be fumigated effectively in barrels.

4.3 Advantages of using Phosphine

- Phosphine has a high degree of penetration and the gas reaches to wherever the insect is at, thus controlling all stages of its development (egg, larva, pupa and adult).
- It does not affect the germination potential of seeds.
- Fumigation does not leave a bad taste or smell on the product treated.
- The tablets do not leave toxic residue on the fumigated grains.
- The tablets can be easily purchased at agrochemical product distributors.
- Gas leaks are easy to detect due to their characteristic garlic-like smell.

4.4 Disadvantages of Phosphine

- Phosphine is a very toxic gas, not only for insects but also for human beings and animals.
- It can only be applied in receptacles or places that are hermetically sealed.
- Phosphine affects noble metals such as copper.

5. Toxicity

As has been stated above, phosphine is a very toxic gas, not only for insects but for human beings as well. A concentration of 2.8 mg per liter of air is deadly for a human. Concentrations of less than 2.8 mg per liter of air are also dangerous because they have secondary consequences that affect internal organs and may cause, for example, defective coordination of movements.

Symptoms in case of intoxication with Phosphine include general discomfort, headache, vomiting, dizziness, distress, an oppressive sensation in the chest and a buzzing sound in the ears.

The dose and concentration used are lethal and must be handled with extreme care during the application of the fumigant as well as when ventilating the product. The gas has no antidote.

5.1 In case of intoxication

- Place the intoxicated person at rest, in a horizontal position, outside and in the shadow.
- Calm the intoxicated person and unbutton or loosen any tight clothing.
- Call a doctor immediately, advising him / her what type of intoxication the victim is suffering from.

6. Recommended Precautions

The application of phosphine should be carried out only by responsible persons capable of reading the instructions on the label, and who have been instructed in its use. It is advisable that the tablets be kept in the original a tube or can in which they were acquired, and are placed in a fresh, dry place outside of the sun and beyond the reach of children.

The following advice is basic to an effective, low-risk fumigation:

The first step in applying phosphine consists in ascertaining that it will indeed be possible to hermetically close the structure or cover the bags to be fumigated so that

they are airtight. Then calculate the dose to be used and apply it in the most expeditious manner possible.

It is advisable that two (2) persons apply the fumigant, or at least advise someone else that the fumigation is to take place. Thus that person will be forewarned of the risk the fumigator is incurring.

It is recommended to check the fumigated grains between 3 and 5 hours after having introduced the tablets so as to detect any existing leaks.

The leftover tablets should be stored in hermetically sealed bottles in a cold, fresh and dry place. It is stressed that whenever possible they should be kept far from people's homes and beyond the reach of children. It is further recommended the bottles be kept away from fire.

Fumigation with phosphine is a practice that has been in use for several decades. Many factors in the application process should be considered important. If not aware of all of them, the producer should consult an extensionist and never endeavor to guess what practices he / she should be carrying out.