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Large scale grain fumigations using pure cylinderized phosphine together with the HORN DILUPHOS SYSTEM

P. Horn[1], F. Horn[2]

Since the Horn Diluphos System was developed in the year 2001, the number and size of the fumigations has increased considerably. The Horn Diluphos System uses a patented method for direct blending of phosphine with air.

The first model of phosphine blending device, developed in 2001, has a phosphine dispensing capacity of 1.2 kg/hour. The second model, developed in 2003, has a capacity of or 3 kg/hour.

Since year 2002, this method has been used in Chile, Australia, the United States and Argentina, with great success.

As this technology has proven to be very efficient and effective, the size of the fumigations has increased, and thus the time required for fumigations. In Chile, many fumigations use more than 10 kg of phosphine on one site. In Australia these numbers are even larger. In some sites more than 100 kg of phosphine have to be applied for one fumigation.

In order to reduce the time required for large fumigations, a new model was developed in the year 2005. This model is able to dispense 200 g/minute or 12 kg/hour of phosphine.

The first large fumigation made with this equipment was in the port of Kwinana in Perth, Australia in July 2005.

In 12 hours, 144 kg of phosphine were applied on one large flat storage with approx. 300,000 tons of grain. Great results in gas distribution and insect control were obtained.

After this great success, more than 1,400,000 tons of grain have been fumigated and more than 700 kg of pure cylindered phosphine have been applied since July 2005 with one HDS 800 in Australia.

Since April 2006, one of these phosphine dispensing units is also being used in Chile for large fresh fruit fumigations. This reduced the time required for standard fumigations from 4 hours to less than 1 hour.

In the year 2001, FOSFOQUIM developed the Horn Diluphos System (HDS), a patented method for the blending of pure cylindered phosphine with air.

The system dilutes pure phosphine with air without risk of ignition, using a patented dilution device developed by Fosfoquim. The unit controls the different parameters with a PLC, indicating to the operator the steps to follow through an LCD screen. The unit has several safety measures to ensure that the phosphine- air mixture will not burn, even in case of power failure.

The first model of phosphine blending device, had a phosphine dispensing capacity of 1.2 kg/hour of pure phosphine, which means 19 g of phosphine per minute.

This unit was used in silos and grain warehouses up to 5,000 tons, but even though the labor required for the grain fumigations was reduced and the safety increased considerably compared to other alternatives of phosphine fumigation, since the gas could be easily applied from outside the facility, the time required to apply the gas for large fumigations was still of several hours.

[1] Dipl. Eng., Fosfoquim S.A., Chile. Marchant Pereira 367, of 901, Providencia, Santiago, Chile. phorn@fosfoquim.cl

[2] Dr., Fosfoquim S.A., Chile. Marchant Pereira 367, of 901, Providencia, Santiago, Chile. phorn@fosfoquim.cl

For that reason, and knowing the beauty and advantages of the system, FOSFOQUIM developed the second model in the year 2003. This model had a capacity of 3 kg/hour or 47 - 50 grams per minute of pure phosphine.

The capacity of this unit was larger than the capacity of all the available alternatives of phosphine dispensing equipment, going from generators and other cylindered mixtures.

Since the year 2002, the great advantages of this fumigation method and equipment, have allowed its use in Chile, Australia, the United States and Argentina for different applications, as for example grain fumigations, empty space fumigation, mill fumigation, nut fumigations and fresh fruit fumigations among others.

The advantage for grain fumigations is the fast distribution of the fumigant achieved through the use of this technology combined with the H-System, a fumigation method developed by FOSFOQUIM, in which the interstitial air of the grain storage is replaced by a mixture of gas and air at a concentration close to the required concentration. The source of gas used for this phosphine air mixture, comes from the Horn Diluphos System and if required, gas concentration can be adjusted using an additional fan for dilution. This permits getting an immediate even gas distribution, shortening the time of the fumigation, depending on the type of facility, several days.

On the other hand, the capacity of this fumigation system to control exactly the amount of gas added to the structure to be fumigated, allows applying phosphine to empty space and flour mill fumigations, controlling the risk of corrosion. Using the HDS system, a controlled, low but effective concentration of gas can be added to the mill in a short period of time, obtaining immediate gas distribution, and thus reducing the shut off time, killing the insects and controlling corrosion. In Chile and Argentina this system is applied in different mills and factories several times a year with excellent results. One of the advantages of the system is that the air for the dilution of the gas can be taken from the inside of the facility to be fumigated, avoiding in that way the build up of a positive pressure that would increase the gas leaks to the atmosphere.

As this is a clean method, where only pure phosphine is applied, and no residues are left behind, this is an excellent method for the fumigation of high value stored food commodities like nuts and dried fruits, that cannot be fumigated with products that leave residues after fumigation, and where the content of ammonia produced by other alternatives of phosphine generating fumigants, can damage the product and change its color and value.

Going further and looking for alternatives to methyl bromide, Fosfoquim developed and patented in the year 2003 a method for fresh fruit fumigation using pure phosphine free from ammonia. This method allows fumigating fruits using the Horn Diluphos System, applying high concentrations of gas at low temperature to control insects and pests on fruits, without producing damage or changes to the fruits and controlling effectively the pests. This method is applied now in Chile commercially for the export of fruits to different countries worldwide.

The advantages of this technology are:

- The fumigator does not need to enter into the facility to be fumigated
- An even gas distribution is achieved shortly after the beginning of fumigation
- No need to collect or deactivate spent material after fumigation
- Reduced labor for gas application
- The exact required amount of gas can be applied
- Only pure phosphine is applied

With these advantages, this technology has proven to be very efficient and cost effective, for the control of pests in stored food, commodities and empty spaces.

Since this technology was developed in the year 2001, Fosfoquim has performed more than 2500 fumigations only in Chile using the HDS technology. Large volumes are being fumigated also in Australia, Argentina, and the United States of America.

This has caused that the size of the fumigations, where this technology is applied,

has increased in the past years, from silos varying from 5,000 cubic meters up to 50,000 cubic meters or more, and for that reason the time required for fumigations has also increased considerably compared to the use of this technology some years ago.

Only in Chile, more than 15 kg of phosphine are often applied on one site. In Australia and Argentina these numbers are even larger. In these two countries, as also in other countries off the world, more than 150 kg of phosphine have to be applied sometimes only for one simple fumigation.

Considering the amount of cylinders required for these fumigations, if there were used phosphine - nitrogen or phosphine - carbon dioxide mixtures, with 1.5 to 2 % of phosphine, it would not be possible to make those fumigations, since more than 200 cylinders would be required for each fumigation.

But using the HDS (Horn Diluphos System) technology, the number of cylinders is reduced by several times. One pure phosphine cylinder has a content of 18 to 22 kg of pure gas, while the mixtures contain less than 1 or 0.5 kg of pure phosphine.

Grain handling companies are trying to build larger and larger grain storage facilities, in order to reduce the unitary storage cost for their product. When the engineers design those monster grain storages, normally they do not consider fumigation as one of their key aspects. For that reason, as fumigation cannot be avoided, the grain handling companies have to spend large amounts of money for fumigation in equipment and labor.

Considering the traditional fumigation methods, several people have to be employed for each fumigation in order to place the fumigant, and after fumigation collect and deactivate spent material, using several hours of labor.

In metal phosphide fumigation, additional risk has to be considered because workers are entering into a confined space, where gas is being liberated and where other risks are constantly present.

In order to reduce the time required for large fumigations, a new model was developed in the year 2005. This large model, called the HDS 800 (Figure 1), is able to dispense 200 g/minute or 12 kg/hour of pure phosphine (Table 1).

Figure 1. Horn Diluphos System, model HDS 800. This unit uses four phosphine cylinders and 1 nitrogen cylinder for purging and I able to dispense 12 kg of pure phosphine per hour.

Table 1. Specifications of HDS 800.

Air Flow	800	Cubic meter /hour
Phosphine flow	200	Grams/minute
PH3 concentration	10.000	ppm
Weigth	500	kg
Phosphine cylinders used	4	
Nitrogen cylinders	1	

After manufacturing, testing, and calibrating the unit in Chile, the first unit of this model was sent to Perth in Australia to fumigate the largest flat grain store worldwide.

In 12 hours, 144 kg of phosphine were applied on one large flat storage with approx. 300,000 tons of grain in the port of Kwinana in Perth, Australia in July 2005 (Figure 2).

Figure 2. Port Kwinana, Perth, Australia, 300,000 ton flat storage first fumigated wit the HDS 800 in 2005. 144 kg applied for one fumigation

Great results in gas distribution and insect control were obtained. The 300 meter long, 70 meter wide and 28 meter high storage was put completely under gas with an even gas concentration in less than 20 hours, only a couple of hours after finishing gas injection (Figures 3, 4 and 5).

The gas was added through one of 18 recirculation ducts into the headspace of the storage, by disconnecting the aeration fan. The fresh air used to dilute the phosphine gas, was taken from the tunnel under the storage, to which the recirculation fan was connected. The other 17 recirculation fans were used during gas injection and then 12 hours after gas injection to distribute the gas evenly, taking the fresh air from the tunnel into the headspace. After achieving an even distribution, the recirculation was turned of.

In order to reestablish gas concentration in those low concentration spots caused by small leaks, like for example behind doors, the recirculation fans were turned on once a day in order to move the gas inside the storage.

Labor required for the fumigation of this storage was reduced several times and the risk of exposure to high phosphine concentrations of the fumigators controlled, since the fumigators did not require to enter into the bin to place the fumigant. Twenty years ago, fumigators in Germany where asked to use 10 or more tablets per ton of grain. This means that for a storage like the above named, 9,000 kg of metal phsophides would be required, and it is easy to imagine the labor and worker exposure involved in the distribution of the tablets and after fumigation the collection of the spent product.

After this great success in July 2005 and until July 2006, more than 1,500,000 tons of grain have been fumigated and more than 800 kg of pure cylindered phosphine have been applied with one unit of the HDS 800 in Australia.

The unit is being used with success in bunker storages, where the gas is distributed in less than 24 hours in storage sizes varying from 20,000 to 60,000 tons. The unit is used also for flat warehouses and silos, where the possibility of adding large amounts of gas in a short period of time has interesting advantages for the grain handling companies.

One of the great advantages for the grain handling companies is the reduction in time required for fumigation, which saves and increases their existing capacity for fumigations and thus avoids the need for construction of new storages and fumigation facilities.

Figure 3. Fumigation van used by FOSFOQUIM in Chile for its fumigation. This unit has one HDS 800 installed inside and travels to the different locations where gas has to be applied.

Figure 4. Fumigation of a bunker storage with the HDS 800. The phosphine-air mixture is applied into the headspace that is generated between the tarp and the grain while the gas is injected.

Figure 5. Detail of bunker storage fumgation with the HDS 800. The phosphine-air mixture is applied into the headspace that is generated between the tarp and the grain while the gas is injected, and diluted with an additional fan.

The fast distribution of the gas obtained with the use of the HDS technology, allows reducing fumigation time several days.

Considering the success of this new model, new units are being built, to be used in Chile, Argentina, Australia and the USA.

Since April 2006, one of these large phosphine dispensing units is being used in Chile for large scale fresh fruit fumigations. This great tool allowed to reduce the time required for standard fumigations from 4 hours to less than 1 hour, increasing the response capacity of Fosfoquim's fumigation branch Fosfoquim Fumigaciones S.A.

In Chile, more than 20 fumigations per day are being performed by Fosfoquim, during almost three quarters of the year using the Horn Diluphos System.

This new tool will allow opening the doors to a whole list of new markets for the pure cylindered phosphine business.

As for example ship fumigations with grain, where large amounts of gas have to be delivered in short periods of time in order to avoid demurrage costs to the shipping companies. Until this large capacity unit was developed, the best available alternative for ship fumigation was metal phosphides with recirculation.

This traditional method for ship fumigation using metal phosphides has a series of disadvantages like:

- Residues in the grain
- The need to collect, deactivate and dispose of spent material after fumigation.
- Long time for gas generation, which means that the method cannot be used for short trip fumigations as for example ships traveling from the US to Mexico or New Zealand or Australia to South Asia.
- No control of gas concentration.

On the other hand, there are a series of advantages of the HDS System for ship fumigations, like:

- Reduced gas injection and distribution time, which allows starting to control pests immediately after gas injection.
- Method can be applied for short voyage in transit fumigations.
- No residues are left behind after fumigation.
- The gas can be applied to a sealed structure from outside, avoiding people entering into confined spaces.

For several countries, phosphine is applied for in transit timber fumigation. Until the HDS technology was developed, only metal phosphides could be applied for those fumigations, but this fumigation method had a series of disadvantages.

Timber and log fumigation require high dosages of gas to be able to control the pests. This is obtained normally overdosing metal phosphides in order to achieve on one side a fast generation of lethal gas concentrations, and additionally avoid concentration reductions due to leakage. But this practice has a great risk in generating gas explosions, since often these ship holds contain liquid water. When metal phosphides get in contact with water they generate high concentration of phosphine that can ignite spontaneously and explode.

As the HDS system applies a controlled mixture of air and phosphine, where the concentration is always below 10,000 ppm, this risk is eliminated.

Also the same advantage for grain ship in transit fumigation, of reduced gas distribution time, acquires importance where voyage time is too short as to allow the gas generation from meal phosphides.

This means also that much less gas can be applied since it is not necessary to overdose in order to achieve a fast gas distribution.

A third new market for pure cylindered phosphine is the fumigation of empty space and flour mill fumigation. Since in Chile and Argentina it is not allowed to apply methyl bromide or other gases, different than phosphine, to empty space fumigations, mills have started to apply pure cylindered phosphine since it became available through the HDS technology. The beauty of this method is that corrosion can be avoided if concentration is maintained below certain limits, which depends on temperature and moisture content of air.

As mills have not too much down time, it is of great importance to achieve a fast gas distribution, which at this time can be done with the HDS 800 in a very short period of time.

In large facilities, natural distribution by diffusion, convection and other natural air movements, are very slow to distribute the gas, and it can take sometimes several days to get an even distribution in very large or tall storages, and in some cases gas never is distributed completely.

Fort that reason researchers have developed a series of different gas distribution methods, like the J-System, the SCIRO-Flow, SCIRO-Circ, the method where the metal phosphide tablets are dispensed to the belt while loading the grain storage among others. But the larger the storage, the harder it is to distribute the gas and the more labor and time are involved for fumigation. In some cases large storages are tremendous technical challenges for the grain handling companies. And especially for those cases it is of great importance to count with a method like the HDS system, and specifically the model HDS 800, able to dispense large amount of gas in only a short time.

As conclusion it is recommended that in the future, when building new facilities where any product has to be fumigated, fumigation is considered as one of the key points in design. Materials have to be chosen in order to facilitate sealing labor, but it is of most importance to look for available technologies like the Horn Diluphos System and install the systems in order to allow applying these technologies effectively. At this time, existing facilities have to be adapted and modified in order to apply this new method, but in the future this application should be considered from the conception of the projects.