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المؤسسة العامة لتجارة وتصنيع الحبوب
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UNIDO

PHASE OUT OF METHYL BROMIDE IN GRAIN FUMIGATION

PROGRESS REPORT: SEPTEMBER 2005

UNIDO Project No.: MP/SYR/01/182 and MP/SYR/03/107

26 September 2005

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1 BACKGROUND

The 'General Establishment for Cereal Processing and Trade' (GECPT) is a state owned organization that manages the grain market in Syria and stores the major quantity. GECPT defends a floor price for wheat and barley, set by the Higher Council for Agriculture.

GEPCT has 132 storage facilities in Syria; the centers receive grain directly from farmers, mostly in bags although few larger farms deliver in bulk. The harvest season starts at the end of May until the beginning of July and the buying season ends in August. The moisture content is not taken into account because Syrian wheat is grown under very hot dry conditions, therefore the incoming grain has a moisture content that is always lower than 7-8%.

The total amount of grain stored in Syria has grown from about 2.5 million tonnes in 1999 to about 7.5 million tonnes in 2005. Grains are stored in silos or in bag-stacks, in warehouses or in open-air stacks covered with sheets. The grain storage facilities belong to the GECPT and only GECPT's staff is authorized to carry out fumigations.

Indoor storage facilities are usually cement rendered brick walls and flat cement roofs. Stored bag stacks vary in size from 100 to 400 tonnes and are built directly on the concrete floor without pallets or base sheets.

For outdoor storage, bag stacks are built on a thick, grounded, polyethylene sheet, large enough to be folded upwards and fixed by the second layer of bags to give protection to the sides of the first layer. About ten layer bags are built and a further nine layers are added in a pyramid shape, giving 19 layers and about 160 tonnes of grain in each.

From the storage facilities, the grain is distributed to state owned flour/feed mills. Grain generally moves slowly through the system so that the typical storage period is 2 years and some stocks may remain in store for as long as four years. Grain loss during storage is estimated to be around 1%.

2 PROJECT OBJECTIVE

The aim of the project is to phase out 175 tonnes of methyl bromide (105 ODP tones) used for grain fumigation in Syria in 2000. Methyl bromide will be substituted by an effective and safe use of solid phosphine for outdoor bag-stacks and by the improvement of solid phosphine fumigation for indoor bag-stacks and bulk.

The project is implemented at three different levels:

2.1 Policy: through the introduction of policy measures and new regulations to control methyl bromide imports and use;

2.2 Awareness and training: to enable GECPT's staff to use solid phosphine in an effective and safe manner and avoiding the insurgence of insect resistance to phosphine. The training programme is also focused on good grain storage practices to prevent reinfestation and therefore minimizing the need for fumigation; and

2.3 Equipment and supplies: the provision of equipment for phosphine gas monitoring and plastic sheets suitable for phosphine fumigation.

The General Commission for Scientific Agricultural Research (GCSAR) has been appointed to implement the project, through a contract with UNIDO, and under the supervision of the National Ozone Unit (NOU).

3 PROJECT STRATEGY

The project has been implemented in three phases, according to the disbursement plan agreed with the ExCom. of the MLF, to facilitate a smooth and secure change of technology in a strategic sector such as grain storage. At this stage, it is important to note that in Syria, grain is stored by state owned GECPT and only GECPT's staff is authorized to carry out fumigations and GCSAR acts as a consultancy body.

Despite the fact that the project was approved in July 2001 (34^{th} ExCom. Meeting), the project implementation only started in May 2003, with a two-year delay due to various inconveniences.

3.1 PHASE I:

Phase I covers the period from May 2003 to May 2004. GCSAR carried out the following tasks:

3.1.1 Established a national steering committee to provide guidelines and to supervise the project management;

3.1.2 Raised awareness concerning the country's commitment to phasing out methyl bromide and Montreal Protocol tasks;

3.1.3 Established the database for all storage facilities;

3.1.4 Monitored grain fumigation practices;

3.1.5 Through GECPT, monitored methyl bromide consumption;

3.1.6 Established a training programme;

3.1.7 Produced English & Arabic brochures on storage management and fumigation technology;

3.1.8 Produced the first draft of protocols on good practices for storage management and phosphine fumigation; and

3.1.9 Selected the equipment needed for an effective and safe use of solid phosphine for outdoor bag-stacks and improved solid phosphine fumigation for indoor bag-stacks and bulk.

3.2 PHASE II:

Phase II covers the period from June 2004 to August 2005. The main goals were:

3.2.1 To prepare the technical specifications for the procurement of the first set of equipment;

3.2.2 To purchase the equipment and deliver it to the project sites;

3.2.3 To train GECPT's staff on the use of PH3 meters, good practices for storage management and phosphine fumigation as well as to focus on phosphine concentration monitoring;

3.2.4 To further develop the protocols about good practices for storage management and phosphine fumigation. With regard to storage management, focus on positioning and management of bag-stacks in indoor storage and the prevention of fire in outdoor storage; and

3.2.5 To update the database and continue to monitor grain fumigation practices.

3.3 PHASE III:

Phase III covers the period from September 2005 to December 2007 (expected date of total phase-out). The main goals are:

3.3.1 To prepare the technical specifications for the procurement of the second set of equipment;

3.3.2 To purchase the equipment and deliver it to project sites;

3.3.3 Further training of GECPT's staff on PH3 meters use and calibration, good practices for storage management and phosphine fumigation;

3.3.4 To finalize the protocols for storage management and phosphine fumigation; and

3.3.5 To update the database and continue with the monitoring of grain fumigation practices.

4 ACHIEVEMENTS

At the time of project formulation (2000), the total methyl bromide consumption was 188 ODS tonnes (113 ODP tonnes); of which 175 ODS tonnes (105 ODP tonnes) were used for grain fumigation and the remaining amount for soil fumigation. Due to the crop growing cycles, the methyl bromide consumption increased in 2001, reaching the level of to 275.5 ODS tonnes (175 ODP tonnes).

Since the beginning of the project, in the grain fumigation sector, the consumption data showed a decreasing trend, which was very slow in 2002, as the project had not yet entered into force, and faster in subsequent years.

Methyl bromide consumption data, both total and in the grain fumigation sector, are shown in Table 1 below.

Table 1: Methyl bromide consumption data:

YEAR	Total MB consumption		MB consumption for grain fumigation	
	ODS	ODP	ODS	ODP
Base line	314.25	188.55	314.25	188.55
20% Reduction target	251.40	150.84	251.40	150.84
1999	148.85	89.31	n.a.	n.a.
2000 Project formulation	188.00	113.00	175.00	105.00
2001 Project approval	275.50	165.09	261.81	157.09
2002	254.52	152.71	241.19	144.71
2003 Field activity started	214.50	128.70	201.16	120.70
2004	166.67	100.00	153.33	92.00

By summarizing the above table, the following three major facts are evident:

a. Methyl bromide consumption sharply increased (by 49%) the same year that the project was approved (2001), therefore the starting point was no longer the same as the one that was calculated in the approved project document;

b. The phase-out achieved in 2002 was modest, because the project was not immediately carried out, therefore filed activities were delayed; and

c. As soon the fieldwork started (2003) the annual phase-out was about 50 ODS tonnes/year as planned.

As for the above consideration, we can estimate that the total methyl bromide phase-out in the grain storage sector will be achieved in 2007.

4.1 PHASE I

Phase I had been completed; the achievements are reported in the progress report submitted in October 2003.

4.2 PHASE II

With phase II of the project, we have started the implementation of the fieldwork. The following paragraphs present a summary of the activities implemented and achievements.

5 EQUIPMENT

With regard to the equipment that was purchased, it is necessary to mention the fact that the procurement of some items required more time than expected, because of:

a. Phosphine meters: the first round of bidding was cancelled because the price that was offered greatly exceeded the allocated budget. Finally, after searching for more potential suppliers, we found the appropriate equipment at a reasonable price; and

b. Sheets for outdoor phosphine fumigation: due to the very severe environmental conditions for outdoor fumigation in Syria, it took almost 6 months to identify the suitable material; phosphine gas that is impermeable and resistant to heat, wind and abrasion from sand.

However, all the equipment was delivered to the project sites by the end of June. Below is a short description of the purchased equipment and supplies:

- Wooden pallets: 2,400 wooden pallets of Europallet design were purchased. They are used for outdoor fumigation, to prevent the contact between bag-stacks and the ground and to improve phosphine gas circulation in the stack;
- 168,000m^2 of virgin polyethylene film, silage type, of 150 micron thickness: to be used as ground sheets for outdoor fumigation;
- 90,000m^2 of virgin polyethylene film, of 50 micron thickness: to be used as cover sheets for indoor fumigation;
- 180,000m^2 of reinforced polyethylene film for phosphine fumigation, of 150 micron thickness: to be used as cover sheets for outdoor fumigation; and
- 20 phosphine meters low concentration and 20 phosphine meters high concentration, plus 2 phosphine cylinders and accessories for calibration.

The selection of suitable monitoring equipment required much discussion among GECPT and GCSAR's staff and the UNIDO project manager. Finally, we selected electronic phosphine meters as the most suitable instrument to carry out phosphine concentration monitoring and to provide an efficient safety device to operators.

The following considerations were made:

1. 1 high concentration phosphine measuring tube cost approximately 2.5 $;
2. The minimum number of measurements to carry out per stack, is 5 (in a 5 day treatment), which results in at least 12.5 $/stack, considering only one sampling point;
3. The average cost of the phosphine meter, including the cylinder for calibration (1 for 20 phosphine meters), is 900 $;
4. After monitoring 72 stacks, the cost of the phosphine meters is the same as the cost of the tubes, therefore, any additional stacks that are monitored will result in a saving;
5. The use of electronic phosphine meters released the technicians from economical constraints (cost of tubes); it also enables the performance of a high-quality phosphine concentration monitoring, from multiple sampling points, for the entire duration of the treatment (5 days);
6. The data obtained is more reliable, therefore it can be used for the IPM programme;
7. Low concentration phosphine meters: this tool has two main purposes: a) to constantly monitor phosphine concentration in the environment (for indoor fumigation); and b) to ensure workers' safety, as it detects gas leakages from the stack. In using such meters, we ensure the highest phosphine gas concentration possible for the entire duration of the treatment and prevent the dangerous accumulation of PH3 gas in the environment; and
8. Maintenance and calibration: electronic phosphine meters are well-developed and reliable instruments that require low-level maintenance. The package also provides phosphine gas cylinders, mixed with nitrogen, for calibration. Training is provided to make GECPT and GCSAR's staff self-sufficient. In addition, the local experts are able to manage the instrument, which represents a progression from old monitoring practices.

In conclusion, electronic phosphine meters are reliable instruments: they fit with Syrian environmental conditions and expertise, and phosphine cylinders for calibration are provided to ensure that GECPT and GCSAR's staff are self sufficient from the supplier, as well as being able to measure accurately for a long period of time. In the medium and long term, electronic phosphine meters are cheaper than tubes.

6 TRAINING

Training is definitely the key point for the success of the project. Phosphine has been used in Syria for a long time. Nevertheless, due to the lack of expertise, it has always had significant limitations. As in many other countries, phosphine fumigation technology was never fully developed because methyl bromide was available, cheap, easy to use, relatively safe and very efficient. This efficiency led to mistakes being made and negligence in managing the storage facilities.

The main subjects that are being focused on, through the training service provided by GCSAR and the assistance of international experts, are:

- The efficient application of solid phosphine: phosphine is a very efficient fumigant but requires a longer exposition time than methyl bromide. Therefore, to ensure an effective treatment the bag-stacks need to be properly closed and the phosphine concentration needs to be monitored. The equipment provided is an indispensable tool to reach such a goal;
- The safety application: the major problem for outdoor phosphine application is the risk of fire. In contact with free water, solid aluminum phosphine catches fire. In order to solve this, it is necessary to improve "phosphine generation place" design, to prevent water, from rain or condensation, to drip on the aluminum phosphine;

- Indoor storage facilities management: this issue is quite complex due to the number of components that work together. In big storage facilities, grain is placed in bag-stacks of 100 to 400 tonnes. To make good use of the room available, only narrow corridors are left between the stacks, therefore if a stack is found infested and must be shipped, it blocks the stack at the back for some days as it must be fumigated before being shipped. With the use of methyl bromide, the treatment is relatively quick: 2-3 days, whereas with phosphine it takes at least 5 days. The best way to solve the problem is to establish a reliable monitoring system to identify infested stacks long before they might be shipped, and treat them accordingly.

The main training activities performed in the reporting period are summarized in the following table.

Table 2: Training:

Subject	Trainer	Date	Site	Participants	Note
Workshop	GCSAR's staff	6-7 Sep 2005	Raqa	GECPT's staff 70 Participants	
Workshop	GCSAR's staff	16-18 Aug 2005	Hama	GECPT's staff 20 Participants	
Phosphine meter use and phosphine fumigation practices	Mr. Patrick Ducom International expert	5 –11 Jul 2005	Damascus Hama	GECPT's staff	See Annex I
Workshop	GCSAR's staff	19-21 Oct 2004	Dir Alzour	GECPT's staff 20 participants	
Workshop	GCSAR's staff	16 – 18 Dec 2003	Hama	GECPT's staff 33 participants	

A detailed description of the activities implemented and outcomes of the training section performed from 05 to 12 of July 2005 is given in the Annex I.

7 PROTOCOLS

The expected outcome of the work done and the experience gained, through the utilization of new equipment and the implementation of the training programme, is the preparation of protocols for phosphine fumigation practices and good grain storage management. Summary information is provided in the brochures attached (see Annex II).

The main subjects in the protocols are:

- Chemical and physical propriety of phosphine and methyl bromide, background information;
- Grain analysis: physical and biological, recognize insects, sampling methods;
- Guidelines for building bag-stacks, safety measures preventing fire in outdoor bag-stacks;
- Phosphine fumigation practices;
- Monitoring and inspection;
- Safety measures for phosphine application;
- Good grain storage management to prevent rodents and insect re-infestation; and
- Most common active ingredient, tools and practices for storage disinfestations and rodent control.

8 EXPENDITURE

The Executive Committee of the Multilateral Fund, at its 34th meeting approved, in principal, US $ 1,084,139 for phasing out 105 ODP tonnes of methyl bromide in grain fumigation. Further on, at its 34th and 41st meetings, it approved the disbursement of the first two of three tranches for a total amount of US $ 651,725. From January 2002 to September 2005, the total expenditure sum is US $ 482,770.77, therefore, the funds still available are US $ 168,954.23 (see Table 3 below).

Table 3: Project expenditure:

ITEM	TOTAL US $
Polyethylene pipes and accessories	10,445.31
Polyethylene film, various thickness	50,540.00
Polyethylene reinforced film for phosphine outdoor fumigation	128,700.00
Wooden pallet	48,000.00
Phosphine meters, cylinders for calibration and accessories	37,729.00
Subtotal equipment	275,414.31
National experts	65,797.94
Short-term international consultants	9,113.91
Subcontracts GCSAR	126,738.61
Travel	5,706.00
Total expenditure from Jan 2002 to Sep 2005	**482,770.77**
Total funds approved – first and second tranche	**651,725.00**
Balance, September 2005	**168,954.23**

The provisional budget for the year 2006 is shown in Table 4 below.

Table 4: Provisional budget 2006:

ITEM	TOTAL US $
Polyethylene pipes and accessories	15,667.97
Polyethylene film, various thickness	75,810.00
Polyethylene reinforced film for phosphine outdoor fumigation	193,050.00
Wooden pallet	72,000.00
Phosphine meters, cylinders for calibration and accessories	56,593.50
Subtotal equipment	413,121.47
National experts	27,000.00
Study tour and international meetings	16,000.00
Short-term international consultants	15,000.00
Total expenditure from October 2005 to December 2006	471,121.47

9 CONCLUSION

Solid phosphine is an effective grain fumigant in the Syrian environment and can technically and economically substitute the use of methyl bromide.

The local staff is very well organized, prepared and knowledgeable, the present protocol for grain fumigation ensures a very high quality standard.

The major problems linked to phosphine fumigation are:

- The insurance of adequate phosphine gas concentration for the entire length of exposition time, the reduction of the dosages and the prevention of insect resistance;
- The prevention of fire in outdoors stacks;
- The improvement of grain storage management, related to phosphine fumigation, to ensure an efficient shipment of grain lots.

To achieve the tasks above it is necessary to:

a. Supply personnel with appropriate monitoring equipment;

b. Equip grain storage of high quality fumigation sheets; and

c. Train personnel at all levels: storage managers, fumigation personnel, support staff.

As for the above, and considering the great effort to be made throughout the year 2006, to ensure the adequate financial support to achieve the total phase-out of methyl bromide used in grain fumigation at the end of 2007, we are requesting the Executive Committee of the Multilateral Fund to approve the disbursement of the last tranche of US $ 432,414.

ANNEX I: Training report, Mr. Patrick Ducom

PHASE-OUT OF METHYL BROMIDE IN GRAIN FUMIGATION IN SYRIA

DAMASCUS and HAMA 5 - 11 JULY 2005

1. ABSTRACT

The training enabled a very good understanding of the use, but as soon as this was practiced, many problems were faced related to the dosage. For further trials, it could be useful to have a meter being able to allow readings higher than 1200 ppm, i.e. 1999 ppm. These meters do not completely solve the problem, as it is possible to obtain much more than 2000ppm after 2 or more days, possibly reaching up to 3000 or more.

Logistical issues for commodity storage management could be overcome by separating the usual good practice of grain storage as it is made currently and what we could call the trade security grain (to make reference to food security). To be able to sell grain when customers request it, a special number of bag stacks are fumigated long enough in advance, regardless of their actual number. This stock is ready to be sold anytime when the fumigation time for the grain temperature is achieved and as long as they are under effective phosphine concentrations.

The fire can take place only if water is in direct contact with the generator. To avoid this, the solution of placing some pallets between bags does not allow contact with the rain if there is a tear or condensation on the inner side of the sheet from the transfer due to differences in temperature in different parts of the stacks.

The dosage used in Syria is exceeds that of elsewhere, except Germany: it is 12g/t 9.6 g/m3 of formulation which releases 3.2 g /m3of phosphine (2240 ppm). Most countries use 1 or 1.5 gPH3/m3 and the active concentration is only 200 ppm. Trials are to be made to see if the dosage could be reduced.

2. MISSION JOURNAL

- **Tuesday, 5th July 2005:**
  - ➔ 02:00, arrive in Syria.
  - ➔ 09:00 to 16:00, discussion with representatives of GCSAR and GECPT.
  - ➔ Definition of the training programme.

- **Wednesday, 6th July 2005:**
  - ➔ 06:30 Departure from Damascus to Hama.
  - ➔ Beginning of the training course: use of phosphine generators, palettes and fumigation sheets.
  - ➔ Laying the tubes, coverage with fumigation sheets.
  - ➔ Fumigating the bag-stacks.
  - ➔ Monitoring gas concentration.

- **Thursday, 7th July 2005:**
  - ➔ Gas measurements, discussion of the results.
  - ➔ Laying the tubes on a second bag-stack, in exactly the same way of the first stack.
  - ➔ Monitoring gas concentration.

- **Friday, 8th July 2005:**
  - ➔ Free day.

- **Saturday, 9th July 2005:**
  - ➔ Monitoring gas concentration, discussion on the results.
  - ➔ Calibration of part of the high concentration level: Every person made at least one calibration.
  - ➔ Return to Damascus.

- **Sunday, 10th July:**
  - ➔ Calibration of the remaining high concentration meters in Damascus.
  - ➔ Bad news from Hama: one phosphine meter was stuck. To solve the problem, we left to Hama. After the resetting and recalibration everything was in order. We made good use of it, in comparison to other meters: from the 18 measures done the difference was less than 3%. Very good!
  - ➔ Return to Damascus in the night.

- **Monday, 11th July**
  - ➔ Summary of mission outcomes.
  - ➔ Calibration of some more low concentration phosphine meters.
  - ➔ Short visit to down-town Damascus.
  - ➔ End of mission.

- **Tuesday, 12th July.**
  - ➔ Departure from Damascus to Paris.

3. MISSION COORDINATION

The mission was kindly coordinated by:

- ➔ Dr Madj JAMAL, National Project Coordinator, Director of GCSAR.
- ➔ Dr Bahaa ALRAHBAN, Local project manager, GCSAR.
- ➔ Dr Mazé BILAL, Prof. of Entomology of plants and stored products at Damascus University.
- ➔ Mr Hassan ALSAYED, Grain Expert, Head of Marketing Department at GECPT.
- ➔ Mr Najdat ALIJAN, Head of Fumigation Department at GECPT.

4. TRAINING OF TRAINERS ON PH3 METERS, USE AND CALIBRATION

The following GECPT staff attended the training on phosphine meters calibration:

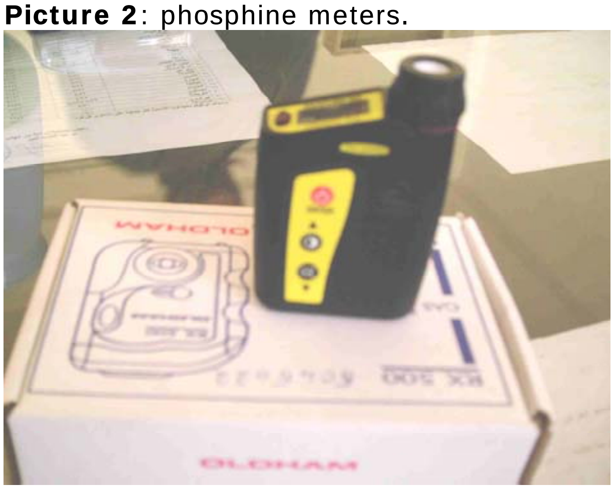
- ➔ Mustaffa KHALIL, responsible of fumigation in RAQQA Branch
- ➔ Abdo BAHNI, future head of fumigation Department at HASSAKI
- ➔ Haitham KHADOR, responsible of fumigation in Hama Branch
- ➔ Hassan MAHMOUD, vice responsible in Kamishli Branch
- ➔ Nasrat MANLA HAYDAR, responsible of fumigation in Aleppo Branch
- ➔ Marwan AL NAJAR, Head of Hama Marketing Centre
- ➔ Samir Jamal, Director of Hama branch

5. USE OF PHOSPHINE METERS

The training allowed GECPT's staff to gain good knowledge of the technical characteristics, performance and use of the phosphine meters.

Picture 1: Calibration cylinder and drum at 700 ppm.

Picture 2: phosphine meters.



5.1 CALIBRATION

The microvalves of the phosphine cylinders had not yet arrived. We checked with the supplier and they confirmed their arrival in Damascus in one week.

In Damascus, we found find a similar device, not as good as it should be, nevertheless it was possible to calibrate all the high concentration meters and, due to the lack of time, only some low concentration meters, but the method is now well known by GCSAR and GECPT's staff, which will carry on the calibration of the remaining low concentration phosphine meters.

5.2 TRAINING ON PH3 FUMIGATION, INDOOR AND OUTDOOR

GECPT's staff possesses the skills and knowledge to carry out phosphine fumigation. Their technique to build the bag-stack, lay down the pipes for monitoring, covering and carrying on the phosphine application is excellent and well established. Training has to be focused on monitoring and grain storage management to improve the efficacy of phosphine fumigation and to reduce any inconveniences due to re-infestation and movement of grain lots.

5.3 MONITORING

As soon we got into practice, we faced a dosage problem. The high concentration meters are set to a maximum concentration of 1,200 ppm, which is suitable for phosphine fumigation done with 1g/m^3, or less, dosage.

To overcome the problem, we have designed a classic dilution bypass, using a "T" fitting. See pictures 3 and 4 below:

Picture 3: "T" dilution bypass device:

Picture 4: Detail:

As for the Syrian standards and practices, after 2 days or more, the concentration is higher than 2000 ppm, probably 3000ppm, or even more.

For monitoring bag-stacks phosphine concentration, we have established the following protocol:

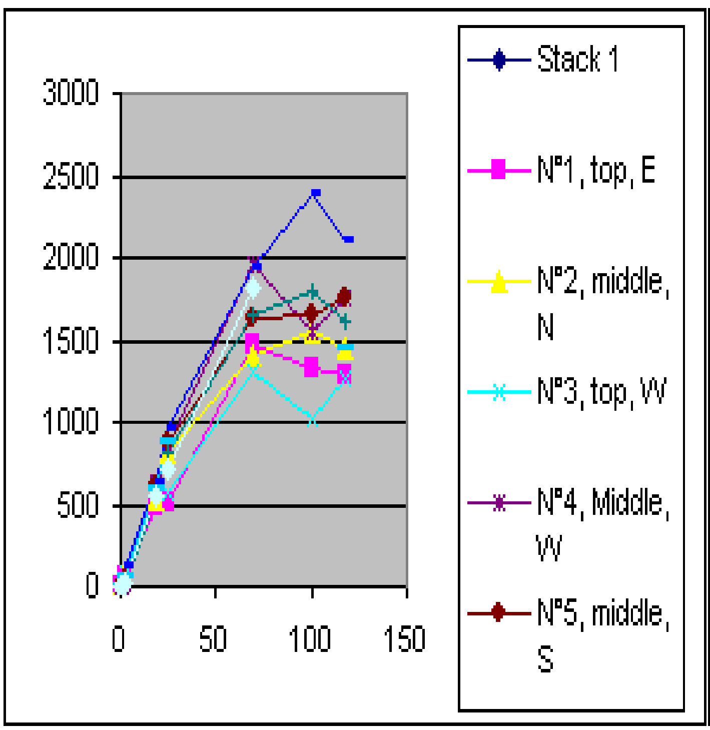
a. Week 1, two measurements per day: It is important to obtain the maximum phosphine concentration, which gives an idea of the gas tightness of the stack and the speed of phosphine gas released. Then, the frequency may change since the gas concentration, if there is no leakage, will decrease slowly;

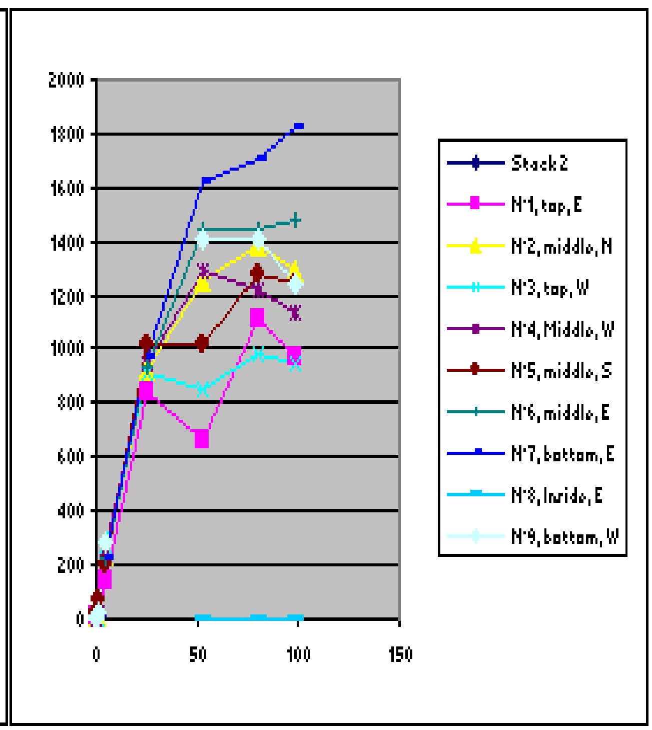
b. 2nd week: every two days; and

c. 3rd week onwards: every three days;

Table 1: PH3 concentration data collected in the course of the training section:

Generators in six pallets, three sides									
Date of fumigation: 06/07/05 at 14:00 / Date					07/07/05				11/07/05
Time hours / Stack 1 ppm PH3	**0**	**0.5**	**1**	**2.5**	**19**	**25**	**69**	**101**	**118**
N°1, top, E	0	0	1	66	497	508	1,466	1,326	1,276
N°2, middle, N	0	0	0	72	531	823	1,400	1,544	1,454
N°3, top, W	0	1	1	78	635	574	1,300	1,012	1,256
N°4, middle, W	0	0	0	23	633	863	1,956	1,554	1,758
N°5, middle, S	0	0	0	49	614	885	1,630	1,644	1,746
N°6, middle, E	0	0	0	11	538	818	1,660	1,790	1,614
N°7, bottom, E	0	13	47	127	637	958	1,948	2,384	2,100
N°8, Inside, E	0	0	0	62	591	879	na	na	1,440
N°9, bottom, W	0	0	9	29	544	722	1,820	na	na
Generators in two pallets, one side									
Date of fumigation: 07/07/05 at 10:00 / Date					08/07/05	09/07/05	10/07/05	11/07/05	
Time hours / Stack 2 ppm PH3	**0**	**0.5**	**1**	**5**	**25**	**53**	**80**	**99**	
N°1, top, E	0	6	8	143	845	660	1,116	976	
N°2, middle, N	0	5	11	242	927	1,252	1,380	1,290	
N°3, top, W	0	5	5	276	910	856	982	942	
N°4, middle, W	0	5	21	255	950	1,290	1,220	1,136	
N°5, middle, S	0	20	72	206	1,020	1,020	1,282	1,246	
N°6, middle, E	0	6	17	223	937	1,448	1,440	1,482	
N°7, bottom, E	0	7	13	226	970	1,618	1,704	1,828	
N°8, inside, E	na	na	na	na	na	na	na	na	
N°9, bottom, W	0	6	28	279	na	1,414	1,410	1,244	





The level of phosphine concentration achieved ensures an effective disinfestation of the grain.

5.4 LOGISTICAL ISSUES FOR COMMODITY STORAGE MANAGEMENT

Phosphine characteristics and performances are well known; therefore, application time constraints cannot be avoided. To obtain the same results as for methyl bromide, the only way is to modify our habits and improve the grain storage management.

We should distinguish between the common “good practice for grain storage”, as it is meant nowadays, and what we could label “trade security grain”. To be able to sell much grain when the customers request it, the quick methyl bromide fumigation habit must be exchanged with the following procedure:

a. A number of bag-stacks must be fumigated at a fixed schedule, whatever their actual infestation is. Checking for insects wastes time, as even the most thorough inspection cannot guarantee that there would not be any insects in two, three or more weeks;

b. This stock should always be ready to be shipped at any time. When the fumigation time has passed, according to the grain temperature, as long as the bag-stack is kept covered, the phosphine concentrations would remain high enough (50ppm or more) for several weeks. After the fumigation, the concentration, as low as 30 - 50 ppm, is enough to keep the stack free of live insects;

c. 12 to 24 hours after exhausting the free gas, we consider that the absorption is finished and the grain is shipped; and

d. The preventive treated bag-stacks should be placed in a position that is easily accessible and ready to be shipped.

6. PRECAUTION FOR THE USE OF THE PHOSPHINE METER

6.1 High concentration meters

Two problems may occur with high concentration phosphine meters:

6.1.1 Measurement above the scale: the meters are made to read a maximum of 1.200-ppm of phosphine. When the actual value is higher, the instrument omits the alarm sound and is on standby. Procedure: shut down the meter and reset the memory; and

6.1.2 Starting the meter the display shows “used”: the meter was, mistakenly, calibrated. Calibrate with phosphine gas 700 ppm and restart the procedure.

Only trained staff must have access to the programming mode.

6.2 Low concentration meters

No problem.

7. PHOSPHINE DOSAGE

The phosphine dosage used in Syria exceeds that of elsewhere, except Germany. The regular dosage is as much as 12g of aluminium phosphine per 1 tonne of grain. Taking into account that 1 tonne of grain is about 1.25 $m^{3,}$ we have 9.6g of aluminium phosphine per m^3 of grain, which will release 3.2g of phosphine gas. Therefore, the final concentration of phosphine gas is 3.2g/m^3.

Below are some examples of phosphine gas dosages in different countries:

- ➔ Australia: from 0.2 to 0.5g/m^3;
- ➔ France, USA and Canada: 1 g/m^3;
- ➔ Egypt: 1.5 g/m^3;
- ➔ Tunisia: 2 g/m^3; and
- ➔ Germany: 5 g/m^3.

It is difficult to establish the appropriate dosage. A better understanding of the phosphine mode of action enables lower dosages to be tried. The possibility of reliable gas measurement is an easy way to reduce concentration keeping a secure standard. Security means, never less than 200 ppm of phosphine during the first week of exposure. The grain temperature gives the exposure time, since tolerant stages, like eggs and pupae, must finalize the development to become susceptible to phosphine.

8. SAFETY MEASURES

A safety measure protocol has been presented and discussed. To prevent phosphine contamination, the usual canisters are very effective since the chemical reaction of oxydo-reduction, burns PH3 into PO4. The issue must be further discussed in the next training section.

Annex II: Brochure (see attached file)

Annex III: Phosphine issues

PHOSPHINE EFFICACY

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The very specific way in which phosphine works explains the great variety of issues raised that neither other pesticide nor other fumigant encounters. For example, recommended dosages vary from 0.5 to 5 g/m3 and the exposure time from 3 to 30 days. What should be done?

1. HOW PHOSPHINE WORKS

The way phosphine works is complex. Price (1985) set out the principles involved and more recently, Chaudhry (1997) and Hebert et al. (2004) clarified the sites and reactions.

Phosphine acts on two main enzymes, oxydase cytochrome and catalase. These two enzymes regulate the conditioning of oxygen to enter the mitochondrion. Blocking their action makes it impossible for oxygen to penetrate into the cell leading to the formation of super oxides (Bolter and Chefurka, 1989), which are the true biocide agents. Phosphine applied in atmospheric conditions lacking oxygen does not kill insects. (Bond and Monro, 1967). The mainspring of this system is iron, the change from ferrous iron to ferric iron ($Fe^{++} \rightarrow Fe^{+++}$). The insect's capacity to allow the phosphine to attack the iron depends on a gene that can take several forms, some of which lead to a tolerance, while others lead to sensitivity. Crossing them can bring about very high resistance (Hebert, 2004).

The inactivation of the enzymes occurs at low phosphine concentrations, but it proceeds according to the acquisition of resistance. For example, in Australia, the minimum phosphine concentration, considered being necessary to block the enzymes, changed, for all species, from 25 ppm in 1990 to more than 100 ppm in 2004. This “minimum concentration” is the subject of choice in each country, founded on a conception or observation of resistance. In Germany, it is estimated that 1,000ppm is the minimum concentration required to avoid any resistance (Reichmuth, personal communication). It should be noted that in Germany, fumigations often take place at low temperatures.

In many countries, like France, the UK or Australia, 200ppm is the most common dosage. In France, we have not yet failed with this concentration. However, we should remain cautious, because phosphine resistance is not an empty word: presently, we find adult insects withstanding concentrations of 1,000-2,000 ppm, whereas a susceptible insect dies in a few hours at 30 ppm (Ducom et al, 2004).

Besides the dosage factor, there is a time factor. Phosphine acts on the respiratory chain. Insects with a low respiratory rhythm such as in the case of low temperatures or for stages with low respiratory rates, like eggs and pupae, need much longer exposure to gas than those with a high respiratory rhythm, as larvae and adults.

Finally, there are species that have high intrinsic levels of tolerance such as grain weevils. For those, the egg and pupae stages cannot be killed rapidly with phosphine. On the other hand, they continue to inevitably evolve towards more sensitive forms like the neonatal larvae, after the egg, and the adult, after the pupae. The gas exposure length will thus depend on the temperature, which determines the length of time needed for an insect to develop from a tolerant stage to a sensitive stage.

Below 10°C, this time is several weeks and phosphine fumigation is almost impossible. This is a huge limitation to its usage. Beyond that, the development speed will increase considerably with temperature and, above 30°, we have exposure times of 3 to 5 days, compared to 10 to 30 days at 15°.

We thus now have theoretical data allowing us to make deductions about the dosage-gas exposure length relationship in the context of a stored product and a trail known to pests. The dosage should allow one to maintain a higher concentration than the minimum necessary to inhibit the enzymes. Two factors could have an influence on the decrease in concentration over the course of fumigation: a) Leak: is a circumstantial phenomenon and can be managed; b) sorption: depends on the product, the phosphine dosage, the temperature and the exposition time. As an example, the table below gives an idea of the adsorption intensity for different groups of stored products.

Table 1: Adsorption scale for different groups of stored products:

Type of stored Product	Adsorption Level
Dried fruit, tobacco	Low (10-30%)
Grains	Medium to high (>30-70%)
Oil-producing plants and high-fat dried fruit, pulses with pods, paddy rice.	High (>70%)

Sorption is accelerated for a given product through an increase in temperature and moisture content. The quantity of gas absorbed increases with the gas exposure length or the moisture content.

2. DOSAGE

Phosphine concentrations depend on:

a. The amount applied;
b. The amount absorbed by the commodity;
c. The gas tightness of the storage; and
d. Where phosphine is applied as formulation such as aluminium phosphide, the time at which gas is released must also be considered.

The goal is to gain a concentration of 200 ppm of phosphine, at the end of fumigation time, whatever the parameters above are interacting.

Table 2: Dosage of fumigant (g/m3) in relation to its sorption capacity;

Stored product and presentation	Dosage in g/m^3	
	Bulk	Bag-stack
Low adsorption	1	1
Medium adsorption	1,5	1
High adsorption	2	1,5

If gas tightness is likely to be poor, the dosage should be increased by 0,5 g/m3.

There is no benefit in exceeding that, due to the fact that defective gas tightness does not allow one to maintain enough gas throughout the fumigation and control will be poor, regardless of what quantity is used.

In practice, the standard dosages vary significantly between countries:

0.2 to 0.5g/m^3	Australia;
1g/m^3	Canada, France, UK, USA;
1.5g/m^3	Egypt;
2g/m^3	Tunisia; and
3 to 5g/m^3	Germany, Syria.

3. EXPOSURE TIME

The gas exposure length is a function of temperature of the product. An important point for fumigation is the hygrometry that surrounds phosphine formulations, which plays a role in defining fumigation length. The following table gives an idea of the influence of relative humidity.

Table 3: Hydrolysis speed in ppm/h (S) and time in hours (T) to obtain 90% of the reaction of different phosphine formulations at different hygrometry (in g/m^3 of water in the air).

	Water content	**9.7 g/m^3**		**13 g/m^3**		**17.4 g/m^3**		**25.4 g/m^3**	
Formulation		**S**	**T**	**S**	**T**	**S**	**T**	**S**	**T**
Tablets	Phostoxin	13	42	18	30.5	23	25	29	20
Pellets	Phostoxin	26.1	20.5	33.8	17	48	13	-	-

Countless references exist on phosphine efficacy trials. The table below shows what we have proposed for a long time in France to kill all the stages, including the egg and pupae stages.

Table 4: Length of exposure time (days) for total efficacy of phosphine on all stages, including eggs and pupae (dosage of 1.5 g/m3):

Grain temperature Typical cases	**Length (Days)**	**5° to <10°**	**10° to <15°**	**15° to <20°**	**20° to <25°**	**25° to <30°**	**> 30°**
Insects having tolerant stages (*Sitophilus* spp) or insects presenting hidden forms (*R.dominica*,	Optimum	-	30	20	15	10	7
	Minimum	-	20	15	10	7	5
Other insects		10	8	7	5	4	3

4. CONCLUSION

The effective use of phosphine as a commodity fumigant lies on two independent factors, dosage and exposition time:

a. The dosage depends on: I) the assessment we make concerning insect resistance, II) the type and characteristics of the commodity, and III) the gas tightness we can achieve; and

b. The exposition time depends on the temperature, which leads the insect development and rate of breathing, and, for a minor part, of the relative humidity when it is very low.