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FINAL REPORT

DEMONSTRATION PROJECT
MP/VIE/98/161
CONTRACT 2000/122/VK

Alternatives to the Use of Methyl Bromide (MeBr)
in Fumigation on Stacked Bags of Rice, Grain in Silos,
and Timber in a Warehouse under tarpauline

INTERNATIONAL INSPECTION-FUMIGATION JS CO.
VIETNAM FUMIGATION COMPANY

VIETNAM, MARCH 2003

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1. PROJECT BRIEFING

It is widely known that Vietnam produces on annual basis of 19–21 million tons of rice, besides other agro-products such as maize, coffee, tobacco leaves, tapioca, cashew nut, etc. This could means a prospective growth rate for domestic economy and better future for VN people, many Vietnamese are still proud of being "second rice exporter". However, people also know that this point will not be approaching higher, but in fact it could be lower in this competitive market. Vietnam, putting aside some 15-16 millions for local consumption and reserve, appr. 3.6-5 million tons of rice for export through officially trade and some 0.6 million tons unofficial, still has to battle against severe insect attack due to poor or average storage conditions, meanwhile ways to better rice quality is still tranquil, and this is an unpardonable lost.

Commodities are often stored up in meager facility, small brick-walled, tole roofing, soil floor warehouses right from the field in short time, then to warehouses-in similar conditions of dealers and exporters. Pest and commodity quality management, storage monitoring are of pure simplicity, people easily accept insect exist with no wonder thus it is understood that treatment is called only if situation is worst, loss is obvious. The question is that these works are not in people's awareness, and they keep thinking that cost is always much and unnecessary, farmers just can not afford for cheap agro-commodities. Recently things change in a positive way, better storing house have been built especially in Mekong Delta – western provinces, what people needs is more systematic plan with suitable technical guidance.

Conferences on national and international scale have been focusing on Post-harvest technology, in particular storage management. But the situation require an overall master plan for preventive actions, in which Vietnam can not manage on their own when new and advanced methods and cost issues are so demanding. Treatments when called often require to apply chemicals and certain standards which might be not – in farmers' opinion – cost-effective and worthwhile. They instead do 'treatment' on their own ways, and reinfestation appears with more vigorous attacks.

So far, grain treatment for quarantine purposes, storage pest control are often done with Methyl Bromide - MeBr - CH_3Br. As volume for treatment in Vietnam increases, volume of MeBr also soars up, from some 100 MTS in 1992 to 350 MTS in 1997. The problem is this chemical is an Ozone Depleting Substance (ODS) as per list of ODS by Montreal Protocol -1986 and going to be completely phased out in 2015. How can Vietnam be better-off and participate in environment protection?

As the first fumigation company in Vietnam and also the biggest consumer of Methyl Bromide, Vietnam Fumigation Company - now known as International Inspection-fumigation JS. Co. has been selected as national coordinator for the Demonstration Project – Alternatives to the Use of Methyl Bromide on Stacked Bags of Rice, Grain in Silos, and Timber on Warehouse under tarpauline. This later on was added with another objectives on Integrated Pest Management on the view of Vietnam poor conditions on this field. The project was funded by UNIDO under budget from Multilateral Fund for ODS project within Vietnam territory.

The principal target of this Demonstration Project takes advantage of changing direction of a pest control service provider in their using Methyl Bromide as major fumigants, and by chain reactions to the customers / rice traders – to warehouse managers – to farmers since the root of the matter lay from very field of paddy rice and other crops. Not only reduce volume of Methyl Bromide used, this project aims at more overall measures to help Vietnam by giving more optional approaches and solution. As quote from Project Document "This program of accelerated Phase-out of Methyl Bromide can be an example to developed and developing countries" with assistance from Vietnam Government and international organizations, VFC started the project in late 1998 same year with several regional projects in Thailand, Indonesia and completed on early 2003. Facts and figure will be presented in following pages.

We acknowledge with gratitude direction and participation in this project of Multilateral Fund, Ministry of Agriculture and Rural Development of Vietnam, UNIDO Head Quarter In Vienna, UNIDO Vietnam, Vietnam National Ozone Unit - Ozone Office – Hydrometeorological Service of Vietnam, Quarantine Department of Vietnam

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Ho Chi Minh City, March 15, 2003

2. METHODS AND MATERIALS

Projects concerning phase-out the use of Methyl Bromide were designed to be in line with local conditions and affordability. Primarily, main stored products which was targeted for Demonstration Project MP/VIE/98/161 are rice, coffee, maize, and timber in according facilities included local warehouse and silos; objectives of the Project is to demonstrate the technical and economic feasibility of *three alternative methods* to MeBr: (1) Phosphate pellets or tablets, (2) improved use of phosphine with cylinderized liquid phosphine, and (3) Integrated Storage Pest Management in the protection of i) bagged rice in stacks, ii) silos containing bulk grains (maize), iii) timber in warehouse under tarpauline. The Project was started in late 1998. The trainings for VFC staffs on ISPM and Pheromones, Phosphine in USA, the use of ECO_2FUME and $VAPORPH_3OS$, with SIROFLO®, SIROFUME® and SIROCIRC™ in Australia and modification necessary such as scope of work, facilities for demonstration were made along the time until 2000.

After discussion with project experts and practical conditions, selected products are: (a) Maize in Silo; (b) Bagged Rice in Warehouse; (c) Timber in Warehouse.

Alternatives now focused on (a) Phosphine pellets and tablets of Detia Degesch GMBH – Germany; (b) Improved use of phosphine with cylinderized liquid phosphine: ECO_2FUME of CYTEC Australia Holdings Pte. Ltd. - A new phosphine fumigant: Phosphine (2% by weight) mixed with carbon dioxide (98% by weight) developed by CSIRO.– the J-system® Low Air Flow Fumigation Method in fumigation patented by Degesch America Inc. Associated with these demonstration is Integrated Storage Pest Management with control experiments performed in rice lots in warehouse.

The activities conducted were technical and financial analysis of fumigation, workshops and trainings, and public information activities. Silo fumigations on maize were done three times with current silo system and once more with brand new silo in a short time at Silo of Cargill in Bien Hoa Industrial Zone II, warehouse fumigation on rice was done three times for control experiment at warehouse of VFC that was newly built for the project. ISPM application trials were done in Tan Binh Dong Warehouse.

Another target of demonstration project - alternatives to the use of Methyl Bromide is to improve the use of alternative provided that technical issue and economic categories such as cost and balance, saving analysis, grain quality assurance are all involved and suitable or customized to local conditions. Since Methyl Bromide has been so widely used in storage pest control, fungi, and pre-shipment treatment, its efficacy and short exposure time plays key role for such long-standing use, thus finding an absolute alternative is not easy and this work demands sound and close study in all aspect involved.

ECO_2FUME fumigant gas is pre-mixed cylinderized mixture of phosphine and carbon dioxide since it is an good carrier for phosphine and diluting phosphine to this concentration ensures ECO_2FUME is non-flammable in all proportions with air. Facilities which can be treated with ECO_2FUME fumigant gas include transport facilities, empty storage facilities, on-farm storage, food processing facilities, as well as quarantine storage facilities for raw agricultural commodities, processed foods, stored tobacco, animal feeds, and non-food products. ECO_2FUME was designed from potential of Phosphine tolerance levels vary with the different stages of insect development. Previous methods of phosphine fumigations, including phosphine tablets and pellets, sometimes resulted shortly. While no live adults were present, the more tolerant eggs and pupae of the insects survived unnoticed, only to grow and subsequently re-infest the product with a few months. ECO_2FUME fumigant gas, when held to its required concentration over a longer exposure time, ensures a total elimination of all insect stages. ECO_2FUME fumigant gas is the right approach to eliminate all stages of insect life, egg, larvae, pupae and adults.

$VAPORPH_3OS$® is another potential alternative, Phosphine in form of flammable compressed gas in 49-liter size steel cylinders which is typically used in the preparation of fumigant gas mixtures. It can be blended (on site) with any inert gas to render it non-flammable. This mixture can then be used to fumigate any structure or stored product. The on site blending of these mixtures greatly reduces the amount of cylinder handling required. With large quantity commodity this is a worthy option in conditions of VN.

Results of demonstrations were presented in three national training-workshops, first two were held in Ho Chi Minh City. The first one was on Integrated Storage Pest Management held on April 4-5 2001, with the participation of 90 people in charge of storage management in the southern region of VN and staffs from Quarantine Dept. Objectives included (a) introduce Phase-out Methyl Bromide according to Montreal Protocol, (b) Storage Management and ISPM, (c) use of Phosphine and physical barriers - Pheromones, (d) Total Quality Management.

The second one on Silo and warehouse fumigation, reporting was organized on 14 October 2002 with participation of 100 staffs of major grain traders, feel mill manager, etc. on the subjects of (a) warehouse fumigation (b) silo fumigation with the use of ECO2FUME® in comparison with Methyl Bromide and Phosphine in form of tablets. Another training with demos was held in Long Xuyen Town, 2002 for 40 people of Mekong Delta (store/warehouse staffs) with main subjects like those of the first two.

The final report will be held in April 2 and 3, 2003 in Ho Chi Minh City with participation of representatives of VN Ministry of Resource & Environment, Ministry of Plan & Investment, Ministry of Agriculture & Rural Development, National Office for Climate Change and Ozone Protection, Plant Protection Department, Quarantine Officers, 50 staffs of major grain traders and plantation, other fumigation companies in Vietnam. International guest will be representatives of UNIDO Headquarter, UNIDO Vietnam, international experts of the project and regional project counter partners from Thailand, Indonesia, Malaysia, and Pakistan. With this meeting, it will be a chance to review the demonstration project, discuss result achieved and experiments, preparing for follow-up actions and conclusions.

3. INTEGRATED STORAGE PEST MANAGEMENT

Integrated Storage Pest Management is a supportive part to our demonstrations targeted for finding alternative to Methyl Bromide, it is not a single technical solution but require many factors involved. In Vietnam conditions, when conditions of storing facility is poor and people' awareness concerning pest management and control has not reached sufficient level, IPM / ISPM is very important, it then was decided that this part should proceeded earliest to ignite people' attention.

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3.1 Theory Briefing

3.1.1 Theory

ISPM adopts a similar approach to those IPM practices employed in the management of pests damaging crops in the field. The primary aim is to minimize pest damage whilst also minimizing the use of chemical pesticides. ISPM program do not necessarily eliminate completely the use of chemical pesticides, but should remove the requirement for practices such as 'calendar fumigations'. These are conducted on the basis of a regular treatment program, often without any real regard to the need for a treatment being actually identified.

Many of the techniques now considered as components of ISPM program have been recognized and used by warehouse keepers for many years. These include good sanitation practice in which warehouses are regularly cleaned to remove the spilled grain that may provide food for insect pests. If regular cleaning is not carried out more or less permanent residual insect infestation may occur in storage buildings, and this can easily lead to the re-infestation of grain quite soon after it has been fumigated. Another technique that has long been recognized in good warehouse management is the 'first in first out' principle. This is because the longer commodities are retained, the more likely they are to deteriorate. The separation of infested stocks from uninfested stocks (e.g. recently fumigated) is another practice recognized to help limit the spread of insect infestation.

It may be difficult to exclude all pests from warehouses by physical methods alone, such as by the installation of screens. Although screens can effectively exclude rodents, it has long been recognized that their use to exclude insect pests is probably not worth the cost of installation, except in special situations, such as where high-value processed products are being stored. A major component of ISPM program is regular inspection and monitoring, both of warehouses and commodities, for insect pests. The sooner pests are detected the sooner remedial action can be taken to minimize the multiplication and spread of an infestation. This action, that may include fumigation and spraying with insecticide, must aim to limit the degree of infestation and prevent its movement in grain further along the marketing system.

In addition to regular sanitation, another useful non-chemical ISPM technique is the use of barrier covers on bag stacks. Covers should be of cotton material or insecticide-treated mosquito mesh that avoids condensation and moisture migration in the grain, but provide a good physical barrier against the entry of insect pests. A good overlapping margin at the floor level is essential, and it may be useful to apply insecticide at this level to ensure control of insects that may attempt penetration at this level. The employment of covers is particularly applicable to commodities stored for several months or longer, and where there is a significant risk of cross infestation by insects, possibly from newly delivered grain that may be infested. Covers are placed on stacks prior to the application of fumigation sheets, and left in place after the treatment for as long as may be necessary to protect the commodity against reinfestation. The employment of stack covers is aimed primarily at reducing the need to re-fumigate commodities during prolonged periods of storage by providing a physical barrier against cross infestation. Trials have demonstrated that commodities can be safely stored for long periods under cotton covering sheets even in humid tropical climates.

Inspection and monitoring are a major component of ISPM program and must be backed up by an effective recording and reporting system that results in follow-up action being taken as and when necessary. Inspection program should be considered to be a routine operation, warehouses should be inspected every day, and commodities inspected at least once a week. Monitoring for insect pests may be by spear sampling or by the use of traps such as bait bags. Regular monitoring allows an 'early warning' of infestation, and decisions can then be taken on whether or not remedial action such as fumigation is necessary. Such decisions may be dependent upon the degree of infestation detected, e.g. numbers of insects per kilogram, and whether a pre-determined threshold limit for insect numbers exists, and on which remedial action depends.

Insect infestation of commodities is most likely to take place during the periods they are in storage, but may also occur elsewhere, such as during transportation. Road vehicles or river vessels regularly used to transport grain are likely to contain residues that may be infested. It is essential, therefore, to inspect all such vehicles before loading, and any infestation removed. Physical removal such as by sweeping may be sufficiently effective, but if access is difficult spraying with a suitable insecticide may be required. As with all such activities, a written record must be made of the treatment carried out, since its effectiveness may determine future action taken in similar situations.

Computer-based decision support program are useful in helping warehouse managers to reach the correct conclusion about a problem. Various program are available including the most cost effective timing for fumigation.

It has long been recognized that where there is significant need for chemical pesticide application on a regular basis, storage management techniques are poorly employed or not used at all. Conversely, where there is only occasional use of pesticides, storage management is likely to be well practiced.

3.1.2. Milestones

Objectives of any concrete plan ISPM/ICM/IPM originate from actual site-conditions. Prior our demonstration, site survey was made at Vietnam warehouses, silos, storing facilities, most common characters were recognized:

- storing facilities is not in good conditions, they are aged and of outdated design, even newly built ones were not suitably design for standard storing especially to prevent pest attacks, protect grain and commodity in hot, humid climate,

- poor or insufficient knowledge on pests and insects can not help staffs prepare commodity treatment plan, or discover infestation or apply simple, affordable preventive methods, etc. and finally estimate loss and judge storing conditions for further improvement,

- store management of staffs and shortage of staff are the ones that make situations impeachable, such as regular sanitation and cleanliness, risks and source of infestation, loss rate and matters related to commodity quality,

- people's awareness on pest and commodity management is small due to temporary working time in year, namely commodity accumulates in huge volume in a few months then fall down to nil, causing temporary shut down of facility, in this period, repair or improvement is not well-attended.

From this base, we set up a complete ISPM design with identified factors included (a) demonstrations for proof and supporting statistics; (b) awareness program through daily contacts and communication with clients, correspondence, consulting activities, workshops in Ho Chi Minh City and in Mekong Delta (c) training for key people mostly storage managing staffs, providing new info and knowledge that will reach further to their staff so as they together could step by step apply and prepare ISPM for their own daily work. Details of the jobs are as follows:

VFC with international expert's guidance carried out demonstration in form of trial applications of ISPM in actual conditions (At Tan Binh Dong Co. Warehouse in HCMC) and standard conditions at VFC new warehouse of three stages for a period of 16 months. These were scheduled with: (1) stage 1 from February 28 to 28 September 2000, (2) stage 2 from 5 October 2000 to 6 February 2001; (3) stage 3 was ISPM Control application at VFC super warehouse in District 12 has been done for 4½ months from November 1, 2002 to February 28, 2003. The new warehouse was newly built with better design - four separate fumigation chambers for pest preventive and can be made gas-tight. Result and statistic collected from demonstrations were analyzed and summarized for technical and financial reports.

Figures of trial application and most common issues of ISPM, Total Quality Management were reported in a workshop held on April 6-8 at HCM, with a site visit to Tan Binh Dong warehouse with participation of 35 guests from grain trading and storing companies, they are people directly involved and in charge of storing facility. It was the feedback from this workshop motivated us to proceed further demonstration, participants were impressed by reported deductive results that they applied shortly after attended the courses, still we think that to provide better background for follow-up actions we should provide more specific and comparisons to win their whole attention and belief.

The a.b.m content plus basic knowledge on pests/insects, fungi introductory, full application of Phostoxin in solid forms were presented in two other workshops, one in Ho Chi Minh City for 90 managing staffs of Vietnam major grain trading companies in October 2001 and the other at Long Xuyen Town in October 2002 for 40 staffs working as warehouses in Mekong Delta provinces.

From these three workshops we had a better position to view on what has been happening to Vietnam storing conditions, discussing with all people involved from input to output, commodity quality control to sanitation work, then took a firm grip to reality in order to move on with out demonstrations.

3.2. Demonstrations

3.2.1. Place and Site Description *(see layouts on next page)*

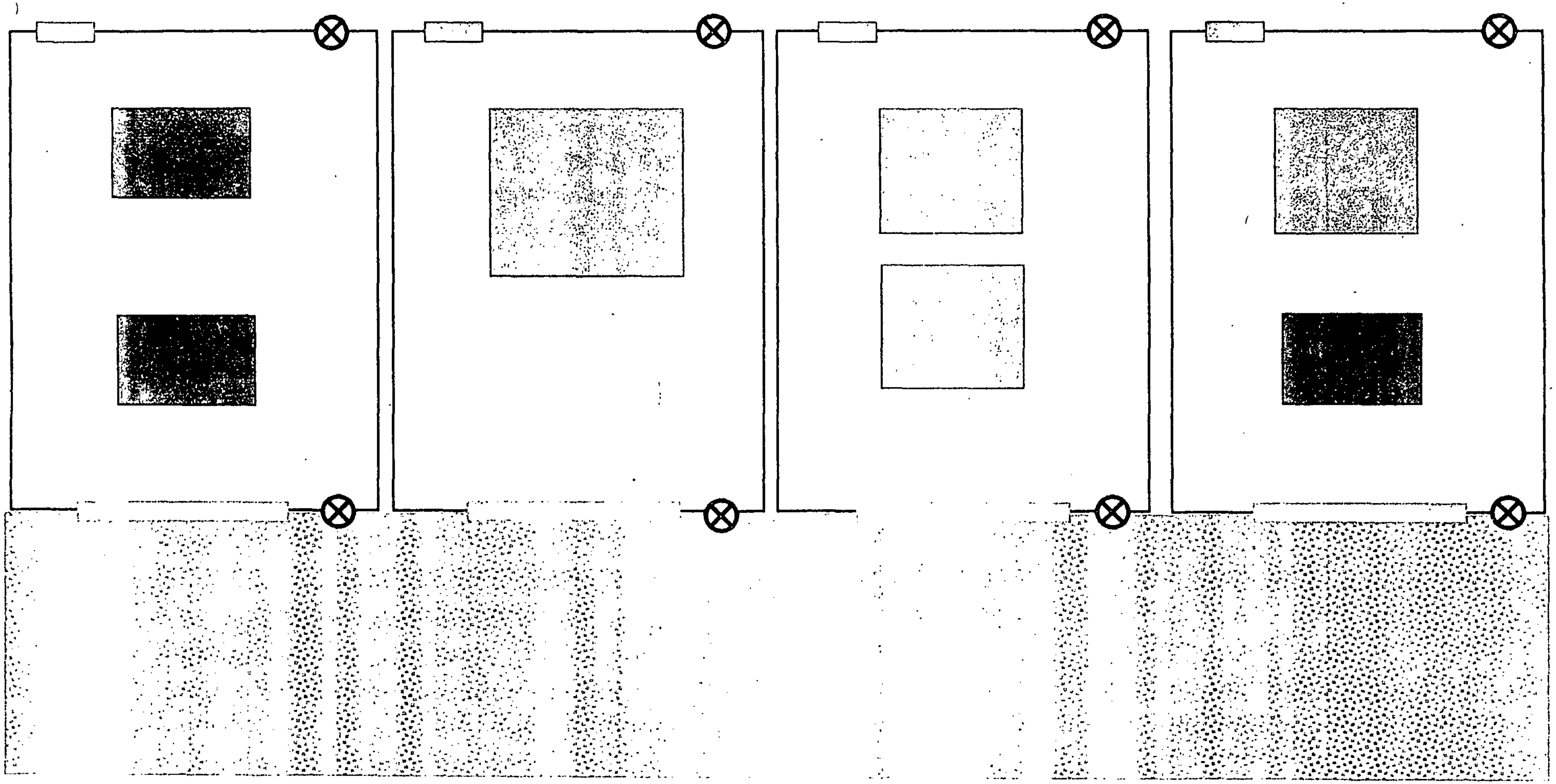
(1) Tan Binh Dong Premise: Warehouse A at District 8, HCMC. This is of typical type in a very place for warehouses in Ho Chi Minh City. It is a structure with total area of 2000 sqm, brick walls, tole roofing, 5 entrances/doors, natural ventilation through holes on the part of the wall at appr. 60cm height and through open between two layers of roof. There were one rice processing chain for rice cleaning, polishing and packing in side, VFC use only a part of warehouse, the other part for rice and broken rice stacks of Tan Binh Dong Company.

(2) VFC Premise: this 1200 sqm warehouse capacity 200 MTS as a.b.m. was newly built in 2000 on a premise of more than 14000sqm, with four separate chamber, brick walls, tole roofing with metal ceiling proofing which can be made gas tight with electric ventilation system, solid floor. Each chamber consists of one main entrance affordable for truck moving and one glass sub entrance at the back, these doors are tight and can prevent bird, rat, mice entries, ventilation system consists of 2 electric fans.

3.2.2 Primary preparations

(2) Sanitation for demonstration site at Tan Binh Dong's premise: rice, broken rice stacks had been there before, with processing chain worked every day. Primary sanitation included dusting to floor, walls, roof of warehouse A, collecting and disposal old bags, commodity spilled on the floor. Periodical sanitation was

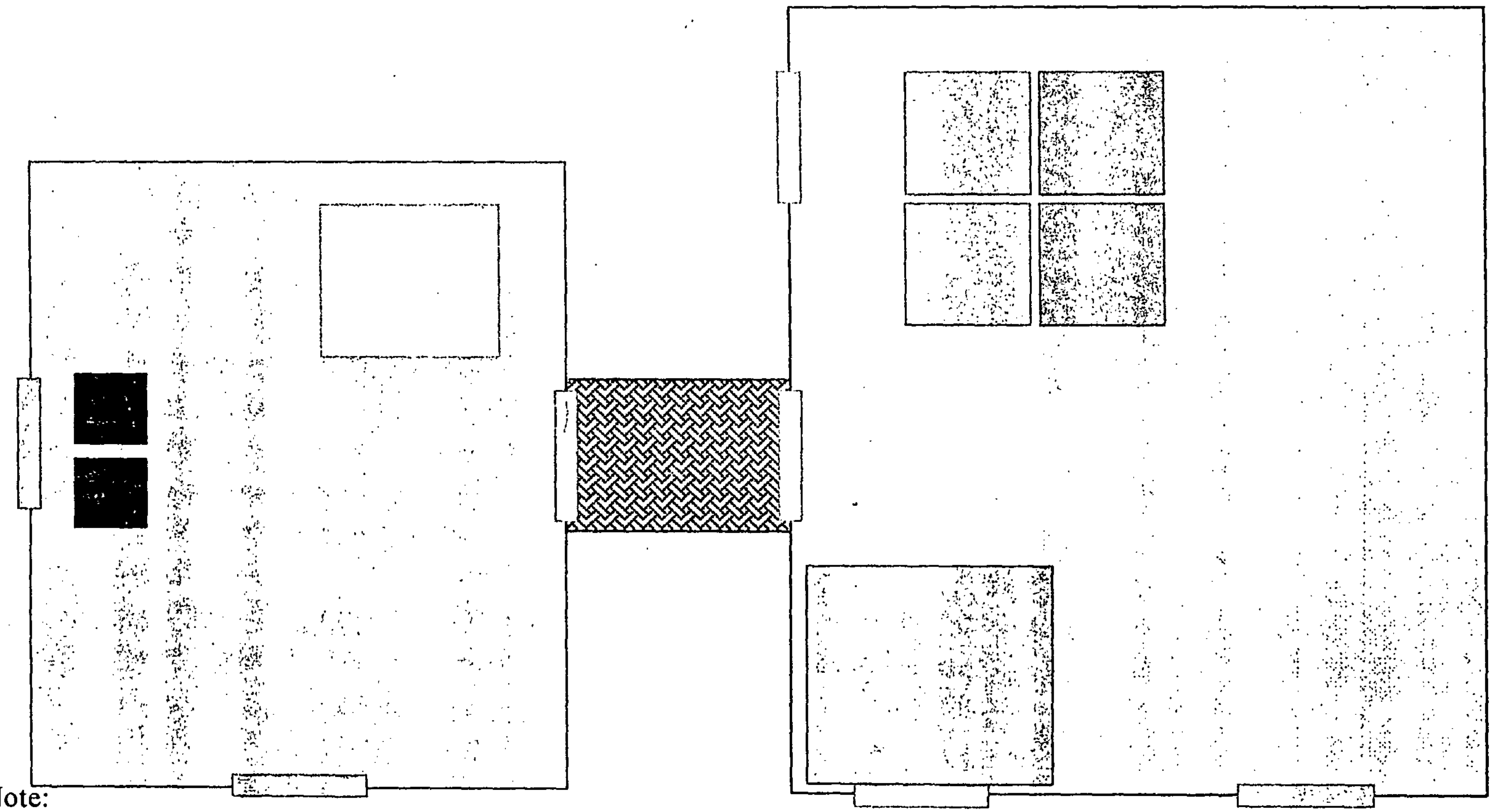
WAREHOUSE LAYOUT AT VFC PREMISE



Note:

Timber	▇	Bagged rice	░	Ground	⁚
Main entrance	☐	Glass Subentrance	☐	Electric Ventilation	⊗
Chamber measurements:	30mx40m				

WAREHOUSE LAYOUT AT TAN BINH DONG CO.



Note:

- Warehouse A
- Experiment lots
- Office block
- Path connected Warehouse A and B
- Warehouse B
- Processing chain
- Doors
- Rice Stacks

done twice week by hired people (of Tan Binh Dong Company) for the whole time of demonstration.

(2) Sanitation for demonstration site at VFC's premise: this warehouse was designed and constructed for project purposes. Sanitation was done in the same manner like those to Tan Binh Dong warehouse but by VFC staffs.

(3) Insect physical barrier: it was a brand new cotton sheet, thin enough and wide enough to cover 10 tons rice.

(4) Insect-Bait-Traps: they were made of aluminium mesh, eye holes dimension is 2mm, in form of round cylinder shape, diameter 10cm, height 6cm, with bottom and cover top, bait for each trap was 100gr of brown glutinous rice.

3.2.3 ISPM Demonstration Arrangement

(1) At Tan Binh Dong Warehouse:

- Two rice lot 10 tons each were arranged side by side at 1m, and from 2 to 5 meters away from other lots/stacks in the same warehouse, the rice we used was of normal quality. The rice lots and the cotton sheets as physical barrier were fumigated prior insects-bait-traps placing.

- Insect-bait-traps placing: After the lots and cotton sheet had been treated, bait-traps were placed in two lots, ten traps for each lot and other ten traps were placed evenly on other parts of the warehouse.

- Insect barriers: the cotton sheet was used to cover one rice lot after placing traps, its footing was weighed properly, the other was not cover for control experiment.

(2) At VFC's warehouse

ISPM at VFC's warehouse was conducted in parallel with demonstration of fumigation in warehouse of 200 MTS rice in the same manner as in Tan Binh Dong.

3.2.4. ISPM Stages and Methods: This was done for a period of 14 months with three stages

(1) Stage 1: from February 28 to 28 September 2000. In the stage, cotton sheet was used purely as an physical barrier, without weighing by sand snake, contact pesticide spraying (Sumithion concentration 0.02%) onto the sheet and

perimeter floor. Bait traps were collected and checked, replaced with new ones once a month. The bait traps were treated with PH3, after that result were analyzed at lab to determine quantity and species of insects.

(2) Stage 2 from 5 October 2000 to 6 February 2001: procedures were repeated, the only difference is cotton sheet was weighed at footing with sand snakes and contact pesticide was sprayed (Sumithion concentration 0.02%) onto the sheet and perimeter floor.

(3) Stage 3: from November 1, 2002 to February 28, 2003: we continued to use rice lots, timbers stacks in four separate chambers after demonstration in warehouse (see details in Warehouse Fumigation). The procedure was alike to previous stages.

3.3 Results and Conclusions

3.3.1 Results: according to samples analysis presented in following tables showing statistics of three stages of ISPM application in two place, it showed :

(a) At TBD warehouse

Insect density always stayed at high threshold / level which require fumigation, control lot after one month was infested with insect level similar to other lots in the warehouse. This presented the case that:

- TBD warehouse was not assured with high level of sanitation due to deeply infested lots which were left untreated for a long period,
- New stock input for processing and then packing did not go under any control for pests and insects,
- First In First Out basic principal were not followed properly, in fact there were rice and broken rice lots stored for quite a long period which were indeed source of infestation,
- Sanitation practice and scheme were not correct, spilled grain and old bags, wastes were not controlled absolutely,
- Contact pesticide spraying could not achieve expected result due to infested lots already placed inside warehouse.

(b) At VFC's warehouse

After four months, almost no insects was found in lots for experiment, only in chamber 2 which was treated by ECO2FUME (CO2) under tarps at low level

(3 insects) but this did not get higher. According to stage 3 at VFC's warehouse, it has proven that with standard warehouse conditions, high level of sanitation, with good control over source of infestation, stock can be stored for a period of more than 4 months if input had been assured free from insects and eggs, larvae before putting into warehouse, then good sanitation would help to restrain development of insect population.

(c) Benefits and Financial Statement of Insect Barrier

1. Costs for cotton sheet and insecticide spraying
(for a rice lot of 400 tons = 640m3)

- Cotton sheet 20mx30mx0.55 USD/sq.m	=	330 USD
- Use time 24 month	=	13.75 USD/month
- Sumithion + labour	=	3.6 USD/month
Total cost for 12 months:	=	207.6 USD/year

2. Minimum Cost for fumigation on year

- Fumigation: 4 times		
- Costs per each treatment	=	130 USD
Total costs for 12 months:	=	520 USD/year

3. Financial statement:

- The use of insect barrier help reduce 50% times of treatment from 4 times to 2 times a year (in Tan Binh dong warehouse)

- Saving two treatments means sum saved will be 260 USD, after extract cost for insect barriers 207.6 USD/year, totally we can save up to 52.3 USD/year

- Other benefits: (a) reduce residue in commodity according with times of treatment, thus improve grain quality; (b) better for environment, (c) reduce risk of resistance, (d) reduce volume of chemical used namely MeBr.

3.3.2 Conclusions

(a) Physical barrier was proven to be a good preventive measure against infestation in this case cotton sheeting, especially flying insects mostly moths. Referring to results in tables, it shows that grain will need no refumigation for 3 months if protected with cotton sheeting, and it can be 6 months if cotton sheet's footing is weighed with sand snake and spraying contact pesticides onto cotton sheet and grain stack footing. This method in general is suitable with agro-products (rice, coffee), finished products stored in short time for consumption for sales or export in inadequate conditions of storing facilities which can not afford insect separation / preventive properly.

(b) Warehouse design especially details involved with door system, drainage, ventilation, etc demand great attention to inhibit attack and damage caused by rat, bird, etc. Evaluating two site conditions, it is clear that level of damages caused by rats in Tan Binh Dong is extremely serious in contrast at VFC's warehouse, this issue is nil thanks to tight doors and ventilation system.

(c) Level of insects attack showed demands for better warehouse/stock management. it should consist of stock rotation with basic FIFO, daily dusting an sanitation, warehouse condition checking and minor immediate repair, etc to quality control.

(d) Preservation commodity in most affordable means and insects /pest preventive plan should be in people's habit in order to minimize loss and degradation on quality from moisture, insects / pest's droppings, long storing time. It also means threshold limit should be named therefore with daily checking staffs can identify risks of infestation and apply suitable measures.

Table 1. STAGE 1 - 1/1

Number of insects recorded in the stack covered with a cotton sheet w/o insecticidal spraying

NO	Time (months) Amount Insect species	First		Second		Third		Fourth		Fifth		Sixth	
		Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva
1.	Oryzaephilus surinamensis L	7		50	10	70	20	120	17	94	10	150	30
2.	Ahasverus advena Walt	14	2	2		3		3		1		2	
3.	Tribolium castaneum Hrbst					3		1					
4.	Sitophilus oryzae L			1		1							
5.	Lophocateres pusillus KL												
6.	Cryptolestes minutus OL											1	
7.	Rhizopertha deminica F												
8.	Corcyra cephalonica												
	Total no. of species	2		3		4		3		2		3	
	Total no. of insects	23		63		97		141		105		183	

Table 2. STAGE 1 - 1/2

Number of insects recorded in the control (uncovered) stack

NO.	Time (months) / Amount / Insect species	First		Second		Third		Fourth		Fifth		Sixth	
		Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva
1.	Oryzaephilus surinamensis	4	1	13		16	1	22	1	20		43	5
2.	Ahasverus advena Walt	500	93	93	2	33	10	64		65	4	227	6
3.	Tribolium castaneum Hrbst			2								1	1
4.	Sitophilus oryzae L			5		1				2			
5.	Lophocateres pusillus KL												
6.	Cryptolestes minutus OL									1		1	
7.	Rhizopertha deminica F							1					
8:	Corcyra cephalonica							1	4	1		4	5
	Total no. of species	2		43		3		3		4		5	
	Total no. of insects	598		113		61		141		101		293	

Table 3. STAGE 1 - 1/3

Number of insects recorded in the warehouse

N O.	Time (months) / Amount / Insect species	First		Second		Third		Fourth		Fifth		Sixth	
		Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva
1.	Oryzaephilus surinamensis	80		19		36	60	20		22	309	336	80
2.	Ahasverus advena Walt	518	121	180	6	19	105	14		17	100	43	20
3.	Tribolium castaneum Hrbst	4				1							
4.	Sitophilus oryzae L					13							
5.	Lophocateres pusillus KL							1			1		
6.	Cryptolestes minutus OL												
7.	Rhizopertha deminica F									4			
8.	Corcyra cephalonica					17	35	1	20	1	70	2	4
	Total no. of species	3		2		5		4		5		3	
	Total no. of insects	723		205		286		147		524		485	

Table 4. STAGE 2 - 2/1

Numbers of insects recorded in the stack covered by a cotton sheet with contact insecticide spraying (Sumithion concentration 0.02%) and footing weighing

NO.	Time (months) / Amount / Insect species	First		Second		Third		Fourth		Fifth		Sixth	
		Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva
1.	Oryzaephilus surinamensis	7		1	1	9		12	17				
2.	Ahasverus advena Walt	4		1		13		24					
3.	Tribolium castaneum Hrbst												
4.	Sitophilus oryzae L					14		2					
5.	Lophocateres pusillus KL												
6.	Cryptolestes minutus OL												
7.	Rhizopertha deminica F							2					
8.	Corcyra cephalonica					1							
	Total no. of species	2		1		4		4					
	Total no. of insects	11		3		41		40					

Table 5. STAGE 2 - 2/2

Numbers of insects recorded in the uncovered (control) stack

N O.	Time (months) / Amount / Insect species	First		Second		Third		Fourth		Fifth		Sixth	
		Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva
1.	Oryzaephilus surinamensis	8	10	3		5	2	35	24				
2.	Ahasverus advena Walt	44	80	94	50	20	3	11	5				
3.	Tribolium castaneum Hrbst			4	5			1					
4.	Sitophilus oryzae L			1		5		2					
5.	Lophocateres pusillus KL												
6.	Cryptolestes minutus OL												
7.	Rhizopertha deminica F												
8.	Corcyra cephalonica			1	52	1	60	1	6				
	Total no. of species	2			5	4		5					
	Total no. of insects	142			210	96		85					

Table 6. STAGE 2 - 2/3

Numbers of insects recorded in the stack covered by a cotton sheet with contact insecticide spraying (Sumithion concentration 0.02%) and footing weighing

NO.	Time (months) / Amount / Insect species	First		Second		Third		Fourth		Fifth		Sixth	
		Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva	Adult	Larva
1.	Oryzaephilus surinamensis	71	30	55	11	46	10	30	7				
2.	Ahasverus advena Walt	25	20	26	10	2	10	1					
3.	Tribolium castaneum Hrbst	3		10	2								
4.	Sitophilus oryzae L	2		1		4		300	40				
5.	Lophocateres pusillus KL												
6.	Cryptolestes minutus OL												
7.	Rhizopertha deminica F												
8.	Corcyra cephalonica	1	6	2	160	1	117	2	50				
	Total no. of species	5		5		4		4					
	Total no. of insects	152		277		189		430					

Table 7. STAGE 3 - 3/1

Insect development at VFC's warehouse

NO	Species	No. of insects before treatment	No. of insects after fumigation			
			First month	Second month	Third month	Fourth month
1.	Ahasverus advena walt	100	0	2	0	0
2.	Oryzaephilus surinamensis	40	0	2	0	0
3.	Sitophilus orizae L	2	0	0	0	0
	Total no. of species	3	0	2	0	0
	Total no. of insects	142	0	4	0	0

DIAGRAM 1.

INSECT DEVELOPMENT AT VFC'S WAREHOUSE

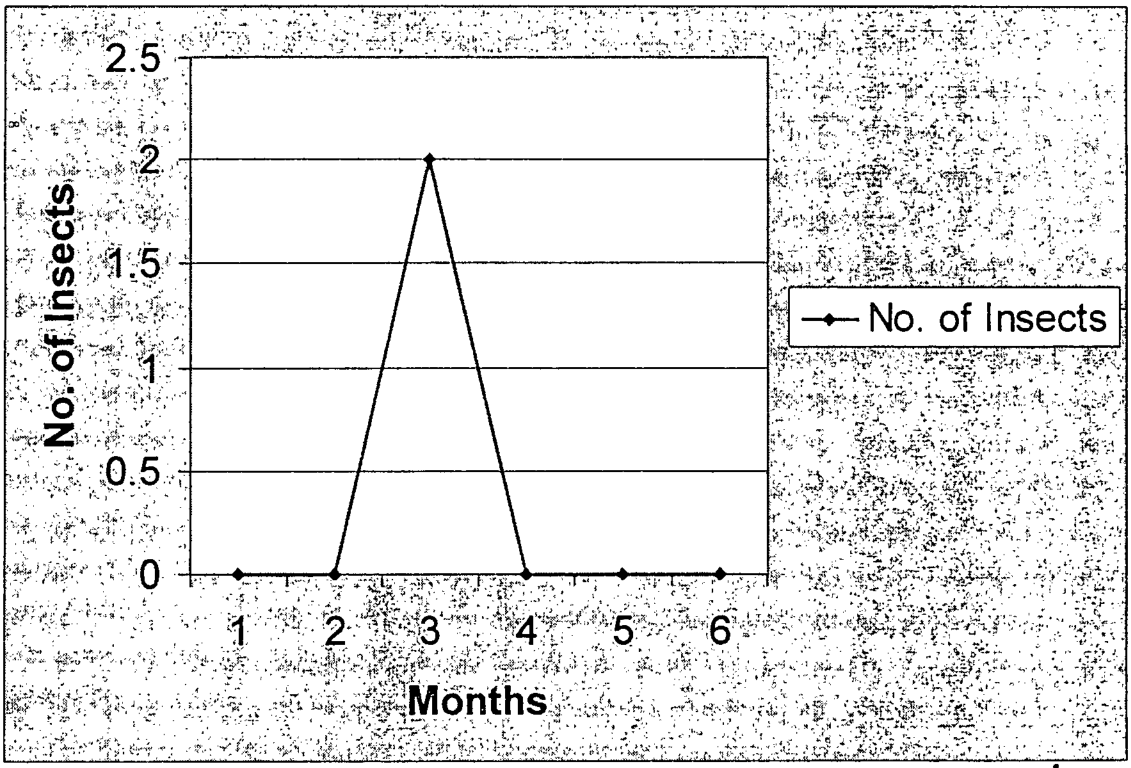


DIAGRAM 2

INSECT DEVELOPMENT AT TAN BINH DONG'S WAREHOUSE

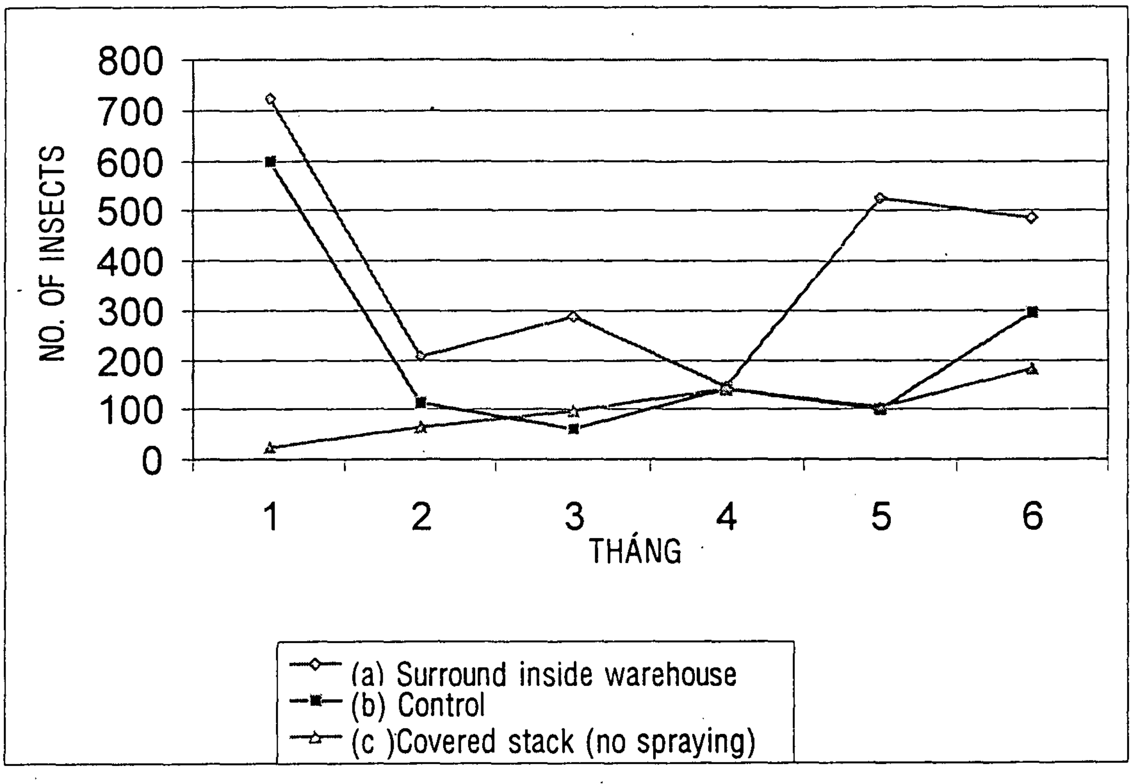
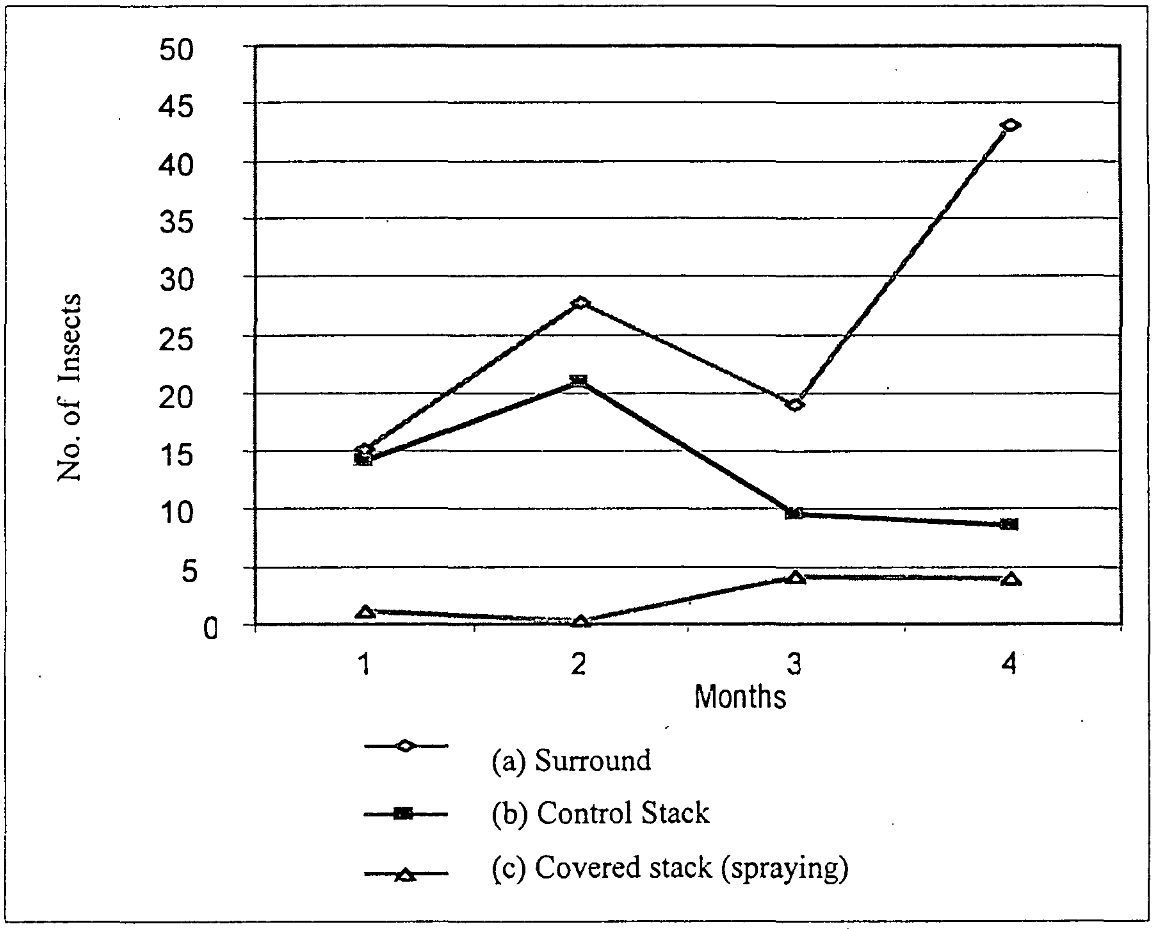


DIAGRAM 3.

INSECT DEVELOPMENT AT TAN BINH DONG'S WAREHOUSE



4. SILO FUMIGATION WITH LIQUEFIED PHOSPHINE

Most important demonstrations of this project are applications of liquefied phosphine and phosphine in solid forms of tablets to evaluate treatment results against Methyl Bromide which has been a long-term favourite fumigant with target materials used were bagged rice and timber. In fact Methyl Bromide has been widely used thanks to fast and effective impact for grain treatment, low risk of insect resistance and convenient use, deep and even gas penetration, that explains for hard road to find an absolute alternative to it.

Mr. Robert Ryan - International Expert
BOC – Australia

And

Mr. Tran Quang Minh - National Expert
Quality Assurance Manager
Int'l Inspection-Fumigation JS. CO.
HCMC, Vietnam

4.1 Theory Briefing

4.1. Theory

Demonstration with phosphine in silo has applied technology called SIROFLO® with fumigant gas named ECO_2FUME® and the J-System Low-Air-Flow Method with Phostoxin Tablets and Blankets. SIROFLO and ECO_2FUME were developed by CSIRO Australia, property of CYTEC Australia Holdings Pte. Ltd.; the J-System belongs to Degesch America Incorp.

Briefing on these technology are as hereunder:

(a) SIROFLO®

SIROFLO is a pressurized low flow, fumigant distribution system that drives a constant low concentration of phosphine through a grain mass for the predetermined time. The small positive pressure is calculated to overcome the forces that otherwise lead to air ingress and consequent loss of fumigant concentration, which is the prime cause of failure of other types of fumigation methods. When properly applied, SIROFLO kills all stages and types of insect that infest grain. It does this by maintaining a sufficient concentration of phosphine for periods long enough for the tolerant insect "stages" to become susceptible. The egg and pupae stages are usually much more tolerant to phosphine than the larvae and adult stages, which is why it is important to maintain fumigant concentrations for long enough to allow the tolerant stages to develop into the susceptible stages which are more easily killed. SIROFLO allows the use of prolonged exposure times in order to maximize the effectiveness of phosphine. Longer exposure times also permit the use of lower concentrations. Short exposure times to phosphine can only be effective if high concentrations of fumigant are used and good distribution of fumigant is achieved throughout the grain mass. SIROFLO is a uniquely flexible fumigation system, since it makes it possible for the fumigator to very precisely control both the fumigation time and the fumigant concentration, whilst at the same time ensuring good distribution of fumigant throughout the stored grain mass. This flexibility and control makes it possible to guarantee the effective control of all stored grain insect pests.

SIROFLO is also a uniquely safe fumigation system. By comparison to phosphide tablet fumigation, PH_3 concentrations are normally very low, the risks of harmful workspace concentrations are small, and fumigators are normally not exposed to the gas when undertaking the fumigation. SIROFLO fumigation systems have been custom-designed to ensure that effective phosphine fumigation can be undertaken. However it must be remembered: there are two requirements for a successful fumigation using phosphine: the fumigant must be properly distributed throughout the grain mass and an effective dose must be achieved. "Effective dose" means a high enough concentration of phosphine is applied throughout the grain mass for a long enough period of time to kill all insects present in the grain. The SIROFLO spreadsheet was used to calculate dimensions of pipes and orifices delivering the air / phosphine mixture required. The initial inlet concentration was 90ppm PH_3 to achieve ~50ppm at the top of the silo. The inlet concentration can be altered if desired - the ability to "dial" the concentration is one to the unique benefits of the SIROFLO fumigation system thus it can help kill insects in all stage even in place where gas-tightness not required. The "J" System low rated but commonly available fan was able to deliver the specified airflow when both silos were being treated.

There must be certain pre-requisites to apply SIROFLOW: (1) equipments and materials for SIROFLO; (2) ECO_2FUME cylinders; (3) fans for slow air flow to pump even air mixed with phosphine and carbon dioxide gas inside; (4) silos walls made gas-tight and installed with ventilation system at the bottom for air inlet; (5) stable power source.

(b) J-SYSTEM © LOW-AIR-FLOW METHOD

J-System® was developed by Degesch America, VFC is exclusive agent in Vietnam. This is a fumigation technology using phosphine in solid forms in a closed recirculation system with slow air flow in which low concentration of PH3 works continuously, thus people can control fumigant concentration in an air-tight warehouse, means of conveyance regardless their measurements and shapes.

Chemical used in this system is phosphine (tablet, blanket, strip, etc.) placed on top of cargo, when exposed to open air, it releases phosphine gas which is sucked in by recirculation fans into piping system to the bottom of cargo then pumped back to top of commodity. Thanks to recirculation fans, we can achieve a stable concentration and even penetration which can assure an effective control on insects. In the demonstration at Cargill, dosage was 2gr of PH3/cbm, most common dosage.

There must be certain pre-requisites to apply J-System: (1) gas tightness: this is similar to other fumigation methods in which gas-tightness is very important during exposure time and it is even more important when apply constant recirculation system like J-System; (2) standard motors that can works continuously min. 15 days with no shut-down; (3) stable power source (220voltage recommended or at least 100voltage); (4) a completed air transportation (piping system) between bottom and surface of commodity; (5) min exposure time of this method is 5 days, still most preferable is from 7-10 days, best period is 15 days or more (if grain humidity and time allow) to kill eggs.

(c) Fumigation with Methyl Bromide

This method uses MeBr as fumigant gas in a closed and airtight chamber, silo, warehouse, etc. the gas from pressurized cylinders penetrates into commodity stacks for insect control. Thus the first step is sealing bottom and top of silo with adhesive tapes and glue, install gas inlet pipes from top of silo, common dosage in Vietnam is 50gr/cbm, exposure time is 48 hours.

4.1.2 Milestones

Demonstrations of this part included adaptation of ECO_2FUME and J-System for silo treatment, and certainly in parallel with control treatment with MeBr. The silo system selected is most typical and available in Vietnam located in the premise of Cargill VN Ltd. Bien Hoa Industrial zone II, Dong Nai Province, ~27km from HCMC.

Schedules for all the works done as follows:

(a) Fumigation to maize in Silo with Methyl Bromide as control experiment

(b) Fumigation to maize in Silo with Phosphide tablets with J-System

(c) Fumigation to maize in Silo with SIROFLO – ECO_2FUME

4.2 Demonstrations

4.2.1 Place and site description

(a) Place: silo system at Cargill is considered standard in Vietnam, it includes 5 silos, in which silos no. 1, 2, 3, 4 are in identical shapes and measurement (see next page drawing) all used for demonstrations with different methods. These silos were constructed with cement foundation, walls made of steel tole connected to each other by large bolts, at connection points it was sealed with silicon, there is manhole on top of silo roof, inlet door and 8 natural ventilation holes. Between roofing and walls it is a small space of 0.5cm. At its bottom, it was installed with ventilation trench connected to outside and outlet.

(b) Arrangement:

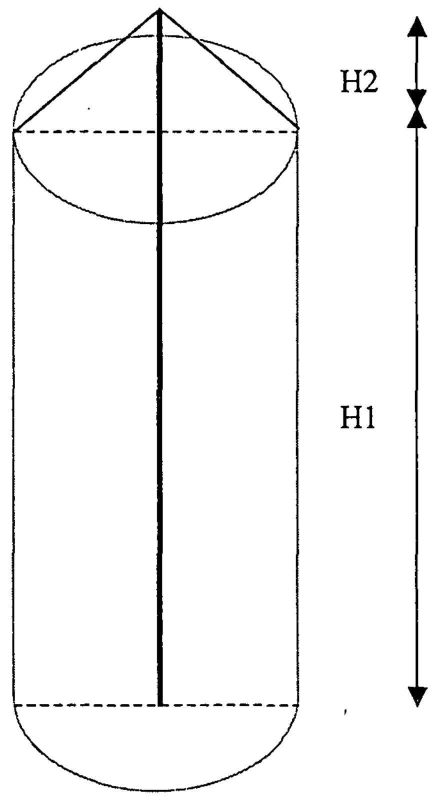
- Silos No.1 and 2 were treated with MeBr on July 2000,

- Silos No. 2 and 4 were treated with liquefied Phosphine twice, the first in September 2001, and second in December 2001,
- Silos No. 1 and 3 were fumigated with Phosphine tablets – J-System from 31 December 2000 to 6 January 2001

(c) Material: maize was used for all the silo system with target species (which have strong resistance characters) namely Tribolium castaneum and Sitophilus sp. In addition, maize used for demonstration had been infested with many species (see tables no. 1, 4, 7) this was also a point of interest to review later. Maize was transported in bulk into silo, top of commodity below manhole 3.8m.

Measurement:

V	=	1711,3 cbm
Diameter	=	10m
Height 1	=	20.7m
Height 2	=	3.3m



4.2.2 Primary Preparation

(a) Insects samples: for each silo there were six samples, each consisted of one holed plastic with 0.5kg of wheat and grinned maize with 30 adults of the two a.b.m species (three samples contained Tribolium, others for Sitophilus). Four samples placed on top of maize, two other hung up above maize 1m with string tied outside.

(b) Fumigant:

- Methyl Bromide: manufactured by Dead Sea Bromine Group – Israel, chemical was in liquid forms pressurized into cylinder, type of 50kg net, content of ingredient 98% CH3Br plus 2% Chloropicrin as warning agent.

- Phosphine tablet for J-System: manufactured by Detia Degesch GmbH, Germany, content of ingredient 55-57 % Aluminium Phosphide.

- Liquefied Phosphine: trade name ECO_2FUME with 2% of PH3 in 98% Carbon Dioxide in liquid form, pressurized into cylinder type 31kg manufactured by CYTEC Australia Holdings Pte. Ltd..

(c) Piping system: for gas concentration checking

In order to check gas concentration during fumigation time, before loading maize into silo, plastic pipe (PE) dia. 0.7cm was installed into empty silo with one end to outside at four measuring points: (1) at maize surface, (2) + (3) inside maize near silo's walls 10m and 15 m from silo's bottom, (4) 1.0m from bottom, inside 1m from silo wall.

(d) Measuring devices: for MeBr: Riken Keiki model IF-18, for PH3 is Silocheck of Canary Australia and PUMP MSA and detector tubes. Each time we checked concentration, it was measured four times, three by SILOCHECK and one by MSA for average value of four times.

4.2.3 Fumigation with Methyl Bromide (Control Experiment)

(a) Procedures

Maize was loaded into silo, top of commodity below manhole 3.8m, hydro concentration in maize is 14.6%, air temperature 34^0C. (see table next page for insects record after loading before treatment)

This experiment proceeded at Silos No.1 and 2 of Cargill from 11.00 on 15 July, 2000 and finished on 17.00 on 17 July 2000. Volume of MeBr used per silo: 85.5kgs at 50 gr/m3 dosage.

(b) Results

Table 8: Insect species and density in maize in Silos No.1 and 2 – Cargill at time of fumigation in July, 2000

Species	Silo 1(adult/ kg)	Silo 2 (adult/ kg)
Tribolium castaneum	2	3
Sitophilus sp.	3	1
Criptolestes minutus	1	0
Oryzaephilus surinamensis	2	3
Alphitobius sp.	1	0

Table 9: MeBr concentration records at Silo No.1

Measuring point	Ave. concentration CH_3Br (g/m3) from time of fumigation					
	After 1h	After 3h	After 6h	After 24h	After 46h	After 48h
Surface	72,5	44,7	30,5	14,8	7,8	7,8
15m from bottom	35	38,7	31,6	20	11	11
10m from bottom	36,3	47,5	57	28,4	18,3	17,8
1m from bottom	25,7	60,4	85,5	42	21,3	21

DIAGRAM 4A.

MEBR CONCENTRATION RECORDS AT SILO NO.1

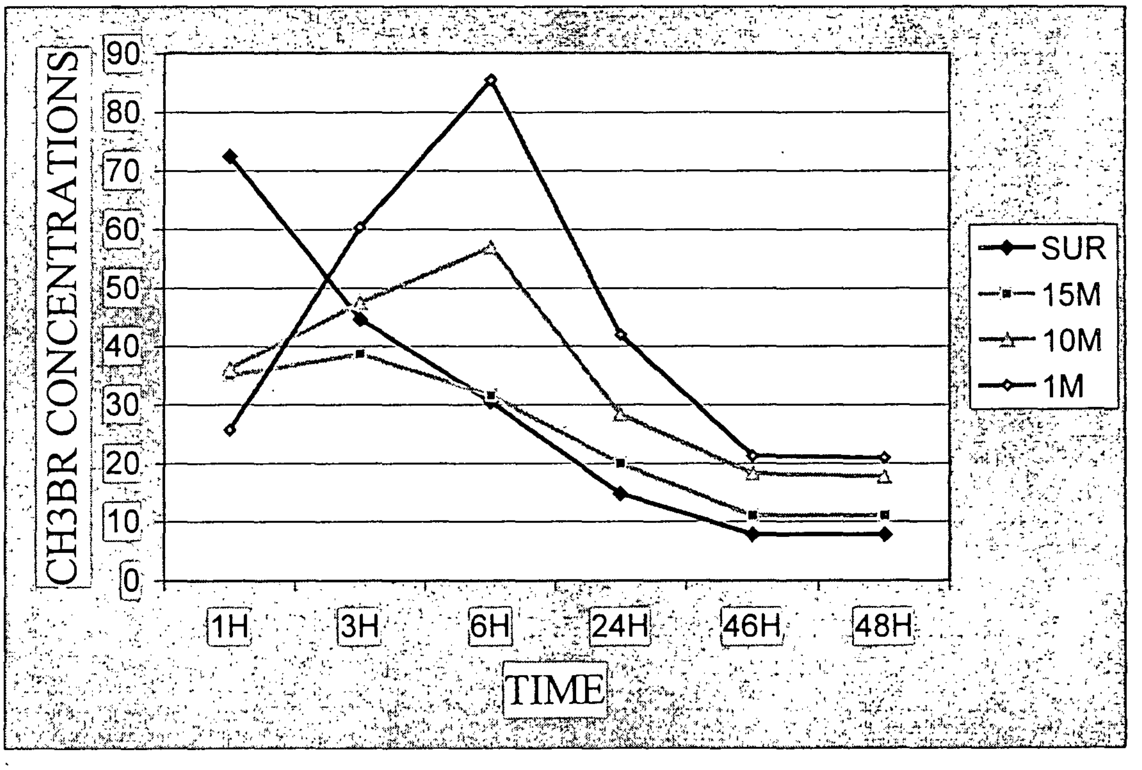
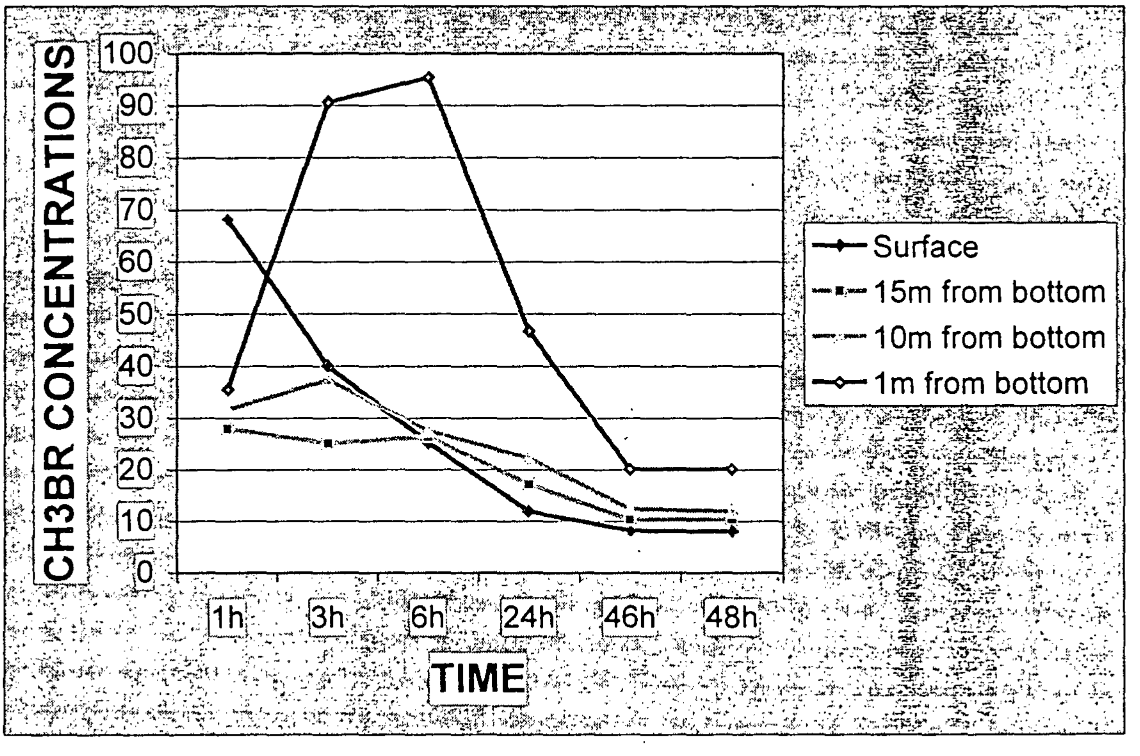


Table 10: **MeBr concentration records at Silo No.2**

Measuring point	Ave. concentration CH_3Br (g/m3) from time of fumigation					
	After 1h	After 3h	After 6h	After 24h	After 46h	After 48h
Surface	68,2	40	25,3	12	8,2	8
15m from bottom	28	25,2	26,5	17,3	10,4	10,5
10m from bottom	31,7	37,5	27,6	22,4	12,5	12
1m from bottom	35,6	90,7	95,4	46,7	20,2	20,2

DIAGRAM 4B.

MEBR CONCENTRATION RECORDS AT SILO NO.2



Result after treatment by checking samples: both species (Tribolium castaneum and Sitophilus sp.) were dead, absolute control.

Result after checking maize after treatment: three maize samples, 2kg each were taken at tow point one of top of commodity, two from checking door 1.5m from silo bottom. All insects in these three samples were dead, absolute control. Two other samples, 1kg each taken in silo were kept in hygiene jars showed no live insects after 1, 2 , 3 months, no infestation.

4.2.4 Demonstration with Phosphine in Solid Form (Tablet) in J-System

(a) Procedures

Maize was loaded into silo, top of commodity below manhole 1.7m, hydro concentration in maize is 14.2%, air temperature 32^0C. (see below table for insects record after loading before treatment)

This demonstration proceeded at Silos No.1 and 3 of Cargill from 10.00 on 31 December, 2000 and finished on 6 January 2001. Volume of Phostoxin used for each silo: 10.3kg at 2 gr/m3 dosage.

(b) Results

Table 11: Insect species and density in maize in Silos No.1 and 3 – Cargill at time of fumigation in January 2001

Species	Silo 1 (adult/ kg)	Silo 3 (adult/ kg)
Tribolium castaneum	2	1
Sitophilus sp.	2	2
Criptolestes minutus	1	2
Rhizopertha dominica	2	1

Table 12: PH3 concentration records at Silo No.1 - Cargill

Measuring point	Ave. concentration PH_3 (ppm) from times of fumigation						
	After 24h	After 48h	After 72h	After 96h	After 120h	After 144h	After 168h
Surface	938	1010	790	418	252	94	44
15m from bottom	892	900	680	410	258	95	57
10m from bottom	912	908	677	434	262	95	65
1m from bottom	920	918	685	437	263	97	66

DIAGRAM 5A.
PH3 CONCENTRATION RECORDS AT SILO NO.1 - CARGILL

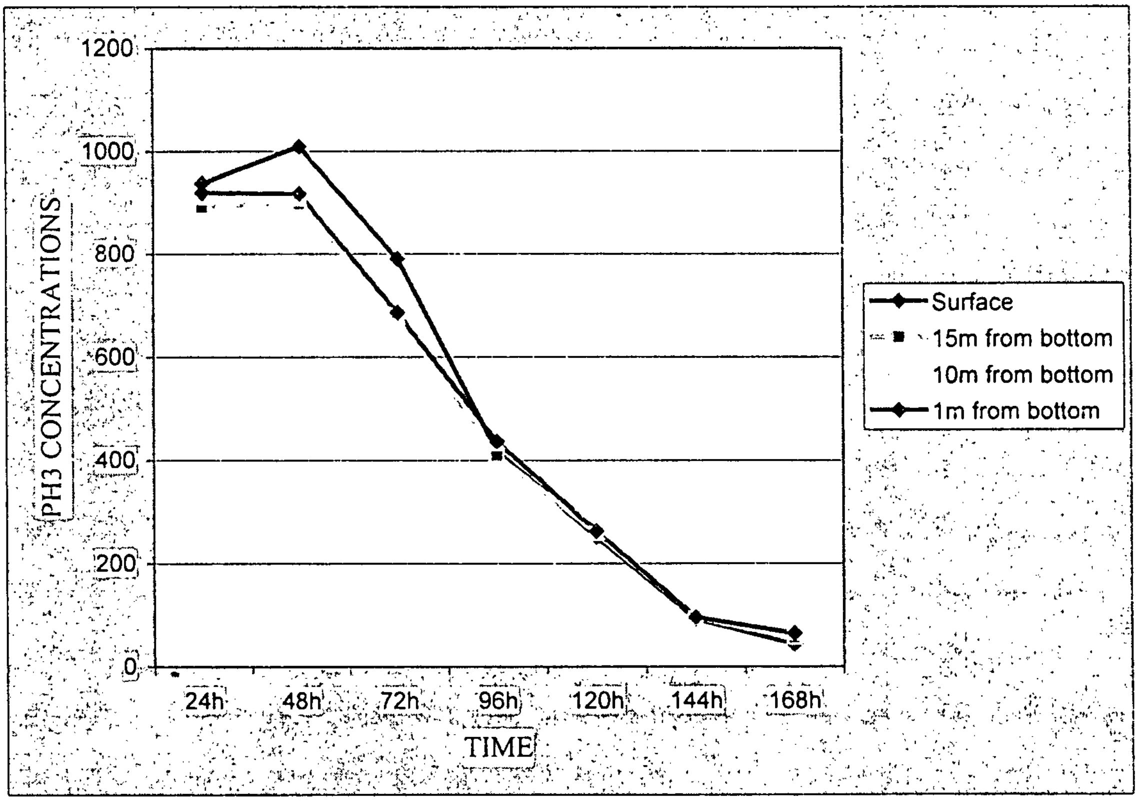
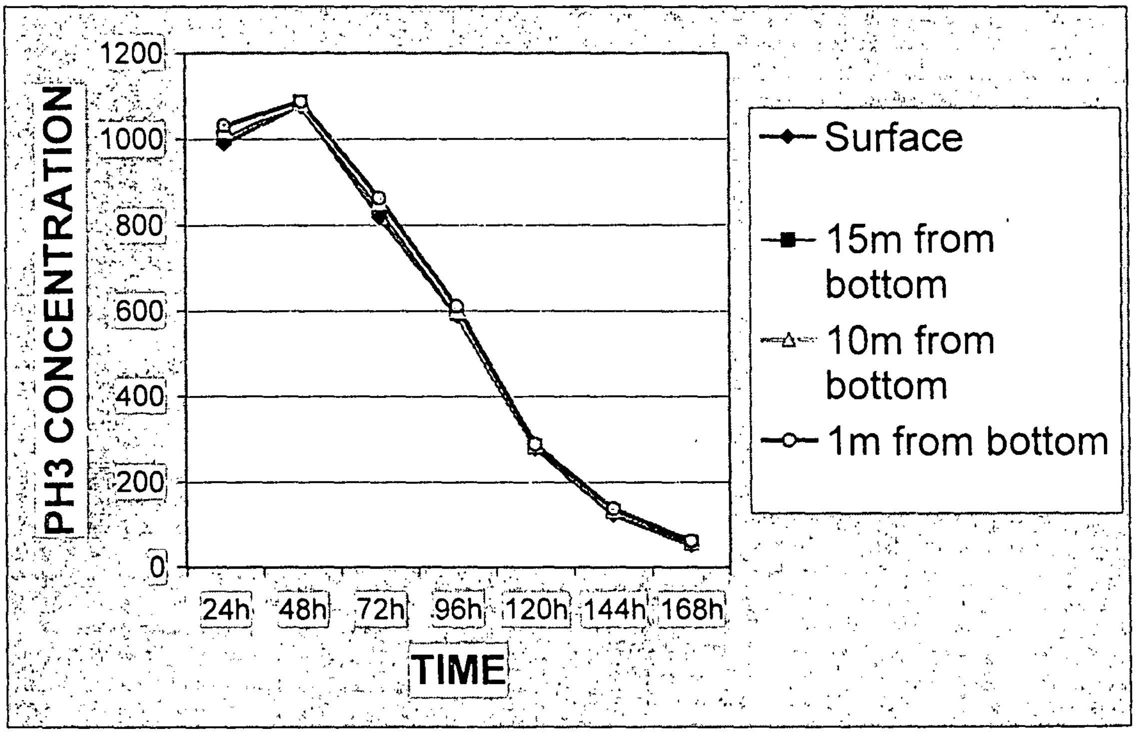


Table 13: PH3 concentration records at Silo No.3 - Cargill

Measuring point	Ave. concentration PH_3 (ppm) from times of fumigation						
	After 24h	After 48h	After 72h	After 96h	After 120h	After 144h	After 168h
Surface	990	1078	820	589	278	123	51
15m from bottom	1003	1087	838	595	282	131	58
10m from bottom	1021	1083	855	602	287	135	62
1m from bottom	1032	1088	864	612	288	138	62

DIAGRAM 5B
PH3 CONCENTRATION RECORDS AT SILO NO.3 - CARGILL



Result after treatment by checking samples: both species (Tribolium castaneum and Sitophilus sp.) were dead, absolute control.

Result after checking maize after treatment: three maize samples, 2kg each were taken at tow point one of top of commodity, two from checking door 1.5m from silo bottom. All insects in these three samples were dead, absolute control. Two other samples, 1kg each taken in silo were kept in hygiene jars showed no live insects after 1, 2 , 3 months, no infestation.

4.2.5 Demonstration with Cylinderized Liquefied Phosphine ECO$_2$FUME by SIROFLO

This job was done at Silo No. 2 and 4 of Cargill two times

A. First trial

(a) Procedures

Maize was loaded into silo, top of commodity below manhole 1.5m, hydro concentration in maize is 14.5%, air temperature 34^{0}C. (see below table for insects record after loading before treatment).

Table 14: Insect species and density in maize in Silos No.2 and 4 - Cargill at time of fumigation in October 2001

Species	Silo 2 (adult/ kg)	Silo 4 (adult/ kg)
Tribolium castaneum	6	3
Sitophilus sp.	4	6
Criptolestes minutus	2	4
Rhizopertha dominica	1	4
Oryzaephilus surinamesis	2	0

This demonstration proceeded at Silos No.2 and 4 of Cargill from 12.00 September 26, 2001 and finished on 12 October 2001. Volume of ECO$_2$FUME used for each silo: 62kg, total appro. 124 kg.

The guidelines for fumigant dosage are given in Table below. These concentrations are based on limited knowledge of phosphine tolerance currently existing in Vietnam.

GUIDELINES FOR EFFECTIVE FUMIGANT DOSAGES			
Commodity Temperature	Min Concentration for 7 days (ppm)	Min Concentration for 15 days (ppm)	Min Concentration for 28 days (ppm)
More than 20°C	700	50	25

Note:

(1) The above recommendations refer to minimum PH_3 concentrations in the grain mass. Slightly higher concentrations must be provided in the delivery duct in order to achieve these concentrations in the grain.

(2) The above times represent minimum "exposure periods", which means the time during which the recommended concentration is present at all points within the grain mass – in other words it excludes the time taken for the fumigant to distribute through the grain

Precautions and other procedures

* **Safety:** Phosphine is a highly toxic gas, and all care should be taken during fumigation practice. During leak checking of the fumigant delivery equipment, and when the level of phosphine in the air exceeds Threshold Limit Value (TLV) of 0.3 ppm, a gas mask fitted with the correct filter should be worn. The Short-Term Exposure Limit (STEL) for phosphine has been set at 1 ppm. It is recommended that local first aid officers and medical emergency centers be given copies of the ECO2FUME Material Safety Data Sheet which details symptoms, first aid treatment and advice for physicians. Safety signs should be placed at all entry points to silos under fumigation. All equipment associated with the production and reticulation of the fumigant should be suitably signed e.g. "Danger - Fumigation in Progress" .

* **Air/Fumigant Distribution:** The two SIROFLO® systems installed in Silos #2 & #4 at Cargill Feed Mills, Ho Chi Minh can be fumigated separately or simultaneously. Prior to the commencement of any fumigation, it is necessary to decide which silos are to be fumigated, prepare them for fumigation and maintain records of the system set-up. For safe and effective fumigation the following should be essential steps should be followed: Seal all openings in the target silo; Set the System Pressure to the correct value (500Pa); Operate the fumigant dispensing system; Ventilate the fumigated silos before releasing the grain in them.

* **Selecting the silos to be fumigated:** Select the silos to be fumigated based on insect population in the grain.

* **Preparing Silo for Fumigation**: Insert air-sampling lines as required; Close and seal all doors and seal all other openings in silos; Seal and isolate grain inloading and outloading valves to the silos; Close isolation valves below silo that is not to be fumigated; Put up safety signs at all man entry points to the silos; Attach safety tags where necessary (e.g. to man-entry points, grain entry and discharge valve operating handles etc). eg "DO NOT OPERATE - FUMIGATION IN PROGRESS"

* **Setting the "System Pressure":** Turn on the fan in each of the systems that are to be used for fumigation; Set the "System Pressure", by adjusting the large ball valve on the outlet of the fan, to the commissioning value (500 Pa). Note: the "System Pressure" remains the same regardless of the number of silos being fumigated. Pressure Drops across Orifice Plates - Pressure drops across orifice plates are pre-set at the time of system commissioning [400Pa]. It should not be necessary to check these pressures in the normal course of events. However in the event that changes have been made to the system, or damage repaired, or where doubts exist about the amount of fumigant being delivered to an individual silo, the pressure drop across the orifice plates may be checked and compared to the commissioning figures. In the event of significant disparity (>10%), then it will be necessary for the system to be thoroughly checked and (if necessary) re-calibrated.

* **Installation of equipment and operation** - The selection of the silos to be fumigated should be based on an insect monitoring program. The silos should be prepared by sealing openings, setting valves and (where appropriate) pressure testing. The dispenser is set to deliver the correct fumigant concentration by manually adjusting ECO_2FUME flow rate after monitoring the fumigant concentrations in the delivery supply pipe. It is important for both management and operators to understand that good fumigation practices alone cannot be relied on to provide a complete defense against insect pests. Effective insect control requires a properly planned, managed and coordinated approach to hygiene in general, and the application of a broad spectrum of measures.

* **Hygiene**: Phosphine fumigation is a non-residual insect control technique and as such offers no protection from reinfestation by insects after the completion of fumigation. To insure an acceptable level of protection from reinfestation, a high level of hygiene must be maintained throughout the storage complex. Grain residues must not be allowed to build up in elevator boots or other grain conveying equipment. Any grain spills must be cleaned up immediately, and all grain dust removed from storage structures and from the surrounding vicinity at frequent intervals. Silos hoppers should also be cleaned regularly to remove residual grain (this is also important as a general operational procedure for the preventing of admixtures).

* **Insect Monitoring**: Decision to Fumigate - The decision to conduct a fumigation should be based on the accurate evaluation of the insect population in the silo. To determine the level of infestation an effective system of insect monitoring must be put in place and rigorously adhered to. To prevent spoilage of grain from insect damage it is essential to detect insects at a low level of infestation. This may be achieved if a system of regular monitoring of insect numbers is carried out by one or a combination of several of the following techniques: Trapping (both by probes and the use of pheromones); Probing and sieving; Visual inspection; Temperature monitoring.

* **Fumigation Monitoring** - can identify potential problems at an early stage and so can prevent them becoming serious problems. Two potential problems that can develop in fumigation installations are: fumigant leaking into the work-space, and air leaking into the silo; Fumigant leaking into the workspace is potentially dangerous to workers and is also expensive as it wastes fumigant. Air leaking into the silo can cause localized fumigant dilution that may lead to insect survival. This has the potential for selecting insects for phosphine resistance. In a new installation it is advisable to monitor each fumigation daily until the characteristics of the silos are determined. After the operators become familiar with achieving effective fumigations using this equipment, less frequent monitoring may be possible. Even with experience all fumigations should be monitored at intervals not exceeding three days.

* **Monitoring Fumigant Concentration in Grain** - It is not practical to monitor fumigant concentrations more than a few meters below the grain surface itself unless special equipment is used to drive sample lines into the grain. Normally, this is only warranted for research or experimental purposes. Similarly, it is not practical to monitor fumigant concentrations at the surface of the grain mass, because the fumigant will be diluted at is mixes with the air in the head-space. Thus when monitoring fumigant concentrations in the grain, it has become normal practice to insert monitoring tubes at least 150mm below the surface of the grain, and to set the start of the target fumigation period as the time that the target concentration is obtained from air samples taken from these tubes. Insertion of sampling lines into the grain surface should be carried out as follows:

  - Cut appropriate lengths of 1/8" (or 3mm) nylon sampling tube, and attach tags to both ends of each length. Clearly mark each tag with an identification mark relating to its intended position in the silo;

  - For shallow probing, where it is possible to walk over the grain surface, simply push the end of each sampling tube into the grain to the desired depth (at least 150mm below the surface); ensure that each tube is correctly placed, according to its tag markings;

- For deeper probing, or when it is not possible to gain access to the grain surface, tape the end each tube to the bottom of a probing rod, and press the rod into the grain mass to the desired depth; ensure that each tube is correctly placed, according to its tag markings;

- Care must be taken not to block the end of the tube, and not to bend or kink the tube, such as may inhibit the flow of air through it;

* **Safety Monitoring** - At intervals during fumigation, it is important to check for fumigant leaks, both from the equipment and from the silos under fumigation. Where these are found, they should be rectified as required. (Rectification should be made immediately where a hazardous situation is created). From time to time, all joints in the fumigant mixing and delivery equipment and pipe work should be checked, and any leaks found repaired immediately. Safety equipment should be worn when checking for leaks in this equipment because any leak will be high concentration fumigant. All entry points to the silos should be checked and any leaks found repaired immediately. This is important for two reasons: (a) to stop the fumigant entering the workspace and possibly causing a work-safety hazard, and (b) to prevent air entering the silo and diluting the fumigant which may lead to insect survival and a failed fumigation. The workspace should be regularly monitored. Fumigant concentration monitoring and leak checking is best carried out using a hand-held electronic detector.

* Fumigation Recording Procedures - It is important that all fumigation processes are fully monitored and recorded. Records should be maintained for future reference, for the development of long-term strategies for insect control, and for general management purposes.

(b) Result

Table 15 : Concentration readings of PH_3 at different times Silo No. 2 - Cargill

Time	Concentration (ppm) at measuring points			
	On stock surface	15m from bottom	10m from bottom	1m from bottom
27 / 09 / 2001	4	0	0	0
28 / 09 / 2001	45	0	0	0
29 / 09 / 2001	50	0	0	0
1 / 10 / 2001	50	0	0	0
3 / 10 / 2001	48	0	0	0
5 / 10 / 2001	51	0	0	0

7 / 10 / 2001	50	0	0	0
9 / 10 / 2001	48	0	0	0
10 / 10 / 2001	50	0	0	0
11 / 10 / 2001	50	0	0	0
12 / 10 / 2001	50	0	0	0

Table 16: Concentration readings of PH_3 at different times Silo No. 4- Cargill

Time	Concentration (ppm) at measuring points			
	On stock surface	15m from bottom	10m from bottom	1m from bottom
27 / 09 / 2001	2	0	0	0
28 / 09 / 2001	40	0	0	0
29 / 09 / 2001	50	0	0	0
1 / 10 / 2001	47	0	0	0
3 / 10 / 2001	50	0	0	0
5 / 10 / 2001	50	0	0	0
7 / 10 / 2001	48	0	0	0
9 / 10 / 2001	49	0	0	0
10 / 10 / 2001	49	0	0	0
11 / 10 / 2001	50	0	0	0
12 / 10 / 2001	50	0	0	0

From checking insects sample placed in upper part of silo after treatment, it showed that both species Sitophilus and Tribolium were dead. However no concentration above nil was recorded inside silo, insects in samples placed in lower parts were alive.

B. Second trial

The first trial did not bring up expected result it was repeated at the two silos from 11-20 December 2001. Technical procedure were similar to first trial, the only difference was wall of Silo No.2 was sealed off with Emerclad polymer – specific paint from bottom to height of 5m as per expert's request. However, the result was not positive.

A brand new silo has just been built on the site (replaced one that had collapsed) and joints are well sealed with soft rubber material. The area of contention is the sealing of the aeration fan as this is the route for the SIROFLO air /PH_3 input. We have tried to start it over again with a newly built silo and the result showed some bright prospect but still it did not reach expected and theoretical results.

4.3 Technical and financial analysis

One objective of this demonstration is apply new alternatives in silo fumigation versus Methyl Bromide in real Vietnam condition to see its level of effectiveness in terms of both technical and financial categories thus select most eligible one. Below are our analysis in terms of technical view and finance.

4.3.1 Technical View

Base on progress of gas penetration and PH3, CH3Br concentration records collected during demonstrations, we can see that depending on type of fumigants and method of treatment, they varied greatly by measuring time and points in commodity.

(a) Silo Fumigation with Methyl Bromide

MeBr is a heavy gas (three times higher than normal air), it is a character that helps it penetrate down inside commodity quickly as seen in Tables 9 and 10, and diagrams 4a and 4b. Concentration in the stock (16m from bottom of silo) after 1 hour reached 25g/m3, after 6 hours was 85gr/m3, and after 24 hours possibly due to super tiny holes on silo walls gas leaked out, and partly absorbed by stock concentration readings reduced gradually, especially on top of where it rested at 7-8g/m3 (appro.1800ppm). This is a disadvantage of MeBr, and it explain for additive pumping MeBr to commodity during exposure time, or people use it in combination with PH3 in order to increase control power over insects.

In our demonstration, insect samples given inside and insects already existed in silo were dead for two reasons: (1) height of commodity was not high, silo was not full, and (2) silo air-tightness is average, a considerate of CH3Br remained on top of commodity that helped killed insects. In case high load of grain with less air-tightness, absolute control (100% mortal) can not be achieved easily.

Fumigant effectiveness to different development stage of insects, especially eggs, is fine as stated in Fumigation with Methyl Bromide, since no insect found after 1, 2, 3 months storing in samples taken and preserved in lab. However, this was not a precise and solid proof since sample was taken at only one point, small quantity, most of the grain after treated was brought into processing and consumption completely.

Another point should be mentioned is exposure time, Methyl Bromide requires on average 48hours, this is sufficient to kill pests/insects. Checking concentrations in demonstrations showed prolonged exposure time would not bring up more efficacy, because concentration readings at these times were rather low due to low air-tightness of silo tole walls which can not provide absolute air-tightness, in addition commodity also absorbed large volume of fumigant. MeBr's short exposure time is reputed advantage, and this is always favoured by customers.

(b) Fumigation with J-System

With concentration readings in Table 11 and Table 12 and illustrated in Diagrams 5a and 5b, Phosphine gas penetrated quite evenly with support of well-planned air flow speed from J-System fans, concentrations was rather similar on top, middle and bottom of grain stacks, especially in the first four days. In following days, PH3 concentration faded but still at control limit to insects. This stage is very important, in our viewpoint, in killing other adults especially eggs. Although observation on their relapse after treatment and later on was not feasible as explained in treatment with MeBr, with our experience in using J-System in Vietnam, it shows that this is an effective method that can kill insects in almost every stages of development. Disadvantage of this method is long exposure time, in case time can not be spared and customer in hurry, it is not quite applicable.

(c) Fumigation with ECO_2FUME

It is great regret that demonstrations with ECO_2FUME could not be adapted successfully due to many technical reasons. However, we do hope that if budget allows, we shall continue with it, because as above mentioned, the third time – so-called, showed prospective result. If VFC can make it, this will have a bright potential in Vietnam, for this is a method of treatment requiring no absolute gas-tightness, whilst Vietnam has many silos of steel tole, usually with top open partly and difficult to seal-off, even impossible with normal equipment, it means that we can not apply J-System to replace fumigation with MeBr.

Explanation for failure with ECO_2FUME and SIROFLO adaptation

- Initial trials conducted on two ~1700m^3 silos at Cargill Feed Mill, HCMC gave concentrations of ~50 ppm PH_3 at the top and 0 ppm PH_3 at bottom sample point. The bottom sample point was ~1m away from a large square "U" diffuser [surface area ~21m^2) in the silo floor (the sample point was located at the lower manhole with entry point ~1m above silo floor and the 1.5m probe was pushed into the maize in the direction of the end of one leg of the square "U" diffuser). The inlet concentration at the orifice plate was ~90 ppm PH_3. The total volume of the aerator tunnel & under the diffuser is ~5m^3 and this should be filled in ~5 minutes by the air/PH_3 flow.

- The 0-ppm reading the sampling point at the bottom of the silo and the 50-ppm reading at the top suggests that PH3/CO2/air mixture is by passing the location of the sampling point. The PH3/CO 2/air mixture could be following through a different direction to the top of the silo (most likely to the path of less resistance to airflow). If there is ingress and dilution with air at the sampling point it should still give some reading no matter how low it is.

- Although the air leaks into aeration fan would dilute the phosphine concentration, yet there should be still some low ppm reading at the bottom section. If the air leaks from the aeration fans has greatly diluted the phosphine concentration that there is 0ppm at the bottom of the silo then how come there is 50ppm reading at the top. There is likelihood of air leak into aeration fan but it is not enough to cause 0-ppm reading at the bottom section and yet 50-ppm reading at the top. The more likely reason for 0-ppm reading at the bottom is the presence of caked grain or accumulation of high concentration of dockage or fines at the bottom section which prevented the PH 3/Co 2/ air mixture to pass through.

- The results to date were mixed with insects specimens placed at the top of the silo completely controlled (100% mortality) while sample point at the bottom of the silo (height from bottom: 2m, length from silo wall: 40cm) didn't not receive measurable levels of PH_3. Also live insects were found in the outloading chutes.

- The low concentration at the bottom of the silo (0 ppm) was adjudged to be caused by the very high temperature associated with the heavy insect infestation. The high temperature differential in a strong "chimney effect" i.e. air/phosphine mixture (+ atmosphere air if allowed via leaks) is sucked into the hot silo resulting in a distorted PH_3 concentration profile ("inverted cone" plus some dilution with any air inlet). While SIROFLO airflow can accommodate up to a 10°C temperature the temperature differential observed in the Silo was in excess of 20°C. Efforts to compensate for this higher temperature (pressure) differential) using increased air flow / air pressure was not practical using the existing circulation fan (the use of a high flow fan with associated excessive PH_3 usage is not economic). High temperature differentials indicates an out of control situation which often requires more drastic solutions (aeration can assist in cooling grain; "turning" the grain can dilute the hot spots in the grain prior to re-treatment). Effective insect control requires a properly planned, managed and coordinated approach to hygiene in general, and the application of a broad spectrum of measures.

- A strong chimney effect was observed and external sealing of the 3m height of the silo wall using tape was carried out. The temperature of the maize was high - the metal sample tube used at the bottom sample point was "hot" to touch (>45°C). Further trials were conducted at different input concentrations and increased pressure however similar results were obtained. After 5m height of one silo wall was sealed by membrane experts resulted in no improvement in PH_3 distribution an inspection of an empty silo indicated reasonable good condition of the metal walls of the silo.

- The SIROFLO system depends on good sealing at the bottom - similar to a water bucket i.e. no concern about the top of the bucket but leaks at the bottom are an issue. The early diagnosis of dilution with air leaks associated with poor wall-floor joints, leaks from the outloading ducts, joints in iron may still be a factor. While VFC commissioned a specialist flexible membrane paint company to treat the bottom 5m of Silo 4 there was no treatment of the aeration duct which may have porous cement/brick sealing around the metal aeration duct (the former may not have been warranted in light of interior inspection of the empty silo however the latter is very critical especially if a strong "chimney effect" is present).

- Acceptance of this fumigation application will be strongly influenced by pragmatic techniques acceptable to the fumigators and within the customer's budget. Obviously there should be a focus on grain temperature ("chimney effect") and good housekeeping (insect populations are out of control; clean-up of old grain; clean out of diffusers each time silo is emptied; effective sealing around the bottom of silo etc). "It would be very helpful to get a cross-sectional profile (across the diameter) of the phosphine concentration inside the silo.

- The phosphine gas sampling could be done at the top of the silo and at grain depth of at least 1m. from the top grain layer. The phosphine concentration profile will provide a picture of the uniformity of gas distribution across the diameter. In the absence of actual phosphine fumigation, the air velocity profile across the diameter could also be used to describe the uniformity of gas distribution. The air velocity should be measured with the SIROFLO fan running. From this profile, if there is uneven gas or airflow distribution, the dead spots can be located.

- Strong chimney effect inside the silo indicates a big temperature difference between the grain temperature and the ambient air temperature. The high temperature difference of the grain (maize) shows that the grain is much warmer than the ambient temperature. This temperature difference creates convection current inside the silo, hence, chimney effect results.

- The high maize temperature can be due to high insect activity in the particular spot in the silo of high temperature. It could also be due to respiration of moist grain, wherein the high moisture grain was brought about by moisture migration. Moisture migration would result from air convection current inside the silo. Corrugated steel silos like the ones in Cargill Feed Mill has high thermal conductivity and are greatly affected by sunlight and wide temperature fluctuation during the day. This fluctuation in ambient air temperature could contribute to moisture condensation on the wall and accumulation of moisture at the bottom section of the silo leading to caking. It is possible that due to moisture migration, caking of grain (hard solid mass of deteriorated grain) would be formed at bottom section of the silo. The caked grain would prevent air of fumigant to pass through. In this case, the fumigant/air mixture would bypass the location of caked grain and will be diverted to the loose grain (the path of less resistance airflow).

- If the grain at the bottom section of the silo has high concentration of dockage, fines or grain dust that accumulated, this would create high to resistance to airflow and prevent fumigant/air mixture to pass through. Loading of the grain on the center portion at the top of the silo without a spreader can lead to concentration of fines at a particular section in the bottom of the silo.

- The design of perforated aeration duct (diffuser) could also affect the distribution of air or fumigant. However, the particular configuration has enough diffuser area and though there may be uneven airflow at the bottom there should be some fumigant gas going into the different locations at the bottom and provide some ppm reading (not 0-ppm)

4.3.2 Financial Analysis

Below tables presents materials, equipment and labor cost breakdown.

Table 17: Costs for fumigation a silo of 1711 m3 with different methods

Content	Unit	Unit price in USD	Volume used	Total value In USD)
Fumigation with MeBr :				
- CH_3Br	Kg	3.1	85,5 Kg	265.05
- Piping	Kg	1.645	8 Kg	13.16
- Kraft paper	Kg	0.9	2 Kg	1.75
- Nylon	Kg	0.913	5 Kg	4.57
- Adhesive tapes	Roll	0.53	4 rolls	2.13
- Labour	Day	3.333	6 day	20
TOTAL:				**306.71**
Fumigation with PHOSPHINE with J-System :				
- Phostoxin	Kg	14.466	10,3 Kg	149.01
- J-System Fans for recirculation (Deduction 10%)	Set	1033.33	10 %	103.33
- Kraft paper	Kg	0.9	2 Kg	1.8
- Nylon	Kg	0.913	5 Kg	4.53
- Adhesive tapes	Roll	0.53	4 rolls	2.13
- Piping (Deduction 5%)			10 %	3.33
- Cotton bags	Bag	0.133	20	2.67
- Labour	Day	3.333		
For pipe installation			10	33.33
For silo sealing			6	20
For Equipment installation + fumigation			3	10
TOTAL:				**330.14**

Fumigation with liquid				
PHOSPHINE SIROFLO :				
ECO_2FUME cylinders	Kg	6.72	62 Kg	416.43
Monitoring system (deduction	Set	3628.03	2 %	72.56
2%)	Set	1033.33	10 %	103.33
Recirculation fans (deduction	Set	133.33	2 %	2.67
10%)		0.9	10 %	4
Material Storing Unit	Kg	0.913	2 Kg	1.8
(deduction 2%)	Kg	0.53	5 Kg	4.53
Piping system (deduction 10%)	Roll	3.33	4 rolls	2.13
Kraft paper	Day		2 days	6.67
Nylon				**614.13**
Adhesive tapes				
Labour				
TOTAL :				

Results showed that fumigation with Phosphide tablets and J-System is less expensive. ECO_2FUME is quite costly, but for demonstration it consumed a small quantity thus explained for high costs, once world consumption increases, the cost would go down much lower and more competitive.

4.4. Conclusion and Suggestive

(a) Conclusions

- Adaptation of new technology has primarily given Vietnam new choices in fumigation in preparation for MeBr Phase-out, especially silo treatments. J-System in fact partly helps solve the puzzle to deal with erect silos but not with MeBr, because if we use Phosphide tablet without J-System fans, chemical can not penetrate well to lower layers and kill insects .

- However, it has a disadvantage, its top pre-requisite is good air-tightness, while in Vietnam open silos or silo which can not be made gas-tight are very common, in some storing facility, people are not allowed to enter silo to make seal it off. Thus we do need to look further for more widely applicable methods.

- ECO_2FUME with its characters seems to be top eligible candidate. It has worked very well in Australia and in fact its adaptation brings up some advantages such as: (1) unnecessary to seal off and make air-tight at the top of silo, it is thus less dangerous and more economic. In Vietnam, generally people is not allowed to get inside silos for sealing and gas-tight, SIROFLO can be applied easily with silos with open top; (2) handy monitoring: easy control by switch board unit by silo, this means target concentration can be reached and maintained every day under proper care.

- As from observation from on-the-job training in Australia, sanitation conditions in wheat silos that have been fumigated by SIROFLO are very good, therefore it requires no fumigation prior shipment or on board the vessel. Though in Vietnam conditions, it is not yet feasible but people should learn and adjust work procedures in this manner.

(b) Suggestive:

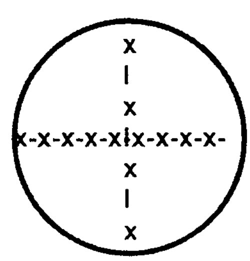
Main reasons for failure with first two trials with SIROFLOW in Cargill were silo structure, commodity quality, loading method. We had a chance to adapt it third time at a brand new silo, and it showed much better result. We expect that application SIROFLO with similar silo system to those of Cargill, as well as to other types of silos such as silo of cement concrete wall, silo with cone bottom, will bring up better results.

After discussion with experts of CYTEC, following are their suggestives, primary conclusions, and some details which should be taken care before proceeding fumigation:

- Silo structure: this factor effects profoundly to gas penetration.
- Aeration system: this system must be equipped with good aeration fans, air-tight, in addition the aeration should be done before fumigation to cool and keep the grain temperature equalized;

- Grain moisture content and uniformity in quality throughout the whole bulk of grain: should they be assured with the use of seed spreader or other good manner of loading will help to maintain ambient air temperature and fluctuation during the day, and control wheel on grain temperature particularly at the bottom sampling point, thus avoid chimney effect and stagnation in grain bulk. Also, initial grain quality (moisture content, purity, insect count) and insect monitoring must be checked regularly.

- The distribution of phosphine gas should be made more evenly, inlets should be arranged across diameters (see drawing) on top of silo.



- Size of the SIROFLO fan used (air flow rate, total static pressure head) should be studied so as we can select most suitable fans and well arrange them.

Possible interventions:

- Use a spreader to load the grain evenly and spread the fines evenly across the diameter;
- Make sure the grains of uniform quality throughout the whole bilk in the silo before fumigation;
- Minimize of prevent chimney effect by keeping the grain at uniform temperature by proper aeration protocol before fumigation and use of correct size of SIROFLO fan (correct flow rate and pressure drop);
- Paint whole silo wall and top cover with while paint to minimize chimney effect or solar radiation;
- Make sure the walls, bottom section and aeration fan well sealed;
- Make sure the diffusers are clean and the holes unclogged.

5. FUMIGATION WAREHOUSE WITH LIQUEFIED PHOSPHINE

To continue applications with liquefied phosphine, grain and timber were treated in control experiment with Methyl Bromide .

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And

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5.1 Theory Briefing

5.1.1 Theory

Same as Part 4.

5.1.2 Milestones

ECO_2FUME, non-flammable 2wt% phosphine with 98% liquid carbon dioxide ("cylinderised liquid phosphine") was used for warehouse fumigation at VFC's warehouse for 4 months from November 2002 to March 2003.

Target materials were:

- Two hundred tones (200MTS) of rice of average quality, most common standard in Vietnam with 10% broken packed in PP bags
- Timber lots

Demonstration are listed below:

- Rice Fumigation with ECO_2FUME under tarps;
- Rice Fumigation with ECO_2FUME in sealed chamber;
- Control experiment to rice under tarp with Methyl Bromide in sealed chamber;
- Timber fumigation with Phosphine in solid form under tarps in warehouse;
- Control experiment to timber fumigation with Methyl Bromide in sealed chamber.

5.2. Demonstrations

5.2.1. Place and Site Description *(see layouts on next page)*

Demonstration was carried out at VFC new warehouse a mentioned in part 4.

5.2.2 Primary preparations

- Rice: 100 tones were divided into two lots for fumigation under tarps, other 100 tones were put into one sealed chamber for demonstration in air-tight chamber fumigation. two hundred tones of rice were placed in two 2 stacks;

- Timber loaded into stacks;

- Biological bait-trap: most common species are tribolium Castaneum and Sitophilus Zeamais, adults were collected from flour mill and feed mills, then put into cotton bags with food (like those at catch places), these bags then sewed up at both end and placed near measuring points.

- Tools and equipments used included: (a)tarpaulin imported from Thailand (PVC transparent sheet 30mx20m, (b) sand snake, (c) ECO_2FUME cylinders, (d) piping and pump heads, (e) measuring device Dräger PAC III and SILO CHECK, and (f) equipment for analysis.

5.2.3 Demonstration Methods and adaptation

A. Rice Fumigation with ECO_2FUME under tarps

\+ Adaptation: Two rice stacks of same quality, weight and type 50tones were covered with tarpauline with footing arranged carefully and weighed by sand snake. Plastic pipe for gas pumping and sampling were placed before putting tarps. ECO_2FUME cylinders were pumped into at dosage 1gr PH_3 per cbm equal to 50g ECO_2FUME per cbm. Exposure time 96 hours. After treatment time, air in rice stacks were sucked out, tarps removed and sample collected for analysis.

\+ Effective analysis:

PH_3 concentration measuring: to measure PH3 concentration, plastic pipe dia. 8mm were placed at top, corner and beneath points of the stacks. Measuring device were Riken Keiki GAS Indicator Model IF 18 and SILOCHECK – Fumigation Monitoring.

Sample analysis: after collecting bait traps and sample bags from treated stacks, death/alive ratio were recorded ad and compared with control bags. Later insect samples were put into new cotton bags and observed one week, meanwhile food left-over were ventilated and stored properly in same condition for 4 weeks to evaluate of chemical to phases of development.

B. Rice Fumigation with ECO_2FUME in sealed chamber;

\+ Fumigation Super warehouse of VFC consisted of 4 sealed chambers with total area of 1200 square meters with entrance affordable for trucks moving and back door for checking, structure was mentioned in previous parts. One of the silo was chosen, tested for air-tightness and 100 tones of rice were loaded into this chamber with same quality and specs as the one used for fumigation under tarps.

\+ Method treatment, bait trap and samples preparation, pipe for sampling and measuring, sample analysis were carried out in the same manner like Demonstration A Rice Fumigation with ECO_2FUME under tarps. Exposure time/period of treatment is 168 hours (7 days)

C. Control experiment to rice under tarp with Methyl Bromide and in sealed chamber

\+ Control Fumigation Rice with MeBr would give us categories/ standard to evaluate and compare to those of demonstrations with liquefied phosphine. This control experiment was done to same size of rice stacks, rice of same quality, in chamber of same size, method of treatment and others are similar to the way we proceeded with ECO_2FUME. Dosage was standard one of 50gr/m3, exposure time 48 hours.

D. Timber fumigation with Phosphine in solid form under tarps in warehouse

E. Timber fumigation with Methyl Bromide - Control experiment under tarps in sealed chamber

\+ Two stacks of timber, 30 cubic meter of each were treated under tarps, one with MeBr and the other with Phostoxin Round table (56% a.i AlP)

\+ Dosage of MeBr used was 50 gr/m3. Dosage of Phostoxin: 6gr/m3 (equal to 2gr of PH 3 per m3). Exposure time 72 hours. Biological samples were not done, only PH3 and MeBr concentration measuring done.

5.3 Results and Conclusion

A. Results

5.3.1 Concentration readings of PH3 (ECO_2FUME) in stack under tarps and in sealed chamber

Table 18. Concentration readings of PH3 in Rice stack fumigated under tarps (Unit: part per million - ppm)

Measuring Points at \ Time	After 1 hour	After 21 hour	After 42 hour	After 66 hour	After 88 hour
Bottom	1800	1300	820	660	535
Side	1010	1001	752	850	571
Top surface	1200	1009	772	440	565

DIAGRAM 6
CONCENTRATION READINGS OF PH3 IN RICE STACK FUMIGATED UNDER TARPS
(unit: part per million - ppm)

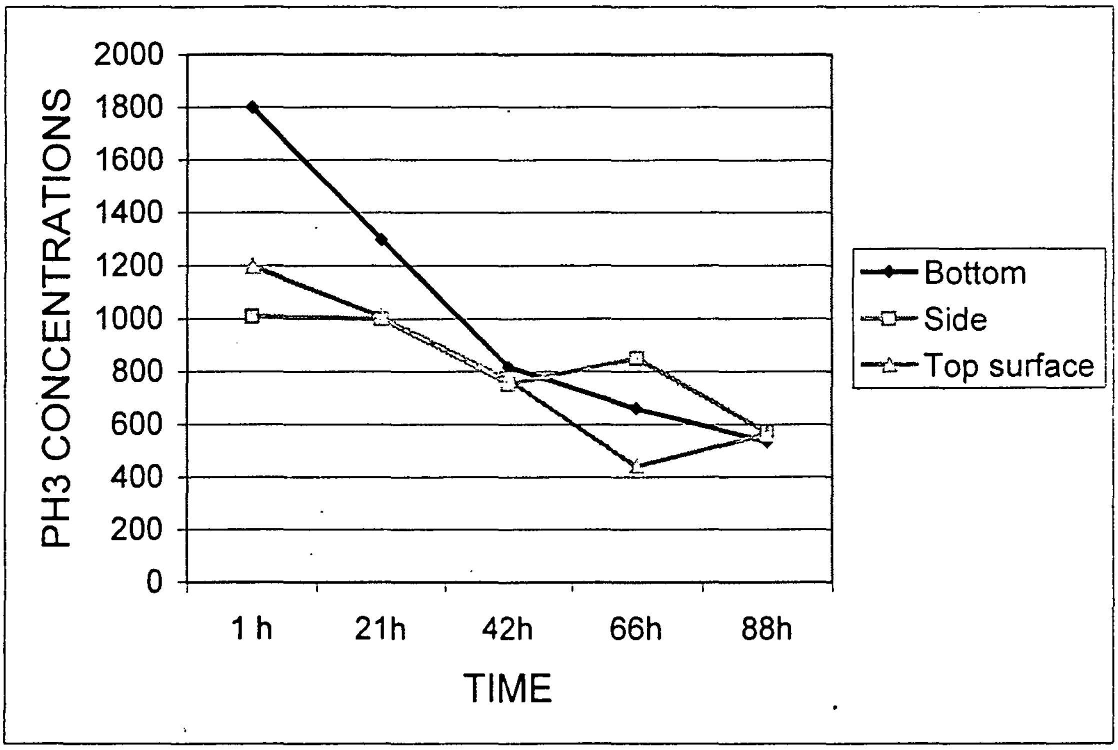
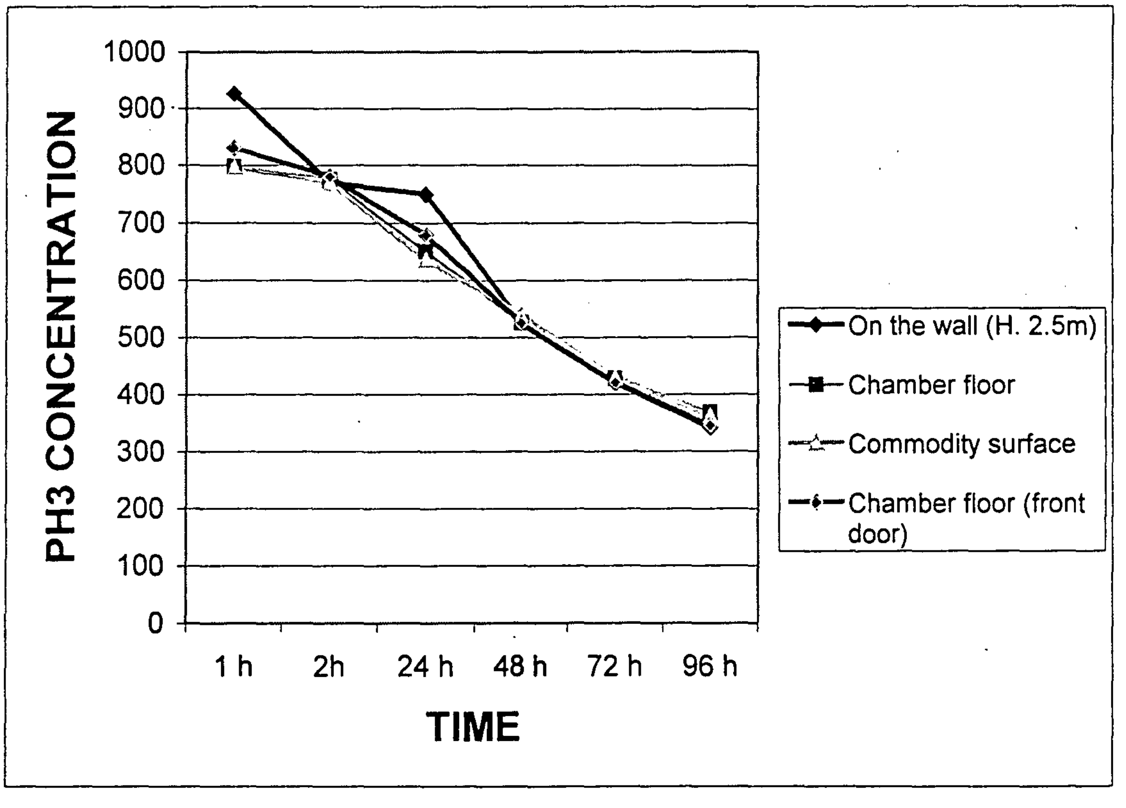


Table 19. Concentration readings of PH3 in Rice stack fumigated in sealed chamber (Unit: part per million - ppm)

Time / Measuring Points at	After 1 hour	After 2 hour	After 24 hour	After 48 hour	After 72 hour	After 96 hour
On the wall (H. 2.5m)	927	770	750	526	420	342
Chamber floor	798	775	650	526	428	368
Commodity surface	797	771	636	540	430	363
Chamber ceiling (front door)	831	780	680	525	421	345

After 96 hours, measuring stopped, on the eight day (namely after 192 hours) ventilation was done.

DIAGRAM 7
CONCENTRATION READINGS OF PH3 IN RICE STACK FUMIGATED IN SEALED CHAMBER



5.3.2 Concentration readings of MeBr

Table 20. Concentration readings of CH_3Br in Rice stack fumigated under tarps (Unit: gram per cubic meter)

Time / Measuring Points at	1 hour	24 hour	48 hour
Surface	108	35	27
Bottom	120	41	30
Side	110	38	28

DIAGRAM 8
CONCENTRATION READINGS OF CH_3BR IN RICE STACK FUMIGATED UNDER TARPS

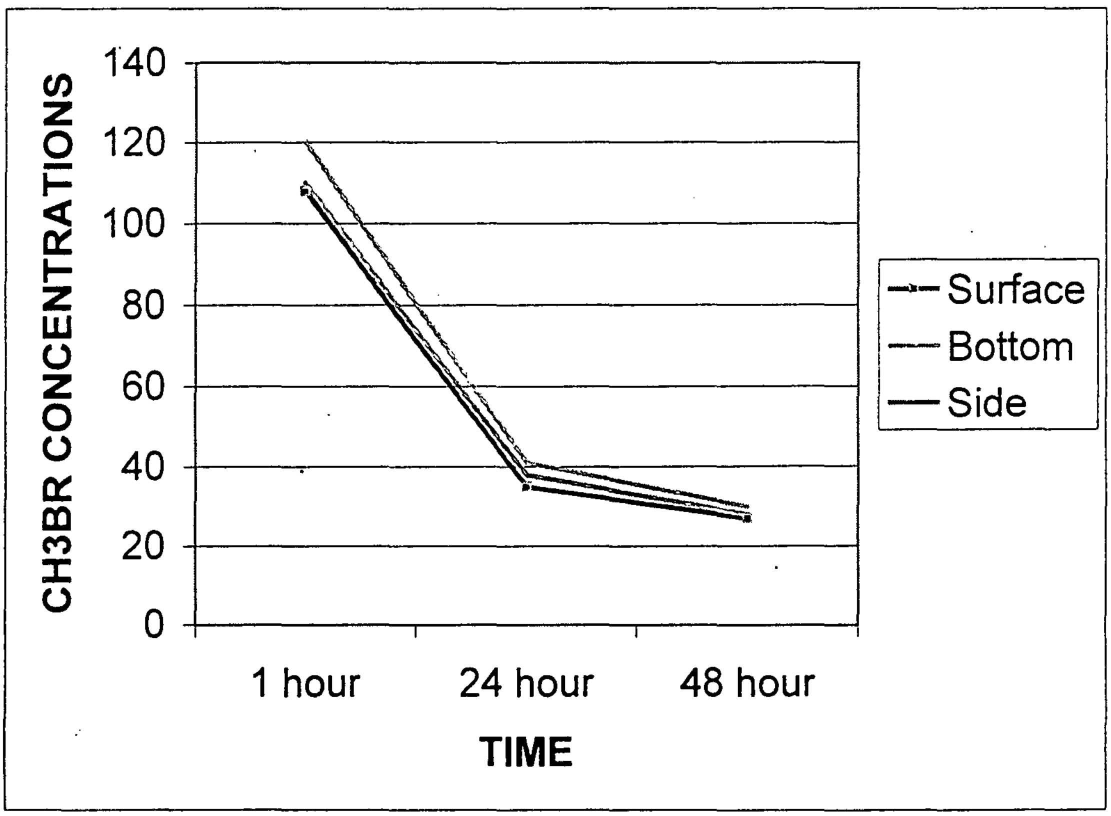


Table 21. Concentration readings of CH_3Br in rice stack fumigated in sealed chamber under tarps (Unit: gram per cubic meter)

Measuring Points at \ Time	1h	2h	24h	48h
Pipe at high point H.> 3.5m	4	10	13	12
Pipe on commodity's surface	48	44	35	30
Pipe at commodity's bottom	60	55	50	41

DIAGRAM 9
CONCENTRATION READINGS OF CH_3BR IN RICE STACK FUMIGATED IN SEALED CHAMBER UNDER TARPS

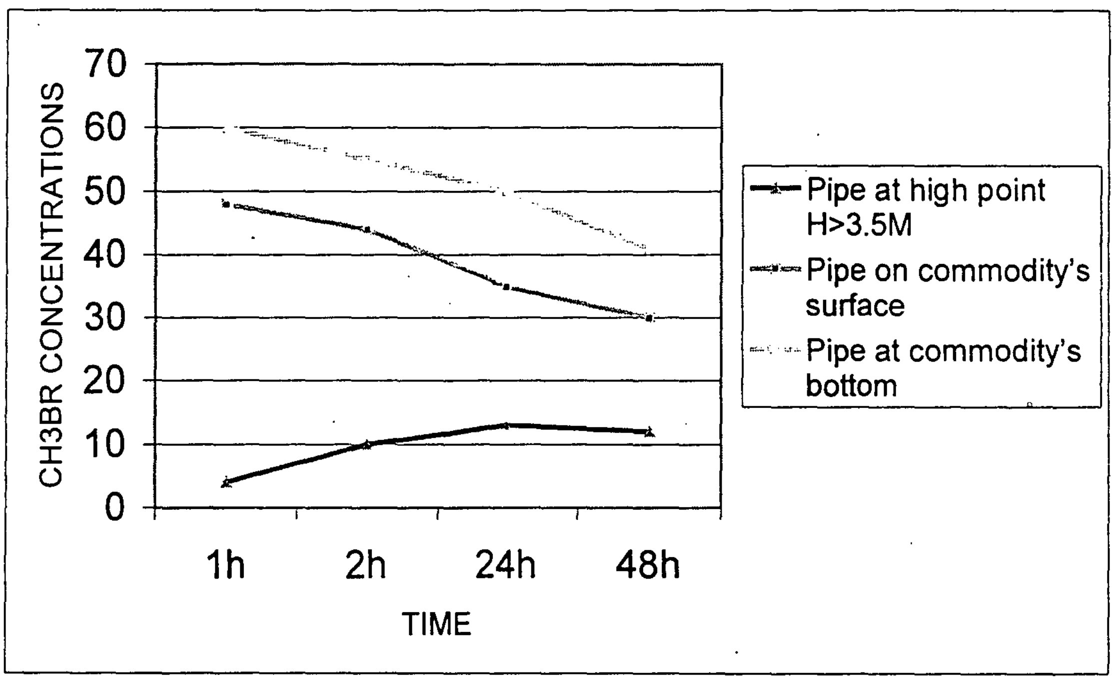


Table 22. Concentration readings of CH_3Br in timber stack fumigated under tarps (Unit: gram per cubic meter)

Time / Measuring Points at	1h	2h	24h	48h
Pipe on commodity's surface	109	108	34	30
Pipe at commodity's side	120	110	45	31
Pipe at commodity's bottom	108	106	48	31

DIAGRAM 10
CONCENTRATION READINGS OF CH_3BR IN TIMBER STACK FUMIGATED UNDER TARPS

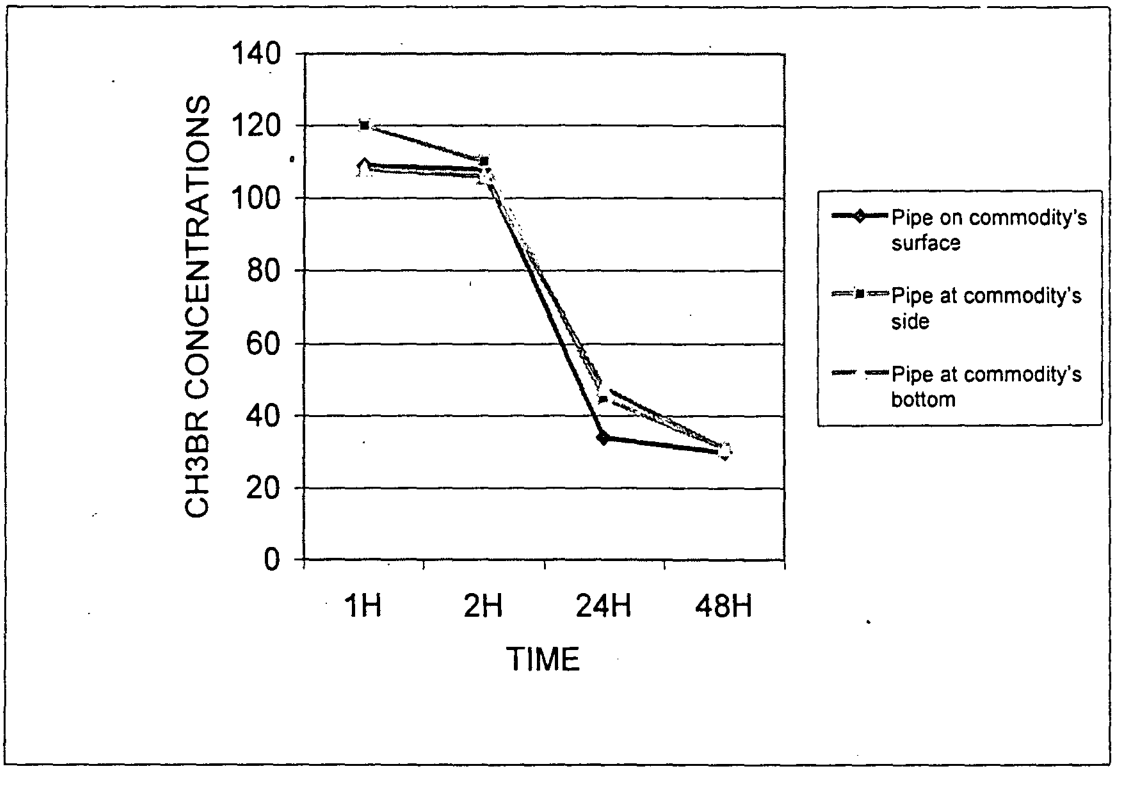
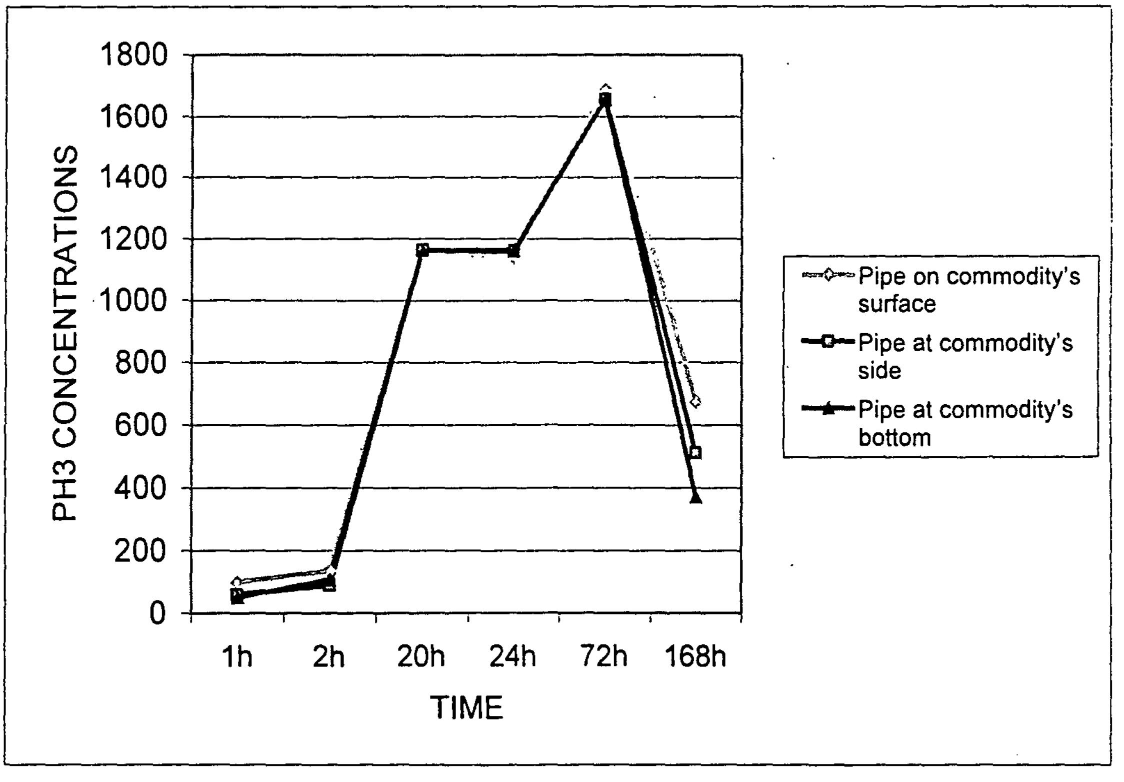


Table 23. Concentration readings of PH_3 in timber stack fumigated under tarps with PHOSTOXIN tablet (Unit: ppm)

Measuring Points at \ Time	1h	2h	20h	24h	72h	168h
Pipe on commodity's surface	100	137	1162	1140	1690	673
Pipe at commodity's side	60	90	1164	1160	1656	510
Pipe at commodity's bottom	50	108	1163	1163	1656	371

DIAGRAM 11
CONCENTRATION READINGS OF PH_3 IN TIMBER STACK FUMIGATED UNDER TARPS WITH PHOSTOXIN TABLET (UNIT: PPM)



5.3.3 Biological samples analysis

Table 24. In rice stack fumigated with ECO_2FUME under tarps

Time / Insects	Before treatment		After treatment		After one month	
	Alive	Dead	Alive	Dead	Alive	Dead
Tribolium castaneum	180	0	0	180	0	180
Sitophilus zeamais	180	0	0	180	0	180

Table 25. In rice stack fumigated with ECO_2FUME in sealed chamber

Time / Insects	Before treatment		After treatment		After one month	
	Alive	Dead	Alive	Dead	Alive	Dead
Tribolium castaneum	150	0	0	150	0	150
Sitophilus zeamais	100	0	0	100	0	100
Ahadberus advena	100	0	0	100	0	100

Table 26. In rice stack fumigated with MeBr under tarps

Time / Insects	Before treatment		After treatment		After one month	
	Alive	Dead	Alive	Dead	Alive	Dead
Tribolium castaneum	100	0	0	100	0	100
Sitophilus zeamais	100	0	0	100	0	100

Table 27. In rice stack fumigated with MeBr in sealed chamber

Insects \ Time	Before treatment		After treatment		After one month	
	Alive	Dead	Alive	Dead	Alive	Dead
Tribolium castaneum	100	0	0	100	0	100
Sitophilus zeamais	100	0	0	100	0	100

5.3.4 Financial Analysis

1) Evaluate fumigation costs in chambers (1800m3/chamber) between CH3Br, ECO 2FUME and Phostoxin 56%

a. Table 28. Fumigation with CH_3Br (chamber volume: 1800m3)

Categories	Unit	Unit price in USD	Qty	Amount
Methyl Bromide	Kg	3.1	90	279
Plastic tube	Kg	1.645	5	8.225
Sealing materials				8.666
Labour	Day	3.34	7	23.333
Total				319.224

b. Table 29. Fumigation with CH_3Br (chamber volume: 1800m3)

Categories	Unit	Unit price in USD	Qty	Amount
ECO_2FUME	Kg	6.716	93	624.588
Dispenser (depreciation 20%)	Set	13.333	1	2.666
Copper pipes (depreciation 20%)	M	1.00	6	1.20
Gas sample piping	Kg	1.645	2	3.29
Sealing materials				8.66
Labour	Day	3.333	7	23.333
Total				662.737

c. Table 30. Fumigation with Phosphine (56%)(chamber volume: 1800m3)

Categories	Unit	Unit price in USD	Qty	Amount
Phosphine tablets	Kg	14.467	10.8	156.243
Cotton bags	Set	0.133	55	7.333
Gas sample piping	Kg	1.645	2	3.29
Sealing materials				8.666
Labour	Day	3.33	7	23.333
Total				198.856

2) Evaluate fumigation costs to rice stack under tarps between CH3Br, ECO_2FUME and Phostoxin 56%. 400 MTS bagged rice = 640 m3

a. Table 31. Fumigation with CH_3Br (400MTS = 640m3)

Categories	Unit	Unit price in USD	Qty	Amount
CH_3Br	Kg	4.00	32	128.0
Plastic piping	Kg	1.645	4	3.29
Plastic (PVC) sheet / tarps (depreciation 10%)	Piece (20m x 30m)	310	1	31.0
Sand snakes (depreciation 10%)	M	0.666	104	6.933
Labour	Day	3.333	10	33.333
Total				205.846

b. Table 32. Fumigation with ECO_2FUME (400MTS = 640m3)

Categories	Unit	Unit price in USD	Qty	Amount
ECO_2FUME	Kg	6.716	32	214.30
Gas sample piping	Kg	1.645	2	3.29
Plastic (PVC) sheet / tarps (depreciation 10%)	Piece (20m x 30m)	310	1	31.00
Sand snakes (depreciation 10%)	M	0.666	104	6.933
Labour	Day	3.333	10	33.333
Total				288.856

c. Table 33 Fumigation with PHOSTOXIN 56% (400MTS = 640m3)

Categories	Unit	Unit price in USD	Qty	Amount
PHOSTOXIN 56%	Kg	14.467	3.84	55.55
Cotton bag	Bag	0.133	20	2.666
Gas sample piping	Kg	1.57	2	3.29
Plastic (PVC) sheet / tarps (depreciation 10%)	Piece (20m x 30m)	310	1	31.00
Sand snakes (depreciation 10%)	M	0.666	104	6.933
Labour	Day	3.333	10	33.333
Total				132.772

(for illustrative diagrams, pls. refer to next pages)

DIAGRAM 12
Evaluation: Fumigation Costs In Chamber (1800m3)

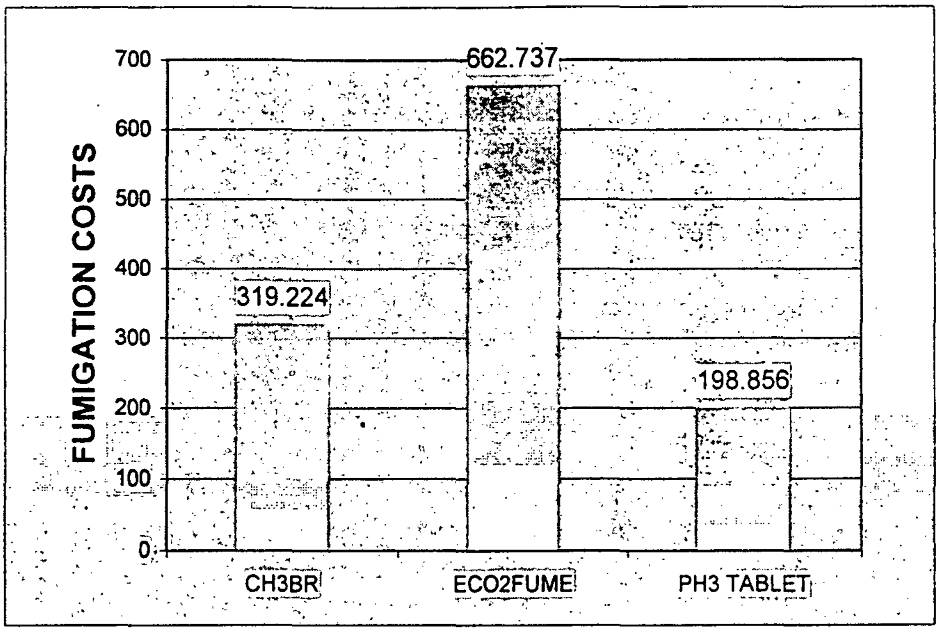
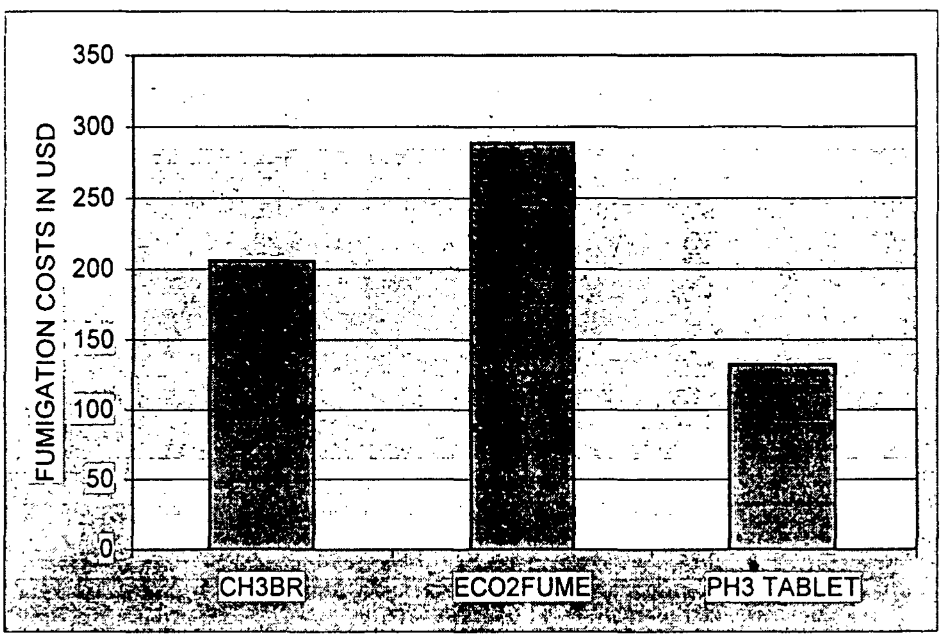


DIAGRAM 13

Evaluation: Fumigation Costs In Rice Stack (400 MT/640m3)



B. Conclusions

(a) Effectiveness on insect Control:

From results and analysis of biological samples collected from demonstration it showed equal effectiveness of Methyl Bromide - CH3Br (dosage 50gr/m3 – 48 hours exposure) and Phosphine - PH3 in ECO_2FUME (1g/m3 – 4 to 7 days exposure). After one month, no alive insect was found, this a proof of chemical on insects in all phases of development.

(b) Technical categories:

- Preparation works for fumigation with ECO_2FUME, CH_3Br, PHOSTOXIN tablet in terms of technique and standard are similar. Thus installing equipment, pipe for fumigant distribution, gas concentration measuring, sampling, etc can be done properly by professional workers after a course of training.
- Concentration when apply ECO_2FUME and CH_3Br as we observed can easily achieve target level to control insects, meanwhile Phosphine in solid forms needs longer time, appro. 20hrs to reach expected concentration. Therefore, ECO_2FUME and CH_3Br can help save time in comparison to Phosphine in solid form.

- The use of recirculation fan/motor with MeBr in fumigation in chamber is a supportive to avoid fumigant gas deposit at bottom and lower parts thus causes uneven penetration and distribution in the whole chamber.

- The use of recirculation to suck and pump out air inside grain stacks before pump ECO_2FUME or CH_3Br will help prevent air pressure inside commodity and gas leaking via footing way.

- Gas concentration can be monitored easily with ECO2FUME and CH3 Br but not with phosphine tablets.

(c) Financial category

With same method of treatment, same commodity and quantity, costs for labour and equipment are quite equal, ECO_2FUME due to highest price is most expensive, second MeBr and the least one is Phosphine in forms of tablets. In fact ECO_2FUME is 2.17-3.3 times more expensive than Phostoxin and 1.4-1.6 times to MeBr.

In future, once MeBr price goes up due to world phase-out, thus to reduce costs for fumigation it requires:

+ Increase the use of Phosphine in forms of tablets, blanket strip, plates, etc. if time is sufficient.

+ Carry out the use of liquid cylinderized Phosphine 99% (VAPORPH$_3$OS)

+ Investment for mixing equipment for PH3 99% with CO_2 in Vietnam to reduce shipping costs from abroad.

6. CONCLUSIONS AND SUGGESTIVES

1. Vietnam Demonstration Project on alternative technology to Methyl Bromide was carried out in the years 1999-2003 from the original plan of 1998. Works done included adaptation of Phosphide tablets – PHOSTOXIN – J-system , Liquefied phosphine – ECO_2FUME / SIROFLO in maize treatment in silo; rice, timber fumigation under tarps, and Integrated Storage Pest Management (ISPM), training-workshops. With results and achievement, it have brought up some bright alternatives to Methyl Bromide in non-QPS section.

2. The application of J-System with PHOSTOXIN was successful with considerate records for its and applicability in Vietnam conditions. The biggest disadvantage is long exposure time. In long terms use, this method requires very standard storing facility which can afford gastight with well-designed structure.

3. The application of ISPM was a winning rewards, it provided persuasive outcomes to storing staffs, made them start to pay more attention to basic pest management in warehouse ands storehouse., gave them better understand regarding hygiene sanitation and simple preventive methods against pests and loss, eventually commodity quality management.

4. Regarding SIROFLO/ECO_2FUME, though it did not achieve expected target due to several technical reasons, it showed a good option and a sample to be applied in large scale and longer terms to adjust itself to Vietnam conditions. As mentioned above, third trial showed better results, we are finding new approach and procedures to bring success of SIROFLO-ECO_2FUME application right in Cargil silo conditions. In the mean time we suggest that study should be underway, make room for new alternatives, new technology developed and introduced.

5. Financial keepings identified least cost alternative in current conditions is fumigation with Phosphide tablets by J-System or under tarps. The treatment with phosphide tablet is becoming most economic solutions, Methyl Bromide still holds second, and ECO_2FUME if used more expansively and more competitive price will become a promising choice. The margins between method of treatments at this point is not wide, thus the top priority is technical efficacy on insects control in current storing status.

6. In our anticipation, ECO_2FUME price is certainly going to get lower once $VAPORPH_3OS$ brought into use with equipment for site-mixing/blending. This 99% phosphine gas in cylinder should be applied in reality to get precise cots breakdown and evaluation. Also, new equipment such as Doctor Horn's Phosphine generator should be considered, if possible apply shortly

7. A provision for success of alternatives in mass application is awareness program that should be done continuously and systematically. From our experience, in order to implement ISPM successfully, the first step is to make it known to very people it involved with such as: warehouse managers, quality controller, warehouse staffs, etc., then to end-consumers / mass public. Poor information is the first factor that delay uses of alternatives - many attendants informed that they never heard of Methyl Bromide phase-out until the date of workshop. Once people are provided with strong and firm background on necessity to phase-out Methyl Bromide, they are motivated to participate wholly in overall progress. The next thing to assure ISPM requires understanding of various factors such as: causes on decrease of product quality which begins with the emphasis on achieving sound initial conditions of products, understanding of physical factors of environment; knowledge and experience on entomology, especially storage pests through continual monitoring program; an integration of various control methods in line with economic feasibility, food safety and environment protection. Thank to coordination of these factors, the use of chemical could only be supplementary to the whole system.

8. In storing status of Vietnam, though we have observed J-System's effectiveness, but it is not feasible to all once its requirement beyond many local's affordability. Most common local storing facilities are open, not air-tight, with frequent human entries and casual working manner that demand safer fumigation method.

9. SIROFLO requires less labour, simpler storing facilities and much safer. Thus SIROFLO and ECO2FUME or VAPORPH$_3$OS blending locally are much better options in theory. They are well-designed to cover up strictness of J-System. Also, research for better alternatives should be continued, chemical prices should be reconsidered and more competitive, if necessary with special support from government and international organizations.

10. Noticeable risk with Phosphine fumigation is insect tolerance/ resistance. Thus fumigation should be performed most properly with careful insect monitoring. J-System shows no such worry so far, but if evaluated against ECO2FUME, chance for this problem is much lower and in long terms this is rather carefree for fumigator and storing managing staffs.

11. In national scale, project's results can help reduced gross volume of MeBr in fumigation for storing and national reserve. Still Vietnam's major MeBr consumption is for export 200-300 MTS / year, if we can apply J-System in ship fumigation (QPS) further, it can swiftly cut off total volume MeBr that VN uses every years. In fact, VFC has applied J-System since 1995 for ship fumigation, this number is not many, only 4-6 ship / years, if international organization can encourage and go further to restriction on ship fumigation with MeBr, it will be a huge success and soon phase-out is obvious in very near future. For example, Nestle Corporation Worldwide noticed from March 15, all cargos of Nestle will be

fumigated with Phosphine only, other developed countries in recent years have increased their orders for Phosphine fumigation instead of MeBr. This friendly-activities has been welcomed around the world.

12. Vietnam is heading for better rice quality and more variety, e.g. aromatic rice, organic rice for upper market, packed in small bags for retail in department stores which requires higher standards, application of ECO_2FUME has been judged a promising method of treatment with low residue, absolute insect control for long terms with no reinfestation from eggs remained.

13. In addition, Vietnam is switching to other agro-products instead of rice, stored commodities besides rice are feed mill, tapioca, etc. these products should be noted in follow-up action plans of Methyl Bromide projects.

14. With Vietnam Project's results, it can be helpful and supportive to other agricultural countries, especially regional and neighboring countries such as Laos, Cambodia, Myanmar, rice growing nations.

15. This is a demonstration project, apply alternatives in small scales to evaluate in terms of technical and finance, as well as point out best options and motivated for more expansive adaptation, therefore in order to prepare for a complete phase-out in due time, we strongly recommend to have more supportive in technique and finance from governmental and international organizations.

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8. REFERENCE

LIST OF TABLES AND DIAGRAMS