PHOSPHINE FUMIGATION OF STORED AGRICULTURAL COMMODITY

PROGRAMMATIC ENVIRONMENTAL ASSESSMENT

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Cover photos: Phosphine fumigation monitoring equipment (top left), DIMEGSA Pest Control staff in Guatemala (top right), USAID food commodities stored in a warehouse (bottom).

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TABLE OF CONTENTS

LIST OF ACRONYMS

ACDI/VOCA	Agricultural Cooperative Development International and Volunteers in Overseas Cooperative Assistance
AchE	Acetyl cholinesterase
AE	Aerosol
AI	Active Ingredient
APHIS	Animal and Plant Health Inspection Service (USDA)
ARS	Agricultural Research Service
BEO	Bureau Environmental Officer (USAID)
BEST	Bellmon Estimation Studies for Title II project (USAID)
BP	Best Practices
BFS	Bureau for Food Security (USAID)
CA	Certified Applicator
CATAMA	Committee on Aviation Toxicology, Aero Medical Association
CCC	Commodity Credit Corporation
CFR	Code of Federal Regulations (US)
CCOHS	Canadian Centre for Occupational Health and Safety
CO2	Carbon dioxide
CRG	Commodity Reference Guide
CRS	Catholic Relief Services
CSB	Corn soy blend
DCHA	Bureau for Democracy, Conflict & Humanitarian Assistance (USAID)
DHHS	Department of Health and Human Services (US)
EC	Emulsifiable Concentrate
EWG	Environmental Working Group (USAID)
ESR	Environmental Status Report
FACG	Food Aid Consultative Group
FAO	Food and Agricultural Organization of the United Nations
FAS	Foreign Agricultural Service
FDA	Food and Drug Administration (DHHS)
FFP	Food for Peace (USAID)
FGIS	Federal Grain Inspection Service (US)
FGPFS	Food Grain Protection and Fumigation Specialist
FHI	Food for the Hungry International or Feed the Hungry International
FMP	Fumigation Management Plan
FSA	Farm Service Agency (USDA)
FSP	Fumigation service provider
FtF	Feed the Future (USAID)
FY	Fiscal Year
GAO	Government Accountability Office (US)
GEMS	Global Environmental Management Support
GMO	Genetically modified organism
GUP	General Use Pesticide
HDPE	High density polyethylene
HHRE	Human Health Risk Evaluation
IEE	Initial Environmental Examination
IFADC	International Food Aid and Development Conference
IGR	Insect Growth Regulator
IO	International organization
IPM	Integrated Pest Management

IRIS	Integrated Risk Information System
ITSH	Internal Transport, Shipping and Handling
KCCO	Kansas City Commodity Office
LOE	Level of Effort
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries (Uganda)
MSHA	Mine Safety and Health Administration (US)
MOE	Margin of Exposure
MT	Metric Ton
N2	Nitrogen
NGO	Non-Governmental Organization
NIOSH	National Institute for Occupational Safety and Health (US)
NOAEL	No Observed Adverse Effect Level
O2	Oxygen
OSHA	Occupational Safety and Health Administration (US)
PBO	piperonyl butoxide
PEA	Programmatic Environmental Assessment
PEL	Permissible Exposure Limit
PERSUAP	Pesticide Evaluation Report and Safe Use Action Plan
P.L. 480	Public Law 480 (US)
Ppb	Parts per billion
PPE	Personal protective equipment
Ppm	Parts per million
PSA	Participatory Stakeholder Analyst
PVC	Poly vinyl chloride
PVO	Private Voluntary Organization
RED	Reregistration Eligibility Decision (published by USEPA)
RUP	Restricted Use Pesticide
SC	Soluble Concentrate
SIA	Social Impact Assessment
SOP	Standard Operating Procedure
SOW	Scope of Work
UN	United Nations
UNESCO	United Nations Education, Scientific and Cultural Organization
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USDHHS	United States Department of Health and Human Services
WBSCM	Web Based Supply Chain Management
WFP	World Food Programme (of the UN)
WP	Wettable Powder
WV	World Vision

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SUMMARY

PURPOSE OF THE PROGRAMMATIC ENVIRONMENTAL ASSESSMENT

The United States Government (USG) is committed to the promotion of global food security through its international food assistance and other foreign assistance programs. The US Agency for International Development's Bureau for Democracy, Conflict and Humanitarian Assistance, Office of Food for Peace (USAID/DCHA/FFP) contributes to this commitment by working to minimize hunger in the world so that people everywhere can enjoy active and productive lives, and ultimately, to ensure that one day food aid is unnecessary.

USAID's FFP Program works toward a world free of hunger and poverty, where people live in dignity, peace, and security. To this end, the FFP office, through funding provided by the 2008 Farm Bill through Title II of the Food for Peace Act, makes agricultural commodity donations to private voluntary organizations (PVOs) and international organizations (IOs) such as the UN's World Food Program [WFP]). These resources directly address food insecurity and provide emergency food aid.

The Title II supply and distribution chain is complicated and involves many parties in the US and internationally. Title II commodities are purchased from US farmers and shipped abroad from US ports on the east coast, west coast, Great Lakes, and Gulf of Mexico. Transit time from port to port varies from approximately 2 weeks to 2 months, as disruptions of the logistics chain can take place. Upon arrival at the host country port of entry, food aid may remain on the vessel while other high-priority commodities are cleared at port. Based on interviews with the port authorities and supply chain managers, delays can occur as a result of constraints along the distribution chain, such as a country's port facility capacity, availability of trucks, and the demand for materials such as fertilizers and cement. Alternatively, food may immediately be unloaded from the vessel yet stored for longer than expected (i.e., more than 15 days) at a port facility due to shortages of trucks or warehouse space. Additionally, once commodities arrive at a PVOs' primary and secondary warehouses, there may be further delays in distribution, during which time insect infestation can occur. Once at the local distribution point, food aid is generally quickly distributed to beneficiary communities, where infestation is less likely to occur. Delays in distribution could predispose food aid commodities to infestation and spoilage, especially by insects hatching from stored-products; therefore, fumigation is an important tool to prevent loss.

The need for this PEA was clearly stated in the *USAID 2011 Scoping Statement for the Programmatic Environmental Assessment for Title II Food Aid Commodity Protection and Fumigation,* which is the primary guiding document for the PEA. Most Title II commodities, with the exception of tinned food aid commodities such as vegetable oil, are fumigated with pesticides as they are prepared for shipment from the US, during transit and local storage, or upon arrival in port. As with any program involving post-harvest storage of an agricultural commodity, Title II food aid may become infested with common pests such as weevils, grain borers, flour beetles, mites, moth larvae, mice, and rats. Prevention and control of pest intervention in food aid commodities is critical to delivering food to those most in need. As such, FFP partners and producers, commercial silo managers, handlers, shippers, and commodity brokers commonly rely on fumigants, contact insecticides, and rodenticides to prevent or minimize the loss of valuable commodity (USAID, 2006).

The issue of fumigation for USG food aid commodities requires thorough analysis by USAID, other donors, the United Nations (UN) or non-government organizations (NGOs). The existing USAID guidelines in the Commodities Reference Guide are a critical source of information but not necessarily applicable for practical use in host countries because of logistically difficult conditions. Different partners are using distinct approaches with varying degrees of sophistication that are not fully effective in ridding the food aid of insect pests. There is also a concern that some commodities may be exposed to an excessive number of fumigation cycles. Furthermore, FFP partners have had to destroy hundreds of metric tons of commodity due to infestation. In addition to preventing food from reaching malnourished and critically food insecure beneficiaries, disposing of large quantities of spoiled or contaminated food aid is an environmental management challenge.

The purposes of this PEA are to guide those involved in Title II food aid, whether representing USAID or its PVOs, to:

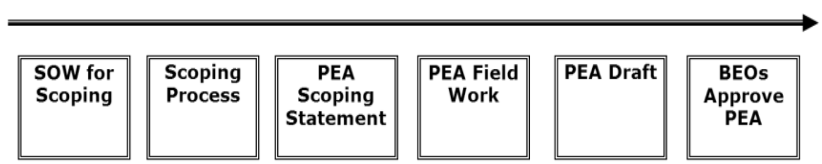
- Bring the Public Law(PL) 480, Title II program into overall compliance under the precepts of the Agency's environmental regulations;
- Identify the potential for adverse human health and environmental impacts from fumigation of food aid and recommend mitigation and monitoring measures to counter them;
- Develop tools and guidance that will lead to safer fumigation procedures and thus safeguard food aid quality, protect human health, and mitigate adverse environmental impacts; and
- Build capacity for best management practices related to food aid protection via integrated pest management (IPM) and fumigation across the full array of stakeholders involved in Title II food aid.

Partner compliance requirements are synthesized in the Tools Annexes; partners that follow instructions in the Tools Annexes will satisfy the requirements of the PEA.

APPROACH OF THE PEA

The approach for this PEA was developed based on the findings of the *USAID 2011 Scoping Statement for the Programmatic Environmental Assessment for Title II Food Aid Commodity Protection and Fumigation.* The Scoping Statement included a desk study and stakeholder consultation with USAID FFP/Washington DC, the PVOs headquarters food aid experts, the Food Aid Consultative Group (FACG), and the Environmental Working Group (EWG). The results of the Scoping Statement outlined the context in which fumigation is used, identified existing knowledge gaps, and answered preliminary questions on the protection and management of food aid commodities from procurement to distribution, with particular attention to fumigation practices. The PEA approach was then refined based on the Scoping Statement data and field work was planned accordingly, as shown in Figure E-1.

FIGURE E-1 – LOGIC PATHWAY FOR SCOPING AND COMPLETION OF PEA.



The PEA Team composition consisted of the following specialists:

- Team Leader/Environmental Review Specialist
- Food Grain Protection and Fumigation (FGPF)/IPM Specialist
- Participatory Stakeholder Analyst (PSA)/NGO Liaison
- Social Impact Assessment (SIA) Specialist
- Technical Quality Control/Quality Assurance Specialist
- Human Health Risk Evaluator

The core team, comprising the team leader, FGPF, and PSA, conducted field visits and stakeholder interviews before preparing the draft PEA report. The SIA Specialist served as an advisor and reviewed the draft PEA. The Technical Quality Control Specialist served as an advisor, primary reviewer, and PEA author.

A concern raised during the Scoping process for the PEA was whether dangerous residues of the fumigant could remain on food aid destined to be consumed by project beneficiaries. To address this issue, the PEA process included the preparation of a Human Health Risk Evaluation (HHRE) to assess the risks from the use of the fumigant, phosphine gas (hydrogen phosphide), at warehouses where USAID FFP food aid commodities were being stored. The HHRE provides semi-quantitative and qualitative estimations of potential risk to human health that may result from phosphine fumigation practices. The PEA used the HHRE as a basis for identifying potential impacts to the health of fumigators, other on-site warehouse workers, warehouse visitors, beneficiaries, and nearby residents.

The PEA process was largely informed by stakeholder consultations in the US and USAID partner countries. Extensive stakeholder consultations were also conducted in Washington DC prior to field visits. These planning sessions included stakeholders throughout the food aid commodity chain, from procurement of food to distribution to beneficiaries. Stakeholders included PVO headquarters' staff, the World Food Program (WFP), transporters, fumigation consultants, commodity suppliers, and logistics experts. The Washington DC engagements provided focus in framing the questions for the field visits, site selection, and PVO in-country coordination. The engagements also gave stakeholders a forum for voicing their organization's concerns and questions. During field visits to Uganda, Ethiopia, and Djibouti, the PEA Team met with USAID Missions, PVOs, fumigation service providers, port authorities (Djibouti), warehouse managers (pre-positioning warehouse in Djibouti), and transporters and surveyors of Title II food aid to discuss processes, logistics, and contracting for each supply chain.

The PEA Scoping Statement identified alternatives to fumigation and key issues to be evaluated in the PEA. Based on review during the PEA process, for a number of reasons the PEA Team revised the initial alternatives as well as the evaluation of critical issues. The analysis of the alternatives' potential impacts constitutes the foundation of the PEA mitigation measures (the Programmatic Environmental Mitigation & Monitoring Plan).

FINDINGS OF THE PEA

The following notes present the major issues addressed in the PEA and the primary findings for the use of fumigants in Title II food aid fumigation.

Issue 1: Use of the fumigant aluminum phosphide, and to a lesser extent magnesium phosphide, can potentially affect the health of applicators and other on-site workers and visitors.

Aluminum phosphide can produce phosphine gas when exposed to ambient air. The potential for acute exposure to applicators and other on-site workers, including loaders and transporters, poses a possible health concern without appropriate safety equipment. The potential for chronic exposure may exist, and precautions should be taken to ensure fumigant applicators and other on-site workers do not suffer adverse chronic effects. Mitigation is needed to minimize the potential impacts associated with acute exposure and reduce the potential for chronic exposures.

Issue 2: Use of the fumigant phosphine gas can affect the health of residents near warehouses being fumigated.

Potential acute and chronic health impacts to nearby residents could result from exposure to phosphine gas emanating from warehouses during fumigation. Mitigation measures should be designed on a case-by-case basis within a delimited area, and should take into account any potential exposure to nearby residents.

Issue 3: The quality of the food commodity may be compromised due to phosphine fumigation.

The study of the impact of phosphine fumigation on food quality is ongoing. Conflicting studies exist regarding the impact of fumigants on food quality, with most findings inconclusive. However, the no-use alternative could have significant implications when it comes to potential for infestation, mycotoxins contamination, and the risk of losing the commodity if it is not fumigated. Safeguards to minimize concerns are available and easily implemented.

Issue 4: Beneficiary populations may be at risk from inhalation, preparation, and ingestion of fumigated commodities.

Based on the current state of knowledge, including the finding from the HHRE that there is a potential for residues on commodities, risks to beneficiaries may exist. Mitigation can minimize potential adverse effects; however, additional research is needed to determine health risks, if any, to USAID Title II beneficiaries.

Issue 5: Phosphine fumigation residuals could affect water quality, soil, and non-target organisms.

The greatest concern for environmental contamination is if spent aluminum phosphide residues (usually containing 3% - 5% phosphine) are not properly managed for disposal. In addition, dispersal of phosphine gas from the site could impact non-target organisms. As such, mitigation to limit environmental contamination is needed.

Issue 6: Poor practices in transport, storage, and disposal of fumigants are a concern for human health

In Title II recipient countries, safeguards may not be in place to ensure proper handling of fumigants (during transport, storage, and disposal). Poorly handled solid waste, such as combining various types of waste, including aluminum and magnesium phosphide residues/byproducts, could present a danger. However, by implementing simple best practices, adverse impacts from improper handling can be avoided.

Issue 7: Improper disposal practices of rodents and birds killed by phosphine gas could affect human health.

Proper practices for rodent and bird disposal, as well as measures for excluding rodents and birds from warehouses, can be implemented to minimize risks.

Issue 8: Phosphine may not completely control fungal contamination.

While phosphine gas should limit fungal contamination, it may only be effective for certain fungal species. Laboratory trials suggest that phosphine fumigation may limit mold development and mycotoxin production, but after the gas dissipates, fungal growth and mycotoxin production may reoccur. The only reliable measure to protect against fungal growth is to purchase commodity that is at 13% or less moisture, and distribute it as quickly as possible.

PROCEDURES AND USE OF THE PEA

In accordance with USAID's Pesticide Procedures, the "procurement or use" of any pesticides for USAID Title II programs requires that an Initial Environmental Examination (IEE) be in place along with a Pesticide Evaluation Report and Safe Use Action Plan (PERSUAP), which includes 12 factors outlined in the Pesticide Procedures described in 22 CFR 216.3 (b)(1)(i) (a through l). The PERSUAP focuses on the particular circumstances of the program in question, the risk management choices available, and how a risk management plan would be implemented in the field.

A PERSUAP consists of two components, a "PER" and a "SUAP" (see Annex T-2 for an annotated template of a PERSUAP for aluminum phosphide). The Pesticide Evaluation Report (PER) section addresses the 12 informational elements required in the Agency's Pesticide Procedures. The Safer Use Action Plan (SUAP) puts the conclusions reached in the PER into a plan of action, including assignment of responsibility to appropriate parties connected with the pesticide program (http://www.usaid.gov/results-and-data/information-resources).

Currently, as part of their environmental compliance documentation, an evaluation of user hazard is required of all Title II PVOs who provide assistance for the procurement or use of aluminum or magnesium phosphides. However, once DCHA BEO approval of this PEA is obtained, due to its programmatic nature, the evaluation of user hazard contained in Section 5, issues #1-4 (as well as the full HHRE) should satisfy the requirement for each PVO to prepare an individual evaluation of user hazard. This PEA (and the corresponding HHRE) is intended to satisfy the Reg. 216 requirement for an evaluation of user hazard. The preparation of a PERSUAP gives a program manager the opportunity to consider practical actions to reduce the risks of using pesticide products in a program, taking into consideration the context in which the products will be used, the particular elements of the program, and the different capacities of the partners involved.

INTRODUCTION

The United States (US) is committed to the promotion of global food security through its international food assistance and other foreign assistance programs. The US Agency for International Development's Office of Food for Peace, within the Bureau for Democracy, Conflict and Humanitarian Assistance (USAID/DCHA/FFP), contributes to this commitment by working to minimize hunger in the world so that people everywhere can enjoy active and productive lives, and ultimately, to ensure that one day food aid is unnecessary.

USAID's FFP Program works toward a world free of hunger and poverty, where people live in dignity, peace, and security. To this end, the FFP office, through funding provided by the 2008 Farm Bill through Title II of the Food for Peace Act, makes agricultural commodity donations to private voluntary organizations (PVOs) and international organizations (IOs) like the UN's World Food Program [WFP]). These resources directly address food insecurity and provide emergency food aid.

1.1. PURPOSE OF THE PEA

The USAID Title II food aid programs have a complicated supply and distribution chain that involves many parties in the US and internationally. Title II commodities are purchased from US farmers and then shipped from US ports on the east coast, west coast, Great Lakes, and Gulf of Mexico. Transit time from port to port varies from approximately 2 weeks to 2 months as disruptions of the logistics chain can take place. Upon arrival at the host country port of entry, food aid may remain on the vessel while other high-priority commodities are cleared at port. Based on interviews with the port authorities and supply chain managers, the delay is dependent on constraints along the distribution chain, such as a country's port facility capacity, availability of trucks, and the demand for other materials, such as fertilizers and cement. Alternatively, food may be unloaded from the vessel, yet may be stored for longer than expected (more than 15 days) at a port facility due to shortages of trucks or warehouse space. Additionally, once commodities arrive at a PVOs' primary and secondary warehouses, further delays in distribution may occur, during which insect infestation can result or increase. Once at the local distribution point, food aid is generally quickly distributed to beneficiary communities, where infestation is less likely to occur. Delays in distribution could predispose food aid commodities to infestation and spoilage, especially by insects hatching from stored-products; therefore, fumigation is an important tool to prevent loss.

Most Title II commodities, with the exception of tinned food aid commodities such as vegetable oil, are fumigated with pesticides as they are made ready for shipment from the US, during transit and local storage, or upon arrival in port. As with any program involving post-harvest storage of an agricultural commodity, Title II food aid may become infested with common pests such as weevils, grain borers, flour beetles, mites, moth larvae, mice, and rats. FFP partners and producers, commercial silo managers, handlers, shippers and commodity brokers, therefore, commonly rely on fumigants, contact insecticides, and rodenticides to prevent or minimize the loss of valuable commodity (USAID, 2006).

Given the large scale of USAID Title II programs and questions regarding the use of phosphine gas for fumigation throughout Title II countries, the USAID/DCHA BEO determined that a PEA framework would be useful to provide environmentally sound information applicable to all Title II programs. The framework for the PEA was designed in the USAID *2011 Scoping Statement for the Programmatic Environmental Assessment for Title II Food Aid Commodity Protection and Fumigation*, which is the primary guidance document for the PEA. The PEA is needed to evaluate alternatives for phosphine fumigation by critically evaluating the knowledge and implementation gaps in best practices, including the safety of fumigation practices for Title II programs. Title II fumigation challenges to address include:

(1) Lack of documentation of best practices for fumigation in host countries.

The issues surrounding food aid fumigation best practices for USG Title II food aid commodities require proper investigation by USAID, other donors, the United Nations (UN) or non-government organizations (NGOs). The UN Food and Agricultural Organization (FAO) produced the Manual of Fumigation for Insect Control for general fumigation of above ground insects, but this manual is significantly outdated (2nd ed. Published in 1969) and does not specifically address Title II food aid or host country considerations (FAO 1984). The existing USAID guidelines detailed in the Commodities Reference Guide (CRG) (http://transition.usaid.gov/our_work/humanitarian_assistance/ffp/crg/sec4.htm) are not detailed enough for practical use under logistically difficult host country conditions. Best practices that are implementable in host-countries need to be identified and methods for accountability (e.g., reporting to the PVO, documenting implementation) need to be established.

(2) Highly variable implementation of pest management best practices due to a lack of tools for fumigators.

Few tools exist for USAID/FFP and Title II partners to ensure fumigation is consistently practiced in accordance with internationally recognized best practices. Different partners are using distinct approaches with varying degrees of sophistication, some of which are not fully effective in ridding the food aid of insect pests, resulting in either multiple fumigations or inedible food. FFP partners have had to destroy many hundreds of metric tons of commodity due to infestation when fumigation was unsuccessful. , In addition to preventing food from reaching malnourished and critically food insecure beneficiaries, disposing of large quantities of spoiled or contaminated food aid is an environmental management challenge. Tools for identifying infestations, evaluating fumigation monitoring procedures, and assessing impacts must be developed, as well as documentation standards and reporting requirements for all the fumigation steps.

3) Lack of environmental and human health and safety information for the use of fumigants.

Reliable information on health effects of fumigation on applicators, warehouse workers, nearby residents, and beneficiaries of food aid, as well as the effect of fumigation on the quality of food commodity, is not readily available. Another issue is that some commodities may be exposed to "too many" fumigation cycles because fumigation is ineffective, and therefore, increase the exposure of these individuals to a highly toxic pesticide. Additionally, there are few standards for the treatment and disposal of spent fumigants in an environmentally sound manner. An evaluation of risk to human health and of the potential threat to the environment needs to be developed.

1.2 GOALS OF THE PEA

To complete the knowledge gaps in the use of fumigants in Title II food aid, the PEA will:

- Bring the Public Law (P.L.) 480, Title II program into overall compliance under the precepts of the Agency's environmental regulations;
- Identify the potential for adverse human health and environmental impacts from fumigation of food aid and recommend corresponding mitigation and monitoring measures;
- Develop tools and guidance that will lead to safer fumigation procedures and thus safeguard food aid quality, protect human health, and minimize adverse environmental impacts; and
- Build capacity for best management practices related to food aid protection via integrated pest management (IPM) and fumigation across the full array of stakeholders involved in Title II food aid.

1.3 OVERVIEW OF FUMIGANTS IN FOOD AID

Commodities intended for food aid must meet standards for live stored-product insects. To ensure that the US government is not liable for any losses due to insect infestations and to minimize food wastage, food aid commodities, with the exception of vegetable oil, are fumigated with aluminum phosphide prior to shipment. Fumigation may occur at various points in the commodity procurement supply chain, such as in a grain silo on the farm or at an elevator, truck, rail car, container, warehouse, distribution center, processing facility, port, or in the vessel hold.

Typically, USAID food aid may become infested with various stored-product insect species in the vessel, upon arrival at the destination port, or when stored at the primary, secondary, or tertiary warehouses (distribution points). Food aid commodities have a shelf life of one year or less, and during the time they are in storage, PVOs must preserve the integrity and safety of the commodity. Prevention of spoilage of food requires proper storage, transportation, handling, and pest management practices.

Fumigations performed in the US are required to be conducted by trained and certified applicators following proper safety precautions, which include developing a fumigation management plan (FMP) [see FMP template in Annex T-3]; using proper personal protective equipment (PPE) that is well-maintained; monitoring phosphine gas during and after a fumigation; notifying proper authorities (fire and police) and bystanders that a fumigation is taking place; and clearance of fumigant from the treated space with or without the aid of fans. Applicator standards and fumigation practices in Title II recipient countries are highly variable. In most cases the applicator training and fumigation practices in recipient countries do not meet the stringent US requirements, and the fumigation process may not be compliant with the product labeling.

Personal Protective Equipment – face mask and Draeger tube gas detector

1.4 OVERVIEW OF REPORTING REQUIREMENTS PER USAID ENVIRONMENTAL REGULATIONS

USAID's environmental regulations per Title 22, Code of Federal Regulations (CFR), Part 216 (http://transition.usaid.gov/our_work/environment/compliance/22cfr216.htm), commonly referred to as Reg. 216, establish the conditions and procedures for the environmental review of activities funded with USAID resources. According to the Pesticide Procedures outlined in 22 CFR 216.3(b), all Title II PVOs who provide assistance for the procurement or use of pesticides, including fumigants, must produce an Initial Environmental Examination (IEE), including an evaluation of user hazard in a 12 factors analysis, aka the Pesticide Evaluation Report and Safe Use Action Plan (PERSUAP). These documents include an evaluation of the economic, social, and environmental risks and benefits of the planned pesticide use. However, concerns have emerged in recent years about whether the environmental documentation submitted by PVOs as part of their Title II requirements (i.e., an IEE and a PERSUAP) is adequately rigorous to fully ensure that the appropriate environmental management measures are being taken for fumigants and that the program operates in an environmentally sound manner as required by USAID's regulations.

Further, in accordance with 22 CFR 216.3(b)(l)(ii), when a project includes assistance for the procurement and/or use of pesticides registered for the same or similar uses by the U.S. Environmental Protection Agency (USEPA) and the proposed use is restricted by the USEPA as a Restricted Use Pesticide (RUP) on the basis of user hazard, a full EA (or Programmatic EA [PEA] such as this one) must be developed. According to the USEPA, all aluminum phosphide and magnesium phosphide fumigant products are classified as RUP based on the criteria "Human Inhalation Hazard." Therefore, in accordance with USAID's Pesticide Procedures, the "procurement or use" of aluminum phosphide or magnesium phosphide fumigants in USAID Title II programs requires an EA and an evaluation of user hazard. In addition, USAID may provide technical assistance to address any risks associated with the use of RUPs. The PEA differs from the EA in that it applies broadly to multiple programs where uses and environmental contexts are similar, as in this case with Title II food aid programs. The PEA must include an evaluation of the user hazards associated with the proposed USEPA restricted uses to ensure that implementation includes mitigation of the risks. This PEA addresses and further resolves these concerns.

1.5 APPLICATION OF THE PEA FOR PARTNER PROGRAMS

This PEA (and the more detailed HHRE) is **intended to satisfy the Reg. 216 requirement for an evaluation of user hazard**. Approval of the PEA by the DCHA BEO for use in partner programs is dependent on:

1) The programmatic nature of Title II activities, and
2) The evaluation of user hazard contained in Section 5 #1-4 as well as the full HHRE in Annex K.

This PEA does not preclude the need for Title II PVOs to prepare PERSUAPs for their programs that provide assistance for the procurement or use of aluminum or magnesium phosphide. Rather, it provides information and tools that can be used when preparing country or PVO partner-specific PERSUAPs (see Annex T-2 for an annotated template of a PERSUAP for aluminum phosphide). As stated above, the user hazard evaluation contained herein applies to all Title II PVO programs. The tools (Annexes T-2, 3, 4, 7, and 9) can easily be used and revised, as needed, for country and partner-specific situations, and thereby, can provide mitigation for proposed aluminum and magnesium phosphide use as described and requested in PVO PERSUAPs.

1.6 METHODOLOGY OF THE PEA

1.6.1 SCOPING STATEMENT

As required by 22 CFR 216.3(a)(4), the *Scoping Statement for the Programmatic Environmental Assessment for Title II Food Aid Commodity Protection and Fumigation* was prepared to guide this PEA (USAID, 2011). Excerpts are provided in Annex C. The Scoping Statement reviewed the current activities associated with the protection and management of food aid commodities from procurement to distribution, with particular attention to fumigation practices. It describes the P.L. 480 Title II food aid program, concerns regarding infestation of Title II food aid commodities, including the main pests and the need for pest management, including fumigation; lists the key stakeholders; and identified the potential adverse environmental impacts. Additionally, issues excluded from further analysis and identification of alternatives to fumigation were identified as necessary to address in the PEA.

The Scoping Statement was developed in a participatory manner through questionnaires to the USAID missions with Title II programs and consultations with the Food Aid Consultative Group (FACG). The FACG was created as part of the U.S. Farm Bill in 1990. The intention of the group is to "review and address issues concerning the effectiveness of the regulations and procedures that govern food assistance programs established and implemented…under PL 480." Therefore, the group was selected as critical stakeholders to direct the PEA. In addition, the FFP Environmental Working Group (EWG), which includes PVOs environmental specialists, reviewed and provided comments on the Scoping Statement. Based on input from these stakeholders, the Scoping Statement was finalized in July 2011; it was widely disseminated among Title II stakeholders.

1.6.2 PEA METHODOLOGY AND STRUCTURE

The PEA evolved from the Scoping Statement, in which three components were identified as necessary to meeting the needs of the PEA. The three main components are:

1) **Stakeholder Consultations**

   The PEA process was largely informed by stakeholder consultations in the US and USAID partner countries. Extensive stakeholder consultations were conducted in Washington DC prior to field visits. These planning sessions included stakeholders throughout the food aid commodity chain, from procurement of food to distribution to beneficiaries. Stakeholders included PVO headquarters' staff, the World Food Program (WFP), transporters, fumigation consultants, commodity suppliers, and logistics experts. The Washington DC engagements provided focus in framing the questions for the field visits, site selection, and PVO in-country coordination; the engagements also provided stakeholders a forum for voicing their organizations concerns and questions.

2) **Field Work**

   During field visits to Uganda, Ethiopia, and Djibouti, the PEA Team met with USAID Missions in each country, PVOs, fumigation service providers, port authorities (Djibouti), warehouse managers (pre-positioning warehouse in Djibouti), and transporters and surveyors of Title II food aid to discuss processes, logistics, contracting, and specifics of each supply chain.

3) **Human Health Risk Evaluation**

   A concern raised during the Scoping process for the PEA was whether dangerous residues of the fumigant could remain on food aid destined to be consumed by project beneficiaries. Therefore, the PEA process included the Human Health Risk Evaluator prepared a Human Health Risk Evaluation (HHRE) to assess the risk to beneficiary consumers, fumigation applicators, warehouse workers, and

Checking for insects with Bug Lamps at a food storage warehouse

nearby residents due to use of the fumigant, phosphine gas (hydrogen phosphide),at warehouses where USAID FFP food aid commodities were being stored. The HHRE provides semi-quantitative and qualitative estimations of potential risk to human health that may result from phosphine fumigation practices. The PEA used the HHRE as a basis for identifying potential impacts to the health of fumigators, other on-site warehouse workers, warehouse visitors, and to beneficiaries.

From stakeholder consultations, fieldwork, and HHRE this PEA evaluates the proposed actions (i.e., phosphine fumigation), recommends and evaluates alternatives, revises the alternatives proposed in the Scoping Statement. Section 3 provides a description of the proposed alternatives and the environmental impacts of those proposed actions. Section 4 discusses the affected environment for those alternatives, and Section 5 provides the analytic basis for the comparison of alternatives. A toolkit developed as a resource for partners is provided in Annex T.

KEY PERSONNEL

The selection of key personnel for the PEA Team was identified as a critical factor to the success of the PEA in the Scoping Assessment. The PEA Team was integrated into all aspects of the stakeholder assessments, desk studies, and field work. Each team member was selected based on their expertise in the subject area (i.e., fumigation/food specialist, social and gender impact, and human health risk evaluation). A short description of their duties is provided below and in Annex C. The final PEA Team composition consisted of the following specialists (biographical sketches of team members are included as Annex D):

- **Team Leader/Environmental Review Specialist**

  As the overall team lead, the Team Leader was responsible for oversight of the design and implementation of the PEA activities, acted as lead author for the PEA, and was responsible for editing and compilation of the PEA report. The Team Leader also managed interactions and communications with USAID/FFP, USAID Missions, and PVOs.

- **Food Grain Protection and Fumigation (FGPF)/IPM Specialist**

  The Food Grain and Fumigation (FGPF)/IPM Specialist was required to have internationally-recognized expertise with extensive real exposure and involvement in fumigating food aid commodities in different settings around the world. The FGPF/IPM was responsible for identifying potential adverse environmental and health impacts of the proposed and alternative activities as well as developing mitigation measures and the monitoring plan. The specialist also informed the HHRE on host-country fumigation practices and evaluation of impact of fumigants on commodities.

- **Participatory Stakeholder Analyst (PSA)/NGO Liaison**

  The Participatory Stakeholder Analyst (PSA) and NGO Liaison (PSA) was responsible for obtaining stakeholder views on potential social/health and gender impacts and their thoughts and recommendations on how to mitigate (minimize or avoid) those impacts.

- **Social Impact Assessment (SIA) Specialist**

  The SIA was responsible for interviewing both community leaders and local stakeholders (staff of the CSs/NGOs and host government agencies) and the beneficiaries themselves about the premises of the food aid programs in which they are involved. The SIA worked directly with the Team Leader and the PSA.

- **Technical Quality Control/Quality Assurance (QA/QC) Specialist**

  An expert in pesticides/IPM, and USAID environmental compliance processes including PERSUAPs provided expert for QA/QC review for the PEA planning and final report.

- **Human Health Risk Evaluator**

  A critical component to the PEA is the Human Health Risk Evaluation presented in its entirety in Annex K. The Human Health Risk Evaluator was responsible for this desk study, which was also informed by the PEA field visits. The HHRE duties included the compilation of toxicity information on fumigants and their alternatives as well as the evaluation of exposure pathways, determination of key populations at risk, and the review of literature regarding exposure concentrations.

FIELD SITE SELECTION

Field site visits were a critical aspect of the PEA for highlighting the host country issues with logistics and fumigation. The visits tracked food aid from the primary ports. The Scoping Statement recommended that the PEA Team should visit country programs that included both relatively small and well-organized programs and ones that would illustrate some of the more difficult circumstances under which food aid is stored up-country. The Scoping Statement also envisioned visits to two or three pre-positioning warehouse facilities.

The Scoping Statement described field work as consisting of visits to two country programs in Eastern and Southern Sub-Saharan Africa (possibly Kenya and Zimbabwe), from primary warehouses (like Mombasa) to community distribution points. In addition, the Scoping Statement surmised that travel to the port of Jacinto (Houston) might be useful. Finally, if time and resources allowed, the Scoping Statement recommended a visit to the port of Chittagong in Bangladesh and/or to the FFP program in Haiti.

In the final SOW for the PEA (an excerpted version of the SOW is in Annex E), the number of site visits was decreased to two country programs. In consultations with PVOs, FFP, USAID missions, and the PEA Team, Ethiopia and Djibouti were chosen as the locations for site visits. The recommendation for these countries was based on the opportunity to visit stakeholders along the entire Title II food aid chain; to meet with several PVOs (five PVOs are active in Ethiopia); to follow the food aid from distribution point to port; and to visit a port operation with a significant focus on food aid storage and distribution. In addition, because the Participatory Stakeholder Analyst is based in Uganda, she undertook site visits there.

The total LOE was decreased by about 50% from the LOE envisioned in the Scoping Statement; as above, this was primarily because of lack of sufficient funding.

STAKEHOLDER ENGAGEMENT

The PEA process was largely informed by stakeholder consultations in the US and USAID partner countries, namely Uganda, Ethiopia, and Djibouti. USAID FFP offices in these countries provided contact information of, or made appointments on behalf of the PEA Team, with their food aid stakeholders. A detailed list of contacts is provided as Annex F.

The Participatory Stakeholder Analyst (PSA), with assistance from the Social Impact Analyst (SIA Specialist), developed a participatory stakeholder research instrument to inform the consultation process and ensure that interviews were carried out constructively, to achieve maximum outcome. The research instrument document contains a set of questions, specific for each stakeholder group that was consulted. The multi-disciplinary PEA Team ensured that the methods and techniques used in data collection were complementary and that each method verified data collected by another tool or method. For example, by using a combination of telephone or individual in-person interviews, small group discussions, and site visits, the PEA Team could verify, correct, and build onto information previously collected. Additionally, the Team ensured they used more than one reliable source for information gathering; this involved meeting with more than one of the specified stakeholder categories.

As part of the stakeholder research instrument, the PSA and the SIA Specialist conducted a stakeholder analysis along the USAID food aid supply chain to best determine which groups of affected and otherwise interested parties should be consulted during the PEA process, especially as relates to fumigation practices and potential impacts. The PEA Scoping Statement also recommended stakeholders to be consulted during the PEA. Based on the stakeholder analysis and taking the Scoping Statement recommendations into consideration, the PSA and SIA Specialist identified the following groups of stakeholders to target during the PEA process:

- PVOs, FFP Officers and FFP staff
- Fumigation staff and fumigation company representatives (managers)
- Warehouse workers
- Beneficiary communities
- Transportation companies representatives and workers
- Port Authorities (private or government)
- Surveyors
- Fumigation training and certification companies
- Residents in close proximity to the storage sites where fumigation is normally carried out

The PSA and SIA Specialist selected these groups of stakeholders based on:

- Those involved in the development of food aid programs and who also have considerable influence on the entire supply chain from procurement to the distribution of food aid. This group also makes decisions on the types of food protection techniques applied along the chain, i.e., fumigation.
- Workers, including supervisors at food commodity storage facilities (primary and secondary warehouses) and distribution centers at the community level
- Those directly involved in application/use of fumigants, including the supervisors
- Those involved in transporting food commodity
- Companies providing fumigation services
- Companies that train personnel involved in application of fumigants
- Those involved in certifying fumigation companies
- Those who come into direct contact with fumigated food commodities, i.e., workers and managers at storage facilities and silos

- Food aid recipients/communities (to test the social hypothesis of whether they are satisfied with the quality and safety of food aid)

The PSA and SIA Specialist identified fumigation issues relevant to the above stakeholders (Table 1). Based on these issues, the PEA Team (Team Leader, PSA, and FGPF Specialist) then developed research questions specific to the different stakeholder groups (see Annex G). Responses to these questions have informed much of the PEA.

Table 1 describes the roles the stakeholders play and the impacts they have on the fumigation process. These roles (or dimensions) are described as "power" (making the decisions), "support" (carrying them out), and "need" (beneficiary recipients of the food aid). These differences are important when one considers impacts because stakeholders in these different categories are affected differently. For example, the FFP officers in USAID would be stakeholders with "power." The fumigation workers are "support" – they carry out the instructions from those with power. And the beneficiaries have "need" – they simply receive the product supplied to them. Those with "power" often experience very little impact, but their decisions can increase or decrease harmful impacts on the other stakeholders.

TABLE 1: STAKEHOLDER CATEGORIES AND ROLES AND EXAMPLES OF FUMIGATION ISSUES RELEVANT TO EACH GROUP

STAKEHOLDER CATEGORY	ROLE/ DIMENSION (POWER/ SUPPORT/NEED)	RELEVANT ISSUES (EXAMPLES)
USAID, Recipient Country government, Port Authorities FFP Officers	Power Power/Support	Monitoring and supervision; ensure application of food aid commodity guidelines; protection of US and recipient country reputation
Cooperating Sponsors Involved in: Monetization through commercial suppliers Distribution to beneficiaries	Power/Support	Choice of fumigation program and products; ensuring fumigation compliance through reputable pesticide companies; monitoring fumigation; ensuring food commodity protection and safety; food commodity clearance at the port
Fumigation company representatives; Fumigation training and certification company Fumigant applicant workers	Power/Support Support	Certification to authorize practice; experience and reliability; application products, methods, schedules for fumigation; human resources processes: selection, training, occupational health and safety procedures, supervision, and reliability
Commercial buyers/Suppliers	Support/Need	Compliance with fumigation/food commodity protection regulations; quality of storage facilities
Shippers to-country Truckers in-country	Support	Attempt to protect food commodity en-route; containers, holds sealed against infestations and rodents; application of food commodity protection procedures, e.g. fumigation on board/in-transit?
Community beneficiaries	Need	Perceived quality/equity of supply; protection of product

		during travel to collect supply and storage thereafter- any food commodity protection training offered? Any feedback mechanism in place if commodity is infested or deteriorated?
Affected communities Community or School leaders Near-storage facility populations	Need/Support	Safety and protection of product en route; cleanliness and safety of distribution centers at the community level; responsibilities/competence to store and protect food commodity; maintain and ensure quality of supply; safety of the fumigated bags for staff and children; any human health impacts of fumigation or potential for re-infestation?
All	Any	Stakeholder relationship issues that impact food quality and protection, e.g., lack of communication; distrust; poor or dishonest practices; lack of training and capacity; lack of transparency; ethics; disturbances because of perceived unfairness by beneficiaries in distribution procedures, etc.

In discussions with USAID FFP Officers and PVOs, the PEA Team recognized it was important to explain the purpose of the PEA in a manner that would not raise alarm among stakeholders. To this end, the PEA Team decided that residents living on-site or nearby the storage facilities would not be consulted. The warehouses visited in Uganda, Ethiopia, and Djibouti were not located near residential areas. In addition, the PEA Team did not manage to meet with companies that train and certify personnel in fumigation. However, questions relating to training on fumigation, certification, refresher courses, including institutions that offered these, were posed to, and discussed with select stakeholders, namely PVOs and fumigation companies.

1.6.4 INTERVIEWS WITH COOPERATING SPONSORS, STAKEHOLDERS, AND FOOD AID COMMODITY SPECIALISTS PRIOR TO SITE VISITS

The PEA began with stakeholder consultations in Washington, D.C. on January 25 and 26, 2012. The PEA Team Leader represented the PEA Team at these information gathering sessions, and the USAID/DCHA BEO and DCHA Post-Crisis Environmental Advisor attended each meeting.

For the information gathering sessions with Title II PVOs and USAID staff, the PEA Team Leader used the questionnaire developed during the scoping process, as revised for the PEA phase (The stakeholder research instrument had not yet been prepared.) A list of those interviewed during these sessions is included in the List of Contacts in Annex F.
Key objectives of the Washington, D.C.-based PEA consultations were to identify:

- Government, private sector, and PVO players involved in the food aid commodity chain;
- Roles and responsibilities for fumigation of Title II commodities;
- Additional concerns regarding fumigation not already identified during the scoping exercise;
- Contacts in the US and field that should be interviewed for the PEA; and
- Recommendations for PEA fieldwork locations.

The PEA Team Leader held remote interviews with food aid specialists and other stakeholders who had expressed interest in the PEA yet were unable to attend the Washington, DC-based PEA consultations. The questionnaire used during the Washington, DC consultations, revised as applicable, was also used for remote interviews. Those interviewed remotely are listed in Annex F.

The USAID/DCHA Post-Conflict Environmental Advisor presented the PEA framework and initial findings of the PEA exercise at the International Food Aid Development Conference (IFADC) Special USAID and USDA Workshop in Kansas City in May 2012. The objective of the talk presentation was to inform PVOs on the preliminary results of the PEA and solicit feedback and additional participation. Follow-up questions from the audience included the implication of the PEA on environmental reporting requirements to USAID, the use of alternatives to aluminum phosphide, and interest in guidance for overseas fumigators.

1.6.5 LITERATURE REVIEW AND DESK STUDY

The PEA phase built on the literature review that was started during the scoping phase. During scoping, documents related to the protection and fumigation of food aid commodities were identified and compiled. To ensure this literature was accessible to the PEA Team and to stakeholders, a "Community of Practice" on SharePoint was established. As stated in the Scoping Statement, the intention is to eventually share this site with a wider stakeholder audience.

Documents currently available at the SharePoint site provide a great range of information on fumigation of Title II food aid and related topics. Documents range from highly technical to basic information for laypeople, and include USAID, WFP, and PVO guidelines for fumigation, documents produced as part of the scoping and PEA process, research papers on such topics as sorption/desorption and packaging of food aid commodity, and other areas of interest to Title II PVOs and FFP.

A literature review on the current knowledge for fumigation impacts, alternatives, and mitigation measures and a cross-sectoral review on the social and gender interactions with alternatives and mitigation measures were produced as part of the PEA. A short description of the reviews is provided below.

1. The Fumigation Review is a state of the art literature review consisting of a summary of key fumigation impacts, such as potential adverse health and environmental impacts; possible mitigation measures; a summary of fumigation and IPM alternatives identified from the literature; and recommendations for areas of team focus for the PEA site visits.

2. The PSA literature review on (a) the most current and appropriate literature on potential social/health and gender impacts and mitigation and monitoring measures related to food aid protection and fumigation, especially for fumigation workers and fumigation company staff, but extending to warehouse workers and, to a more limited extent, beneficiary communities; and (b) traditional methods of protection against pests of stored food (See Annex I).

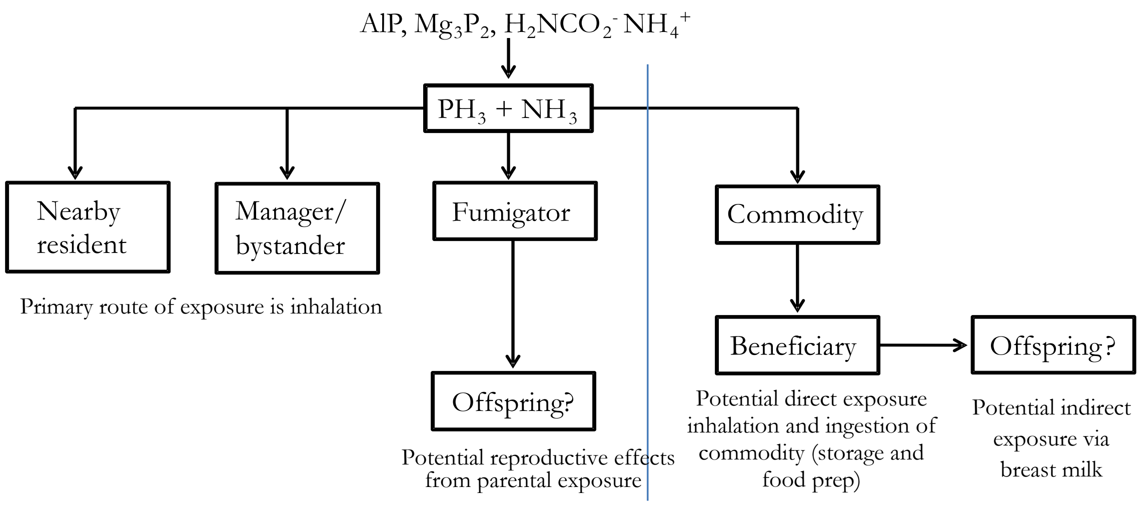
1.6.6 HUMAN HEALTH RISK EVALUATION

The HHRE was included as part of the PEA because data gaps exist that prohibit site-specific quantitative risk estimates for receptor populations exposed to fumigants in Title II food aid commodities. The potential risk of fumigant use to key populations was also a critical factor into the assessment of the proposed action and evaluation of alternatives. Therefore, a separate report, prepared simultaneously with the PEA, was included in the final PEA design. *The Screening Human Health Risk Evaluation (HHRE) on the Use of the Fumigant Phosphine Gas and its Primary Precursor Aluminum Phosphide* was commissioned as a desk study, to be informed by site-specific details garnered from the field visits. The findings were fed into draft and final PEA results, recommendations, and guidance presented herein. The detailed HHRE is provided in Annex K.

The draft HHRE was based on the available data from guidances, peer-reviewed literature, as well as expert opinion, to conservatively estimate threshold exposure limits to beneficiary consumers. In the absence of complete exposure pathways, toxicity data, or exposure point concentrations, risk was qualitatively evaluated. Upon collection of data from the field visits, relevant information was used to revise the HHRE, and the conceptual site model for the HHRE was developed (Figure 1.1). The conceptual site model summarizes the primary routes of exposure and populations potentially at risk.

The focus of the HHRE was to assess the risk to beneficiary consumers, fumigation applicators, warehouse workers, and nearby residents due to the use of phosphine gas as a fumigant to protect food aid commodities for USAID FFP international humanitarian assistance programs. The HHRE provides quantitative and qualitative estimations of potential risk to human health that may result from phosphine fumigation practices.

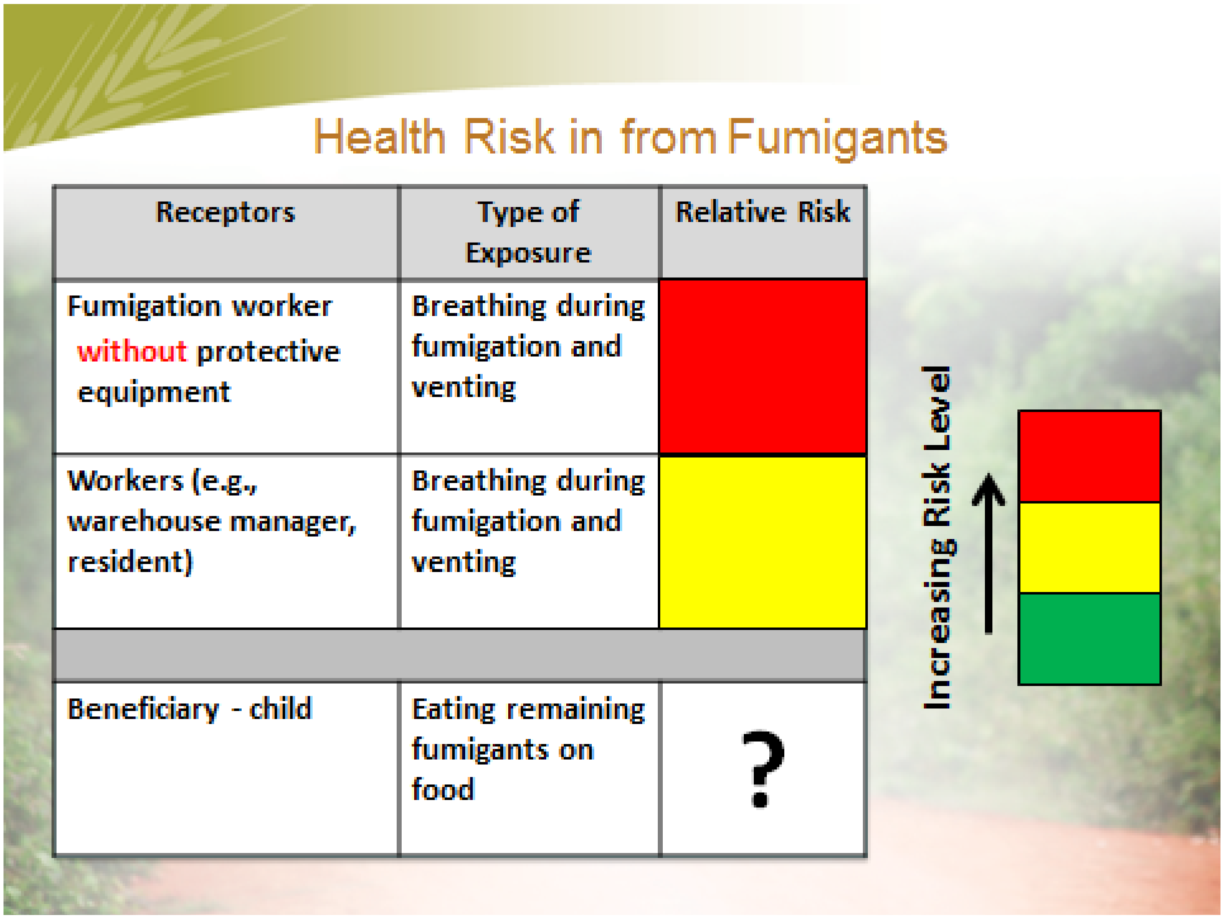
FIGURE 1.1. CONCEPTUAL SITE MODEL FOR FUMIGANTS IN FOOD AID



Exposure information for the HHRE was obtained through observations and interviews with fumigation personnel at sites where USAID-distributed commodities are fumigated. This exposure information was used in conjunction with an example data set from USEPA from a tobacco warehouse to illustrate the potential risk associated with the inhalation of phosphine gas to fumigators and managers/bystanders during fumigation operations. Residents that may live in close proximity to fumigation sites are discussed qualitatively.

As the HHRE states, Risk Characterizations are typically supported by field data that can be used to reliably estimate the concentrations of a chemical or chemicals that are present during human exposure scenarios. However, for the HHRE of phosphine fumigation, site-specific field data on phosphine concentrations were not collected or available. In light of this, other information and data sources were substituted, including anecdotal information, interviews, literature, and air monitoring data from the USEPA Reregistration Eligibility Decision (RED) document for aluminum and magnesium phosphide (USEPA, 1998).

The PEA Team worked closely with the HHRE Team to obtain information the HHRE Team needed to complete their analyses. To that end, the PEA Team included questions in the stakeholder research instrument that would ensure HHRE-requested data were gathered during fieldwork in Uganda, Ethiopia, and Djibouti. The PEA Team has incorporated HHRE results into the PEA; in particular, the PEA draws heavily on the HHRE for the analyses in the Environmental Consequences section (Section 5), issues #1 to #4. The figure below provides a snapshot of the potential health risks from fumigation.



1.6.7 FIELDWORK

TEAM LEADER STUDY TOUR TO MANHATTAN, KANSAS

In January 2012, the PEA Team Leader traveled to Manhattan, Kansas, home of Kansas State University, and where Professor Bhadriraju Subramanyam (Subi), the FGPF/IPM Specialist, is based. They visited the grain sciences laboratory, where they looked at various degrees of grain infestation; a grain silo as it was being prepared for a fumigation; and Central States Enterprises in Salina, Kansas, to get firsthand experience of fumigation company operations and fumigation practices in the US, including various methods of fumigant monitoring and personal protective equipment (PPE).

PSA FIELDWORK IN UGANDA

In early April 2012, prior to the site visits in Ethiopia and Djibouti, the PSA held the following meetings in Kampala, Uganda:

- A briefing session with the USAID/Uganda Mission: The purpose of this meeting was to ensure that there was a common understanding for both USAID and their PVOs, of the PEA process and what it intends to achieve.
- Small group discussions with two USAID PVOs, Mercy Corps and ACDI/VOCA: These discussions were aimed at gaining insight into their food aid supply chain and food commodity protection methods and practices, especially with regard to the use of fumigants.
- A tour of the ACDI/VOCA warehouse: The PSA visited the warehouse to see how food commodity is stored and to obtain firsthand information on their fumigation schedule.

- An interview with the Operations Manager of Supreme Fumigation Services Ltd: The aim of the meeting was to gain an understanding of the company's fumigation practices.

PEA TEAM'S FIELDWORK IN ETHIOPIA

The Team Leader, PSA, and FGPF Specialist met, as a team, for the first time in Addis Ababa, Ethiopia. There, they reviewed and revised the draft participatory stakeholder research instrument developed by the PSA and the SIA Specialist; revised the alternatives to be analyzed in the PEA; and revised the list of potentially significant impacts to be analyzed in the PEA and provided justification for eliminating potential impacts from further study.

The PEA Team held a briefing for the USAID/Ethiopia Mission to discuss fieldwork plans, PEA methodology, including opportunities for USAID input to the PEA, and expected outcomes of the PEA. Prior to conducting site visits, the PEA Team met with USAID/Ethiopia Title II PVOs to discuss the PEA process and interview methodology, and to finalize fieldtrip plans.

The PEA Team visited warehouses in Adama (Nazareth) managed by Save the Children (Save), Catholic Relief Service (CRS), and World Food Program (WFP). The site visits aimed at learning about warehouse operations including sanitation, commodity management, and pest control, including fumigation and IPM measures. The FGPF Specialist conducted warehouse inspections during these visits. The Team toured storage units where fumigation supplies (PPE, sandsnakes, and tarps) are kept and a WFP pesticide storage unit (container converted to a storage shed). They also met with representatives of a community that receives Title II food aid.

Upon the Team's return to Addis Ababa, the PEA Team met with commodity transport companies. These transport companies provide trucks to transport commodity from Djibouti (the port and the pre-positioning warehouse or "pre-po" warehouse) to primary warehouses in Ethiopia. The Team also met with pest management companies that provide fumigation services for USAID/Ethiopia PVOs.

The PEA Team de-briefed the PVOs; this included a short information session on best practices in warehouse management, including sanitation, and fumigation. The PEA Team also provided a de-brief to USAID/Ethiopia on the initial findings of the fieldwork.

PEA TEAM'S FIELDWORK IN DJIBOUTI

The PEA Team followed the food aid backwards, from Ethiopia (the beneficiaries) to Djibouti, the port of arrival in east Africa. In Djibouti, site visits focused on the port, and included the pre-positioning warehouse and other commodity storehouses at the port. The Team held meetings with warehouse management companies, food commodity surveyors, and a pest control company that performs fumigations at commodity warehouses. The PEA Team toured the port operations and visited the commodity bagging facility.

From the individual site visits and interviews with Ethiopia- and Djibouti-based stakeholders, the PEA Team identified key information and lessons that can be applied to Title II on a global basis.

2. BACKGROUND INFORMATION

2.1. USAID FFP TITLE II FOOD AID PROGRAM

The United States (US) is committed to the promotion of global food security through its international food assistance and other foreign assistance programs. USAID's Bureau for Democracy, Conflict and Humanitarian Assistance/Food for Peace (USAID/DCHA/FFP) contributes to this commitment by working to minimize hunger in the world so that people everywhere can enjoy active and productive lives and, ultimately, to ensure that one day no one needs food aid. USAID's FFP Program works for a world free of hunger and poverty, where people live in dignity, peace, and security.

The FFP office, through funding provided by the 2008 Farm Bill, 207(f) Oversight Authority under the Food for Peace Act, P.L. 480, Title II, makes agricultural commodity donations to Cooperating Sponsors (PVOs or NGOs, cooperatives, and public international organization agencies, i.e., the UN's World Food Program, WFP) to address food security in development and emergency food assistance programs. USAID and the State Department submit an annual budget to Congress, which reviews the budget request, determines the level of funding, and approves appropriations bills. Thereafter, FFP establishes annual guidance (posted online) for development and emergency proposals. Once a Title II program is approved, PVOs or IOs order ("call forward") commodities. On behalf of USAID, USDA procures requested commodities listed on "call forwards," evaluates commodity bids, and awards commodity contracts. Working closely with USAID, PVOs or IOs arrange the shipping of commodities from the U.S. port to the recipient country.

In fiscal year (FY) 2010, the U.S. provided more than $1.9 billion of food assistance to developing countries (approximately 2.1 million metric tons under FFP Title II), which reached over 55 million people in 46 countries (U.S. International Food Assistance Report, 2010). In FY 2011, FFP provided approximately 1.4 million metric tons of Title II food aid as part of programs valued at approximately $1.6 billion in 48 countries.

Title II food aid is used in a variety of ways, but always for the people most vulnerable to the effects of hunger: children under age five, pregnant women, the elderly, and the poorest families in a community. During a food emergency[1] in which people face imminent food insecurity, food—wheat, sorghum, corn, and other commodities—is distributed to save lives. If the symptoms of extreme malnutrition have already appeared, a nutritionally fortified ration with blended, fortified, and processed food is provided. In less dire circumstances, food can be used to compensate people for work, such as building roads or repairing water

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[1] A food emergency does not automatically constitute "emergency circumstances" under 22 CFR 216. Reg. 216 exempts projects, programs, and activities from the Environmental Procedures if they are carried out under international disaster assistance, emergency circumstances, or circumstances involving exceptional foreign policy sensitivities. To be exempt, a formal written determination including the justification for an exemption must be made by the Assistance Administrator having responsibility for the program, project, or activity or by the Administrator where authority to approve financing has been reserved by the Administrator.

and irrigation systems. In turn, these projects help protect communities from future hunger by providing a consistent food supply and providing them access to local markets for their produce, preventing chronic malnutrition, and improving their harvests.

Food aid programs may also support:

- Improving in-country agricultural production (linking agricultural producers with American "know-how")
- Improving women's education about nutrition, resulting in healthier babies and children
- Encouraging the production of higher value commodities that could earn money in local markets
- Providing micronutrients, such as vitamin A, iodine, zinc, and iron, that hungry children often lack
- Feeding children at school to encourage attendance and improve academic performance

The USAID Commodity Reference Guide (CRG: (http://www.usaid.gov/our_work/humanitarian_assistance/ffp/crg/sec2.htm) lists a total of 27 commodities that are distributed in food aid programs to countries in the Africa, Asia, Middle East, and Latin America, and Caribbean regions. The types of food and the food aid programs vary by region and country.

Food aid commodities include 13 whole commodities and 13 processed commodities (plus fortified refined vegetable oil). The CRG has links to various USDA sites that provide information on the standards for food-aid commodities, including processed commodities that are distributed either in bulk or in 25 to 50 kg bags made of multi-walled paper or polypropylene (http://pdf.usaid.gov/pdf_docs/PNACK393.pdf). The commodity fact sheets provide information on the purchased commodity characteristics, such as nutritional value, components in processed fortified or blended foods and their percentages, desired packaging, and minimum shelf life, which in most cases is one year. All of the whole cereal grains and legumes purchased for food aid must comply with the United States Department of Agriculture (USDA) Federal Grain Inspection Standards (FGIS) for human consumption.

A LIST OF FOOD AID COMMODITIES THAT MAY BE DISTRIBUTED AS FOOD AID

- beans
- bulgur
- corn
- corn soy blend
- cornmeal
- crude degummed soybean oil
- defatted soy flour
- dehydrated potato products
- emergency food products
- lentils
- peas
- ready-to-use therapeutic food
- rice
- sorghum
- soy protein ingredients
- soy-fortified bulgur
- soy-fortified cornmeal
- soybeans
- textured soy protein
- vegetable oil
- wheat
- wheat flour
- wheat soy blend
- whey protein concentrate

The "Bellmon Amendment" of 1977 to section 401.b of P.L. 480 states that no agricultural commodity shall be made available under Sec. 403 of the Food for Peace Act unless adequate storage facilities are available in the recipient country at the time of export of the commodities to prevent the spoilage or waste of the commodity, and that distribution of the commodity in the recipient country will not result in substantial disincentive or interference with domestic production or marketing in that country. The USAID BEST Project has conducted 13 independent market analyses to ensure that these requirements are met. (Studies can be found at http://www.usaid.gov/our_work/humanitarian_assistance/ffp/bellmonana.html.)

In addition, to complement USAID's in-kind food aid, in 2010 USAID started the Emergency Food Security Program (EFSP). EFSP is a cash-based program used primarily when U.S.-purchased, in-kind food aid cannot arrive fast enough to respond to an emergency or when other interventions may be more appropriate than U.S. in-kind food aid due to local market conditions. In FY 2012, EFSP benefitted over 10.7 million* food insecure people worldwide through a variety of emergency food assistance interventions, including:

- Local and Regional Procurement (LRP) - Food commodities purchased within the country where the food is to be distributed or from a nearby country
- Cash Transfers - Cash provided to beneficiaries to be used to purchase essential food and non-food items for their food security
- Food Vouchers - A voucher for specific essential food items or a set cash amount which beneficiaries use at participating local market vendors

http://www.usaid.gov/what-we-do/agriculture-and-food-security/food-assistance/quick-facts/fiscal-year-2012-emergency-food

2.2 USAID TITLE II FOOD AID VALUE CHAIN

As mentioned, the USAID FFP office makes agricultural commodity donations to PVOs, who are involved in development and food relief programs globally. To this end, USDA works with USAID/DCHA/FFP to determine the amounts that will be procured for international food aid commodity distribution, out of the available commodity stocks or projections thereof. Procurement of food aid commodities is further programmed to coincide with the food preferences and/or past food aid programs of the recipient countries, which leads to the overall annual procurement list.

USAID provides a list to PVOs of eligible US agricultural commodities, including processed and value-added products. PVOs can then choose from this list, and based on their local assessments of markets and needs, PVOs identify the types and amounts of commodities required and a schedule for delivery. In some cases, on their website, the USDA's Foreign Agricultural Service (FAS) solicits requests for food aid.

USDA's Kansas City Commodity Office (KCCO) of the Farm Service Agency (FSA) solicits bids for specific commodities being procured for aid distribution. The KCCO is responsible for buying the types and amounts of commodities identified on PVO's call forward. Commodities may be furnished from the inventory of USDA's Commodity Credit Corporation (CCC) acquired under price support programs or purchased from private stocks.

USDA procures the requested commodities by issuing a tender to commodity suppliers and processors. USDA evaluates the commodity bids and picks the one(s) that would result in the lowest landed cost based on a combination of the cost of the commodity and the cost of shipping it to the destination country. USDA awards the commodity contract, which identifies the dates that the commodities must arrive at a US port and be ready for shipping. The PVO, through a tender process, arranges for the cargo to be shipped from the US port to the recipient country. Once the PVO acquires ownership of the commodity, it is responsible for handling and management of the commodity, including storage and distribution of the food aid to beneficiaries in accordance with its agreement with USAID.

Whole commodities within the US may be transported, by truck or railcar, directly to port and shipped as bulk commodity; or they are shipped from the farm to processing facilities to make processed foods such as flour or various fortified blends. Flour is usually bagged in polypropylene bags to prevent condensation and spoilage by molds and bacteria, whereas blended products are bagged in multi-walled plastic and paper bags to prevent insect infestations, product contamination, and spoilage. Trucks then transport processed and bagged materials to ports.

Food aid may be shipped overseas from ports on the east coast, west coast, Great Lakes, and Gulf of Mexico. In FY 2008, about 80.6% of the 2.8 million MT of food aid was shipped from Gulf Coast ports, mainly in Texas and Louisiana (Anonymous, 2010). At ports in the US, food aid commodities are shipped as dry bulk (unprocessed commodities) in vessel holds or as bags (unprocessed and processed) in containers of 6.1 to 12.2 m (20 to 40 feet) long. General cargo shipments may include packaged commodities shipped break bulk in vessel holds or barges. Tanker-type vessels are used for liquids such as vegetable oil. (Vegetable oil is not of concern for infestations, is not fumigated, and therefore, is not included in this PEA.)

ABOVE: USAID provided humanitarian aid in the aftermath of several disasters in 2007, including Cyclone Sidr, which struck Bangladesh Nov. 15. Sue McIntyre. 2007.

Upon reaching its destination, the food is used in a variety of ways. Food aid intended for use in disaster relief, economic development, and other assistance must comply with 22 CFR Part 211 (http://www.usaid.gov/work-usaid/get-grant-or-contract/grant-and-contract-process). The regulations cover transfer authorization for government and non-governmental PVOs receiving food aid. Delivery by the US to the PVO is regarded as complete if the commodity ordered for shipment is within a tolerance of 5% (2% in the case of quantities over 10,000 metric tons) of the quantity ordered. There is no tolerance with respect to the ocean carrier's responsibility to deliver the entire cargo shipped and the US assumes no obligation for failure by an ocean carrier to complete delivery to a port of discharge. The PVO must provide assurance to USAID that all necessary arrangements for receiving the commodities have been made, and must assume full responsibility for storage and maintenance of the commodities from time of delivery at port of entry abroad or, when authorized, at other designated points of entry abroad agreed upon between the PVO and USAID.

Prior to shipment, food aid may be fumigated at US port warehouses, in containers, or in in-transit vessels. Only phosphine can be used for in-transit treatment of commodities in vessels (see Annex A for information on fumigation of vessels during transport); stationary commodities can be fumigated with sulfuryl fluoride, methyl bromide, or phosphine. Port or in-transit fumigations are done to kill any live insects in raw commodities or to kill eggs present in processed commodities.

Food aid shipped in vessels is received at designated ports for delivery to various countries (http://www.worldportsource.com/countries.php). When it reaches the receiving port, marine surveyors contracted by the PVO inspect the cargo to determine quantities received and their general condition. The fumigation and phytosanitary certificate that was issued when the cargo left the US port is examined. Surveyors may make a recommendation for fumigation of the containerized or bagged commodities at the port or in a warehouse near the port prior to loading of trucks.

After clearance by marine surveyors and customs, bulk dry commodity is unloaded at the port pneumatically and by conveyor belts either to a flat temporary storage or to feeders above bagging lines for continuous bagging in USAID-labeled bags. Torn or damaged bags holding raw commodities are re-bagged at the port. Damage to multi-walled paper bags is repaired by sealing them with tape.

If all the unloaded material cannot be bagged, the remainder of the bulk material is stored in flat storages. If delivery is to occur to a landlocked country, bagged commodity at the ports is loaded onto containers or trucks and shipped to a primary warehouse. All shipments to secondary, and tertiary (distribution points) warehouses, before reaching beneficiaries, are by trucks (see Annex B for a chart of the commodity supply chain). Some PVOs, such as World Vision (http://www.worldvision.org), use a web-based supply chain management (WBSCM) system throughout the commodity supply chain from the US to the final destination to track and document food aid procured and shipped.

Depending on a country's capacity of port facilities, availability of trucks, and the demand for other materials, such as fertilizers and cement, rather than unloading immediately, food aid may remain on the vessel and unloading may be delayed until other commodities have cleared the port. Delays in unloading could predispose commodities to infestation and, especially by insects, and spoilage. The limited supply of trucks may also result in commodities being stored in containers or at a port warehouse, where they may be exposed to insect infestations.

Commodities may become infested if stored for more than 30 days, and fumigation may be necessary. Insect infestations may be severe especially if bags are damaged or torn. Therefore, reducing the time food aid is stored from the time it arrives at the port until it reaches the beneficiaries, maintains the commodity's integrity and quality, may reduce insect incidence, and may reduce the need for pesticides, including fumigants.

2.3 INTRODUCTION TO PHOSPHINE FUMIGATION AND PHOSPHINE CHEMISTRY

2.3.1 PHOSPHINE FUMIGATION

Fumigation is the act of introducing a pesticide into an enclosed space in such a manner that it disperses quickly and acts in a gaseous state on the target organism. Pesticides formulated as fumigants have physical characteristics which cause them to occupy all air spaces within an enclosed area and to penetrate the commodity within these areas. Phosphine is adsorbed into each kernel, killing insects within the kernel, and then desorbs when exposed to air.

Presently, methyl bromide, phosphine, sulfuryl fluoride, and carbon dioxide are the four most commonly used fumigants. Several fumigants used in the past such as hydrogen cyanide, carbon disulfide, ethylene dibromide, and carbon tetrachloride are no longer used because of adverse human health and environmental effects. Under the Montreal Protocol, because of its ozone-depleting effects, methyl bromide was phased out in 2005 in developed countries and will be phased out by 2015 in developing countries. Methyl bromide is currently used in the US for pre-shipment and quarantine treatments. Before the phase-out, it was used for disinfesting empty grain- and food-processing facilities, but not for commodities. Sulfuryl fluoride, a non-ozone depleting fumigant, was registered in 2004 by the USEPA for use as a commodity and structural fumigant. Currently, USEPA is soliciting a second public comment before making a regulatory decision to revoke its food tolerances. Phosphine is the generally accepted alternative to methyl bromide for treatment of commodities. Carbon dioxide is cost-prohibitive and requires special equipment, leaving phosphine as the cost-effective front-line fumigant to control insect pests in the world's grain stocks. Most modern fumigation is done using aluminum phosphide; magnesium phosphide releases phosphine too quickly for optimum fumigator safety.

Various means can be employed to prevent insects from attacking stored products, but once they get into a stored product, few practical solutions, besides aluminum and magnesium phosphide, are available (http://www.aces.edu/pubs/docs/A/ANR-1154/). Aluminum and magnesium phosphide may be used to eliminate insect infestations in a variety of commodities, including animal feed and animal feed ingredients, corn, cottonseed, grass seed, millet, oats, peanuts, pecans, popcorn, rye, sorghum, soybeans, triticale, and wheat. They may be used for a variety of processed foods as long as the residue dust does not get in direct contact with the product. They can be used on some non-food commodities including straw and hay, cotton, feathers, tobacco, dried plants, and flowers, and on seeds. Phosphine fumigants may be used in a variety of structures including grain bins and silos, rail cars, warehouses, and flat storage structures. One of the major advantages of fumigation with phosphine is that insects can be controlled without moving the stored commodity.

The fumigation process starts with the introduction of the fumigant into a space or commodity that has been properly enclosed, placarded, and secured. It ends when aeration has rendered the space or commodity at or below established safe limits specified in the product label. An integral part of the fumigation process is the safe disposal of the spent fumigant, according to label directions, upon the completion of fumigation.

Fumigant application methods differ depending on (i) the fumigant formulation being used, (ii) the site/area being treated, and (iii) the target pest. Aluminum phosphide is available in several forms, including tablets, pellets, granules in a sachet or small, porous bag, ropes, and blankets. Fumigation of infested grain using a solid fumigant product may involve applying tablets/pellets into the grain with a probe, the use of an automatic dispenser at grain elevators, which uniformly applies the fumigant throughout the grain mass as the bin or silo is filled, or placement of tablets on trays or in envelopes which are then placed beneath pallets of commodity enclosed by polythene sheets or tarps. When liquid phosphine (liquefied gas or liquefied gas under pressure), is used as a fumigant, such as in the ECO2FUME® (http://www.cytec.com) formulation, it is introduced into the treated site through approved tubing, where it disperses as a gas for quick distribution throughout the fumigated area. Cylinderized phosphine greatly minimizes worker hazards inherent when using tablets/pellets, but the formulation is not registered in many countries.

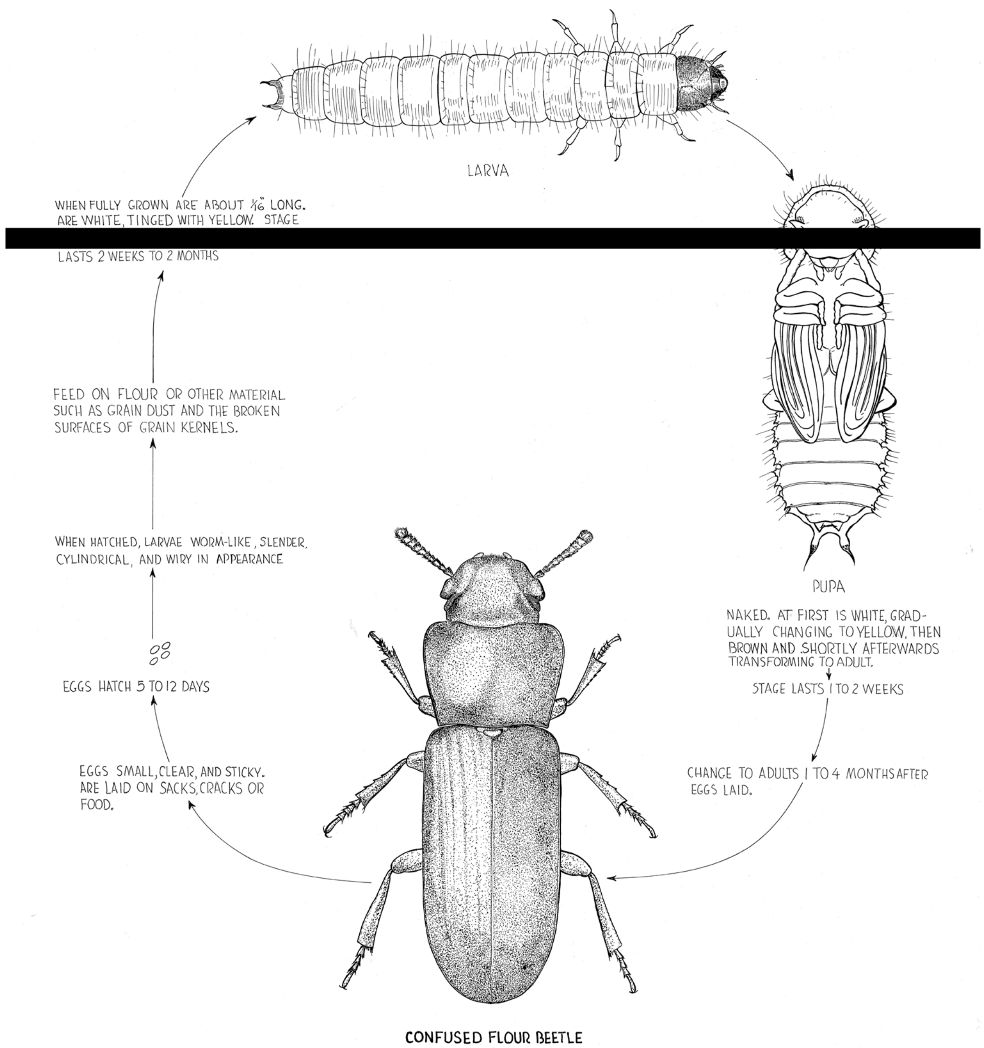
Each aluminum phosphide tablet weighs 3 grams and releases 1 gram of gas; pellets weigh 0.6 grams and release 0.2 grams of gas, and sachets weigh 34 grams and release 11 grams of gas. The speed of gas release is faster with pellets, followed by tablets, then sachets in accordance with surface area. At high temperatures, it may be safer to use tablets because they break down slower than pellets. Tablet residues in grain can be avoided by putting tablets in a single layer on trays, suspending trays in the headspace, or placing trays on the grain surface to assure full reaction. An alternative to using tablets is to use phosphine products that are sold as bag chains, belts or blanket formulations; disposal of spent residue is easier to do with these formulations.

While phosphine is very toxic to mammals, its toxicity to insects is more variable, and depends on the concentration of the gas, grain temperature, and exposure time. Its effectiveness differs from one insect species to another, and between each life stage of the insect; the eggs and pupae are usually least susceptible to the effects phosphine. Furthermore, effectiveness is influenced by the development of insect resistance that results from selective breeding of survivors in poorly sealed fumigated structures.


ABOVE: Flour Beetle (Tribolium castaneum).

Stored-product insects have developed resistance to different classes of pesticides including fumigants (Subramanyam and Hagstrum, 1996). According to http://graintechsystems.com/Fumigation.htm, the gradual (and sometimes rapid) development of insect resistance has forced fumigators to increase the minimum recommended dosages, which in some cases may be as high as 100 ppm for 28 days or 200 ppm for 15 days. However, it is no longer possible to make generalized recommendations for insect management since insect resistance to phosphine can vary widely among countries, regions, and even individual storage situations. In most countries, good fumigation practices are not techniques practiced routinely (e.g., maintenance of fumigant concentrations during the effective period); as such, fumigation does not guarantee the mortality of all insect populations. Instead, application of phosphine under leaky storage conditions and shortened fumigation times may allow some insects to survive; the survivors have the greatest tolerance to phosphine. Through this selection mechanism, the most tolerant insects pass on their phosphine resistant genes to their progeny, developing increased insect resistance. In many cases, insect resistance has dramatically reduced the effectiveness of phosphine as a fumigant. This may represent a serious threat to the world's food-stocks of the future if nothing is done to reverse the trend (Subramanyam and Hagstrum, 1996).

As the gas is released from tablets and pellets, the concentration of phosphine increases rapidly in a linear fashion in the fumigated enclosure; then the gas dissipates or decays exponentially; and after clearance, the gas loss becomes semi-logarithmic (Anonymous, 1989). Phosphine gas moves readily through grain from the point of application. The intent of any fumigation is to maintain sufficient concentration of the fumigant for enough time to kill pests. Because of its high vapor pressure (40 mm Hg at -129.4°C), phosphine gas that permeates from the fumigated site dissipates quickly into the atmosphere, where it is degraded by photoreaction with hydroxy radicals. Its half-life in sunlight is five hours. Phosphine leaks quickly through holes in silos or sheeting; therefore impervious containerization is important for effective fumigation. Wind and large temperature changes accelerate phosphine loss. Most phosphine is lost within four days from fumigations in ordinary, unsealed storages.



CONFUSED FLOUR BEETLE
(*Tribolium confusum* (Duv.))

BEETLES ELONGATE, SHINY, REDDISH-BROWN, ABOUT 1/7" LONG. HEAD AND UPPER PARTS OF THORAX DENSELY COVERED WITH MINUTE PUNCTURES AND WING COVERS ARE RIDGED LENGTHWISE AND SPARSELY PUNCTURED BETWEEN THE RIDGES. RESEMBLES RED FLOUR BEETLE.

FLOUR BEETLE LARVAE

The minimum exposure periods with phosphine vary with temperature. Fumigation is not recommended at temperatures below 15°C because insects are inactive at these temperatures. Phosphine is usually most effective at temperatures between 20 and 35°C. At temperatures of 25°C or above, the exposure periods should be 7 to 10 days (Anonymous, 1989; van Someren Graver, 2004). Some labels recommend 2 to 3 days of fumigation, but such short fumigations provide ineffective insect control. Insects are killed slowly by phosphine gas. The fumigant must be kept in contact with the insects for at least 7 to 10 days to kill insects in all stages (eggs, larvae, pupae, and adults) of their life cycle. All life stages are typically found in stored grains. Extending fumigation to 7 days or longer allows the tolerant egg stage to develop into the susceptible larval stage and the tolerant pupal stage into the susceptible adult stage. Longer exposures are also effective for controlling insect strains resistant to phosphine. Fumigation in ordinary, unsealed storages will kill some adults and larvae but most eggs and pupae will survive to adulthood and continue the breeding cycle. Fumigation gives no residual protection to stored grain—insects can re-infest the commodity after the phosphine gas concentration has dissipated.

Phosphine is effective against insects in most types of grain. But some commodities (for example, brown rice, paddy rice, legumes, linseed, and cottonseed) soak up (adsorb) phosphine very quickly, leaving little to kill insects (http://www.aces.edu/pubs/docs/A/ANR-1154/). Therefore, dosage rates of phosphine vary with the commodity being fumigated. For highly sorptive commodities the dosage may need to be doubled from 3 tablets/metric ton to 6 tablets/metric ton. (See: "The relation between phosphine sorption and terminal gas concentrations in successful fumigation of food commodities." http://www.ncbi.nlm.nih.gov/pubmed/17051623 and Food Protectants and Infestation Control Department, Central Food Technological Research Institute, Mysore 570 020, India.)

After fumigation, the gas must be vented to a legal and safe level for human exposure; in the United States, this level is ≤ 0.3 ppm. This is required regardless of the type of structure; however different types of structures may require different safety considerations or engineering controls (http://www.aces.edu/pubs/docs/A/ANR-1154/).

2.3.2. PHOSPHINE CHEMISTRY

Phosphine gas is produced when aluminum or magnesium phosphide formulations react with moisture in ambient air. As phosphine gas is generated through reaction with water that is present in ambient air, ammonium carbamate decomposes to ammonia gas and carbon dioxide gas. The reactions for the generation of phosphine and ammonia are shown in the following equations (Degesch America, Inc., 2010; 2011):

$$AlP + 3H_2O \rightarrow PH_3 + Al(OH)_3$$
$$Mg_3P_2 + 6H_2O \rightarrow 2PH_3 + 3Mg(OH)_2$$
$$H_2NCO_2\text{-}\ NH_4+ \rightarrow 2NH_3 + CO_2$$

In addition to phosphine, each metallic phosphide produces the corresponding metallic hydroxide (aluminum and magnesium hydroxides, Al(OH)3 and Mg(OH)2). The spent hydroxides, depending on the formulation, may contain 0.5-1.0% phosphine gas. After decomposition, phosphide formulations leave a grayish white powder consisting of aluminum hydroxide and other inert ingredients. When exposed properly (i.e., allowed to react for adequate duration and applied at a rate consistent with the volume to be fumigated) the residual materials are considered to be non-hazardous (Degesch America, Inc., 2010; 2011).This spent powder with minute amounts of unspent phosphine must be retrieved for disposal after fumigation, usually buried in the ground away from the fumigated structure or deactivating in a drum containing water and soap. Several other methods for deactivation are given in phosphine product labels.

The inert ingredients in phosphine formulations include ammonium carbamate, ammonium bicarbonate, urea, and paraffin wax, and may include other impurities such as calcium, sodium, and heavy metals (Pan et al., 2005). Some formulations of aluminum and magnesium phosphides contain ammonium carbamate to reduce fire and explosion hazard and as an odoriferous warning agent (USEPA, 2006).Phosphine formulations can be corrosive and can damage equipment if used improperly. Pure phosphine does not have an odor; the odor (most often described as garlic, acetylene, or decaying fish) detected during a phosphine fumigation is due to substituted phosphines and diphosphines (Anonymous, 1999). While the odor can serve as a warning, it is not meant to be used as an indicator of a safe or unsafe work environment, nor does it have an impact on commodities.

3. ALTERNATIVES INCLUDING THE PROPOSED ACTION

The sections below provide a description of the proposed action—fumigation of food aid commodity using aluminum or magnesium phosphide; and of alternatives to fumigation, as identified in the Scoping Statement and revised by the PEA Team. (In some cases in this PEA, aluminum phosphide is discussed rather than both magnesium and aluminum phosphides because aluminum phosphide is far more common in Title II countries. Under warm conditions found in most Title II countries, magnesium phosphide releases gas more quickly than aluminum phosphide, thus increasing risks to fumigation personnel; in cooler weather, magnesium phosphide would be a better choice than aluminum phosphide, but in Title II countries, if magnesium phosphide were to be used, the gas will be released too quickly, while workers are still putting tablets under pallets.)

3.1. DESCRIPTION OF THE PROPOSED ACTION: FUMIGATION OF FOOD AID COMMODITY USING ALUMINUM/MAGNESIUM PHOSPHIDE

This section describes the fumigation process as it is implemented in accordance with international standards and best practices (i.e., in accordance with labeling). Section 1 (Summary) and Section 5 (Environmental Consequences), describe the PEA Team's findings regarding how fumigation is actually practiced in the field and the potential health and environmental impacts resulting from those practices.

3.1.1. ALUMINUM/MAGNESIUM PHOSPHIDE FUMIGATION PROCESS

Decision to fumigate: In the US, fumigation with phosphine is done on a calendar-basis rather than as a result of pest monitoring indicating a need. In Title II situations, a decision to fumigate may be made on a calendar-basis or may be based on the observation of live insects, either in the warehouse or in the commodity (i.e., a threshold should be established, and if in excess of this "infested" category, fumigation would be initiated). Decision making based on the results of pest monitoring avoids repeated treatment of the commodity with phosphine and allows PVOs to use phosphine only when needed (see Annex T-611 for decision-making criteria). Sampling-based decision-making is useful when only a portion of the total storage structure will be fumigated. If the entire structure is to be fumigated, sampling adds additional costs for storehouse managers; in this case, it is more cost-effective to use a calendar-basis fumigation schedule.

The PEA Team found that at Title II warehouses, a range of decision-making practices is in place. At some, a decision to fumigate is based on observation of insects; some warehouses probe bags to check for insects; and other warehouses automatically fumigate every six weeks to three months. During field visits to Ethiopia and Djibouti, PVOs and fumigation service providers indicated that if live insects are found in the commodity or on the bags and in the warehouse, all of the stacks in that warehouse are treated with phosphine to prevent cross contamination to uninfested stacks.

Preparation of a Fumigation Management Plan: In the US, a Fumigation Management Plan(FMP) for grain in a bin/silo, warehouse, rail car, trucks, or vessels is a label requirement when fumigating with phosphine. An FMP is a written description of the steps designed to plan for a safe, legal and effective fumigation. Site inspection, sealing, notification of emergency responders and bystanders, gas monitoring plans, placarding, and post-application procedures are all part of the FMP(Annex T-3). Some plans are more comprehensive than others. In the US, the certified applicator and owner of the property to be fumigated addresses characterization of the structure and/or area and includes all safety requirements in the plan prior to application. A new FMP is not needed for every fumigation of a facility if conditions will remain the same; only general updates such as temperature and humidity recordings are needed in such cases. The FMP and related documentation, including monitoring records, is maintained for a minimum of two years. See FMP template in Annex T-3.

Fumigation workers: Federal (US) labeling allows trained workers to do certain activities associated with fumigations, but some US states may be more restrictive than others and require that a certified applicator (CA) always be physically present on site (see Annex H). A CA is someone who has passed a state (US) exam and is trained in a particular category such as aerial application or fumigation to use restricted use pesticides. Individuals receiving specific instructions from a CA in documented training sessions are classified as trained applicators. One CA and another trained person are the minimum personnel required when aluminum/magnesium phosphide is applied in the US. Most fumigation activities in the US are carried out by a CA or by a trained worker under the direct supervision of a CA. In some US states, certain activities can be turned over to a trained worker to complete the fumigation independently in the absence of a CA. The CA may remain in voice contact if needed but not physically present (some form of communication device, such as a radio, a walkie-talkie, or a cellular phone is required).

The specific activities that a trained worker may undertake in the absence of a CA are the following (http://www.epa.gov/oppsrrd1/reregistration/alphosphide/fumigation_qa.pdf):

- Monitoring the fumigation site for gas leaks and accumulation of phosphine gas above permissible limits
- Completing the aeration of a structure after the aeration has progressed and stabilized
- Removing placards after the aeration is completed
- Receiving, aerating, and releasing the content of a vehicle fumigated in-transit (in the US, transporting vehicles under fumigation over public roads is prohibited)
- Transferring an unaerated commodity from one in-transit container to another storage site to continue degassing
- Disposal of any spent fumigant
- Maintenance of written records of all permitted actions performed.

Preparing the structure or stack: According to http://www.aces.edu/pubs/docs/A/ANR-1154/, the structure or stack must be sealed because:

- If not, the gas will probably leak before it reaches a sufficiently high concentration to kill all the insects, which can lead to spoilage and insect resistance.
- Unsealed or poorly sealed structures are safety hazards.
- Sealing the structure before fumigation is the law (in accordance with the labeling).

Various materials are used to seal structures and stacks, including plastic (1 mm (4-mil-thick) or thicker non-gas permeable), duct tape, expanding foam, and caulk (see Annex T-6 for fumigation tarp specifications). Prior to fumigation, all cracks and crevices are filled and treated with an approved residual contact insecticide prior to loading the commodity into the structure. Sealing quality of the area to be fumigated is determined by a simple pressure (half-life) test (Adler et al., 2000), where a drop from 100 Pa to 50 Pa should be 30 to 180 seconds.

Gas monitoring during fumigation: Respiration rates of insects are much slower than those of humans, especially in cooler temperatures. Only minutes of exposure of a given concentration of phosphine can be very dangerous to humans while the same concentration may take days to kill insects. Monitoring for safety of workers and bystanders is mandatory according to the label (US) and is performed to determine (i) when and where respiratory protection is required, (ii) whether phosphine gas is escaping and is accumulating at unsafe levels in areas other than the treated area, and (iii) to take proper actions to prevent occupational or accidental exposures. Once fumigation has started and gas containment has been adequately characterized, spot checks are made, especially if conditions change significantly (e.g., windy weather) or if an unexpected garlic odor is detected (as mentioned above, garlic odor is not a reliable indicator of leakage) or a change in phosphine concentration outside the fumigation area is detected.

Knowledge of the phosphine gas concentrations during the fumigation process is required as part of compliance with label instructions primarily for protection of workers and bystanders. The (US) label requires that a log be kept showing phosphine gas concentration at key locations surrounding the structure. The type of respiratory equipment used depends on the gas concentration (Annex T-8 provides information on respiratory equipment and other PPE). Furthermore, the gas inside the structure is monitored (using pre-positioned plastic/nylon gas monitoring lines from a safe outside location) to make sure a concentration of gas lethal for insects is present for the duration of the fumigation.

In the US, the CA is responsible for ensuring plans are in place for conducting required safety monitoring during the fumigation period. Trained workers or the CA may perform monitoring (trained individuals may want to verify gas concentration in a railcar are 0.3 ppm or below prior to unloading the cargo, or verify efficacy of grain fumigation underway, etc.). Trained workers must know how to properly use the detection equipment and how to implement site-specific evacuation procedures if necessary.
There are a number of devices on the market for the measurement of phosphine gas. The devices range from glass tubes to electronic and photo ionization equipment. Detection tubes for low and high range concentrations with air sampling pumps, portable devices, and electronic devices may be used to monitor phosphine gas concentration. The average accuracy (percent of time the readings are close to actual concentration) among the available electronic devices ranges from 60 to 100% (Danley et al., 2005). Electronic devices need to be calibrated every four to six months for accurate reading. Tube-type devices are more accurate, but are subject to operator error when reading the tubes. A ±20% accuracy in fumigation readings during commercial fumigations is acceptable, but a ±5% accuracy is needed for fumigant residue determinations (Anonymous, 1989). Gas monitoring equipment is discussed in detail in Annex T-8.

Monitoring for efficacy involves the placement of gas monitoring lines within the structure/stack and determining whether adequate phosphine gas concentration has been reached. Measurement within the commodity will determine whether lethal concentrations (200-300 ppm) have been held for the duration of exposure (7 to 10 days). Efficacy monitoring will also help to determine whether or not to add more fumigant during fumigation because of poor distribution within the structure/stack or to supplement gas loss due to leakage. This type of monitoring is not a label requirement, but it is typically conducted for effective insect control.

Aeration/Ventilation: The fumigated warehouse and commodity is aired before entering or handling the product to ensure that the phosphine gas levels have dropped to 0.3 ppm or less. If there is a need to enter the structure during ventilation, respiratory protection is used until the air-monitoring equipment indicates that the concentration of phosphine gas is less than 0.3 ppm. Finished foods and feeds that have been fumigated with phosphine are typically aerated for 48 hours before being offered to the end consumer. An alternative is to test the commodity to determine if the phosphine residue is less than 0.1 ppm in animal feed, 0.01 ppm in processed foods, or 0.3 ppm for nonfood items.

Personal Protective Equipment: Cotton or other gloves are worn when handling phosphine tablets and pellets to prevent any gas release and burns from moisture (sweat) on hands. Respiratory protection is important when applying or aerating fumigated structures/sites. A self-contained breathing apparatus or a line with air supply is worn when entering an area where the fumigant concentration is unknown or exceeds 15 ppm or exceeds the short-term exposure limit (STEL) of 1 ppm for 15 minutes. A NIOSH/MSHA approved full-face gas mask is used at levels up to 15 ppm. A full-face canister mask can be worn at concentration of 15.1 to 1,500 ppm only for escape (to remove another affected person from the fumigated area). The approved respirators and concentration limits are given in the NIOSH/MSHA Pocket Guide DHHS (NIOSH) 97-140 or the NIOSH Alert-Preventing Phosphine Poisoning and Explosions. Respirators need to be properly fitted so they are tight to the face and do not allow leaks, and need to be regularly maintained. Evidence to support these worker exposure standards is described in detail by Pepelko et al. (2004).Annex T-8 contains information on the use and maintenance of PPE.

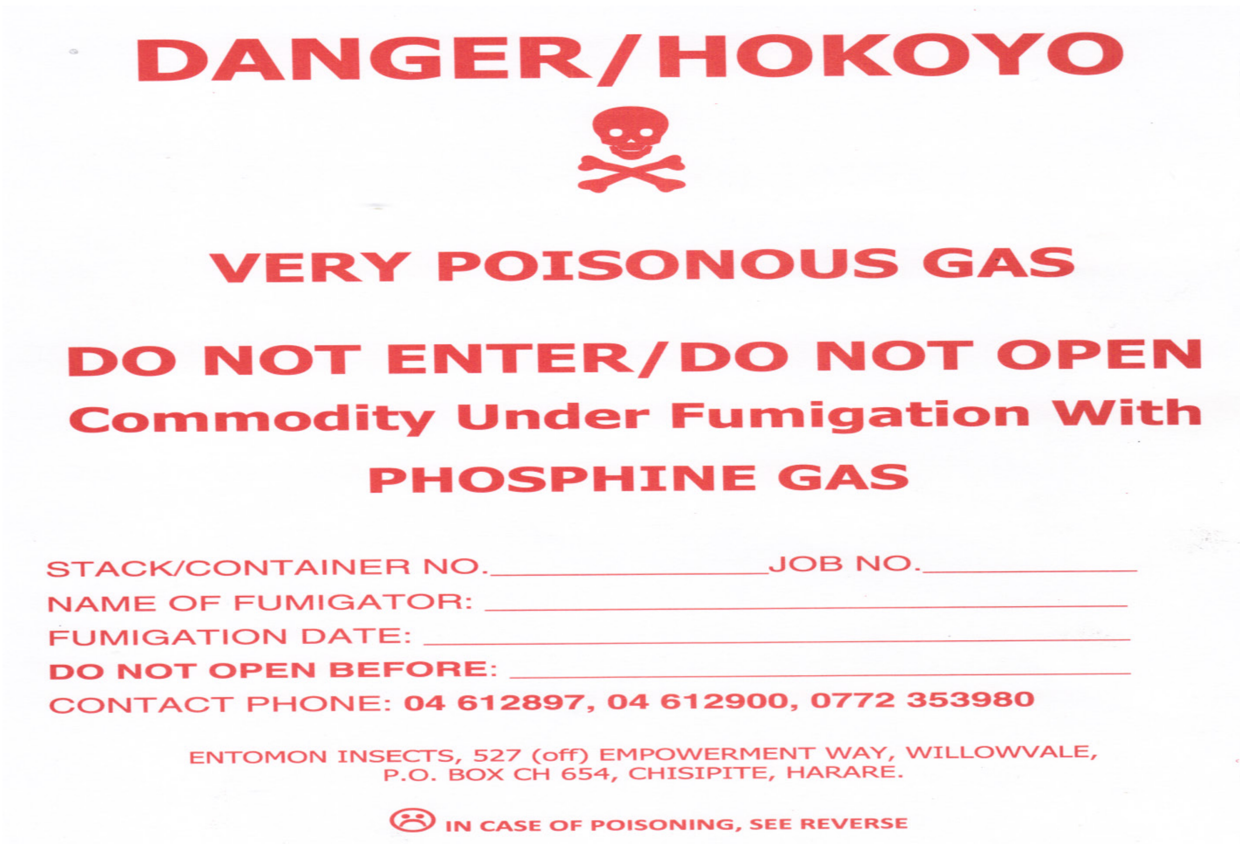
3.2 DESCRIPTION OF ALTERNATIVES TO PHOSPHINE FUMIGATION

Alternatives to the proposed action (*Phosphine Fumigation of Food Aid Commodities*) from the Scoping Statement as revised by the PEA Team are described below, as well as additional alternatives developed during PEA preparation. The alternatives described in this section meet the purpose and need of the project (to control pests in Title II food aid) and are considered practicable. These alternatives will be analyzed in Section 5 against the potentially significant adverse impacts. Alternatives that the PEA Team eliminated, after further analysis, from detailed study in this PEA are described in Section 3.3.

Alternative 1) Use modified and controlled atmospheres: The use of modified and controlled atmosphere treatments for stored commodities has received increasing attention from the scientific community over the last 35 years. Banks (1981), Adler et al. (2000), and Jayas and Jeyamkondan (2002) provide information and assessments on stored-product protection by modified/controlled atmospheres.. These alternatives use carbon dioxide (CO2) or nitrogen (N2) to replace oxygen (O2) levels within commodities or structures. They are used to control pest insects, microorganisms, or to maintain product quality. They are a popular form of pest management in organic farming in the US. In a controlled atmosphere treatment, a constant low oxygen atmosphere is maintained at a level lethal for organisms; in a modified atmosphere treatment, the atmospheric composition changes during the treatment period. Controlled atmospheres are used in ECO2 chambers (see below), where a constant level of CO2 or N2 can be maintained. Lethality in low O2environments is due to limited oxygen availability for respiratory metabolism; whereas high carbon dioxide environments inhibit respiratory enzymes and lead to less energy (adenosine triphosphate [ATP]) generation and the accumulation of toxic products (Mitcham et al., 2006).

Modified and controlled atmospheres can be used to treat stored rice, grain, and other bagged and packaged commodities. This alternative can be used for commodities in stacks, stored in sealed bins, or in other enclosures. Stacks, enclosures, and containers must be airtight with a facility to add gas, if needed. Treatment success depends on the quality of the plastic sheeting used, and tightness of the seal between the polythene on the floor and on the stacks. An enclosure treated with carbon dioxide atmospheres should be checked for gas tightness using a pressure test (Banks and Annis, 1980). An applied pressure of 500 Pa (using compressed air or CO2) should decay to 250 Pa within 5 minutes. For N2this half loss time should be 15 minutes (Bailey and Banks, 1975). For effective insect control, atmospheres should have at least 60-95% CO2 and O2 levels should be 2% or less. Unlike N2, CO2rich atmospheres also exert a toxic effect due to hypercarbia (Calderon and Navarro, 1979). Insects under these atmospheres open their spiracles (respiratory openings on the exterior of the body), which facilitates their rapid desiccation. Mortality of stored-product insects and mites in low O2 atmospheres or in high CO2 atmospheres can take 2 to 56 days depending on the species, insect life stage, temperature, and relative humidity (Bell, 1996; Krishnamurthy et al., 1986; Banks and Fields, 1995) (see Table 2 below).

A DANGER PLACARD IN ENGLISH AND SHONA FOR A PHOSPHINE FUMIGATION EVENT IN ZIMBABWE



A company in Netherlands (ECO2 , http://www.eco2.nl) developed a controlled atmospheric treatment chamber that creates low O2 environments by means of an O2 burner or a N2 generator, resulting in O2 levels of less than 2%. The system has the ability to control temperature, gas concentration, and humidity to ensure 100% control of all insect stages of stored-product insects within 3 to 5 days. Chambers of various sizes can be custom built at warehouses, food-processing facilities, or port terminals to treat palletized products, products on trucks, and products within containers. The systems are available in 14 countries in Latin America, Asia, Africa, the Middle East, and Europe. One thousand to 20,000 metric tons can be treated yearly with the chambers.

The ECO2 chambers are of two types. One is a mobile unit for treating commodities stored in silos, while the other is a permanently installed structure. Both types can be used at port warehouses and primary warehouses. All ECO2 chambers can be leased or purchased. Each permanently installed chamber can hold 52 pallets with bags in two layers or 26 pallets in one layer. If one assumes one treatment per week for one year (52 weeks), a total of 2,704 pallets with bags can be treated. It costs about US$60 per year or US$11.2 per pallet per ton to rent the permanent systems—much more expensive than fumigation with phosphine which costs about US$ 0.59 per ton. If purchased, the system would cost about US$268,000 with a yearly maintenance cost estimated at US$10,000.

Efficacy: Mortality of stored-product insects and mites in low O2 atmospheres or in high carbon dioxide atmospheres can take 2 to 56 days depending on the species, insect life stage, temperature, and relative humidity (Bell, 1996; Krishnamurthy et al., 1986; Banks and Fields, 1995) (see Table 2 below). The recently developed rapid treatment system of ECO2 chambers provides complete insect control within5 days.

TABLE 2: EXPOSURE TIME IN DAYS REQUIRED TO CONTROL DIFFERENT STORED-PRODUCT INSECTS AND MITES WITH MODIFIED ATMOSPHERES AT DIFFERENT TEMPERATURES (SOURCE: BELL, 1996).

Species and stages	60-95% carbon dioxide			<1% oxygen		
	15°C	20°C	25-30°C	15°C	20°C	25-30°C
Grain mite, all stages[a]	6-10	8-14	____[b]	7	____	____
Rusty grain beetle, adults	7	____	____	10	6	2
Almond moths, eggs and larvae	7	____	____	6	5	2
Cigarette beetle, all stages	____	____	6	____	9	6
Psocids, all stages[c]	10	8-14	____	____	____	____
Sawtoothed grain beetle, adults	5	____	3	10	3	____
Indianmeal moth, eggs and larvae	7	7	____	>14	>4	____
Lesser grain borer, all stages	28	____	____	>28	____	____
Rice weevil, all stages	28	____	>18	____	>28	>18
Granary weevil, all stages	42-56	____	>9	>49	>14	____
Red flour beetle, adults	6	____	3	7	4	2
Khapra beetle, larvae in overwintering stage	____	>18	>17	____	____	14
Cheese/mold mite, all stages[d]	____	>14	6	____	____	____

[a]Grain mite species is *Acarus siro* L.; [b]Data not available; [c]Psocid species is *Liposcelis bostrychophila* (L.); [d]Cheese mite species is

Alternative 2) Use hermetic or airtight storage structures: The use of hermetic structures is sometimes described as an "old" technology (Hyde et al., 1973; De Lima, 1990). Unlike modified/controlled atmospheres that are used to purge commodities or structures (Alternative #1 above), in hermetic storage structures, respiration by insects, molds, and grain results in a lowered resident O_2 level with a concomitant increase in CO_2. Grain stored hermetically must be properly dried to recommended moisture (or dryness) levels for each grain or product. Hermetic storage structures, such as airtight metal drums, have been used successfully for controlling stored-product insects in Africa (Seck et al., 1996; Murdock et al., 2003; and Obeng-Ofori, 2011). GrainPro has conducted a cost-benefit analysis comparing hermetic storage versus alternative storage facilities (http://www.grainpro.com/)

Triple-bagging technology, developed by the Purdue Improved Cowpea Storage (http://www.ag.purdue.edu/ipia/pics) in collaboration with research institutes in west and central Africa, is a hermetic storage technology in which grain is sealed in two high-density polyethylene (HDPE) sheets which are then placed in a polypropylene outer bag (Murdock et al., 2003). Two HPDE bags of at least 80 – 100 µm thickness should be used to prevent insects from damaging the bags and to obtain effective insect control (Sanon et al., 2011). Extensive tests conducted with cowpeas and the cowpea weevil, Callosobruchus maculatus (F.), under laboratory and field conditions (Sanon et al., 2011) showed that this technique was effective in providing very good control of bruchids over the even-month test period without loss of seed germination. Observed O_2 level 5 days after storage was 6%; low levels of insects were alive for at least 28 weeks because of residual O_2 present; therefore, with this technology, some grain damage is expected. The cost of the metal drum is US$13.6 - 18.8 per metric ton and the cost of triple bags is US$16.4 – 24.0 per metric ton (Moussa et al., 2011).

Polyvinyl chloride (PVC) cocoons (0.83 μm thick) and SuperGrain bags from Grain Pro (Concord, Massachusetts, US, http://www.grainpro.com) are used in many parts of the world. SuperGrain bags are made of co-extruded gas barrier plus 78 μm thick polyethylene. These bags can be used to store up to 100 kg of a commodity. The rectangular cocoons, with two halves that can be sealed airtight by a zipper, can be used to store bagged commodities of 5 to 1,050 tons. They are gas and moisture proof and have an aluminized reflective sheeting to minimize temperature fluctuations. Cocoons have also been modified so that after the commodity is stored, CO_2 or N_2 can be pumped into the enclosure. This is recommended when cocoons are used for processed materials. Alternatively, one can create low O_2 atmospheres by attaching a vacuum pump to the cocoons to suck the air out and create anoxic conditions.

A GrainPro cocoon, which was used to store paddy rice in Bangladesh, offered the best insect control and lowest O_2 levels compared with (a) a Germax cocoon made of polyester fabric coated with PVC, (b) a storage bag made by the International Rice Research Institute, (c) a Rexin cocoon, (d) a polyethylene bag, (e) a thick poly bag, (f) a poly plus gunny bag, and (g) a gunny bag (Alam et al., 2009). The initial O2level of 19.1% in the GrainPro cocoon immediately after storage dropped to 3.7% at the end of the storage period (3 months). The insect population was reduced by 99%. All other storage structures had O2levels that ranged from 7 to 19% at the end of the storage period, and provided 10 to 94% insect control. The paddy rice moisture content was unaffected (11%, wet basis) because of stable relative humidity inside the cocoon even though ambient temperatures during the study fluctuated from 24 to 34°C.

The hermetic metal bins, triple bags, and SuperGrain bags may be more suitable for storing clean, uninfested spilled commodity in warehouses or commodities from torn bags. These bags may not be best suited for bagging bulk grains delivered at the ports, because the open ends need to be tied or the zipper system has to be sealed manually and would delay filling bags as the grain is being unloaded from vessels. Stitching machines cannot be used as stitches placed on the bags will make them gas permeable.

Efficacy: Effectiveness with modified atmospheres can be rapid (a few days) at high temperatures (30-40 °C) and at low relative humidity because desiccation of insects tends to be faster at lower humidity (Jay et al., 1971). Effectiveness can be increased if exposure to modified atmospheres occurs under vacuum or high pressures (10-15 bar) (Locatelli and Daolio, 1993;Le Torc'h and Fleurat-Lessard, 1991).

Alternative 3) Use contact pesticides as the primary means of stored-product pest control: There are several contact insecticides that the USEPA has approved for use in warehouses and in food-processing facilities (White and Leesch, 1996). Only contact insecticides belonging to the pyrethroid, organophosphate, and N-methyl carbamate classes are included in this alternative. As a group, all pyrethroids have a similar mechanism of action. Both organophosphates and N-methyl carbamates have a similar mechanism of action; these two classes of pesticides are discussed together below.

Food aid bags/packaged products should not be treated with insecticides that leave a residue (USAID's CRG prohibits use of residual products in or around bags and recommends their use only in empty warehouses.) This alternative involves pyrethroid and organophosphate/N-methyl carbamate applications to floors, interior and exterior walls of empty warehouses, along aisles among bag stacks, in empty surfaces of containers and also involves fogging. (Compliance requirements of the PEA Tools require that warehouse be empty during applications). Arthur and Peckman (2006) review factors influencing effectiveness of insecticides applied to surfaces.

Natural pyrethrins extracted from the flowers of chrysanthemum grown commercially in Ecuador and Kenya, and their synthetic cousins, pyrethroids, provide quick knockdown of insects; however poisoned insects often recover quickly. Many insects have developed resistance to these chemicals by being able to physiologically break them down. These compounds also breakdown rapidly—often in a matter of hours—in the environment, especially when exposed to direct sunlight. To prevent rapid insect recovery, a synergist chemical called piperonyl butoxide (PBO) is almost always added to pyrethrins and pyrethroids2. And, to prevent UV radiation from rapidly breaking down pyrethrins and pyrethroids, UV protectants have been developed and added to the pesticides. Additionally, scientists have developed a second generation of synthetic pyrethroids that are more resistant to UV degradation, and thus last longer in the environment.

Pyrethroids are formulated as wettable powders (WP) or as emulsifiable and soluble concentrates (EC, SC). Wettable powder formulations form insecticide suspensions in aqueous phase, and are best for treatment of absorbent and porous materials, such as brick, cement, concrete, and timber; they are filtered by the surface, resulting in retention of the insecticide powder on the surface (Parkin, 1966).

Organophosphate insecticides, such as chlorpyrifos, chlorpyrifos-methyl, and pirimiphos-methyl and carbamate insecticides such as carbaryl, propoxur, disulfoton, azinphos-methyl, and fonofos are widely used in agriculture and household applications. The toxicity of organophosphates and carbamates to insects and vertebrates is attributed to their ability to inhibit acetylcholinesterase, a class of enzymes that catalyzes the hydrolysis of the neurotransmitting agent, acetylcholine (Fukuto, 1990). Acetyl choline is found in the central and peripheral nervous system, neuromuscular junctions, and red blood cells. Several studies have documented the inhibition of acetyl cholinesterase and serine hydrolases by organophosphate and carbamate esters (Fukuto, 1990). Since the phosphorylated or carbamylated enzyme is no longer capable of hydrolyzing acetyl cholinesterase, the neurotransmitter builds up at a nerve synapse or neuromuscular junction.

Pirimiphos-methyl is one of the most effective organophosphates (Huang and Subramanyam, 2005) to use against stored product pests. Malathion is an organophosphate that has been used for many decades worldwide and many insect species are now resistant to it. In fact, resistance to organophosphates and carbamates is common in insect species associated with stored products due to extensive use over the years.

Contact pesticides can also be dispersed in air as aerosols (AE) containing tiny particles, mist or fogs. This process involves the use of dispersing insecticides as a mist or aerosol of approximately 10-µm size particles to kill insects active in storage structures. Several classes of insecticides are used for fogging; these include synergized pyrethrins, pyrethroids, organophospahates, and Insect Growth Regulators (IGRs) or a combination of pyrethrins or pyrethroids with IGRs (Boina and Subramanyam, 2011). Fogs are applied within seconds to minutes and the mist takes two to eight hours to settle on warehouse surfaces or any live crawling or flying insect bodies. In addition to respiration exposure, insects may succumb to the aerosols by picking-up lethal amounts of insecticides from exposed surfaces.

Aerosols are best suited to control exposed insects, and the particles can disperse and kill insects present beneath pallets, as these particles will drift some distance. Some aerosols degrade within two days (for example, the organophoshide pesticide dichlorvos) while others like deltamethrin have a long residual life

[2] Synergists suppress enzymes responsible for insecticide breakdown in the insect body. Synthetic pyrethroids, such as allethrin, permethrin, cypermethrin, deltamethrin, resmethrin, fenvalerate, cyfluthrin, and lambda-cyhalothrin, to a name a few, have improved insecticidal activity, provide long residual activity when applied to surfaces, and improved stability in sunlight compared to pyrethrins (Gosselin 1984). Pyrethroids affect ion channels, primarily voltage-gated sodium channels, in the nervous system and prolong neuronal membrane depolarization, resulting in large amounts of neurotransmitter release (Bloomquist, 1996). Pyrethroids that lack the α-cyano moiety in the molecule are called Type I pyrethroids (permethrin) and those that have the α-cyano moiety are called Type II pyrethroids (deltamethrin). Type II pyrethroids produce more delayed repolarization of the nervous system than Type I pyrethroids.

(Boina and Subramanyam, 2011). Several hand-held or permanently installed systems can be used for aerosol dispersion. During application, air circulation systems should be turned off, and any other air movement should be minimized. Air movement results in an exponential decay of the aerosol particles and will result in uneven settling on surfaces.

Fogging technology is popular because of its low cost and the ability to do tactical (room-specific) treatments. Treatment costs vary based on the product used, but estimates range from US$0.003 for 0.006/m3 of storage space. The feasibility of treating only a portion of a facility makes aerosol application a desirable option for facility managers. Fogging can be used in food-aid commodity warehouses only if the commodity is protected by an overlay of plastic sheeting to prevent settling and deposition of insecticides directly onto bags or packages.

Efficacy: The effectiveness of pyrethroids, organophosphates, and carbamates varies with the insect species, life stage, whether or not insects had access to food, temperature, tolerance/resistance to the insecticide, and the type of surface treated—cement, concrete, steel, and tile (Subramanyam and Harein, 1986; Subramanyam and Cutkomp, 1987; White and Leesch, 1996; Johnson 1990; Arthur and Peckman, 2006). Generally, pyrethroids are more effective at cooler than warmer temperatures; pyrethroids degrade at warmer temperatures (Noble and Hamilton, 1985). Organophosphates and carbamates are more toxic at warmer than cooler temperatures, while residual effectiveness decreases with an increase in relative humidity or moisture. Degradation is also greater at warmer temperatures.

Pyrethrins with the synergist PBO, called synergized pyrethrins, are not effective against stored-product insects (Huang and Subramanyam, 2005). If food is present on surfaces treated with contact insecticides, effectiveness against insects will decrease, and insects will recover faster when exposed to pyrethroids (Arthur, 1998).

The main limitation of fogging is that aerosols will not penetrate packaged food. Therefore, insects, mostly in the egg stage, inside packaged food, are unaffected and need to be controlled by another method (i.e., fumigation). To improve control of insects, aerosol applications can be integrated with other management tactics, such as fumigation, application of residual contact insecticides, and sanitation (Toews et al., 2006). Also, aerosols may complement control achieved by insect-resistant packaging. The limitation can also be offset to some extent by fogging empty warehouses and then bringing clean raw, finished, or packaged products into the facility; this reduces the chance of cross contamination and thereby, of infestation. The presence of flour as a food source may decrease the effectiveness of aerosol treatments; therefore, sanitation of the warehouse prior to aerosol application is essential (Arthur and Campbell, 2008; Toews et al., 2010).

Alternative 4) Implement good sanitation practices as the primary means of stored-product pest control: Sanitation in the case of stored food commodity takes into consideration design of buildings, condition of building exterior and interior, food production practices, and distribution of food(Gould, 1994). Good sanitation practices refer to proper storage of food aid commodities to prevent insect or vertebrate pest infestations, and removal of spillages and clean-up of grain residues in a timely fashion to discourage establishment of insect and vertebrate pests.

Good sanitation practices involve daily, thorough inspections to identify areas where food is accumulating and immediate removal of food sources that allow pests associated with stored grains to infest, seek refuge, and reproduce; stored-product insects require very little food to survive and reproduce (Hagstrum and Subramanyam, 2006). Larson et al. (2008) found very few insects in facilities that were cleaned on a regular basis versus those that there were unclean. Sanitation alone, however, will not control stored-product insects, especially the long-lived species that can survive without food for extended periods (Subramanyam and Hagstrum, 1996; Hagstrum and Subramanyam, 2009).

For proper sanitation, building design must facilitate inspection of the storage structure and products and must include techniques to exclude pests from entering the storage structure (Subramanyam et al., 2005). The storage structure must be well lit to enable thorough inspection and must be well sealed to exclude rodents and birds. The facility must be constructed to prevent entry of pests from outdoors via gaps in the storage structure such as outside floor-wall junctions, gaps near doors and windows, and gaps where pipes from the outside lead to the inside(Imholte and Imholte-Tauscher, 1999; Mullen and Pedersen, 2000; Toews et al., 2006).When rodents and birds enter a storage facility, they not only consume commodity, they also can damage bagged/packaged products creating an entry point for pest insects and defecate/urinate on commodities.

Efficacy: Effectiveness of sanitation is dependent on: the ability to thoroughly inspect facilities to determine sanitation issues; the timely removal of all food sources; and the ability to prevent entry of pests. Application of an insecticide, such as pyrethroids, organophosphates, insect growth regulators, or diatomaceous earth should accompany sanitation, because after sanitation activities are performed (such as removing food spillage), insects will actively forage for food sources and will come in contact with the applied insecticide deposits (Roesli et al., 2003). Sanitation also improves effectiveness of insecticides applied to storage surfaces (Arthur and Peckman, 2006).

Alternative 5) Use inert dusts as the primary means of stored-product pest control: The use of amorphous synthetic silica dusts and diatomaceous earth dusts for pest control has been known for almost a century. Amorphous silica (silica aerogels) is produced synthetically by heating silicon dioxide to high temperatures (Subramanyam and Roesli, 2000). These materials are chemically unreactive in nature; hence they are considered inert dusts.

ABOVE: Diatomaceous earth dusts are derived from fossilized skeletons of fresh or salt water diatoms. The dusts absorb the epicuticular waxes of insects causing dehydration and death.

This alternative involves application of inert dusts to surfaces of storage structures to control stored-product insects. Inert dusts adsorb the epicuticular waxes of insects causing insects to desiccate and die. Compared with diatomaceous earth dusts, amorphous silica has a greater oil adsorption capability, and hence they are more effective in killing insects than diatomaceous earth dusts.

Several formulations have been commercialized in various countries; the effectiveness of different formulations varies greatly. They are considered safe for human use and are exempt from a residue tolerance (Subramanyam and Roesli, 2000). Inert dusts do not work well on high moisture grains (>14%) and under humid conditions (>70%), because the rate of desiccation (their mode of action) is reduced. Application of dusts affects the physical properties of grains, such as bulk density, flowability, and how grains pile when placed on a flat surface (angle of response) (Korunic et al., 1996) may be adversely affected.

Efficacy: Efficacy varies with relative humidity, type of dust, insect species and stage at which exposed (Arthur and Peckman, 2006). Insect kill is slow and at 28oC and 65% relative humidity, mortality among insect species tested can range from 2 to 14 days (Subramanyam and Roesli, 2000); chemical insecticides act more rapidly.

Alternative 6) Use insect growth regulators (IGRs) as the primary means of stored-product pest control: IGRs are synthetic insecticides that mimic insect hormones so that when insects are exposed to them, they are unable to complete development to the adult stage; for insects in the adult stage, exposure affects the reproductive organs. When larvae are exposed to IGRs they fail to become a pupae; and when pupae are exposed, they fail to become viable adults. IGRs do not kill adults but affect growth and development of immature stages. In exposed adults, the number of eggs laid and egg hatchability are adversely affected (McGregor and Kramer, 1975; Oberlander and Silhacek, 2000; Wijayaratne et al., 2011). IGRs can be applied to surfaces to provide long-term control of insects in storage environments (Arthur and Peckman, 2006).

Efficacy: IGRs may not be effective against the adult stages of insects. Efficacy varies with the insect species. The time to death is not immediate and larvae tend to remain in the larval stage for extended periods (~50 days).

Alternative 7) Use insect-resistant packaging as the primary means of stored-product pest control: Among stored product insects, some are package penetrators, of which certain stages (adults or larvae) can chew a hole in packages and gain entry. Other stored product pest species are invaders, gaining access through already available openings. A majority of common stored product insect adults are able to pass through openings that are <0.25 mm (Cline and Highland, 1981). Young larvae that hatch from eggs can enter through openings smaller than 0.2 mm.

This alternative uses packages designed to protect products from insect infestation. Insect-resistant packaging is packaging that is glued (continuous glues at seams), not stitched; includes an internal bag to contain the product; uses multi-walled paper; and uses odor barriers as an overwrap. Insect-resistant packaging can help prevent insect entry into packages (Mullen and Mowery, 2006); it can control insects, by exclusion, from the point of manufacture to the point of consumption.

Some insect-resistant packaging is impregnated with pesticides. Provisiongard TM is an example of how insecticides can be impregnated into the packaging matrix to repel or prevent insects from entering packages (http://www.provisiongard.com/empirical.html). In airtighthttp://www.provisiongard.com/empirical.html). In air tight packages the use of oxygen scavengers can be ideal, especially for processed food aid commodities (http://www.agmcontainer.com/desiccantcity/desiccant_oxygen_absorbers.htm?gclid=CL-pnrGrpLACFSdeTAodExLLXA).http://www.agmcontainer.com/desiccantcity/desiccant_oxygen_absorbers.htm?gclid=CL-pnrGrpLACFSdeTAodExLLXA).

When bags are stitched coarsely which is common practice with food aid commodities, openings remain between the stitches. Food odors emanate from the bags and attract insects (Mowery et al., 2002). An insect-resistant bag without stitches is a solution to this issue.

Efficacy: The level of insect resistance is based on the materials used for packaging, the type of seal, and the package design (Hagstrum and Subramanyam, 2006). Continuous glue or locking type of mechanism, multi-layered bags, and bags without stitches tend to be insect-resistant. The addition of modified or controlled atmospheres to packages prior to sealing is used to control insects and mites in many pet foods, and could be used in some cases for Title II commodities. The use of odor barriers improves insect resistance as well.

Alternative 8) No Action: This alternative involves taking no action against pests. It is presented in the PEA for comparative purposes only. Under the *No Action* alternative, no chemical or nonchemical control is applied for insect management in food aid commodity storage once it arrives from the US and is at the host-country port.

As noted in the Scoping Statement, even with fumigation, USDA and FFP partners have had to destroy many hundreds of mega tons of commodity in recent times due to infestation, although these losses were estimated at 1% or less. Disposing of large quantities of spoiled or contaminated food aid is itself a challenge. The *No Action* alternative would result in a significant increase in the amount of commodity that would have to be destroyed due to infestation. Essentially, the *No Action* alternative would not meet the *purpose* and *need* of this "project"—to control pests in Title II food aid.

Globally, the procurement, transport, storage and distribution of food aid under US Government programs is a massive undertaking involving numerous partners and stakeholders, occurring on a worldwide basis. The total amount of food aid shipped in recent years ranges from a high of 3.716 million kilograms in 2003 to a low of 1.372 million kilograms in 2007[3]. All of this food aid with the exception of vegetable oil and other commodities packaged in tins is fumigated before leaving the US and then must be protected and occasionally re-fumigated during shipment or once it reaches its destination country and/or local distribution area. If the No Action alternative is chosen, there would be significant food wastage and USAID would not fulfill its Title II commitments to meet food aid needs. Without food aid, many more people in recipient countries would go hungry and die of starvation and suffer from nutrition-related disorders.

3.3 ALTERNATIVES ELIMINATED FROM ANALYSIS AND RATIONALE FOR ELIMINATING THEM

The PEA team used the Scoping exercise to eliminate some alternatives from consideration in the PEA. These, as well as an additional alternative that the PEA team identified, are listed below. The discussions include justifications, mostly due to high costs and scalability concerns, of why the alternatives were eliminated.

3.3.1. ALTERNATIVES PROPOSED IN THE SCOPING STATEMENT AND ELIMINATED BY THE PEA TEAM

(1) Entoletion of milled wheat (use of impact machines): Impact machines (initially called entoleters but now called infestation destroyers) are used in the milling industry to kill insects developing inside kernels of wheat. It also destroys the eggs of stored-product insects in flour prior to bagging (Subramanyam, 2007a,b; Plarre and Reichmuth, 2000). The entoletion process involves passing raw wheat through a rotor that spins at 1750-2100 rpm. The kernels are thrown against the rotor pegs and steel casing and the kernels containing insects inside are broken and are aspirated after exiting the rotor. The same principle is used for flour that may contain insect eggs, mainly of red and confused flour beetles that are found throughout the milling process (Good, 1937). Commodity throughput, commodity moisture, and rotor speed, all influence the degree of insect control (Plarre and Reichmuth, 2000)

The entoletion process reduces the level of all stages of insects in whole wheat, reducing fragment counts so the commodity is in compliance with the US Food and Drug Administration's (FDA)defect action levels (http://www.fda.gov/food/guidancecomplianceregulatoryinformation/guidancedocuments/sanitation/ucm056174.htm) for unavoidable and innocuous filth that can occur in processed food. The US FDA's Federal Food

[3] These figures are taken from the latest USDA/USAID Global Humanitarian Food and Risk Assessment Summary for Fiscal Year 2007 (dated September 2009).

Drug and Cosmetic Act established a maximum defect action level of 75 insect fragments per 100 g of flour (Dogan and Subramanyam, 2010);flour containing higher than the prescribed limit is considered adulterated and unfit for human consumption. Millers in the US do not accept wheat containing more than 6 insect damaged kernels per 100 g of wheat compared with the FDA standard of 32 insect-damaged kernels per 100 g of wheat (Kenkel et al., 1993). Kernels damaged by insects have round holes where an internally developing insect has emerged and exited as an adult. The low levels of insect damaged kernels at time of purchase by US wheat millers will result in producing wheat flour that is essentially free of insect fragments. Impact machines are used in the wheat milling industry to comply with this standard, but many mills now have been successfully meeting the federal standards without their use.

Justification for eliminating from PEA: The milling industry uses other pest management practices to control insect infestation of bagged wheat flour (Subramanyam et al., 2005). Entoletion is only one part of an integrated program. Entoletion is a costly proposition, and entoleters consume large amounts of electrical energy to operate (US $ 80,000/year; Andy Allen, Horizon Milling, personal communication). Entoletion would not be practicable in most Title II recipient programs. On its own, it does not control infestation, unless it is part of a milling process. Additionally, entoletion of grain after receipt in the recipient country may result in broken kernels, which may be unacceptable for Title II commodity.

(2) Application of treatments using temperature extremes and irradiation
Heat and cold treatments. The use of extreme temperatures (Fields, 1992) is attractive and chemical- free, but it is suitable for a limited range of facilities. Cold treatments may be possible where food aid is sent to countries in colder climates, where temperatures reach <15°C. Chillers (http://temp-air.com/contactus.aspx; http://www.coolseed.com.br; and http://www.frigortec.de) produce refrigerated air to cool grain to 15 °C. High temperatures are used to disinfest grain and structures where food is stored or processed (Beckett et al., 2007). Heat from electric, steam, and gas heaters can be used to disinfest empty containers, bins (Tilley et al., 2007), and warehouses (Subramanyam et al., 2011)—high temperatures can only be applied to empty warehouses, silos, or containers storing food aid. Insects succumb in hours when ambient temperatures are raised to 50 to 60°C and maintained for 12 to 24 hours (Dosland et al., 2006).

To heat-treat commodities, special systems are needed, such as spouted or fluidized beds to treat commodities, and a bin to cool heated commodity which can be expensive (Beckett et al., 2007). Both heat and cold treatments require a large capital investment, they are expensive to maintain and operate, and require a reliable source of electrical power. Grain is a poor conductor of temperature, so to maintain grain temperatures with grain chillers below 15°C for extended periods, a constant supply of electricity is required. Commodities subjected to elevated temperatures or chilled air may kill insects or arrest their development butre-infestation can occur as the commodity warms to 20oC or above. Therefore, these treatments are analogous to phosphine treatment in that they fail to provide long-term insect control.

Irradiation. Commodities can be subjected to both non-ionizing and ionizing radiation to kill insects (Halverson and Nablo, 2000). Non-ionizing radiation includes the use of infrared and microwaves while the use of ionizing radiation involves the use of radioisotopes, Cobalt-60 or Cesium-135. There are also accelerator sources capable of applying energetic electrons (electron beams) directly to the product, and capable of doing this at much higher dose rates than can be achieved with gamma ray sources. Much of the work with microwave and infrared energies has been conducted under laboratory-scale experiments (Halverson et al., 1997; Khamis and Subramanyam, 2011) and commercial use of these technologies is still in its infancy. Treatment with ionizing radiation has been studied for four decades (Tilton et al., 1966; Watters and MacQueen, 1967). Ionizing radiation affects reproductive cells more than somatic cells. Bulk irradiators that can treat 4.5 metric tons of commodity per hour have been built (Tilton and Brower, 1973), but they can cost millions of dollars and annual throughputs of commodity make them less cost competitive compared with existing technologies. They require a reliable source of power.

Justification for eliminating from PEA: The cost of heaters and chillers is expensive (about US$ 100,000-250,000), and the use of heat treatment requires a facility with natural gas or propane for gas heaters, or reliable power supply for electric heaters, and a boiler for steam heaters. Based on tests at Kansas State University using gas heaters, the cost was US$2.96 to 3.11/$m^3$ of space (Brijwani et al., 2012). The use of extreme temperatures also requires training in use of these technologies, and the presence of a local provider or company with engineering experience to troubleshoot problems. Maintenance requires that a service provider is present in food aid countries to provide services and repairs if needed. In addition, according to http://www.aces.edu/pubs/docs/A/ANR-1154/, small amounts of products can be frozen or heated to kill the insects; but for pest control for large quantities, fumigation is needed.

Non-ionizing radiation has not seen commercial success yet. Ionizing radiation with electron beams and radioisotopes has potential, but it requires expensive equipment with safety considerations. Effectiveness decreases with product depth (Halverson and Nablo, 2000). Efficacy against insects varies with the insect stage and species (Halverson and Nablo, 2000; Khamis and Subramanyam, 2011). For food aid that is bagged, use of this technology would require additional infrastructure and safety factors, and this technology is more suitable for treatment of commodities prior to shipping or bagging in the US and not in the receiving countries. These concerns, along with the initial and ongoing expense, maintenance requirements, and the need for a reliable energy source, make heat, cold, and irradiation alternatives not practicable for use in countries receiving Title II food aid.

(3) Greater use of genetically modified organisms (GMOs) which would be more resistant to insect infestation of food commodities: Transgenic technology is a method of crop protection which can generate "superseeds" that may resist insect attack (Gatehouse and Gatehouse, 1998). Seeds of various commodities exhibit some level of tolerance to infestation, which translates to reduced rates of insect development and reproduction (Throne et al., 2000).

There are three limitations to consider prior to using this technology for commodity protection (Throne at al., 2000):

i. Traits conferring resistance to one species may not confer resistance to another species attacking the same commodity.
ii. Insects are overcoming resistance by altering their physiological processes that prevent enzyme inhibition.
iii. GMO crops are bred for resisting insects and pathogens in the field and not for resisting stored-product insect attack. Therefore, insect resistant factors are not expressed at their maximum in the seeds to protect them from stored product insect attack.

Justification for eliminating from the PEA: Acceptance of transgenic technology worldwide has been controversial, and it is an issue that has to be addressed if this technology will be embraced in the future. To date, commercial companies have not marketed transgenic seeds to claim that they protect them against stored-product insects.

(4) Tiered pesticide application approach: This alternative is described in the Scoping Statement as: lower toxicity pesticides applied first as a preventative measure, with higher toxicity pesticides, such as aluminum phosphide applied only if needed based on observation and data collected, not simply as a matter of routine and time schedule. According to USEPA there are four toxicity categories, based on lethal dose that kills 50% of the tested animals (LD50) based on oral and inhalation routes and based on eye and skin effects (http://www.fs.fed.us/r6/invasiveplant-eis/Region-6-Inv-Plant-Toolbox/Herbicide%20Info/EPA-Toxicity-Categories-081607ver.pdf). The least toxic material to mammals may not be the most effective against insects.

Justification for eliminating from the PEA: This is a decision making tool (part of IPM) that should be used when deciding the measures to take to protect food aid commodities. Alternatives for evaluation in a PEA (or EA) should be clearly distinguishable from each other, and should provide a good basis for making comparisons. The tiered pesticide approach fails the alternative formulation test for EAs because it is not clearly distinguishable from the other alternatives being considered herein. The tiered pesticide approach should be a part of PERSUAPs and is a method to ensure that least hazardous pesticides are selected first and the most toxic one as a last resort approach, with due consideration of their costs and effectiveness against stored-product insects. Pesticides that may be considered as possible alternatives to phosphine fumigation are already being considered in this PEA.

(5) Use traditional practices of protection against stored food pests: Annex I contains a description of traditional practices of pest control of stored-product insects. The report was required as part of the SOW. The description in this section of the traditional practices alternative is excerpted from that report.

The use of traditional methods of protection for stored products is very popular among small-scale subsistence farmers. The methods are numerous, diverse and widespread across the continents, with some regional and country differences. The report in Annex I discusses the following storage methods and botanical control methods.

Hermetic storage: Gas tight storage is an ancient way of storing grains. Grain stored under hermetic conditions creates an atmosphere high in CO2 and low in O2, thus protecting the stored seeds from insect infestation as these conditions are not conducive for insect production and survival. Hermetic storage methods include underground granaries/pits, earthen pots, metal drums, and off-the-ground mud/dung plastered structures.

Botanical pest control agents: The use of plants and also their local names changes from place to place. Chili pepper and finger euphorbia are among the most commonly used biological pest control agents in most countries in Africa. When grain is stored for seeds, as in some parts of Tanzania, for preservation, farmers sometimes sprinkle urine from a cow or goat or salt over the grain. This is done two days before putting the grain into storage to ensure that it is dry. When salt is only used, the grain can be stored directly after dressing. Farmers in Uganda use banana juice, pepper, Mexican marigold and eucalyptus leaves, for pest control in stored grains (FAO, 2012; Nukenine, 2010). In India, neem leaves are mixed along with ragi, a staple millet food crop for Hunsur region to, keep it free of pests. Additionally, when rice is stored "Umi" or "Husk" is mixed with it in order to keep it free from pests (UNESCO, 2007).

Other naturally-occurring products for protection, such as black pepper and coconut oil (Swella and Mushobozy, 2007) have pest control properties and are used in many countries worldwide for control of insects for post-harvest storage.

Justification for eliminating from the PEA: All natural products and botanicals have to be applied at high rates to commodities and their efficacy is questionable. Many of the natural products are applied as crude extracts, and the active insecticidal component is rarely isolated and tested for environmental stability, adverse health and environmental effects, and long-term efficacy against insects. These natural products have to be admixed with commodities (The CRG prohibits applying insecticides directly to commodities, except in fumigation.). The currently available—but un-commercialized—natural products are unable to provide effective pest control for the large quantities of Title II food aid. They are more suitable for small, on-farm post-harvest storage pest control, and their practical value for Title II food aid commodities is questionable.

3.3.2. ALTERNATIVE IDENTIFIED BY PEA TEAM, BUT ELIMINATED:

(1) Sulfuryl fluoride: Sulfuryl fluoride is a non-ozone depleting insecticide registered by the USEPA for disinfesting structures and commodities, and is used as a fumigant against pests in stored grains. Several studies have documented the effectiveness of sulfuryl fluoride against stored product insect pests (Bell and Savvidou, 1998; Reichmuth et al., 1999; Schneider and Hartsell, 1999; Wontner-Smith, 2005). It is similar in its gas distribution characteristics to methyl bromide, an ozone depleting gas (Cryer, 2008; Chayaprasert et al., 2012); however there are differences between sulfuryl fluoride and methyl bromide. Sulfuryl fluoride is more effective than methyl bromide at reaching insects residing deep in cracks and crevices, in grain bulks, and in residual flour. Bell (2006) reported that methyl bromide sorption on flour was 750 mg/kg while sulfuryl fluoride sorption was less than 75 mg/kg. Low sorption of sulfuryl fluoride means that it leaves little or no residues on treated commodities when compared with methyl bromide.

Justification for eliminating from the PEA: The pesticide registrant needs to register this chemical in the country of use. The registrant of sulfuryl fluoride, Dow AgroSciences(Indianapolis, Indiana, US) requires all users to go through a competency training program in the use of the fumigant and in the use of a software program (FumiguideTM) that introduces the precision fumigation concept designed to optimize fumigant use, maximize efficacy against insects, and minimize risk to humans, and the environment. Sulfuryl fluoride is registered only in the US, Australia, Europe, and Canada, and according to sources, Dow AgroSciences has no intention to register it elsewhere (Joe Demark, Dow AgroSciences, personal communication). In addition, as with aluminum/magnesium phosphide, an FMP, respiratory protection, and other safeguards must be used; if PPE is not used and safeguards are not in place, sulfuryl fluoride toxicity is similar to aluminum/magnesium phosphide.

3.4 COMPARISON OF ENVIRONMENTAL IMPACTS OF ALTERNATIVES

The matrix below (Table 3) illustrates the relative benefits and adverse impacts of fumigation with phosphine and the alternatives being considered in this PEA. The matrix provides a comparison. The analysis that underlies the comparison is presented in Section 5.

TABLE 3: COMPARISON OF PHOSPHINE ALTERNATIVES

Ratings are made below without considering potential mitigation: +2 significant positive effect; +1 positive effect; 0 neutral; -1 negative effect; -2 significant negative effect

Alternatives Potential significant Impacts	Proposed Action: Fumigate with AP (as currently practiced)	Modified/ Controlled atmosphere	Hermetic storage structures	Use of contact pesticides, i.e., pyrethroids, organo-phosphates, & carbamates	Sanitation	IGRs	Inert dusts	Insect-resistant packaging No pesticides/ pesticides		No Action (no fumigation)
Health of applicators & on-site workers & visitors (includes transporters)	-2	0	0	-2	0	0	-1	0	0	0
Health of nearby residents	-2	0	0	-2	0	0	-1	0	0	0
Commodity quality	0	0	0	-1	0	0	-1	0	0	-2
Health of beneficiaries	0 (more study needed)	0	0	-2	0	0	-1	0	-1	-2
Water quality, soil, non-target organisms	-1	0	0	-2	0	-1	-1	0	-1	-1 (disposal of infested commodity
Solid waste management	-1	0	0	-2	0	-1	-1	0	-1	-2 (infested commodity will have to be disposed)
Disposal of dead birds & rodents	-1	-1	0	-2	-1	0	-1	-1	-1	-1
Fungal diseases	0	+1	+1	0	0	0	0	0	0	0

4. AFFECTED ENVIRONMENT

As required in 22 CFR 216.6(c)(4), this section succinctly describes the environment of the area(s) to be affected or created by the alternatives; the descriptions provide the detail necessary to understand the effects of the alternatives. The "Affected Environment" section contains a general description of the social characteristics of those affected by fumigation of Title II food aid on a global scale, as well as the physical and biological characteristics common to Title II countries. As part of the PERSUAP process, PVOs are required to describe the conditions under which the pesticide is to be used, including climate, flora, fauna, geography, hydrology, and soils.

4.1 GEOGRAPHIC CHARACTERISTICS

Title II recipient countries are located in Africa, Europe and Eurasia, Asia-Near East, and Latin America and Caribbean regions (see Text Box 2). Title II food aid to these countries may be for commodity for development or emergency situations. The countries are prone to, or have been affected by natural disasters such as flood, droughts, cyclones or a combination of natural disaster, conflict, and insecurity, thus resulting in food insecurity.

TITLE II RECIPIENT COUNTRIES 2010/2011

African countries

- Burkina Faso
- Burundi
- Cameroon
- Chad
- Republic of Congo
- Central African Republic
- Djibouti
- Ethiopia
- Gambia
- Ghana
- Guinea
- Ivory Coast
- Kenya
- Liberia
- Madagascar
- Malawi
- Mali
- Mauritania
- Mozambique
- Niger
- Rwanda
- Senegal
- Sierra Leone
- Somalia
- Sudan
- Tanzania
- Uganda
- Zambia
- Zimbabwe

Asia region

- Afghanistan
- Bangladesh
- Cambodia
- East Timor
- India
- Kyrgyzstan
- Laos
- Mongolia
- Nepal
- North Korea
- Pakistan
- Philippines
- Sri Lanka
- Tajikistan

Latin American and Caribbean

- Bolivia
- Colombia
- Dominican Republic
- Ecuador
- Guatemala
- Haiti
- Honduras
- Nicaragua

Middle East

- Algeria
- Libya
- Yemen

For example, some parts of Ethiopia experience drought conditions due to insufficient rainfall. In addition, some areas receive heavy rains resulting in floods and mudslides that wash away food crops and displace people, creating an emergency situation. Therefore, the Government of Ethiopia's Safety Net Program (PSNP) receives support from USAID's development and emergency food assistance program. Niger is described as a chronically food insecure country and receives food aid support from USAID. The country is reported to have ranked 167 out of 169 countries in the 2010 United Nations Development Program Human Development Index. Nearly 60 % of the population lives in poverty and over 80 % of the population relies on farming. Threats to Niger's food security include poverty, crop infestation, and unfavorable weather conditions. Another example of a USAID food aid recipient country, Guatemala, has the highest national level of chronic malnutrition in the western hemisphere and one of the highest in the world, resulting in its designation as a food deficit country. Food insecurity is most severe in the highlands and some areas in the east where drought is recurrent; most people in these regions rely on subsistence agriculture on non-irrigated land. Liberia is a post- conflict country that receives Title II food aid. Though the country is on the road to recovery, there are residual effects of war resulting in food insecurity. Liberia is working to rebuild its agricultural sector with an aim to transition from food aid to market-driven development (and thus, transition out of Title II food aid).

4.2 SOCIAL CHARACTERISTICS

Beneficiaries are stakeholders involved in Title II food aid are discussed in this section.

Beneficiaries: Title II food aid beneficiaries are directly affected by fumigation (or decisions not to fumigate). Food aid beneficiaries are as diverse as the countries that receive food commodity assistance. Food aid assistance to a country may be for development or emergency relief. Emergency programs are usually one year in length, while development programs last up to five years (FFP, 2012). The purpose for which food aid is provided determines the food aid beneficiaries.

For emergency food aid, a binding factor for the beneficiaries is their vulnerability to the effects of hunger as a result of food insecurity in their respective countries. In this scenario, FFP target beneficiaries include children under the age of five, pregnant women, lactating mothers, the elderly, and the poorest families the food aid recipient countries. Women and children are the largest beneficiary groups. Additionally, there are beneficiaries with the economic ability to purchase monetized food aid commodity or those who benefit through programs such as food for work, school feeding programs, to mention but a few.

ABOVE: A USAID-supported program provides monthly rations to poor families as an incentive to send their children to school. Naz Gul sits outside school in her village of Chakai with her monthly ration of wheat for her family.
WFP. 2009.

Food aid earmarked for development may be used to motivate children to attend school, compensate people for work, such as building roads or repairing water and irrigation systems, or improving maternal-child health. Food for development could also be monetized if a recipient country is facing domestic supply shortfalls, which could be filled through commercial imports and food aid, while ensuring that local market prices are not destabilized, but that fair market prices are obtained (USAID-BEST, 2009). In turn, these development projects help protect communities from future hunger by providing them access to local markets for their produce, keeping them healthy and improving their harvests. In this latter category, the beneficiaries are not vulnerable to the effects of hunger but they could be described as those with an economic ability to purchase monetized food aid commodity or those that may require the following: some form of payment for their labor; food through school children feeding programs to guarantee regular school attendance and hence improve academic performance; additional or knowledge/skills enhancement in areas such as farming, nutrition, production of high value commodities that could earn money in local markets, to mention but a few (FFP, 2009).

Governments of recipient countries also participate in determining the type of beneficiaries for food aid. For example, the FFP Fact Sheet (2011) on Ethiopia indicates that the Government used their own local eligibility criteria to select their food aid target communities. However, a common factor with FFP's criteria is that the beneficiaries were food insecure.

Table 4 below gives an overview of the type of food aid beneficiaries (as of 2011 to 2012) that can be found globally across select recipient countries.

Stakeholders: FFP describes its work as a collaboration of farmers, businessmen, grain elevator operators, truckers, bargemen, freight forwarders, port operations, non-governmental and international organizations, and government officials. Together these categories of Title II stakeholders are described as forming an unbroken chain of humanity stretching from fertile fields in the US to hungry families half a world away (FFP 2009, 2012).

These stakeholders have different but important roles along the food aid supply chain. Some are involved in agricultural production of food, while others focus on the purchase of food aid, food handling and storage, while another stakeholder category transports the food commodity to recipient countries by sea, land, or rail, and yet another group distributes the food commodity to the beneficiaries in the earmarked communities.

Table 4: Detailed Description of Food Aid Beneficiaries by Country

Recipient Country	Description of Beneficiaries
Djibouti	Chronically food insecure Djiboutian pastoralists and refugees from neighboring Somalia
Kenya	Food insecure Kenyan agro-pastoralists and Somali, Sudanese and Southern Ethiopian refugees
Niger	Malnourished children, pregnant and lactating women in food-insecure households
Afghanistan	Food insecure Afghans in the rural and urban communities
Bangladesh	Households participating in the following development related projects: agriculture; livelihood; maternal and child health and nutrition; infrastructure development; emergency preparedness and disaster mitigation capacity building
India	Food-insecure orphans and People living with HIV (PLWHIV) benefiting from a supplementary food program.
Honduras	Rural food-insecure and marginalized Hondurans in western Honduras participating in the following development related projects: maternal and child health and nutrition; economic and agriculture development; business management; production and marketing.
Madagascar	Food-insecure individuals in select households participating in the following development related projects: agricultural development; natural resource management; health and nutrition; disaster preparation and mitigation

Source: FFP Country Fact Sheets (2010, 2011) http://foodaid.org/food-aid-programs/food-for-peace/

Stakeholder groups that may be directly affected by fumigation are a sub-group of the Title II stakeholders (Section 1.6.3). They include fumigant applicant workers (involved in application or use of fumigants); storage facility workers (this group of stakeholders comes into contact with fumigated food commodities); residents living on-site or nearby to the storage facilities; those involved in loading and transporting fumigated food commodity; and the food commodity beneficiaries (discussed above).

Anecdotal data from Uganda, Ethiopia, and Djibouti suggest that women are unlikely to be involved in a fumigation process. The fumigation preparation process is considered laborious, requiring strength that a woman may not possess, i.e., fumigation sheets are heavy and strength is required to pull them over the high food stacks (see Annex J, photos 13 and 14). Women were on the staff in all of the storage facilities that the PEA Team visited. In countries sampled by the PEA Team, men over 18 years of age and with at least a basic level of education make up 100% of the fumigant applicant personnel. Loaders and transporters may have lower education levels than the fumigators.

Other Title II stakeholders who may be indirectly affected by fumigation include bi- and multi-lateral international donor agencies. WFP, a public international organization agency (PIOA) is the world's largest humanitarian agency dedicated to fighting hunger and is entirely funded by voluntary donations (In addition to purchasing and distributing food aid independently of USAID, WFP is a PVO in some Title II countries.). On average, WFP aims to bring food assistance to more than 90 million people in 73 countries globally. Fumigation of Title II food aid commodity can affect WFP and other donors who address hunger; less efficient, effective Title II food aid could result in increased demand on other donors.

In the fight against hunger, WFP responds to emergencies by getting food aid to the hungry in a timely manner. WFP also works to help prevent hunger in the future through programs that use food as a means to build assets, spread knowledge and nurture stronger, more dynamic communities, thus helping communities to become more food secure. WFP has expertise in a range of areas including food security analysis, nutrition, and food procurement and logistics to ensure the best solutions for the world's hungry.

WFP purchases more than two million metric tons of food every year. At least three quarters of it comes from developing countries as per WFP's policy which requires that food is bought as close as possible to where it is needed. By buying locally, WFP saves money on transport costs and also helps sustain local economies. WFP handles its food aid, generally in partnership with NGOs and government institutions, which are in charge of food distributions in recipient countries (WFP, 2012).

Many bilateral donor agencies contribute to the food aid sector. Bilateral relationships in the food aid supply chain are based on agreements between governments in two participating countries i.e., the donor (bilateral donor) and recipient. This relationship differs among countries. Food aid is granted and distributed on a government-to-government basis. For example, food aid contributions by a donor country could be in the form of "in-kind aid," whereby food is grown in the donor country for distribution or sale abroad. Rather than being free food as such, recipient countries typically purchase the food with money borrowed at lower than market interest rates (Global Issues, 2007).

4.3 ENVIRONMENTAL CHARACTERISTICS: PHYSICAL AND BIOLOGICAL RESOURCES

US food aid programs stretch from sub-Saharan Africa to the former Soviet Union and from Latin America and the Caribbean to south Asia. Given the broad coverage of the Title II food aid program, a discussion of the environmental characteristics is daunting. Rather, below are some key points and considerations of the physical and biological resources that should be taken into account when considering the alternatives that are being evaluated in this PEA.

- USAID food aid programs target "the poorest of the poor." They also respond to disasters, such as the January 2010 earthquake in Haiti and the 2010 and 2011 flooding in Pakistan.
- While the "poorest of the poor" often live in rural areas, poor people have been migrating to urban centers in greater numbers; Title II food aid distribution centers may be located in rural or urban environments.
- The poor often live in areas prone to disasters such as earthquakes and flooding, and they are more affected by natural disasters. Food aid distribution centers may be located in areas prone to disasters.
- The bulk of recipient countries are located in tropical climates. Climate has an effect on the incidence and severity of infestation; the fumigation process; and on the willingness of pesticide applicators to wear PPE. Therefore, of the biological and physical resources, the role of climate may be most important for this analysis.
- The "poorest of the poor" are also the most susceptible to contaminants in water due to malnutrition and reduced body weights. They have fewer options to obtain clean water if water sources are contaminated by pesticides, or for legal recourse.

- Food aid often targets the rural poor, and these locations may also be areas rich in fish and wildlife. Use of pesticides, in particular organophosphates, carbamates, and pyrethroids discussed in this PEA as alternatives to fumigation, can be highly toxic to terrestrial and aquatic receptors.
- Subsistence farmers rely on pollinators to pollinate some crops. Depending on the formulations and method of use, pyrethroids, carbamates, and organophosphates can be highly toxic to some pollinators, including bees.

4.4 POLICY, LEGAL, AND REGULATORY REQUIREMENTS

The two sub-sections below discuss host country regulations with a focus on Uganda, Ethiopia, and Djibouti, and international standards as they apply to fumigants and fumigation.

4.4.1 HOST COUNTRY GOVERNMENT REGULATIONS WITH REGARD TO FUMIGATION

Most food aid recipient countries have in place pesticide regulations that spell out allowable pesticides, and safe handling, storage, application, and disposal procedures, although the degree of enforcement varies. Fumigant application companies may also be required to be authorized or certified to handle and apply fumigants; this may require various degrees of training/certification and re-training/re-certifying.

For example in Uganda, a fumigation company is first expected to register as a company with the Registrar of Companies. Thereafter, an application is put through the Ministry of Agriculture, Animal Industry, and Fisheries (MAAIF) for a license to operate as a fumigator/commercial applicator. The applicant is invited for an interview at the MAAIF, where s/he faces a Board and responds to industry-specific questions about qualifications and training. The Board, which sits once a year, consists of representatives from the Agricultural Chemical Board, National Environmental Management Authority, MAAIF, and the National Agricultural Research Organization. The license issued specifies national and international industry-standards that a company is expected to adhere to. Training is required and entails a three-week training offered by Makerere University, Department of Crop Science. The training focuses on safe handling and application of pesticides. Refresher trainings are only applicable where there is a change in technology or methodologies in pesticide management and handling. Through regular liaison of the fumigation company with Makerere University, the company keeps abreast of emerging technologies and training needs (personal communication with Mr. Maju Champlain, April 10, 2012).

According to Messrs. Bedassa Olana and Said Moussa of Djibouti Pest Control, Djibouti uses international standards to guide the practice (this is typical of many other countries with no specific regulations on fumigation). Through a train the trainer concept, select fumigation applicants are trained in neighboring agriculture-active countries such as Ethiopia and they consequently train their colleagues in Djibouti (personal communication, April 23, 2012). Djibouti's Ministry of Environment is responsible for controlling chemicals, particularly pesticides, to ensure the protection of the environment and human life. The Ministry of Health is in charge of public health (e.g., pesticides for vector control), while the Ministry of Agriculture is responsible for plant and animal protection (e.g., veterinary chemicals and crop pesticides).

For information about international conventions related to pesticides (including banned pesticides) and lists of countries that have ratified them, see http://www.pic.int/Countries/CountryProfile/tabid/1087/language/en-US/Default.aspx ;

http://www.pops.int; http://www.basel.int/; and http://www.unep.org/OZONE/pdfs/Montreal-Protocol2000.pdf.

Discussion of host country policy and institutional frameworks for pesticide use is a requirement of all USAID PERSUAPs. Host country-specific information will need to be gathered when preparing the PVO request (IEE and PERSUAP) to USAID. (An annotated template for a PERSUAP is included as Annex T-2.)

4.4.2 INTERNATIONAL STANDARDS AND BEST PRACTICES

The International Code of Conduct on the Distribution and Use of Pesticides (http://www.fao.org/agriculture/crops/core-themes/theme/pests/pm/code/en/) is the worldwide guidance document on pesticide management for public and private entities engaged in, or associated with, the distribution and use of pesticides. It was adopted for the first time in 1985 by the Twenty-fifth Session of the Food & Agriculture Office (FAO) Conference. The Code recognizes, and is mainly aimed at, countries where good regulation and enforcement systems are not fully developed or currently in place. The Code also recognizes that stewardship is not solely the responsibility of industry, but should be supported and promoted by a range of stakeholders. Adherence to the Code is a condition of membership in Crop Life International, a global federation of companies representing the plant science industry.

To conform to the Code, most pesticide distributors have a program of product stewardship. *Product stewardship* is the responsible and sustainable management of agrochemical and biotechnology products throughout their life cycle, which covers development, production, distribution, use, and disposal of pesticide products. Pesticide distributors' product stewardship efforts include training programs to ensure that those who procure their products are storing, transporting, applying, and disposing of them in a safe manner.

Below, USAID (the CRG) and WFP guidance is used to illustrate international practices in fumigation.

The USAID CRG, Section IV: Controlling damage to food commodities (http://www.usaid.gov/our_work/humanitarian_assistance/ffp/crg/sec4.htm) has generic information on pest management. It stresses that anyone using pesticides should read the manufacturer's label and comply with instructions for safety, use, and disposal. Fumigation is recommended to manage insects and rodents that could potentially infest food aid commodities. The CRG states that fumigation will not eliminate molds and bacteria, and that fumigation will not prevent re-infestation of commodities, therefore it places emphasis on sanitation and use of surface sprays and fogs.

The CRG outlines key components for effective and safe fumigation with phosphine: appropriate temperature, proper use of tarpaulins and sealing technique, proper dosage and time exposure, monitoring for presence of fumigants, safety precautions, inspection and follow-up post-fumigation. No detailed guidelines for each of the outlined steps are provided.

The CRG prohibits use of insecticide sprays on and around the commodities/products and recommends they be used only to treat floors and walls of empty warehouses. Insecticide fogs and mists are recommended to kill flying insects and insects that the residual sprays do not reach. To control rodents, the CRG recommends the use of poison bait stations outside the warehouses, and suggests sealing all openings to prevent rodent entry into warehouses. It also recommends the use of snap traps and glue boards, and limited use of zinc phosphide tracking powder in non-food areas to control mice inside warehouses. The CRG provides no information on fumigator training requirements, the need for monitoring during fumigation, or the need to procure fumigation services from reliable, competent service providers. The CRG pays significant attention to warehouse inspection and other non-fumigation measures to control pests.

The WFP (http://www.foodqualityandsafety.wfp.org) uses Codex Alimentarius guidelines for fumigation of food aid. WFP has SOPs for contracted fumigation. The SOP guidelines suggest fumigation should be performed by trained and certified applicators, and for application speed and safety, teams of two people should conduct fumigation. Fumigation is recommended for the whole store and not just the infested stacks. WFP prohibits fumigation of lined bags and flour, and also prohibits fumigation during windy weather. Based on data gathered in the US, the SOPs state that fumigation sites should be greater than 100 m from human habitation. The fumigation is considered successful if the terminal concentration of phosphine after 5 days is at or above 150 ppm, or at or above 100 ppm after 7 days, especially at temperatures of 25°C or above.

WFP requires implementation of best practices, such as checking warehouse floors for cracks and roofs for water leaks prior to fumigation (rain entering the warehouse could cause a fire hazard when using phosphine tablets/pellets); use of good quality plastic tarpaulins with no tears; placement of two nylon gas sampling lines—one from the top of the stack and one on the side of the stacks just above the ground to measure gas concentration after 5 to 7 days of fumigation; proper alignment and sealing of multiple gas-proof sheets over stacks; placement of sachets or tablets of phosphine below pallets in a single layer on trays; sealing of the sheets to the floor using two rows of sand snakes; closing and locking all warehouse doors; and placing DANGER placards in English and/or the local language.

WFP SOPs state that after 5 to 7 days, fumigators should enter, wearing an approved canister mask for phosphine, and measure gas concentration using a Bedfont electronic phosphine meter (EC80 or better). Gas concentrations of 150 ppm at the top and bottom of the stacks indicate that treatment is effective.

The SOPs describe the aeration process. After fumigation all doors and vents of the warehouse are opened and fumigators should enter the warehouse wearing canister masks and partially remove the gas proof sheets to allow phosphine to clear the warehouse and the stacks. After two hours, fumigators wearing canister masks should measure gas concentrations with detector tubes (http://www.draeger.us/sites/enus_US/pages/Mining/tubes-for-short-term-measurements.aspx) to determine if phosphine gas readings are at or below 0.3 ppm to be considered safe for workers to enter the warehouse.

For disposal, SOPs state that phosphine dust in trays should be buried onsite, if possible, away from the warehouse, at least 50 cm below the soil surface. The WFP SOPs recommend that prior to fumigation, floors and walls should be sprayed with approved residual products to a point of run-off. Details of all pest management activities must be recorded and a fumigation certificate for each stack should be provided to the WFP. WFP also requires that the registered/certified fumigator be present to supervise fumigation and spraying, and that phosphine meters must be calibrated by the manufacturer every six months.

5. ENVIRONMENTAL CONSEQUENCES

The Environmental Consequences section describes the potential environmental and health impacts of fumigation and its alternatives. The discussion includes unavoidable adverse impacts, direct, indirect, and cumulative impacts.

Based on interviews and fieldwork, the PEA Team revised the potential significant issues developed during the scoping process. The PEA Team re-phrased the issue statements from the Scoping Statement, and separated one of the issues into two. The Scoping Statement issue regarding dispersal from the fumigation site is now two separate issues, one related to human health impacts to nearby residents, the other related to potential contamination of soil and water, and impacts to non-target organisms. One potential impact included in the Scoping Statement, but excluded from this PEA is noted, and the justification for eliminating it is described below. Potentially significant impacts, as revised by the PEA Team, are evaluated below for all alternatives described in Section 3.

much of the information presented below is excerpted from the Human Health Risk Evaluation (HHRE). The HHRE includes a detailed discussion of methodology and also describes toxicology basics; it should be referred to for this background information and other more technical information on health risk analysis

5.1 ENVIRONMENTAL CONSEQUENCES OF PHOSPHINE FUMIGATION

Numbers one through eight are the potentially significant adverse impacts as revised by the PEA Team. For Issues #1-4, the following definitions are provided:

- Acute health effects are characterized by sudden and severe exposure and rapid absorption of a substance. Normally, a single large exposure is involved. Acute health effects are often reversible.

- Chronic health effects are characterized by prolonged or repeated exposures over many days, months, or years. Symptoms may not be immediately apparent. Chronic health effects are often irreversible.

Issue 1) Use of the fumigant, phosphine, can affect the health of applicators and other on-site workers and visitors.

For purposes of the HHRE and for this PEA, the fumigator and those aerating the treated area are assumed to be the same person and herein is identified as the “applicator.” The applicator places tarps, applies metallic phosphide at the start of fumigation, and enters the warehouse to start the ventilation/aeration process (remove tarps, open doors and vents). The applicator also enters the warehouse after ventilation/aeration.

“Other on-site workers or visitors” are those who may be on-site during a fumigation event, including truck loaders and transporters. On-site workers continue to work during fumigation, and may be in close proximity to the fumigation warehouse for approximately eight hours a day over the course of the fumigation, but they typically have no direct contact with fumigation chemicals, no contact with the fumigation structure, and therefore, do not have protective equipment to mitigate against exposure to fumigants. An on-site visitor may be in close proximity to the fumigation warehouse for only minutes or may remain there for hours, and may return over the course of the fumigation period. This category of individual normally would not enter the warehouse until it is re-opened to workers and the public after the fumigation process is complete.(For transporters, potential risk is mainly during their time on-site rather than when transporting commodity; the direction of de-gassing is toward the vehicle behind them.)

The HHRE states that applicators may be exposed to phosphine primarily at three stages of the fumigation process. On-site workers and visitors and nearby residents (see Issue #2) may also be exposed to phosphine during the fumigation process:

- On Day 1, after the tarpaulins are secured to the commodity stacks, trays of aluminum phosphide are deployed. Once the tablets/pellets are removed from their container, the evolution of phosphine commences.
- On the final day of fumigation, applicators enter the warehouse to pull back the tarpaulins so the warehouse can be ventilated.
- During warehouse ventilation, applicators and other workers may be working on-site in the vicinity of the fumigation warehouse.
- Other potential exposures include: on-site workers and visitors, and nearby residents during all stages of fumigation (the warehouses may not be fully sealed).
- When ventilation/aeration is "complete," applicators and other workers/visitors may enter the warehouse to finish removal of tarpaulins and to conduct other work. Since phosphine monitoring is not performed (see below), the level of phosphine remaining in the structure, which would reflect the "completeness" of ventilation/aeration, is an area of high uncertainty.

As the PEA Team found, and as the HHRE states, poor fumigation practices are common in countries where USAID commodities are shipped. These include, but are not limited to:

- Unsupervised fumigations;
- A lack of use, improper use, and lack of maintenance of personal protective equipment (PPE), especially proper respiratory protection. For example, the PEA Team found that expired and/or inappropriate respirators and cartridges, not meant for phosphine, are being used. See Annex J, photo 12;
- A lack of phosphine concentration monitoring (the PEA Team found that monitoring during a fumigation rarely occurs);
- Use of improper commodity enclosure equipment (for example, the PEA Team found that tarpaulins are used many times over and may have tears, whereas in the US, tarpaulins are typically discarded after a single use); and
- Fumigating in warehouses that are not properly secured (i.e., with open roof vents, gaps between walls or floor and doors, and without adequate sealing and placarding of storage facilities.) See Annex J, photo 3.

Several of those interviewed stated to the PEA Team that applicators monitor gas leakage by odor detection, rather than using monitoring equipment to detect the presence of phosphine gas. However, as the HHRE states, considering the range of possible odor thresholds for phosphine (see HHRE and Table 5), odor is likely insufficient to warn applicators or other on-site workers/visitors of the presence of phosphine at concentrations in excess of the U.S. Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 0.3 ppm. USEPA indicates that the sense of smell varies from individual to individual and olfactory fatigue may raise the odor threshold (USEPA, 1998).

TABLE 5: SOME BASIC PROPERTIES OF PHOSPHINE AND AMMONIA

	Molecular Weight (g/mol)	Vapor Density[1,2] (Air = 1)	Odor Threshold (ppmv)[3]	Odor Threshold (ppmv)[4]	Odor Threshold (ppmv)[1]	Odor Threshold (ppmv)[5]	Odor Charateistic[1,2]
PH3	34.00	1.17	0.51	1.0	1-3	0.02	garlic; decaying fish
NH3	17.03	0.597	5.2				Sharp

1 ATSDR, 2011 (PH3).
2 ATSDR, 2004 (NH3).
3 Amoore and Hautala, 1983.
4 USEPA, 1992.
5 USEPA, 1998.

Given the above findings, there are concerns that fumigators and other on-site workers and visitors at Title II warehouses may be exposed to phosphine gas. USEPA has classified phosphine as *not classifiable as to human carcinogenicity* (Group D) on the basis of inadequate data in animals and no tumor data in humans. USEPA notes that phosphine has not been associated with cancer in humans, but there is some evidence of chromosomal damage (transient chromatid deletions, gaps and breaks, persistent chromosomal translocations). A relationship between these genetic effects and the development of cancer in humans is sometimes postulated (USEPA, 2003). This appears to be an acknowledgment by USEPA to the work of Garry and co-workers (see below).

The HHRE, with examples excerpted below, describes toxicological data on phosphine gas exposure, as well as specific incidents of exposure. Effects from acute exposure are well documented, but chronic health effects from phosphine gas exposure are less certain. The overall picture painted by the HHRE is that there are potential risks to applicators and other on-site workers and visitors, especially given that aluminum/magnesium phosphide may not be used in compliance with the label.

Toxic effects associated with acute inhalation exposure to phosphine range from irritation to mortality. Symptoms of mild phosphine inhalation may resemble upper respiratory tract infections, such as coughing, nausea, vomiting, diarrhea, headache, fatigue, and dizziness (Memis et al., 2007). Symptoms of severe exposure include lung irritation with persistent coughing, ataxia, paresthesia (tingling),, tremors, diplopia (blurred vision), hypotension, weak pulse, jaundice, metabolic acidosis, cardiovascular collapse, oliguria (reduced urine output), proteinuria, and anuria (kidney failure) (Memis et al., 2007). In terms of occupational exposure standards, OSHA cites pulmonary edema, gastrointestinal disturbances, and dizziness as adverse effects in human and respiratory irritation as the adverse effect in test animals (OSHA, 1989). NIOSH cites nausea, vomiting, abdominal pain, diarrhea, thirst, chest tightness, dyspnea (trouble breathing), muscle pain, chills, stupor or syncope (fainting), and pulmonary edema.

In 2011, Preisser, et al. studied 26 cargo-workers exposed to fumigants; four of these individuals were exposed to phosphine during unloading or loading of cargo and while fumigating. All the workers exhibited general symptoms of phosphine exposure. Similarly, Gard News (2011) reported several cases of crew fatalities due to poor ventilation aboard grain cargo ships in which phosphine fumigation was used to kill pests in the cargo holds. These incidents included three fatalities and at least 23 cases of illness; phosphine was detected in the crew quarters (Gard News, 2011). In most cases, exposure occurred due to improper inspection of the vessel to ensure its physical integrity prior to actual fumigation; inadequate care taken by fumigators to ensure that fumigation would proceed as planned; and inadequate guidance provided by fumigators to the crew regarding the risks and management of phosphine (Gard News, 2011).

The HHRE cites a case where exposure to phosphine by 22 fumigators led to temporary (15 minutes to three hours) respiratory symptoms including suffocation, breathing difficulty, and chest tightness.

Neurological symptoms (31.8% reported headaches) and gastrointestinal effects were also observed (Misra et al., 1988, as cited in USEPA, 2003). Crew members exposed to phosphine on a grain freighter exhibited symptoms that included shortness of breath, cough, vomiting, fatigue, headache, drowsiness, paresthesia, and tremor (Wilson et al., as cited in USEPA, 2003). Workers who handled aluminum phosphide tablets have noted numbness and tingling (Misra et al., 1988, as cited in USEPA, 2003).

A Hazard Summary for phosphine (USEPA, 2000) indicates that chronic occupational exposure to phosphine may lead to inflammation of the nasal cavity and throat, weakness, dizziness, nausea, gastrointestinal, cardiorespiratory, and central nervous system symptomology, jaundice, liver effects, and increased bone density. The HHRE provides the documentation on chronic effects of phosphine exposure to applicators and other on-site workers and visitors. The studies below discuss the association between phosphine exposure and developmental/reproductive toxicity, chromosome damage (clastongenicity), increased cancer risk (), carcinogenicity),, and possible gender effects.

Garry et al. (1989) conducted a study of 24 fumigators. Of the 24, nine were exposed to only phosphine, 11 were exposed to phosphine and other pesticides, and four had no exposure to phosphine. The authors observed both stable and less stable chromosome rearrangements (translocations) in the workers that were exposed to phosphine and/or other pesticides. The stable rearrangements were observed six weeks to three months after exposure to phosphine while the less stable rearrangements were observed only during the fumigant/pesticide application season.

In a follow-up study to Garry et al. (1989),) (Tucker et al., 2003) found that), 20 applicators who used phosphides/phosphine were evaluated for chromosomal translocations. The majority of the 20 applicators had participated in the Garry et al. (1989) study. Of these subjects, seven no longer use phosphine, five applied other pesticides, five use an automated phosphide pellet applicator that greatly reduces exposure inhalation, and eight deploy phosphides manually. The authors indicate that unlike in the Garry et al. (1989) study, fewer translocations were observed in the phosphine applicator group relative to a control group. Tucker et al. (2003) attribute this observation to the use of proper respiratory equipment that was not used in the Garry et al. (1989) study.

Garry et al. (2002) reported the results of their study on pesticide applicators, including those that fumigated with phosphine, from the Red River Valley in Minnesota, U.S. Phosphine is indicated as the only fumigant in common use, although applicators did use other pesticides. Of children fathered by fumigators using phosphine, two cases of congenital cataracts from two different families were observed in 290 children born to 113 phosphine applicators. No family history or other indicating factors were noted. According to the United States Department of Health and Human Services (USDHHS), the frequency of congenital cataracts is 1.1-2.2 per 10,000 live births (USDHHS, 1993, as cited in Garry et al., 2002). Both observed cases were in the right eye, which led the authors to postulate that germ-cell mutation might be the cause, based on other research in this area (Paulozzi and Lary, 1999, as cited in Garry et al., 2002). The authors indicate that, unexpectedly, both children with congenital cataracts were female.

In Garry et al. (1989), the observed chromosome rearrangements were cited as an indication for the need to further evaluate phosphine for carcinogenicity; in particular, non-Hodgkin's lymphoma. Garry et al. (1992) expounded on the possible link between phosphine and non-Hodgkin's lymphoma. Groups of workers that used phosphine as the primary pesticide and a group that used multiple pesticides showed higher rates of chromosome rearrangements during pesticide application periods. Notably, when use of phosphine ceased, there was a significant decline in chromosome rearrangement within one year.

At the occupational exposures to phosphine of less than 2.4 ppm/hour, Barbosa and Bonin (1994) found no association between phosphine exposure and genotoxic or toxicological effects on fumigators; however, Garry et al. (1989) found reversible chromosomal aberrations in fumigators (transient chromatid deletions, gaps and breaks, persistent chromosomal translocations). It is unclear whether the genotoxic effects observed lead to cancer or non-Hodgkin's lymphoma (Garry et al., 1989).

USEPA (1998) noted limitations in the study suggesting mutagenicity (i.e. chromosomal damage) by Garry et al. (1989) (discussed above). As a result, USEPA sponsored additional studies (i.e., Kligerman et al., 1994a and Kligerman et al. 1994b, both as cited in USEPA, 1998) to evaluate the potential for the mutagenicity of phosphine. Kligerman et al. (1994a, as cited in USEPA, 1998) involved exposure of mice to 0, 5, 10, or 15 ppmv phosphine for six hours. Lethargy and shallow breathing was observed at 15 ppmv. A significant reduction in splenocyte cell cycling was observed at all levels, indicating that phosphine is cytotoxic to splenocytes; however, there was no observed effect on bone marrow cells and phosphine did not induce sister chromatid exchange or chromosomal aberrations in splenocytes.

Kligerman et al. (1994b, as cited in USEPA, 1998) involved the exposure of mice and rats to phosphine at 1, 1.25, 2.5, or 5.0 ppmv for six hours a day, five days a week over 11 days. No genotoxic effects were noted in bone marrow cells or peripheral blood lymphocytes. USEPA concluded that phosphine is not mutagenic in bacteria, but is clastogenic in vitro (using portions of a live organism outside of the live organism). Phosphine is not clastogenic in mice or rats, based on in vivo (within the live organism) studies. This conclusion is supported by the results of a two-year inhalation and oncogenicity study in rats (Newton, 1997, as cited in USEPA 1998).

Based on the PEA Team's interviews and findings during field work, applicators may be at risk of acute exposure to phosphine; as stated above, this can occur because best practices are not followed (i.e., tarpaulins may be used many times over, gas concentrations may not be monitored, monitoring equipment may not be properly calibrated). The evidence presented above and additional information in the HHRE and on the USEPA website indicate that acute exposure is potentially a concern when best practices are not used; mitigation is needed to minimize potential health impacts to applicators.

The PEA Team also finds that workers performing non-fumigation tasks on-site and on-site visitors may be exposed to the gas if the adjacent areas are not sealed off, if the tarps on the commodities are not tightly sealed, and if there are open vents in fumigation warehouses. They also may be exposed during aeration. Because of inadequate placarding, sealing, and securing, other on-site workers and visitors may inadvertently enter a warehouse undergoing fumigation. As above, and as indicated in the HHRE, the potential for acute exposure to on-site workers (including loaders and transporters) and visitors poses a possible health concern, and mitigation is needed to minimize impacts of acute exposure on on-site workers and visitors.

The HHRE evaluated a series of acute exposures, but chronic exposures are also possible. There may be concern for chronic exposure if frequent fumigations are performed by the same fumigators. Fumigators may also apply other pesticides, and use of PPE when applying them may not be in compliance with labels. The potential for chronic exposure exists, and precautions should be taken to ensure fumigant applicators suffer no adverse chronic effects.

Of importance, the USEPA indicates that most margin of exposures (MOEs; body burden levels where adverse effects occur) were acceptable when respirators were used. However, the on-site worker and visitor and the nearby resident (see below) will not be wearing respirators and their exposure duration may be much longer than for the applicator. In addition, in cases where monitoring of phosphine concentrations during ventilation does not occur, applicators will not know when ventilation is actually complete and when the warehouse is safe to enter. This indicates a need to apply mitigation measures not only to protect the applicator, but also to protect all those who may enter the property while a fumigation is being conducted, i.e., other on-site workers and visitors, as well as nearby residents (Issue #2).

Issue 2) Use of the fumigant, phosphine, can affect the health of residents nearby to the warehouse being fumigated.
This PEA defines "nearby residents" and "close proximity" to the fumigation warehouse in accordance with the WFP SOPs, which recommend that for contracted fumigations, fumigation sites should be greater than 100 meters from human habitation. Therefore, these terms—*nearby residents* and *close proximity*—identify residents who live less than 100 meters from the fumigation site. *Immediately adjacent* describes those whose homes or businesses are next to the warehouse compound.

At some distance away from the warehouse (undefined because there are so many variables, such as wind and temperature), phosphine concentration is greatly reduced as is the potential for risk. For purposes of this PEA, the fumigation service provider is responsible for identifying the distance from the warehouse that is considered "safe"—where potential risk is greatly reduced. This information would be included in the fumigation management plan (Annex T-3).

According to the HHRE, MOEs are not estimated for the *nearby resident* because USEPA cites no related data (from Mansdorf et al., 1998), i.e., there were no phosphine data in the USEPA RED data for aluminum and magnesium phosphide that adequately represents a residential exposure scenario. However, if the residence is located *immediately adjacent* to a fumigation warehouse, the HHRE states that a case could be made that the residents are exposed to concentrations of phosphine similar to those which the on-site worker and visitor (above) is exposed. Further, the exposure at the residence should be assumed to be 24 hours a day and not eight hours a day as it would be in an occupational situation. The assumption that residential exposure is 24 hours a day is valid because the residents may include sensitive subpopulations, such as a young child, the elderly, or the infirm, who may not leave the residence.

Residents nearby to a warehouse that is being fumigated may be at risk of phosphine exposure if fumigation within the warehouse is not conducted under tightly sealed conditions (WFP's guidelines assume it is safe beyond 100 meters). Typically, in food aid receiving countries fumigation of bagged commodities occurs under tarps, and the warehouse is rarely fully sealed during the fumigation process (Vents and gaps between doors and floors are common, and even when a warehouse is sealed, these often remain open.) Nearby residents may also be exposed to phosphine during the aeration cycle, when doors are purposefully opened.

Generally, phosphine concentration decreases with distance from the fumigated site (Pratt, 1998). Pratt (1998) reported a decrease in phosphine levels with distance from fumigated bins, stacks, and sheds. In barley fumigated under tarps, gas readings ranged from 100-600 ppm (mean=340 ppm). Air samples within a meter from the tarp on the sides and top was 30-60 ppb; and at 15 meters from the tarp, in a well-ventilated area, it was 4 ppb. Pratt observed the highest readings soon after fumigation when gas concentrations were peaking and during aeration; all of the readings were below the 0.3 ppm threshold (however, this OSHA PEL only applies to workers in good health who are exposed for eight hours a day over a 40 hour work week at most; therefore, it is irrelevant to the nearby resident, who would not be wearing PPE.).Phosphine in the atmosphere is rapidly degraded, and wind aids in rapid loss of the fumigant outdoors (Rajendran and Muralidharan, 2001). The half-life in air is approximately five hours; the degradation mechanism is a photoreaction with hydroxy radicals.

However, there are several recorded cases of phosphine poisoning in adults living in close proximity to warehouses being fumigated. The HHRE states that USEPA (1998) cites two cases of mortality involving residents near fumigation facilities. In August 1989, a woman living approximately 350 feet (just above 100 meters) from a grain fumigation facility in North Dakota, U.S. died. Although factors such as heat and chronic grain dust inhalation confound the case of the woman's death, the woman's husband was treated for loss of peripheral motor control (uncontrollable shaking of the hands and feet), diarrhea, headache, burning gums, lips and teeth, skin irritation, dry mouth and throat, and watering eyes during his hospitalization on October 7, 1989. October 1989 corresponded to the greatest monthly use of aluminum phosphide at the fumigation site and the husband's symptoms were reported to be at their worst when the facility aerator was operating.

The second case (Garry et al., as cited in USEPA, 1998) involved the death of a pregnant woman who was removing laundry from her yard approximately 27 meters (30 yards) from a large grain fumigation facility in a rural section of the U.S. that was not well-sealed. Upon coming into the home, she indicated to her husband that the odor was "real strong tonight." A couple of hours later she went to her local physician who observed tachycardia and vomiting. She died in the hospital approximately three to four hours after bringing in her laundry. USEPA believes that these incidents are likely related to phosphine fumigation.

Due to the PEA Team's findings that warehouses may not be tightly sealed and that gas concentrations are not monitored (during fumigation and aeration), the PEA Team finds that there is a potential for nearby residents to be exposed to phosphine gas. The distance of concern from the fumigation warehouse to the residence is based on site-specific conditions and is a matter for the fumigation service provider to determine in the FMP (If there is a scientific basis to assume that beyond 100 meters residents are safe from the potential effects of fumigation, the PEA Team is unaware of it.).As stated in Issue #1, potential acute and chronic health impacts could result from exposure to phosphine gas; **mitigation is needed to minimize the potential impacts to residents within a distance to be determined on a case-by-case basis; mitigation should apply to all residents within the identified limit.**

Issue 3) The quality of the food commodity may be compromised due to phosphine fumigation. This issue is related to cumulative impact and whether the number of fumigations has an effect on the commodity. (Potential impacts on the health of those who consume the commodity are discussed in Issue #4. Both issues # 3 and 4 are related to the ability of phosphine to adsorb and desorb from food commodity.)

The HHRE and the PEA Team evaluated the issue of sorption/desorption of phosphine from fumigated commodities, focusing on the potential for phosphine or phosphorus-containing phosphine degradation products to remain on fumigated commodities at concentrations that may pose a risk to persons coming into contact with fumigated commodities, especially the ultimate beneficiaries (see Issue #4). The following is a summary of the most reliable data on sorption/desorption (from a review by the HHRE and the PEA Team).

Commodities sorb phosphine through both physisorption, a reversible process that allows for phosphine to desorb over time, and chemisorption, which is non-reversible (Berck, 1968). Berck (1968) reported that chemisorption is generally slow and is dependent upon temperature, time and the moisture content of the commodity.

Robinson and Bond (1970) postulate that sorbed phosphine will undergo air oxidation to diphosphine, and the oxyacids hypophosphite, phosphite, and ultimately ortho-phosphate (these phosphorus compounds are much less toxic than is phosphine). Tkachuk (1972) supports Berck's assertion (Berck, 1968) that not all phosphine is recovered during commodity aeration and agrees with Robinson and Bond (1970) that phosphine appears to form non-volatile (i.e., not phosphine) residues.

Dumas (1980) reported that wheat fumigated with phosphine continued to off-gas phosphine for 220 days (over seven months). While the majority of phosphine desorption occurred during the first three days of aeration, after 71 days, phosphine was measured at 0.01-0.02 nanograms per gram (ng/g, which is equivalent to μg/kg). After 220 days, the residual phosphine in the wheat was measured at 0.0002-0.004 ng/g.

Reed and Pan (2000) studied the effect of repeated fumigation of hard red wheat on phosphine sorption in both sealed drums and open bins. Repeated fumigations were found to reduce the phosphine sorption rate into the wheat. The authors concluded that repeated fumigations were not likely to add significant amounts of phosphine to the wheat, and did not result in an increase in phosphorus content of the various fractions milled from wheat. Matthews et al. (1970, as cited in Plimmer, 1977) indicate that baked products made from wheat that had been fumigated with phosphine exhibited some deterioration of physical qualities.

Minor amounts of sorbed phosphine bind to proteins in wheat (Tkatchuk, 1972). The magnitude of gas uptake is based on the type of grain, its condition, and relative quantities of gas to grain. In dry grains phosphine sorption is 0.05-0.20/day. Paddy rice, but not brown or milled rice, and high moisture grain absorb phosphine rapidly (Banks, 1990). Dumas (1980) reported that in wheat and corn treated with 0.5-5 mg/kg (ppm) at 25, 45, and 85°C, the amount of phosphine adsorbed was influenced by length of phosphine exposure and grain temperature. Adsorption not chemisorption was observed. The majority of the phosphine desorbed in the two to three days of aeration, but small amounts continued to desorb for many weeks and at 200 days phosphine still was desorbing in small amounts (10-12 g).

Corn treated with 0.5 mg/kg and aerated for 26 days desorbed 0.004 ng of phosphine in 48 hours. This could be a concern in large-scale fumigation of commodities. Rauscher et al. (1972) have also reported that cereal products do not chemisorb applied phosphine. The loss of phosphine through leakage and desorption in wheat stored in unsealed bins was positively related to grain moisture (11.1-13.5%) and grain temperature (20-30°C) (Reed and Pan 2000).

However, Berck (1968) reported chemisorption of phosphine in his tests with raw cereal commodities and milled products exposed to 0.15-0.60 mg/L. Uptake of phosphine by wheat gluten powder, middlings, bran, and shorts was greater than that by wheat starch, flour and wheat germ. Berck provided presumptive evidence that phosphine binds to proteins and complexes with mineral components of the substrates tested.

Although phosphine tends to be more sorbed by pulses (cowpeas, pea, and mung), aeration for couple of days after a 5-day fumigation reduced tolerance levels to 0.01 ppm (Singh and Srivastava, 1980). Washing and cooking further reduced residue levels. Phosphine did not adversely affect seed germination. Different legumes desorb phosphine at different rates (Rangaswamy and Gunasekaran 1996), and aeration times should be altered to ensure all of the gas has desorbed to acceptable residue (0.01 ppm) levels.

Phosphine can be used to treat processed products in polypropylene bags that are stacked in heavy paper cases or cartons and has the ability to penetrate packaged products (McGregor et al., 1966). However, in order to comply with the 0.01 ppm tolerance for phosphine residues in processed food, a 48 h aeration period is required.

Based on discussions the PEA Team had in Uganda, Ethiopia, and Djibouti, the HHRE noted the issue of residual (i.e., unreacted) aluminum or magnesium phosphides in or on fumigated commodities. The application of the metallic phosphides on trays below stacks of commodities (common practice, as the PEA Team found in Uganda, Ethiopia, and Djibouti) would essentially remove the risk of residual metallic phosphides on the commodities being fumigated; however, given the range of Title II countries and fumigation practices, there is a chance that in some cases, metallic phosphides may be applied directly to commodities. Theoretically, if the amount of metallic phosphides deployed is grossly over the amount needed, the reaction may not proceed to completion, but it is anticipated that this scenario would be extremely rare.

The HHRE mentions a case where samples of wheat with 13.8% moisture content had been fumigated in boxcars and aerated for two weeks were found to contain a mean value of 0.04 ppm (mg/kg) phosphine. Berck (1968) indicates that such traces of phosphine were "faintly detectable by smell."

The HHRE makes the following comments on sorption:

- Berck (1968) indicated that residual phosphine was detectable by smell. This suggests that not all of the 0.04 ppm was irreversibly sorbed;
- While Reed and Pan (2000) indicate that repeated fumigations were not likely to add significant amounts of phosphine to the wheat, if Berck (1968) is correct in his theory that phosphine binds to proteins, the nutritional value of a commodity could be affected;
- The literature suggests that there is potential for residues of phosphine to remain on fumigated commodities for extended periods of time (months) and oxidation of phosphine to oxyacid species is also a possibility; and
- Two primary types of packaging materials are used for Title II food aid: those that are gas-permeable and those that are not gas-permeable. There may be variations in the degree of permeability for those that are gas-permeable. Based on a review of sorption and desorption processes described in the literature, the ease with which phosphine is able to permeate a package should reflect its ability to be removed via aeration. However, the issue of phosphine residues discussed earlier in this section still remains.

As stated, the effect of fumigation on food quality is related to phosphine's ability to adsorb/desorb from food commodity. However, the potential impacts of fumigation on food quality are not completely understood. This uncertainty indicates 1) there may be a need to implement mitigation measures; and 2) there is a need for additional research in this area.

Phosphine reduces the amino acid cystine to cysteine in vitro (Bond et al., 1969); phosphine reacts with metals such as iron or copper (Rajak, 1971). Also, as mentioned above, baked products made from wheat that had been fumigated had some deterioration of physical qualities. Therefore, mitigation/best practices would involve avoiding phosphine fumigation of processed/fortified foods. WFP does not allow fumigation of wheat flour and blended products. Processed commodities with live insects would be considered adulterated and the use of fumigation does not change that status.

Besides fortified foods, even though some studies indicate food quality may be affected by fumigation, the potential impacts are minor, especially as compared to the potential for infestation and the risk of losing the commodity if it is not fumigated. Based on most studies, if commodities are aired properly, there will be no issues with phosphine residues; depending on the temperature, commodity aeration may take 1 to 5 days. However, verifying if the phosphine gas within stacks or in treated commodity (by opening the bag) is ≤ 0.3 ppm would provide a rational basis to determine if complete aeration has occurred. This aeration period and other safeguards are easily implemented by Title II programs, and would serve to minimize concerns. For example, both the USAID CRG and the WFP SOP for fumigation state that the fumigant should not be in contact with the commodities; tablets should be placed in trays below the pallets, or if sachets are used they should be hung on the sides of the stacks under the tarps.

Issue 4) Beneficiary populations may be at risk from inhalation, preparation, and ingestion of fumigated commodities.

ABOVE: Three young girls participate in USAID-supported food security projects. S. Dominguez. 2008.

Beneficiary populations identified in the PEA are lactating women, children under five, and chronically malnourished individuals who may be more susceptible to neurological or immunological impacts of exposure to phosphine residues. Scientific evidence has shown (see above and the HHRE) that phosphine residues can persist in fumigated commodities. The following discussion is from the HHRE and other relevant literature and provides an evaluation of the potential for impacts to beneficiaries (vulnerable populations) that may inhale, prepare, and/or ingest fumigated commodities.

Phosphine comes in contact with food aid commodities in the gaseous phase, and (as stated in Issue# 3 above), there may be negligible residues in the treated commodities following fumigation and aeration. Research suggests that phosphine residues may remain in fumigated commodities for several months or more and that higher concentrations of phosphine during fumigation may result in greater potential for residual phosphine in fumigated commodities. The HHRE states that there is potential for beneficiaries to ingest phosphine if there is chemisorbed phosphine remaining in fumigated commodities. For the estimation of ingestion risk (in the HHRE), a sensitive receptor (a young, 10-kg child) is assumed to ingest 0.1 kg (100 g) of fumigated commodity a day for two years. From these assumptions, the concentration of phosphine that would have to be in the fumigated commodity at the threshold of risk/no significant risk was estimated to be 0.03 ppm. This concentration is less than USEPA's allowable tolerance of 0.1 ppm for many commodities, although processed foods and pod vegetables have an allowable tolerance of 0.01 ppm. As such, ingestion of phosphine from fumigation of food commodities poses a relatively small risk, though the available data are not sufficient to make a complete assessment.

There is evidence that adsorbed phosphine will tend to oxidize to less toxic oxyacids of phosphorus. Food preparation, especially cooking, may remove most, if not all, residual phosphine. Depending on the phosphine residuals, there may be some level of exposure via inhalation during food preparation. (This potential risk pathway was beyond the scope of the HHRE.)

The chronic Reference Dose (RfD), the amount of pesticide that could be consumed daily, likely without an appreciable risk of adverse effects, for phosphine is 0.0003 mg/kg-day. This RfD is based on the NOAEL (No Observed Adverse Effect Level)of 0.03 mg/kg-day from a two-year feeding study in rats (USEPA,2003). A phosphine residue of 0.03 mg/kg is needed to achieve a Hazard Index of 1 (i.e., the threshold for potential risk) for a young child weighing 10 kg and consuming 0.1 kg of the fumigated food daily for two years.

The preparation of the HHRE included an Internet literature search (using Science Direct and Google Scholar) to evaluate whether there is the potential for phosphine to be transferred from mother to infant via the ingestion of breast milk. No research papers were uncovered on this topic. As discussed above, there has been research on the transformation of phosphine to less toxic phosphorus species within fumigated commodities. However, the kinetics of those transformations and the kinetics of human metabolism of low levels of phosphine are important to understanding whether phosphine might persist long enough in a fumigated commodity or in the mother's body (i.e., the kinetics of human metabolism of low levels of phosphine) to suggest the possibility of transfer from mother to infant. This is an area where more research is needed to accurately assess potential impacts.

In most cases for Title II food aid, it would not be feasible to monitor the residual concentrations of phosphine in fumigated commodities once the commodity has left the fumigated warehouse. As a result, the HHRE states, if a residual concentration of phosphine is present subsequent to fumigation, estimating the potential risk to the beneficiary via ingestion [inhalation and food preparation] may be a difficult task. Aluminum and magnesium phosphide are in Toxicity Category I, the highest (most toxic) of four categories for acute effects via the inhalation route. However, USEPA expects no significant exposure to phosphine gas via the oral or dermal routes; this is the case where typical fumigation best practices are in place. This may not be the case in Title II recipient countries.

The discussion of potential impacts to beneficiaries is not intended to apply to any specific beneficiary of Title II food aid. It does, however, support the position that good fumigation practices--proper commodity stacking, handling, and warehouse ventilation/commodity aeration—are important parts of the fumigation and commodity protection process so that potential exposure to phosphine via inhalation, preparation, and ingestion routes, is kept to the lowest feasible levels.

Given the current state of knowledge, and that the HHRE indicates that the potential for residues is real, it is impossible to find that there is no potential risk to beneficiaries. Mitigation-as above-good fumigation practices, can minimize potential adverse effects. Additional research is needed to determine health risks, if any, to beneficiaries.

Issue 5) Phosphine fumigation can affect water quality, soil, and non-target organisms.

Aluminum phosphide and magnesium phosphide are non-persistent under most environmental conditions and are non-mobile in soil because of their instability at atmospheric moisture contents (USEPA, 1998). The products of hydrolysis, aluminum and magnesium hydroxides, react to produce mineral phases that occur naturally in the environment. Inorganic phosphate and other phosphorous oxyacids are the other products formed from the oxidation of phosphine gas in soils.

Under normal environmental conditions, phosphine exists as a gas. Phosphine below the soil surface is quickly adsorbed and degraded. The small amounts of phosphine present in spent residues will degrade in days and is at low risk for contaminating ground or surface waters. Phosphine near the soil surface will diffuse into the atmosphere and be removed by photodegradation. Phosphine trapped beneath the soil surface will bind to soil, inhibiting movement, and will be oxidized to phosphates. Therefore, aluminum and magnesium phosphide are not expected to pose a significant ecological risk to soil and water resources under normal circumstances of use.

If phosphine disperses from the warehouse site, non-target organisms could be at risk. One of the main concerns regarding non-target organisms is if aluminum phosphide is used to control burrowing animals (not when it is used to treat food aid commodities). The USEPA has required that precautions be taken to protect endangered species when using any of the phosphine producing fumigants to kill rodents in burrows. Any non-target species inhabiting the burrow will also be killed. However, this PEA analyzes fumigation of food commodities only, not for use in natural rodent burrows in soil or vegetated mounds.

The greatest concern for environmental contamination is if spent phosphine residues are not properly disposed of; the spent residues can still contain 3-5% phosphine (see Annex J, photo 22). In addition, dispersal of phosphine gas from the site could impact non-target organisms and mitigation is needed, as above (Issues 1 and 2) to ensure fumigation sites are well sealed. Further, best practices for disposal of phosphine residues must be implemented to ensure no soil or water contamination results.

Issue 6) Poorly handled solid waste, such as combining various types of waste (including aluminum and magnesium phosphide residues/byproducts), could present a danger. Mixing toxic residues during disposal could have unforeseen effects. Poor handling of fumigants includes poor practices in transport and storage, as well as disposal (see Annex J, photo 11).
[The PEA Team expanded this issue, identified in the Scoping Statement, to include transport and storage.]

Aluminum/magnesium phosphide and phosphine residues must be handled with caution to minimize risk to applicators, on-site workers and visitors, nearby residents, and firefighters. Improper transport, storage, and disposal or inactivation of residues and phosphine generating formulations can result in exposure to phosphine gas, fires, and explosions. In Title II recipient countries, safeguards may not be in place to ensure proper handling (during transport, storage, and disposal). However, by implementing simple best practices, no impacts would be expected to result. Although they may not currently be in place, these best practices are easily implemented and practical for all Title II recipient countries (see Annex T-6).

Issue 7) Improper disposal practices of rodents and birds, etc. killed by the fumigant, phosphine, could affect human health.

Phosphine can be used to control rats and mice and many other burrowing rodents. Although it is not labeled for control of birds, it is toxic to them. Rodents and birds can enter warehouses where doors are not closed tightly during normal operating hours. As witnessed by the PEA Team, it is common practice in tropical countries to keep warehouse doors open during working hours to allow for ventilation and temperature control (see Annex J, photos 2 and 9).

When warehouses are fumigated, rodents and birds that have inadvertently entered the warehouse will die. Dead animals can spread disease to humans, presenting a potential hazard for warehouse staff. The greatest hazard related to dead animals is the potential for the indirect spread of human disease by live animal parasites such as fleas and ticks. Risk of exposure to fleas and ticks increases when handling dead animals, because these parasites are actively seeking a live host and may be abundant on the dead animal or in the immediate area. Carcasses must be carefully disposed of to minimize the potential for transmission of disease to humans (Corrigan, 2001; Mamadaliyev et al. 2007; http://www.pestproducts.com/bird-diseases.htm).

Proper practices for rodent and bird disposal (as well as measures for keeping rodents and birds from entering warehouses) can be easily implemented to minimize risks. These are discussed in Annex T-6.

8) Phosphine may not be effective for the control of fungal contamination.
Mycotoxins are produced under certain conditions in the field or in storage on commodities. Mycotoxins could affect the health of beneficiaries if they consume contaminated food and advisory levels have been established for various mycotoxins associated with food. Phosphine gas can reduce the rate of mold growth and mycotoxin production but does not provide complete control of molds (Khair and Safeulla, 1994). Phosphine's effect on molds and microorganisms was observed during the late 1960s (Sinha et al., 1967; Raghunatan and Majumder, 1969). Phosphine- treated wheat and rice showed decreased mold development (Hocking and Banks, 1991a,b; Castro and de Pacheco, 1995). Castro et al. (1992) observed complete arrest of aflatoxin production on shelled peanuts fumigated at 0.5 g/m3 for 14 days. Similarly, aflatoxin production by *Aspergillus flavis* was effective on corn, and phosphine concentration tended to have a greater effect than exposure time (Castro et al., 2000). *Fusarium verticillioides* was tolerant to phosphine under high moisture conditions, and *Pencillium* on freshly harvested corn were also tolerant to phosphine. In a toxigenic species of *Aspergillus parasiticus* NRRL 2999, phosphine concentrations of 400 ppm or higher arrested growth of the fungi on agar plates (Antonacci et al., 1999). However, after venting to air, 100% of fungal colony forming units (CFU) initially exposed to <300 ppm developed fully grown colonies, but only 50% of the CFU on plates exposed to 400 ppm or high developed fully grown colonies some reduction at higher phosphine concentrations. Corn inoculated with the same fungi and exposed to 1000 ppm phosphine showed reduced mycelial growth and complete absence of the mycotoxin for over 20 days.

Higher phosphine concentrations may be needed to adversely affect fungi and mycotoxin production. The degree of control of molds and or mycotoxin production is temporary and may vary with the species of fungi present. These laboratory trials suggest that phosphine fumigation may indirectly and adversely affect mold development and mycotoxin production, but after the gas dissipates, fungal growth and mycotoxin production may reoccur.

The only effective control of fungal diseases is to maintain 13% moisture level in the commodity and to distribute commodity quickly so once it arrives in the host country, moisture level has no chance to increase to 14.5% or higher, a level that promotes mold growth.

5.1.1 ENVIRONMENTAL CONSEQUENCES OF THE ALTERNATIVES TO FUMIGATION WITH ALUMINUM PHOSPHIDE

This section contains an evaluation of the potential significant impacts (Issues 1 to 8 above) of the alternatives to the use of the fumigant phosphine.

Modified/controlled atmospheres: For this alternative, CO_2 and N_2used for treatment of commodities in chambers or in stacked bags under tarps is delivered using 99.9% pure gas in pressurized cylinders to create hypoxic conditions. Nitrogen is an unreactive gas and is considered inert. But exposure to high N_2atmosphere along with a lack of O_2, will result in CO_2 accumulation in the human body and can cause asphyxiation (Fowler et al., 1985); also, exposure to high levels of CO_2 and low levels of O_2 can be dangerous. Gases are delivered to enclosed areas from cylinders or generators, so the only risk to applicators and other on-site workers and visitors would be from entering treated areas or by accidental exposure.

Oxygen can be toxic at levels of 19% or below and above 60%. Symptoms include dizziness, impaired thinking, seizures, unconsciousness, pulmonary toxicity, or death depending on the severity of exposure (Clark, 1974). Carbon dioxide acts as both a stimulant and depressant on the central nervous system (OSHA, 1989; Wong, 1992), and adverse effects are related to the concentration and time exposed. Exposure of humans to 17to 30% CO_2concentrations leads to unconsciousness, coma, convulsions, and death within one minute (OSHA, 1989; CCOHS, 1990). Exposures of 10to 15% cause dizziness, drowsiness, severe muscle twitching, and unconsciousness within minutes (Wong, 1992; CATAMA, 1953; Sechzer et al., 1960). Symptoms at <10% CO_2 concentrations include headache, increased heart rate, shortness of breath, dizziness, sweating, rapid breathing, mental depression, shaking, and visual and hearing dysfunction that were seen following exposure periods of 1.5 minutes to 1 hour (Wong, 1992; Sechzer et al., 1960; OSHA, 1989). Short-term exposures (5 to 22 minutes) to carbon dioxide-air mixtures (2 percent to 8.4 percent carbon dioxide) also caused a distinct hearing loss (Gellhorn and Spiesman, 1934; 1935).

No potential impacts to nearby residents or to vulnerable populations (beneficiaries) are likely. There are also no potential impacts to soil or water from implementation of this alternative. Contribution to solid waste is minor. Disposal of bird and rodent carcasses due to this technique presents the same issues as fumigation with aluminum phosphide. This alternative may retard fungal growth, as these microorganisms are aerobic.

Hermetic storage: There are no potential impacts to human health or the environment from hermetic storage structures because modified atmospheres are created with airtight enclosures by commodity respiration; by creating a vacuum; or by purging CO_2 or N_2into the enclosures (suitable for processed commodities). These systems are self-contained and there is no direct human exposure or exposure to the environment. There are also no effects on food aid beneficiaries (vulnerable populations). Airtight enclosures retard fungal development because of reduced oxygen levels. Rodents and birds are unable to enter hermetic storages; there would be no need to dispose of dead rodents and birds.

Use of contact pesticides (including fogging): This alternative covers the use of pyrethroids, organophosphates, and carbamates.

Use of pyrethroids can have negative impacts on mixers/loaders, applicators, on-site workers and visitors, nearby residents, and on beneficiaries. Pyrethroids can have environmental effects also--water and soil, and non-target organisms may be affected. Pyrethroid containers contribute to solid waste and need to be disposed of safely per label requirements and local ordinances. Disposal of rodent carcasses killed by pyrethroids presents the same issues as with fumigation. Pyrethroids are not used for controlling storage fungi.

The acute toxicity to mammals varies with the specific formulation. Use of natural pyrethrins and synthetic pyrethroids without appropriate safeguards may cause contact dermatitis and produce asthma-like reactions, although absorption through the skin is minimal. Other symptoms of acute toxicity due to inhalation (which could affect applicators, other on-site workers and visitors, and nearby residents) include sneezing, nasal stuffiness, headache, nausea, incoordination, tremors, convulsions, facial flushing and swelling, and burning and itching sensations. The most severe poisonings have been reported in infants (on-site visitors or nearby residents), who are unable to efficiently break down pyrethroids (ETN, Pyrethroids, 1994). If ingested by beneficiaries or by using pyrethroid containers as food containers (a potential impact for applicators, other on-site workers and visitors, nearby residents, and beneficiaries) nervous symptom affects may occur, which include excitation and convulsions leading to paralysis, accompanied by muscular fibrillation and diarrhea (ETN, Pyrethroids, 1994). Death may occur, as well, and is due to respiratory failure. Symptoms of acute exposure last about two days.

Rats exposed to Type I pyrethroids exhibit aggression, hyperexcitability, fine tremor, prostration with coarse whole body tremors, increased body temperature, coma and death (USEPA, 2011).Behaviors observed after exposure to Type II pyrethroids include pawing and burrowing, salivation, hyperexcitability, abnormal hind limb movements, coarse whole body tremor, sinuous writhing, coma and death. The onset of neurobehavioral effects occur within a few minutes to over an hour, depending on the route of exposure and the chemical, but can take 2 to 8 hours to peak. Recovery from pyrethroid toxicity is rapid, typically within 24to48 hours, because of the limited absorption of some pyrethroids in mammals and rapid biodegradation through ester hydrolysis and oxidation by liver enzymes.

Some pyrethroids are classified by USEPA as possible human carcinogens, because they contain human-made, or xenoestrogens, which can increase the amount of estrogen in the body (Garey et al., 1998). Certain pyrethroids demonstrate significant estrogenicity and increase the levels of estrogen in breast cancer cells (Go et al., 1999). Pyrethroids, especially those registered prior to 1976, were not teratogenic in rats, mice, and or rabbits (Miyamoto, 1976). They were also not mutagenic to several bacteria strains. A recent USEPA cumulative risk assessment of pyrethroids (USEPA, 2011) concluded the recommended use practices for pyrethrins and pyrethroids provides sufficient margin of safety.

Non-target organisms may be adversely affected by pyrethroids and pyrethrins. They are extremely toxic to aquatic organisms, including fish such as the bluegill and lake trout, with LC50 values less than 1.0 ppb. Lobster, shrimp, mayfly nymphs and zooplankton are the most susceptible non-target aquatic organisms (Mueller-Beilschmidt, 1990). The non-lethal effects of pyrethroids on fish include damage to the gills and behavioral changes. Pyrethroids are moderately toxic to birds, with most LD50 values greater than 1000 mg/kg. Birds can also be indirectly affected by pyrethroids, because of the threat to their food supply. Waterfowl and small insectivorous birds are the most susceptible (Mueller-Beilschmidt, 1990). In soil the half-life of cypermethrin can be 8 weeks, and in water it can be 100 days (ETN, Cypermethrin, 1996).

The synergist PBO is added to natural pyrethrins and pyrethroids to increase their potency against insects by suppressing enzymes. PBO is added in surface and/or fogging applications. PBO inhibits hepatic microsomal oxidase enzymes in laboratory rodents. Chronic toxicity studies have shown increased liver weights, even at the lowest doses, 30 mg/kg/day (USEPA, 2011). PBO exposure leads to skin irritation, anorexia, vomiting, diarrhea, intestinal inflammation, pulmonary hemorrhage and possibly mild central nervous system depression. Animal studies have shown hepatocellular carcinomas at treatments levels as low as 1.2% (Takahashi et al., 1994).

Pyrethroids unlike pyrethrins break down slowly when exposed to sunlight light, heat and moisture, and since warehouses are devoid of sunlight surface residues may persist for weeks to months. For example, deltamethrin products persist from 1 to 2 weeks in the environment (ETN, Deltamethrin, 1995).

For Title II commodity warehouses, pyrethroids and pyrethrins would most likely be used for general surface, spot, and crack/crevice application in and around warehouses. Dermal exposure and inhalation exposure are the main risks during and after application. Wearing a long sleeved shirt, pants, boots, goggles, coveralls, and approved canister type of respiratory protection during application reduces dermal and inhalation exposures. Pyrethroids have low vapor toxicity so breathing vapors post-application is not a concern. Potential impacts to workers may occur if they work in warehouses with bare feet. During PEA site visits, the PEA Team noted that most of the warehouse workers did not use footwear. The use of boots or other footwear would minimize risk due to dermal absorption of residues.

Post-application inhalation exposure due to the use of indoor foggers may occur if during application full face respiratory protection is not used by the applicators. Dispensing fogs using a permanently installed system poses the least exposure risk to applicators/workers. Labels provide information about the need to cover commodities during application.

The CRG recommends application of residual products only to empty warehouses. During site visits, the PEA Team found that treating empty warehouse floors and walls and outside with pyrethroids prior to bringing in food aid commodities is a common practice. Prior to a fumigation event, pyrethroids are used in empty warehouses to treat the floor-wall junction and floor areas to control insects escaping from tarped commodities during fumigation. Risks to beneficiaries can occur from pyrethoid residues only if the sprays are applied directly or accidently to the bags. Risk of residues contaminating the commodity may occur only if commodity spilled on the floor is collected and rebagged for distribution to beneficiaries. The pattern of use of applying pyrethroids to surfaces of the warehouse greatly diminishes any adverse impact to beneficiaries, because of lack of direct commodity exposure.

Use of organophosphates and carbamates can have negative impacts on mixers/loaders, applicators, on-site workers and visitors, nearby residents, and on vulnerable populations (beneficiaries). They can have environmental effects also--water and soil, and non-target organisms may be affected; however, the magnitude of adverse effects varies with the product. Containers contribute to solid waste and need to be disposed of safely. Disposal of rodent carcasses that succumb to these pesticides presents the same issues as fumigation presents. Organophosphates and carbamates are not labeled for the control of storage fungi.

The mechanism of action of organophosphates and carbamates, on both target and nontarget species, is irreversible inhibition of acetylcholinesterase enzyme (AchE) found in red blood cells and in nicotinic and muscarinic receptors in nerve, muscle, and gray matter of the brain. Plasma acetylcholinesterase is found in the central nervous system white matter, pancreas, and the heart. Its decrease results in a decrease of cholinesterase activity in the central, parasympathetic, and sympathetic nervous systems.

Organophosphates will phosphorylate and carbamates will carbamylate the serine hydroxyl group at the site of action of acetylcholine. This irreversible binding, deactivating the esterase, results in accumulation of acetylcholine at the endplate causing persistent depolarization of skeletal muscle, resulting in weakness and involuntary muscle twitching (fasciculations). In the central nervous system, neural transmission is disrupted. If this block is not reversed by a strong nucleophile such as pralidoxime (2-PAM) within 24 hours, large amounts of acetylcholinesterase are destroyed.

Chronic neuropsychological effects have been seen in 4to9% of patients exposed in occupation-related use (Alavanja et al., 2004; Eskenazi and Maizlish, 1988). Glutathione transferase polymorphism 1 (GSTP1) genotypes may predispose people exposed to organophosphates to develop Parkinson's disease (Menegon et al., 1998; Bhatt et al., 1999). Organophosphate-induced neuropathy has also been implicated to cause amyotrophic lateral sclerosis (Rainier et al., 2008).

Human birth defects have been associated with exposure to the organophosphate chlorpyrifos. In pregnant laboratory animals, exposure to chlorpyrifos caused fetal death. Pups that survived were smaller than pups from unexposed mothers, and also showed decreased survival. Male rats exposed to chlorpyrifos caused cell death in male rat testes and a decrease in sperm production in exposed cattle. Chlorpyrifos has caused genetic damage in human blood and lymph cells, mice spleen cells, and hamster bone marrow cells. Immune system abnormalities have been reported from patients exposed to chlorpyrifos (Cox, 1994). PVOs reported to the PEA Team that the organophosphate pirimiphos-methyl was one of the products of choice. This product is more toxic via dermal absorption (acute LD50 to rats, 1505 mg/kg) than by inhalation (acute LD50, 2050 mg/kg). According to the USEPA's pirimiphos-methyl fact sheet (http://pmep.cce.cornell.edu/profiles/insect-mite/mevinphos-propargite/pirimiphos-methyl/insect-prof-actellic.html) it is not a dermal irritant or sensitizer. It did not cause delayed neurotoxicity at 10 mg/kg/day for up to 90 doses, is not teratogenic, mutagenic, and does not affect reproduction. The product is metabolized quickly and does not bioaccumulate.

In developing countries, Eddleston et al. (2008) estimates organophosphorus pesticide self-poisonings kill 200,000 people a year. A recent cumulative risk assessment by USEPA for organophosphates (USEPA, 2006) and N-methyl carbamates (USEPA, 2007) concluded that the current use patterns of these compounds provides sufficient margin of safety to applicators/workers. This is the case only if precautions are taken.

Most organophosphorus pesticides are chemically unstable and are degraded by microbes in soil and water. Enhanced biodegradation of many organophosphorus pesticides, upon their repeated applications to soil and water, is well-established (Cáceres et al., 2010). Several soil microorganisms, bacteria in particular, are able to transform many organophosphorus pesticides. For example, fenamiphos can undergo rapid microbially mediated degradation via oxidation to its oxides (sulfoxide and sulfone) and eventually to CO2 and water in soils, or via hydrolysis, in cultures of the soil bacterium, *Brevinbacterium* species.

The USEPA fact sheet for pirimiphos-methyl shows that it is toxic to birds by oral and dietary routes. The tested birds include mallard duck, ring-necked pheasant, and bobwhite quail. It is toxic to cold water fish (rainbow trout) and warm water fish (bluegill, sunfish) at <3 ppm. Fresh water invertebrates such as *Daphnia* are susceptible at 0.21 ppb.

Like organophosphates, carbamates do not cause delayed neurotoxicity. Evidence is lacking about the adverse health effects from long-term exposure at levels that do not affect acetylcholinesterase levels. Carbamates are not regarded as mutagenic, carcinogenic or teratogenic substances (USEPA 2007). Carbaryl, a commonly used carbamate, has a half-life of hours to days at a water pH of 7 or above and degradation is about 1500 days at a pH of 5 (http://www.cdpr.ca.gov/docs/emon/pubs/fatememo/carbaryl.pdf). It is toxic to aquatic invertebrates (*Daphniamagna*, shrimp), vertebrates (rainbow trout, catfish, and blue gill sunfish) as well as beneficial insects, such as honeybees (LD50 1.54 – 26.5 g active ingredient [a.i]/bee).

Carbaryl has a low vapor pressure, 1.17 x 10-6 mmHg, and is not readily volatilized into the air. In water, the primary degradation route is by hydrolysis, which his pH dependent, and microorganisms accelerate the rate of degradation. Some degradation is expected due to sunlight. Carbaryl is not persistent in soil. It can be degraded through hydrolysis, photolysis, as well as by microorganisms.

As with pyrethroids, organophosphates and carbamates should not be directly applied to food aid commodities. However, these products may be applied to floors and walls of empty warehouses. Application around bagged stacks is a common practice prior to fumigation of stacks to kill insects escaping the fumigation. The chance of food aid commodities directly coming in contact with these products is minimal, if sprays are made away from stacks. Another source of cross contamination with these pesticides can occur if spilled commodity material on the treated warehouse floors is put back into bags and sent to beneficiaries. Therefore, on treated warehouse floors, collected spilled commodity materials should be discarded. There is no evidence to suggest that application of pyrethroids, organophosphates, and carbamates to empty warehouses or to warehouses with food aid commodities away from stacked bags poses a potential adverse impact to beneficiaries.

Insect growth regulators (IGRs): This alternative has minimal potential for adverse effects on applicators, other on-site workers and visitors, nearby residents, beneficiaries, water, and soil. However, it may have adverse impacts on non-target and beneficial insects. Safe disposal is a consideration for use of IGRs. IGRs have no effect on rodents, birds, or molds.

The USEPA (1991) fact sheet (http://www.epa.gov/oppbppd1/biopesticides/ingredients/factsheets/factsheet_igr.htm) considers methoprene and s-hydroprene as having the same mechanism of action but the IGR pyriproxyfen's mechanism of action is different (http://pmep.cce.cornell.edu/profiles/insect-mite/mevinphos-propargite/pyriproxyfen/pyriprox_tol_0802.html). The IGRs are generally placed in USEPA Toxicity Categories III and IV based on dermal and oral toxicity to rats, dogs, and rabbits (LD50s > 2000 to 50,000 mg/kg). Methoprene is exempt from a residue tolerance because of its low mammalian toxicity. The acute (four hour) inhalation LC50 for racemic methoprene in the rat and guinea pig is >210 mg/L. Methoprene does not cause any skin or eye irritation. These data indicate an extremely low potential for acute toxicity to humans from overexposure to methoprene via the oral, dermal, ocular or inhalation routes of exposure.

Chronic feeding studies with rats and mice fed 0 to 5000 ppm daily for two years did not result in any adverse health effects even at the highest dose as compared to control animals. Methoprene is not oncogenic or mutagenic and does not affect the endocrine system. Methoprene in animals does not impair developmental or reproduction, suggesting lack of developmental toxicity in humans during pregnancy or during early childhood. In two decades of methoprene use, including stored grain, no health hazards have been reported that could be related to the ingestion of methoprene residues. In water, methoprene is degraded quickly by microorganisms and sunlight to form at least fifty products. In soil, under aerobic or anaerobic conditions, the half-life is 10 to 14 days. Various studies indicate that methoprene is not an oncogen, developmental toxicant, or mutagen. Further studies indicate no detectable endocrine effects in mammals (USEPA, 2001).

Impacts to those who mix, load, and apply IGRs are expected to be minimal due to the low mammalian toxicity via dermal and inhalation routes. Impacts to others on-site also are expected to be low or non-existent. Wright (1976) arrived at these same conclusions based on research on several IGRs.

Methoprene has a moderate vapor pressure and has the potential to volatilize from water or moist soil. Binding to soil may retard volatilization (Csondes, 2004). In air, methoprene degrades by sunlight to hydroxyl radicals (half-life 1.5 hours) and ozone (48 minutes). Methoprene showed rapid degradation in both sterile and nonsterile pond water exposed to sunlight, more than 80% of applied methoprene was degraded within 13 days (USEPA, 1982).Extensive studies have shown that methoprene breaks down rapidly in the environment and displays relatively low risk to most non-target organisms (USEPA, 1991).

Methoprene undergoes demethylation, hydrolysis and oxidative cleavage in microbes, insects and plants and is rapidly metabolized in fish, birds, and mammals (Glare and O'Callaghan 1999). Acute, short-term and sub-chronic aquatic effect studies have been conducted on non-target adult and immature arthropods, including Crustacea, Insecta, and Mollusca. These studies reported 24 and 48 hours LC50 values greater than 900 ppb (Glare and O'Callaghan, 1999). Other non-target organisms in early life stages (nymph, larvae) and non-target organisms that are closely related to mosquitoes such as dragonfly (order Odonata or suborder Anisoptera) are not affected by methoprene up to 1,000 ppb (Glare and O'Callaghan 1999). Methoprene is slightly toxic to aquatic macroinvertebrates such as Daphnia, Mysid and Hyallela (Siemering 2004).Methoprene is moderately toxic to cold water and freshwater fish and practically non-toxic to warm water fish. The reported LC50 are 4.62 ppm for bluegill, 4.39 ppm for trout, and >100 ppm for channel catfish and largemouth bass, and

methoprene bioaccumulates in the fish body (Glare and O'Callaghan, 1999). Use of methoprene could result in impacts to some non-target species if safeguards are not in place.
The discussions on health and environmental consequences are from the pyriproxyfen MSDS (http://www.cdms.net/ldat/mp48S001.pdf) and from data provided by the Pest Management Regulatory Authority of Health Canada (http://www.hc-sc.gc.ca/cps-spc/alt_formats/pacrb-dgapcr/pdf/pubs/pest/decisions/rd-dh/rd2007-03-eng.pdf). Like methoprene, the acute toxicity of pyriproxyfen is low. It can be minimally toxic when inhaled or ingested. Therefore, fumes of pyriproxyfen from a fire could pose an inhalation hazard. Combustion products are carbon monoxide, carbon dioxide, oxides of nitrogen and water vapor. It is an eye and skin irritant. Chronic exposures produced liver, kidney, and red blood cell changes, but not cancer. People with kidney and liver disease may be susceptible to pyriproxyfen exposures. No developmental and reproductive toxicities were observed.

IGRs have lower mammalian toxicity than pyrethroids, organophosphates and carbamates. The careful application of these products only to warehouse surfaces and walls will not result in direct contact with the bagged food aid. If permanently installed systems or foggers are used to disperse the IGRs, covering the bags with polythene sheets protects from the aerosol coming in contact with the commodity. Given the use pattern, there is essentially no risk to the beneficiaries consuming food aid. As mentioned above, any spilled commodity in treated warehouses should not be rebagged for distribution to beneficiaries. Instead it should be discarded (this is included as a best practice below).

Inert dusts: Inert dusts are chemically unreactive in nature. Inert dusts have low mammalian toxicity and are placed in USEPA Toxicity Category IV. The USFDA considers them *Generally Regarded as Safe* (this rating is related to consumption only). These products are also exempt from a residue tolerance when used on surfaces or commodities (Subramanyam and Roesli, 2000).

Two special journal volumes presented risk assessments of silica-based products (Goldsmith et al., 1995; 1997). Some diatomaceous earth dusts and synthetic silicas may contain none or <1 to 4% crystalline silica. In 1996, the International Agency for Research on Cancer (IARC) changed the classification of crystalline silica from a probable human carcinogen (category 2A) to confirmed human carcinogen (category 1) (http://www.osha.gov/dsg/topics/silicacrystalline/index.html).

Therefore, when using DE or silica dusts there is concern about inhalation hazard to applicators. Silicosis is an irreversible lung disease in which fibrous tissue is formed as a response to inhaling the silica particles. The link between silicosis and lung cancer is unknown, but acute and chronic exposures to crystalline silica may cause cancer (Checkoway et al., 1993). In the US, inert dusts have been in use for many decades and no adverse effects have been reported in applicators. However, in Title II recipient countries, where safeguards may not be properly used or available, the potential to cause cancer is a concern. There are no environmental concerns (soil, water, non-target organisms) or concerns to beneficiaries from using these inert dusts. Containers can be disposed of in regular sanitary waste streams. This alternative has no effect on rodents, birds, or molds.

Packaging: Packaging is an alternative to fumigation to prevent insect entry into stored commodities. Unless packages are treated with an insecticide or extruded with insecticide in the packaging matrix, the risk from packaging has no adverse effects to anyone handling the bags or consuming the product.

Packages impregnated with insecticides may pose potential health effects to workers involved with handling the bags (dermal exposure). Packages with insecticides may also have adverse effects on soil, water, and non-target organisms if improperly disposed, and on beneficiaries if translocation of the insecticide into the commodity occurs. Disposal is an environmental concern for packages impregnated with chemicals. Insect-resistant packaging has no effect on rodents, birds, or molds.

5.1.2 POTENTIAL ADVERSE IMPACTS EXCLUDED FROM CONSIDERATION

The Scoping Statement had considered and then excluded the following potential impacts from the PEA:

- **Inappropriate risks associated with pesticide use:** Are they using banned pesticides for fumigation purposes and if so, why? This matter is not considered significant because it is understood that the use of methyl bromide, now prohibited because of its negative impacts on the ozone layer, has been banned from fumigation programs worldwide.
- **Post-Harvest Storage loss in FFP Development Programs is a related topic but beyond the scope of the present PEA.** FFP may wish to consider working with the Bureau for Food Security to address post-harvest loss, either as a separate PEA or general program study in the context of the broader Feed the Future (FtF) initiative.
- **Disposal of Spoiled Food Aid Commodities is another closely related issue but one that will require separate and concerted attention** beyond the means of the planned PEA.
- **Food Aid Quality** as a broader issue will not be considered here because pest infestation is only a small part of the wide range of characteristics currently being considered as part of an effort to enhance food aid quality. See for example the May 2011 GAO Food Aid Quality report.

The PEA Team has excluded the following issue, identified in the Scoping Statement, from further consideration in the PEA:

Confusion about pesticides intended for use in sanitizing warehouse facilities and grounds: The Scoping Statement describes this issue as: Pyrethroids are commonly applied for crack, crevice, and spot spray treatment in and around an empty warehouse. However, some deltamethrin or cypermethrin synthetic pyrethroids, are being applied improperly on food aid commodities and contaminating them.

Justification for excluding from the PEA: Synthetic pyrethroids and organophosphates/carbamates are discussed in the PEA as alternatives to phosphine for suppressing insects present in empty warehouses or containers. This is not a potential significant adverse impact of aluminum or magnesium phosphide fumigation (the potential impacts that are being evaluated in this PEA), but rather an impact of improper use of insecticides in general, which should be addressed in PERSUAPs.

5.2 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The proposed action, fumigation of food aid commodities, when undertaken in accordance with best practices (discussed in Annexes T- 2, 3, 4 and 9) would result in only minor irreversible and irretrievable commitment of resources. There is no irreversible commitment of land area (disposal of residue and packaging requires a deep pit, which is typically located on the warehouse site, in an already disturbed area. Once it is filled in, it will revert to natural conditions). Phosphine fumigation results in no irreversible and irretrievable commitment of ecological resources; as shown above in Section 5, potential environmental impacts are minor.

The safeguards required to ensure that human health remains unaffected by fumigation require a commitment of financial resources to implement training, ensure proper PPE is available and maintained, and to conduct possible follow-up studies, as suggested in Section 1.

However, as described, the proposed action (fumigation of food aid commodities with phosphine) often includes pre-fumigation application of contact pesticides. Use of contact insecticides (belonging to the pyrethroid, organophosphate, and N-methyl carbamate classes) prior to fumigation may result in irreversible and irretrievable commitment of resources. The potential impacts resulting from the use of contact pesticides prior to fumigation will need to be analyzed separately in a PERSUAP, and measures should be proposed to mitigate impacts; if mitigation is unavailable or impossible, the PERSUAP should make note that there may be irreversible and irretrievable commitment of resources. Without further country, site-, and pesticide-specific evaluation, no determination can be made at this point regarding irreversible and irretrievable commitment of resources from pre-fumigation spraying.

Modified atmospheres and hermetic storage would require financial commitments. In addition, the significant energy requirements would result in irreversible and irretrievable commitment of energy resources (coal, hydropower, etc.) No mitigation is available to minimize the potential impacts from the high demand for energy.

No irreversible and irretrievable commitment of resources would result from other alternatives considered in this PEA: inert dusts, IGRs, and sanitation. Essentially, these are part of IPM, as mentioned in Section 5.3.

5.3 MEANS TO MITIGATE ADVERSE HEALTH AND ENVIRONMENTAL IMPACTS

The following section discusses the means to mitigate potential impacts of the alternatives, with a focus on the proposed action, phosphine fumigation of Title II food aid commodities. Mitigation measures are presented in Section 5.3.1 and in Annex T-7. Partner compliance requirements consistent with this section are synthesized in the Tools Annexes; partners that follow instructions in the Tools Annexes will satisfy the requirements of the PEA.

As shown in Table 3 and as discussed in Section 5.1, significant adverse impacts may result from fumigation. The main concerns are for the health of fumigators, other on-site workers, visitors, and nearby residents (these populations are rated -2 in Table 3). Typical best practices—for example, as implemented in the US—can minimize potential health concerns. However, as stated above, the PEA Team found that best practices are often not applied in Title II food aid fumigation.

Yet many of the best practices are inexpensive and simple to implement (i.e., use of good quality, undamaged tarps, good sealing of stacks, adequate warning signs on the outside of warehouses, adequate notification of workers and nearby residents). Annex T-6 describes these best practices. Of particular interest for USAID Title II PVOs may be the product stewardship programs that reputable distributors provide; these programs offer training opportunities and advice for PVO staff who fumigate and for fumigation service providers.

Some of the best practices are IPM practices that, in concert with fumigation, minimize the need to fumigate. Yet, as mentioned above, the PEA Team found that some common IPM measures are currently not broadly applied in food aid warehouses, or they are poorly applied (i.e., good sanitation practices, keeping warehouses closed-to the degree acceptable in hot, humid climates--so pests are unable to enter, use of rodent traps). Annex T-6 describes these best practices.

Other best practices, such as monitoring phosphine gas during fumigation and wearing required PPE are more costly. These items need to be procured and maintained, and personnel must be trained to use them. Recurrent training and replacement parts must also be made available. However, the cost of monitoring equipment and PPE, maintenance, and training is not expected to be prohibitive; various means are available to obtain regular training (including online, see Annex T-13), and equipment is available at a range of costs (See Annex T-9).

Annex T-7, the Programmatic Environmental Mitigation & Monitoring Plan, lists mitigation (best practices), responsible parties, and monitoring and reporting requirements. Fumigation "best practices" are presented in Annex T-6; with implementation of these, adverse health effects to fumigators, other on-site workers, visitors, and nearby residents are not expected to result.

Additionally, potential impacts to these groups could be minimized by improvements to infrastructure. However, the cost of these improvements to USAID and PVOs, as well as warehouse ownership issues, may preclude implementation of improvements. Infrastructure improvements are recommended as a mitigation measure since in certain cases, funding may be available.

While many studies indicate that potential health effects to beneficiaries is less likely an issue than potential effects to those in direct contact with the fumigant (as above, fumigators, other on-site workers, visitors, and nearby residents), as noted, insufficient information is available to make a definitive determination. It is likely that with implementation of best practices (mainly, providing for an adequate aeration period and placing phosphine beneath pallets rather than directly on commodity), concerns are minimal. These mitigation measures are easily implemented and are at no cost. Given the uncertainty further study is called for on the effects to Title II beneficiaries.

Potential effects of fumigation on soil, water, and non-target organisms can be mitigated by ensuring safe storage, transport, and disposal; these are easily implemented, no cost best practices (Annexes T-6 and T-7).

As shown in Table 3, and as discussed above, use of contact pesticides would require mitigation as well. Potential significant adverse impacts to applicators, other on-site workers, visitors, and nearby residents could result (rated -2 in Table 3). As with fumigation, training, use of PPE, and implementation of best practices in handling (storage, transport, mixing, application, and disposal) are needed to mitigate potential human health and environmental impacts. Critically, use of contact pesticides has the potential for significant adverse impacts to the environment (rated -2 in Table 3). These potential impacts can be difficult to mitigate and monitor. For the USAID Title II program, a PERSUAP is required prior to procuring or using pesticides, and this would require detailed mitigation, including training, the use of PPE, and implementation of environmental safeguards.

Except for the *No Action* alternative, none of the other alternatives under consideration have the potential to result in significant adverse impacts. Yet some of the alternatives (modified/controlled atmospheres and hermetic storage) may face other constraints: they may be cost-prohibitive, they require a reliable power supply, and they may have significant maintenance needs. While these would not preclude their use, before recommending widespread application of these controls, additional exploration is needed. On a case-by-case basis, they may be practicable and effective.

Concerns over efficacy limit the usefulness of other alternatives: sanitation, IGRs, inert dust (IGRs and inert dust would require a PERSUAP prior to use/procurement). While on their own, they will not control infestations of stored pests within a commodity, in combination with fumigation they can decrease the number of fumigations needed. In essence, this is IPM; and as required in all cases where pesticides will be used or procured, USAID advises that they should only be used within an IPM framework. Pesticides, including fumigants, should be used as a last resort control, and the least toxic, effective pesticides should be used first.

5.3.1 RECOMMENDATIONS: MITIGATION MEASURES TO MINIMIZE POTENTIAL ADVERSE IMPACTS OF PHOSPHINE FUMIGATION OF TITLE II FOOD AID

Note that the requirements in this section are consolidated in a user friendly format in the Tools Annexes. Partners that complete the templates and plans in the Tools Annexes will be environmentally compliant with their requirements.

COMPLIANCE WITH 22 CFR 216

Programs without Existing PERSUAPs for Fumigation

1) If the PVO has provided assistance for the procurement or use of aluminum/magnesium phosphide without an approved PERSUAP (i.e., if the PVO has fumigated or purchased fumigation services at their Title II warehouse, but has not received USAID/DCHA/Bureau Environmental Officer (BEO) approval of a PERSUAP which includes the fumigant), the PVO shall note this in the next Environmental Status Report (ESR), and shall, as soon as possible, take corrective action by preparing a PERSUAP for procurement and/or use of the fumigant.
2) The PERSUAP for procurement or use of aluminum/magnesium phosphide shall integrate mitigation measures (see #3 below) guide implementation, monitoring, and reporting on mitigation measures.
3) For integration into the PERSUAP, the PEA best practices (Annexes T-6 and 8, with supporting Annexes, T-2 and 3) may be modified to fit the country-, project-, and site-specific situation. However, the PEA BPs are standards that have been identified to minimize the potential for significant impacts to human health and the environment. The PVO should justify the need for modifications, and should identify any additional measures the PVO will take to monitor to ensure adverse impacts will not result from fumigation with aluminum/magnesium phosphide.
4) The PVO shall report on implementation of mitigation (successes, issues, failures) in Title II semi-annual progress reports and in the annual ESR.

Programs with Previously Approved PERSUAPs for Fumigation

1) If the PVO has an approved PERSUAP for aluminum/magnesium phosphide, the PVO shall review the PERSUAP to determine whether modifications are needed to comply with the PEA.
2) As necessary, the PVO shall submit an amendment to the IEE with a PERSUAP.
3) For integration into the PERSUAP, the PEA best practices (Annexes T-6 and 8, with supporting Annexes, T-2 and 3) may be modified to fit the country-, project-, and site-specific situation. However, the PEA BPs are standards that have been identified to minimize the potential for significant impacts to human health and the environment. The PVO should justify the need for modifications, and should identify any additional measures the PVO will take to monitor to ensure adverse impacts will not result from fumigation with aluminum/magnesium phosphide.
4) The PVO shall report on implementation of mitigation (successes, issues, failures) in Title II semi-annual progress reports and in the annual ESR.

MITIGATION MEASURES

Based on the analyses in Section 5.1, the following mitigation measures will minimize potential adverse effects of phosphine fumigation of Title II food aid. Mitigation is separated into measures to be implemented by PVOs and measures to be implemented by USAID.

MITIGATION MEASURES FOR IMPLEMENTATION BY COOPERATING SPONSORS

A) To minimize the potential adverse impacts related to:
Issues 1 through 7: Use of the fumigant, phosphine, can affect the health of applicators and other on-site workers and visitors; the health of nearby residents; food quality; the health of beneficiaries; and soil, water, and non-target organisms. Inappropriate practices in handling (transport, storage, and disposal) and in disposing of dead rodents and birds could result in adverse health and environmental impacts,

1) PVO shall use Annex T-4, Model RFQ and Contract (or revised) when procuring fumigation services, which require that the fumigation service provider (FSP) complies with best practices (BPs), such as fumigation tarp specs, use of PPE, phosphine gas monitoring, securing the warehouse, notifications, safe disposal etc. (Full details of BPs are in Annexes T-6 and T-7, with supporting material in Annexes T-2 and 3).

PVO shall evaluate proposals/quotes from pest management companies based on their ability to implement the BPs stipulated in the RFQ and Model Contract.

2) If PVO finds that FSPs are unable to comply with BPs and Model Contract in Annexes T-6 and T-5, PVO shall take corrective actions, such as:

- Sponsoring a meeting with FSPs to identify compliance concerns;
- Procuring phosphine gas monitoring equipment;
- Procuring PPE;
- Procuring fumigation sheets;
- Providing training for PVO and/or FSP staff in use and maintenance of the above;
- Investigate good stewardship programs offered by pesticide distributors; and/or
- Other measures that would address non-compliance issues.

3) Based on FSP's ability to perform in accordance with BPs (and Model Contract), PVO shall discuss with USAID possible actions to take to strengthen capacity of FSPs and/or to modify the BPs, RFQ, and contract so that they are implementable, while also providing adequate safeguards.

4) PVO shall ensure that during fumigation, BPs are implemented by FSP, as stipulated in Annexes T-6 (Best Practices) and T-5, Model Contract, and as revised from #s 2 and 3 above.

5) In consultation with the FSP, PVO shall prepare Fumigation Management Plans (FMP, Annex T-3) for each fumigation event, which shall provide guidance for the fumigation process. Each FMP shall be retained for two years in project files.

6) If PVO has fumigators on staff who serve as FSPs, the above mitigation measures 2 through 5 shall be followed. In addition, applicable mitigation measures below (B through D) shall be followed.

7) The PVO shall retain the MSDS, label, and emergency/first aid measures at the warehouse office or other nearby, convenient location (See Annexes T-2, T-3 and T-7). This information shall be made available to all staff, and if required, key sections should be translated to local language.

8) Prior to fumigating, if contact pesticides are to be used, PVO shall ensure that spraying is done in accordance with USAID's Pesticide Procedures, which require that a PERSUAP is approved prior to using/procuring pesticides, and that they are used in an environmentally sound manner that reduces potential impacts to human health.

9) PVO shall ensure that phosphine fumigation is implemented within an IPM framework that involves use of non-chemical measures (see warehouse checklist, Annex T-6), and the use of pesticides as a last resort control, using least toxic (i.e., IGRs, inert dust), efficacious, cost-effective pesticides before more toxic.

10) Based on Annex T-6, Warehouse Inspection Checklist, PVO shall revise, as necessary, PVO-specific warehouse sanitation and inspection procedures.

11) PVO shall include warehouse infrastructure improvements in DFAP budget for Title II program (if allowable).

B) to minimize potential adverse impacts related to Issue 2: Use of the fumigant, phosphine, can affect the health of residents nearby to the warehouse being fumigated

1) PVO shall develop a plan for notification of nearby residents (see Annex T-6), which shall be implemented prior to conducting fumigation.

C) The quality of the food commodity may be compromised due to phosphine fumigation; beneficiary populations may be at risk from inhalation, preparation, and ingestion of fumigated commodities.

1) When procuring an FSP, PVO shall use Annex T-4 and T-5, Model RFQ and Contract (and see Annex T-6) to ensure that BPs are implemented regarding placement of aluminum/magnesium phosphide under the stack.

2) When procuring an FSP, PVO shall use Annex T-4 and T-5, Model RFQ and Contract (and see Annex T-6) to ensure FSP provides an adequate aeration period.

D) To minimize potential adverse impacts related to Issues 5, 6, & 7: Phosphine fumigation can affect water quality, soil, and non-target organisms; poor handling (transport, storage, and disposal) of fumigants could have adverse impacts on human health and the environment; and Improper disposal practices of rodents and birds, etc. killed by the fumigant, phosphine, could affect human health

1) When procuring an FSP, PVO shall use Annex T-4 and T-5, Model RFQ and Contract, to ensure that FSP implements proper transport, storage, and disposal practices, including disposal of dead rodents and birds.

2) PVO shall ensure that on PVO sites, fumigants are stored safely and securely to minimize potential impacts to human health and the environment; and that PVO responsibilities in regard to transport and disposal are conducted in accordance with BPs (see Annex T-6).

ADDITIONAL RECOMMENDATIONS

To strengthen capacity of PVO staff and FSPs:

1) PVO shall ensure that PVO staff who review quotes/proposals from FSPs are trained to evaluate technical fumigation issues.

2) PVO shall ensure that PVO staff who supervise/oversee warehouse fumigation are trained to monitor fumigation in accordance with Annex T-6 and the supporting Annexes, T-2 and T-8.

3) PVO shall ensure that at least one PVO staff is trained to inspect the warehouse post-fumigation to ensure a successful fumigation; and to identify key stored-product pests of the country/region (see below issue, resistance).

4) PVO shall ensure that warehouse staff are well trained in implementing warehouse sanitation procedures and inspections (see Annex T-6).

7) For capacity strengthening of FSPs, see Mitigation Measure A #2.

To address issues with insect resistance due to implementation of poor fumigation practices (shorter than needed fumigation periods, leaky fumigation):

1) In addition to measures above requiring implementation of BPs during fumigation (use of good quality tarps, airtight seals, and sufficient length of time for a fumigation event), PVO shall inspect warehouse post-fumigation and track fumigation successes and failures in ridding commodities of infestations.

MITIGATION MEASURES FOR IMPLEMENTATION BY USAID

The following mitigation measures apply to USAID/DCHA Bureau Environmental Officer and USAID/FFP offices at Missions with Title II programs.

1) PVO-specific PERSUAPs must be approved prior to providing assistance for the use or procurement of aluminum/magnesium phosphide. USAID shall:

- Work with PVOs to ensure they understand the need to submit a PERSUAP for fumigation.
- Ensure that PEA mitigation measures and BPs are incorporated into the PERSUAP.
- Provide timely review and approval of fumigation PERSUAPs.

2) PEA BPs/mitigation measures may need to be modified to take into account country and project-specific situations. USAID shall:

- Work with PVOs to develop practical BPs for the specific country and/or PVO project.
- Ensure that modified BPs are integrated into the PVO PERSUAP.

3) The USEPA requires that only certified applicators use aluminum/magnesium phosphide, considered Restricted Use Pesticides. USAID shall:

- Collaborate with PVOs and FSPs to determine the need to support in-depth and recurrent training on proper fumigation practices (This could be provided through online services or by other means, see Annexes T-13; and could be funded through cost-sharing or other innovative means).

- Work with PVOs and FSPs to identify product stewardship programs, offered by pesticide distributors, that PVOs and FSPs could collaborate with to provide ongoing technical assistance and training.

4) Aluminum/magnesium phosphide does not control fungal contamination. The only reliable measure to protect against fungal growth is to purchase commodity that is at 13% or less moisture, and distribute it as quickly as possible so that once it arrives in the host country, moisture level has no chance to increase to 14.5% or higher, a level that promotes mold growth. USAID shall:

- Collaborate with USDA partners to ensure that purchased commodity complies with 13% of less moisture level.

5) For control of infestation and to control fungal growth

- Continue to promote "First In First Out" method of commodity management.
- Promote web-based tracking systems that can help ensure commodity moves quickly through the Title II food aid commodity chain.

6) To fill data gaps/research needs identified in the PEA, USAID/DCHA BEO shall collaborate with USAID/Washington/FFP, private sector, other US and host country government agencies, and universities to determine measures to fill the following gaps:

- Health risks to nursing mothers/infants and health risk to all beneficiaries
- Chronic health effects: The HHRE evaluated only acute health effects of phosphine
- Insect-resistant packaging: Further exploration is needed of improved packaging
- Toxicity of inert ingredients
- Use and commercialization of traditional practices, such as neem and hermetic storage: If promising, they could be promoted as potential environmentally sound, low impact means of stored-product pest management.
- No information collected by the PEA Team from nearby residential areas: Further exploration may be needed regarding potential health impacts experienced by nearby residents.

6. CONCLUSIONS AND RECOMMENDATIONS

The following are the PEA Team's major conclusions, based on literature reviews, fieldwork, and interviews, as well as their prior experience in the field. Recommendations are also outlined.

6.1 MAJOR CONCLUSIONS

The PEA Team evaluated fumigation of Title II food aid from arrival at the receiving port to distribution centers at beneficiary communities. The PEA Team found that fumigation may take place at receiving ports, pre-positioning warehouses, and primary and secondary warehouses. Fumigation at distribution centers is rare because food aid is quickly moved out to beneficiaries, whereas at port and other warehouses along the chain, food aid commodity may remain in storage for three months or longer.

Warehouse managers and PVOs may make a decision to fumigate using both a calendar basis (every six weeks to three months) and by monitoring stored food aid to identify potential infestations. When monitoring, PVOs interviewed by the PEA Team stated that if they see a stored-product insect, they make a decision to fumigate; there is no lower threshold level. However, the PEA Team noted that warehouse workers (those conducting monitoring) were unable to identify stored-product insects.

The PEA Team identified possible shortcomings in implementation of integrated pest management (IPM) and other best practices:

1) Standard sanitation practices at warehouses may not be adequate: commodity may not be swept up between deliveries, when bags break open, or when commodity leaks out of stitching; pallets may not be cleaned well between deliveries; warehouses are not well lit; and flashlights may not be used during warehouse inspections (see Annex J, photos 6, 7, 18, 19, and 21).

2) Warehouse construction may not meet US standards: The majority of warehouses are rented, not owned by the PVOs; landlords may not agree to upgrades, and PVOs may not have funding available to make upgrades. Vents allow pests in; gaps at floor to wall junctions allow rodents and insects to enter; vents in the ceiling allow birds to enter; floors are not smooth and food gathers in the cracks, providing a regular source of food for insects and rodents (see Annex J, photos 2, 3, 8, 9, 15, and 20).

3) Trucks may not be cleaned well between deliveries and loading.

4) Personal protective equipment (PPE) may not be used, or may be used and maintained incorrectly: Issues with PPE include use of masks with expired canisters, use of canisters that are not meant for phosphine fumigation, and use of dust masks by fumigators (see Annex J, photo 12).

5) Food aid bags allow considerable leakage during transport and storage at warehouses. The seams on the bags may be only single seams with gaps in stitching, from which commodity easily leaks and where insects can easily enter. The material of the food aid bag –because of the stacking and the pressure created on the lower bags in the stack—has gaps that expand and allow leakage and insect entry (see Annex J, photos 4, 5, 6, 16, and 17).

6) Because of the hot, tropical climate, warehouse doors may be left open during the day to allow for ventilation. This also allows birds and rodents to enter. In the U.S. warehouse doors are always closed; however, in tropical climates, that may not be practical (see Annex J, photos 2 and 9).

7) Regular training in fumigation, including IPM, may be unavailable to those in charge of conducting and monitoring fumigation.

8) Prior to and/or after fumigating, contact pesticides (i.e., pirimiphos methyl formulated as an Emulsifiable Concentrate—or EC) may be applied to an empty warehouse walls, pallets or to floor surfaces between and outside stacks.

9) Fumigators may not possess phosphine meters or be monitoring phosphine gas concentrations under enclosures to determine effectiveness neither against insects, nor outside the sheets for worker and bystander safety. Yet, monitoring is a quintessential part of fumigation, and is the only way successful and safe fumigation can be ensured.

10) Fumigation usually lasts for three to seven days including placement of tarpaulins and fumigant, aeration, and removal of tarps; this may be too short to ensure successful fumigation and to control resistant strains of insects. Short fumigations predispose insects to develop resistance.

11) Stacks in a warehouse are enclosed with plastic or tarps. Warehouse doors and vents, however, may not be sealed during fumigation. Because of the gaps, gas can leak from the warehouse. In addition, fumigation tarps may be re-used too often, may weaken and get torn, and therefore, would not create a gas tight seal. The warehouse compound may remain open during fumigation, potentially exposing workers in adjacent warehouses, office workers, and others working on-site to phosphine gas. Placarding may be inadequate to ensure that no entry will occur; warning signs may not have sufficient information about emergency procedures.

12) Fumigants may not be transported and stored under secure and environmentally sound conditions; phosphine residues may not be disposed of in accordance with labeling requirements.

The PEA Team reviewed existing international fumigation guidance, including those published by USAID and PVOs. The USAID Commodity Reference Guide (CRG)[4]has generic information on pest management. The WFP has a standard operating procedure (SOP) for contracted fumigation that outlines site preparation, use of aluminum phosphide tablets/pellets, phosphine gas monitoring, placarding, clearing (aeration), disposal of spent phosphine tablet residues, and spraying warehouses with residual chemicals after fumigation. Many PVOs have developed commodity management guides, which address pest management, as well as other aspects of commodity management. The technical quality of the guidance varies. Most of the guidance documents have shortcomings; for example, training information, insect resistance, and phosphine gas monitoring are often briefly or not at all covered.

In the US, and in accordance with labeling, a Fumigation Management Plan (FMP) is required prior to fumigation. The FMP summarizes the steps that will be taken before, during, and after the fumigation. It helps ensure that the fumigant is applied effectively and safely. From USAID and PVO guidance and procedures that the PEA Team reviewed, and from those interviewed, an FMP, a critical part of fumigation and a label requirement, is not typically part of the Title II food aid fumigation process.

While best practices and standards for fumigation are typically followed in the US, as described above, the PEA Team found that once food aid arrives at the host country port, fumigation guidance may be inadequate, knowledge and training of applicators and supervisors is highly variable and may be outdated, and best practices for fumigation are inconsistently applied. Development and implementation of standard procedures for safe and effective fumigation and non-fumigation based IPM practices are essential for prevention and management of insects associated with food aid commodities in the receiving countries.

[4]CRG Section IV: Controlling damage to food commodities http://www.usaid.gov/our_work/humanitarian_assistance/ffp/crg/sec4.htm)

Fumigation with aluminum/magnesium phosphide is an integral part of managing pests of stored-product commodities. If fumigation is conducted without implementation of best practices, negative human health impacts may result; environmental impacts, although of concern, are less likely and less likely to be significant than the potential impacts to human health. Safeguards are available and can be implemented by USAID Food for Peace (FFP) offices, Title II PVOs, and their partners to minimize potential impacts to fumigators, warehouse workers and visitors, and nearby residents. Section 5 of this PEA includes an analysis of the potential significant impacts, as identified in the Scoping Statement and revised by the PEA Team, and briefly describes mitigation measures to minimize potential impacts.

6.2 DATA GAPS

While the toxicity of phosphine gas and its precursors, aluminum and magnesium phosphide, have been well-studied, data gaps remain in evaluating sensitive subpopulations and potential risks in the context of food aid for developing countries, as follows:

1) Health risks to nursing mothers/infants: Pregnant and nursing mothers may ingest food that has been fumigated prior to reaching their households. As a potentially sensitive subpopulation, there is concern that mothers could pass phosphine and/or its breakdown products to their unborn or nursing children. Although phosphine is not considered to be bioaccumulative, inadequate information is available to properly evaluate the exposure, fate, clearance, and transfer of chronic to subchronic levels of phosphine gas in these populations from gas adsorbed into food commodities following fumigation. There is also no information available on the sensitivity of women and infants to low levels of phosphine gas.

Phosphine de-gasses quickly once aeration begins; it is unlikely that ingesting food that has been fumigated could impact human health. However, data are insufficient to confidently determine the potential for risk.

2) Health risk to all beneficiaries: A thorough evaluation is needed of the kinetics of phosphine desorption and residue transformation in and on the surface of food commodities to determine exposure and evaluate risk to beneficiaries. Measuring and predicting these residue levels is confounded by variables such as temperature, concentration and duration of fumigation, duration of aeration, type of commodity, and type of bagging, which can result in substantially different concentrations of phosphine once they reach the beneficiary level. Additionally, a realistic model for chronic exposure is impossible to formulate, as food aid is an intermittent exposure pathway with a high degree of unpredictability. It will be difficult to impossible to provide a data set that adequately surveys the range of beneficiaries.

Because phosphine de-gasses quickly from food commodities, and little if any phosphine remains adsorbed to food (see Section 5 of the PEA for research conducted to date), this route of exposure is unlikely to lead to a potential human health impact. However, to confidently state that no potential impact to the health of Title II beneficiaries is possible, additional studies are needed.

3) Chronic health effects: The HHRE evaluated only acute health effects of phosphine. In addition to information on the health risk to beneficiaries discussed above, research is needed on the potential chronic health impacts to fumigators, other on-site workers, and nearby residents. This is of special concern since fumigators in Title II countries, use required other on-site workers (present in the warehouse compound during fumigations) and nearby residents are unlikely to have, properly maintain or use PPE. The current US standards (Occupational Safety and Health Administration, OSHA, and US Environmental Protection Agency, USEPA) may not apply in Title II cases. For example, occupational standards are applicable only to those workers who are trained in the use of specific chemicals. Fumigation may affect other persons (bystanders, nearby residents, etc.) who are not aware of the risks of these chemicals and who may, unlike the trained workers, be in worse health, much younger or older, and/or exposed for durations that exceed typical worker exposure scenarios of 8 hours/day, five days/week.

4) Insect-resistant packaging: Further exploration is needed of improved packaging. A number of new sealing techniques, odor barriers, alternative natural fumigants, and multi-walled types of bags are now available that could be explored further. These alternative measures could make packages insect resistant and decrease the quantities of pesticides and fumigants needed.

5) Toxicity of inert ingredients: Pesticides are formulated with active and inert ingredients. Aluminum phosphide tablets are commonly formulated at 55-60% active ingredient (AI) along with ammonium carbonate and inert ingredients related to the effectiveness against pests. However, many inert ingredients are not chemically, biologically, or toxicologically inert to other receptors. Generally, inert ingredients are minimally tested for potential adverse health and environmental impacts, although many are hazardous to human health.

6) Residues from application of grain protectants in the US: The PEA Team did not evaluate the presence of residues on commodities due to application of grain protectants on farms in the US. Detectable amounts of these residues may be found in both raw and processed commodities. The U.S. Department of Agriculture's (USDA) Pesticide Data Program maintains an online database of commodities tested for multiple pesticide residues. In most cases, residue levels on commodities are well below the established tolerance levels. However, because the PEA focused on fumigation from host country port to beneficiary community, the PEA Team did not explore potential impacts of pesticides used in the US and residue levels in raw and processed commodities.

7) Use and commercialization of traditional practices, such as neem and hermetic storage: Some traditional practices have potential to be scaled up and used in Title II warehouses as an alternative, or partial alternative to fumigation. However, information is insufficient as to the potential for scale-up and efficacy. Traditional measures should be further explored, and if promising, could be promoted as potential environmentally sound, low impact means of stored-product pest management.

8) No information collected from nearby residential areas: The PEA Team visited warehouses in Uganda, Ethiopia, and Djibouti; however, none were located near residential areas. Further exploration may be needed regarding potential health impacts experienced by nearby residents. This remains an information gap.

9) No information from companies that train and certify personnel in fumigation in Title II countries: The PEA Team was unable to meet with companies in Uganda, Ethiopia, or Djibouti that train personnel in fumigation. The PEA Team overcame this information gap by interviewing fumigation service providers.

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**The weblink is unavailable as of June 21, 2012, because the site is under construction.