The Bahamas Maritime Authority

Marine Safety Investigation Report

into a fumigant poisoning fatality on board mv Jupiter on 17 May 2022

The Bahamas conducts marine safety or other investigations on ships flying the flag of the Commonwealth of the Bahamas in accordance with the obligations set forth in International Conventions to which The Bahamas is a Party. In accordance with the IMO Casualty Investigation Code, mandated by the International Convention for the Safety of Life at Sea (SOLAS) Regulation XI-1/6, investigations have the objective of preventing marine casualties and marine incidents in the future and do not seek to apportion blame or determine liability.

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Contents

1. Summary

Due to restrictions imposed as a result of the coronavirus pandemic, the BMA investigation team could not travel to the vessel to gather evidence and conduct interviews. Therefore, this investigation was conducted following the hierarchy of controls recognised by IMO Circular Letter No.4204/Add.16 establishing effective safety control measures and reducing the risk to personnel. The evidence, including the witness testimonies and images used for the purpose of this investigation, was collated via online interviews and with the assistance of the Singapore Transport Safety Investigation Bureau acting as a Substantially Interested State.

What happened

On the morning of 17 May 2022, the Bahamas flagged bulk carrier, mv Jupiter, was at anchor outside Qinzhou, China, when an ordinary seafarer collapsed in a cargo hold containing soya beans. The alarm was raised and the chief officer who entered to help also collapsed.

Both the chief officer and ordinary seafarer were recovered from the hold by a team wearing breathing apparatus. Both were transferred to hospital ashore where the chief officer made a full recovery. The ordinary seafarer died as a result of exposure to lethal levels of phosphine gas.

Why it happened

The crew were carrying out a routine check on the condition of the cargo in the holds before discharge. Whilst the cargo had been fumigated at the load port, the holds were not considered to be dangerous as the vessel was in possession of a gas free certificate, issued by fumigant removal contractors, and the hatches had been open and ventilated for some time. This was re-enforced as entry into the other holds had occurred without incident the previous days.

There was no effective hazard identification so work commenced as planned.

As part of the pre-planning for discharge an opportunity was missed to retest the space prior to crew entering to inspect the cargo for wet spots.

What can we learn

Fumigated cargoes are incredibly dangerous. Cargo holds that contain fumigated cargo should not be entered. Lethal doses of fumigant may remain in pockets or trapped within the cargo. A gas free certificate does not guarantee your safety, therefore precautions should always be taken to mitigate the risk and likelihood of gas poisoning.

2. Factual Information

Jupiter

Vessel Type	Bulk Carrier	**Flag**	Bahamas
Owner	Piccadilly Shipping Company Ltd	**Manager**	Gestmar Tehnika do.o
Classification Society	American Bureau of Shipping (ABS)	**Gross/Net Tonnage**	40,017/25,935
Built	2006, Oshima, Japan	**Propulsion**	B&W A/S, 6 cylinder Diesel 12,680 horsepower

IMO No.	Callsign	Length overall	Breadth	Moulded Depth
9287194	C6YB6	225.0m	32.3m	19.39m

Last BMA Inspection	Last PSC Inspection
Paranagua, Brazil. 23 September 2021. No deficiencies.	Lorient, France. 18 October 2021. No deficiencies

Image courtesy of FleetMon

Crew details

Rank/Role on board	Master	Chief Officer	Second Officer	Third Officer	Chief Engineer	Bosun	OS1 (victim)
Qualification	Master Mariner	Chief Mate	Chief Mate	OOW	Chief Engineer	COP 4B	COP rating
Certification Authority	India	India	Russia	Ukraine	Ukraine	India	India
Nationality	Indian	Indian	Russian	Ukrainian	Ukrainian	Indian	Indian
Age	54	58	33	36	38	42	30
Time in rank	18 years	15 years	6 years	6 months	2 years	3 months	3 years
Time on board	3 months	3 months	3 months	3 months	3 months	3 months	3 months

Environmental Conditions

Wind Direction	Wind Force	Wave Height	Swell Height	Precipitation / Sky	Visibility Range	Light Conditions
E	4	1 metre	1.5 metre	Clear	Good	Daylight

Voyage Details

Departure Port	Paranagua, Brazil	Arrival Port	Qinzhou, China
Time of departure	05 April 2022	Estimated time of arrival	14 May 2022
Voyage duration	39 days	Voyage distance	12,858 NM
Cargo	Approx. 63,000Te of soya beans	POB	20
Stage of passage	At anchor	Traffic density	low

Narrative

All times in this report are local time

On 5 April 2022, the Bahamas flagged bulk carrier mv Jupiter was alongside in Paranagua, Brazil, loading its final consignment of soya bean, bound for Qinzhou China. On completion of loading, five of the seven holds were loaded to 100% capacity and the other two holds at 80%. At 16:20 fumigation contractors boarded the vessel and held a meeting with the ships master and deck officers, where the process of applying the fumigant was discussed, along with an agreed effective period of fumigation.

At 16:40 and in preparation for departure, the fumigator in charge, along with three technicians applied aluminium phosphide tablets in sleeves on the surface of the cargo in each hold - 271kg in total.

On completion of the fumigant application to all seven cargo holds, the hatch covers were secured for sea, danger signs affixed to the side of the hatches and the hold vents closed and covered over with plastic to prevent water ingress whilst on passage. All holds were to remain sealed for ten days, before the hold vents could be opened to start the ventilation and aeration process. (Figures 1&2).

Figure 1. Aerial view of No.6 cargo hold and hold vent

Following the sealing of all the holds, a further meeting was held between the ships officers and fumigator in charge, where safety equipment was provided (comprising four full face masks, air filters, phosphine colorimetric detector tubes and a manual plunger) for use by the crew when testing machinery and accommodation spaces to ensure that the presence of gas was not detected during its voyage, as well as for when opening of hatches during the ventilation process.

Instructions for aeration and ventilation was provided. The deck officers were advised on safety precautions and provided with a safety booklet along with one part of the completed voyage checklist.

Figure 2. Danger signs affixed to sides of cargo hatches

Once the vessel was in receipt of its cargo declaration and fumigation certificate (Appendix 1 & 2), it departed Paranagua shortly after 18.30 bound for Qinzhou via Singapore for bunkers.

During its voyage, the vessel encountered a period of prolonged heavy and wet weather which restricted the crew from opening the hold vents, to begin the aeration and ventilation process following the ten day fumigation period. However, a break in the weather on the 7 May 2022 allowed the crew to open all of the cargo hatches for several hours at a time, to allow the spaces to be naturally vented in preparation for arrival in Singapore on the 9 May 2022.

CARGO HOLDS VENTILLATION RECORDS.

DATE	TIME	
07.05.2022	0800-1800	All cargo holds opened and ventilated.
08.05.2022	0800-1700	All cargo holds opened and ventilated.
09.05.2022	0900-1500	All cargo holds and fumigation material removed.
11.05.2022	0800-1700	All cargo holds opened and ventilated.
12.05.2022	0800-1700	All cargo holds opened and ventilated.
13.05.2022	0900-2400	All cargo holds opened and ventilated.
14.05.2022	0000-0900	All cargo holds opened and ventilated.
15.05.2022	0800-1700	All cargo holds opened and ventilated.
16.05.2022	1500-1800	Holds 1,2,3,4,5. Opened and ventilated.

Extract from cargo hold ventilation record (extract)

On the morning of 9 May 2022 at 08:12 the vessel arrived and anchored in Singapore in preparation for bunkering fuel for its onward journey to China.

Shortly before bunkers were taken, fumigant removal contractors boarded the vessel and in consultation with the chief officer commenced removing the fumigant sleeves from the holds. These were carefully removed, sealed and contained in bags before being removed from the vessel.

At 13:00, all sleeves of fumigant had been removed and the open areas to the holds and adjacent hatch coamings were tested with the use of a handheld gas meter with readings recorded at less than 0.3 parts per million (ppm) which satisfied the necessary requirement of being issued with a gas free certificate (Appendix 2).

At 10:16 on the morning of 10 May 2022, the vessel departed Singapore bound for its final destination at Qinzhou. En route, the chief officer along with members of the deck crew held an informal briefing outlining the proposed rotation plan of opening the cargo hatches and checking the cargo. Hatches were left open for several hours at a time as and when weather was favourable and when time permitted.
En route, the master was contacted by the harbour control at Qinzhou and notified that a berth was not available for discharge and that the vessel was requested to anchor outside the port and wait for further instructions. At 20:24 on the 14 May 2022, the vessel arrived and anchored at No.2 anchorage.

On the morning of 15 May 2022, the chief officer along with a party of deck crew consisting of two ordinary seafarers (OS1 and OS2) and two able bodied seafarers (ABs) commenced opening all the holds, to allow for further ventilation. The following day (16 May 2022) holds 1-5 were opened and ventilated. The plan, which was discussed by the chief officer with the deck crew, was to remove any damaged cargo due to ship sweat, as the understanding was that they were safe to enter as the vessel had recently been declared gas free.

At 10:30 on17 May 2022, the chief officer held an informal safety meeting and instructed the crew to open hold 6, followed by hold 7, to inspect the cargo. Whilst the hatches were being opened by the bosun and AB, OS2 went to fetch some buckets which he and OS1 would use to collect any damaged soya beans

During this time OS1 fetched a portable ladder as hold 6 was only 80% full and therefore access could only be gained with the use of a ladder, when placed inside the hold resting it on the highest point of the soya bean and positioning it against the coaming of the hold (Figure 3).

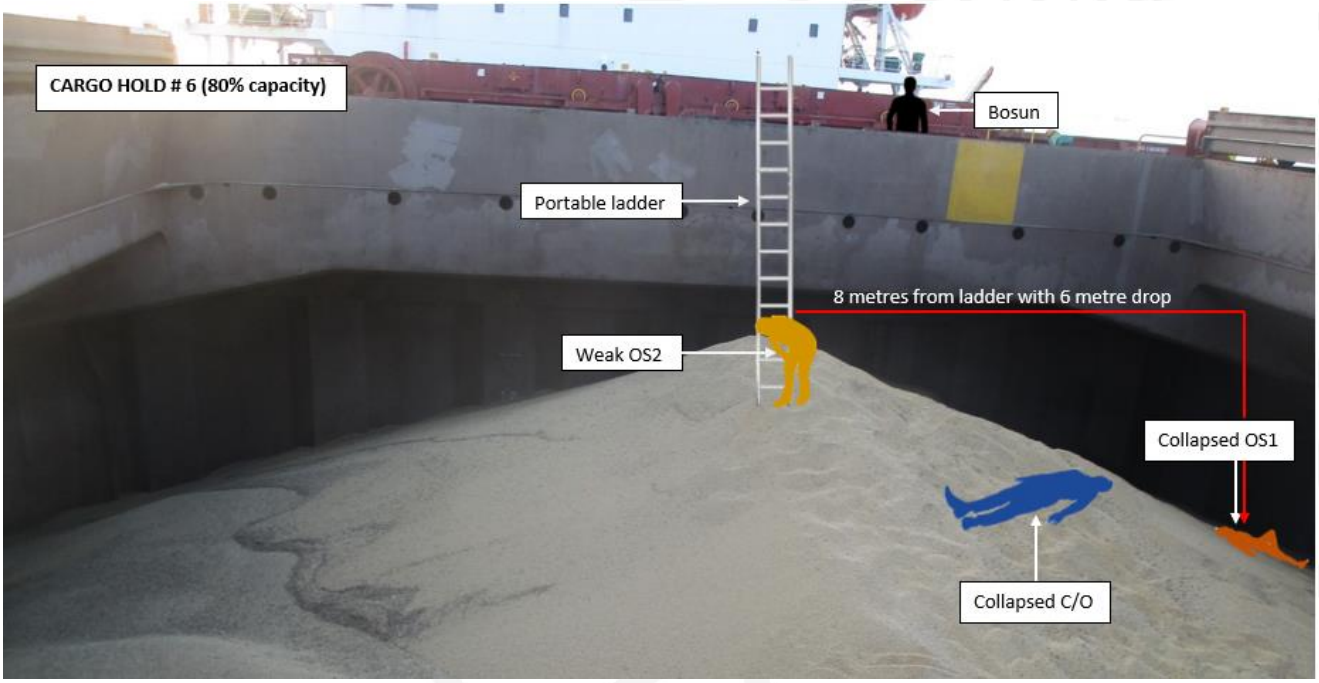


Figure 3. Positioning of crew inside cargo hold 6 at time of casualty

At 10:45 OS1 made his way into hold 6 and shortly after OS2 arrived at the opening and dropped the two buckets into the hold, one of which rolled down the slope of the soya bean in the hold, before then making his way inside the hold via the ladder to join his colleague. OS1 made his way down to the port side to fetch the bucket that had rolled down and collapsed.

OS2 who had now entered the hold was making his way aft, when he observed that his colleague had collapsed and immediately called for help. OS2 started to feel weak, breathless and nauseous, and made his way back to the base of the ladder. When the chief officer heard OS2's calls for help, he notified the master of the emergency and requested assistance, before then making his way into hold 6, and headed straight to OS1 to help. The master summoned the third officer to gather a rescue team and attend to the emergency.

Shortly after arriving beside OS1, the chief officer struggled to offer assistance or pull OS1 clear to the middle of the cargo hold, and was struggling to breathe, and called out for help from OS2, before managing to make his way back towards the centre of the hold where he collapsed, complaining of chest pains, struggling to breathe and see clearly.

On hearing the calls from the chief officer and OS2, the bosun who was removing the hatch cleats on cargo hold 7 arrived on scene and immediately called for the AB to fetch two sets of breathing apparatus and notify another AB to bring additional crew to help with recovering the crew inside hold 6 (figure 3).

OS2 managed to climb out of the hold to the area between cargo holds 6 and 7 where the second officer who arrived on scene checked him over before turning his attention to recovering the OS1 and the chief officer from the hold. The second officer instructed the AB to don his breathing apparatus set and assist the bosun.

The third officer, now on scene, along with the bosun entered the hold wearing breathing apparatus, and whilst the third officer was attending to the chief officer, the bosun made his way to OS1. On arriving at OS1 the bosun noticed that OS1 was not responding or breathing and struggled to remove OS1 from his position due to the steep incline and called to the AB who had now entered the hold wearing a breathing apparatus to assist in recovering OS1 into the centre of the hold.

At 11:00 the third officer, bosun and AB along with assistance from crew on deck, managed to recover the chief officer and OS1 from the hold, before transferring them to the ship's medical room to provide emergency medical care. The chief officer and OS1 were then later evacuated ashore to a medical facility.

The chief officer was seriously injured and was hospitalised for thirteen days. OS1 did not recover - post mortem results identified phosphine gas poisoning as the cause of death.

3. Analysis

The purpose of the analysis is to determine the contributory causes and circumstances of the casualty as a basis for making recommendations to prevent similar casualties occurring in the future.

The ordinary seafarer died as a result of exposure to lethal levels of phosphine gas in a space that had been certificated as fumigant gas free by shoreside fumigation contractors eight days earlier.

Atmosphere - Phosphine gas

Aluminium phosphide is a pesticide that is commonly used in agriculture. It is often dispersed as pellets and can be contained in gas permeable sleeves; the compound reacts with moisture present in the atmosphere to produce toxic phosphine gas (PH_3). As phosphine is heavier than air, the gas sinks, penetrating the cargo, and thus protecting the cargo by killing insects and pests.

The effects of exposure to aluminium phosphide are usually rapid. There is no antidote for exposure - treatment is to provide oxygen. Both aluminium phosphide and PH_3 are listed as dangerous cargoes in the International Maritime Dangerous Goods Code (IMDG), Class 2.3[1], when carried in bulk.

Pure phosphine gas is odourless; however, where impurities are present, as is usually the case with aluminium phosphide tablets, it may smell of garlic, decaying fish or carbide. This smell is often referenced as providing an olfactory warning of the presence of the gas but the crew working on deck and in the holds did not report any instances of smelling the fumigant.

The **threshold limit value** (**TLV**) is the maximum concentration of a hazardous material to which a healthy adult can be exposed without experiencing significant adverse health effects. A TLV has three components:

- **Time-weighted Average (TWA) concentration:** The concentration of a contaminant averaged over a workday (usually 8 hours long).
- **Ceiling value:** A concentration of a toxic substance in air that ACGIH recommends should not be exceeded at any time during the workday. This value is often used in conjunction with the TWA.
- **Short-term Exposure Limit (STEL) value:** A TWA concentration over 15 minutes that ACGIH recommends not to exceed—even if the 8-hour TWA is within the standards. TWA-STELs are given for contaminants for which short-term hazards are known.

The fumigation contractors identified a TLV of 0.3 parts per million (ppm) and provided safety equipment for detecting phosphine in the accommodation and gas masks for use when crew might be exposed to phosphine (such as when opening the holds for ventilation). The gas detection equipment provided was of the colorimetric tube type: detection tubes had to be opened and inserted into a pump and the air sampled by manually operating the pump to draw air through the tube. Discoloration of the tube indicates the presence of the gas.

The equipment came with a clear message in the safety booklet: **do not enter fumigated holds.**

The ship's Marine 4 PS 200 gas detectors were fitted with sensors to measure oxygen (%O_2), lower explosive limits (%LEL), carbon monoxide saturation levels (ppm C) and hydrogen sulphide levels (ppm H_2S). there was no means for continuous monitoring of phosphine.

[1] As detailed within Appendix A (List of generic and N.O.S. proper shipping names) – Insecticide Gas, Toxic, Flammable, N.O.S.

Figure 4. Safety equipment supplied by the fumigation contractors at Paranagua

When the fumigation removal contractors boarded the vessel in Singapore, their gas free certificate indicated that all holds had a phosphine content below 0.3ppm and were considered safe. However, readings were taken using a handheld meter at the level of the hatch coamings – no attempt was made to sample the atmosphere at the level of the cargo in the two holds that were not at full capacity despite low-lying areas being at the highest risk of having phosphine present.

Management of Risk and Hazard identification

The ISM Code requires that the safety management objectives of the Company should, amongst other things, assess the risks associated with all identified hazards in respect of its ships, personnel and the environment, and establish appropriate safeguards.

The cargo holds were identified as enclosed spaces on the safety management system's "List of enclosed spaces onboard the vessel." Procedure SM-15 laid out protocols to be followed to enter any enclosed space. The procedure recognised that the potential hazards of each enclosed space are different and that they needed to be identified in during the risk assessment. An entry permit system was recommended but not mandatory.

The procedure included the following requirement prior to entry:

> Chief Officer or other competent person should always make a preliminary assessment of any potential hazards in the space to be entered, taking into account previous cargo carried, ventilation of the space, coating of the space and other relevant factors.
>
> The competent person's preliminary assessment should determine the potential for the presence of an oxygen-deficient, flammable or toxic atmosphere. Excluding emergency situations, no entry is permitted into an enclosed space prior that the internal atmosphere is verified, and a proper permit is issued.

Risk assessment S-18 (Identification of enclosed spaces onboard with regard to enclose space entry) was last reviewed on 04 September 2017, specifically focusing on enclosed space entry, and was reviewed and signed by the chief officer and master on the same day.

• poor atmosphere	• Entry procedures / training on the use of personal protective equipments and drills explaining safe entry. • attendant at entrance – contact with bridge • regular communication between attendant and entry personnel • emergency signal established • entrants wearing personal monitors • rescue equipment on stand-by including breathing apparatus,harness, and lifeline	Ch/Off	Before	3	2	6
Person entering collapses in the space	• poor atmosphere	• all lines leading into the space secured • space emptied • space remotely cleaned prior to entry if possible,i.e. COW washing of oil tanks or filling tanks with water then pumping out • atmosphere tested and found safe prior to entry • atmosphere tested at regular intervals • continuous ventilation		3	3	9

Extract from Risk Assessment form S-18.

The chief officer's morning meeting included a brief discussion on the opening and venting of cargo holds in preparation for discharge, but safety precautions for work in the hold were not considered when OS1 and OS2 were tasked with checking for wet spots. There was no recorded discussion around the assessment for potential hazards, risks or testing the spaces prior to entry. The whole morning meeting took approximately five minutes. Prior to entry into the cargo holds for inspection, neither risk assessment form S-18 nor SM-15-01/02 Enclosed spaces (General) were consulted or completed as part of the management of risk protocols.

None of the control measures identified in the risk assessment were discussed as part of the morning meeting or implemented for the task. However, given that the vessels multi-gas detector was not fitted with sensors to detect the presence of phosphine or chlorine gas, effective controls could not be implemented.

Contractors who carried out the application of fumigant in Paranagua, provided training and items of safety critical equipment to the crew, as well as a document pack containing details on the known risks associated with fumigation and precautions to be taken by ship's crew when carrying out work in spaces where fumigant had been applied, yet these were not consulted on, or used prior to entry, informed by an understanding that the holds would pose no risk as they were in possession of a gas free certificate.

1.7	How - Procedure	The design of particular deck areas may impede air flows to dissipate cargo vapours. There could be many such areas on ships, but they commonly found in the vicinity of hatches, ullaging points and sampling points. Such areas should be identified and checked to determine the potential presence of an oxygen-deficient, oxygen-enriched, flammable or toxic atmosphere.
	SM-15-02 Assessment of Risk	
2.1	Why - Requirement	In order to identify the potential hazards and to determine proper safeguards to be adopted, a risk assessment must be completed prior to entry into an enclosed space.
2.2	Why - Requirement	The Risk Assessment is intended to identify: • the real condition of atmosphere inside the enclosed space using proper and tested equipment; • the number, competency and role of people involved in the job inside the space and the others assigned in assistance; • the applicable mitigation measures able to reduce identified risks; • if there is another more safely way to perform the same job.
2.3	Why - Requirement	The results of Risk Assessment are to be documented and approved by the responsible person before being countersigned by the Master, who confirms that the entrance is safe and in compliance with the ship's Safety Management System. Such document will be used to issue the entry permit, or other enabling document, that shall be sighted and completed by the person assigned to the job prior to entry.

Extract from SM-15-02 Assessment of Risk. Highlighting Risk Assessment to be completed.

Enclosed or dangerous spaces (Precautions)

The company's safety management system addressing Enclosed Space Entry (procedure SM-15-01) outlines the requirements for additional precautions to be taken when entering enclosed or dangerous spaces onboard that pose a potential risk to health, where previous cargo carried presented with a toxic atmosphere are to be assessed. These precautions were not considered or adopted as crew had been operating in the holds the previous day without incident, whilst under the assumption that it was safe to enter as they had been declared gas free.

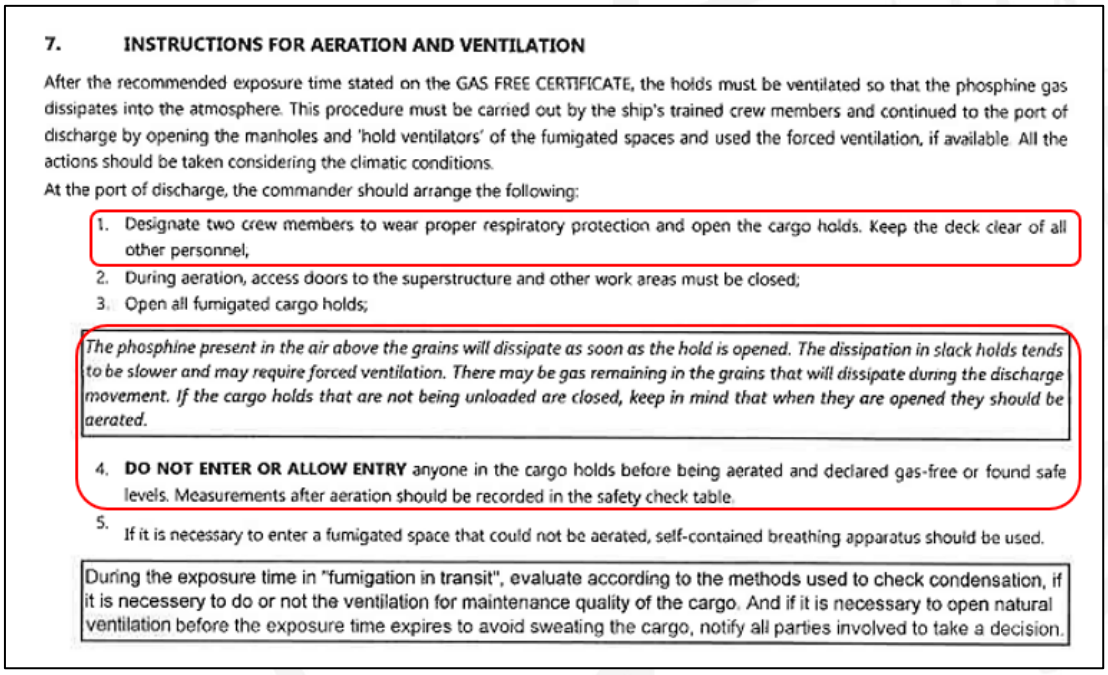
2.7	How - Procedure	Chief Officer or other competent person should always make a preliminary assessment of any potential hazards in the space to be entered, taking into account previous cargo carried, ventilation of the space, coating of the space and other relevant factors.
2.8	How - Procedure	The competent person's preliminary assessment should determine the potential for the presence of an oxygen-deficient, flammable or toxic atmosphere. Excluding emergency situations, no entry is permitted into an enclosed space prior that the internal atmosphere is verified, and a proper permit is issued.

Extract from procedure SM-15-01

The International Maritime Organisation (IMO) Regulation A.1050(27) "Revised recommendations for entering enclosed spaces aboard ships" section.9 - Additional Precautions for Entry into a Space where the Atmosphere is Known or Suspected to be Unsafe, states:

- ***9.1 Spaces that have not been tested should be considered unsafe for persons to enter. If the atmosphere in an enclosed space is suspected or known to be unsafe, the space should only be entered when no practical alternative exists. Entry should only be made for further testing, essential operation, safety of life or safety of a ship. The number of persons entering the space should be the minimum compatible with the work to be performed.***
- ***9.2 Suitable breathing apparatus, e.g. of the air-line or self-contained type, should always be worn, and only personnel trained in its use should be allowed to enter the space. Air-purifying respirators should not be used as they do not provide a supply of clean air from a source independent of the atmosphere within the space.***
- ***9.3 Persons entering enclosed spaces should be provided with calibrated and tested multi-gas detectors that monitor the levels of oxygen, carbon monoxide and other gases as appropriate.***

The fumigant contractor in Brazil provided the vessel with guidance and instructions, for the ventilation of, and access to fumigated holds. However, following the removal of fumigant in Singapore, it was assumed that the special precautions and restrictions on entry were no longer relevant, as the holds had been declared gas free.



7. INSTRUCTIONS FOR AERATION AND VENTILATION

After the recommended exposure time stated on the GAS FREE CERTIFICATE, the holds must be ventilated so that the phosphine gas dissipates into the atmosphere. This procedure must be carried out by the ship's trained crew members and continued to the port of discharge by opening the manholes and 'hold ventilators' of the fumigated spaces and used the forced ventilation, if available. All the actions should be taken considering the climatic conditions.

At the port of discharge, the commander should arrange the following:

1. Designate two crew members to wear proper respiratory protection and open the cargo holds. Keep the deck clear of all other personnel,
2. During aeration, access doors to the superstructure and other work areas must be closed;
3. Open all fumigated cargo holds;

The phosphine present in the air above the grains will dissipate as soon as the hold is opened. The dissipation in slack holds tends to be slower and may require forced ventilation. There may be gas remaining in the grains that will dissipate during the discharge movement. If the cargo holds that are not being unloaded are closed, keep in mind that when they are opened they should be aerated.

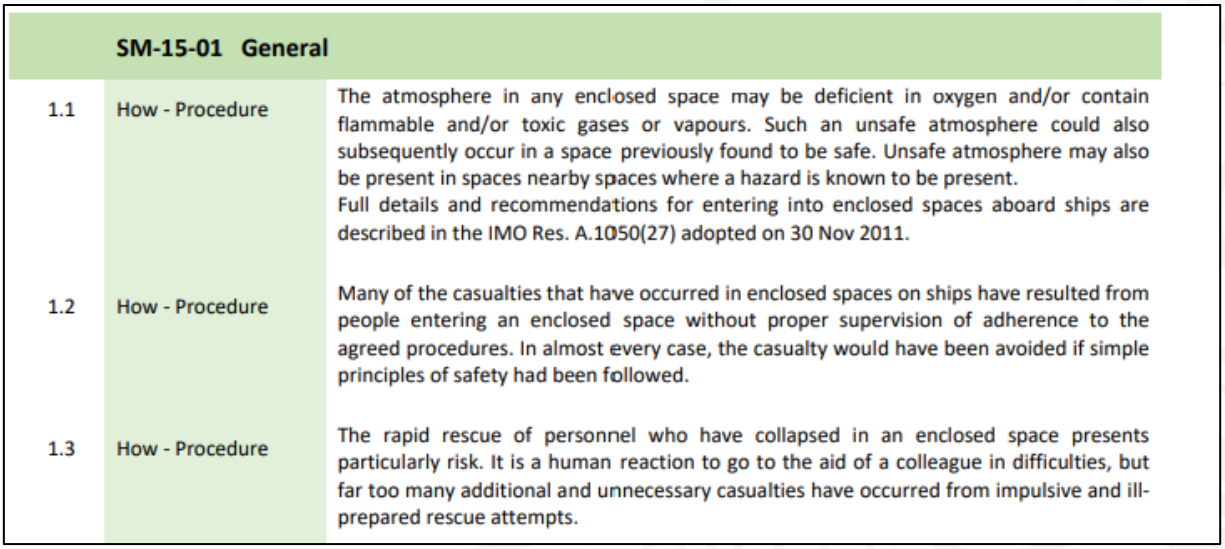
4. **DO NOT ENTER OR ALLOW ENTRY** anyone in the cargo holds before being aerated and declared gas-free or found safe levels. Measurements after aeration should be recorded in the safety check table.
5. If it is necessary to enter a fumigated space that could not be aerated, self-contained breathing apparatus should be used.

During the exposure time in "fumigation in transit", evaluate according to the methods used to check condensation, if it is necessery to do or not the ventilation for maintenance quality of the cargo. And if it is necessary to open natural ventilation before the exposure time expires to avoid sweating the cargo, notify all parties involved to take a decision.

Extract from Fumigant Pack provided by contractor

Enclosed or dangerous spaces. (Rescue)

The International Maritime Organisation (IMO) Regulation A.1050(27) "Revised recommendations for entering enclosed spaces aboard ships" section 8.5 states: ***In the event of an emergency, under no circumstances should the attending crew member enter the space before help has arrived and the situation has been evaluated to ensure the safety of those entering the space to undertake rescue operations. Only properly trained and equipped personnel should perform rescue operations in enclosed spaces.***



	SM-15-01 General	
1.1	How - Procedure	The atmosphere in any enclosed space may be deficient in oxygen and/or contain flammable and/or toxic gases or vapours. Such an unsafe atmosphere could also subsequently occur in a space previously found to be safe. Unsafe atmosphere may also be present in spaces nearby spaces where a hazard is known to be present. Full details and recommendations for entering into enclosed spaces aboard ships are described in the IMO Res. A.1050(27) adopted on 30 Nov 2011.
1.2	How - Procedure	Many of the casualties that have occurred in enclosed spaces on ships have resulted from people entering an enclosed space without proper supervision of adherence to the agreed procedures. In almost every case, the casualty would have been avoided if simple principles of safety had been followed.
1.3	How - Procedure	The rapid rescue of personnel who have collapsed in an enclosed space presents particularly risk. It is a human reaction to go to the aid of a colleague in difficulties, but far too many additional and unnecessary casualties have occurred from impulsive and ill-prepared rescue attempts.

Extract from SM-15-01

When the chief officer entered the hold to help OS1 he did so under the assumption that safety equipment such as breathing apparatus was not required, as entry posed no risk, as work had been carried out incident free on previous days in the other holds.

This was further highlighted, when on hearing the alarm being raised by OS2, the chief officer, with demonstrable experience in on board safety procedures, medical first aid, emergency response and enclosed space entry procedures, failed to stop and consider the environmental conditions or reasons for OS1 collapsing

and what effects this would pose on his physical state. It was most likely that his emotional state was impaired, or most likely complacent, informed by the fact that all holds posed no risk when entering as the vessel holds had been certificated gas free.

Whilst there is nothing to indicate that the atmosphere directly above point of entry was dangerous, at no point was an attempt made to test the atmosphere to confirm it was safe. The assumption was that the hold was safe to enter due to the regularity at which the holds were opened as part of the ventilation and aeration process following the removal of fumigant and declared gas free, as well as the fact that crew had entered other holds the previous day with no ill effects.

Nevertheless, the enclosed space rescue training and education the crew had received as part of their mandatory training as well as from the fumigant contractor was not sufficient to highlight a potential risk posed by the presence of toxic gases which were not, or could not be tested for prior to entry, as the gas detection equipment held onboard was not calibrated to detect for phosphine gas. This inability to adequately test the space prior to entry, either to commence work or when planning for recovery, placed themselves in the way of potential harm.

Neither OS1 nor OS2 entering the cargo hold considered that they would be exposed to phosphine gas. Furthermore, the consideration for an entry guard, entry permits, safety and rescue equipment were not requested or placed at the entry to the holds, as they had been operating in holds one through to five without incident, the days leading up to the incident.

Decision making

The unintentional decisions taken by the chief officer in not properly planning for entry into the cargo holds, in accordance with the control measures identified in the risk assessment S-18 and SM-15, was due to his focus on one particular piece of information, or biased[2] in his decision making process, as the vessel had been provided with a gas free certificate, and therefore it was assumed that the holds would pose no risk and were safe to enter.

The issue of a gas free certificate removed all safety barriers raising the likelihood of a hazardous consequence occurring due to the incorrect application of an existing good rule, i.e.; risk assessment S-18 and enclosed space entry procedure SM-15 being carried out and all available control measures being adopted and applied.

The chief officer's knowledge on the associated risks and dangers posed by fumigant in cargo holds was known, as he had spoken of the risks to the removal contractors, insisting that they were to take all necessary precautions, as he had read an article where there had been two fatalities reported, from other vessels when procedures were not followed when working in areas where fumigant had been present.

Owing to the fact that the chief officer and crew were skilled, aware of the rules and were knowledgeable in their respective tasks, all available safety barriers and control measures were not put in place as there was an assumption that there was no need for them, as the vessel had been provided with assurance that the cargo holds were gas free, in the form of a gas free certificate.

[2] Anchoring bias describes people's tendency to rely too heavily on the first piece of information they receive on a topic. Regardless of the accuracy of that information, people use it as a reference point, or anchor, to make subsequent judgements (Judgment under Uncertainty: Heuristics and Biases Amos Tversky; Daniel Kahneman, Sep. 1974)

4. Conclusions

- An ordinary seafarer lost his life when overcome by phosphine gas poisoning after entering a cargo hold without verifying the atmospheric condition that had been fumigated and declared gas free.
- A chief officer was seriously injured by phosphine gas poisoning when entering the cargo hold without appropriate protective equipment as part of an attempted rescue.
- It was assumed the space was safe, and personal protective equipment was not required, as the vessel was in possession of a gas free certificate, and hatches were open.
- The cargo holds were identified as “enclosed spaces” but enclosed space procedures were not followed. However, the procedure and associated risk assessments for enclosed or dangerous spaces were not robust enough to have identified the presence of phosphine gas.
- Phosphine gas detection equipment was onboard but was not considered necessary due to the gas free certificate. The vessel’s multi-gas meter used for “enclosed space” entry did not have phosphine sensors.
- None of the crew reported smelling the carbide additive provided as an olfactory warning of the presence of phosphine.

5. Lessons to be learned

- Fumigated cargoes are incredibly dangerous. Cargo holds that contain fumigated cargo should not be entered. Lethal doses of fumigant may remain in pockets or trapped within the cargo. A gas free certificate does not guarantee your safety.
- Even after a space has been declared gas free and found to contain a safe atmosphere, local concentrations of toxic gas should always be suspected.
- Risk assessments and associated control measures are ineffective if the hazards associated with a task are not identified – the presence of fumigant in the hold was not considered and therefore no steps to identify or control the risk were taken.
- The enclosed space rescue training and familiarisation the crew had received was not sufficient to highlight a potential risk posed by the atmosphere before placing themselves in the way of potential harm. The chief officer did not consider that he would be exposed to the same hazard as the injured OS, when entering the hold.
- When personnel are in need of rescue from an enclosed or dangerous space, and in the interest of saving life, rescue operations should not be attempted until assistance has arrived and a planned approach can be made
- The importance of following industry best practice guidelines, as well as company procedures when entering enclosed or dangerous spaces should be reaffirmed.

6. Actions taken

Gestmar Tehnika has:

- Reviewed and amended procedures regarding enclosed and dangerous spaces and circulated via companywide bulletin
- Implemented a series of additional safety training on working in enclosed or dangerous spaces for all persons prior to joining vessels.
- Acquired the services of an external training provider to visit vessels and carry out training and boost safety culture onboard.
- Implemented a company policy on the donning of Breathing Apparatus when entering holds where fumigant has been present.
- Adopted a programme of providing all ships with phosphine/chlorine gas detectors.
- Reviewed IMO recommendations on safe use of pesticides on ships and provided new forms for the appointment of responsible person in charge.

7. Recommendations

Gestmar Tehnika is recommended to:

- Ensure the mandatory completion of a detailed risk assessment as part of the permit to work process for entry in to dangerous or enclosed space entry.
- Consider providing additional material to assist crews to identify the hazards associated with fumigation, symptoms and the correct actions to take when dealing with a rescue attempt.

The Bahamas Maritime Authority is recommended to:

- Consider, together with other interested States, proposing to the International Maritime Organization the requirement for carriage of continuous gas monitoring equipment on board vessels carrying fumigated cargoes.
- The Bahamas should also consider a review of the effectiveness of the ISM audits carried out by Recognised Organisations pertaining to the adequacy of risk assessments for the safe carriage of fumigated cargoes.

8. Glossary and Definitions

AB	Able Bodied Seafarer
Bosun	Senior rating for the deck department
CO	Chief Officer
Coaming	a raised border round the hatch on board a vessel to keep out water.
Colorimetric tube	A tube which is fitted to a gas meter to sample and measure for specific gases in a specific area.
g	Gram
Hydrolysation	A chemical reaction in which one substance reacts with moisture to produce another
IMO	International Maritime Organization
ISM Code	International Safety Management Code
m	Metre
MSC/Circ.	Maritime Safety Committee circular
OOW	Officer of the Watch
OS	Ordinary Seafarer
PH_3	Hydrogen phosphide gas. Also known as phosphorous trihydride, phosphine or phosphane
ppm	parts per million
SOLAS	International Convention for the Safety of Life at Sea
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
STEL	Short Term Exposure Limit
Ship sweat	Sweating of cargo due to moisture build up during concealment of cargo holds during passage
TLV	Threshold limit value, the acceptable limit of a chemical to which a person may be exposed without negative effects.
TWA	Time weighted average is the acceptable average exposure to a substance over a working day, typically 8-10 hours (varied by country).
UTC	Coordinated Universal Time
VHF	Very High Frequency

Appendices

Appendix 1 - Cargo Declaration certificate

CERTIFICATE NBR. PNG 279/2022
(on previous average sampling)

TO THE MASTER OF THE VESSEL:

VESSEL:	**MV JUPITER**
CARGO:	**BRAZILIAN SOYBEANS, IN BULK**
LOAD PORT:	**PARANAGUA, BRAZIL**
DESTINATION:	**CHINA PORT(S)**
QUANTITY TBL:	**57,682.000 MT**
SHIPPER:	**LDC BRASIL**

By the present, we inform characteristics of cargo to be loaded on board above mentioned vessel, based on shipper's declaration:

- Stowage factor: 47/49
- Angle of Repose: NOT APPLICABLE
- Moisture Content: 14.0% max.

Remark: Specifications as per Anec 41 contract:

-Oil content basis 18.5%

-Moisture maximum 14%;

-Foreign matter basis 1% maximum;

-Damaged beans basis 8%, maximum 8.5%; of which maximum 4% heat damaged and burned (being maximum 1% burned) and 6 % mouldy;

-Broken beans maximum 30%;

-Greenish beans maximum 8%

The cargo is not Harmful to the Marine Environment.

Paranaguá, March 30th, 2022

CONTROL UNION LTDA (BRAZIL)

(This report covers only work at the point indicated and does not evidence shipment of the described goods).

CONTROLUNION

Appendix 2 – Fumigation certificate

Real Marine

Gafta APPROVED FUMIGATOR

CO. NEUTRO

FUMIGATION CERTIFICATE

Certificado de Fumigação

Certificate: 141-2022-PR

The undersigned certifies that the products reported of the under described dispatch were submitted fumigation accordingly following indications:
O abaixo assinado certifica que os produtos constantes da remessa abaixo descritas foram submetidos a expurgo conforme indicação a seguir:

DESCRIPTION OF THE CONSIGNMENT

Descrição da Remessa

Lot number / Nº do lote	*Gross weight / Peso bruto*: 63,070,375
Origin / Origem: PARANAGUA, BRAZIL	*Destination / Destino*: CHINA PORT(S)
Mark/Label / Marca: N/A	*Quantity of packages / Quantidade de volumes*: IN BULK
Kind of product / Natureza do produto: SOYBEAN	
Name and address of shipper / Nome e remetente: [redacted]	*Name and address of consignee / Nome e endereço do destinatário*
Notify address	

TREATMENT

Tratamento

FUMIGATION /DESINFECTION TREATMENT

Vessel (Navio): M/V JUPITER	
Fumigation at (Fumigado em): HOLD(S) NUMBER(S): 1 / 2 / 3 / 4 / 5 / 6 / 7	*Place (Local)*: PARANAGUA, BRAZIL
Fumigation product (Produto utilizado): PHOSPHINE	*Date of fumigation (Data da fumigação)*: 05 / APRIL / 2022
Dosing (Dosagem) - PHOSPHINE (PH3): 1 G/CUBIC METER	*Exposition time (Tempo de exposição)*: 240 HOURS
Temperature (Temperatura): 25,5 °C	*Start time (Hora de início) / Conclusion (Término)*: 16:40 / 18:00
Remarks (Observações): METHOD: SACHETS/ SLEEVES	

Place and date (Local e Data): PARANAGUA, BRAZIL - 05 / APRIL / 2022

[redacted]

REAL MARINE AGRONOMIA LTDA
MAPA REGISTER - BR PR 0643

Ship's Master - sign & stamp

M.V. JUPITER
IMO NO: 9287194

[redacted]

MASTER / CHIEF OFFICER OF M/V 'JUPITER'
SIGNATURE AND VESSEL STAMP

Appendix 3- Gas free certificate

JIM'S FORCE SERVICES
Vector Control & Environment Care
Reg. No: ENV52916725E

DISPOSAL OF FUMIGATION MATERIALS / GAS FREE CERTIFICATE REF: 0165/22

STATEMENT OF VESSEL

Vessel: **JUPITER** IMO: **9287194**

Flag: **BAHAMAS** Location: **SINGAPORE ANCHORAGE**

DESCRIPTION OF THE CONSIGNMENT

Fumigant Loading Date : 5 April 2022

Fumigant Loading Port : Paranagua, Brazil

Minimum Exposure time : 240hrs

Fumigant Unloading Date : 07-MAY-2022

Time: 1300HRS

Est.weight: LESS THAN 30000KGS.

Used product: ✓ Aluminium phosphide ( ) Others:

Cargo Hold	PH3 phosphine concentrations (PPM)			Fumigant removed	Remarks
#1	( ) <0.1	✓ <0.3	( ) >3.0	OK	ALL SLEEVES REMOVED FROM CARGO HOLDS.
#2	( ) <0.1	✓ <0.3	( ) >3.0	OK	
#3	( ) <0.1	✓ <0.3	( ) >3.0	OK	
#4	( ) <0.1	✓ <0.3	( ) >3.0	OK	
#5	( ) <0.1	✓ <0.3	( ) >3.0	OK	
#6	( ) <0.1	✓ <0.3	( ) >3.0	OK	
#7	( ) <0.1	✓ <0.3	( ) >3.0	OK	

*PH3 concentrations: < 0.1 PPM: smell frontier, harmless.
< 0.3 PPM: TLV-value (International)
> 3.0 PPM: dangerous, even for relative short period without gas mask

A gas free situation means that nowhere the concentration of the gas exceeds the TLV. This must be measured with the gas detection equipment. A part of the gas will be absorbed into cargo and will be released slowly. Therefore it is necessary to measure directly at the surface of the cargo. In case of bags cargo one has to carry out regular checks between the bags at different stages of discharge. Only when the gas concentration is under the TLV-limit the unloading operations can start.
There will be no more danger for the workers then, even when working continuously.

Operator Present Employer Particulars:

- Company Name of Collector/Country: Jim's Force Services. Singapore
- National Environment Agency Reg No: ENV52916725E
- Hazardous Substances Permit No: J017P16034
- Licensed Toxic Waste Disposal: ECO Special Waste Management Pte Ltd (Reg No:199704908M)
- Treatment Method Incineration

Technical personal particulars [redacted]

Name & PCO license no. [redacted]

Acknowledge

Master/Captain/C.Officer [redacted]

Ship Stamp

Add: No.11 Mandai Estate #03-15 Eldix Singapore 729908
Tel: +65 6487 3487 Fax: +65 6487 3478
Email: admin@jimsforce.com.sg Web: www.jimsforce.com

Appendix 4 – Material Safety Data Sheet (MSDS)

MATERIAL SAFETY DATA SHEET: ALUMINUM PHOSPHIDE

	U.S. EPA Reg. No.	Canada Reg. No.
FUMITOXIN® TABLETS	72959-1	19227
FUMITOXIN® PELLETS	72959-2	19226

PROPER DOT SHIPPING NAME: ALUMINUM PHOSPHIDE, 4.3 (6.1) UN1397 PG I DANGEROUS WHEN WET, POISON LABELS APPLY

SECTION I - PRODUCT INFORMATION
Manufacturer:

[redacted]

Fumitoxin tablets and pellets are available as 0.6g pellets and 3.0g tablets.

Date of Revision: March 2011

SECTION II - HAZARDOUS INGREDIENTS INFORMATION
Identity:
Fumitoxin and Aluminum Phosphide (AlP) - react with water to produce phosphine (hydrogen phosphide, PH_3) as shown in Equation 1. Fumitoxin is formulated with 55% aluminum phosphide and also contains ammonium carbamate (AC) and inert ingredients. Ammonium carbamate releases ammonia and carbon dioxide as shown in Equation 2.

1) $AlP + 3H_2O \rightarrow Al(OH)_3 + PH_3$

2) $NH_2COONH_4 \rightarrow 2NH_3 + CO_2$

AlP	CAS No. 20859-73-8	NH_2COONH_4	CAS No. 1111-78-0
PH_3	CAS No. 7803-51-2	NH_3	CAS No. 7664-41-7
$Al(OH)_3$	CAS No. 21645-51-2	CO_2	CAS No. 124-38-9

NFPA Chemical Hazard Ratings:
Flammability Hazard 4
Health Hazard 4
Reactivity Hazard 2
Special Hazard W

SARA Physical and Health Hazards:
Fire
Reactivity
Immediate (Acute)

Inhalation Exposure Limits:

Component	OSHA PEL TWA (ppm)	ACGIH TLV TWA (ppm)	ACGIH TLV STEL (ppm)	NIOSH IDLH (ppm)
Phosphine (Hydrogen Phosphide, PH_3)	0.3	0.3	1.0	50
Ammonia	50	25	35	300
Carbon Dioxide	5,000	5,000	30,000	40,000

SECTION III - PHYSICAL CHARACTERISTICS
Boiling Point:
AlP >1000°C
PH_3 -87.7°C

Specific Gravity of Vapors (Air = 1):
AlP N/A
PH_3 1.17

Vapor Pressure:
AlP 0mm Hg
PH_3 40mm Hg @ 129.4°C
AC 100mmHg @ 26.7°C

Solubility in Water:
AlP Insoluble, reacts
PH_3 26cc in 100 ml water at 17°C
AC Very soluble, reacts