

# **REPUBLIC OF THE MARSHALL ISLANDS** Maritime Administrator

BARRAMUNDI MARINE SAFETY INVESTIGATION REPORT

Occupational Fatality of Bosun

South China Sea | 3 July 2021

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IMO Number: 9813113



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## AUTHORITY

An investigation, under the authority of the Republic of the Marshall Islands laws and regulations, including all international instruments to which the Republic of the Marshall Islands is a Party, was conducted to determine the cause of the casualty.



Maritime Administrator

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# LIST OF ABBREVIATIONS AND ACRONYMS

2/0	Second Officer
AS/NZS	Standards Australia/Standards New Zealand
ASD.	Able Seafarer Deck
BA	Breathing Apparatus
ВІМСО	Baltic and International Maritime Council
С	Celsius
С/О	Chief Officer
CFR	Code of Federal Regulations
COSWP	Code of Safe Work Practices
COVID-19	Coronavirus Disease 2019
CPR	Cardiopulmonary Resuscitation
DPA	Designated Person Ashore
EN	European Standard
EU	European Union
EU-OSHA	European Agency for Safety and Health at Work
HSEQ	Health, Safety, Environment, and Quality
GT	Gross Tons
ILO	International Labour Organization
ΙΜΟ	International Maritime Organization
IMO Circular MSC.1/Circ.1264	Recommendations on the Safe Use of Pesticides in Ships Applicable to the Fumigation of Cargo Holds
IMO Circular MSC-MEPC.2/Circ.3	Guidelines on the Basic Elements of a Shipboard Occupational Health and Safety Programme
IMO Circular MSC.1/Circ.1358	.Recommendations on the Safe Use of Pesticides in Ships
IMSBC Code.	International Maritime Solid Bulk Cargoes Code
ISM	International Safety Management
ISO	International Organization for Standardization
ISO 7243:2017Ergonomics of the Thermal Environ	ment - Assessment of Heat Stress Using the WBGT Index
kn	Knots
LC50	Lethal Concentration
LFL	Lower Flammable Limit
m	Meters

m <sup>3</sup>
MN
mg Milligram
MLC, 2006
mm
MRCC
MTMetric Tons
OOWOfficer of the Watch
OSOrdinary Seafarer
PA Public Address
PPE Personal Protective Equipment
ppm
SDS
SOHSP
SMSSafety Management System
SOLAS
SOLAS      International Convention for the Safety of Life at Sea         STCW Code      Seafarers Training, Certification and Watchkeeping Code         STEL      Short-term Exposure Level         T.      True         TWA      Time Weighted Average         UK HSE      United Kingdom Health and Safety Executive         UK NHS      United Kingdom National Health Service
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SOLASInternational Convention for the Safety of Life at Sea STCW CodeSeafarers Training, Certification and Watchkeeping Code STELShort-term Exposure Level TTrue TWATime Weighted Average UK HSEUnited Kingdom Health and Safety Executive UK NHSUnited Kingdom National Health Service UK MCAUnited Kingdom Maritime and Coastguard Agency USCGUnited Kingdom Maritime and Coastguard Agency USCGUnited States Coast Guard US NIOSHUnited States National Institute of Occupational Safety and Health US NWSUnited States National Institute of Occupational Safety and Health US NWSUnited States National Safety and Health US NWS



## PART 1: EXECUTIVE SUMMARY

On 14 June 2021, the Republic of the Marshall Islands-registered combination carrier BARRAMUNDI, managed by Klaveness Ship Management AS (the "Company"), departed Tacoma, Washington, United States of America (hereinafter "United States"), laden with 67,382.9 MT of corn. The planned discharge port was Xinsha, People's Republic of China (hereinafter "China"). Fumigant had been applied in each of the ship's cargo holds prior to its departure from Tacoma.

On 1 July 2021, the charterer's agent, at the planned discharge port of Xinsha, informed BARRAMUNDI's Master that it was necessary for the ship's crewmembers to remove the fumigant from the cargo holds prior to the ship's arrival. The message was received while the ship was underway on the North Pacific Ocean. The stated reason for this was that shore personnel would not be permitted to embark the ship due to restrictions imposed because of the ongoing COVID-19 pandemic. The Company agreed to have the ship's crewmembers remove the fumigant.

On the morning of 3 July 2021, the C/O and Bosun conducted a Toolbox Talk with the deck ratings to review the plan for opening the hatch covers to ventilate the cargo holds and then remove the fumigant from each of the cargo holds. They also reviewed the risk assessment that had previously been conducted by the Master and the C/O for ventilating the cargo holds. At 0815,<sup>1</sup> two of the ASDs went out on deck to open the hatch covers to ventilate the cargo holds. None of the crewmembers remained on deck while the cargo holds were being ventilated.

At 1030 on 3 July 2021, the Master met with the C/O, Bosun, and two of the ASDs to conduct a risk assessment and review the plans he had previously discussed with the Company for removing the fumigant from the ship's cargo holds.

Unless otherwise stated, all times are ship's local time (UTC +8).

They also reviewed the required PPE, which included full face respirators with filters and single-use, non-woven polyethylene coveralls. Following this meeting, the Master and C/O checked the atmosphere on top of the cargo and on deck near the hatch coamings and then the Bosun and ASD1, who were both wearing the required PPE, started removing the fumigant from the cargo holds.

Just before 1130, the Bosun told the C/O that he needed to rest after he and the ASD1 had finished removing the fumigant from Cargo Holds Nos. 1-3. After being relieved by ASD2, the Bosun went aft toward the Accommodations. A short time later, an OS called the C/O and reported that the Bosun was asking for him. The C/O immediately went aft to check on the Bosun. The Bosun asked to be taken to the ship's Hospital. It was reported that the Bosun vomited just before reaching the Hospital. While being assisted in the Hospital by the 2/O, the Bosun was reported to have experienced several different symptoms, including an elevated body temperature, difficulty breathing, loss of feeling in his fingers, and chest pain. After being informed, the Master sought shoreside medical advice.

At about 1215, the Bosun was reported to have lost consciousness. The Master was immediately informed. He called MRCC Taiwan and requested that arrangements be made to evacuate the Bosun. At about the same time, it was reported that the Bosun had stopped breathing and did not have a pulse. The 2/O along with the crewmembers who were assisting him, immediately started CPR. The ship's crewmembers continued CPR until the Bosun was placed on the rescue helicopter, which landed on board BARRAMUNDI at 1420. The helicopter took off from the ship at 1440 and transported the Bosun to a hospital in Kaohsiung, Republic of China (hereinafter "Taiwan"). It was reported that the Bosun died in the hospital at 1629 on 3 July 2021.

The marine safety investigation conducted by the Republic of the Marshall Islands Maritime Administrator (the "Administrator") identified the following:

- 1. Causal factors that contributed to this very serious marine casualty include:
  - (a) ineffective assessment of the existing weather conditions and the potential for the seafarers tasked with removing the fumigant to suffer moderate to severe heat stress;

## SHIP PARTICULARS

## Vessel Name BARRAMUNDI

**Registered Owner** KCC Shipowning AS

ISM Ship Management Klaveness Ship Management AS

Flag State Republic of the Marshall Islands

<b>IMO No.</b>	Official No.		Call Sign	
9813113	8009		V7QX3	
Year of Bui 2019	ld	Gross Tonnage 54,043		
Net Tonnage		Deadweight Tonnage		
21,095		82,447		
,				

Length x Breadth x Depth 224.8 x 34.5 x 23.2 m

> Ship Type Combination Carrier

Document of Compliance Recognized Organization DNV

Safety Management Certificate Recognized Organization DNV

> Classification Society DNV

Persons on Board 20 (b) the COVID-19 related port access restrictions at the discharge port that prevented qualified shore personnel going on board the ship to remove the fumigant from the cargo holds following its arrival; and

- 2. Causal factors that may have contributed to this very serious marine casualty include:
  - (a) the portion of the Company's SMS addressing the safe handling of cargo and their circular letter did not include procedures for implementing the recommendations in IMO Circular MSC.1/Circ.1264 or the GARD circular on board Company-managed ships;
  - (b) inadequate internal communications within the Company when making the decision whether to permit the ship's crewmembers to handle the fumigant;
  - (c) the Master's decision to:
    - (i) not consult with the Company's HSEQ Department or Vetting and Marine Department when planning how the cargo holds would be ventilated or how the fumigant would be removed from the cargo holds; and
    - (ii) not sending the risk assessments for opening the hatch covers and for removing the fumigant from the cargo holds to the shore team for review before those jobs were started.
- 3. Additional issues that were identified but that did not contribute to this very serious marine casualty include:
  - (a) the pre-task planning and risk assessment did not address the potential consequences associated with the storage of the fumigant on board the ship after it was removed from the cargo holds;
  - (b) the Master and C/O went on deck together to check the atmosphere in Cargo Holds Nos. 1 and 2 without wearing respiratory protection; and
  - (c) the Company's SMS did not include a requirement that the occupation exposure limits listed on the relevant SMS must be complied with when a task involving handling or potential exposure to chemicals was being conducted.

## **PART 2: FINDINGS OF FACT**

The following Findings of Fact are based on the information obtained during the Administrator's marine safety investigation. Due to travel restrictions in place that had been imposed in response to the COVID-19 pandemic, the Administrator was not able to arrange for onboard attendance as part of its marine safety investigation of this very serious marine casualty. All related information available to the Administrator was obtained remotely.

1. Ship particulars: see chart on page 9.

### Voyage Information

2. On 14 June 2021, the seven cargo hold combination carrier BARRAMUNDI *(see Figure 1)* departed Tacoma, Washington, United States laden with 67,382.9 MT of corn. The planned discharge port was Xinsha, China.

Republic of the Marshall Islands Maritime Administrator

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Figure 1: BARRAMUNDI's General Arrangement.

#### Fumigation of Cargo

- 3. Prior to the ship's departure from Tacoma, the corn was fumigated<sup>2</sup> by laying two lengths of connected cloth tubes, filled with fumigant, on top of the loaded corn. These tubes resembled sausages and extended from the forward to aft end of each cargo hold. The hatch covers were closed and sealed after the fumigant had been applied.
- 4. The active ingredient in the fumigant applied to the cargo was aluminum phosphide, which reacts with moisture in the atmosphere to produce hydrogen phosphide, or phosphine.<sup>3</sup>
- 5. The company that applied the fumigant provided the Master with a copy of the applicator's manual for the fumigant that was used. This manual included technical information and instructions for the safe and proper handling, application, ventilation (i.e., aeration) of the cargo holds, and disposal of the fumigant.<sup>4</sup>
- 6. The company that applied the fumigant also provided the Master with:
  - (a) a copy of the SDS for the fumigant;
  - (b) two full-face respirators with phosphine filters;
  - (c) single-use, non-woven polyethylene coveralls; and
  - (d) an air sampling pump with colorimetric tubes for detecting phosphine.
- 7. As required by the applicator's manual for the fumigant, the qualified person<sup>5</sup> assigned by the fumigation company reviewed the following with the Master and C/O:
  - (a) the health hazards associated with the fumigant;
  - (b) allowed exposure levels and associated PPE requirements;
  - (c) proper use of the full-face respirators;

<sup>2</sup> The applicable USCG regulations for shipboard fumigation are found in 46 CFR Part 147A. These regulations were applicable to BARRAMUNDI while the ship was within the navigable waters of the United States. These regulations were promulgated in 1974. They are generally consistent with the recommended guidelines contained in IMO Circular MSC.1/Circ.1358 – Recommendations on the Safe Use of Pesticides in Ships that were adopted in 2008. Relevant details of these guidelines are discussed later in the report.

<sup>3</sup> Hazards associated with exposure to phosphine and controls for reducing the potential of exposure, including ventilation and respiratory protection, are discussed later in the report.

<sup>4</sup> Relevant details from the applicator's manual are discussed later in the report.

<sup>5</sup> Qualified person is defined by USCG regulations as "a person who has experience with the particular fumigant or knowledge of its properties and is familiar with fumigant detection equipment and procedures, or an applicator who is certified by the Environmental Protection Agency if his certification covers the fumigant that is used." See 46 CFR § 147A.7 (a).

- (d) use of the air sampling pump and column metric tubes;
- (e) safe handling of the fumigant; and
- (f) emergency procedures.
- 8. The two full-face respirators provided at the load port had been tested and approved in accordance with standard EN 136 and marked in accordance with EU Regulation 2016/425.<sup>6</sup> Based on the manufacturer's product information, they were one size fits all, had a double layer face seal with triple sealing edges, and a single threaded connection to which filters for a variety of different toxic gases could be attached.
- 9. The provided filters had been tested and approved by US NIOSH in accordance with the applicable regulatory requirements and were appropriate for use in atmospheres with 19.5% or more oxygen containing concentrations of phosphine of 15 ppm or less.<sup>7</sup>
- 10. According to the manufacturer's instructions, the colorimetric tubes that were provided had a measurement range of 0.1-10 ppm. No correction was required to the observed concentration when the tubes were used in air temperatures between 0-40°C and when the relative humidity was between 10-90%. It was not reported how many tubes had been provided to the Master. The air sampling pump was not fitted with an extension hose.
- 11. Neither the charter party agreement nor the charterer's instructions to the Master included any provisions addressing cargo fumigation.<sup>8</sup>

## Instructions for Removing Fumigant

- 12. The charterer did not inform the Master regarding arrangements at the planned discharge port for removing and disposing of the lengths of cloth tubes containing the fumigant that had been placed in each of the ship's cargo holds prior to the ship's departure from Tacoma.
- 13. On 1 July 2021, BARRAMUNDI's Master received an e-mail from the charterer's agent in Xinsha. At the time, the ship was in the East China Sea about 200 NM east of Zhoushan, China. The agent informed the Master it was necessary for the ship's crewmembers to remove the fumigant from the cargo holds because shore personnel would not be permitted to embark the ship due to port access restrictions imposed in response to the ongoing COVID-19 pandemic. The agent also advised that the crew should place the fumigant in bags after it was removed from the cargo holds and then stored in a dry location for disposal on shore after the ship berthed.
- 14. The Administrator was not able to establish if the charterer was aware prior to the ship's departure from Tacoma on 14 June 2021 that shore personnel would not be able to go on board BARRAMUNDI at the discharge port to remove the fumigant.

<sup>6</sup> The respirators had also been approved by US NIOSH per the applicable regulatory requirements and the requirements of the AS/NZS 1716:2012.

<sup>7</sup> Based on the SDS, full face respirators with a filter for phosphine may be worn when the concentration of phosphine in the atmosphere is less than 15 ppm. See also US NIOSH Pocket Guide to Chemical Hazards regarding respirator recommendations when entering atmospheres containing known and unknown concentrations of phosphine.

<sup>8</sup> It is noted that in 2015, BIMCO developed a cargo fumigation clause for use in both voyage and time charter parties. The background information for this clause includes the following statement: "When using this clause, the parties are obliged to follow the safety standards set out in the IMO Recommendations, including removal of fumigants and remains by competent entities and properly trained personnel only. By incorporating the IMO Recommendations as a binding standard, the parties secure a mutually agreed level of safety and detailed procedures for carrying out fumigation operations on board the ship." (See https://www.bimco.org/contractsand-clauses/bimco-clauses/current/cargo\_fumigation\_clause\_for\_charter\_parties\_2015 and https://www.bimco.org/contracts-and-clauses/current/cargo\_ fumigation\_clause\_for\_charter\_parties\_2015#Background (accessed 7 April 2022)). IMO Circular MSC.1/Circ.1264 is discussed later in the report.

- 15. The Master informed the Company's Operations Department that the charterer's agent had informed him that it was necessary for BARRAMUNDI's crewmembers to remove fumigant. It was reported that the charterer had not previously advised either the Company or the Master that the ship's crewmembers might need to remove the fumigant from the cargo holds.
- 16. The Company's Operations Department contacted the charterer's agent to determine if arrangements could be made to have shore personnel embark the ship to remove the fumigant at a port other than the scheduled discharge port. The charterer's agent advised this could not be arranged due to port access restrictions that were in place because of COVID-19. It was reported that the Company agreed to have BARRAMUNDI's crewmembers remove the fumigant from the ship's cargo holds given the absence of any viable alternative.
- 17. On 2 July 2021, the Company's Operations Department informed the Master that it was not possible to arrange to have shore personnel remove the fumigant and that it would need to be done by BARRAMUNDI's crewmembers.
- 18. It was reported that neither the Company's HSEQ Department nor the Vetting and Marine Department were made aware of the instructions the Master had received from the charterer's agent or that the Operations Department had agreed to have BARRAUMUNDI's crewmembers remove the fumigant from the ship's cargo holds.

#### Pre-task Risk Assessment and Planning

- 19. The Master met with the C/O after he had been informed that the ship's crewmembers would need to remove the fumigant from the cargo holds. They discussed how the work, including opening the hatch covers to ventilate the cargo holds, would be completed.<sup>9</sup> The Master and C/O also completed risk assessments for ventilating the cargo holds and removing the fumigant from the cargo holds.
- 20. The risk assessment for ventilating the cargo holds identified the following hazards:
  - (a) ship's crewmembers opening / closing cargo holds;
  - (b) risk of intoxication of crewmembers outside of Accommodations;
  - (c) fumigant gases entering Accommodations; and
  - (d) weather conditions wind blowing toxic gases to living areas.

<sup>9</sup> As discussed later in the report, the Company's SMS did not include guidance or procedures addressing cargo fumigation.

21. The identified consequences of each of these four ventilation hazards were risk of intoxication or poisoning. The existing pre-identified and additional barriers for each of these hazards were:

HAZARD	PRE-IDENTIFIED BARRIERS	ADDITIONAL BARRIERS	
Ship's crewmembers opening / closing cargo holds	<ul> <li>Toolbox Talk</li> <li>SDS</li> <li>Equipment and procedures</li> <li>Having experienced crewmembers perform the work</li> </ul>	<ul> <li>Crewmembers equipped with BA set (or respirator with appropriate filter)</li> <li>Safety gloves</li> </ul>	
Risk of intoxication of crew outside of Accommodation	• All crew to be notified about ventilation schedule and risks by PA system	• Warning signs posted on the doors inside Accommodation stating it was prohibited to leave the Accommodation while the cargo holds were being ventilated	
Fumigant gases entering Accommodation	• Accommodation ventilation to be switched to recirculation mode and all exterior doors and natural vents to be kept closed	• No additional barriers were identified	
Wind blowing toxic gases to living areas	• Cargo hold ventilation must be done when the wind blows from the side	• Accommodation ventilation to be switched to recirculation mode and all exterior doors and natural vents to be kept closed	

22. The risk assessment for removing the fumigant from the cargo holds identified the ship's crewmembers removing fumigant from a cargo hold as the hazard associated with this task. The identified consequences were risk of intoxication or poisoning. The pre-identified and additional barriers that were identified were:

PRE-IDENTIFIED BARRIERS	ADDITIONAL BARRIERS
<ul> <li>Conducting a Toolbox Talk</li> <li>Ventilating the cargo holds</li> <li>Equipment and procedures</li> <li>Having experienced crewmembers perform the work</li> <li>C/O supervision of the crewmembers removing the fumigant</li> </ul>	<ul> <li>Testing the atmosphere in the cargo holds for toxic gases</li> <li>Crewmembers equipped with protective breathing masks (respirators), full body disposable coveralls, and safety gloves</li> </ul>

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### Ventilation of Cargo Holds

- 23. At about 0700 on 3 July 2021, the Bosun went to the Bridge to discuss the jobs planned for the day with the C/O. The planned jobs for the Deck Department were opening the cargo holds so they could be ventilated and removing the fumigant from the cargo holds.
- 24. Between 0800–0815, the C/O and Bosun conducted a daily Toolbox Talk with the deck ratings to review the plan for opening the hatch covers to ventilate the cargo holds and then removing the fumigant from each of the cargo holds. They also reviewed the risk assessment for ventilating the cargo holds. No additional hazards, consequences, or barriers were documented during this review.
- 25. Before the ASD1 and ASD2 went out on deck after the Toolbox Talk was finished, an announcement was made on the PA system informing the ship's crewmembers that the hatch covers were going to be opened and the potential risks. Signs prohibiting crewmembers from going on deck were also posted on the doors in the Accommodations that opened to the weather deck.
- 26. The winds were Beaufort Force 3 from the west. Based on BARRAMUNDI's course of 225° T and speed of 13 kn, the apparent wind was from 10-15° off the ship's starboard bow at 18-20 kn. The sky was clear.
- 27. Following the Toolbox Talk and following the announcement via the PA system, the two ASDs went out on deck and opened all the cargo hold hatch covers. It was reported that they worked from forward to aft so that they were not standing near an open cargo hold while opening hatch covers. The C/O energized the cargo holds exhaust fans after the two ASDs returned inside the Accommodations.

### **Removal of Fumigant**

- 28. At 1030, the Master, C/O, Bosun, ASD1, and ASD2 met in the ship's Conference Room to review the SDS for the fumigant, the risk assessment, and the plans for removing the fumigant from the cargo holds. It was planned that after the C/O checked the atmosphere at the top of a cargo hold using the air pump and colorimetric tubes that were provided by the fumigation company, the Bosun and ASD1 would then remove the fumigant. It was also planned that ASD2 would be on standby on deck by the Accommodation.
- 29. No additional hazards, consequences, or barriers were documented on the risk assessment during the review. The Master stated the weather conditions were discussed but they were not included on the risk assessment since the temperature (29-30°C) was considered normal. He also said that the C/O had instructed the Bosun and ASDs to take frequent breaks and to drink plenty of water.
- 30. During this meeting, the Bosun and ASD1 were both provided full face respirators with filters and a set of single-use, non-woven polyethylene coveralls. The ASD2 was also provided a set of single-use, non-woven polyethylene coveralls. Both the Bosun and the two ASDs put these coveralls on over their standard work coveralls. The Bosun and ASDs were all instructed how to check to ensure that the face respirators were properly tightened.
- 31. After the meeting with the Master, the C/O stopped the cargo holds exhaust fans. He and the Master then went out on deck to start checking the atmosphere at the top of each cargo hold. Neither were wearing a full-face respirator with filter or BA set when they went out on deck. It was not reported if they remained on the windward side of the cargo holds when going forward and when checking the concentration of phosphine in and around the cargo holds.

- 32. Using the test equipment provided by the company that applied the fumigant, the Master and C/O determined that the concentration of phosphine was 0.1-0.2 ppm on deck in the vicinity of hatch coamings for Cargo Holds Nos. 1 and 2, and 2 ppm on the surface of the cargo in these two holds. It was not reported how close the colorimetric tube was to the corn when the atmosphere on top of the corn was checked.<sup>10</sup>
- 33. Based on the manufacturer's instructions for the colorimetric tubes, each individual measurement would have required a minimum of two minutes to complete.
- 34. Just before 1100, the C/O called the Bosun and ASD1 to come out on deck. He and the Master both reminded the Bosun and ASD1 how to check to make sure that their respirators were properly tightened. After determining that their respirators were on properly, the Master returned to the Accommodation and the Bosun and ASD1 started removing the tubes of fumigant from Cargo Hold No. 1.
- 35. A white powder was observed coming from the cloth tubes as they were removed from the cargo holds. The cloth tubes were placed in a metal drum that could be sealed so that the remnants of the fumigant would remain dry while being stored on board the ship before being discharged ashore.
- 36. The ASD1 stated the C/O asked how he and the Bosun were doing after they had removed the fumigant from Cargo Hold No. 1. The Bosun reportedly asked if it was possible to have more crewmembers assist with the task. The C/O said it was not possible since they only had two respirators and that the risk of having crewmembers without respirators assist was too high.
- 37. The Bosun and ASD1 then removed the fumigant from Cargo Hold No. 2 *(see Figure 2)*. The C/O watched them while he was measuring the concentration of phosphine near Cargo Hold No. 3 and on top of the cargo in that hold. He reported that the concentration of phosphine on top of the cargo in Cargo Hold No. 3 was 0 ppm.



Figure 2: The Bosun and ASD1 removing the second of two lengths of tubes of fumigant from Cargo Hold No. 2. The apparent wind was from 10-15° off the ship's starboard bow.

38. The C/O checked how the Bosun and ASD1 were doing as they rested after they finished removing the fumigant from Cargo Hold No. 2.

<sup>10</sup> As stated previously, the air pump was not equipped with an extension hose.

- 39. It was not reported if the Bosun and ASD1 went aft near the Accommodations or remained on deck in the vicinity of the cargo holds after removing the fumigant from Cargo Holds Nos. 1 and 2. It was also not reported if they removed their respirators and drank water while resting.
- 40. After resting, the Bosun and ASD1 removed the fumigant from Cargo Hold No. 3 as the C/O monitored their progress while checking the concentration of phosphine near and on top of the cargo in Cargo Holds Nos. 4-7. It was reported that no phosphine was detected in any of these cargo holds.
- 41. Just before 1130, when the C/O asked the Bosun and ASD1 how they were after they removed the fumigant from Cargo Hold No. 3, the Bosun stated that dragging the tubes of fumigant residue across the corn and then lifting them out of the cargo holds was heavy work and asked that the ASD2 take his place. He also said it was very hot and that it was hard to breath with the respirator on, but that he felt he could start working after he rested awhile. The ASD1 also indicated it was hard to breath with the respirator on and that he was hot, but that he could continue working.
- 42. The C/O then called the ASD2 and an OS to both come forward. Both had been on deck near the Accommodation. He also informed the Master that the Bosun looked exhausted, was having difficulty breathing, and needed to take a break.
- 43. After the ASD2 came forward, the Bosun gave him the respirator that he had been wearing. The Bosun then told both ASDs to be careful and checked to make sure that ASD2's respirator was properly tightened.

#### Assistance to Bosun

- 44. The C/O instructed the OS to take the Bosun aft to the starboard (windward) side of the Accommodation. He also instructed the OS to get the Bosun some water and to then stay with him and provide any assistance he might need.
- 45. A few minutes after going aft with the Bosun, the OS called and informed the C/O that the Bosun was asking for him. The C/O immediately went aft to check on the Bosun, while the ASDs continued to remove fumigant.
- 46. When the C/O reached him, the Bosun asked to be taken to the ship's Hospital. The C/O and OS then proceeded to assist him to the Hospital. The Bosun vomited just before they reached the Hospital. They continued to the Hospital and laid the Bosun down on the bed. The C/O called the 2/O to the Hospital to assist the Bosun, whose body temperature was elevated. It was also reported that he was having chest pain, difficulty breathing, and that he could not feel his fingers.
- 47. Within minutes, the 2/O arrived in the Hospital and started administering medical oxygen. He and the OS then removed the Bosun's clothing. They then started fans to try to cool the Bosun. As the 2/O was assisting the Bosun, the C/O went to the Bridge and informed the Master, who immediately went to the Hospital to check on the Bosun's condition.
- 48. After informing the Master, the C/O went out on deck to check on the two ASDs. They were resting after removing fumigant from another cargo hold. The C/O told them that the Bosun was not feeling well and directed them to not continue the job. He then went back to the Hospital.
- 49. The Bosun told the C/O that he felt a bit better and had regained feeling in his hands. He also told the C/O that he had hypertension that was controlled by medicine.

- 50. At 1155, the Master returned to the Bridge and called Radio Medico for medical advice. While the Master was on the phone, the C/O went to the Bridge to update the Master on the Bosun's condition and that he had hypertension.
- 51. Soon after the C/O went to the Bridge, the 2/O and OS helped the Bosun into the toilet.<sup>11</sup> The Bosun lost consciousness while he was in the toilet. The OS immediately went to the Bridge and informed the Master and C/O. The Master updated Radio Medico regarding the Bosun's condition and decided to request that arrangements be made to evacuate him for medical treatment on shore.
- 52. The C/O immediately went back to the Hospital where he, along with the 2/O and some other crewmembers who had stopped by the Hospital to see the Bosun before lunch, helped move the unconscious Bosun back to the bed. The 2/O restarted medical oxygen and the C/O went back to the Bridge to update the Master.
- 53. At 1220, the Master called MRCC Taiwan and requested that arrangements be made to evacuate the Bosun. MRCC Taiwan provided the Master a position where a rescue helicopter would rendezvous with BARRAMUNDI.
- 54. As the Master was contacting MRCC Taiwan, the 2/O observed that the Bosun had stopped breathing and did not have a pulse. With assistance from other crewmembers, he immediately started to administer CPR to the Bosun.
- 55. The C/O left the Bridge after the Master contacted MRCC Taiwan and went back to the Hospital. He then asked two of the ASDs to assist him with closing the cargo hold hatch covers. After closing the hatch covers, they removed the guardrails from the top of the hatch covers for Cargo Hold No. 3 so the rescue helicopter could land.<sup>12</sup> It was not reported if the C/O and two ASDs wore any respiratory protection when they went out on deck to close the hatch covers.
- 56. The Master informed the ship's DPA of the Bosun's condition and that he had arranged for him to be medically evacuated. It was reported that this was the first time the DPA or other members of either the HSEQ Department or the Vetting and Marine Department were made aware that BARRAMUNDI's crewmembers had been removing fumigant from the ship's cargo holds.
- 57. At 1306, the Master ordered the ship's course be changed to proceed to the position provided by MRCC Taiwan for the planned rendezvous with the rescue helicopter.
- 58. At 1420, the ship reached the rendezvous location and the rescue helicopter landed on board BARRAMUNDI. The ship's crewmembers transported the Bosun from the Hospital to the helicopter. It was reported that the crewmembers continued their efforts to revive the Bosun until they placed him on board the helicopter.
- 59. At 1440, the helicopter took off from BARRAMUNDI and transported the Bosun to a hospital in Kaohsiung, Taiwan. The ship resumed its planned voyage after the helicopter took off.
- 60. The Certificate of Death issued by the local authorities in Kaohsiung, stated that the Bosun died at the hospital at 1629 on 3 July 2021.
- 61. The report of the autopsy conducted by the forensic medical examiner in Kaohsiung stated the Bosun's death was an accident and that the cause of death was:

<sup>11</sup> It was not reported why the Bosun needed to go into the toilet.

<sup>12</sup> Cargo Hold No. 3 is the ship's designated helicopter pad.

- (a) heart, liver, and kidney necrosis<sup>13</sup> and pulmonary edema;<sup>14</sup> and
- (b) possible intoxication by an unidentified toxic fume and/or fumigant while cleaning the ship's cargo holds.
- 62. Based on the autopsy report, the forensic medical examiner also determined:
  - (a) the Bosun had an enlarged heart;<sup>15</sup>
  - (b) there was no evidence of coronary heart disease or myocardial fibrosis;
  - (c) there was no indication of a hemorrhage or tumor of the cerebrum, brain stem, or cerebellum; and
  - (d) there was no indication of a hemorrhage or vascular sclerosis at the base of the skull.
- 63. The toxicology report did not include any findings indicating that phosphine or another similar substance was present in the Bosun's body.

#### Crew

- 64. BARRAMUNDI had a complement of 20 crewmembers, four more than what was required by the Minimum Safe Manning Certificate issued by the Administrator. All of the crewmembers held Republic of the Marshall Islands seafarer certification appropriate for their position onboard.
- 65. The experience of BARRAMUNDI's crewmembers who were involved with removing the fumigant from the cargo holds is in the table below.

RANK	TIME ON BOARD BARRAMUNDI	TIME IN RANK	TIME WITH COMPANY	TOTAL TIME AT SEA
Master	1 month	1.5 years	2 years	16 years
C/O	1 month	3 years	2 years	12 years
Bosun	7.5 months	3.2 years	16.9 years	16.9 years
ASD1	1 month	4.1 years	1.9 years	7 years
ASD2	1 month	1 month	4.5 years	4.5 years

- 66. Although the Master and C/O had been on board BARRAMUNDI for short periods of time when this incident occurred, both they, the Bosun, and the two ASDs were experienced seafarers and were familiar with the Company's safe work procedures. Although the Master and C/O were not experienced with the carriage of dry bulk cargoes, they did have experience on board chemical and oil tankers and were familiar with the hazards associated with handling hazardous materials.
- 67. None of the seafarers who were involved with removing the fumigant from the cargo holds were reported to have prior experience handling fumigant.

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<sup>13</sup> Necrosis is the death of cells in body tissue. See Cleveland Clinic, Health Library / Diseases & Conditions / Necrosis (https://my.clevelandclinic.org/health/diseases/ 23959-necrosis).

<sup>14</sup> Edema is swelling due to fluids trapped in body tissue. See Cleveland Clinic, Health Library / Diseases & Conditions / Edema (https://my.clevelandclinic.org/ health/diseases/12564-edema).

<sup>15</sup> An enlarged heart is an indication of another condition, such as high blood pressure, a heart defect, damage, or heart disease. An enlarged heart can increase the risk of heart failure or stroke. See Cleveland Clinic, Health Library / Diseases & Conditions / Enlarged Heart (Cardiomegaly) (https://my.clevelandclinic.org/health/ diseases/21490-enlarged-heart-cardiomegaly) and Mayo Clinic, Patient Care & Health Information / Diseases & Conditions / Enlarged heart (https://www.mayoclinic. org/diseases-conditions/enlarged-heart/symptoms-causes/syc-20355436).

- 68. The Bosun had been found fit for duty without restrictions during his most recent pre-employment medical exam, which was conducted on 16 October 2020. The medical exam report documented that he had a history of hypertension which dated back to 2018 and that he was taking maintenance medication.<sup>16</sup> The report also stated that he should continue taking maintenance medication as advised.
- 69. The Administrator did not observe any indication that any crewmembers involved with removing the fumigant from the cargo holds had failed to receive the amount of rest mandated by the IMO's STCW Code, Section A-VIII/1, paragraphs 2 and 3 and the ILO's MLC, 2006, Regulation 2.3.

#### SMS

- 70. As required by the ISM Code, the Company's SMS included safe work procedures. It also included procedures for the handling of both dry bulk and petroleum cargoes and a circular letter addressing fumigation.<sup>17</sup> The Company had also issued a Safe Work Handbook, which provides practical guidance for implementing the procedures in the SMS. The portion of the Company's SMS addressing safe work procedures includes a statement advising that the UK MCA's COSWP should be consulted "when in doubt or if more detailed guidance is desired."
- 71. The Company's safe work procedures required that a risk assessment be completed for any:
  - (a) non-routine job; and
  - (b) routine job that either inherently involves significant hazards or the conditions that exist when the work is planned pose hazards not regularly associated with that job.
- 72. The Company maintains a library of risk assessments for different shipboard jobs. The library of risk assessments did not include ones for conducting in-transit fumigation, ventilating fumigated cargo holds, or removing fumigant from cargo holds.
- 73. Based on the Company's safe work procedures, factors that are supposed to be considered when evaluating hazards included:
  - (a) the crewmember's prior experience performing the task;
  - (b) human factors such as fatigue, etc.;
  - (c) available PPE;
  - (d) the configuration of the workplace;
  - (e) hazards from other activities taking place; and
  - (f) weather and environmental conditions.

The Company's SMS did not include guidance for assessing the potential for heat stress. The guidance in the UK MCA's COSWP for working in hot or sunny climates includes a warning that "high humidity and high temperature

<sup>16</sup> Losartan, 50 mg tablet once per day. Losartan is an angiotensin receptor blocker commonly used to manage high blood pressure (e.g., hypertension). See UK HSE, Medicines A to Z (https://www.nhs.uk/medicines/losartan/) and Mayo Clinic, Drugs and Supplements (https://www.mayoclinic.org/drugs-supplements/losartan-oralroute/description/drg-20067341). The inventory of the Bosun's cabin that was conducted after his recorded death identified a 180-day supply of this medication. It is not known if he was taking it daily.

<sup>17</sup> Circular letters issued by the Company are considered to be part of their SMS.

can lead to heat exhaustion and heat stroke." The recommendations in the UK MCA's COSWP for ensuring the safety of crewmembers working in these conditions include:<sup>18</sup>

- (a) drinking at least 4.5 liters of cool water a day;
- (b) limiting the length of time that seafarers are exposed to hot conditions and that guidance on thermal comfort from the UK HSE should be consulted;
- (c) wearing light clothing and avoiding exposure to the sun, particularly during the hottest part of the day;
- (d) when wearing respiratory equipment (e.g., full-face respirators), taking regular breaks in the fresh air or shade; and
- (e) removing protective clothing and equipment when taking breaks.
- 74. The section of the safe work procedures in the Company's SMS that addresses toxic or harmful substances includes requirements intended to prevent accidents associated with the handling and storage of such substances on board ships in the Company-managed fleet.<sup>19</sup> These procedures require:
  - (a) maintenance of a shipboard index of product data sheets (e.g., SDSs) for the toxic or harmful substances that are on board the ship; and
  - (b) that the person in charge of a planned task ensure that the crewmembers assigned to complete the planned work are aware of:
    - (i) the health hazards associated with the substance;
    - (ii) the type of PPE that is required; and
    - (iii) vital information from the product data sheet.
- 75. The Company's SMS required that risk assessments for non-routine or new jobs be sent to the HSEQ Department for review and possible inclusion in the Company's library of risk assessments. The SMS did not indicate if such risk assessments were supposed to be sent before the planned job was started. The Company's Safe Work Handbook required that risk assessments for non-routine and new jobs be reviewed by the shore team<sup>20</sup> before starting the job.
- 76. The Company's SMS required that the person in charge of the planned work conduct a Toolbox Talk with the crewmembers assigned to complete it. Based on the guidance in the Company's Safe Work Handbook, Toolbox Talks are supposed to include:
  - (a) completion of the risk assessment and any work permits that might be required for the planned work;
  - (b) a discussion of the existing environmental conditions and any limitations it might impose;
  - (c) reviewing the PPE required; and
  - (d) discussing how the work will be conducted.

<sup>18</sup> See UK MCA COSWP, section 3.7.

<sup>19</sup> Based on the Company's SMS, these requirements are based on the Norwegian Maritime Authority, Regulations of 1 January 2005 No. 8 on the working environment, health and safety of persons working on board ship. The UK MCA COSWP, paragraph 21.1.4 includes similar guidance.

<sup>20</sup> The shore team included the ship's Superintendent and staff from the HSEQ and Marine Departments.

- 77. The guidance in the Company's SMS addressing the safe handling of cargo required that crewmembers be provided information regarding the potential hazards of any cargo that might be on board. It also highlights hazards related to oxygen depletion, fire, emission of toxic fumes, and dust. It further required that dry bulk cargoes be handled in accordance with the procedures contained in the IMSBC Code. It did not address hazards related to the fumigation of cargo or procedures for ensuring crewmember safety either when a fumigant was applied or during in-transit fumigation, nor did it include a reference to the Company's circular letter addressing the use of fumigants.
- 78. The Company circular letter addressing fumigation required that any use of fumigants on board Company-managed ships be conducted in accordance with IMO Circular MSC.1/Circ.1358.<sup>21</sup> The letter also included an article published by Gard Services addressing the in-transit fumigation of bulk cargoes.
- 79. The Gard Services' article included with the Company's circular letter provides a summary of the risks associated with fumigation, along with recommendations for how those risks should be managed. The article also states that the fumigation company should provide instructions for the safe and proper disposal of fumigant residues. The article states that fumigation should not be conducted by crewmembers unless they are certified after receiving special training. It does not expressly address the removal of fumigant, including residue, by the ship's crewmembers.
- 80. Neither the Company circular letter nor the portion of the Company's SMS addressing the safe handling of cargo included any guidance or procedures to facilitate the implementation of the IMO recommendations for the safe use of pesticides or those in the GARD Services' article on board ships in the Company-managed fleet.
- 81. The Company's SMS also addressed the need to implement appropriate controls to workplace hazards that may have short- or long-term adverse consequences on seafarer health. Some of the workplace hazards that were identified included environmental factors (e.g., noise, vibration, and extreme temperatures), exposure to chemicals, and fatigue.
- 82. The Company's SMS did not include a direct statement requiring that the occupation exposure limits included on therelevant SDS be complied with when a task involving handling or potential exposure to chemicals was being conducted.<sup>22</sup>

## IMO Requirements and Guidance

- 83. SOLAS regulation VI/4 requires that appropriate precautions be taken when using pesticides in ships, particularly when used for fumigation, and is applicable to ships of 500 GT and upwards laden with solid bulk cargoes, including grain.<sup>23</sup> Although the regulation includes a reference to IMO Circular MSC.1/Circ.1264, it does not make compliance with the circular mandatory.
- 84. IMO Circular MSC.1/Circ.1264 includes detailed guidance intended to ensure the safety of a ship's crew and of any other persons who may be onboard when fumigant is applied, during a voyage when in-transit fumigation is being conducted, and during cargo discharge. This guidance includes among other things that:<sup>24</sup>

<sup>21</sup> IMO Circular MSC.1/Circ.1358 contains guidance regarding the use of pesticides to control insect and rodent infestations of different spaces on board ships and the safety precautions that should be taken by crewmembers when fumigants are used. Based on this circular, crewmembers should not handle fumigants. Rather, fumigation operations should only be conducted by qualified persons. Based on the guidance in this circular, the fumigation of loaded or partially loaded cargo holds should be conducted in accordance with IMO Circular MSC.1/Circ.1264.

<sup>22</sup> It is noted that the Company's SMS does include exposure limits for hydrogen sulfide and benzene.

<sup>23</sup> See SOLAS regulation VI/1.

<sup>24</sup> The guidance included in the circular is extensive and addresses things such as atmospheric testing of the Accommodations, Engine Room, Bridge, and other working spaces once the person in charge of the fumigation turns that responsibility over to the ship's Master. Only the guidance most relevant to this particular very serious marine casualty is included in this report.

- (a) in transit fumigation should only be carried out at the discretion of the ship's Master;
- (b) a ship's crewmembers should not handle fumigant and that "such operations should be carried out only by qualified operators;"
- (c) the person in charge of applying the fumigant is to provide the Master with written instructions for the fumigant that was used that include the manufacturer's recommendations concerning methods of detecting the fumigant in the atmosphere, its hazardous properties, symptoms of poisoning, and relevant first aid and emergency procedures, and a copy of the relevant SDS. The person in charge should also ensure that the ship has onboard gas detection equipment and adequate supplies for the fumigant that was applied to conduct any atmospheric testing that might be required during the voyage, and at least four sets of respiratory protective equipment that are in good working order;
- (d) instructions for the disposal of residual fumigant be on board the ship (the circular does not address whether the disposal instructions that are included in the fumigant manufacturer's written instructions fulfills this requirement, or whether it is intended that the ship have instructions regarding the removal of fumigant from the cargo holds prior to cargo discharge);
- (e) cargo holds sealed for in-transit fumigation should never be opened at sea "except in extreme emergency." The circular does state that if it is necessary to ventilate one or more cargo holds that have been sealed for in-transit fumigation that "every effort should be made to prevent a fumigant from accumulating in accommodation or working areas."<sup>25</sup> It also indicates that the atmosphere in these spaces should be checked and that the crew be evacuated from any spaces where the concentration exceeds the occupational exposure limit set by the flag State<sup>26</sup> and the cargo holds re-sealed; and
- (f) the fumigated cargo be handled in accordance with the discharge port State's applicable requirements and that a trained person from a fumigation company or other authorized person tests the cargo holds before anyone enters them during cargo discharge.
- 85. The guidance in IMO Circular MSC.1/Circ.1264 does not address the removal of any remaining fumigant or materials, such as the cloth tubes containing the fumigant that had been placed in BARRAMUNDI's cargo holds prior to the ship's departure from Tacoma.
- 86. The IMSBC Code, section 3.6 requires that in-transit fumigation of cargo be conducted in accordance with IMO Circular MSC.1/Circ.1264. This section of the IMSBC Code also includes requirements for ensuring fumigants that generate phosphine or other toxic gases do not endanger the safety of a ship's crewmembers during a voyage. Particular attention is given to actions that should be taken to prevent fumigant from entering spaces crewmembers might occupy. It also requires atmospheric monitoring for the presence of the fumigant in the Accommodation, Engine Room, Bridge, and other spaces as advised by the person responsible for applying the fumigant be conducted at least every eight hours throughout the voyage.
- 87. Per SOLAS regulation VI/1-2, the IMSBC Code is not applicable to carriage of grain, which includes corn.

<sup>25</sup> The accumulation of fumigant inside the Accommodation or another occupied space can be fatal. See The Bahamas Maritime Authority, FRI DOPHIN, Report on Cargo Fumigant Poisoning Leading to a Fatality on 13 February 2020; Hong Kong Marine Department, Merchant Shipping Information Note No. 8/2020: Fatal Accident Caused by Cargo Hold Fumigation; Republic of Turkey Transport Safety Investigation Center, Marine Safety Investigation Report: RIMEO (6 March 2017); Republic of Poland State Marine Accident Investigation Commission, M/V NEFRYT Poisoning of the Ship Crew After the Fumigation of Cargo in the Port of Abidjan on 25 and 26 September 2015; and United Kingdom Marine Accident Investigation Branch, Preliminary Examination Summary: MONIKA (28 October 2007). Based on a review of these investigation reports, there was a general lack of awareness by the ships' Masters of the guidance in IMO Circular MSC.1/Circ.1264.

<sup>26</sup> The Administrator has not established occupational exposure limits for phosphine or other hazardous materials.

88. IMO Circular MSC-MEPC.2/Circ.3 provides guidance addressing the basic elements of a SOHSP. It also includes guidance regarding methods for identifying and evaluating workplace hazards, including chemical exposure. The identified methods for evaluating hazards include conducting a comparison of industrial hygiene exposure levels to standards identified in the SOHSP.

## Flag State Regulations

- 89. The flag State regulations for the carriage of grain are found in *Carriage of Grain* (MN 2-011-3). These regulations mandate that the provisions of SOLAS chapter VI apply in full to approvals of grain loading arrangements for Republic of the Marshall Islands-registered vessels of greater than 20 GT.
- 90. The regulations in MN 2-011-3 do not mandate compliance with the guidance in IMO Circular MSC.1/Circ.1264.
- 91. Flag State regulations requiring that Republic of the Marshall Islands-registered ships have a SOHSP are found in *Shipboard Occupational Health and Safety, including Hazardous Work Issues for Seafarers Under 18 Years Old* (MN 7-049-1). These regulations require the SOHSP be included as part of an SMS and that it take into account the guidance in IMO Circular MSC-MEPC.2/Circ.3.

## Phosphine Gas

- 92. Phosphine is a colorless, toxic gas, that can smell like garlic. It has a vapor density of 1.18 and is heavier than air. Phosphine can spontaneously ignite on contact with air if the concentration in the atmosphere exceeds its LFL of 1.79%.
- 93. The TWA exposure limits<sup>27</sup> for phosphine that have been established by different occupational safety and health administrations worldwide are between 0.1-0.3 ppm. The STELs<sup>28</sup> that have been established for phosphine are between 0.2-1.0 ppm.<sup>29</sup> Concentrations of phosphine of 50 ppm or more are immediately dangerous to human life.<sup>30</sup> Based on the SDS for the fumigant, the LC5031 of phosphine is 190 ppm for a one-hour exposure.
- 94. The SDS for the fumigant applied at Tacoma listed the following as symptoms of possible exposure to phosphine:
  - (a) mild exposure: malaise, ringing in the ears, fatigue, nausea, and pressure in the chest;
  - (b) moderate poisoning: weakness, vomiting, abdominal pain above the stomach, chest pain, diarrhea, and difficulty breathing; and
  - (c) severe poisoning: pulmonary edema, dizziness, elevated liver enzymes, kidney hematuria and anuria, loss of consciousness, and death.

<sup>27</sup> The TWA exposure limit is the maximum average airborne concentration of a substance that it is acceptable for a person be exposed to over an 8-10 hour work day during a five day work week. The length of the work day varies by country. See EU Commission Directive 2006/15/EC, Safe Work Australia Workplace Exposure Standards for Airborne Contaminants (effective 18 April 2013), and the US NIOSH Pocket Guide to Chemical Hazards.

<sup>28</sup> The STEL is the maximum average airborne concentration of a substance calculated over a 15 minute period that should not be exceeded during an 10-hour workday. *See* Safe Work Australia *Workplace Exposure Standards for Airborne Contaminants* and US NIOSH *Pocket Guide to Chemical Hazards*.

<sup>29</sup> For example, the EU-OSHA has established the TWA exposure limit for phosphine as 0.1 ppm and the STEL as 0.2 ppm. Safe Work Australia and the US NIOSH have established the TWA exposure limit for phosphine at 0.3 ppm and the STEL at 1 ppm. See the EU Commission Directive 2006/15/EC, Safe Work Australia Workplace Exposure Standards for Airborne Contaminants (effective 18 April 2013), and the US NIOSH Pocket Guide to Chemical Hazards. The SDS for the fumigant that was provided to the Master stated that the TWA exposure limit was 0.3 ppm, and that the STEL was 1.0 ppm.

<sup>30</sup> See US NIOSH Pocket Guide to Chemical Hazards.

<sup>31</sup> LC<sub>50</sub> is the airborne concentration of a chemical that will kill 50% of test animals during a single exposure. *See* Canadian Centre for Occupational Health and Safety, *What is a LD<sub>50</sub> and LC<sub>50</sub>*? (https://www.ccohs.ca/oshanswers/chemicals/ld50.html) (accessed 24 March 2022).

- 95. The SDS did not indicate what concentrations of phosphine might be associated with mild exposure or what concentrations can cause either moderate or severe poisoning. The onset of symptoms of poisoning can occur within a few hours to several days from when the exposure occurred.
- 96. Based on the SDS for the fumigant that was given to the Master by the fumigation company, full face respirators with a filter for phosphine may be worn when the concentration of phosphine in the atmosphere was less than 15 ppm.<sup>32</sup> A BA set was required if the phosphine levels were 15 ppm or more.
- 97. The SDS stated that local ventilation is "generally adequate" to reduce the concentration of phosphine in fumigated areas to below the TWA exposure limit. It also recommended the use of exhaust fans to more rapidly ventilate a cargo hold or similar space.
- 98. The manufacturer's instructions state that a certified applicator must be physically present and maintain contact (visual or voice) with all fumigant workers, both when the fumigant is applied and when the structure (e.g., cargo hold) that was fumigated is opened for aeration.
- 99. Based on the manufacturer's instructions, properly applied fumigant will produce a greyish-white powder as the active ingredient (aluminum phosphide) reacts with moisture in the atmosphere.<sup>33</sup> The instructions state this powder will contain a small amount of unreacted aluminum phosphide and that it should be placed in burlap, cotton, or other porous cloth bags. The instructions also state that the storage of large quantities of dust can result in a fire hazard and that the dust should not be collected in large drums or plastic bags or similar containers where confinement is possible to prevent the accumulation of phosphine from any unreacted aluminum phosphide.

### Heat Stress

- 100. Heat stress<sup>34</sup> is caused by the internal production of heat due to physical activity, environment factors (e.g., air temperature, humidity, air flow, and heat radiation), and the clothing and PPE being worn. Mild heat stress can cause discomfort, whereas moderate and severe heat stress can cause heat exhaustion, heat stroke, or death. Symptoms of heat stress can include:
  - (a) mild heat stress: loss of concentration, muscle cramps, heat rash, and severe thirst;
  - (b) heat exhaustion: fatigue, dizziness, nausea or vomiting, headache, heavy sweating, fainting; and
  - (c) heat stroke: hot dry skin, confusion, nausea, loss of consciousness. Heat stroke can also affect the nervous system and cause liver, kidney, muscle and heart damage.
- 101. Although anyone can potentially be impacted by heat stress, individual risk factors that can increase the potential for a person to be adversely impacted by heat stress include hypertension (e.g., high blood pressure) and the use of some blood pressure medications.<sup>35</sup>

<sup>32</sup> As previously stated, the filter was approved for use in an atmosphere containing 19.5% or more oxygen.

<sup>33</sup> According to the instructions, incomplete reaction of the aluminum phosphide will produce a green dust requiring special care.

<sup>34</sup> There are several sources providing information regarding heat stress and heat related illnesses. Some of these include: Safe Work Australia, Heat Stress (https://www.worksafe.qld.gov.au/safety-and-prevention/hazards/hazardous-exposures/heat-stress); UK HSE, Heat Stress in the Workplace: A Brief Guide (see https://www.hse.gov.uk/pubns/indg451.pdf); UK HSE, Heat Stress Check List, (https://www.hse.gov.uk/pubns/indg451.pdf); UK HSE, Heat Stress Check List, (https://www.hse.gov.uk/temperature/assets/docs/heat-stress-checklist.pdf); US NIOSH, Heat Stress – Heat Related Illness (https://www.osha.gov/heat-exposure/ illness-ftrst-aid) (accessed 24 March 2022); and WHO, International Medical Guide for Ships (3<sup>rd</sup> edition), pp. 87-89.

<sup>35</sup> Other risk factors include age, obesity (body mass index greater than 30 kg/m), lower levels of fitness, cardiac disease, diabetes mellitus, and respiratory disease. See Kenny, G. P, Heat Stress in Older Individuals and Patients with Common Chronic Diseases, Canadian Medical Associate Journal 182(10):1053-1060; US NIOSH, Heat Stress Risk Factors (https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/2017-125.pdf); and US OSHA, Safety and Health Topics, Heat (https://www.osha.gov/ heat-exposure/personal-risk-factors).

- 102. ISO 7243:2017 provides an objective method of assessing heat stress for a healthy person.<sup>36</sup>
- 103. The potential for a person to be subject to heat stress based on ISO 7243:2017 is determined by comparing WBGT<sub>eff</sub> with the reference limits in the WBGT heat stress index.<sup>37</sup> WGBT<sub>eff</sub> is established by applying a clothing adjustment value corresponding with what the person is wearing to the WBGT.<sup>38</sup> The reference limit is determined based on the persons metabolic rate<sup>39</sup> and whether the person is acclimated to working in the heat.
- 104. The metabolic rate was estimated to be moderate to high based on the C/O's and ASD1's statements that the Bosun had reportedly stated that pulling the tubes across the corn and then lifting them out of the cargo holds was heavy, that it was both hot, and that it was hard to breathe while wearing the respirator. Both ASDs also reported that it was hot and hard to breathe as they removed the fumigant while wearing the respirators. This estimate also accounts for the fact that the Bosun and ASD1 had removed six tubes of fumigant residue from Cargo Holds Nos. 1-3 between 1100–1130.<sup>40</sup>
- 105. The WBGT on the deck of BARRAMUNDI when the fumigant was being removed from the cargo holds was estimated<sup>41</sup> for different levels of relative humidity<sup>42</sup> using the reported weather conditions at the time the work was being conducted.
- 106. The WBGT<sub>eff</sub> values that were calculated using the estimated WBGT for different humidity levels, the PPE being worn by the Bosun and ASDs, and the reference limits for persons acclimated<sup>43</sup> to working in the heat for the work that was being performed are shown in the following table:

		CLOTHINC	WBGT (°C) REF	ERENCE LIMIT	
RELATIVE HUMIDITY	ESTIMATED WBGT (°C)	ADJUSTMENT VALUE	MODERATE METABOLIC RATE	HIGH METABOLIC RATE	WBGT <sub>eff</sub> (°C)
75%	28.9	3	28	26	31.9
80%	29.4	3	28	26	32.4
85%	30.0	3	28	26	33.0

Note: The WBGT reference limit for unacclimated persons is 26°C for moderate metabolic rate and 23°C for high metabolic rate.

- 36 WBGT is a function of the wet bulb temperature, the black globe temperature, and, for locations directly affected by the sun, the air temperature. Black globe temperature is based on solar radiation and any cooling provided by wind blowing across it. It can be measured directly using a sensor located at the center of a 150 mm diameter copper sphere painted matte black. See ISO 7243:2017, Annex B.
- 37 The values are in ISO 7243:2017, Annex A.
- 38 The clothing adjustment values range from 0 (standard coveralls) to 13 (vapor-barrier coveralls worn over cloth coveralls with a hood). See ISO 7243:2017, Annex F.
- 39 Metabolic rate is classified resting, low, moderate, high, and very high. See ISO 7243:2017, Annex E.
- 40 It is noted that they did take breaks between cargo holds during this period.
- 41 The WBGT was estimated using a tool from the US NWS. The tool is currently considered experimental. See https://www.weather.gov/eax/wbgt. An explanation of the basis for this is tool is provided in the paper "Estimation of Black Globe Temperature for Calculation of the WBGT Index," by Vincent E. Dimiceli and Steven P. Piltz. See https://www.weather.gov/media/tsa/pdf/WBGTpaper2.pdf.
- 42 The average relative humidity levels in July in Pacific Ocean archipelagos at latitudes similar to BARRAMUNDI's on 3 July 2021 are typically between 75-80%.
- 43 An acclimated person is defined as a "one who has been exposed to the hot working conditions (or similar or more extreme conditions) for at least one full working week immediately prior to the assessment period." See ISO 7243:2017, section 10.

# PART 3: ANALYSIS

The following Analysis is based on the above Findings of Fact.

#### Charterer's Instructions Regarding the Removal of Fumigant

The charterer's agent informed BARRAMUNDI's Master that it was necessary for the ship's crewmembers to remove the fumigant prior to arrival because port access restrictions put in place by the port State in response to the ongoing COVID-19 pandemic prevented qualified shore personnel from going aboard the ship after its arrival at the planned discharge port. The Master informed the Company's Operations Department, who then contacted the charterer's agent to determine if arrangements could be made to have the fumigant removed at another port in the region.

The Company's Operations Department agreed to have BARRAMUNDI's crewmembers remove the fumigant from the ship's cargo holds after contacting the charterer's agent to determine if it was possible to arrange for this to be done by qualified personnel at another port. After being advised by the charterer's agent that there were no viable alternatives, the Operations Department informed the Master that the ship's crewmembers would need to remove the fumigant from the cargo holds.

It was reported that the Operations Department had not made either the Company's HSEQ Department or the Vetting and Marine Department aware of the instructions that had been received from charterer's agent or that they had advised the Master that the ship's crewmembers would need to remove the fumigant. Further, based on the information that is available to the Administrator, these departments were also not aware that BARRAMUNDI's crewmembers had been removing fumigant from the ship's cargo holds until the Master informed the DPA that arrangements had been made for the Bosun to be medically evacuated.

#### IMO Circular MSC.1/Circ.1264

IMO Circular MSC.1/Circ.1264 provides detailed guidance regarding the fumigation of cargo holds. Based on the guidance in this circular, fumigant should not be handled by a ship's crewmembers and any fumigation operations should only be conducted by qualified personnel. In addition, the manufacturer's instructions for the fumigant that was applied to BARRAMUNDI's cargo prior to the ship's departure from Tacoma required that a certified applicator be physically present and maintain contact (visual or voice) with all fumigant workers both when the fumigant is applied and when the fumigated structure (e.g., cargo hold) is opened for aeration (e.g., ventilation).

Although SOLAS regulation VI/4, which requires that appropriate precautions be taken when using pesticides on board ships, particularly when used for fumigation, includes a reference to IMO Circular MSC.1/Circ.1264, this reference does not make the circular mandatory. In contrast, the IMSBC Code section 3.6.1 requires that fumigation be performed based on IMO Circular MSC.1/Circ.1264. However, based on SOLAS VI/1-2, the IMSBC Code is not applicable to the carriage of grain. Further, the applicable flag State regulations do not mandate compliance with IMO Circular MSC.1/Circ.1264. The implication is that there were not any applicable international or national regulations governing the removal of fumigant from BARRAMUNDI's cargo holds while the ship was en route from Tacoma to Xinsha.

Neither the charter party agreement nor the charterer's instructions to the Master included any provisions addressing cargo fumigation in general or IMO Circular MSC.1/Circ.1264 in particular.

#### SMS

The Company's SMS included procedures for handling both dry bulk and petroleum cargoes. These procedures did not address hazards related to the fumigation of cargo or procedures for ensuring crewmember safety either when a fumigant was applied or during in-transit fumigation.

The safe work procedures in the Company's SMS also required that a pre-task risk assessment be conducted prior to starting any non-routine job or a routine job that either inherently involves significant hazards or the conditions that exist when the work is planned pose hazards not regularly associated with that job. Based on these procedures, pre-task risk assessments were required to consider several different factors when identifying potential hazards. These included an assessment of the existing weather conditions.

The SMS did not include guidance to assist crewmembers with recognizing potential hazards due to the temperature. As previously stated, the portion of the Company's SMS addressing safe work procedures includes a statement advising that the UK MCA's COSWP should be consulted "when in doubt or if more detailed guidance is desired." The UK MCA's COSWP includes advice regarding the potential hazards of working in high temperatures as well as controls to ensure the safety of seafarers when working in hot or sunny climates.

To facilitate the completion of pre-task risk assessments when required by the SMS, the Company maintained a library of risk assessments for different shipboard tasks. This library did not include risk assessments for in-transit cargo fumigation, ventilation of fumigated cargo holds, or the removal of fumigant from the cargo holds.

The Company's SMS included a circular letter requiring that any fumigation on board Company-managed ships be conducted in accordance with IMO Circular MSC.1/Circ.1358. As previously noted, this circular stated that fumigation of loaded or partially loaded cargo holds should be conducted in accordance with IMO Circular MSC.1/Circ.1264. The decision to have BARRAMUNDI's crew remove the fumigant from the ship's cargo holds was not consistent with the Company's circular letter and, as previously stated, was made by the Operations Department without consulting with either the Company's HSEQ Department or the Vetting and Marine Department.

The portion of the Company's SMS addressing the safe handling of cargo does not include any guidance related to the safe handling of cargoes that require fumigation or a reference to the Company's circular letter addressing the use of pesticides. Further, neither this portion of the Company's SMS nor the Company circular letter addressing the use of pesticides did not include any guidance or procedures to facilitate the implementation of the IMO recommendations for the safe use of pesticides or those in the GARD Services' article on board ships in the Company-managed fleet.

The Company's SMS and Safe Work Handbook included requirements that risk assessments for non-routine tasks and new risk assessments be sent to the HSEQ Department for review and possible inclusion in the Company's library of risk assessments. The SMS is not clear if risk assessments for non-routine tasks were supposed to be reviewed by the HSEQ

Department before the planned job was completed. However, the Safe Work Handbook does include a requirement for the shore team<sup>44</sup> to review risk assessments for non-routine tasks before the planned job is started.

The Company's safe work practices included requirements intended to prevent accidents associated with the handling and storage of toxic and harmful substances on board ships in the Company-managed fleet. These requirements included maintaining a record of SDSs for any such materials that might be on board the ship. They also required the person in charge of a planned task that required handling a toxic or harmful substance to make the crewmembers aware of the health hazards associated with the substance, required PPE, and vital information. Although inferred, the SMS does not require compliance with the exposure limits included on the relevant SDS.

#### **Pre-task Risk Assessment and Planning**

The pre-task risk assessment and planning for removing the fumigant from BARRAMUNDI's cargo holds was done by BARRAMUNDI's Master and C/O taking into consideration the recommendations in IMO Circular MSC.1/Circ.1264 after the Company's Operations Department informed the Master that the ship's crewmembers would need to perform this job. In addition to agreeing on how the work would be conducted, they developed risk assessments for opening the cargo hold hatch covers and for having the crewmembers remove the fumigant since risk assessments for these tasks were not included in the Company's library of risk assessments.

There is no indication that the Master consulted with the Company's HSEQ Department or Vetting Marine Department when he and the C/O planned the work or developed the risk assessments for opening the hatch covers and removing the fumigant. There is also no indication that he sent these risk assessments to the shore team for review before hatch covers were opened on the morning of 3 July 2021.

The Master met with the C/O, Bosun, ASD1, and ASD2 at 1030 on the morning of the day that it was planned to remove the fumigant to review the SDS for the fumigant, the risk assessment, and the procedure for how the task would be performed.<sup>45</sup> The risk assessment identified the ship's crew removing the fumigant as the one hazard associated with this task. The consequences associated with this hazard was the risk of intoxication and poisoning. No additional hazards were identified during the review of the risk assessment that was conducted before the work was started.

Based on the fumigant manufacturer's instructions and the SDS, an additional hazard of removing the fumigant was associated with the onboard storage of the fumigant until it could be discharged ashore. This was due to the potential for phosphine to be given off by any unreacted aluminum phosphide and for it to spontaneously ignite if the concentration in the atmosphere exceeded its LFL, which is 1.79%. Neither this consequence nor the barriers to reduce the potential of it from occurring were identified on the risk assessment.

The weather conditions were addressed, as required by the Company's SMS, when the Master and other crewmembers reviewed the risk assessment from the Company's risk assessment library. They considered the temperature (29-30°C) to be normal and did not identify working in it as a potential hazard. This is in contrast to the warning in the UK MCA's COSWP that working in "high humidity and high temperature can lead to heat exhaustion and heat stroke." Although

<sup>44</sup> As previously noted, the shore team consists of the ship's Superintendent and staff from the HSEQ and Marine Departments.

<sup>45</sup> As previously stated, the C/O and Bosun had conducted a Toolbox Talk earlier that morning with the deck ratings to review the plan for opening the hatch covers to ventilate the cargo holds and then remove the fumigant from each of the cargo holds. They also reviewed the risk assessment that had previously been conducted by the Master and the C/O for ventilating the cargo holds. Two ASDs went out on deck and opened the hatch covers immediately after the Toolbox Talk was completed.

the C/O's instructions to the Bosun and ASDs to take frequent breaks and drink plenty of water were consistent with the recommendations in the UK MCA's COSWP, there is no indication that consideration was given to removing the fumigant later in the day when there would be less direct exposure to the sun. There is also no indication that consideration was given to whether any of the crewmembers who were assigned to remove the fumigant had any pre-existing health conditions that might have increased the potential that they would be adversely affected by performing the assigned task in the existing conditions. This indicates that the assessment of the weather conditions during the pre-task planning meeting was inadequate.

An additional potential hazard associated with the removal of the fumigant from BARRAMUNDI's cargo holds was that the Master and C/O went out on deck together without wearing either a respirator or BA set to check the atmosphere in and around the cargo holds. This unnecessarily created a situation where both senior deck officers could potentially have been incapacitated due to phosphine exposure.

A pre-task planning meeting should be long enough to review the planned work and relevant safety information (e.g., SDS) to ensure that the hazards associated with the task and required barriers are identified and understood by the crewmembers who will be performing the work. This is particularly important for non-routine or new tasks, such as having the crewmembers remove the fumigant from the cargo holds.

The following was reported to have occurred between 1030 and 1100:

- (a) the pre-task planning meeting was conducted, which included reviewing the SDS for the fumigant, the risk assessment, and the plans for removing the fumigant from the cargo holds as well as instructing the Bosun and ASDs how to properly tighten the full-face respirators;
- (b) the cargo hold exhaust fans were stopped;
- (c) the Master and C/O went forward and checked the atmosphere in and around Cargo Holds Nos. 1 and 2;<sup>46</sup> and
- (d) the Master and C/O also checked to make sure that the Bosun's and ASD1's respirators were properly tightened when they came forward after being called by the C/O.

As previously stated, no additional hazards were identified during the review of the risk assessment that was conducted during the pre-task planning meeting that the Master conducted with the C/O, the Bosun, and the two ASDs. However, there are indications the risk assessment had not identified at least two potential hazards associated with removing the fumigant from the cargo holds and that the assessment of the weather conditions was ineffective.

### **Phosphine** Exposure

The Bosun was wearing a respirator with filter while he was removing the fumigant. However, he would have needed to remove it to drink water when taking a break and when he gave it to the ASD2 before going aft toward the Accommodation to rest. Therefore, it is possible that the Bosun may have been exposed to phosphine while he was out on deck.

The level of phosphine around Cargo Holds Nos. 1 and 2 (0.2 ppm) when the atmosphere was checked before the Bosun and ASD1 started removing the fumigant was within the TWA exposure limit established by different occupational

<sup>46</sup> As previously stated, based on the manufacturer's instructions for the colorimetric tubes, each measurement would have required a minimum of two minutes to complete. The actual time would have been longer since it was necessary to fit a new tube for each measurement.

safety and health administrations. Although the level of phosphine on top of the cargo in both of these holds (2 ppm) exceeded the STEL, it is noted that:

- (a) the apparent wind was 18-20 kn;
- (b) the hatch covers had remained opened since being opened earlier that morning; and
- (c) none of the other crewmembers, including the C/O who was not wearing a full-face respirator, who were on deck when the fumigant was being removed from the cargo holds, reported experiencing any symptoms consistent with phosphine exposure.

Therefore, it is not considered likely that the Bosun was exposed to concentrations of phosphine that would have been immediately dangerous to human life (50 ppm or more).

#### Heat Stress

Heat stress is a heat related occupational illness caused by the internal production of heat due to physical activity, environmental factors (e.g., air temperature, humidity, air flow, and heat radiation), and the clothing and PPE being worn. Mild heat stress can cause discomfort, whereas moderate and severe heat stress can cause heat exhaustion, heat stroke, or death.

As previously stated, the ship's crewmembers considered the temperature (29-30°C) to be normal and did not identify working in it as a potential hazard. Other than the C/O telling the Bosun and ASDs to take frequent breaks and drink plenty of water, there is no indication that they considered the potential consequences of this temperature in full sun, wearing non-woven polyethylene coveralls and respirator with filter, and while conducting a task that required moderate to high physical exertion.

According to ISO 7243:2017, the WBGT reference limit for an acclimated person engaged in an activity with a moderate to high metabolic rate is between 28-26°C, the WBGT reference limit for an unacclimated person engaged in the same activity is between 26-23°C. Based on the information available to the Administrator, the Bosun and ASDs were acclimated persons per ISO 7243:2017. Considering that the estimated WBGT<sub>eff</sub> of 31.9-33°C exceed the WBGT reference limit for an acclimated person by 3.9-7°C, it is likely that the Bosun and the ASDs experienced some degree of heat stress as they removed the fumigant from BARRAMUNDI's cargo holds. The severity of the heat stress that may have been experienced by each of the seafarers would have varied based on several factors, including their ages<sup>47</sup> and any pre-existing medical conditions that they might have had.

#### Bosun's Symptoms and Cause of Death

Some of the symptoms (vomiting and loss of consciousness) that the Bosun reportedly experienced between the time he was relieved by the ASD2 and when he was evacuated by helicopter for medical treatment on shore were common symptoms of moderate and severe phosphine poisoning and heat exhaustion and heat stroke. He was also reported to have experienced symptoms that were associated with moderate phosphine poisoning (chest pain)<sup>48</sup> and heat stroke (elevated temperature).

<sup>47</sup> It is noted that on 3 July 2021, the Bosun, who was 46 years old, was 17 years older than ASD1 and 15 years older than ASD2.

<sup>48</sup> Although it cannot be determined with certainty, it is possible that the chest pain the Bosun reported experiencing may have been related to hypertension.

The cause of death listed in the autopsy report was heart, liver, and kidney necrosis and pulmonary edema. Based on the SDS for the fumigant applied at Tacoma, severe phosphine poisoning can cause pulmonary edema. Although the autopsy report also stated that possible intoxication of an unidentified toxic fume or fumigant could have been a secondary cause of death, the toxicology report did not include any findings indicating if phosphine or another similar substance had been detected in the Bosun's body.

Although it was possible that the Bosun could have been exposed to phosphine while removing fumigant from BARRAMUNDI's cargo holds, it is considered likely that moderate to severe heat stress contributed to the Bosun's death given:

- (a) the inconclusive findings of the autopsy with respect to the inhalation of a fumigant;
- (b) the apparent wind of 18-20 kn that was blowing across the deck as the Bosun and ASD1 were removing fumigant from the cargo holds;
- (c) that the cargo hold hatch covers had been open for 2 hours or more;
- (d) that the measured concentrations of phosphine was 2 ppm on top of the cargo in Cargo Holds Nos. 1 and 2 and 0.1-0.2 ppm on deck in the vicinity of these same cargo holds;<sup>49</sup>
- (f) that neither the ASD1 nor ASD2 reported having experienced any symptoms of even mild phosphine exposure; and
- (g) that heat stroke can cause liver, kidney, and heart damage.

Based on the report of his pre-employment medical exam, the Bosun had a history of hypertension dating back to 2018 and was taking maintenance medication. Further, based on the autopsy report, he had an enlarged heart. Both hypertension and an enlarged heart can increase the likelihood of a heart attack or stroke. However, the findings of the autopsy report do not indicate that the Bosun had either a heart attack or a stroke while he was removing fumigant from BARRAMUNDI's cargo holds or after he stopped to rest. The absence of findings indicating that the Bosun had either a heart attack or stroke along with the fact that hypertension can increase the potential of a person being adversely impacted by heat stress is a further indication that severe heat stress likely contributed to his death.

# **PART 4: CONCLUSIONS**

The following Conclusions are based on the above Findings of Fact and Analysis and shall in no way create a presumption of blame or apportion liability.

- 1. Causal factors that contributed to this very serious marine casualty include:
  - (a) ineffective assessment of the existing weather conditions and the potential for the seafarers who were tasked with removing the fumigant to suffer moderate to severe heat stress;
  - (b) the COVID-19 related port access restrictions at the discharge port that prevented qualified shore personnel going on board the ship to remove the fumigant from the cargo holds following its arrival; and

<sup>49</sup> As stated previously, the concentration of phosphine on top of the cargo in Cargo Holds Nos. 3-7 was 0 ppm.

- (c) the absence of international or national regulations mandating compliance with IMO Circular MSC.1/Circ.1264 during in-transit fumigation of ships laden with grain.
- 2. Causal factors that may have contributed to this very serious marine casualty include:
  - (a) the portion of the Company's SMS addressing the safe handling of cargo and their circular letter did not include procedures for implementing the recommendations in IMO Circular MSC.1/Circ.1264 or the GARD circular on board Company-managed ships;
  - (b) inadequate internal communications within the Company when making the decision whether to permit the ship's crewmembers to handle the fumigant;
  - (c) the Master's decision to:
    - (i) not consult with the Company's HSEQ Department or Vetting and Marine Department when planning how the cargo holds would be ventilated or how the fumigant would be removed from the cargo holds; and
    - (ii) not sending the risk assessments for opening the hatch covers and for removing the fumigant from the cargo holds to the shore team for review before those jobs were started.
- 3. Additional issues that were identified but that did not contribute to this very serious marine casualty include:
  - (a) the pre-task planning and risk assessment did not address the potential consequences associated with the storage of the fumigant on board the ship after it was removed from the cargo holds;
  - (b) the Master and C/O went on deck together to check the atmosphere in Cargo Holds Nos. 1 and 2 without wearing respiratory protection; and
  - (c) the Company's SMS did not include a requirement that the occupation exposure limits listed on the relevant SDS must be complied with when a task involving handling or potential exposure to chemicals was being conducted.

## **PART 5: PREVENTIVE ACTIONS**

In response to this very serious marine casualty, the Preventive Actions were taken by both the Company and the Administrator.

- 1. The following actions have been taken by the Company:
  - (a) A risk assessment for in-transit cargo hold fumigation, ventilating fumigated cargo holds, and handing of fumigant was developed and added to the Company's risk assessment library. The identified barriers for mitigating the potential consequences associated with identified hazards were based on IMO circular MSC.1/ Circ.1264. These barriers include requiring that fumigant be removed by qualified shore personnel.
  - (b) A notice was sent to all ships in the Company-managed fleet reporting that more of their ships were carrying grain. This notice included a copy of IMO circular MSC.1/Circ.1264, Gard Circ. No. 13-11, a North of England loss prevention bulletin addressing the risks associated with fumigation, and a RightShip Inspection Questionnaire regarding the carriage of grain.

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- (c) Established internal requirements for:
  - (i) the Operations Department to notify both the HSEQ Department and the Vetting and Marine Department when a Company-managed ship was fixed to carry grain;
  - (ii) both the HSEQ Department and the Vetting and Marine Department to verify that the ship was prepared for cargo fumigation; and
  - (iii) a Management of Change be completed if due to exceptional circumstances it was necessary for a ship's crewmembers to remove fumigant from the cargo holds.
- (d) The dry bulk cargo handling procedures in the Company's SMS were revised to include a section addressing cargo fumigation. These procedures were based on IMO circular MSC.1/Circ.1264.
- (e) The safe work procedures in the Company's SMS were revised to address the hazards of heat stress and guidance for assessing existing weather conditions to determine if heat stress was a potential risk when conducting pre-task risk assessments and actions that should be taken to reduce the potential adverse effects of heat stress.
- 2. The following actions have been taken by the Administrator:
  - (a) The Administrator issued Marine Safety Advisory No. 13-22, Fumigation of Dry Bulk Cargo, on 17 June 2022.

## **PART 6: RECOMMENDATIONS**

The following Recommendations are based on the above Conclusions and in consideration of the Preventive Actions taken.

- 1. It is recommended that the Company:
  - (a) consider revising its SMS to include a statement requiring that the occupation exposure limits listed on the relevant SDS must be complied with when a task involving handling or potential exposure to chemicals are conducted on board ships in their fleet.
- 2. It is recommended that the Administrator:
  - (a) consider submitting a proposal to the IMO to amend SOLAS regulation VI/4 to make compliance with IMO Circular MSC.1/Circ.1264 mandatory.

The Administrator's marine safety investigation is closed. It will be reopened if additional information is received that would warrant further review.