MARINE SAFETY INVESTIGATION REPORT

Safety investigation into the gas inhalation by seven crew members on board the Maltese registered oil/chemical tanker

BOMAR MERCURY

in the port of Rotterdam, The Netherlands

on 21 July 2015

201507/017

MARINE SAFETY INVESTIGATION REPORT NO. 15/2016

FINAL
The MSIU gratefully acknowledges the assistance and cooperation of the Dutch Safety Board during the safety investigation of this accident.


This safety investigation report is not written, in terms of content and style, with litigation in mind and pursuant to Regulation 13(7) of the Merchant Shipping (Accident and Incident Safety Investigation) Regulations, 2011, shall be inadmissible in any judicial proceedings whose purpose or one of whose purposes is to attribute or apportion liability or blame, unless, under prescribed conditions, a Court determines otherwise.

The objective of this safety investigation report is precautionary and seeks to avoid a repeat occurrence through an understanding of the events of 21 July 2015. Its sole purpose is confined to the promulgation of safety lessons and therefore may be misleading if used for other purposes.

The findings of the safety investigation are not binding on any party and the conclusions reached and recommendations made shall in no case create a presumption of liability (criminal and/or civil) or blame. It should be therefore noted that the content of this safety investigation report does not constitute legal advice in any way and should not be construed as such.

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Malta
CONTENTS

LIST OF REFERENCES AND SOURCES OF INFORMATION ........................................ iv
GLOSSARY OF TERMS AND ABBREVIATIONS ....................................................... v
SUMMARY .............................................................................................................. vi

1 FACTUAL INFORMATION .................................................................................. 1
  1.1 Vessel, Voyage and Marine Casualty Particulars ......................................... 1
  1.2 Description of Vessel ................................................................................. 2
  1.3 Description of Cargo System and Equipment ............................................. 3
    1.3.1 Cargo system ....................................................................................... 3
    1.3.2 Cargo tank washing equipment ............................................................ 5
    1.3.3 Gas measuring equipment .................................................................... 6
  1.4 Vessel’s Procedures ..................................................................................... 8
    1.4.1 Cargo tank washing ............................................................................. 8
    1.4.2 Ventilation ............................................................................................ 10
    1.4.3 Atmospheric testing and enclosed space entry ...................................... 11
  1.5 Manning .................................................................................................... 11
    1.5.1 The crew .............................................................................................. 11
    1.5.2 Hours of work ...................................................................................... 12
  1.6 Weather Conditions ................................................................................... 12
  1.7 Narrative .................................................................................................... 12

2 ANALYSIS ......................................................................................................... 17
  2.1 Purpose ..................................................................................................... 17
  2.2 Drug and Alcohol Abuse .......................................................................... 17
  2.3 Hours of Work and Fatigue ........................................................................ 17
  2.4 Cargo Tank Cleaning Guidance and Implementation .............................. 19
    2.4.1 Cargo tank cleaning machine maintenance programme........................ 20
    2.4.2 Cargo tank cleaning machine programme implemented on 21 July 2015 20
    2.4.3 Tank cleaning - pre-wash cycle ............................................................ 21
    2.4.4 Cleaning efficiency ............................................................................. 23
  2.5 Cargo Tank Ventilation and Testing ............................................................ 25
    2.5.1 Cargo tank ventilation ........................................................................ 25
    2.5.2 Atmosphere testing .............................................................................. 25
  2.6 Entry into Enclosed Space ........................................................................... 31
  2.7 Specific Training ......................................................................................... 34
  2.8 Aniline Intoxication and the Use of BA Sets .............................................. 36
  2.9 Suspending the Cleaning Operation Inside the Cargo Tank .................... 36
  2.10 Other Safety Concerns – Safety Equipment ............................................. 37

3 CONCLUSIONS ................................................................................................. 39
  3.1 Immediate Safety Factor .......................................................................... 39
  3.2 Latent Conditions and other Safety Factors ............................................. 39
  3.3 Other Findings ............................................................................................ 40

4 ACTIONS TAKEN ............................................................................................... 40
  4.1 Safety Actions Taken During the Course of the Safety Investigation .......... 40

5 RECOMMENDATIONS ....................................................................................... 42

LIST OF ANNEXES ............................................................................................... 43
LIST OF REFERENCES AND SOURCES OF INFORMATION

Crew members – MT *Bomar Mercury*

Dutch Safety Board

Managers – MT *Bomar Mercury*

Safety Management System Manuals Company and MT *Bomar Mercury*
### GLOSSARY OF TERMS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
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<tbody>
<tr>
<td>ºC</td>
<td>Degrees Celsius</td>
</tr>
<tr>
<td>AB</td>
<td>Able Seaman</td>
</tr>
<tr>
<td>BA</td>
<td>Breathing Apparatus</td>
</tr>
<tr>
<td>BV</td>
<td>Bureau Veritas</td>
</tr>
<tr>
<td>BHP</td>
<td>Brake horse power</td>
</tr>
<tr>
<td>HCC</td>
<td>Harbour Coordination Centre</td>
</tr>
<tr>
<td>IARC</td>
<td>International Agency for Research on Cancer</td>
</tr>
<tr>
<td>IBC Code</td>
<td>International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk</td>
</tr>
<tr>
<td>ISGOTT</td>
<td>International Safety Guide for Oil Tankers and Terminals</td>
</tr>
<tr>
<td>ISM</td>
<td>International Safety Management</td>
</tr>
<tr>
<td>IV</td>
<td>Intravenous</td>
</tr>
<tr>
<td>kW</td>
<td>Kilowatt</td>
</tr>
<tr>
<td>LT</td>
<td>Local Time</td>
</tr>
<tr>
<td>m</td>
<td>Metres</td>
</tr>
<tr>
<td>ml</td>
<td>Millilitres</td>
</tr>
<tr>
<td>mm</td>
<td>Millimetres</td>
</tr>
<tr>
<td>MSD</td>
<td>Material Safety Data Sheet</td>
</tr>
<tr>
<td>MSIU</td>
<td>Marine Safety Investigation Unit</td>
</tr>
<tr>
<td>No.</td>
<td>number</td>
</tr>
<tr>
<td>ODME</td>
<td>Oil Discharge Monitoring Equipment</td>
</tr>
<tr>
<td>OS</td>
<td>Ordinary Seaman</td>
</tr>
<tr>
<td>P&amp;A</td>
<td>Procedures and Arrangement</td>
</tr>
<tr>
<td>Pa</td>
<td>Pascal</td>
</tr>
<tr>
<td>ppe</td>
<td>Personal Protective Equipment</td>
</tr>
<tr>
<td>ppm</td>
<td>Parts Per Million</td>
</tr>
<tr>
<td>rpm</td>
<td>Revolutions per minute</td>
</tr>
<tr>
<td>SOLAS</td>
<td>The International Convention for the Safety of Life at Sea, 1974 as amended</td>
</tr>
<tr>
<td>SSOM</td>
<td>Safety and Ship Operation Manual</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
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</tbody>
</table>
SUMMARY

The Maltese flag chemical carrier *Bomar Mercury* had loaded a cargo of Aniline in Tees, UK from 1625 on 17 July 2015 until 1705 on 18 July 2015, spending 31 hours in port before sailing to Rotterdam Vopak Terminal on 19 July 2015.

Upon arrival, the vessel carried out the normal procedural checks for cargo discharge operations, which started on 20 July 2015. Cargo discharge and a follow up ‘commercial wash’ were completed at 2300 on 20 July 2015, followed with the disposal of cargo tank washing water to slops tanks ashore. On completion of the commercial wash and receiving an empty cargo tank certificate, the vessel embarked a pilot at 0200 (21 July 2015) and proceeded to Botlek Lay-by Buoy No. 61, arriving and declaring all fast at 0400.

At 0500 on 20 July, the vessel commenced cleaning procedures in preparation for the loading of the next cargo – gasoil. The cleaning operations were completed at 0830 before the commencement of the ventilation procedures. The crew members had to access the cargo tanks to ensure that all traces of the previous cargo had been removed by means of an air driven pump. At about 1130, atmosphere monitoring was carried out and recorded as being safe for the cargo tank entry. Four crew members were detailed to carry out these final cleaning checks and to enter the cargo tanks under the enclosed space permit-to-work procedures.

During the afternoon, two crew members started feeling unwell and had to be attended by the other crew members. Oxygen was also administered. Eventually, the master contacted the agent to request shore medical assistance. By 2000, the injured parties had been disembarked and transferred to a local hospital. Other crew members visited the hospital for precautionary checks, but were subsequently cleared to return to the vessel.

Subsequent attendance by port State Control resulted in the vessel attracting two Code 17 deficiencies under Code 04118 – Enclosed space entry and rescue drills, a general heading of ‘Lack of training’ in accordance with SOLAS Chapter III – 19.3.6.2 and Code 15150 – ISM under ISM regulation 1.2.2.2. The vessel was also detained.
The MSIU found that the immediate cause of the accident was intoxication due to contact with Aniline, either through the skin and / or by inhalation of the cargo vapour. As a result of the safety investigation, two recommendations were issued to the managers of the vessel and one recommendation to the manufacturer of the testing equipment, aimed to enhance safety during related cargo operations.
# 1 FACTUAL INFORMATION

## 1.1 Vessel, Voyage and Marine Casualty Particulars

<table>
<thead>
<tr>
<th>Name</th>
<th>Bomar Mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flag</td>
<td>Malta</td>
</tr>
<tr>
<td>Classification Society</td>
<td>Bureau Veritas</td>
</tr>
<tr>
<td>IMO Number</td>
<td>9428889</td>
</tr>
<tr>
<td>Type</td>
<td>Oil/Chemical Tanker (Type II)</td>
</tr>
<tr>
<td>Registered Owner</td>
<td>BM Chemical Mercury Ltd.</td>
</tr>
<tr>
<td>Managers</td>
<td>Armona Denizcilik A.S.</td>
</tr>
<tr>
<td>Construction</td>
<td>Steel (Double hull)</td>
</tr>
<tr>
<td>Length overall</td>
<td>119.60 m</td>
</tr>
<tr>
<td>Registered Length</td>
<td>111.85 m</td>
</tr>
<tr>
<td>Gross Tonnage</td>
<td>4808</td>
</tr>
<tr>
<td>Minimum Safe Manning</td>
<td>13</td>
</tr>
<tr>
<td>Authorised Cargo</td>
<td>Liquid in Bulk</td>
</tr>
<tr>
<td>Port of Departure</td>
<td>Tees, UK</td>
</tr>
<tr>
<td>Port of Arrival</td>
<td>Rotterdam, The Netherlands</td>
</tr>
<tr>
<td>Type of Voyage</td>
<td>Short International</td>
</tr>
<tr>
<td>Cargo Information</td>
<td>In ballast</td>
</tr>
<tr>
<td>Manning</td>
<td>17</td>
</tr>
<tr>
<td>Date and Time</td>
<td>21 July 2015 at 1500 (LT)</td>
</tr>
<tr>
<td>Type of Marine Casualty</td>
<td>Serious Marine Casualty</td>
</tr>
<tr>
<td>Place on Board</td>
<td>Cargo &amp; tanks areas – cargo tanks</td>
</tr>
<tr>
<td>Injuries/Fatalities</td>
<td>Two serious injuries</td>
</tr>
<tr>
<td>Damage/Environmental Impact</td>
<td>None</td>
</tr>
<tr>
<td>Ship Operation</td>
<td>Normal Service – Cleaning/washing</td>
</tr>
<tr>
<td>Voyage Segment</td>
<td>Anchored</td>
</tr>
<tr>
<td>External &amp; Internal Environment</td>
<td>Dry and partially cloudy. The air temperature was 20 °C. There was a light West Southwesterly force 4 wind. There was no swell in the port. Sunrise on 21 July 2015 was at 0558 and it was daylight at the time of the accident.</td>
</tr>
</tbody>
</table>

| Persons on Board      | 17                                 |
1.2 Description of Vessel

*Bomar Mercury* (Figure 1) is a Maltese registered Type 2 oil/chemical carrier, suitable for transporting chemical liquid products that fall under chapter 17 of the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code) and that have appreciably severe environmental and safety hazards characteristics. *Bomar Mercury* is owned by BM Chemical Mercury Ltd. and managed by Armona Denizcilik A. S., Turkey (Company). The vessel was built by Umo Gemi Sanayi Ve Ticaret Ltd. in Turkey in 2008 and is classed by Bureau Veritas (BV).

*Bomar Mercury* has a length overall of 119.60 m, a moulded breadth of 16.90 m and a moulded depth of 8.34 m. The vessel has a summer draught of 6.75 m and a summer deadweight of 7010 tonnes.

Propulsive power is provided by a 6-cylinder Caterpillar Motoren GmbH & Co. KG, medium speed diesel engine producing 3000 BHP at 600 rpm. This drives a single, controllable pitch propeller through a reduction gearbox, giving a service speed of 13.0 knots.

Figure 1: MT *Bomar Mercury*
Source: Dutch Safety Board
1.3 Description of Cargo System and Equipment

1.3.1 Cargo system
The vessel has 12 cargo tanks coated with a ‘MarineLine’ coating system, with a total capacity of 7894 m$^3$ at 98% filling. The cargo tanks are arranged in six pairs on port and starboard. Two deck slop tanks are located on the main deck. The vessel is not fitted with centreline cargo tanks and each cargo tank is separated by longitudinal and transverse corrugated bulkheads (Figure 2). All the cargo tanks and the slop tanks are fitted with heating coils, placed just above the tank top and supported by ‘I’ beam profiles.

![Figure 2: Longitudinal and transverse corrugated bulkheads fitted inside the cargo tanks](image)

The cargo manifold system is designed to allow 14 different cargoes to be loaded (Figure 3). All cargo tank manifolds can be connected to a common manifold by means of two butterfly valves. The cargo transfer systems have butterfly valves capable of being remotely operated on each cargo tank filling and discharge lines and two manually operated butterfly valves on the manifold port and starboard operated from the catwalk.
Figure 3: Cargo system fitted on board Bomar Mercury
The cargo system can be controlled from the cargo control room by means of a cargo monitoring system, converters and a remote valve control system.

Each cargo tank is fitted with a dedicated MARFLEX deepwell Pump type MDPD-100 electrically driven and rated at 200 m³hr⁻¹. This allows different cargoes to be processed fully segregated. Cargo tank loading and discharge cargo valves are remotely operated via the cargo control panel in the cargo control room.

The deck slop tanks are fitted with electrically driven deepwell pumps and separate discharge and manifold lines. There is an oil discharge monitoring equipment (ODME) system with return pipes connected to the slop tank drop lines.

The cargo tank ventilation system comprises of a fixed tank drying fan with a capacity of 10000 m³hr⁻¹ at 2864 Pa. There is an 170 kW air heater fitted just beyond the cargo tank drying fan. The fan is capable of ventilating two cargo tanks simultaneously.

1.3.2 Cargo tank washing equipment
The cleaning system for washing cargo tanks after the discharge of cargo, comprises of a portable 60 m³hr⁻¹ Butterworth¹ centrifugal pump with an operating pressure of 11 Bar located in the engine-room and a cargo tank cleaning heater of 4000 kW capacity, capable of heating 44.3 m³hr⁻¹ of seawater from 10 °C - 90 °C (Figure 4).

Figure 4: Cargo tank washing machine

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¹ Butterworth is a term originating from the maritime sector and stands in principle for cleaning cargo tanks on board tankers. Butterworth is actually a trade name. The Butterworth machines have become synonymous with cargo tank cleaning. As the name is now used so often, butterworthing has also become a synonym with cargo tank cleaning.
It was possible to wash one cargo tank with sea water at 60 °C using two cargo tank washing machines, although three cargo tank washing machines can be operated simultaneously (without heating). Each cargo tank has two ScanJet SC 30 T fixed cleaning machines, with single 10 mm nozzles and a jet depth of 17.3 m. Each slop tank has one fixed cleaning machine.

Sea water is drawn from the engine-room sea water suction line via the pump and directed to the main deck line. Fresh water or flushing water for the cargo tanks is stored in technical fresh water tanks in the engine-room. The same centrifugal pump is used to deliver both sea water and fresh water. The cargo tank cleaning process takes between 30 and 35 minutes per cargo tank.

1.3.3 Gas measuring equipment
Two sets of measurements were normally carried out on board Bomar Mercury: an O₂, H₂S, an explosion level measurement and a specific measurement for the detection of Aniline concentrations.

A Gas Measurement Instrument Ltd (GMI) type PS241 multigas meter (Figure 5), was used to measure O₂, CO, H₂S quantities and explosion levels inside the cargo tanks’ atmosphere on board Bomar Mercury. The PS241 is a portable gas meter designed for measurements inside confined spaces, both prior to entering as well as while working inside the confined space. Should the atmosphere reach hazardous levels, the equipment alerts the user through sound, light and vibrations.

To measure the atmosphere in a cargo tank prior entry, the apparatus must be equipped with an airflow pump. A hose is attached to this with a weighted bulb on the end. Both the bulb and the hose are lowered down through the cargo tank hatch to just above the cargo tank floor. Once the multigas meter airflow pump is operated, the equipment will indicate when there is a reliable measurement. This mostly takes between one and two minutes, depending on the length of the hose. The multigas meter may be worn when a confined space is entered and it measures the atmosphere continuously.
In addition to the multigas meter, Dräger tubes are used to measure the atmospheric chemical composition. Dräger tubes are glass tubes filled with a chemical substance that reacts with a specific chemical or group of chemical substances. A calibrated 100 ml air sample is drawn through the tube using the Dräger Accuro bellows pump (Figure 6).

If a targeted chemical substance is present, the colour across the length of the substance in the tube changes. The length can be read on a scale printed on the tube, and which corresponds to the measured concentration. The Dräger tube is a widely used gaseous chemical detector. To draw the calibrated air sample, a fixed number of
bellow pump movements are necessary; the number varies and depends on the tube type. In the case of Aniline² (Figure 7), 20 pumping actions were prescribed by the manufacturers.

![Figure 7: Molecular structure of Aniline](image)

1.4 Vessel’s Procedures

1.4.1 Cargo tank washing

Cleaning of cargo tanks after unloading is an extremely important part of the cargo operation. For several chemicals, minute residues of a previous cargo can lead to contamination of the new cargo.

Available on board were different sources of information on cargo tank cleaning.

The vessel’s Safety and Ship Operation Manual (SSOM), section 1.12 (Tank Cleaning and Gas Freeing), discussed cargo tank cleaning in general terms but also referred to several publications such as the International Safety Guide for Oil Tankers and Terminals (ISGOTT), the Tanker Safety Guide (Chemical) and the Vessel’s Procedures and Arrangement (P&A) Manual as applicable. The vessel also carried a copy of Dr Verwey’s Tank Cleaning Guide. It was noticed that other than the P&A Manual, there was nothing specific to the vessel and her systems.

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² Aniline or aminobenzene is an aromatic primary amine, consisting of a benzene ring and an amino group. The substance occurs as a colourless, corrosive liquid. It is an important raw material for synthetic dyes. Aniline is classified in IARC Class 3, i.e., that the substance is unclassifiable as to its carcinogenicity in humans.
Section 1.12.1 of the SSOM stated in bold that, “[i]f there is no (sic) any other cleaning program has been provided by the charterer(s) and/or managers, Tank Cleaning Guide shall be used as a guidance during tank cleaning operation.”

The Tank Cleaning Guide mentioned in the Company’s guidance referred to Dr Verwey’s Tank Cleaning Guide.

The Company’s guidance at section 1.12.9 discussed entrance into a cargo tank for cleaning using the Entry into Enclosed Space Procedure. It stated that the cargo tank atmosphere shall be safe for entry and an entry permit had to be issued.

Specific advice on cargo tank washing in a non-inert atmosphere was covered under section 1.12.9.2. It appeared to recommend that whenever possible, mechanical ventilation had to be continued during washing. It also stated that the ability to mechanically ventilate concurrent with cargo tank washing was recommended.

Section 1.12.10.5, (Mechanical/Manual Cleaning), described wiping down product residues and stripping/cleaning of the remaining cargo as “exceptional” circumstances; there was no reference to precautions with residue slops.

The Cargo Tank Cleaning Guide by Dr Verwey explained that in preparation to load gasoline following a cargo of Aniline oil, crew members would need to follow protocol ‘E’.

According to the guidance, the procedure under protocol ‘E’ required:

- cold seawater ‘Butterworthing’ for three cycles;
- hot seawater ‘Butterworthing’ for six cycles;
- flushing with fresh water;
- steaming;
- draining of cargo tank, pump and lines; and
- drying.

The operators of the vessel also provided cargo handling instructions regarding the cargo of Aniline (Figure 7). Within the operators’ cargo handling instructions for
Aniline, there were directions on pre-wash and cargo tank cleaning in paragraphs 5.8 – 5.10. The guidance was generic rather than specific to this vessel.

It was noticed that there were detailed cleaning procedures within the operators’ guidance to account for cleaning of the cargo tanks after the carriage of benzene, in preparation for taking on Aniline; the guidance described the cleaning medium and the amount of time for each step. There were no detailed procedures for cleaning after a cargo of Aniline had been carried³.

_Bomar Mercury’s_ P&A Manual referred to the procedures for cleaning the cargo tanks in Section 4, with reference to pre-wash procedures at Addendum B. Additionally, there was reference to the shadow plans using fixed cargo tank cleaning machines for the cargo tanks at Plan X. This was the only documentation seen that was specific to the vessel and her systems for cargo tank cleaning.

1.4.2 Ventilation

Ventilation procedures were covered in the SSOM and in the P&A Manual. As the cargo pumps were not able to extract all the cleaning water from the cargo tanks, the residues had to be sucked manually from the cargo tanks, using a small portable pump. The cargo tanks then had to be dried using mops. This necessitated crew members to enter inside. To guarantee the safety of crew members, the cargo tanks which were intended to be accessed had to be ventilated thoroughly prior to the intended entry⁴.

The procedures in the P&A Manual were concerned with ventilation of cargo residues with a vapour pressure greater than \(5 \times 10^3\) Pa at 20 °C and therefore were not applicable in this case. Section 1.12.10.4 of the SSOM addressed cleaning of cargo tanks by ventilation but there did not appear to be any specific routine laid down. In fact, it appeared that ventilation was mentioned only as a means for gas freeing in general terms.

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³ This was only to be expected because there are many different chemicals that could be carried and would have required different cleaning routines.

⁴ The cargo tank atmosphere is then measured several times for explosion hazard and hazardous substance concentrations. The cargo tanks are released for entry after they have been declared safe by the officer on board responsible for cargo operations (chief mate) through the issue of the necessary permits. As an additional measure, the crew members entering the cargo tanks use compressed air breathing apparatus (BA sets).
The MSIU did not come across any literature on board which advised about minimum periods of time to ventilate on completion of cleaning.

1.4.3 Atmospheric testing and enclosed space entry
Atmospheric checking and testing was also covered in the SSOM, at section 1.12. Atmospheric testing was considered to be potentially causal in this case.

Enclosed space entry procedures are covered in the SSOM at section 6.5 (Permit Categories). It was observed that the procedure was significantly detailed and thorough. There were distinct requirements for entering a confined space and there were additional requirements for entering a suspect space.

1.5 Manning

1.5.1 The crew
The vessel was manned by a crew of 17 persons, all Turkish nationals. All crew members were qualified to work in their respective ranks on board.

The ship’s officers compliment consisted of nine crew members, i.e., a master, chief mate, second and third mates, a chief engineer, a second and third engineers, and two deck cadet officers. The remaining 10 were ratings mainly, a bosun, two able seamen (ABs), three ordinary seamen (OS), an oiler and the cook.

The master had about 12 years sea service, eight and a half years on chemical tankers, six years of which as a master (six years with the Company) and with about three months’ service on this vessel.

The chief mate had about 11 years sea service, eight years on tankers, five years of which as a chief mate. He had already worked two (4 month) contracts with the Company and had spent about four months on this vessel.

The second mate had about seven years sea service, all served on tankers; 18 months as second mate (six years with the Company) and less than a month on this vessel. At the time of the accident, the bosun had 19 years sea service, 11 years as a bosun, almost all of which had been served on tankers. This was the bosun’s first voyage with the Company and he had been on board for about a month and a half.
All documentation on board was written in English and Turkish. The working language was English although the spoken language was Turkish.

1.5.2 Hours of work
There were sufficient officers and ratings on board to safely maintain the required bridge and deck watches, both during cargo tank preparation and during loading operations for normal operating schedules.

The schedule being run by *Bomar Mercury* was quite onerous in that the time at sea was short, followed immediately with cargo operations alongside and then almost immediately by sailing.

Hours of work were recorded on a spreadsheet on a daily basis *i.e.*, 0001 to 2359. Several key personnel appeared to have long working days.

1.6 Weather Conditions
On the day of the accident, the weather was dry and partially cloudy. The air temperature was 20 ºC. There was a West Southwesterly force 4 wind. There was no swell in the port. Sunrise on 21 July 2015 was at 0558 and it was daylight at the time of the accident.

1.7 Narrative

On 20 July 2015, *Bomar Mercury* was discharging a cargo of Aniline at VOPAK Terminal in Rotterdam. The discharging operation was completed at 2300, following which, the vessel shifted to the waiting berth at 0400 (21 July) in order to commence the cargo tank cleaning operations. The waiting berth at Botlek was in the middle of the third petroleum harbour; the vessel moored on mooring buoys without direct access to the quay. Cargo tank cleaning started at 0500 once *Bomar Mercury* had moored on the buoys. Mobile Butterworth machines using pressurised water were used for automatic cargo tank cleaning. This took between 30 and 35 minutes per

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5 Unless otherwise stated, all times are local (UTC+2).
6 It is common for waiting tankers to moor on mooring buoys in the Port of Rotterdam.
cargo tank. Cargo pumps were then used to pump the cleaning water to the slop tanks, which was completed by 0830.

After the cargo tank cleaning, regular ventilation was started to prepare for the cargo tank entry to remove the remaining cleaning water residues. During the ventilation, the chief mate made use of a portable gas meter to carry out atmospheric tests for O₂, CO and H₂S levels in all cargo tanks. It was recalled that in order to do this, the ventilation was interrupted briefly prior to each cargo tank measurement, in order to obtain a reliable measurement.

At 1130, the ventilation was stopped, following which, the chief mate again measured the cargo tanks’ atmosphere, using the portable gas meter. He also determined the amount of Aniline gases in the cargo tanks using the Accuro bellows pump and Dräger tubes suitable for Aniline. After measuring all the cargo tanks, the chief mate issued the cargo tank entry permits⁷. The first permit for cargo tank no. 1S (port) was valid from 1135. Four crew members, i.e. an AB, an OS, a deck cadet and the bosun were authorised to enter the cargo tanks via the cargo access hatches (Figure 8).

The supervision on deck was carried out by the bosun. The available crew members were split into two teams. The bosun and the deck cadet formed one team and the AB and OS formed the other team. The AB and OS started cleaning activities in cargo tank no. 1 starboard at 1141. Being the more experienced crew member, the AB carried out the cleaning activities inside the cargo tank. In the bosun’s team, the activities inside were performed by the deck cadet so that the bosun could retain a good overview of the situation.

The bosun and the OS were standing by the cargo tank access manholes. To perform cargo tank cleaning activities, it was agreed that one member from each team would remain inside the cargo tanks only for a few minutes, after which, they return to the main deck. No BA sets were used although rubber gloves and an overall were worn⁸.

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⁷ Cargo tank entry permits carry the necessary official authorisation for the safe entry of an enclosed space.

⁸ It has to be stated that there were conflicts in the evidence obtained by the MSIU and the DSB. Every single interview made by the MSIU indicated that BA sets were used by the crew members, whereas the evidence collected by the DSB suggested that no BA sets were used. Considering that crew members were either exposed to the gas or feared to have been exposed, the MSIU is of the view that crew members were not wearing any BA sets whilst working in the cargo tanks.
The teams worked in this fashion inside two or three cargo tanks in succession. At around 1200, just before the lunch break, the AB informed his colleagues that he was feeling unwell. It was noticed that his lips had turned blue. Later during lunch, the second mate examined the AB. He tried to take the AB’s blood pressure, but could not get the blood pressure gauge to work.

![Image of Bomar Mercury main deck](image)

**Figure 8: Bomar Mercury main deck**  
*Source: Dutch Safety Board*

Cargo tank cleaning activities were resumed after lunch, at around 1230. The AB also started work again in spite of the fact that he still felt unwell. The AB’s condition worsened in the subsequent period. At around 1430, it was observed that his face was completely blue. He drank some water and it was decided that work should continue, but wearing a BA set. However, this did not help. Just after 1500, the AB was no longer able to continue with his work. He was transferred to the aft deck where, at 1600, the master attended to him.

The master took his blood pressure immediately and found that this was lower than usual. He then decided to administer oxygen, using a portable oxygen kit. After
approximately 15 minutes, the AB felt somewhat better and managed to walk towards the accommodation block together with the master. The master continued to administer oxygen to the AB. The latter had visibly recovered but complained of chest pains and felt dizzy during movement.

In the meantime, the OS continued with the cleaning activities in the cargo tanks together with a second deck cadet, who had just returned from his break. The OS was now the crew member accessing the cargo tanks. In the following hour, the OS also started to feel increasingly unwell. He felt his heart ‘racing’ and his lips had also turned blue. At around 1700, he could no longer continue with the work. He noticed that he was unable to speak and was only able to make howling noises. Within minutes, his colour turned blue, although he managed to walk to the accommodation block to clean himself.

At 1740, the third mate reported the latest situation to the master and that the OS was manifesting similar symptoms to the AB. The master verified this and decided to transfer the OS to the ship’s hospital, where he administered oxygen, using the permanent medical oxygen system.

By 1758, the master was concerned that the situation may get out of control and contacted the vessel’s agent for medical assistance. The agent then called the Rotterdam Harbour Coordination Centre (HCC). HCC advised the agent to have the ship contact HCC on VHF channel 11. At 1805, the master made contact with HCC and explained the situation. At 1840, a Port Authority’s vessel came alongside with the Fire Service and other emergency personnel on board. A police boat was also on standby. After the Fire Service had conducted atmospheric tests on board Bomar Mercury’s deck and found this to be safe, the two emergency personnel came on board.

Following an initial examination and after attaching an intravenous drip, it was decided that the ill seamen should be transferred to hospital as soon as possible. They were then transferred by stretcher to the Port Authority’s vessel, after which they were taken to the Geulhaven hospital in emergency. After the two crew members had left the ship, the master also decided to disembark the other two crew members who had
been on deck during the cleaning activities, and admit them to hospital as a preventive measure. They were taken on board the police boat.

The master was then informed that three other crew members had been on deck during the cleaning activities. They were also taken on board the police boat. Eventually, the police boat took the five crew members to Geulhaven. Upon arrival, the two crew members, who were directly involved, were taken by ambulance to a hospital in Goes. The other crew members were sent by taxi to the Port Health Centre in Rotterdam for a general check-up.

The medical condition of the ill seamen on board the Port Authority’s vessel regressed significantly during the journey from Bomar Mercury to Geulhaven and they fell unconscious several times. Both were eventually resuscitated. Two ambulances were waiting on arrival in Geulhaven, one to take the AB to a specialist hospital in Antwerp (Belgium) and the other to take the OS to a hospital in Amsterdam. When the other two crew members arrived, they were taken by ambulance to the hospital in Goes.

Both the AB and the OS survived the accident but a medical investigation has revealed that they had possibly sustained long-term injuries to internal organs as a result of prolonged exposure to Aniline. The involved two crew members spent a night in hospital where they were treated, after which they returned to Bomar Mercury. The other three were examined and returned on board that same day.
2 ANALYSIS

2.1 Purpose

The purpose of a marine safety investigation is to determine the circumstances and safety factors of the accident as a basis for making recommendations, to prevent further marine casualties or incidents from occurring in the future.

2.2 Drug and Alcohol Abuse

During the course of the safety investigation on board, the MSIU was informed that no alcohol tests were carried out on the day of the accident. However, documentary evidence indicated that an alcohol test was carried out on all crew members on 21 July 2015. The test results indicated that none of the crew members was intoxicated or under the influence of drugs. On the basis of this evidence, the MSIU did not consider alcohol and/or drugs to be a causal factor to this accident.

2.3 Hours of Work and Fatigue

Record sheets for all the crew members covering the month of July 2015 were made available as documentary evidence to the MSIU. Specific focus was made on the record sheets for the chief and second mates. The records suggested that the maximum working period in 24 hours varied between eight and 14 hours. However, the sheets appeared to record ‘watch’ periods only and did not make any reference to sleep (quality and quantity), relaxation or other activities.

The chief mate kept the standard 0400-0800 and 1600-2000 watches when the vessel was at sea. However, he was also responsible for all cargo operations and therefore had to be physically present prior to the start and completion of loading and/or discharging, and also during the cargo tank washing. He also had to test the atmosphere inside the cargo tanks. An analysis of the recorded values for activity for the time period from departure Tees on 18 July 2015 until the discovery of the problem on 21 July 2015 was made. An excerpt is reproduced as Table 1.

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9 There are no requirements, which stipulate that quality and quantity of sleep have to be recorded.
Table 1: Hours of work records sheet

<table>
<thead>
<tr>
<th>Date</th>
<th>Hours of work in 24h period</th>
<th>Hours of rest in 24h period</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.07.2015</td>
<td>X X X X X X X X X X X X X</td>
<td>9 13 11 10 12 14 15</td>
</tr>
<tr>
<td>19.07.2015</td>
<td>X X X X X X X X X X X X X</td>
<td>10 14 11 12 14 12 12</td>
</tr>
<tr>
<td>20.07.2015</td>
<td>X X X X X X X X X X X X X</td>
<td>9 12 12 12 12 12 12</td>
</tr>
<tr>
<td>21.07.2015</td>
<td>X X X X X X X X X X X X X</td>
<td>9 13 11 10 12 14 15</td>
</tr>
</tbody>
</table>

Periods of work are shaded

Note: The table shows the hours of work and rest for each day. The periods of work are shaded to indicate the working hours.
Whilst the heading indicates that the period of work is shaded, the MSIU was informed that it is actually the cells marked with an ‘x’, which indicated the hours of work. Although the recorded hours of work tend to correlate with those given during the course of the evidence collection in the aftermath of the accident, it was interesting to note that there were no records of what happened outside those periods. It was clear that the chief mate had at most five hours sleep overnight between 19 and 20 July 2015 and four hours sleep before the cargo tank cleaning operations on 21 July 2015.

Similarly, on 20 July 2015, the second mate had worked from 1200 to 2000. He was then working from 0000 to 0600 (21 July) and back to work again at 1200. This equated to 14 hours on watch either in the cargo control room or the bridge in a noon to noon period. The second mate had navigational responsibility for voyage planning so it was more than likely that he would have had other time carrying out these duties, relaxing, etc and that were not formally recorded; but nonetheless there would have been hours when he would have been awake (rather than sleeping) and that were not recorded on the time sheet.

Interviews carried out on board revealed the demanding schedules on board and a general acceptance that the long hours came part and parcel of the work on board. To this effect and on the basis of the above analysis, the MSIU was not in a position to exclude fatigue from being a contributory factor to this accident.

2.4 Cargo Tank Cleaning Guidance and Implementation

The fact that two crew members were affected by respiratory intoxication after inhaling Aniline gases indicated that it was likely that the cargo tank cleaning procedure was not as effective as planned.

During the course of the safety investigation, it became evident that the cargo tank cleaning procedure being applied was that provided by the operator, who designed the instructions on the directions from the charterer.
The procedure communicated by the operator necessitated the following steps:

1. Commercial pre-wash procedure with freshwater;
2. “Cleaning time can typically be limited to less than half an hour per tank cleaning machine”;
3. Fresh water rinse;
4. Venting; and
5. Mopping and drying to water white standard.

It was noticed that the various instructions did not give any real indication of the time required to thoroughly clean a cargo tank. In fact, one set discussed a number of wash cycles while another made note of less than half an hour per cargo tank cleaning machine.

2.4.1 Cargo tank cleaning machine maintenance programme

Records of maintenance for the cargo tank cleaning machines were available on board. On the basis of the records provided to the MSIU, it did not transpire that lack of maintenance was contributory in any way to this accident.

2.4.2 Cargo tank cleaning machine programme implemented on 21 July 2015

The actual cleaning routine that was adopted, is shown on SMS Form 102011 – Cargo Tank Cleaning Plan (Annex A).

Evidence gathered from Bomar Mercury determined that the vessel used the ‘Pre-wash’ programme when cleaning the cargo tanks. Initially, the crew members carried out the ‘commercial wash’ which was reportedly a five minute washing cycle in accordance with the instructions from the charterers. (It should be noted that the instructions from the operator stated that the commercial wash should not take more than two hours; however, it did not discuss specific timescales).

The vessel then moved to the Lay-by Buoy No. 61 and carried out a further wash cycle, using again the ‘Pre-wash’ cycle for 20 minutes per cargo tank, followed by a further 10 minutes using fresh water. The crew members then ventilated, mopped and dried out the cargo tank, applying the operator’s procedure.
The operator recommended a ‘commercial’ prewash procedure with the main aim of minimising the amount of Aniline to be disposed into the sea under the relevant International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL) regulations.

Unlike the Verwey procedure, the operator’s procedure required a fresh water wash delivered by barge with all slops being collected into one tank and then being discharged into a shore tank. It was noted that operator urged to carry out this commercial pre-wash operation in less than two hours.

At paragraph 5.10 of the operator’s procedure, there was specific mention that,

Miracle and Verwey procedures provide extensive procedures based on large tanks and inefficient work methods. **On an efficient chemical tanker, cleaning times can typically be limited to less than half an hour per tank cleaning machine**\(^{10}\), provided all loose/dead ends are properly flushed. After subsequent freshwater rinse and venting, mopping and drying the tanks will be in water white standard.

### 2.4.3 Tank cleaning - pre-wash cycle

According to the P&A Manual, there were four wash cycles that defined the duration of the cleaning cycle, the nozzle elevation and the rotation speed of the gun (Figure 9).

<table>
<thead>
<tr>
<th>Action</th>
<th>Standard Elevation</th>
<th>Optional Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>All program knobs in upper position</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>One program knob pushed down</td>
<td>1,5°/rev</td>
<td>2,5°/rev</td>
</tr>
<tr>
<td>Two program knobs pushed down</td>
<td>3,0°/rev</td>
<td>5,0°/rev</td>
</tr>
<tr>
<td>Three program knobs pushed down</td>
<td>4,5°/rev</td>
<td>7,5°/rev</td>
</tr>
<tr>
<td><em>(Optional)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prewash knob pushed fully down</td>
<td>60°/rev</td>
<td>60°/rev</td>
</tr>
</tbody>
</table>

**Figure 9: Excerpts from the Scanjet Instruction Manual, giving an indication of different settings**

The MSIU determined that the mode used on board was ‘pre-wash’ for all washes; in this case, this meant that the pre-wash button was fully engaged (Figure 10). When

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\(^{10}\) Emphasis added.
one considers the timescale referred to above\textsuperscript{11}, then in reality only pre-wash could be used to satisfy the timescale.

Figure 10: Top of the ScanJet 30 cargo tank washing machines

This is also reflected in red on the graph in Figure 11, equating to approximately six minutes and assuming a delivery pressure of 11 Bar.

Figure 11: Duration of the pre-wash at a delivery pressure of 11 Bar

\textsuperscript{11} ‘Pre-wash’ cycle for 20 minutes per cargo tank, followed by a further 10 minutes using fresh water. The use of the pre-wash cycle meant that the gun nozzle rotated through 60° in one revolution of the gun unit in the vertical plane.
2.4.4 Cleaning efficiency

The P&A Manual indicated that a nozzle size of 10 mm was fitted\(^\text{12}\). It has also been established that the pre-wash mode was used for the washing cycles. With 10 mm nozzles operating at 11 Bar, the flow rate would be approximately \(13.5 \text{ m}^3\text{hr}^{-1}\), provided the pump was operating at full capacity.

Since there were two machines per cargo tank and the latter were washed in pairs, four machines would have used water at a rate of approximately \(55 \text{ m}^3\text{hr}^{-1}\) and a water jet length of approximately 17.5 m. Figure 12 provides the relevant details from the Scanjet Manual.

<table>
<thead>
<tr>
<th>Nozzle size</th>
<th>Supply pressure MPa (Bar)</th>
<th>Flow ([\text{m}^3/\text{h}])</th>
<th>Jet length [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\varnothing\ 8\text{mm})</td>
<td>0.6 (6)</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>(\varnothing\ 9\text{mm})</td>
<td>0.8 (8)</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>(\varnothing\ 10\text{mm})</td>
<td>1.0 (10)</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>(\varnothing\ 12\text{mm})</td>
<td>1.2 (12)</td>
<td>10</td>
<td>16</td>
</tr>
</tbody>
</table>

![Figure 12: Excerpts from the Scanjet Instruction Manual, giving an indication of jet length and flow at different supply pressures and nozzle diameters](image.png)

With the machine running, the jet described an elliptical path but with the machine covering 60° in one revolution, the coverage would have had many gaps (Figure 13); the lower the angle, the longer the cycle time but the less the gaps in the helix type pattern and therefore the better the wash.

![Figure 13: Elliptical paths and gaps in the coverage](image.png)

\(^{12}\) Originally, the P&A Manual had 8 mm but this was amended and endorsed by Class.
An important factor in the P&A Manual was a remark that all cargo tanks, other than cargo tank no. 2 starboard, record zero shadow, *i.e.*, depending on the programme used, the cargo tank cleaning machines would clean all areas inside the cargo tanks with zero shadow. Cargo tank no. 2 starboard had shadowed areas of 38.5 m² or 6.1% of the total area of the cargo tank that could not be cleaned by the fixed cargo tank cleaning machines (Figure 14).

**Figure 14:** Excerpts from the P&A Manual, showing the shadow diagram for cargo tank no. 2 starboard

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13 A shadow is an area within the cargo tank that the jets of water from the washing machine nozzles will not reach.
It is the MSIU’s view that taking into consideration the cleaning programme used (pre-wash) and the length of time, it was highly unlikely that cargo tank no. 2 starboard was sufficiently cleaned. However, irrespective of the selected variables, there were areas in the cargo tank that the washing machines would not have been able to reach and clean. It is therefore the MSIU’s conclusion that during the course of the accident, residues of Aniline cargo were still present on the bulkheads of cargo tank no. 2 starboard.

Moreover, the knowledge of shadowing in cargo tank no. 2 starboard did not appear to have been taken into account since no special measures have been taken for this cargo tank. The enclosed space entry form for this cargo tank was checked and it indicated that the atmosphere had been checked and it was safe. The MSIU had doubts that this was actually the case.

2.5 Cargo Tank Ventilation and Testing

2.5.1 Cargo tank ventilation
During the course of the safety investigation, it was established that following the washing of the cargo tanks, the latter would normally be ventilated for 30 minutes per pair of cargo tanks (say, cargo tanks nos. 1 port and starboard). All cargo tank groups were ventilated for 30 minutes and then upon completion, all cargo tanks were ventilated continuously. It transpired, however, that there were no procedures for this and that this procedure was carried out on the basis of past experience.

To this effect, the MSIU did not come across any evidence which specifically defined the duration of the cargo tank ventilation prior to safe entry.

2.5.2 Atmosphere testing
Atmosphere testing was covered in the SSOM at section 1.14 under ‘Gas Testing and Cargo Measuring Equipment’. It discussed the requirements for gas testing in general and generic detail.

_Bomar Mercury_ carried personal monitoring devices that were designed to measure four different parameters. As described previously in this safety investigation report, in the case of the GMI PS200 series, it was possible to attach a tube and pump air
through the unit. During the course of the safety investigation, it transpired that one of these units was used to determine the atmosphere content inside the space.

The technical literature for this device confirmed that the pump equipped unit could be used for testing the atmosphere for pre-entry. However, the manual indicated that the length of extension hose for the pumping was only three metres long.

Following the field deployment, the MSIU noticed that the received copies of the maintenance records referred to a GMI SHIPSURVEYOR 2 unit\(^\text{14}\). The recognised guidance from the International Chamber of Shipping Tanker Safety Guide (Chemicals) is that measurements are taken at several levels. The MSIU could not establish the number of levels where the measurements were made. However, if the PS 200 unit was used, then the chief mate could only measure a depth of three metres (at each level).

In addition to this, the chief mate explained that he used a Dräger Accuro unit to test for the presence of toxic gas.

The Dräger Accuro unit device required the use of a glass tube (Figure 15) containing the chemical which detected the toxic vapours that would arise with Aniline gas. If the gas is present, the chemical reaction would cause a colour change to light green.

\[\text{Figure 15: An unused Dräger glass tube}\]

In order to use the tube, both ends had to be broken off before the tube was inserted into the unit (in the correct direction) and air drawn through the tube by means of a hand pump. For Aniline toxic measurement, the unit had to be pumped 20 times (Figure 16).

\(^{14}\) This unit is the one which one would normally expect to be used for measuring the atmosphere inside a cargo tank, together with the personal units being used by any person making an entry into the cargo tank. This device can pump from a depth of 15 m.
The chief mate told the MSIU that he had operated the hand pump mechanism 20 times when testing the atmosphere of the cargo tanks. However, during the Aniline measurement with the Dräger tubes at a later stage, the chief mate only operated the hand pump three times. When asked whether this was sufficient, the chief mate answered that he always did it this way. The master later confirmed this statement. The MSIU was unable to determine which of the two versions was the more accurate given that the (contradictory) information was volunteered by the same crew member. If the hand pump was indeed operated three times, then the sample of air inside the unit would not have been an accurate representation of the atmosphere inside the cargo tanks.

Further to the above, the chief mate also recalled that he had used six or seven tubes during the testing of the 10 cargo tanks. This suggested less than one glass tube per cargo tank. The MSIU had access to six of these glass tubes\(^\text{15}\) (Figure 17).

\(^{15}\) The batch number of the used tubes were in date, with an expiry date of August 2016.
Publications reviewed by the MSIU did not provide a clear indication on whether the Dräger tube could be used more than once.

However, the Dräger Manual\(^\text{16}\) indicated that,

Dräger-Tubes with direct reading colorimetric indication have many applications. Approximately 500 different substances can be measured with Dräger-Tubes.

Limited selectivity and the fact that Dräger-Tubes are usually capable of only being used once may present a disadvantage. If repeated measurements of the same substance are to be performed daily, a measurement device like Dräger Pac 7000 CO with its electrochemical sensor for the measurement of carbon monoxide is more economic than Dräger-Tubes.

![Figure 17: Spent Dräger tube (six in total)](image)

The above statement is not categorical stating that a Dräger tube can only be used once and in this case, in one position. However, it did seem to suggest a once only use and that being the case, the MSIU would have expected to see at least 20 Dräger tubes (two per cargo tank).

In order to clarify the matter, the MSIU made enquiries with Dräger in Blyth, Scotland. It was confirmed that the tubes should be one-time use only. Dräger also

mentioned that the maximum extension hose should be no more than 15 m and recommended that the tube is attached to the machine.

Moreover, the Dräger tubes shown in figure 15 did not appear to have any clear green colouring. However, in comparison with new tubes, they did look different. A blown up version of Figure 15 appeared to show a green tinge looking from right to left on the fourth tube from the top at approximately 1.0 – 1.5 ppm.

The data sheet that was provided with the tubes indicated that any toxic gas associated with Aniline would turn the agent light green; however, the tubes in Figure 15 did not appear to be giving a *definite* indication of the presence of toxic gas. It had to be noted that there was no mention of how many times a tube should be used; the only advice given was to not exceed the expiry date.

Advice was also provided in the leaflet that accompanied the tubes. It was made clear that concentrations above 100 ppm would not display. However, it was not clear whether this meant that the agent would not change colour. For normal ranges, it described the agent changing colour from light yellow to light green. The crystals within a new Dräger tube are white. On the basis of the above, it was hypothesised that either exposure to normal air made the normally white agent change to a light yellow colour, or the presence of Aniline produces a range of colours from light yellow to light green.

The advice on the leaflet was that the time required to react was normally four minutes. Although the chief mate did mention a waiting time of four minutes, the MSIU was concerned that he may have not been completely familiar with the use of the equipment, mainly:

- he referred to the presence of Aniline turning the chemical light blue;
- described the use of the Dräger tubes rather vaguely;
- did not appear to be completely sure which way the arrow on the tubes was supposed to point; and
- he mentioned that the tube was placed inside the extension hose and lowered into the cargo tank rather than being placed directly into the unit.
The chief mate stated that he measured the atmosphere in two positions in the cargo tank - one forward and one on the aft side through manholes. What was clear, from his relaying the procedure, was that he only took one measurement in each position rather than measurements at different levels. Further checks with the manufacturers revealed that in actual fact, the colour change was not as dramatic as one would expect and is shown below from their data sheets where it can be seen that the lower tube indicates 6 ppm (Figure 18).

![Figure 18: Dräger tube colour change at 6 ppm](image)

Based on this showing in the Manual, it appeared to the MSIU that the fourth tube down in the photograph in Figure 17 could be indicating the presence of Aniline.

The chief mate recalled that he had used an extension hose to sample the atmosphere and that the hose was about 10 m long. The Dräger Accuro Manual specified that the extension hose is 3 m long; in that case, the maximum depth into the cargo tank that was checked was therefore 3 m, provided that the person taking the sample was holding the unit at deck level. However, clarification from the manufacturers revealed that there was a 10 m variant hose that could be used. On the basis of what the chief mate had stated, the MSIU understood that the latter variant was used and the atmosphere was hence sampled to a maximum depth of 10 m.

It was evident to the MSIU that although the chief mate was qualified and competent to assume the responsibilities in his rank on board *Bomar Mercury*, he lacked specific training / awareness on the use of the hand pump. This was a concern especially because the Company normally conducts pre-employment assessment for job competence and training for officers and ratings by using techniques such as simulator training and computer-based assessment. The Company’s initial, on-going and refresher training is extensive and well documented, however, there was no evidence
to confirm that the training provided is detailed to an extent that it also addresses the use of similar ancillary, yet vital equipment.

### 2.6 Entry into Enclosed Space

There was a permit-to-work routine carried out in order to access each cargo tank for mopping and extraction of the final residues. The enclosed space entry routine specifically required the atmosphere to be safe prior to entry.

The requirements on safe atmosphere were thorough:

The master or the responsible person shall determine that it is safe to enter an enclosed space by ensuring that:

1. potential hazards have been identified in the assessment and as far as possible isolated or made safe;

2. the space has been thoroughly ventilated by natural or mechanical means to remove any toxic or flammable gases and to ensure an adequate level of oxygen throughout the space;

3. the atmosphere of the space has been tested as appropriate with properly calibrated instruments to ascertain acceptable levels of oxygen and acceptable levels of flammable or toxic vapours;

4. the space has been secured for entry and properly illuminated;

5. a suitable system of communication between all parties for use during entry has been agreed and tested;

6. an attendant has been instructed to remain at the entrance to the space whilst it is occupied;

7. rescue and resuscitation equipment has been positioned ready for use at the entrance to the space and rescue arrangements have been agreed;

8. personnel are properly clothed and equipped for the entry and subsequent tasks; and

9. a permit has been issued, authorizing entry.

The person authorizing entry shall determine whether an attendant and the positioning of rescue equipment at the entrance to the space are necessary.
In this particular case, items 3 and 8 were examined by the MSIU. The inference in item 3 is that the atmosphere is to be made safe before entry and therefore there would not be a requirement for a BA set when entering the space; there would only need to be an emergency BA set available if things went wrong. With reference to item 8, all the interviewed crew members discussed the use of BA sets. The enclosed space entry forms had a specific section on BA sets and on the checks to be carried out on the BA set; however, it was not clear whether this referred to the emergency standby BA set or whether it was the BA set to be worn prior to the entry inside the cargo tank.

A question on personal protective equipment (PPE) queried whether personnel were properly clothed and equipped. However, the question did not detail what that should be.

Additional entry procedures also addressed circumstances when the atmosphere inside was either unsafe or suspected to be unsafe. The procedures stated that:

Spaces that have not been tested shall be considered unsafe for persons to enter. If the atmosphere in an enclosed space is suspected or known to be unsafe, the space shall only be entered when no practical alternative exists.

Entry shall only be made for further testing, essential operation, safety of life or safety of a ship. The number of persons entering the space shall be the minimum compatible with the work to be performed.

Suitable breathing apparatus, e.g., of the air-line or self-contained type, shall always be worn, and only personnel trained in its use shall be allowed to enter the space. Air-purifying respirators shall not be used as they do not provide a supply of clean air from a source independent of the atmosphere within the space.

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17 It has to be mentioned, however, that the Cargo Tank Cleaning Form described the PPE to be used for this operation as helmet, goggles, gloves and safety shoes. This level of PPE would suggest that there was an expectation that the atmosphere inside the cargo tanks was to be confirmed safe to work in without the need for a BA set.
Persons entering enclosed spaces shall be provided with calibrated and tested multi-gas
detectors that monitor the levels of oxygen, carbon monoxide and other gases as
appropriate.

Rescue harnesses shall be worn and, unless impractical, lifelines shall be used.

Appropriate protective clothing shall be worn, particularly where there is any risk of
toxic substances or chemicals coming into contact with the skin or eyes of those
entering the space.

There were several points in this that highlighted potential issues with the way the
cargo tank entry had been actually performed. Firstly, information which the MSIU
had on the first enclosed space entry permit, suggested that this was reportedly issued
within five minutes from the stopping of the ventilation. The MSIU was of the view
that five minutes may be a relatively short period to ensure that the sample taken by
the measuring equipment was representative of the actual atmosphere inside the cargo
tank. This was considered to be a very important factor, which would have served as
the basis of the decision on the issuance of the enclosed space entry permit.

Secondly, the enclosed space entry form in all cases indicated that the atmosphere was
safe and therefore there was no requirement to wear a BA set. It may have been
possible that there may have not been any suspicion on the atmosphere - otherwise the
form would not have been declared as clear and the readings would not have been
filled in. However, this raised another issue, *i.e.* if as a matter of precaution, BA sets
were nonetheless made available at the cargo tank entry, then one would expect that
other required equipment (personal gas detectors and safety harnesses) would also
have been used, being a suspected space.

On the other hand, if there was suspicion about the atmosphere then, that would have
automatically indicated that there was a suspicion regarding the presence of cargo
residue in the cargo tank. If that was the case, then personnel entering the cargo tanks
should have been wearing at least a light chemical suit but none were, even though
they were readily available. In addition, this raised the question as to why the clean
entry form would have been issued in the first place.
The knowledge of shadowing in cargo tank no. 2 starboard did not appear to have been taken into account since no special measures had been taken for this cargo tank. The relevant enclosed space entry form was checked and it indicated that the atmosphere had been checked and it was safe. The MSIU had doubts whether this was actually the case. Moreover, considering that the personal gas detectors and harness were not used, it may be suggestive that the risk of gas was not appreciated and the availability of BA sets was more of a formality rather than a specific action to have a protection barrier system readily available.

2.7 Specific Training

As already elaborated in sub-section 2.5, the MSIU had reasons to believe that the crew members, including the chief mate, were not completely familiar with the use of the measuring equipment. This was not only the case with the operation of the pumps but also in the use of the Dräger tubes.

As already indicated in sub-section 2.5.2 of this safety investigation report, only six Dräger tubes were used. The chief mate explained that tubes could be used for about 30 minutes, as long as no value had been measured. However, information from the manufacturer confirmed that not only the number of pump movements was crucially important for a correct measurement but a new tube had to be used for each measurement. This suggested that the chief mate was not familiar with the operation of the measurement equipment.

It was therefore not excluded that access into the cargo tanks was authorised in spite of the fact that Aniline gas was still present inside, thereby exposing the crew members to this hazard.

It was also established that the vessel carried a Material Safety Data Sheet (MSD) for Aniline. The MSD quite clearly stipulated that this was a toxic cargo.

The MSIU was unable to ascertain whether specific training regarding this cargo had been undertaken by the crew members. During the course of the collection of evidence, it remained unclear whether specific reference to the hazards associated with the use of Aniline had been provided during the specific training.

18 As the chemical reaction continues and the measurement is influenced by time, the tube is only accurate just after the 20 pumping actions.
with this cargo were communicated to the personnel prior to them carrying out the necessary work.

It was established that all crew members carried out familiarisation training when joining the vessel. Moreover, the Company ran a performance questionnaire (SMS Form 301005) for all personnel to test their understanding of the familiarisation training. The Form made reference to the term ‘enclosed space’. However, given that the form was generic rather than ship-specific, there was no reference to precautions with chemicals and dangers associated with them.

It was noticed that only the Ratings Familiarisation Sheet (SMS Form 301004) (which was in English and Turkish), made reference to chemicals, where there was reference to the use of PPE and chemical suits. Notwithstanding the above, it did not appear that there was any specific familiarisation carried out with regards to chemicals during the familiarisation training.

Training and drills were promulgated in advance by the Company and appeared on SMS From 302001 (Annex B). It was noted that there was a provision for rescue from enclosed space drills once every six weeks.

Evidence revealed that the last drill was carried out at the end of March 2015. Records associated with drills did not indicate any as from the beginning of April 2015. The exercise report of an enclosed space entry drill carried out indicated that it was programmed for the third week of July. The MSIU enquired about the lack of records from April and was informed that the drills’ programme was an issue due to the ship’s schedule19.

Taking into consideration the above, the MSIU believes that the familiarisation process and the follow up questionnaire were examples of good practice. However, it appeared that there were clear issues on training with regards to chemicals. Furthermore, although the entry into enclosed spaces training would cover the use of BA sets and the requirements to enter, it was unlikely to be covering particular scenarios.

19 The entry into enclosed spaces did not train in the use of BA sets but it was not clear whether it had any specific concentration on the potential of chemical hazards.
There was little, if any, direct guidance on the precautions to take with respect to slops. While it is known that the system should be drained and that there will be slops to manually remove from a cargo tank, the MSIU is of the view that there are areas which remained unaddressed, with respect to the cleaning of cargo residues. This was of course an issue because Aniline is a toxic substance. The unaddressed areas were manifested, *inter alia*, in the fact that none of the crew members working in this environment on the day was wearing a light chemical suit.

### 2.8 Aniline Intoxication and the Use of BA Sets

According to statements from the Company and the master, not only is a cargo tank entry permit issued, but a BA set is always worn as preventive measure when entering cargo tanks. However, although the ‘entering confined spaces’ checklist stated that the crew members must be familiar with the use of BA sets, it did not require the crew members to actually don one when entering a confined space. It also appeared that contrary to what had been reported to the MSIU, in practice, no BA sets were used upon entering of the cargo tanks, given that crew members were exposed to the gas, long enough to suffer from long term effects. It was stated that wearing a BA set was not considered necessary when the concerned cargo tanks had been declared safe. In fact, only at the point that the AB began to feel unwell did they start to wear their respective BA sets.

### 2.9 Suspending the Cleaning Operation Inside the Cargo Tank

In spite of the fact that the first crew member became increasingly ill, this was not seen as a reason for an immediate suspension of the cleaning activities. Even after the second crew member became unwell, the activities were not stopped. Yet, the crew began to realise that it was possible that the atmosphere inside the cargo tanks was not safe; so much so that they started to wear their BA set masks.

The MSIU was not convinced that the crew members were fully aware of the dangers of exposure to Aniline. In the months prior to the accident, *Bomar Mercury* had carried Aniline on more than one occasion. During the course of the safety investigation, a number of crew members revealed that on several occasions, they
were referred to the information board in the cargo office, where the information on the cargo would normally be ‘published’. However, the crew members stated that it was not uncommon to find the information board empty.

With respect to the cargo being carried, the MSIU was also informed that the crew members did not have direct contact with the chief mate, who was generally too busy with several issues. Moreover, it was stated that they did not directly talk to the officers, which was normally done through the bosun.

2.10 Other Safety Concerns – Safety Equipment

The safety investigation revealed that there was sufficient safety equipment on the vessel to allow safe operation. The contents of the safety store and lockers were examined. The equipment that was present appeared to be in good condition\(^\text{20}\). The maintenance of the safety equipment was discussed but the relevant crew member was somewhat vague when it came to describing what maintenance was carried out on the BA sets and the chemical suits. It appeared that equipment was returned directly to the safety store but there was no indication that these were cleaned and checked on return. Similarly, the MSIU could not find any records of control of issue and therefore it appeared that their use may well be an uncontrolled process.

There were records in the safety store that related to a checklist of items that should have been there; but there were no checklists to confirm that maintenance had been carried out in accordance with the manufacturer’s recommendations. Maintenance records for safety equipment and which were made available to the MSIU, only covered a small selection of records and did not really detail what checks had been carried out.

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\(^{20}\) The BA sets that were reported to have been used during the incident were not available for inspection at the time of the safety investigation.
THE FOLLOWING CONCLUSIONS, SAFETY ACTIONS AND RECOMMENDATIONS SHALL IN NO CASE CREATE A PRESUMPTION OF BLAME OR LIABILITY. NEITHER ARE THEY BINDING NOR LISTED IN ANY ORDER OF PRIORITY.
3 CONCLUSIONS

Findings and safety factors are not listed in any order of priority.

3.1 Immediate Safety Factor

.1 The safety investigation concluded that the immediate cause of the intoxication was exposure and subsequent contact with Aniline cargo, either through skin absorption or inhalation.

3.2 Latent Conditions and other Safety Factors

.1 At least one of the cargo tanks accessed by the crew members still had traces of Aniline cargo inside following the cleaning process;

.2 Cargo tank cleaning documents and instructions available on board did not give any real indication of the time required to thoroughly clean a cargo tank;

.3 Relevant crew members lacked the necessary knowledge on the different modes of cargo tank washing systems and the likely efficiency of the different modes;

.4 The vessel carried cargo tank cleaning documents and guidelines which seemed to provide contradicting information, some of which focusing on efficiency rather than thoroughness;

.5 The vessel applied the pre-wash procedure only, in all probability because it was the only cycle which completed cleaning in the time required by the charterers;

.6 The fact that cargo tank no. 2 starboard had shadowed areas of 38.5 m² and which could not be cleaned by the fixed cargo tank cleaning machines, did not seem to have been appreciated by the crew members;

.7 The vessel did not have information which specifically defined the duration of the cargo tank ventilation prior to safe entry;
.8 The relevant crew member seemed to lack the necessary knowledge on the correct sampling method of the cargo tank atmosphere;

.9 The MSIU was not convinced that the crew members were fully aware of the dangers of exposure to Aniline;

.10 Considering that the personal gas detectors and safety harness were not used, it may be suggestive that the risk of gas was not appreciated and the availability of BA sets was more of a formality rather than a specific action to have a protection barrier system readily available.

3.3 Other Findings

.1 The MSIU did not consider alcohol and / or drugs to be a causal factor to this accident;

.2 The records of hours of work and rest did not include information on the hours of quality sleep and therefore fatigue was not excluded from being a possible contributory factor to this accident;

.3 Lack of maintenance of cargo tank cleaning machines was not contributory in any way to this accident.

4 ACTIONS TAKEN

4.1 Safety Actions Taken During the Course of the Safety Investigation

Following the accident and further to an internal investigation in accordance with Section 9 of the ISM Code, the Company implemented the following safety actions:

- A refresher training course, including video training, on entry into enclosed and confined spaces and testing of space atmosphere was carried out on board the vessel by a Company’s representative;

- A service engineer from Beukers Marine Instrumentation B.V. was invited on board to conduct a training session on the proper use of different gas test tubes and gas detectors;
• Several training courses were carried out on board on the use of fire fighting and life saving equipment;

• A special Committee, reporting to the Company’s management, was formed and assigned the duty of monitoring the progress of short and long-term corrective / preventive actions;

• Marine consultants were hired to assist the Company in its internal investigation and to make the necessary amendments to the Company’s SMS;

• Circular letters were circulated on all ships in the fleet requesting confirmation that safe entry procedures were being followed and to ensure that the accident is discussed at the following on board safety committee meetings;

• A safety bulletin was issued to all vessels in the fleet with instructions on the annual calibration of all gas measuring equipment by a qualified third party surveyor;

• Extra pre-embarkation training on the use of gas measuring equipment has been developed for all senior officers and is being delivered by a qualified and experienced Company superintendent;

• The Company’s in-house training matrix has been amended to include details of this accident to ensure that it is discussed at training sessions;

• Open fora have been scheduled for crew members who are on vacation leave and for shore personnel in order to enhance safety awareness;

• All Company superintendents have been briefed on the accident and instructed to provide training seminars on tank cleaning, gas freeing and gas measuring operations during their visits on board;

• Random visits by superintendents are in force in order to observe cargo operations and review cargo tank cleaning, gas freeing and gas measuring operation process where necessary.
5 RECOMMENDATIONS

In view of the conclusions reached and taking into consideration the safety actions taken during the course of the safety investigation,

**Armona Denizcilik A. S. is recommended to:**

*15/2016_R1* ensure that crew members are well informed in good time on the characteristics of the cargoes which the vessels would be scheduled to carry.

*15/2016_R2* revisit the procedures available on board with respect to cargo tank washing in order to eliminate potential conflicts created by different information sources.

**Drägerwerk AG & Co. KGA is recommended to:**

*15/2016_R3* amend the instructions for the use of the Dräger tubes in order to eliminate multiple interpretations of the text.
## LIST OF ANNEXES

### Annex A  SMS Form 102011 – Cargo Tank Cleaning Plan

### CARGO TANK CLEANING PLAN

**VESSEL:** Armada Mercury  
**TANK NO.:** 1P.15-2D.75-4P.41-5P.55-6P.65  
**Previous Cargo:** ANILJVE  
**Cargo to be Loaded:** MGO

### Section 1 - Pre-Planning Section

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<td>Steaming to be required</td>
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<td>IN O2%.</td>
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</table>

- **Personnel Protective Equipment to be Used:** HELMET, GOGGLES, CLOTHES, SAFETY SHOES
- **Action to be Taken in Case of Emergency:** STOP CLEANING IMMEDIATELY

### Section 2 - Result

**Cleaning Result:** IN O2%

**Cleaning Completed**  
Date: 21.02.2015  
Time:  

**Revision No:** 1  
**Issue Date:** 12.02.2012  
**SMS FORM NO:** 102011  
**Page 1 of:**
# Annex B  
**SMS From 302001 – Training and Drill Programme**

## SAFETY DRILLS
- Fire in Accommodation (FA)
- Fire in Engine room (FE)
- Fire on deck (FD)
- Fire in cargo tanks (FC)
- Abandon Ship (AS)
- Maneuvering at sea with rescue boat and recovery of persons from water (RBWS)
- Manoverboard (M)

## SOPEP/SMPEP DRILLS
- Flooding of compartments (FO)
- Explosion (E)
- Oil spills Annex I (OS1)
- Oil spills Annex II (OS2)
- Grounding (G)
- Medical manover injury (MI)
- Collision (C)
- Main Engine failure (ME)
- Unexpected list of the ship (UL)
- Search and Rescue (SAR)
- Gyro Failure (GF)
- Cargo leakage into a pennant ballast tank (CL)
- Dangerous Cargo Reaction
- Contamination Yielding (DCR)

## SHIP-SHORE COMBINED DRILL PROGRAMME

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<tr>
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<th>WEEK 1</th>
<th>WEEK 2</th>
<th>WEEK 3</th>
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<td>FE + M + ECD</td>
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<td>AS + JTC + RE</td>
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<tr>
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<td>AS + OS2</td>
<td>FE + M</td>
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<td>AS + DCR</td>
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**Notes:**
1. The drill can be postponed to the nearest date if the vessel is under cargo operation or in unusual weather condition or the vessel is in drydock.
2. Every crew member shall participate in at least one abandon ship drill and one fire drill every month. The drills shall take place within 24 h of the ship leaving a port if more than 25% of the crew have not participated in abandon ship and fire drills on board that particular ship in the previous month.
3. ISPS drills will be implemented and recorded as per Ship Security Plan.
4. Emergency Lighting Drill shall be carried out with Abandon Ship Drill.
5. Drill schedule shall be followed via online ISM module of PMS.
6. ISPS ship-shore combined exercises shall be planned according to convenience of