



STATE MARINE ACCIDENT INVESTIGATION COMMISSION

FINAL REPORT 47/15

Very serious marine casualty

M/V NEFRYT

Poisoning of the ship crew after the fumigation of cargo in the port of Abidjan
on 25 and 26 September 2015

September 2016

The examination of a very serious marine casualty of Nefryt was conducted under the State Marine Accident Investigation Commission Act of 31 August 2012 (Journal of Laws of 2012, item 1068 and of 2015, item 1320) as well as norms, standards and recommended procedures agreed within the International Maritime Organisation (IMO) and binding the Republic of Poland.

The objective of the investigation of a marine accident or incident under the above-mentioned Act is to ascertain its causes and circumstances to prevent future accidents and incidents and improve the state of marine safety.

The State Marine Accident Investigation Commission does not determine liability nor apportion blame to persons involved in the marine accident or incident.

The following report shall be inadmissible in any judicial or other proceedings whose purpose is to attribute blame or liability for the accident referred to in the report (Article 40.2 of the State Marine Accident Investigation Commission Act).

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1. Facts

On 24 September 2015 at 02:00 am, at the port of Abidjan in Ivory Coast, the loading and trimming of cargo of shea nuts onto Nefryt was completed. During the closing of cargo hold covers and clearing of cranes, 2 persons arrived on board to perform the cargo fumigation. When they distributed the fumigating agent, the crew completed the closing of hold covers and preparing the ship to depart to sea.

Before noon, Nefryt with a pilot on board departed to sea to the port of Buchanan in Liberia to take the load of logs.

On the following day, starting from midnight, the crew began to experience stomach pains and vomiting, with accompanying feeling of cold and generalised weakness. From early morning hours, the condition of individual crew members began to deteriorate and symptoms started to worsen.

The officer of the watch, to whom subsequent crew members reported their health problems, informed the chief officer about the situation among the crew. Before 5.00 am, the chief officer notified the master. The master, who also exhibited symptoms of poisoning, came to the bridge. After consulting other officers, he notified the shipowner, and then a physician from the TMAS in Gdynia, about the situation. The master informed both the shipowner and the physician that health problems of the crew could have been caused by food poisoning.

As a result of incoming reports about deteriorating condition of the crew, suggestion made by the TMAS physician to go to the nearest port and recommendations of the shipowner, the master changed the course and headed to the port of San Pedro in Ivory Coast.

After approximately 4 hours, the ship arrived at the roadstead in San Pedro and at 3:00 pm came to anchor. Two hours later, a local physician, who had arrived on a motorboat from the port on board a ship, examined all members of the crew. After the examination, the physician wrote a list of medicines to be purchased on shore. When the medicines had arrived on board, they were distributed among the crew according to individual recommendations of the physician.

At night from 25 to 26 September 2016, the condition of the crew deteriorated further. At around 3:00 am, the chief officer called the officer of the watch on the bridge and asked him to replace him on watch for some time, starting from 4:00 am, since he felt very bad. At 4:15 am, the third officer also informed the officer of the watch that she felt very bad and

experienced blurred vision, and that she had not been able to contact the chief officer by phone.

An ordinary seaman sent from the bridge to the chief officer's cabin found that the chief officer showed no signs of life. The master was alerted and the resuscitation was started.

The master contacted the harbour master office of San Pedro by the radio (VHF) and asked for emergency medical assistance.

During the resuscitation of the chief officer, the condition of the third officer deteriorated. She had breathing problems. She was given oxygen and then the resuscitation began.

The resuscitation of the chief officer lasted for over 2 hours. At around 7:00 am, the rescuers discontinued the resuscitation. The master ordered to prepare the engine for manoeuvres to enter the port.

At 7:50 am, a physician with the ship's agent arrived on board. The physician checked the pulse of the third officer and recommended to continue resuscitation. After 40 minutes, the physician declared the officer dead.

The anchor was weighted several minutes earlier. At 10:00 am, the ship moored in San Pedro.

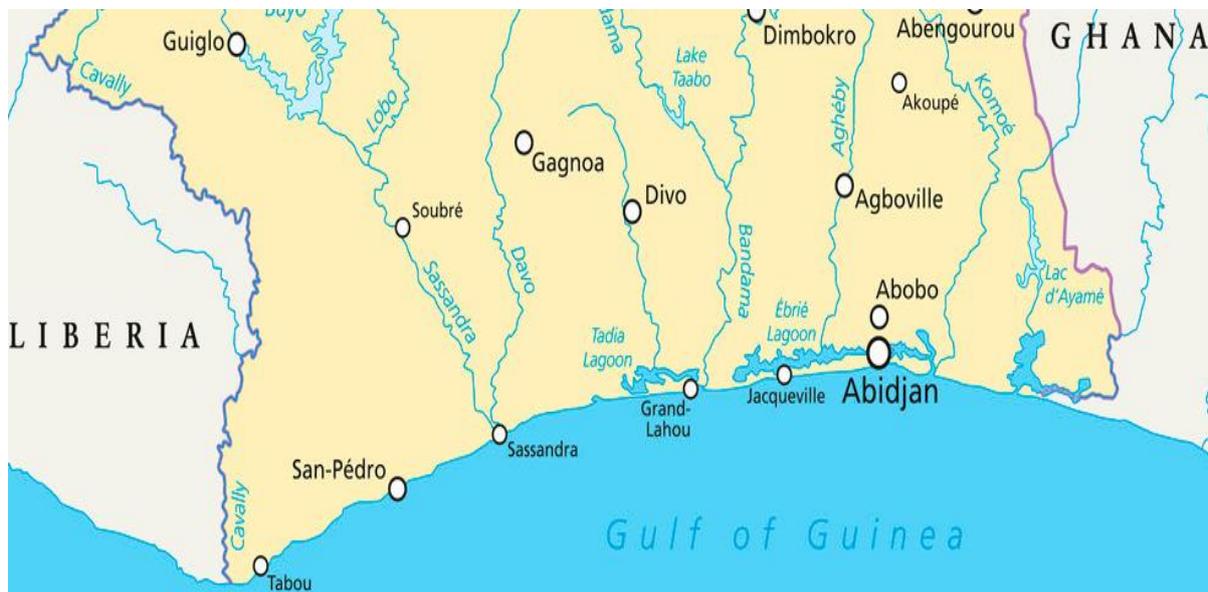


Figure 1. Ports of Abidjan and San Pedro in Ivory Coast on the Gulf of Guinea

After mooring, at 11:00 am a consent was obtained for the crew to leave the ship. 15 crew members, in several groups, were transported to the medical clinic in San Pedro for examination. The examinations were completed on the next day, at around 6:00 am.

The examinations failed to identify the cause of poisoning. The physicians ordered additional tests at the capital Abidjan. The shipowner decided to transport the Nefryt crew to Abidjan by plane and to place them at the international polyclinic.

At the hospital in Abidjan, all members of the Nefryt crew were subject to extended examination as compared to the tests performed at the clinic in San Pedro. After the physicians had diagnosed the poisoning with phosphine gas, appropriate treatment was initiated.

Between 5 and 21 October 2015, the 15 members of the crew were successively, as their health improved, released from hospital and they all returned to Poland.

2. General Information

2.1. Ship Particulars

Flag:	Malta
Owner:	Malpol Shipping Lines Ltd, Valletta (Malta)
Operator:	Euroafrica Services Limited (Spółka z o.o.), Branch in Poland, Szczecin
Time charterer:	Euroafrica Shipping Lines Ltd, Limassol (Cyprus)
Charterer (party to a voyage charterparty):	Tan Mondial Pte Ltd, Singapore (Singapore)
Classification society:	Polski Rejestr Statków S.A.
Type of ship:	general cargo multi-purpose vessel
Call sign:	9HRB5
IMO identification No:	9004475
Gross tonnage:	6 030
Construction year:	1991
Machine power:	4 413 kW (Hanshin Diesel Works 6LF58)
Width:	18.90 m
Total length:	106.42 m
Material of which the hull is built:	Steel
Minimum crew:	11



Photograph 1. M/v Nefryt

2.2. Voyage Particulars

Ports of call in the course of the voyage:	Abidjan, San Pedro (Ivory Coast)
Destination port:	Aarhus (Denmark)
Type of voyage:	international
Cargo:	7250,008 tonnes of shea nuts (nuts of <i>Vitellaria paradoxa</i>)
Crew:	17 Poles

2.3. Accident Information

Type:	Very serious marine casualty
Date and time of the accident:	24-26 September 2015
Geographical location at the time of the accident:	$\varphi = 53^{\circ}54,75'N$ $\lambda = 014^{\circ}16,60'E$ (Abidjan)
Geographical region of the accident:	Gulf of Guinea

Weather at the time of the accident:	Wind direction SW 2–3° B, sea state 2, visibility v. good 12 Mm, water temperature 27°C, air temperature 25°C
Operational status of the ship in the course of the accident:	Loaded; voyage on the route from Abidjan (Ivory Coast) to Buchanan (Liberia); during the cargo fumigation
Human factors in the accident:	Entire crew
Effect of the accident on the ship:	None
Impact of the incident on persons:	Poisoning of 17 crew members, of whom fatal poisoning of 2 persons

2.4. Shore Services and Rescue Action Information

The following units were involved in rescue and lifesaving operations of the Nefryt crew members: services of the shipowner, TMAS service from the University Centre for Maritime and Tropical Medicine in Gdynia, a physician provided by harbour authorities from the port of San Pedro, a clinic (hospital) in San Pedro, a physician providing care to crew members transported by a light aircraft from San Pedro to Abidjan and the polyclinic in Abidjan.

After their return to Poland, the crew members underwent medical examination, as a result of which they received certificates on inability to work for a period from 111 days to 215 days, counting from 27 September 2015.

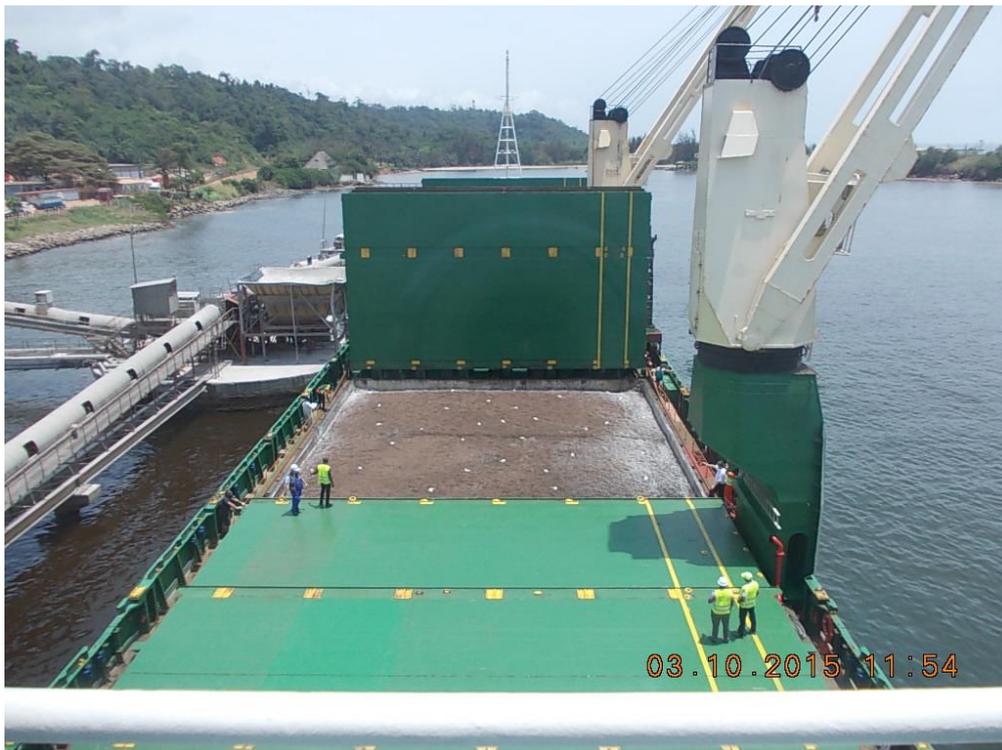
3. Circumstances of the Accident

On 17 September 2015 at 08:20 pm, the ship Nefryt, flying the Maltese flag, weighted an anchor at the roadstead of the port of Abidjan in Ivory Coast. The master submitted the note of readiness (NOR). He informed the agent that the ship was ready for loading, and answered negatively to the question about the necessity of earlier fumigation of the hold.

On the following day, after releasing the anchor at 2:00 am, the ship embarked a pilot at 3:10 am and headed for port. The ship was moored in Abidjan at 4:45 am at berth No 8/9 and the loading of shea nuts¹ in bulk began.

On 23 September 2015 before midnight, when loading was coming to an end and there was only one lorry with shea nuts left to load, the deck crew members, who were not on watch, were called to close the cargo hold hatches and prepare the ship to depart. The loading and trimming of the cargo was completed at 2:00 am on 24 September 2015. The crew closed sections 1 and 2 of cargo hold hatches and began to secure them with hooks.

At around 2:40 am, 2 persons from the land appeared on board and informed the chief officer that they would perform cargo fumigation². The chief officer ordered the cargo hold hatches to be reopened. The fumigators explained that the fumigating agent (fumigant) would begin to work after around 15 minutes from its distribution in the cargo hold and, with their face masks, began to lay out the bags with fumigant and sprinkle them with liquid. The bags were placed (cast) on the surface of the cargo in a way presented on Photograph 2.



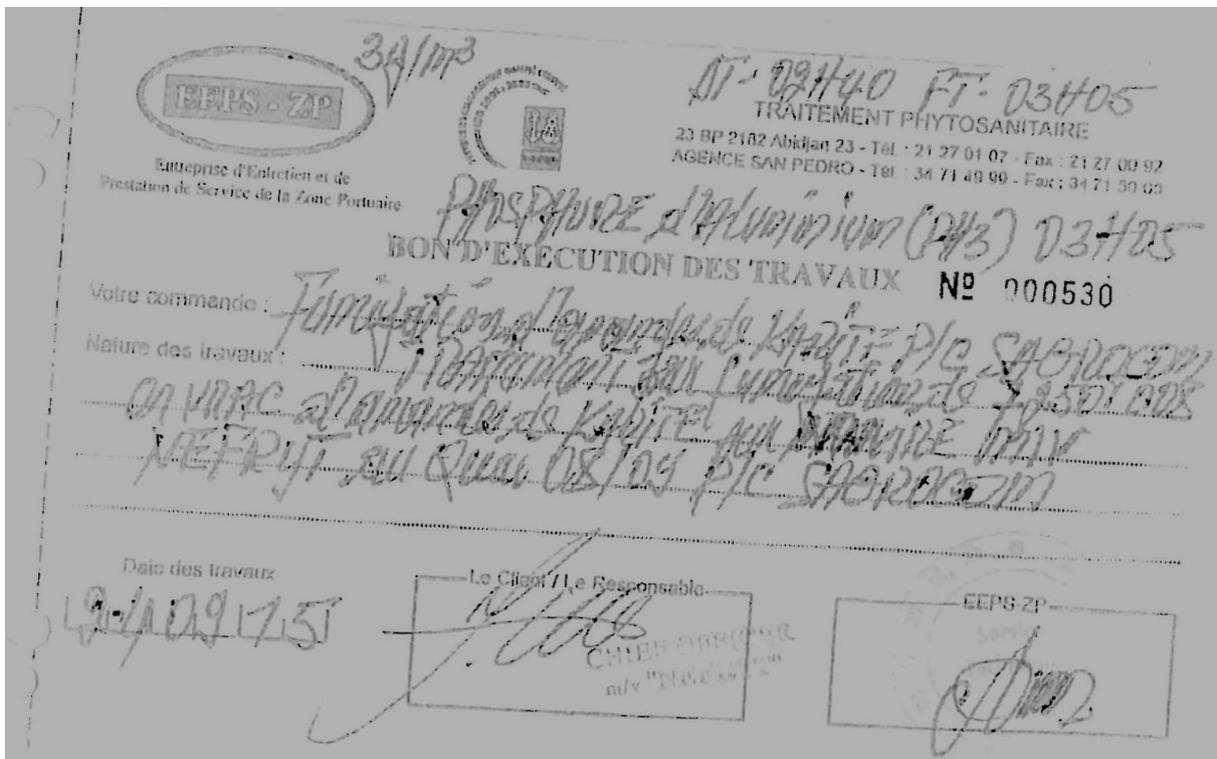
Photograph 2. Bags (white) with fumigant laid out in the cargo hold

¹ Shea nuts (karite) – fruits of the shea tree growing in Central and West Africa, plum-shaped and edible. Inside they have dark brown-red seeds, approximately 2.5 cm long and with a high fat content (around 50%). The nuts are used for producing shea butter (karite) which is the basis for making natural cosmetic and food products.

² Fumigation in a general meaning is a process of using a toxic chemical in gaseous state in a concentration fatal for pests in a cargo.

A total of 120 bags with approximately 18,500 pellets of the fumigating agent were laid out. During the distribution of the preparation, the crew smelled an unidentified sharp odour. When the bags with fumigant were laid out, sections 3 and 4 of the cargo hold hatches were closed as ordered by the chief officer. The chief officer advised the crew to avoid inhaling the smelling substance when closing the hatches.

At 3:05 am, when the hatches were closed and the hooks tightened, the odour was not present anymore. The chief officer signed a receipt confirming the fumigation of cargo with the preparation called *Phosphure d'Aluminium (PH₃)* (Photograph 3). He did not receive any information or warning leaflets about the effects of the fumigant from the fumigators. He entered the information about the fumigation and the name of the fumigant into the deck log.



Photograph 3. Confirmation of the fumigation operations

In the morning, the chief officer informed the master about the cargo fumigation. The master received the information and started to prepare the documents for the ship's departure.

At 11:10 am, a pilot embarked the ship and at 11:50 am the ship unberthed from quay and departed from Abidjan to Buchanan in Liberia. The loading of logs on the ship was planned there.

After lunch, at 1:00 am, the deck crew began to wash the ship and prepare for loading the deck cargo (wooden wedges and steel ropes for fastening the logs were prepared). During the washing of cargo hold hatches, at around 3:00 pm, the seaman who washed them saw a smoke rising at the joining of hatches No 3 and 4 of the ship's hold, at a distance of approximately 1.5 m from the left side. He had called the bosun and together they found that one of the bags with fumigant exhausted thick smoke (as if it was burning) and a sharp strong odour could be felt. The bag was washed overboard and the incident was notified to the officer of the watch on the bridge.

When the work was finished, after dinner, the crew that did not have any watch to perform went to their cabins to rest. Before midnight, the watch motorman advised the third engineer to avoid staying too long in the room adjacent to the ventilation room, adapted for office purposes, since it was filled with a strong smell of horseradish.

On 25 September, starting from midnight, the crew members started to complain about stomach pain, vomiting, diarrhoea, feeling cold and generalised weakness. From early morning hours, the condition of individual crew members began to deteriorate. The symptoms started to worsen by everyone, except for one able bodied seaman. The officer of the watch, to whom subsequent crew members reported their health problems, suggested to the chief officer who was on the bridge although he felt bad to inform the master about the situation. Before 5:00 am, the chief officer called the master. The master, who exhibited similar symptoms, came to the bridge. After the consultation with the remaining officers (all deck officers were on the bridge and all complained about similar health problems), a decision was made to check the condition of other crew members by visiting individual cabins on the ship. The visits were carried out by the second officer assisted by an ordinary seaman. They found that all members of the crew, except for the able bodied seaman who made the round, felt bad. The second officer reported the results to the master on the bridge and then lost consciousness.

After analysing the situation and making another round to check the condition of the crew, the master decided to ask for medical advice by radio. He tried to contact the TMAS³ in Gdynia, but failed. After contacting the DP from the shipowner at approx. 8:30 am and

³ The tasks of the Telemedical Maritime Assistance Service (TMAS) that performs the tasks of the state related to providing medical advice by radio at sea are performed in Poland by the University Centre for Maritime and Tropical Medicine in Gdynia. The phone number to the physician on a 24/7 duty: +48 58 699 84 60 or +48 58 699 85 78, fax No +48 58 699 84 62. E-mail: tmas@ucmmit.gdynia.pl.

reporting the health problems experienced by 16 out of 17 crew members, the master received an additional phone number to the physician on duty at the TMAS and contacted the said physician.

The master reported the following symptoms to the physician: nausea, stomach pain and shivers without increased body temperature. The physician asked how far the ship was from the nearest port, and then suggested that it might be food poisoning or a viral disease. The master confirmed it could be food poisoning as the day before they bought fresh vegetables in Abidjan and they all had vegetable salad for supper. A physician instructed the master on what liquids and medicines can be administered in the case of a severe gastroenteritis, but as the underlying cause of the condition and possible development was unknown, he suggested that the ship enters the nearest port. He also requested that a list of medicines on board be sent to TMAS so that specific available medicines could be administered to crew members.

In line with the TMAS physician's suggestion and recommendation of the shipowner's Emergency Team, at 9:55 am the master changed the ship's course to San Pedro in Ivory Coast, a port 4 hours away. The shipowner decided that a physician would arrive at the ship at the roadstead by a motorboat rented by the agent and the ship would enter the port in case the health condition of any crew member deteriorates or the physician decides it is necessary to get the crew to a hospital.

The master received more and more information on the deteriorating state of the crew. The second mate and the A/B took turns to visit crew cabins on a regular basis, monitoring the health condition of the crew. As one crew member complained about breathing difficulties, an oxygen cylinder was brought to his cabin.

The master sent a list of medicines available on board to TMAS and received recommendations as to the types of liquids and medicines that should be distributed to the crew. The second mate dispensed the medicines indicated by the physician.

After several hours of navigation, with the second mate and A/B on the bridge keeping watch for a dozen or so hours, the ship arrived at the San Pedro roadstead. Past 2:00 pm anchor was dropped about 2.5 NM away from port entry. As according to port authorities the distance was too great to bring a physician by a motorboat, the anchor place was changed and at 3:00 pm anchor was finally dropped about 1 NM south of the port breakwater.

Between 4:50 and 6:30 pm a French-speaking physician arranged by the ship agent, who arrived on a motorboat on board the ship, examined all members of the crew. The

examination consisted in body temperature measurement, visual inspection of the throat, tongue, eye fundus (for hyperaemia). He examined the abdomen of some crew members.

The physician pronounced poisoning of unknown etiology. He did not recommend hospitalisation of crew members. He recommended that the ship remain at anchor until the next day. He gave each crew member a prescription to be dispensed at a pharmacy on the shore. The medicines were bought by the agent and brought on board by seafarer who did not display symptoms of poisoning. About 7:45 pm medicines (mainly for gastric problems) were given to individual crew members, to be taken that evening and the next morning.

When distributing the medicines, the A/B noticed that the third officer had problems with her vision and notified the master. About 8:00 pm the third officer called the bridge and asked the second officer on the anchor watch to replace her on her watch because she was unwell. The second officer agreed although he had been on the bridge for 20 hours. About 9:00 pm the master took over the watch and sent the second officer to rest for 2 hours.

At night from 25 to 26 September 2015, in spite of the medicines they had taken, the condition of the crew members did not improve. Past 3:00 am the chief mate informed the second officer by phone that he had vertigo and was unwell, and asked the second officer to remain on the bridge a little longer on the watch past 4:00 am because he wanted to rest a little longer. About 4:15 am the third officer called the bridge. She informed the officer of the watch that she felt very bad and experienced blurred vision, and that she could not contact the chief mate by phone.

A watchkeeping seafarer sent from the bridge to the chief mate's cabin found that he showed no signs of life. He returned to the bridge and together with the second officer they went to the chief mate's cabin again. They noticed that the chief mate's fingertips and nails were blue, his eyes were blurred and he was cold to the touch. There was no pulse.

At 4:20 am the second officer informed the master that the chief mate was most likely dead. Still before the master came to the chief mate's cabin, the second officer and the A/B started resuscitation.

Upon arrival the master checked chief mate's pulse, but it was not palpable. Even so he ordered to continue resuscitation and oxygen provision. After a while also other crew members joined in.

The master went to the bridge and informed the duty officer at the harbour master's office of the situation on the ship via the VHF radio and asked for immediate medical assistance.

The harbour master officer acknowledged the notification and said he would notify the ship's agent and arrange help.

After an hour and a half, when the chief mate was resuscitated the third officer called the bridge. The master, who came to the bridge to urge the port in sending help in, answered the phone.⁴ The third officer said she had breathing problems. The master went down to her cabin and after a moment he called the second officer to bring an oxygen cylinder. He gave oxygen to the third officer. After a while her condition started to deteriorate, she lost consciousness. Resuscitation started.

Resuscitation using an AMBU in the chief mate's cabin lasted for over 2 hours, until two oxygen cylinders were depleted. The rescuers stopped resuscitation about 7:00 am. At the same time preparation of the ship to weigh anchor to enter the port started.⁵

At 7:50 am, when resuscitation of the third officer was underway, the agent and the physician (the same person who visited the ship the day before) arrived on board. The physician asked about a defibrillator, but there was none aboard. During the examination the physician detected pulse and ordered to continue resuscitation.

Resuscitation continued for several dozen minutes more, until the third officer had an external bleeding. The physician pronounced the third officer deceased at 8:30 am.

The anchor was weighed several minutes earlier. At 8:40 am the pilot came on board the ship and entry to port started. During the manoeuvres one of the A/Bs collapsed. The ship moored at San Pedro berth on 26 September 2015 at 10:00 am.

After mooring, apart from the agent, representatives of port authorities and sanitary authorities, also physicians came on board. The crew was instructed to prepare for a visit in a local hospital. When waiting for an ambulance at the mess, two crew members (electrician and third engineer) started to lose consciousness. When talking to the second officer, the chief engineer learned that the cargo was fumigated before the ship left the loading port (Abidjan). He ordered the second engineer to turn ship ventilation off and the crew to open cabin air ports.

The master informed sanitary authority representatives and physicians it could be possible that the crew had got poisoned with the cargo fumigation agent. He presented the cargo

⁴ The Commission believes that in emergency situations with direct threat to the life of the people on board, the master can call for medical assistance directly to the nearest Rescue Coordination Centre using the MEDEVAC (medical evacuation) procedure from the IAMSAR Manual.

⁵ The master decided to enter the port regardless of port authorities' decision (consent or refusal).

fumigation certificate (a copy of the certificate is shown in Attachment 1). He also informed the shipowner of that fact.

At 11:00 am the ship was granted *Free Pratique*⁶ and the first three crew members were taken to the hospital for examination by an ambulance. After about half an hour 7 more crew members were taken, and more went later.

In San Pedro clinic 15 Nefryt crew members had their blood tested. 14 were also given a drip. Examinations continued, with breaks, until 6:00 am the next day. The examinations failed to identify the cause of poisoning. Physicians from the clinic ordered additional examinations in a better equipped health care centre in Abidjan.

The shipowner decided to immediately transport the crew to Abidjan by plane and to place them at the international polyclinic. The crew refused to go to by plane directly from the San Pedro hospital and crew members returned to the ship to take essential personal belongings. Due to loss of consciousness, one crew member was transported to Abidjan by a light aircraft still on the evening of 26 September, with an assisting physician. 11 poisoned people were transported by plane on 27 September at 7:00 am.

Final 3 crew members whose symptoms were the mildest remained on board the ship until a new crew arrived⁷. They were taken to Abidjan by plane on 28 September 2015.

At the polyclinic in Abidjan, all members of the crew were subject to extended examination as compared to the tests performed at the San Pedro clinic. Two crew members were admitted to the ER ward. All were treated for phosphine gas poisoning.

First 9 people were considered able to travel by plane without medical assistance and discharged from the hospital on 5 October 2015. Four more people went home the next day. The electrician and the third engineer remained at the clinic the longest. They were discharged from the polyclinic on 21 October 2015. They returned to Poland the next day.

Once in Poland, after more examinations by specialised physicians, all crew members were issued certificates of inability to work for 111 to 215 days.

⁶ *Free pratique* – freedom of movement (permit for a ship to contact land, issued by port sanitary authorities). Suspecting haemorrhagic fever on board, port authorities ordered the ship to be fenced in and blocked movement of persons to the ship.

⁷ Five new crew members flew in to Nefryt from Poland on 28 September 2015.

4. The Analysis and Comments about Factors Causing the Accident with Regard to Examination Results and Expert Opinions

During the investigation the Commission learned that Nefryt cargo was fumigated with a preparation with trade name phoslumium⁸ that contains active substance: aluminium phosphide in proportion of 560 g/kg (i.e. 560 g of active substance in one kilogram of preparation) which in reaction with water (or acid) generates phosphine⁹.

Phosphine (chemical formula: PH₃) is a toxic gas used all over the world as a substance to kill insects, mites and rodents in all kinds of stored foodstuffs. Gas is generated using tablets, drops, bags, stripes, tiles and blankets that contain aluminium phosphide.

Phosphine is generated from aluminium phosphide as a result of a chemical reaction which takes place slowly and usually starts within 1 hour after the product is exposed to air. Therefore, tablets or other use forms containing aluminium phosphide can be used without protection of the respiratory tract. Yet phosphine concentration must be monitored to know whether respiratory tract protection is necessary.

The process of gas emission using aluminium phosphide takes a lot of time. The period of fumigated cargo exposure to gas (exposure time) at 20° C and 45–55% relative air humidity is 72 hours. Gas is generated slowly and it may take between 12 and 48 hours before the required phosphine concentration is reached.

Pure PH₃ is a gas that is colourless, odourless, flammable and heavier than air. Technical phosphine used as a fumigant and intermediary product in chemical synthesis smells like garlic or rotten fish.

Phosphine can self-ignite in the air above the flammability threshold exceeding 1.8% (17900 ppm). If phosphine contacts water or acids it may ignite as well. As typical concentration used in gas fumigation is much lower than 17900 ppm, phosphine used for fumigation should not start a fire or cause an explosion¹⁰. To prevent these threats,

⁸ The Commission established that phoslumium is a preparation admitted for use as a fumigation agent in Ivory Coast. (*Liste de pesticides homologues et autorises en Cote d'Ivoire au 16 Decembre 2014. Ministere de l'Agriculture – Republique de Cote d'Ivoire – Direction de la protection des vegetaux, du controle et de la qualite*. List of pesticides certified and admitted for use in Ivory Coast of 16 December 2014, Ministry of Agriculture of the Republic of Ivory Coast, Directorate of Plant Protection and Quality Control).

⁹ Other names of phosphine are: phosphane, phosphamine, phosphorus trihydride, phosphorated hydrogen. Phosphine can be obtained as a result of hydrolysis of phosphides (usually it is aluminium phosphide – AIP) $AIP+3H_2O\rightarrow PH_3 \uparrow +Al(OH)_3$, and by applying acids to metal phosphides.

¹⁰ Self-ignition temperature of chemically pure phosphine is 38°C. Yet residues, especially diphosphides, frequently cause self-ignition of PH₃ at ambient temperature and contribute to generation of explosive mixtures with concentration higher than 1.8% of volume. Experts noticed that inclination of PH₃ to self-ignition is

preparation drops or tablets should always be distributed on the fumigated cargo surface evenly.



Photograph 4. Phosmium bags distributed on top of cargo and placed in a container after the accident, at San Pedro.

The Commission established that on board of Nefryt the quantity of fumigation preparation was calculated adequately to the volume of fumigated cargo in proportion of 3 g/m^3 . The expected effective time of the active substance was calculated at 72 hours.

The effect of the active substance consists in PH_3 penetrating the cargo. After the fumigation, the holds are ventilated and phosphine is released to the air, where it is dispersed and is quickly removed from troposphere, since it turns into phosphine acid which precipitates from the air and falls on the ground where it is adsorbed.

Due to its poisonous properties, PH_3 is dangerous for humans, since even a small quantity of gas may cause headache, nausea, vomiting, drowsiness, coughing and chest tightness. In the case of prolonged contact with PH_3 in higher concentrations, the following symptoms may occur: convulsions, loss of consciousness, cardiac arrhythmia and liver or kidney damage. In general, the longer exposure to phosphine, the more serious the resulting health problems.

The effects of exposure of people to the atmosphere containing phosphine, depending on its concentration:

- 0.3 ppm – exposure for up to 8 hours a day;
- 1.0 ppm – exposure for less than 15 minutes without any effects;

unpredictable. The Commission points to analyses of this phenomenon in two marine incident reports by the Transport Malta Marine Safety Investigation Unit: Safety Investigation Report No. 21/2013 (Explosions in four cargo holds at Rio Grande Outer Anchorage, 22 December 2012) concerning the accident of Theofylaktos and Simplified Safety Investigation Report No. 03/2016 (Explosion in cargo hold no. 5 following departure from Rio Grande, Brazil, 19 March 2015) concerning the accident of Agria.

- 5.0 ppm – exposure for up to 1 hour without life-threatening effects;
- 100 – 190 ppm – exposure for 30–60 minutes results in serious consequences for health;
- 290 – 430 ppm – exposure for 30–60 minutes causes a threat to life;
- 400 – 600 ppm – exposure for 30–60 minutes causes death.

There is no antidote for PH₃. The basic treatment in the case of gas inhaling is to cut out the source of poisoning and providing oxygen to the patient. In the case of acute poisoning with PH₃, as in the case of poisoning with other chemical compounds, the only strategy and the first purpose of treatment is to treat symptoms to support essential life functions. The second goal is to maintain the toxin concentration in essential tissues at the lowest possible level and to increase its removal, while the third goal is to combat toxicological effects in target places (mainly in lungs, kidneys and liver).

4.1. International Requirements for the Use of Pesticides for Cargo Fumigation in Ships and the Relevant Internal Regulations of the Shipowner

The SOLAS Convention, Chapter VI “Carriage of cargoes and oil fuels”, Regulation 4 “The use of pesticides in ships”, stipulates that appropriate precautions shall be taken in the use of pesticides in ships, in particular for the purposes of fumigation and refers to three documents issued by the IMO Maritime Safety Committee (MSC), namely the following circulars: MSC.1/Circ.1358¹¹ of 2010, MSC.1/Circ.1264¹² of 2008 and MSC.1/Circ.1361¹³ of 2010.

The second document, i.e. MSC.1/Circ.1264, is of key importance for fumigation of cargo on general cargo vessels. Its significance is demonstrated by the fact that its contents were included in two IMO codes, i.e. the IMDG Code¹⁴ and the IMSBC Code¹⁵.

The fumigation of cargo carried out on ships is usually the “in-transit fumigation”, i.e. fumigation of cargo in ship cargo holds with the use of gas during the voyage. It consists in applying the fumigating agent to the cargo holds in port, after completion of loading, and

¹¹ MSC.1/Circ.1358 *Revised Recommendations on the safe use of pesticides in ships*. 27 May 2008.

¹² MSC.1/Circ.1264 *Recommendations on the safe use of pesticides in ships applicable to the fumigation of cargo holds*. 30 June 2010.

¹³ MSC.1/Circ.1361 *Revised Recommendations on the safe use of pesticides in ships applicable to the fumigation of cargo transport units*. 27 May 2010.

¹⁴ International Maritime Dangerous Goods Code. Adopted by resolution MSC.122(75), in force since 1 January 2004. The text of MSC.1/Circ.1264 is included in the IMDG Code Supplement.

¹⁵ International Maritime Solid Bulk Cargoes Code. Adopted by resolution MSC.268(85), in force since 1 January 2011. The text of MSC.1/Circ.1264 is included in the IMSBC Code Supplement.

extending the fumigation process for the time of sea voyage. The process usually lasts 2 to 3 days, but some fumigants require a week or more to become fully active, depending on air temperature and humidity.

In transit fumigation reduces the stay of the ship in port. The ship does not have to wait at quay for the result of fumigation. During the cargo fumigation, the crew must maintain caution to prevent exposure to lethal effects of the toxic gas.

MSC.1/Circ.1264 includes guidelines for masters concerning the use of pesticides (fumigants) on ships in a safe way to humans. It defines the methods preventing the infestation of cargo holds and other parts of the ship, the methods of chemical disinfection, describes how fumigants act and provides information about the two major agents used for fumigation, namely: *methyl bromide* and *phosphine*.

The circular provides conditions to be met by both the ship and the crew, as well as by persons performing the fumigation, in order to safely use the pesticides, in particular the precautions for safe cargo fumigation with an active fumigant during the voyage.

The most important requirements include the obligation of the fumigator-in-charge to provide the master with written instructions on the type of fumigant used, the hazards to human health involved and the precautions to be taken, in view of the toxic nature of the fumigant used.

Fumigation in transit should only be carried out at the discretion of the master. No other entity, neither shipowner nor the charterer, may decide instead of the master whether the cargo should be fumigated in a given case. Before a decision is made on fumigation, empty cargo holds should be tested for gas-tightness, and appropriately sealed, if necessary, and the fumigator-in-charge should supply to the master a written statement that the cargo holds are satisfactory for fumigation.

MSC.1/Circ.1264 recommends also taking special precautions, if a decision is made to commence fumigation of cargo in port and its continuation at sea. They include designation of at least 2 crew members (including one officer), who have received appropriate training, as the representatives of the master responsible for ensuring that safe conditions in accommodation, engine-room and other working spaces are maintained after the fumigation and for providing instructions to other members of the crew before a fumigation takes place.

The designated crew members should be provided and familiar with the information about the fumigant included in its Safety Data Sheet (SDS) and the instructions for its use, e.g. on

the fumigant label or package, such as the recommendations of the manufacturer concerning methods of detection of the fumigant in air, its behaviour and hazardous properties, symptoms of poisoning, first aid and special medical treatment and emergency procedures.

The ship where the fumigation is to take place should carry gas-detection equipment, instructions on disposal of residual fumigant material, at least four sets of adequate respiratory protective equipment, as well as a copy of the latest version of the MFAG¹⁶, and appropriate medicines and medical equipment.

After the fumigant is used in the cargo holds, the fumigator-in-charge and the designated crew members must check whether there are no gas leaks and notify the master accordingly. Only then a ship may depart from port.

The circular includes a specimen of “fumigation warning sign” which should be displayed after the use of the fumigant at entrances to all fumigated spaces (Photograph 9) and the model checklist for fumigation. The checklist consists of Part A listing conditions to be met before fumigation and Part B which defines the procedures to be followed after application of fumigant and closing and sealing of cargo holds. The model checklist is presented on the photo in Appendix 2.

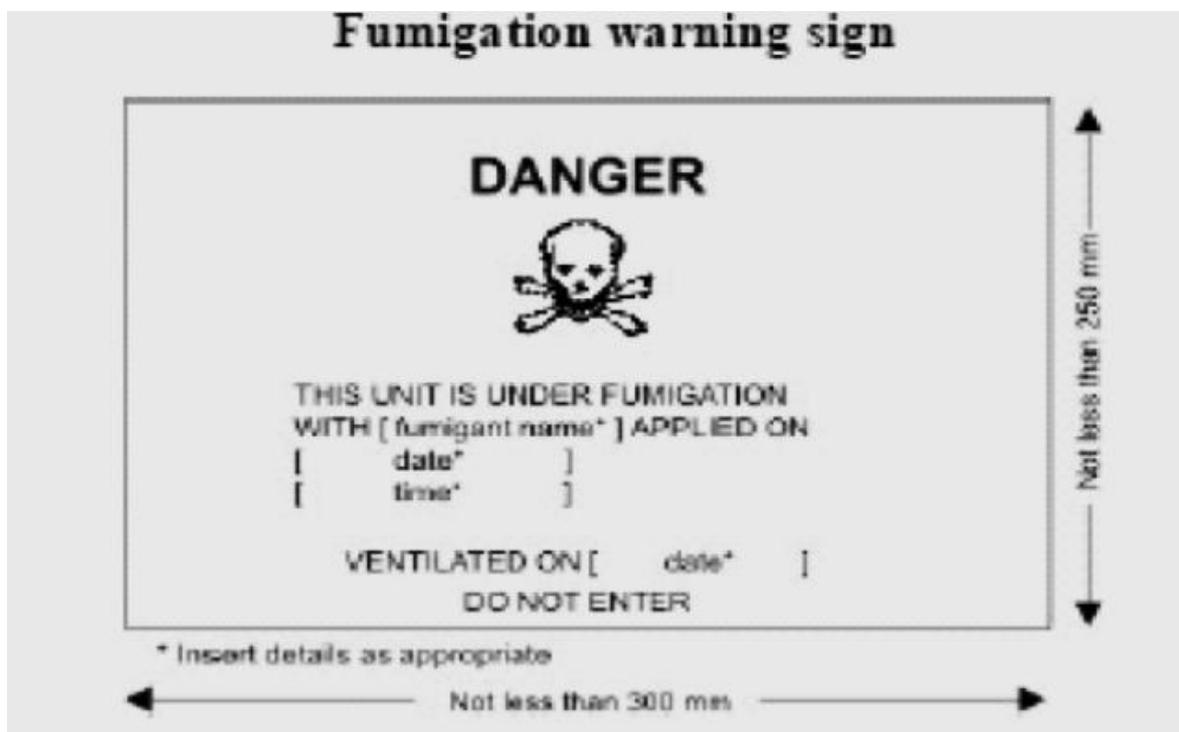


Figure 2. Specimen of the warning sign recommended by IMO

¹⁶ Medical First Aid Guide for Use in Accidents Involving Dangerous Goods.

One of the most important recommendations included in MSC.1/Circ.1264 is the recommendation to perform gas concentration safety checks in such spaces as accommodation, engine-room, navigation bridge and frequently visited working areas. The checks should be performed at least at eight-hour intervals and the readings should be recorded in the ship's log book.

Other - fundamental materials defining the rules of safe fumigation of cargoes in ships include the publication of the International Maritime Fumigation Organisation entitled "Code of Practice on Safety and Efficacy for Marine Fumigation"¹⁷. The publication, which is not a binding legal instrument, but an internal document of the organisation, stipulates the rules and standards constituting guidelines on procedures to be followed in the case of fumigation on the ship that are compliant with the IMO recommendations.

The Nefryt owner regulated the issues related to fumigation on board of its ships in two internal documents comprising the shipowner's Safety Management System (SMS) regarding safety and environmental protection¹⁸: the Cyprus Code of Safe Working Practices for Seafarers¹⁹ and the Health and Safety Guide for ships operated by Euroafrica Linie Żeglugowe in Szczecin²⁰. Both documents include separate sections on the use of pesticides on ships and on cargo fumigation.

The safe use of pesticides is described in paragraph 26.7, Chapter 26 on hazardous substances, of the Cyprus Code. First of all, safety procedures should be in accordance with the IMO publication "Recommendations on Safe Use of Pesticides"²¹, ship's crew should not handle fumigants, fumigation should be carried out with the agreement of the ship's master,

¹⁷ *Code of Practice on Safety and Efficacy for Marine Fumigation*. The International Maritime Fumigation Organisation. IMFO 2010.

¹⁸ As stipulated in Chapter 05 of the Quality and Safety Management Manual, edition 02, 1 June 2013. The Quality and Safety Management Manual is one of the documents constituting the shipowner's quality and safety management system. The system comprises also, pursuant to "Systemic procedure P-01 Supervision over documents": "ship procedures, ship documents, conventions, codes, regulations and guidelines in place in sea transport, nautical charts and publications, Orders, Circulars, Communications of the Marine Safety Department, health and safety and fire protection documentation, website."

¹⁹ *Cyprus Code of Safe Working Practices for Seafarers* (Ministry of Communications and Works. Department of Merchant Shipping. Lemesos. Circular No. 20/2005. 10 August 2005). Polish translation from English – Szczecin, October 2006. The Code applies and functions as a part of the shipowner's SMS system.

²⁰ Health and Safety Guide for ships operated by Euroafrica Linie Żeglugowe in Szczecin. Edition: 1 August 2008.

²¹ The Commission would like to note that the reference used in the document is out-of-date. The information included in the publication referred to in paragraph 26.71 of the Code (i.e. IMO 267E from 1996) is based on MSC/Circ.612 of 1993, as amended, which was repealed in 2010 by MSC.1/Circ.1358 *Revised Recommendations on the safe use of pesticides in ships*. The 2010 Circular is not the applicable document in ships. It is referred to in the SOLAS Convention, in Regulation 4 from Chapter VI.

in-transit fumigation is allowed, provided that safe working conditions are provided for persons who received the appropriate training (at least two crew members, including one officer) and the spaces under fumigation should be appropriately marked.

The Commission points out that the provisions of the Code in paragraph 26.7 only to a small extent refer to fumigation of cargo on ships. They concern mainly the elimination of insects and rodents on ships, prevention of their hatching, as well as control and fumigation of the crew's accommodation spaces and cargo holds. Since the Code has not been updated since 2005, its provisions do not refer to the most important document in this regard, i.e. to MSC.1/Circ.1264 of 2008 on the safe use of pesticides on ships applicable to the fumigation of cargo holds.

The Guide of safe working practices of the shipowner includes more information on the fumigation of cargo. In paragraph 17 of the Guide, the shipowner refers to the conditions for the fumigation of cargo defined in the IMDG Code Supplement and provides the rules applicable to ships flying the Polish flag. The rules include gas-tightness of cargo holds, appropriate functioning of ventilation equipment of the ship, training of the crew on the application and observance of safety measures during loading, carrying and unloading of the fumigated cargo, advising the crew about toxic - poisonous effects of the fumigant, its physical and chemical properties facilitating its detection, first symptoms of poisoning and the principles of first aid. In the case of ships under a foreign flag, the chief officer is considered as the fumigation specialist and has an obligation to ensure the safety of the crew on board during fumigation.

The regulations in the Guide of safe working practices include also "recommendations to be observed during carriage of fumigated cargo with gas exposure." They include: fumigation performed only by an authorised fumigation team, taking into account the instructions of the chief officer and with the consent of the ship's master; closing and sealing of hatches, ventilation ducts and ventilating fans; stamping or sealing with lead, as well as marking the relevant spaces with a skull and crossbones and an inscription in English and Polish warning about the hazard; check performed by the fumigator-in-charge to verify whether the fumigating agent, e.g. phosphine, does not permeate to any other spaces except for the fumigated cargo holds.

The Guide requires that the chief officer responsible for fumigation should have a document confirming the fumigation and specifying the dose of the agent used and the

readings of gas concentration measurements performed by the fumigator in charge after the completion of loading, stating that no gas leak from cargo holds was detected.

The Guide of safe working practices also recommends that gas concentration checks should be made during the voyage at least at four-hour intervals in order to detect possible gas leaks. The checks should be carried out in line with the plan of measurements drawn up by the fumigation specialist and approved by the ship's master. If the highest acceptable gas concentration is exceeded, the master should immediately take protective measures, consisting in evacuation of the crew from the places at risk and elimination of gas leakage, if the relevant place was found and may be sealed.

Apart from the said two documents comprising the SMS, fumigation of cargo holds and cargo is also discussed in the standard instruction for voyages for the vessels operating in West Africa line, which constitutes an annex to the Communication of the Marine Safety Department No. 18/BI/2012. The instruction stipulates i.a. that if the carriage contract requires fumigation of cargo in ship cargo holds, the instruction included in the Health and Safety Guide and recommendations included in the IMDG Code Supplement (*Recommendations of the Safe use of pesticides in ships*) and states that fumigation may only be carried out with the knowledge and consent of the masters, and in case of doubts recommends consulting a specialist on safe working practices or with the shipowner's operating department.

4.2. Mechanical Factors

The mechanical factor that contributed to the incident were leaks in the ventilation trunk of the air conditioning system running inside the starboard side ventilation casing of cargo hold that supplies air to the air conditioning control room and further on to living quarters in ship superstructure (Figure 3).

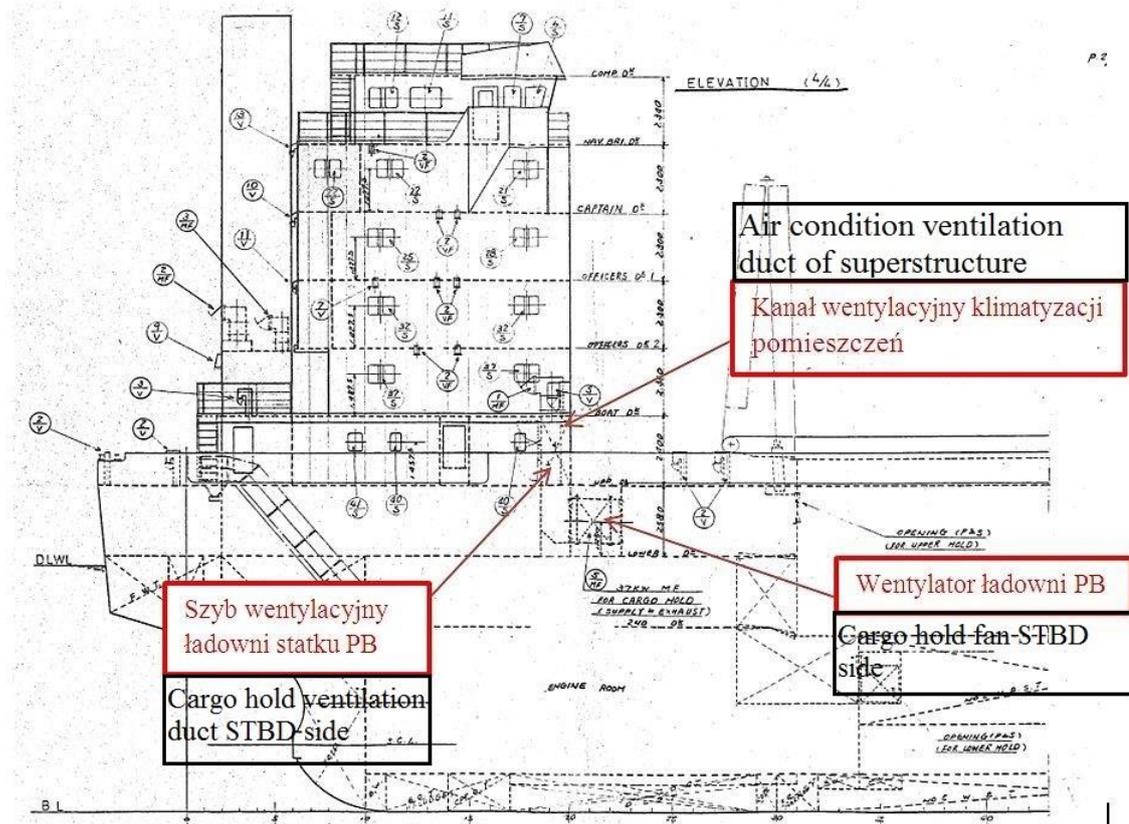


Figure 3. Location of ventilation casing of cargo hold and air conditioning trunk in crew living quarters on ship starboard side.

To enhance the air cooling effect, the air conditioning system in living quarters on Nefryt worked in recirculation mode: air inlet was on the corridor on the superstructure lower deck. Leaks in the upper part of the air conditioning ventilation trunk inside the cargo hold ventilation casing allowed poisonous gas from the fumigated cargo hold to get to the air conditioning control room by the ventilation trunk (Figure 4).

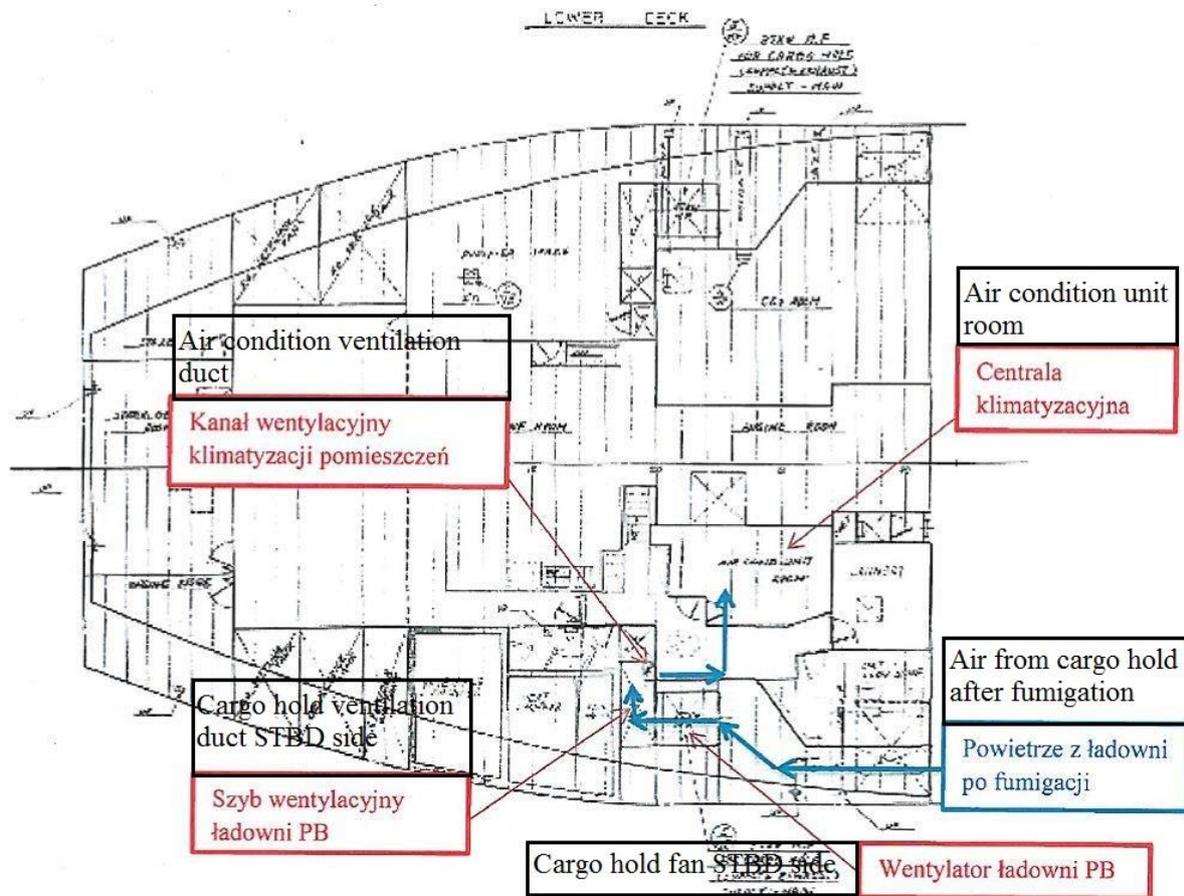


Figure 4. Location of the ventilation casing and trunk on lower deck of Nefryt superstructure.

The air conditioning unit sucked in poisonous phosphine gas from leaking ventilation casing and air from the inside of the superstructure which, after cooling and drying, was sent as a mixture of poisonous gas and air to crew living quarters. Thus, each recirculation cycle of cooled air from the superstructure increased the concentration of poisonous gas blown into the living quarters.



Photograph 5. Air conditioning inlet in ship superstructure on boat deck on starboard side.

Air conditioning inlet in ship superstructure on boat deck on starboard side (Photograph 5) has most probably not been closed after the ship left the port, but even if it was, it would not eliminate the threat of sucking in poisonous gas from the cargo hold generated during cargo fumigation.

The ventilation trunk of superstructure air conditioning system running inside the stern cargo hold ventilation casing²² on starboard side was considerably corroded. There were pronounced cracks in the upper part of the trunk next to gussets along welded metal sheet joints of cargo hold ventilation trunk and the air conditioning trunk, there were visible cracks in the place of the previous repair at the meeting place of both ducts. One of these cracks is shown in photograph 6 taken at San Pedro port on 3 October 2015. Signs of the previous repair are visible in the lower wall of the air conditioning trunk.

²² The Commission established that the existing classification requirements for ship construction and structure do not exclude such a structure. Neither the regulations of the current (PRS) nor of the present classifier (Lloyd's Register) forbid a ventilation trunk to run in the second ventilation trunk or trunks to have adjacent walls.



Photograph 6. Cracks in the upper part of the air conditioning ventilation trunk on welded joints of metal sheets in the ventilation casing of ship starboard side cargo hold.

The Commission established that during the between voyage repair, when the ship was in Gdańsk in November 2014, the damaged front superstructure plate was repaired (during maintenance, two holes leading to cargo hold ventilation trunk were tapped out) on the starboard side at about 2 m over the main deck by cutting and welding in the plate two patches of steel plate with dimensions of 300 x 300 x 8 mm and 300 x 400 x 8 mm. The repair of the front superstructure wall which is at the same time the front wall of the ventilation casing of the cargo hold and the ventilation trunk of air conditioning, was done from the outside (from the deck side). After the repair no in-depth inspection of the condition of both ventilation trunks from the inside was carried out and the cracks were not detected (weld cavity) between the ventilation casing of the cargo hold and the ventilation trunk of air conditioning.

Only careful visual inspection and repair after the accident, i.e. crew poisoning with gas from the cargo hold in October 2015, have shown the actual technical condition of both ventilation trunks, extensive corrosion on trunk metal sheets and cracks at the welded joints.

The condition of some trunks before and after the repair is presented in photographs 7 (taken on 21 October 2015) and 8 (taken on 28 October 2015).



Photograph 7. Air conditioning ventilation trunk before the repair.



Photograph 8. Air conditioning ventilation trunk after the repair.

The technical condition of the air conditioning ventilation trunk was not checked during the flag state control on 18 August 2015 in Aarhus, Denmark, or during ship controls by its classification society (PRS).

Ventilation trunk leaks were not discovered by the ship crew obliged to perform monthly ventilation trunk inspections according to the shipowner's computer database system for

planning and reporting periodic works MRS as the crew was only obliged to perform external visual inspection of ship's ventilation trunks.²³

Ventilation trunk inspection for gas tightness was not performed by the shipowner's specialists either, even in spite of the fact that such a visual inspection is required by the shipowner's by-laws collected in the shipowner's guide of safe working practices in point 17 that concerns cargo fumigation in ship cargo holds. According to these provisions: "A ship that serves for transport of cargo with gas exposure during voyage should undergo a visual inspection of cargo hold structure by the shipowner's specialists, with attention paid to its gas tightness or potential for adequate insulation. It concerns particularly hatches, manholes, emergency exits and similar communication openings as well as holes for pipelines, ventilation pipes, electricity cables, etc."²⁴.

The rules of ship condition maintenance are defined in the shipowner's Quality and Safety Management Book. Chapter 16 of the Quality and Safety Management Book says that ship inspections for the purpose of evaluating actions connected with ship maintenance are to be performed by Technical Division staff at specified intervals. Supervision of the technical condition of a given ship is exercised by the Superintendent. The Superintendent carries out inspections and drafts protocols thereof.

The Commission noticed that in checklist 01/P-12 "Protocol from superintendent's inspection" issued on the basis of System procedure p-12 "Rules of ship maintenance and equipment" there is no item on evaluation of the condition of cargo hold ventilation trunks.

The Commission established that ship class society (PRS) provisions do not provide for a visual inspection of the internal condition of ventilation trunks during ship operation or during annual, intermediate or class renewal inspections. The class society provides for a visual inspection of ventilation trunk condition from the outside during cargo hold condition inspection. The Commission also established that the regulations of the ship's previous class society did not provide for this kind of inspection either.

²³ Analysis of the periodic works records by Nefryt crew concerning ventilation trunks shows that inspections were carried out in line with the requirements, once a month, and there were no comments as to their technical condition. The most recent inspection by the ship's chief mate was recorded in the MRS system on 4 September 2015.

The Commission would like to emphasise that the shipowner's documents use two acronyms: MRS and PMS alternatively to refer to the same system. For example in Chapter 16 of the Quality and Safety Management Book there is MRS while in procedures P-12 and PS-10* PMS is used.

²⁴ According to explanations provided by the shipowner, "shipowner's specialists" referred to in point 17 of the guide of safe working practices who are supposed to perform a visual inspection of cargo hold structure on the shipowner's ships are chief mates.

4.3. Human Factors (fault and neglect)

The chief mate and master of Nefryt did not follow the requirements laid down in both the shipowner's by-laws and international requirements on ship cargo fumigation.

The chief mate did not inform the master of the planned fumigation and did not receive the master's consent. The chief mate did not inform the master that he did not receive information on the effect of the product used and of its hazard to humans from the fumigators. The chief mate did not check, together with the person responsible for distribution of the fumigant, if there were gas leaks on the ship and failed to inform the master thereof. The chief mate did not prepare a plan of gas concentration measurements in crew living quarters and work places, which should be approved by the master.

After obtaining information on completed fumigation, the master did not check whether there were relevant documents that should have been left by the fumigators, saying what kind of fumigant was applied²⁵, its hazards and whether the entire crew was notified of and trained for the fumigation. He did not ensure that after the ship left the port gas concentration measurements were carried out and there fumigation warning signs were displayed (such signs were displayed on the ship several days after the accident when the ship was in San Pedro port, during cargo hold ventilation from phosphine gas residues – photograph 9).

Having been informed about fumigant "fire" by phone by the A/B during his watch at the bridge when the ship departed from the Abidjan port, the second officer of Nefryt failed to pass this information on to the chief mate or to the master and did not record the event in the log book. Thus, he did not draw the ship's management attention to atypical properties or violent reaction of the fumigant, which accidentally got in between cargo hold flaps, to water.

The Commission included the mistakes of the fumigation team in the organisational factors that contributed to the incident. They are presented in point 4.4 of the report.

²⁵ The master did not notice that the documents provided by the agent before the ship left the port lacked a cargo fumigation certificate. The certificate (Attachment 1) was sent to the ship by e-mail. The certificate states PH₃ gas as the fumigant.



Photograph 9. Entry to the Nefryt cargo hold marked during ventilation with a sign warning of fumigation using PH₃.

The Commission concluded that a factor having considerable influence on the course of the rescue operation was that the master wrongly interpreted the symptoms displayed by the crew members as food poisoning because the seafarer who did not have fresh vegetables bought in Abidjan for supper on 24 September 2015 showed no signs of poisoning²⁶.

The Commission established that he was the only crew member who did not use the A/C in his cabin and had an open air port all the time since ship's departure from Abidjan to mooring at San Pedro. The Commission also established that neither the third officer nor the chief mate had fresh vegetables for supper and both of them initially had the same symptoms as the other crew members.

This wrong assumption as to the cause of poisoning was in force until 27 September 2015 as the Marine Accident/Incident Report Form A filled in on that day and sent to the Nefryt flag administration on the next day by the master stated that the cause of death of the chief

²⁶ The opinion drafted for the Commission by the Prof. Dr. Jan Sehn Institute of Forensic Research in Cracow on the basis of analyses of food samples collected by the Commission on Nefryt says that the samples did not contain toxic substances with various effects on human body in concentrations that would allow identification of these substances.

mate and the third officer was “probable food poisoning”²⁷. *Due to this error of judgment, the effort of the medical officer (second officer) on board, advice from Gdynia TMAS and the first visit of a physician on board at San Pedro roadstead focused on treatment of food poisoning symptoms instead of treatment of poisoning with gas from fumigated cargo hold. Delay in establishing the actual cause of poisoning was crucial as crew members who sought to rest in their cabins were ultimately exposed to inhaling new doses of phosphine gas.*

The Commission also noticed an incorrect resuscitation technique applied by ship crew members. Instead of the recommended 30 presses on the chest and 2 breaths for correct cardiopulmonary resuscitation, the seafarers received 6 or 10 presses and 1 breath. Most probably it did not affect the result of resuscitation, but the seafarers on the ship and primarily those who underwent a training in medical care and received a Certificate of Training in Medical Care should know how to perform correct resuscitation.

4.4. Organisational Factors

The voyage charter contract between the ship operator and the charterer for transport of shea nuts from Abidjan (Ivory Coast) to Aarhus (Denmark) included a rider clause marked as No 24 that allowed the charterer to fumigate cargo after loading at the Abidjan port was completed²⁸.

According to the clause, the charterer or shipper was obliged to introduce the measures specified in the Supplement to the IMDG Code concerning safe use of pesticides (the safety measures listed in circular MSC.1/Circ.1264). The clause committed the charterer to take several important actions before and during fumigation, such as: to inform the master about the fumigation at least before loading (not after loading), to perform a gas tightness test of an empty cargo hold (to prevent penetration of the fumigant to living quarters, engine room and other areas where the crew works) and provide the master with a written declaration that the cargo hold was fit for fumigation, to provide the master with the necessary documents, including the MSDS card, with information on safety measures and safe gas concentration values (TLV), to have the fumigator provide the ship with an adequate number of gauges necessary to measure gas concentration throughout the voyage and to have the charterer

²⁷ The Commission emphasises that on 27 September 2015 tests for PH₃ were carried out on board of Nefryt and revealed presence of this poisonous gas in many places, including the master’s cabin.

²⁸ Contract of 3 September 2015 on a GENCON form between Euroafrica Shipping Lines and Tan Mondial from Singapore. The full clause 24 is quoted in Attachment 3.

supply the ship with the necessary medicines and medical equipment (required for treatment of the potential effects of fumigant poisoning), depending on the properties of the fumigant applied.

The charterer failed to discharge all of these duties.

The parties to the contract also agreed that the master may consent to ship fumigation only once the above conditions are met. The decision on fumigation was made by the chief mate, of which the master was not informed.

5. Description of Examination Findings Including the Identification of Safety Issues and Conclusions.

As a result of investigation, the Commission established that the reason behind the Nefryt incident was long-term exposure of the crew members to poisonous phosphine gas. The gas generated during cargo fumigation went up the air conditioning ventilation trunk through the A/C control room and, together with cooled and dried air, made its way to the living quarters of the crew.

The tragic accident occurred due to a leak in the air conditioning ventilation trunk inside the ventilation casing of the cargo hold where the cargo was fumigated with phosplumium, which was contrary to the applicable procedures.

The leaks could have been detected and eliminated, if the ship which was to carry the fumigated cargo with gas exposure during voyage (the charter contract allowed for cargo fumigation) had underwent, in line with the shipowner's internal regulations, a visual inspection of cargo hold structure by the shipowner's specialists, with attention paid to its gas tightness or potential for adequate sealing.

Such accident probably would not have happened, if the regulations of the ship's classification society (PRS) provided for the possibility of placing one ventilation trunk inside another ventilation trunk (or the contact of their walls) and the inspections of the insides of those trunks.

Since the fumigation was carried out in breach of the conditions laid down in the charter contract and contrary to the requirements of the shipowner's internal regulations and the international law, the actions important for human safety were not taken; this concerned in particular the failure to detect the leak of PH₃ to the spaces in the ships' superstructure.

Although both the master and the chief officers were holders of Certificates of Training in Hazardous Cargo Carriage on Vessels, they did not use their knowledge and the IMDG Code on board, which included the Supplement with recommendations on safe in-transit fumigation of cargo exposed to gas.

The master was an experienced employee of the shipowner. He sailed on the West Africa line for around a dozen years, but both he and the chief officer, as well as the majority of the Nefryt crew did not have vast experience with this type of cargo fumigation. When the ship departed to sea after the fumigation, the master did not know which fumigant was used and what kind of hazard it might pose for the crew.

The chief officer spent all his maritime practice, after graduation from the Maritime University, on the ships of the same owner, i.e. Euroafrica Services Limited, operating on West Africa lines, and was gradually promoted to subsequent positions. Nefryt was his second ship, under the third contract as the chief officer, and his entire career from graduation lasted 4 years (he became the chief officer after 2.5 years). The chief officer carried the same cargo of shea nuts on his previous voyage, but the cargo was not fumigated. On the ill-fated voyage, he did not expect fumigation and did not know how to proceed.

The majority of the Nefryt crew members, except for several seamen who witness the placement of the fumigant in cargo holds after the loading, did not know about the fumigation. Some of them learned about it after two days. The Commission established that the crews on the ships of this owner were not always informed about the fumigation and did not receive instructions on the fumigant used and the procedure to be followed in case of poisoning.

The shipowner's SMS system includes numerous requirements in: the Quality and Safety Management Manual, ship's procedures for safe operation in normal conditions and in high risk conditions, ship's procedures for actions in emergency situations, procedures or instructions relating to health and safety at work, and other documents, supervised in line with the applicable systemic procedure P-01 "Supervision over documents".

Among 18 ship's procedures concerning both normal operation of the ship (12 procedures) and high risk operation of the ship (6 procedures), there is no procedure to be followed by the crew in the case of cargo fumigation²⁹.

²⁹ The existing ship's procedure PS-26 "Handling of chemical substances and preparations" does not refer to the carried cargo.

In Chapter 13 of the QSM Manual, the shipowner stipulated that “Typical ship’s operations and high risk operations shall be reviewed in terms of safety and environmental protection. Procedures shall be developed for operations that, if inappropriately performed, may pose a hazard to safety and the environment.”

In the systemic procedure P-10 “Review, development and updating of ship’s procedures/instructions (for operations having an impact on safety)”, which specifies the requirements for identification of key ship’s operations and development of procedures for those operations, the shipowner defines the operating procedure as a document describing the procedure to be followed when performing actions resulting from normal ship operation. Actions described in such procedures, if performed in line with the said procedure, should not pose a threat to safety and environmental protection. The procedure for high risk operation, according to the shipowner, is a document describing the procedure to be followed when performing operations classified as high risk operations. High risk operations are understood as operations with respect to which preventive measures should be taken to minimize the risk that they pose for safety or environmental protection.

The lack of a separate procedure for cargo fumigation on board means that such operations were not considered by the shipowner as high risk operations. The conditions for cargo fumigation, as described in the Guide of safe working practices paragraph 17 “Fumigation of cargo in ship cargo holds”, cannot be deemed as procedures. The information provided in the document constitutes only a set of good practices related to preparation of a ship for fumigation, the fumigation itself, ventilation of cargo holds and cargo at the port of discharge, along with recommendations on safety at the port of loading, during the voyage and at the port of discharge. Similarly, the rules to be followed when using pesticides, as described in the Cyprus Code of Safe Working Practices for Seafarers, cannot be treated as procedures, but only as guidelines for the use of pesticides on board the ships.

In the opinion of the Commission, dispersion of information on cargo fumigation in different documents of the shipowner is not good for transparency and the crew’s understanding of the procedure to be followed in the case of fumigation. The shipowner’s document do not include a direct reference to the IMO’s recommendations included in MSC.1/Circ.1264.

Deaths or injuries of the ship’s crew due to phosphine (PH₃) poisoning are not rare. In recent years, the following incidents were reported: death of a Polish seaman in 2008 on the

ship Monika, flying the flag of Antigua and Barbuda, which carried a cargo of grain, and poisoning of 16 Chinese seamen on the Liberian ship Hermann Schoening which also carried a fumigated cargo of grain, on the Erie Lake in Canada in 2010.

6. Actions taken

After the incident, both the shipowner and the classification society took corrective and preventive actions which may contribute to avoiding similar incidents in future.

6.1. Shipowner

Several days after the accident on Nefryt, the shipowner conducted a technical survey of the ship in San Pedro in order to find out how the fumigant could get into crew spaces. An inspector of the classification society participated in the survey. Leaks were found between the superstructure ventilation trunk and the stern ventilation casing of the hold on the starboard side. Before the voyage was resumed, the ventilation trunk leading to the superstructure had been sealed from the side of the ventilation room.

When shea nuts had been unloaded at the destination port of Aarhus in Denmark, the shipowner performed, under supervision of the classification society, the repair of the ventilation trunk located inside the starboard side ventilation trunk of the cargo hold.

The shipowner decided to replace the 2560 mm long section of the ventilation trunk. Over 6 m² of steel sheet plate were replaced (Photograph 8). After the repair, the tightness tests were performed with the use of compressed air.

The shipowner's Marine Safety Department sent two messages to the ships concerning the accident on Nefryt and specifying the recommended actions.

In the first Message No 16/BN/BI/2015 of 9 October 2015, the shipowner imposed an obligation on the masters of its ships to review the regulations on fumigation, including the IMDG Code, the BC Code³⁰, IMO circulars MSC.1/Circ.1264 and MSC.1/Circ.1358, the Guide of safe working practices and the Cyprus Code of Safe Working Practices for Seafarers. The shipowner recommended to fill any possible gaps in the documents and deliver trainings

³⁰ The Commission notes that the BC Code was withdrawn from ships in 2010 and was replaced with the IMSBC Code.

to the crews of ships of West Africa lines to familiarise them with procedures related to fumigation.

In the second Message No 17/DT/2015 of 9 November 2015, the shipowner recommended that the crews of its ships should pay attention to the construction of Nefryt and her sister vessels in terms of hazards which may occur due to fumigation, including in particular the ventilation trunk providing air to the superstructure ventilation system and running inside the stern starboard side ventilation duct of the cargo hold. The shipowner recommended an obligatory survey of the said ventilation trunk, both outside and inside, and checking its leak tightness. In the case of any leaks in the ventilation trunk, the shipowner recommended to carry out the required repairs and prohibited loading toxic materials and performing cargo fumigation until the repairs would have been completed. In addition, the shipowner recommended to perform inspections of ventilation trunks on ships at least once in 6 months and imposed an obligation on chief officers to include the inspections in the system of planned maintenance (MRS) and to record all performed inspections and repairs in the system.

The shipowner also equipped Nefryt with an additional electronic single gas detector to measure PH₃ concentration.

6.2. Classification society

Polski Rejestr Statków S.A. informed the previous classification society of the ship, i.e. Lloyd's Register, about the accident to enable it to undertake appropriate measures towards the ships with similar technical solutions in the register.

PRS recommended that shipowners of general cargo vessels and bulk carriers classed with PRS should complete the ship's procedures in their SMS systems in the risk management part with an additional risk assessment to be performed in the case of cargo fumigation.

PRS initiated the amendments to its own regulations on ship construction. In Part VI of the Rules for the Classification and Construction of Sea-going Ships, titled Machinery Installations and Refrigerating Plants, in Chapter 11 on ventilation systems. PRS added a new regulation No 11.5 "Ventilation of Cargo Spaces" which reads as follows: "Considering the fumigation operation of cargo holds, ventilation ducts must not have shared structural elements (e.g. common divisions) with ventilation ducts running to any other ships spaces, such as crew spaces, machinery spaces and other working spaces as defined by IMO in

paragraph 3.3.2.3 of MSC.1/Circ.1264, the Recommendations on the Safe Use of Pesticides in Ships Applicable to the Fumigation of Cargo Holds, as amended.”

The new regulations are to apply to newly built ships. Therefore, new ship cannot have ventilation ducts with common divisions. There will be no need to inspect their condition from the inside.

As regards the existing ships, including Nefryt, PRS introduced an information to the ships’ statutory obligations to carry out detailed visual inspection of common parts of ventilation trunks during intermediate and renewal surveys. This means that twice within every 5 years the PRS inspectors will perform a visual inspection of the internal part of the ventilation casing of the ship’s cargo holds. PRS also imposed an obligation on the shipowner to check the leak tightness of the trunks before each fumigation.

7. Safety Recommendations

The State Maritime Accident Investigation Commission has deemed it expedient to issue recommendations on safety, which are proposal of action, which could contribute to preventing similar accidents in future.

7.1. Shipowner

Since the Nefryt shipowner repaired the ventilation trunk of the ventilation system, the Commission has decided that there is no need to formulate recommendations in this regard. The Commission considered the actions taken by the shipowner right after the accident and later to be appropriate corrective and preventive measures³¹, but nevertheless deemed them insufficient.

The State Maritime Accident Investigation Commission recommends that the owner of Nefryt, i.e. Euroafrica Services Limited, should:

- 1) develop and add to the list of “ship’s procedure for normal operation and high risk operations” in the Quality and Safety Management Manual a ship’s procedure for cargo fumigation, with checklists for in-transit fumigation of cargo, recommended by the IMO in MSC.1/Circ.1264;

³¹ Minutes from the meeting of the Accident Commission on the incident on Nefryt, 25–26 November 2015.

- 2) add a subparagraph concerning the assessment of technical condition of ventilation trunks and casings on the ship in the checklist on form 01/P-12 “Protocol of superintendent’s inspection” in paragraph 6 “Deck equipment and devices” or in paragraph 3 “Deck cargo holds/tanks”;
- 3) furnish the ships of its fleet with automated external defibrillators (AED) which analyse the heart rhythm and allow to establish whether the injured needs defibrillation.

7.2. Flag State Administration

The Commission prepared recommendations for the Transport of Malta Merchant Shipping Directorate, representing the flag state administration on the day of accident, concerning the extension of the scope of flag state inspection to enable the flag state inspectors to check also the technical condition of the ship’s ventilation systems, but due to the change of the ship’s country of registration within the period from the accident to the day of drafting the report, the Commission decided to send to the Maltese administration only a copy of this Final Report for information purposes.

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10. Glossary and Abbreviations

- DP (Designated Person) – a person designated by the shipowner to ensure the safe operation of the ship and provide a link between the ship and the shipowner
- QSM Manual – Quality and Safety Management Manual
- MRS – Maintenance Reporting System, a computer system of technical supervision of the owner’s fleet; a database system specifying the dates of planned surveys, maintenance and tests, and including records on those actions
- ppm – parts per million, the number of parts of a given substance in a million parts of the mixture of which the substance is a component
- PMS – Planned Maintenance System
- PRS – Polski Rejestr Statków S.A. (classification society)
- SDS – Safety Data Sheet of a given product in terms of characteristics which determine its safe (or not safe) properties; the acronym MSDS (Material Safety Data Sheet) is also used to highlight the material safety data of a given product
- SMS – Safety Management System
- TLV – threshold limit value, acceptable limit of a chemical to which an employee may be exposed during everyday work, without any negative effects
- TMAS – Telemedical Maritime Assistance Service
- UCMTM – University Centre for Maritime and Tropical Medicine
- UTC – Universal Time Coordinated

11. Information Sources

Notification of the accident

Materials from hearing of witnesses

Materials received from Transport Malta Marine Safety Investigation Unit

Ship's documents and plans received from the shipowner

Documents received from the ship's classification society

Opinion of the Prof. Dr. Jan Sehn Institute of Forensic Research with the chemical and toxicological analysis of food samples from Nefryt

Expert opinion drafted by Hamilton Poland S.A. from Gdynia, i.e. an institutional expert of the SMAIC

12. Composition of the Accident Investigative Team

The team carrying research activities has been composed of:

Team leader: Krzysztof Kuropieska – SMAIC member

Team member: Marek Szymankiewicz – SMAIC Secretary

Team member: Tadeusz Gontarek – SMAIC member

Annexes

Annex 1

Certificate of cargo fumigation on Nefryt



Entreprise d'Entretien et de
Prestation de Service de la Zone Portuaire

N/REF : KYA/09/2014-2015
OBJET : AD 6701 /EEPSZP/09/2015

Abidjan, le 25 Septembre 2015

ATTESTATION DE DESINFECTION

NOUS SOUSSIGNEES **E.E.P.S.-Z.P.**, ATTESTONS AVOIR DESINFECTE PAR NOS SOINS :

DATE : 24/09/2015
PRODUIT : AMENDE DE KARITE, RECOLTE 2015
ORIGINE : COTE D'IVOIRE
DEMANDEUR : SAGROCOM SARL
01 BP 975 BOBO DIOULASSO 01
BURKINA FASO, WEST AFRICA
DESTINATAIRE : TAN MONDIAL PTE LTD,
70A AMOY STREET
SINGAPORE 069889
NOMBRE : EN VRAC
POIDS BRUT : 7 250 008 KGS
POIDS NET : 7 250 008 KGS
DOSSIER : 15131682
MARQUE : S/M
NAVIRE : NEFRYT
DESTINATION : AMSTERDAM (EU)
DESCRIPTION DU TRAITEMENT : FUMIGATION S/B AU PHOSPHURE D'ALUMINIUM PH_3
DOSE : 3g/m^3
DUREE : 72 HEURES

EN FOI DE QUOI NOUS VOUS DELIVRONS LA PRESENTE ATTESTATION POUR
SERVIR ET VALOIR CE QUE DE DROIT./

LE DIRECTEUR TECHNIQUE
P.O KOUADIO CATHERINE



TRAITEMENT PHYTOSANITAIRE : Fumigation, Désinsectisation, Désinfection, Dératisation, Entretien espaces verts, Hygiène publique...

SARL au capital de 7 000 000 F CFA - Rue de la pointe aux fumeurs Vridi - 23 BP 2182 Abidjan 23 - Tél. : (225) 21 27 01 07 - Fax : (225) 21 27 00 92
RCCM : CI-AR.L-1997-B-210015 - CC : 9717391 H - Régime d'imposition : réel normal - Centre des Impôts de Vridi

Model checklist for in-transit fumigation, Part A and Part B, recommended by the IMO

<p style="text-align: right;">MSC.1/Circ.1264 ANNEX Page 13</p> <p style="text-align: center;">APPENDIX 3 MODEL CHECKLIST FOR IN-TRANSIT FUMIGATION</p> <p>Date: Port: Terminal/Quay: Ship's name: Type of fumigant: Method of application: Date & time fumigation commenced: Name of fumigator/company:</p> <p>The master and fumigator-in-charge, or their representatives, should complete the checklist jointly. The purpose of this checklist is to ensure that the responsibilities and requirements of 3.3.2.11, and 3.3.2.12 are carried out fully for in-transit fumigation under section 3.3.2.9.</p> <p>Safety of operations requires that all questions should be answered affirmatively by ticking the appropriate boxes. If this is not possible, the reason should be given and agreement reached upon precautions to be taken between ship and fumigator-in-charge. If a question is considered to be not applicable write "n/a", explaining why, if appropriate.</p> <p style="text-align: center;">PART A: BEFORE FUMIGATION</p> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 80%;"></th> <th style="width: 5%; text-align: center;">SHIP</th> <th style="width: 15%; text-align: center;">FUMIGATOR- IN-CHARGE</th> </tr> </thead> <tbody> <tr> <td>1 The inspection required before loading has been performed (3.3.2.4)</td> <td style="text-align: center;">[]</td> <td style="text-align: center;">[]</td> </tr> <tr> <td>2 All the cargo holds to be fumigated are satisfactory for fumigation</td> <td style="text-align: center;">[]</td> <td style="text-align: center;">[]</td> </tr> <tr> <td>3 Spaces, where found not to be satisfactory, have been sealed</td> <td style="text-align: center;">[]</td> <td style="text-align: center;">[]</td> </tr> <tr> <td>4 The master or his trained representatives have been made aware of the specific areas to be checked for gas concentrations throughout the fumigation period</td> <td style="text-align: center;">[]</td> <td style="text-align: center;">[]</td> </tr> <tr> <td>5 The master or his trained representatives have been made familiar with the fumigant label, detection methods, safety procedures and emergency procedures (refer to 3.3.2.6)</td> <td style="text-align: center;">[]</td> <td style="text-align: center;">[]</td> </tr> <tr> <td>6 The fumigator-in-charge has ensured that gas-detection and respiratory protection equipment carried on the ship is in good order, and that adequate fresh supplies of consumable items for this equipment are available to allow sampling as required by 3.3.2.13.</td> <td style="text-align: center;">[]</td> <td style="text-align: center;">[]</td> </tr> <tr> <td>7 The master has been notified in writing of:</td> <td></td> <td></td> </tr> <tr> <td style="padding-left: 20px;">(a) the spaces containing cargo to be fumigated</td> <td style="text-align: center;">[]</td> <td style="text-align: center;">[]</td> </tr> <tr> <td style="padding-left: 20px;">(b) any other spaces that are considered unsafe to enter during the fumigation</td> <td style="text-align: center;">[]</td> <td style="text-align: center;">[]</td> </tr> </tbody> </table> <p style="font-size: small;">I:\CIRC\MSC\01\1264.doc</p>		SHIP	FUMIGATOR- IN-CHARGE	1 The inspection required before loading has been performed (3.3.2.4)	[]	[]	2 All the cargo holds to be fumigated are satisfactory for fumigation	[]	[]	3 Spaces, where found not to be satisfactory, have been sealed	[]	[]	4 The master or his trained representatives have been made aware of the specific areas to be checked for gas concentrations throughout the fumigation period	[]	[]	5 The master or his trained representatives have been made familiar with the fumigant label, detection methods, safety procedures and emergency procedures (refer to 3.3.2.6)	[]	[]	6 The fumigator-in-charge has ensured that gas-detection and respiratory protection equipment carried on the ship is in good order, and that adequate fresh supplies of consumable items for this equipment are available to allow sampling as required by 3.3.2.13.	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Additional Clause 24 to the charter contract for the Nefryt voyage

Clause 24:

Charterers are allowed to arrange for the fumigation of cargo after completion of loading at Abidjan entirely at their expense.

The Charterers/Shippers must undertake all necessary measures stipulated in SUPPLEMENT TO IMDG CODE (Recommendations on the safe use of pesticides in ships).

1. Fumigation must be declared in advance and such intentions to be known to the Master at least before loading of the cargo (not after loading completion).
2. The Master must be supplied with necessary documentation:
 - a) Safety documentation including MSDS (it must contain but not to be limited to any special precautions and the threshold limit value (TVL))
 - b) First aid information and Ventilation Procedures
 - c) Instructions on disposal of residual fumigant material.
3. Empty cargo hold to be tested for leakage and determined sufficiently gastight to prevent leakage of the fumigant to accommodation, engine room and other working places in the ship. A signed Statement to be presented to the Master that the cargo holds are satisfactory for fumigation.
4. Full complement of measuring equipment (including required quantity of tubes for the whole voyage).
As a rule the equipment should be available onboard.
The quantity of tubes must be identified by the fumigator-in-charge according to period of fumigation and frequency of measuring and supplied onboard prior to fumigation.
5. Necessary medicines and medical equipment must be supplied by Charterers on board taking into account the properties of the fumigant applied.
6. The whole fumigation procedure must be carried out by experienced and professional fumigator-in-charge who must provide inter alia appropriate training onboard to two crewmembers (representatives of the master).
These persons will ensure safe conditions onboard are maintained after fumigator-in-charge has handed over responsibility to the master prior to sailing.

The Master is authorised to give his consent for fumigation only after the above requirements are met.

In case, upon arrival at discharging port cargo has been found infested, Charterers remain ultimately responsible for time and/or costs directly and/or indirectly related to cargo infestation including , but not limited to vessel demurrage and/or 2nd cargo fumigation if requested by fito-santiary authorities.