

# JTSCB Digests

JTSCB(Japan Transport Safety Board)

(Issued in December, 2013)

## Digest of Marine Accident Analyses

### For prevention of “Fatal and Injury Accidents Caused by Oxygen Deficiency or Gas Poisoning”

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#### 1. Preface

We have seen many fatal and injury accidents occurring to seafarers and shore workers while working on board, and when we analyze those accidents which were investigated by the Japan Transport Safety Board by the type of work when they occurred, it is found that most of the accidents occurred while such types of work as working inside tanks and holds, or mooring, anchoring and stevedoring were carried out. These types of accident may not happen frequently compared to collision and capsizing of vessels, but they suggest that factors easily overlooked in normal situations can lead to serious accidents. Almost all of the accidents occurring inside tanks and holds lead to fatality in particular, indicating that they contain a very high fatality risk once they have occurred.

In April this year, the Board made an investigation report public about an accident which occurred in Sakai-Senboku Quarter Section 7 of Hanshin Port in which a crew member who inhaled a toxic gas in a cargo tank of a chemical tanker became unable to breathe and died of hypoxia. In order to prevent occurrence of a similar accident, the Board made recommendations to the Minister of Land, Infrastructure, Transport and Tourism and the operator of the chemical tanker. With respect to the accident which occurred in June 2011 in which four crew members on board a chemical tanker sailing along Nagoya Port North Passage in Aichi Prefecture inhaled hydrogen sulfide gas, causing two of them to die and the other two to be injured, the Board pointed out the need for taking safety actions so that crew members should assess the risk associated with tank washing water, become fully familiar with the handling method of such water and observe evacuation procedures when exposed to a dangerous situation.

Furthermore, a similar accident occurred in July 2012, in which two crew members on board a chemical tanker of foreign nationality sailing off the north coast of Heigunto, Yanai City, Yamaguchi Prefecture inhaled a toxic gas and died.

In view of these ongoing situations and with a view to preventing occurrence of similar accidents, we present some case studies of serious accidents investigated by the Board, various statistical data digesting the features of similar accidents, and preventive actions taken based on the recommendations and opinions of the Board.

We hope that this digest will be used as teaching materials on various occasions such as safety seminars held by parties concerned, and will be able to contribute to the prevention of similar accidents.



## 2. Statistics

### Breakdown by cause category and by the type of accident

#### Most of the accidents were due to “failure to measure oxygen or gas concentration”

According to marine accident investigation reports by the Japan Transport Safety Board and judgments by the former Marine Accident Inquiry Agency, the number of fatal and injury accidents which were caused by oxygen deficiency or gas poisoning occurring on chemical tankers or other types of vessel was 18 (involving 18 vessels) since 1989 (or 2008 in the case of the Board’s reports).

The breakdown by cause category is as follows.

- (1) Failure to measure oxygen or gas concentration (15 cases)
- (2) Failure to maintain pump shaft sealing, wear a breathing device and station an attendant (1 case)
- (3) Chemical reaction caused by mixing different types of cargo tank washing water (1 case)
- (4) Leakage of a toxic gas from a cargo hold to each crew cabin, which was caused by the removal of a cargo hold air duct, and the failure of a shipper to inform an operation manager that the cargo was a dangerous good, which as a result prevented the operation manager from checking whether any dangerous good was on board (1 case)

This breakdown clearly shows that most of the accidents were caused by “failure to measure oxygen or gas concentration.” (See Figure 1)

According to the breakdown by the type of accident, the number of fatal accidents was 16 (88.9% of the total) while the number of injury accidents was 2 (11.1%). (See Figure 2)

\* Fatal accidents cover accidents involving both fatalities and the injured.

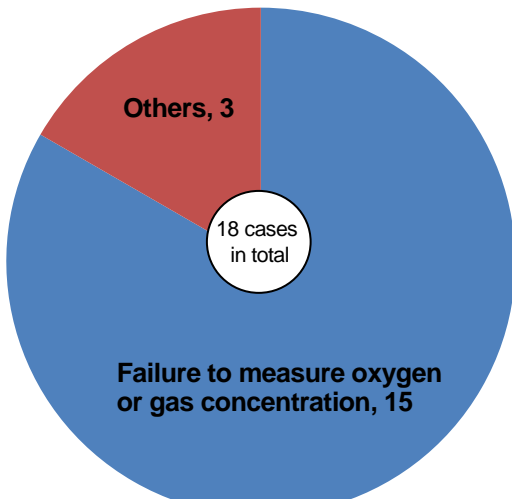


Figure 1: By cause category

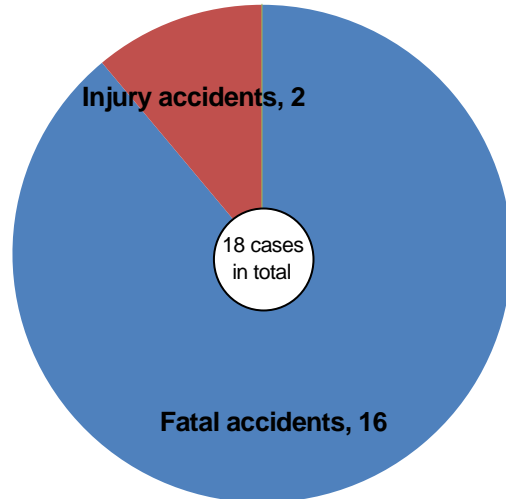


Figure 2: By the type of accident

### Breakdown of the fatalities and injured

The number of the fatalities and injured involved in the 18 accident cases was 41. The breakdown is 24 fatalities (58.4%) and 17 injured (41.5%). The fact that the number of the fatalities accounted for a majority indicates that they contain a high fatality risk once they have occurred. (See Figure 3)

The breakdown by occupational category is 38 crew members (92.7%) and 3 workers (7.3%). (See Figure 4)

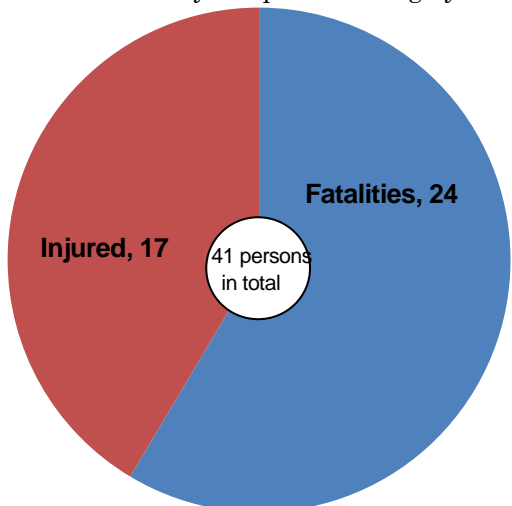


Figure 3: The number of the fatalities and injured

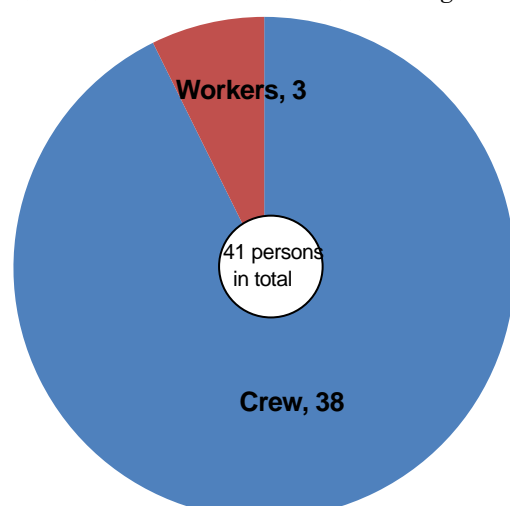


Figure 4: By occupational category

## By the type and tonnage of vessel

By the type of vessel, the number of chemical tankers was 9 (50.0%), the largest among all, followed by cargo ships 5 (27.8%) and oil tankers 3 (16.7%). Our attention is drawn to the fact that the number of accidents occurring on chemical tankers, which involve working inside holds or enclosed spaces and are very likely to handle dangerous goods, accounted for a majority. (See Figure 5)

By the tonnage of vessel, the number of vessels in the range of 100 to 200 tons was 2 (11.1%), 200 to 500 tons 11 (61.1%) and 500 to 1,600 tons 3 (16.7%), showing that the number of accidents occurring on relatively small vessels with a tonnage of 100 to 500 tons accounted for more than 70% of the total. (See Figure 6)

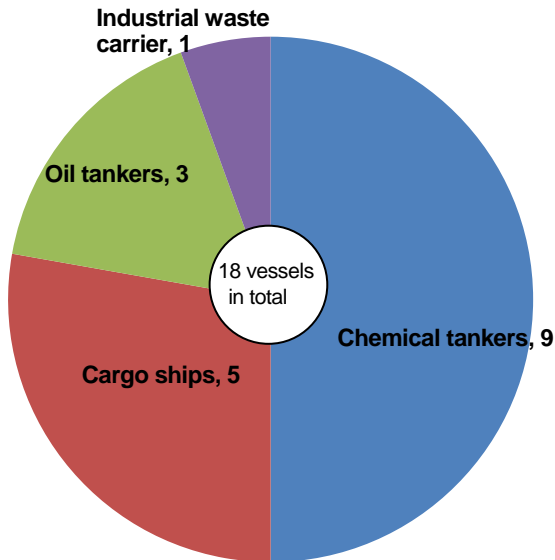


Figure 5: By the type of vessel

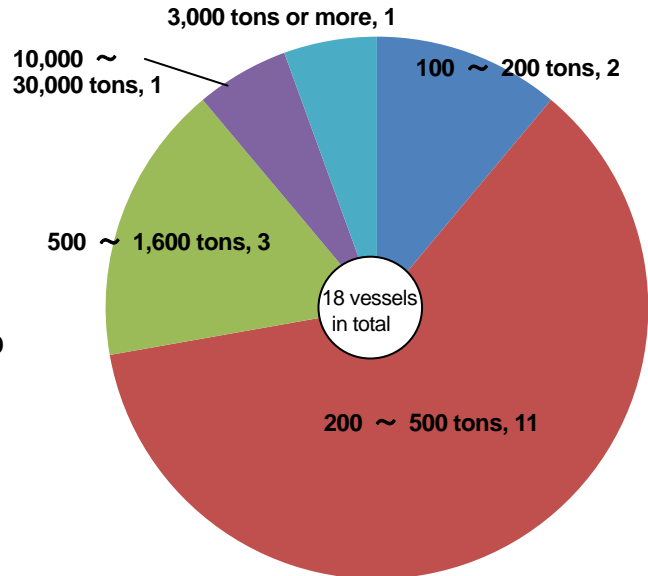
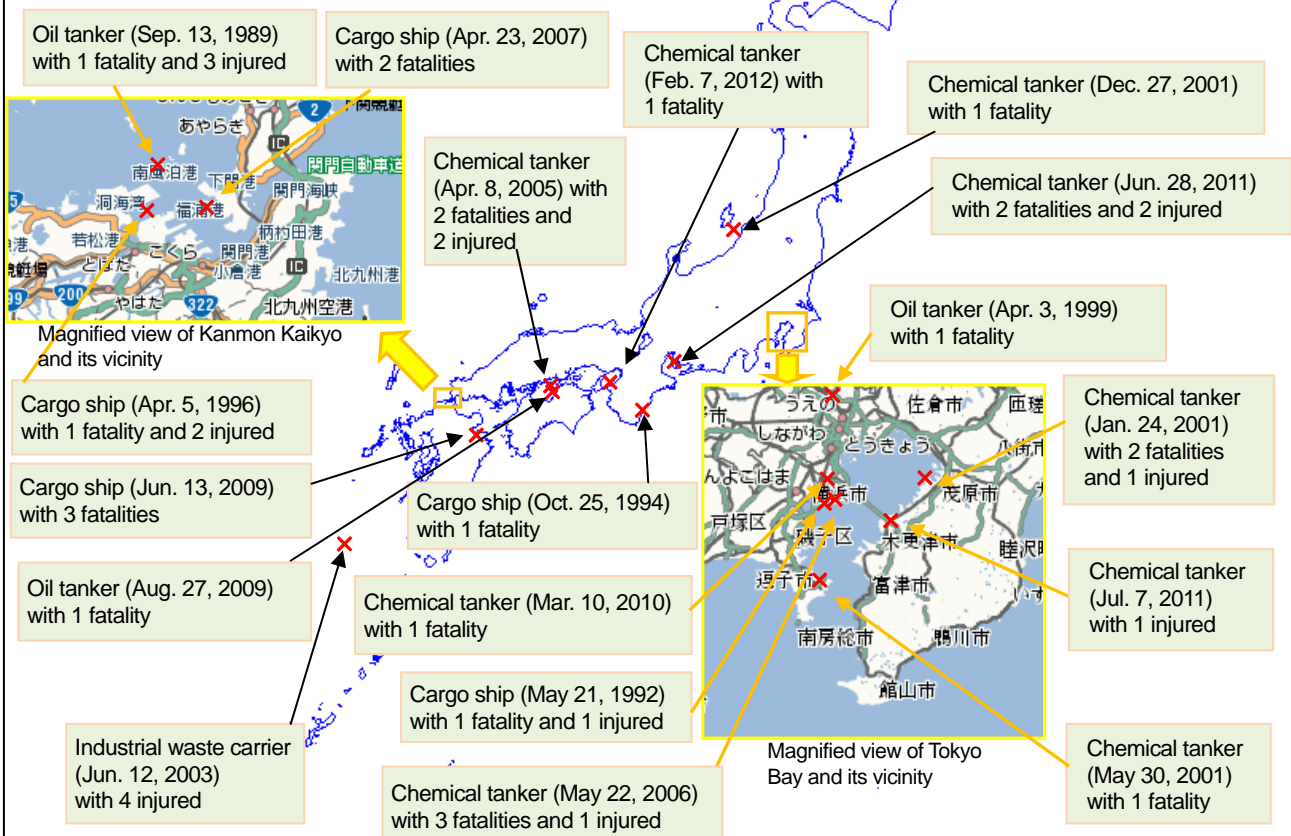


Figure 6: By the tonnage of vessel

## Map showing accident sites

This map shows that 7 accidents occurred in the vicinity of Tokyo Bay, accounting for 38.9% of the total, while 3 accidents occurred in the vicinity of Kanmon Kaikyo (Strait) (16.7%).

\* The Board has started providing on its website "Japan-Marine Accident Risk and Safety Information System", which allows users to search for marine accidents by area or type and displays them on a map. (URL: <http://jtsb.mlit.go.jp/hazardmap/index.en.html>)



## Case 1

# A crew member who inhaled chloroform gas while checking the condition inside a cargo tank became unable to breathe and died of hypoxia

Outline: While the chemical tanker which departed from Komatsu Wharf in Sakai-Senboku Quarter Section 7 of Hanshin Port was sailing north toward Osaka Quarter Section 1 of the Port, the second officer was found lying inside No.1 cargo tank on the port side at around 12:29, February 7, 2012. Although rescued, he became unable to breathe due to toxic gas inhalation and died of hypoxia.

### The Vessel (chemical tanker)

Gross tonnage: 388 tons

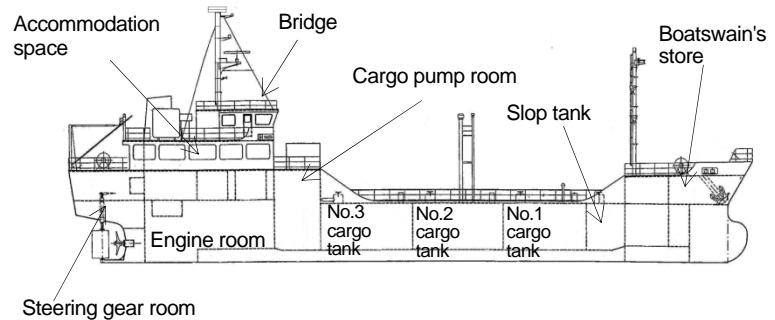
L × B × D : 53.71 m × 8.90 m × 4.40 m

Operator (\*1): Company A

Crew: Master, second officer (2/O) and three other members



### General arrangement



### Events Leading to the Accident

Around 14:05, February 6

After completing cargo unloading, the Vessel washed inside the cargo tanks and transferred washing water to the slop tank.

After that, in order to dry and gas free inside all the cargo tanks after dredging the chloroform (\*2) washing water inside the tanks, the Vessel kept sending air for around 13 hours while operating the turbo fan.

Around 12:10, February 7

The Vessel departed from Komatsu Wharf while the master was stationed at the bridge, the chief officer (C/O) and 2/O at the bow, and the chief engineer and the wiper at the stern.

Around 12:25

Sensing a smell of chloroform when 2/O was opening a manhole hatch to check the condition inside portside No.1 cargo tank, C/O told 2/O not to enter the cargo tank, saying that it contained chloroform.

As C/O went to the accommodation space to get oxygen and gas concentration measuring instruments, there remained only 2/O stationed at the bow.

Around 12:29

The chief engineer found 2/O lying with his back against the bulkhead inside portside No.1 cargo tank.

The master attempted to enter portside No.1 cargo tank four times to rescue 2/O. However, sensing danger by smelling gas inside, he got out of the cargo tank in around 30 seconds each time. There was chloroform inside the cargo tank.

Intending to dry and gas free portside No.1 cargo tank, the Vessel sent air inside the cargo tank.

Although hospitalized, 2/O was confirmed dead.

### Causal Factors of the Accident

According to the findings that there was a smell of toxic gas inside the cargo tank and a residue of washing water inside the suction well at the time of the accident, it is considered somewhat possible that when sending air, a residue of washing water in the piping was pushed out to return inside the cargo tank.

#### "Suction well"

A hollow section placed on the quarter side of a cargo tank, designed to absorb cargo and washing water efficiently, which is normally equipped with a tube for absorbing cargo and washing water.



Situation when the chief engineer found 2/O (inside portside No.1 tank)

It is considered probable that there was a danger of a secondary accident.

It is also considered probable that proper measures against emergencies like when an accident has occurred should have been established.

For details, refer to "Other Safety-related Findings" (page 6)

- \*1: A person or an organization who carries out schedule management for transporting cargo collected from a shipper, and gives instructions for ensuring the safety of transportation for the sake of the vessel in operation and its lessee.
- \*2: A volatile, colorless and transparent liquid with the nature of being nonflammable and poisonous. Its vapor gives a sweet smell.

## Inside portside No.1 cargo tank



### Ordinary operation procedures

Transfer washing water to the slop tank by means of stripping (\*3), followed by another stripping for some of the washing water coming back and building up in the suction well. After ventilating the cargo tank for more than 10 hours, send crew members for going into the tank and dredging the remaining washing water.

\*3: Removing any unnecessary things by absorbing cargo or washing water remaining in a cargo tank or cargo piping system

## Causal Factors of the Accident

### Whether oxygen and gas concentration was measured or not when entering the cargo tank

- ◆ It is considered probable that in spite of replying to C/O's instructions not to enter portside No.1 cargo tank, 2/O did not follow the instructions as he found chloroform washing water remaining in the suction well of the cargo tank, and entered the cargo tank on his own judgment to remove the washing water while C/O went to the accommodation space for getting oxygen and gas concentration measuring instruments (portable and pocketable) (hereinafter referred to as "Both Measuring Instruments").
- ◆ According to the findings that Both Measuring Instruments were not available to 2/O when C/O went for them, it is certain that 2/O did not measure oxygen and gas concentration when entering portside No.1 cargo tank.



Portable measuring instrument

Gas-detecting tube

Gas detector



### Precautions when entering a cargo tank and instructions on oxygen and gas concentration measurement

1. Concerning the precautions when entering a cargo tank, Company A did not clearly define tank cleaning procedures when washing water was remaining in a cargo tank, although it required making sure of absence of any residual liquid or odor.
2. According to the findings that although Company A explained to the master and C/O about the inability of the portable measuring instrument to measure noninflammable and fire-resistant gas concentration, the crew of the Vessel thought that it could measure the concentration of not only oxygen but also all types of gas including noninflammable ones, it is considered probable that the explanation by Company A was not enough for the crew to understand correctly about the ability of the instrument.
3. According to the findings that in spite of being aware of the requirement to use devices like gas detectors for measuring the concentration of noninflammable and fire-resistant gases, Company A thought that replacing a gas detectors for each cargo tank would be time-consuming and laborious, and instructed the crew of the Vessel to judge the existence of noninflammable and fire-resistant gases by a decrease in oxygen concentration instead of by using gas detectors, it is considered probable that Company A did not give instructions conforming to the notices prescribing standards for transporting dangerous goods by vessels or regulations like coastal tankers safety guidelines.

## Causal Factors of Fatalities and Injuries Suffered by Crew

Failure to measure oxygen and gas concentration when entering the cargo tank or the ballast pump room.

It is considered somewhat likely that the casualty did not think it a problem not to measure oxygen and gas concentration.

Entered the cargo tank on his own judgment.

It is considered probable that, assuming that the distance between the upper deck and their working locations such as the cargo tanks was short and the work would not take much time, the casualty entered the cargo tank by judging it possible to work individually even though there might be some smell of a toxic gas.

It is considered probable that although Company A implemented a vessel visiting campaign after the 2010 accident (refer to Case 2 in the next page), and educated and instructed vessels in operation on safety actions, the accident occurred because a crew member of the Vessel (2/O) entered the cargo tank alone on his own judgment without measuring oxygen and gas concentration, underlining that the crew of Company A were not fully acquainted with lessons from the past accidents or the safety actions.

## Other Safety-related Findings

With respect to rescue activities in enclosed space,

- ▶ Notify the bridge team immediately, do not act impulsively or do not act on independent judgment, and wait for assistance until the necessary number of people for initiating rescue activities gather.
- ▶ It is not easy to enter enclosed space with a harmful atmosphere to rescue survivors in need of help.
- ▶ Inhaling chloroform gas in a cargo tank disables breathing, causes the condition of hypoxia and makes it difficult to return alive.

In view of the necessity of teaching these precautions, it is considered probable that Company A should have established proper procedures, such as by training, against emergencies like when an accident has occurred.

## In Order to Prevent Recurrence (Recommendations)

In view of the result of this accident investigation, the Japan Transport Safety Board recommended the Minister of Land, Infrastructure, Transport and Tourism as follows, pursuant to Article 26 (1) of the Act for Establishment of the Board.

### Recommendations to the Minister of Land, Infrastructure, Transport and Tourism

The Minister should instruct coastal shipping companies who operate chemical tankers on the following items.

- (1) The companies should instruct their crew never to fail to implement oxygen and gas concentration measurement when entering enclosed space. They should also visit their vessels on a regular basis to make sure that oxygen and gas concentration measurement has been properly implemented.
- (2) It should be assured that each master has been making a record of implementing oxygen and gas concentration measurement, as well as a record of how many gas-detecting tubes have been purchased, consumed and left unused in case of using gas detectors to measure gas concentration. They should also visit their vessels on a regular basis to make sure that oxygen and gas concentration has been properly measured, by checking records of measurement implementation and gas-detecting tube usage.
- (3) As stated in the coastal tankers safety guidelines and P & A manuals, operation procedures for such categories of work as checking the existence of washing water, removing washing water by stripping, if any, and tank cleaning by drying or gas-freeing should be organized in a plain form so that their crew can understand them easily and check them for confirmation. Such operation procedures should be posted at an easily viewable location close to their working sites.
- (4) Based on the precautions like refraining from acting impulsively or acting on independent judgment in case of emergencies like when an accident has occurred, education and training efforts for the implementation of emergency measures like when an accident has occurred should be made continuously.

The Minister should ensure that in case of conducting an on-site checking, shipping companies should instruct the crew on the measures as mentioned in (1) to (4) above, and make sure oxygen and gas concentration has been properly measured, by checking records of gas-detecting tube usage. The Minister should also make sure, such as by referring to an audit record regularly, that shipping companies have been endeavoring for securing the safety of transportation and improving their business operations.

In view of the result of this accident investigation, the Japan Transport Safety Board also recommended Company A as follows, pursuant to Article 27 (1) of the Act for Establishment of the Board.

### Recommendations to Company A

Company A should adopt the following actions as preventive measures against recurrence.

Same as the Recommendations (1) to (4) as mentioned above which were made to the Minister of Land, Infrastructure, Transport and Tourism.

The investigation report of this accident case is published on the Board's website (issued on April 26, 2013).

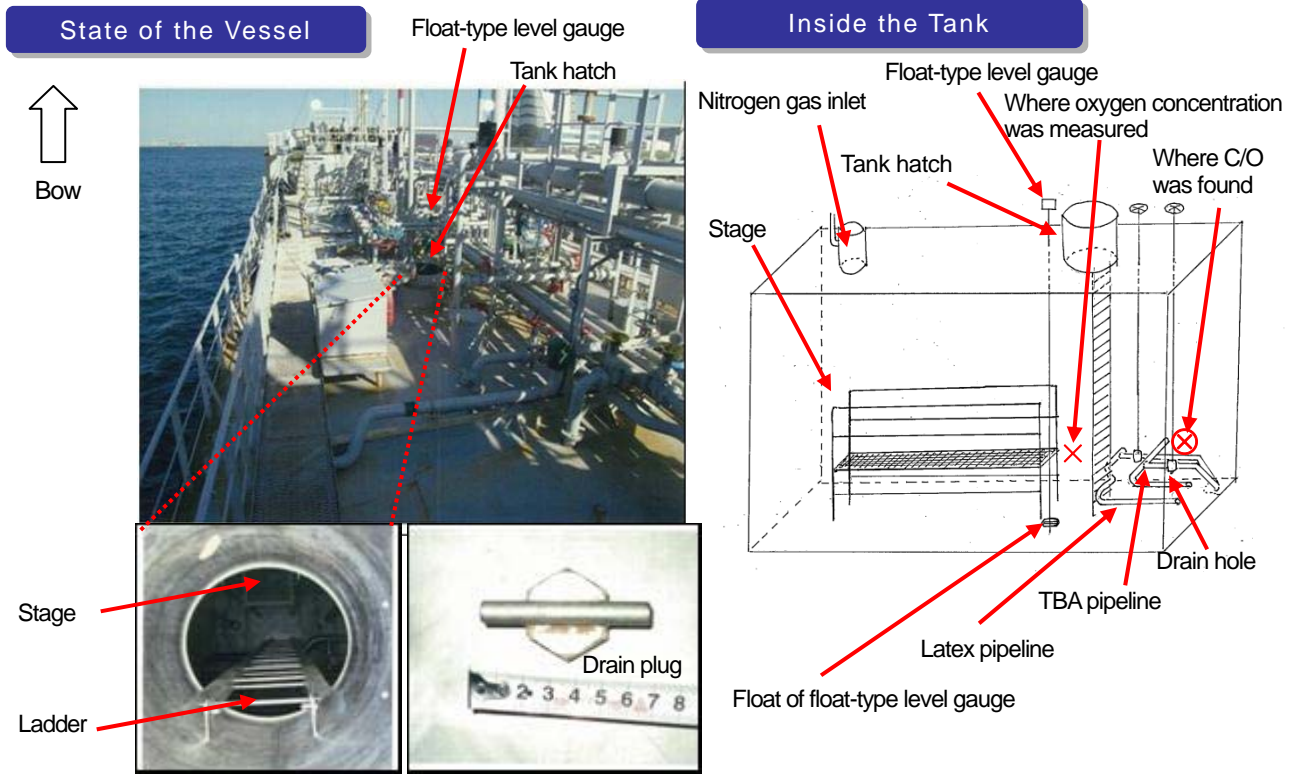
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## Case 2

### A crew member who was engaged in cargo unloading entered a cargo tank and died of suffocation caused by oxygen deficiency

Outline: At around 13:55, March 10, 2010, while the Vessel (same as the vessel in Case 1) was unloading about 380 tons of chemical liquid cargo containing tert-butyl alcohol (TBA) at the consignee's No. 2 pier (the Pier) in Kawasaki Section of Keihin Port, the chief officer who was engaged in cargo unloading entered portside No.2 cargo tank (the Tank), and died of suffocation caused by oxygen deficiency.

The crew of the Vessel: Master, chief engineer, chief officer (C/O), first engineer (1/E) and second officer (2/O)  
Workers of the stevedoring contractor: Worker A1, Worker A2 and Worker A3



#### Events Leading to the Accident

While undergoing a pre-loading inspection of the cargo tank cleaning by a relevant organization's inspectors at the shipper's exclusive pier in Kawasaki Section of Keihin Port, the Vessel took in TBA without restoring the drain plug of the Tank which had been removed, and sailed toward the Pier in Kawasaki Section of the port.

Around 12:00

After arriving at the Pier and having C/O confirm the stevedoring checklist and the checklist for accepting TBA carriers with Worker A1, the Vessel started unloading TBA.

Upon checking inside the Tank from the upper surface of the opened hatch to see why it became unable to unload TBA inside the Tank, C/O found that a drain plug was placed on the stage of the Tank, and was not restored in the proper position.

#### Causal Factors of the Accident

It is considered probable that crew members other than C/O and 1/E were unaware that nitrogen gas was injected, although nitrogen gas was injected into the Tank and other cargo tanks as return gas (\*1) for preventing explosion and negative pressure when the Vessel started unloading.

\*1: Gas which is to be sent back in the direction opposite to the direction of cargo which moves from land to a vessel or vice versa, while loading or unloading work goes on.

According to the findings that the drain plug was not restored in the drain hole of the cargo pipe inside the Tank, it is considered probable that air was absorbed through the drain hole while unloading, and it became unable to transfer TBA.

📌 Drain plug: Although once removed for undergoing a pre-loading inspection, the drain plug should have been restored in the drain hole to prevent air from being absorbed while unloading.

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In order to restore the drain plug, C/O ran for getting a gas mask without measuring oxygen concentration inside the Tank, and entered the Tank after wearing the gas mask.

Around 13:55

Soon after fixing the drain plug in the drain hole by screwing it about three times, C/O stopped moving.

Worker A3 restrained a group of about three crew members of the Vessel from entering the Tank, saying that doing so would cause a secondary accident, and waited for an ambulance to arrive.

Around 14:44

It is considered probable that C/O was confirmed dead, although he was rescued from the Tank and hospitalized by a rescue team. C/O's cause of death was suffocation caused by oxygen deficiency.

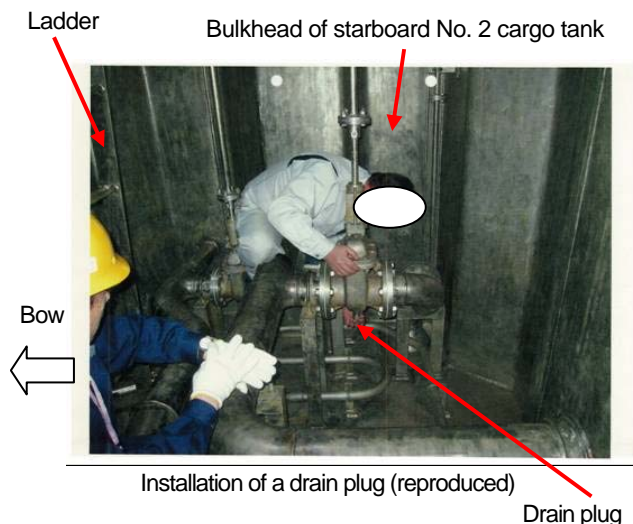
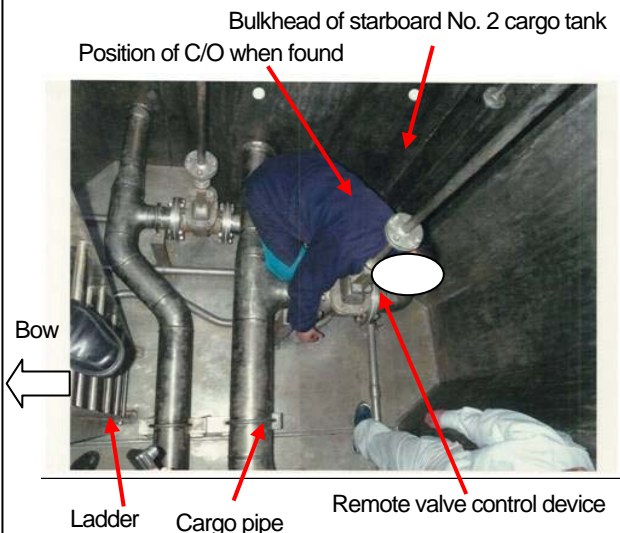
C/O entered the Tank wearing the gas mask without measuring oxygen concentration.

According to the findings that C/O tried to restore the drain plug in a hurry upon finding it placed at a wrong location, it is considered somewhat likely that having forgotten nitrogen gas was injected into the Tank, C/O entered the Tank to restore the drain plug.

It is considered probable that being aware of accident cases caused by oxygen deficiency, Worker A3 was able to prevent a secondary accident from occurring by restraining the crew members wearing only a gas mask from entering the cargo tank.

According to the findings that although the gas concentration inside the Tank was 16% at around 14:23, C/O stopped moving at around 13:55 soon after picking up the drain plug and fixing it in the drain hole by screwing it three times, it is considered somewhat likely that the gas concentration near the drain hole was not so high as to cause instant death, but to the extent of causing the loss of consciousness in a short time (10% or less).

### Reproduction of the Accident Site



### In Order to Prevent Recurrence

It is considered probable that this accident occurred because a crew member on board a chemical tanker entered a cargo tank without measuring oxygen concentration inside the tank, and died of suffocation caused by oxygen deficiency, although nitrogen gas was injected into the tank while unloading TBA.

Accordingly, vessel owners are required to provide the crew of chemical tankers with safety education about the possibility that a state of oxygen deficiency will be caused depending on the nature of cargo to handle, as well as the method of cargo handling, and further to instruct them never to fail to measure oxygen concentration before entering a cargo tank which is feared to turn into a state of oxygen deficiency.

Furthermore, considering that crew members other than C/O and 1/E were unaware when the accident occurred that nitrogen gas was injected into the cargo tank while unloading work was going on, and even C/O may have forgotten it, it is earnestly recommended that stevedores working on the shore side should notify the crew of a chemical tanker properly before injecting gas into a cargo tank to lower oxygen concentration.

The investigation report of this accident case is published on the Board's website (issued on July 29, 2011).

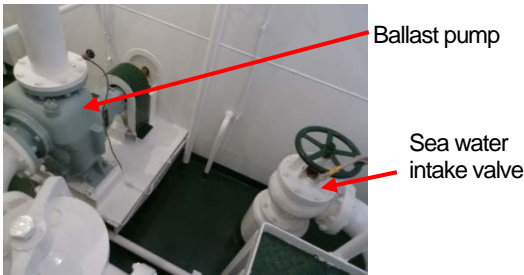
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### Case 3

## After completing the unloading of chloroform, a crew member inhaled chloroform gas and lost consciousness in a ballast pump room

Outline: At around 16:40, July 7, 2011, while the Vessel was sailing north toward an anchorage near Umi-Hotaru, an artificial island on the Tokyo Bay Aqua Line, after completing the unloading of about 50 tons of chloroform at a cargo handling pier in Chiba Section of Chiba Port, the first engineer found a wiper lying without consciousness in a ballast pump room. The wiper was rescued, and recovered consciousness.

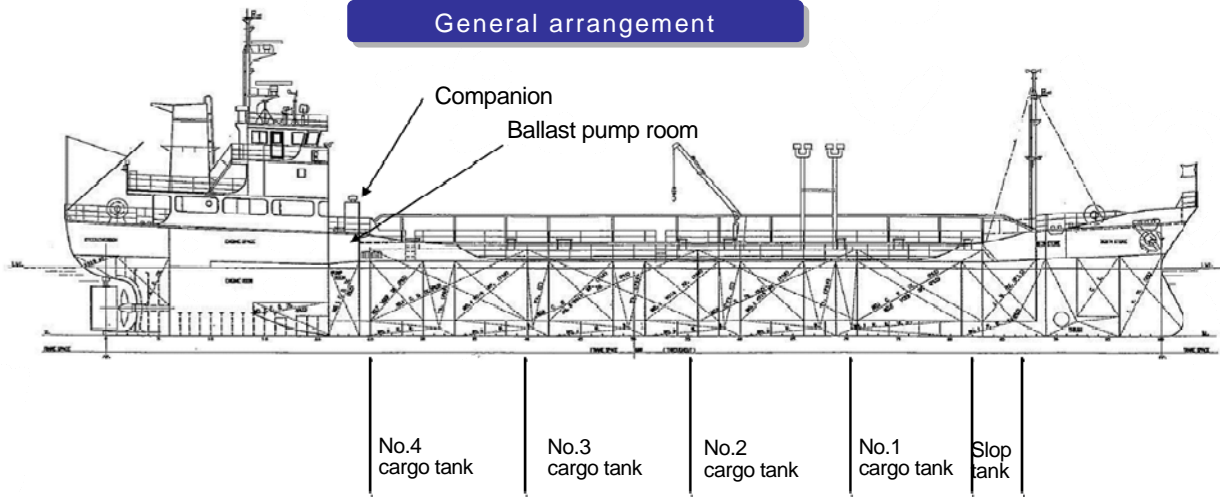


#### The Vessel (bulk carrier for liquid chemicals)

Gross tonnage: 498 tons  
 L × B × D : 64.47 m × 10.00 m × 4.50 m  
 Operator (\*1): Company B  
 Crew: Master, first engineer (1/E), wiper and three others

\*1: A person or an organization who implements schedule management for transporting cargo collected from a shipper, and gives instructions for ensuring the safety of transportation for the sake of the vessel in operation and its lessee.

#### General arrangement



#### Events Leading to the Accident

Around 16:25

The Vessel left port after completing the unloading of about 50 tons of chloroform inside No.4 cargo tank at a cargo handling pier in Chiba Section of Chiba Port.

When the Vessel was pumping water into the ballast tank to adjust the draft, both the partition board and the gate valve which were separating the cargo piping and the air sending piping in No. 4 cargo tank on both sides were opened.

Around 16:25

Noticing sea water flowing out of the air vent over the deck, the wiper entered the ballast pump room to close the sea water intake valve at the bottom of the room.

#### Causal Factors of the Accident

The area between the cargo piping of No.4 cargo tank on both sides and the suction port of the air blowing fan in the ballast pump room became ventilatable through the air sending piping. Then, chloroform gas in the cargo piping was absorbed by the exhaust fan in the room, and came into the room through the suction port of the air blowing fan. Due to the nature of being heavier than air, chloroform gas resulted in stagnating at the bottom of the room.

It is considered probable that when entering the ballast pump room, the wiper did not detect toxic gases because there were no such instructions from Company B.

While giving instructions to measure oxygen concentration, detect toxic gases and make a record of such data when entering a cargo tank or cargo pump room, Company B did not instruct the crew of the Vessel to detect toxic gases, assuming there were no toxic gases in the ballast pump room of the Vessel because there was no cargo pump in the room.

Company B did not make a procedure manual for cargo tank cleaning or ventilating, either.

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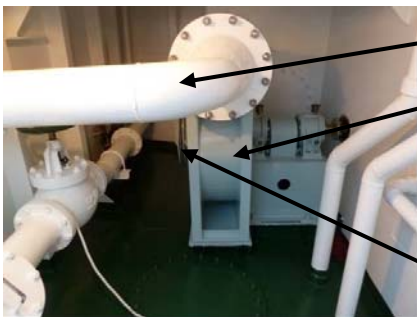
After that, noticing an unusual smell, the wiper went on the deck to report it to 1/E, who said the foreign smell might be due to the wind. Then, the wiper entered the ballast pump room again, and lost consciousness by inhaling chloroform gas which was stagnating at the bottom of the room.

It is considered probable that due to being heavier than air and inclined to stagnate at a lower place, chloroform gas which came into the ballast pump room stagnated at the bottom of the room.

Around 16:40

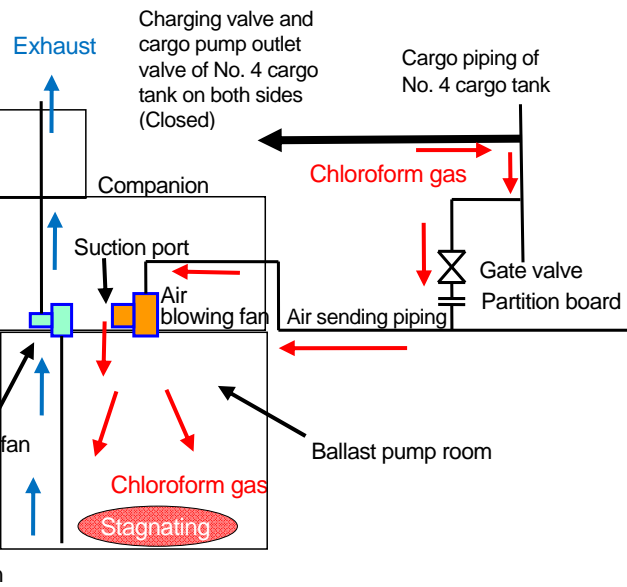
Entering the ballast pump room to look for the wiper, 1/E found the wiper lying without consciousness near the sea water intake valve.

The wiper was rescued by other crew members and taken to hospital by a Japan Coast Guard's helicopter which came for relief.



Air sending piping  
Air blowing fan  
Exhaust fan  
Suction port of the air blowing fan

### Inflow Route of Chloroform Gas



### How the Area between the Cargo Piping and the Air Sending Piping Became Ventilatable

After operating the ballast pump in order to pump water into the ballast tank, 1/E opened the partition board and the gate valve which were separating the cargo piping and the air sending piping in No.4 cargo tank on both sides.

Concerning whether the charging valve and cargo pump outlet valve of the cargo piping were opened or closed when the accident occurred, they were normally closed when cargo handling was not going on.

It is considered probable that chloroform gas in the cargo piping was absorbed by the exhaust fan and came into the room through the suction port of the air blowing fan.

### In Order to Prevent Recurrence

With respect to vessels transporting dangerous goods, it is necessary to establish operation procedures for handling such cargoes and instruct the crew to fully observe the procedures so that cleaning and ventilation of a cargo tank as well as valve opening and closing should be properly implemented. It is also necessary to ensure that measurement of oxygen concentration and detection of toxic gases should be implemented without fail when entering a place where facilities like a ballast pump are installed and a toxic gas is likely to flow in.

It is desired that vessel owners or operators should take the following actions for transporting dangerous goods on board vessels in which there is no cargo pump room, and there is a suction port of an air blowing fan to send air to a cargo tank at a place where a ballast pump is placed (ballast pump room).

- (1) Instruct the crew to ensure that measurement of oxygen concentration and detection of toxic gases should be implemented without fail when entering a ballast pump room, as in the case of entering a cargo tank or a cargo pump room where a toxic gas may exist.
- (2) Be aware of the details of such onboard work as may endanger the crew, establish safety check procedures during work as well as working procedures, and give them instructions on these procedures and ensure observance by them.

## Case 4

### Two crew members died by inhaling hydrogen sulfide gas generated inside a slop tank

Outline: At around 11:27, June 28, 2011, while the Vessel boarded by the master, the chief engineer (C/E), the chief officer (C/O), the first engineer (1/E) and the first officer (1/O) was sailing along Nagoya Port North Passage after completing the unloading of sodium hydrosulfide at a shipper's pier in Nagoya Port, C/O, 1/E and 1/O fell down on the starboard side of the forecastle deck, and C/E became half conscious at the stern. All of the four crew members were engaged in tank cleaning.

C/O and 1/E died while 1/O and C/E were injured.

The Vessel



Type: Chemical tanker  
Gross tonnage: 499 tons  
L × B × D : 64.95 m × 10.00 m × 4.50 m

\* Company A owning the Vessel was in charge of operating the Vessel, and was practically managing the Vessel's tank cleaning.

#### Events Leading to the Accident

Three days before the accident occurred

After completing the unloading of acrylic acid entirely at a pier in Yokkaichi Port, the Vessel left the pier and was **collecting in the slop tank (starboard, port) (\*1) acrylic acid washing water generated during tank cleaning.**

\*1: A tank for collecting washing water generated during tank cleaning

Around 11:10 on the day of the accident

After completing the unloading of acrylic acid entirely at a pier in Nagoya Port, the Vessel departed for Wakayama Shimotsu Port in Wakayama Prefecture for cargo loading.

While the Vessel was sailing in Nagoya Port, C/O started cleaning No.2 cargo tank (starboard, port) while operating a fresh water washing pump with C/E, 1/E and 1/O.

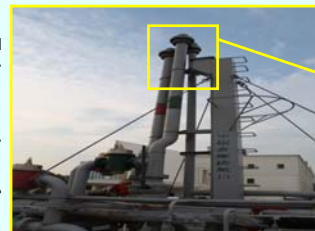
When the Vessel completed cleaning No.2 cargo tank (starboard, port), C/E **transferred sodium hydrosulfide washing water** inside the tank **to the slop tank (starboard, port)** by operating the cargo pump.

Around 11:26

**Inside the slop tank, sodium hydrosulfide washing water and acrylic acid washing water caused a chemical reaction, and generated hydrogen sulfide gas, which spouted out of the discharge port of the slop tank's exhaust pipe while making a sound.**

→ **hydrogen sulfide gas spouted**

Exhaust pipe of the slop tank



Discharge port of the slop tank's exhaust pipe

Manhole hatch covers of the slop tank



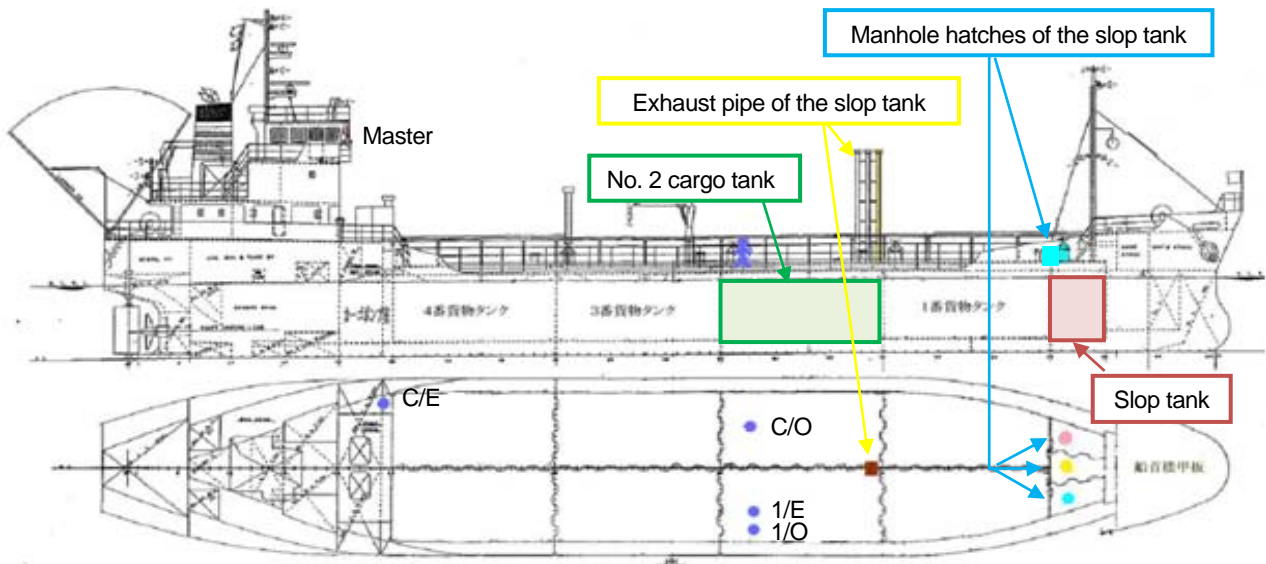
In the middle of evacuating to the starboard side of the forecastle deck on the windward, C/O, 1/E and 1/O opened each of the manhole hatch covers of the slop tank (starboard, port) in order to stop hydrogen sulfide gas from spouting out of the discharge port of the slop tank's exhaust pipe.

→ **hydrogen sulfide gas spouted**

At around 11:27, C/O, 1/E and 1/O fell down on the starboard side of the forecastle deck, and C/E became half conscious in the dining room for a while.

C/O, 1/E and 1/O were rescued and taken to hospital by the staff of Nagoya Coast Guard Office who came for relief, and **C/O and 1/E were confirmed dead. 1/O was hospitalized due to hydrogen sulfide intoxication, and C/E was also hospitalized due to hydrogen sulfide intoxication and chemical pneumonia.**

【Location of the slop tank and other facilities, and positioning of the crew when the accident occurred】

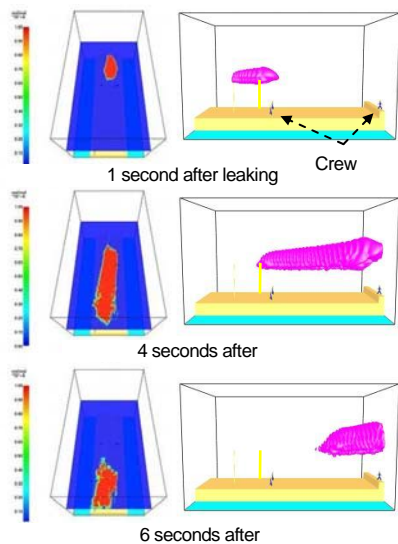
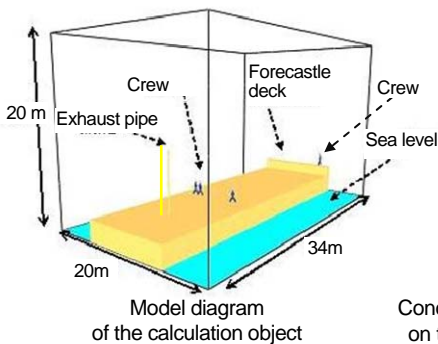


**Research on How the Crew Were Affected by the Hydrogen Sulfide Gas Which Spouted out of the Discharge Port of the Slop Tank's Exhaust Pipe**

The Board entrusted National Maritime Research Institute with a research on the effect on the crew of the hydrogen sulfide gas which spouted out of the discharge port of the slop tank's exhaust pipe. The result of the research is summarized as follows.

【Calculation condition (excerpt)】

- Crew stationing: from the discharge port of the slop tank's exhaust pipe, about 7.5 m astern (C/O, 1/E, 1/O) and about 27.5 m astern (C/E)
- Height of the discharge port of the slop tank's exhaust pipe: 6.5 m
- Relative wind direction: 5° starboard bow
- Relative wind speed: 7.4 m/s



Concentration distribution on the horizontal section      Isosurface changes over time

【Research result and analysis】 (excerpt)

Effect of hydrogen sulfide gas which spouted out of the discharge port of the slop tank's exhaust pipe

- ▶ For C/O, 1/E and 1/O, it is proper to consider that the accident was caused by a different reason, and it is considered probable that they inhaled hydrogen sulfide gas which spouted out of each of the slop tank (starboard, port) manhole hatches.
- ▶ For C/E, it cannot be denied completely that part of hydrogen sulfide gas which spouted out of the discharge port of the slop tank's exhaust pipe reached C/E, and it is considered probable that C/E inhaled hydrogen sulfide gas which spouted out of the discharge port and each of the manhole hatches of the slop tank (starboard, port).

**Probable Cause 1**

It is considered probable that the accident occurred because C/O, 1/E and 1/O who were engaged in tank cleaning inhaled hydrogen sulfide gas which spouted out of each of the opened manhole hatches of the slop tank (starboard, port), and C/E inhaled hydrogen sulfide gas which spouted out of the discharge port of the exhaust pipe and each of the opened manhole hatches of the slop tank (starboard, port), when hydrogen sulfide gas was generated by a chemical reaction caused by mixing sodium hydrosulfide washing water and acrylic acid washing water, soon after the sodium hydrosulfide washing water inside No.2 cargo tank (starboard, port) was transferred to the slop tank (starboard, port) in which acrylic acid washing water was collected when completing the cleaning of No.2 cargo tank (starboard, port) which completed the unloading of sodium hydrosulfide washing water, while the Vessel was engaged in tank cleaning while sailing in Nagoya Port.

**Analysis of Safety Management of the Vessel**

While being unaware of the danger of tank washing water when mixed, Company A neither mentioned about transfer work of tank washing water in the tank cleaning procedure manual, nor instructed the crew on the danger of tank washing water when mixed and the proper use of a slop tank.

To next page

With respect to the Vessel, tank washing water was collected in the slop tank (starboard, port) and two different types of washing water or more were mixed in the tank on a regular basis.

\* “Ship Inspection Regulations” in a notice by Director-General, Maritime Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) specifies as follows.  
Requirements pertaining to a slop tank shall be as follows.

- (4) In case of loading two different types of material or more at the same time which may cause dangerous interaction, tank washing water and bilge water containing such material shall not be loaded in the same slop tank. Accordingly, the number of slop tanks shall be the same as those materials which are to cause dangerous interaction and to be loaded at the same time.

The crew of the Vessel did not know that tank washing water could cause a chemical reaction when mixed and generate a dangerous material, and were unaware of the details of the procedures for handling dangerous goods, either.

### Probable Cause 2

According to the findings that Company A was unaware of the danger of tank washing water when mixed, and neither mentioned about transfer work of tank washing water in the tank cleaning procedure manual, nor instructed the crew on the danger of tank washing water when mixed and the proper use of a slop tank, it is considered probable that the Vessel transferred sodium hydrosulfide washing water inside No.2 cargo tank (starboard, port) to the slop tank (starboard, port) in which acrylic acid washing water was collected because the crew of the Vessel did not know that tank washing water could cause a chemical reaction when mixed and generate a dangerous material, and were unaware of the details of the procedures for handling dangerous goods, either.

### In Order to Prevent Recurrence

On August 4, 2011, for fear of occurrence of a similar accident, the Japan Transport Safety Board provided information for Maritime Bureau, MLIT about the outline and factual data of the accident, with a view to alerting chemical tanker operators and owners.

On September 26, 2011, in response to this information provision, Maritime Bureau, MLIT (Safety/Environment Policy Division, Safety Management and Seafarers Labour Division and Inspection and Measurement Division) issued to the Japan Federation of Coastal Shipping Associations a notice with the following instructions, with a view to alerting them to the danger in the handling of tank washing water on board a chemical tanker.

When keeping different types of cargo washing water in a slop tank, proper management and operation is required, bearing in mind a possibility that washing water, when mixed, may generate a material dangerous to the human body.

For this reason, chemical tanker operators and owners under the Federation shall be fully reminded of the following and the need for ensuring proper management and operation with respect to the keeping of washing water.

- Property management of washing water shall be implemented properly in order to apprehend correctly “what kind of material is included in the washing water kept in a slop tank”
- In order to enable assessing the risk of a toxic substance generated, information related to the reactivity of onboard materials shall be provided for chemical tankers in the form of “procedures for handling dangerous goods” or “material safety data sheet (MSDS)”.
- Procedural information like “procedures for handling dangerous goods” or “material safety data sheet (MSDS)” shall be used to check “if there is a danger that a toxic substance may be generated when mixing another type of washing water with the already collected washing water”.
- When it is possible to discharge washing water in the sea, it shall be done so frequently.
- In the event that a reaction of some sort has occurred inside a tank, attention shall be paid to the existence of any danger to the human body.

In order to prevent occurrence of a similar accident, it should be ensured that coastal shipping operators, owners and masters should disseminate the following instructions to the crew so that these instructions should be observed by them.

(1) Method of handling tank washing water and assessing the risks associated with it

In order to prevent mixing different types of tank washing water likely to cause a dangerous chemical reaction while recognizing that tank washing water includes cargo residue on board and bears similar properties as cargoes, it is necessary to identify in which case mixing tank washing waters is dangerous, such as by making a chemical interaction chart for dangerous types of cargo when mixed while referring to procedures for handling dangerous goods or material safety data sheet (MSDS). This should be fully disseminated to the crew. It is also necessary to fully disseminate the method of tank washing water treatment and slop tank usage to the crew in the form of a manual in order to ensure that they observe such procedures at all times.

(2) Observance of evacuation procedures

In case a toxic substance like hydrogen sulfide gas is generated by chemical reaction while transporting tank washing water without checking the condition inside a slop tank, the manhole hatch covers of the slop tank should not be opened, and crew members staying near the discharge port of the slop tank’s exhaust pipe should evacuate to the windward side of the discharge port of the exhaust pipe while those staying near the accommodation space should evacuate without delay to the closed accommodation sections.

## 4. Safety Actions Taken in Response to the Recommendations and Opinions

### Actions taken in response to the recommendations made for the fatal accident involving workers on board the cargo ship, Singapore Grace

\* For further details of this accident, please refer to the JTSB Digests.

(URL : [http://www.mlit.go.jp/jtsb/bunseki-kankoubutu/jtsbdigests\\_e/jtsbdigests\\_No3/No3\\_pdf/jtsbdi-03\\_0608.pdf](http://www.mlit.go.jp/jtsb/bunseki-kankoubutu/jtsbdigests_e/jtsbdigests_No3/No3_pdf/jtsbdi-03_0608.pdf))

Outline: While the cargo ship was berthed at the wharf of Port of Saganoseki, Oita City, Oita Prefecture, for discharging a cargo of copper sulfide concentrate at around 08:30, June 13, 2009, one of the workers inhaled oxygen-deficient air and developed hypoxia while descending a ladder inside No. 3 cargo hold on his way to undertaking the job of stevedoring. Two of the three other workers who went to rescue him also developed hypoxia in the cargo hold. All of the three workers were rescued from No. 3 cargo hold, but later they were confirmed dead.

In view of the result of this accident investigation, the Japan Transport Safety Board recommended the smelter (Company A) and the stevedoring company (Company B) to implement the following measures, pursuant to Article 27 (1) of the Act for Establishment of the Board.

#### Recommendations to Company A

- (1) To train all employees who have the possibility of being engaged in cargo operation to understand the properties and hazardousness of copper sulfide concentrate.
- (2) To train all employees who have the possibility of being engaged in cargo operation with the handling of O<sub>2</sub> meters in order to measure O<sub>2</sub> concentrations safely and surely as necessary.
- (3) To request the MSDS (\*1) of floatation reagents from shippers.
- (4) To inform all employees who have the possibility of being engaged in cargo operation that depending on the floatation reagent adhering to copper sulfide concentrate, it may generate toxic gas, and since the generated toxic gas is heavier than air, it stagnates in cargo hold, hence, there is a danger of not being replaced by air.
- (5) To make the risks of oxygen-deficient conditions and hypoxia known to all personnel who have the possibility of being engaged in cargo operation and to familiarize them with appropriate measures to be taken in case of fatal accidents occurring in cargo holds loaded with copper sulfide concentrate.

#### Recommendations to Company B

- (1) To train all employees who have the possibility of being engaged in cargo operation to understand the properties and hazardousness of copper sulfide concentrate.
- (2) To train all employees who have the possibility of being engaged in cargo operation with the handling of O<sub>2</sub> meters in order to measure O<sub>2</sub> concentrations as necessary.
- (3) To make the risks of oxygen-deficient conditions and hypoxia known to all employees who have the possibility of being engaged in cargo operation and to familiarize them with appropriate measures to be taken in case of fatal accidents occurring in cargo holds loaded with copper sulfide concentrate.

#### Actions Taken by Company A

- (1) Provided the relevant employees with education on the properties and hazardousness of copper sulfide concentrate.
  - ▶ Main points of the education
    - Copper concentrate, the substance of which is fine powder, has a large surface area, and is likely to generate heat by oxidation when reacting with oxygen in the air inside a cargo hold (copper concentrate consumes oxygen).
    - Oxygen concentration inside a cargo hold of a transport ship is likely to become lower than 18% in most cases while sailing from abroad (oxygen-deficient conditions).
    - In particular, when dew condensation occurs in large amount upon opening hatches of a vessel, careful attention is required because such situation shows that there is heat generation by oxidation to a large extent, and oxygen concentration in the cargo hold may be extremely low.
- (2) The relevant employees of Company A also attended a training course by Company B for handling oxygen concentration meters.
- (3) Provided the relevant employees with training on MSDSs of the floatation reagents which were obtained from the owners of copper concentrate mines. Company B was provided with these MSDSs.
- (4) Provided the relevant employees with education about a danger that some floatation reagents might generate toxic gases, which might stagnate in a cargo hold as they were heavier than air and might prevent substitution with air.
- (5) 1. Disseminated the danger of oxygen-deficient conditions and hypoxia to the relevant employees, in addition to the education as mentioned in (1).

#### ▶ Main points of the education

- Development mechanism of hypoxia and the cause of occurrence
- Symptoms of hypoxia
- Properties and hazardousness of copper concentrate
- Locations likely to cause hypoxia and precautions

2. The relevant employees of Company A also attended a rescue training course by Company B against fatal and injury accidents occurring in a cargo hold loaded with copper sulfide concentrate.

\*1: "MSDS" (Material Safety Data Sheet) is a document that contains information necessary for the safe handling of chemical substances or raw materials containing chemical substances

## Actions Taken by Company B

(1) Provided the relevant employees with education on the properties and hazardousness of copper sulfide concentrate.

### ▶ Main points of the education

- Copper concentrate is likely to generate heat by oxidation when reacting with oxygen in the air inside a cargo hold.
- Oxygen concentration is likely to become 18% or lower in most cases while underway from abroad.
- When dew condensation occurs in large amount, oxygen concentration may be extremely low.
- Some floatation reagents contain toxic gases, and they can cause oxygen-deficient conditions.
- MSDSs of floatation reagents

(2) Provided the relevant employees with training for handling oxygen concentration meters.

### ▶ Main points of the training

- Meter types
- Operation method
- Maintenance method
- Measurement points
- Recording method
- Fitting protectors
- Evacuation in emergency



Oxygen concentration meter

(3) 1. Provided the relevant employees with education on the danger of oxygen-deficient conditions and hypoxia.

### ▶ Main points of the education

- Development mechanism and the cause of occurrence
- Symptoms of hypoxia
- Properties and hazardousness of copper concentrate
- Locations likely to cause hypoxia and precautions

2. Provided the relevant employees with education and training on how to deal with fatal and injury accidents occurring in a cargo hold loaded with copper sulfide concentrate.

### ▶ Main points of the education and training

- Judgment criteria for identifying the cause of an accident, whether by oxygen deficiency or not
- Reporting when finding victims
- Prevention of a secondary accident
- Preparations for relief
- Measurement of oxygen concentrations
- Air supply to victims
- Confirmation of the situation and judgment criteria for entering a cargo hold to rescue victims
- Coordination with a rescue team

In view of the result of this accident investigation, the Japan Transport Safety Board expressed its opinions as follows to the Minister of Land, Infrastructure, Transport and Tourism, pursuant to Article 28 of the Act for Establishment of the Board.

### Opinions to the Minister of Land, Infrastructure, Transport and Tourism

The Board requests the Minister to widely disseminate through the International Maritime Organization (IMO) such information regarding the risks of the use of floatation reagents as that depending upon the properties of the floatation reagent adhering to copper sulfide concentrate, it may generate toxic gas, and that since the generated toxic gas is heavier than air, it stagnates in cargo hold, hence, there is a danger of not being replaced by air.

### Actions Taken by Maritime Bureau, MLIT

At the 17th session of the IMO Sub-Committee on Dangerous Goods, Solid Cargoes and Containers (DSC17) held in September, 2012, the Bureau disseminated the accident information together with the issues identified through the investigation by the Board.

The results of the investigation by the Japan Transport Safety Board are compiled into an investigation report, which then will be publicized. When deemed necessary, the Board also provides recommendations (including safety recommendations) or opinions to relevant ministers or parties involved in the accident, in order for necessary measures or actions to be taken to prevent recurrences and to mitigate the damage caused by accidents.

Safety actions taken in response to the recommendations or opinions provided for a specific accident are publicized on the website of the Board.

[http://www.mlit.go.jp/jtsb/kankokuiken\\_ship.html](http://www.mlit.go.jp/jtsb/kankokuiken_ship.html)

## 5. Summary (Conclusion)

Based on our investigation reports on fatal and injury accidents related to oxygen deficiency or gas poisoning including the four serious accident investigation cases mentioned in this digest, we summarized as follows how these accidents occurred, and what the lessons which will help prevent recurrence are.

### ■ How “Fatal and injury accidents caused by oxygen deficiency or gas poisoning” occurred ■

#### ◆ Breakdown by cause category

**Most of the accidents were due to “failure to measure oxygen or gas concentration”.**

While the number of fatal and injury accidents caused by oxygen deficiency or gas poisoning occurring on chemical tankers was 18 (involving 18 vessels), the number of such accidents due to “failure to measure oxygen or gas concentration” was 15, accounting for a majority of all the cases.

#### ◆ Breakdown of the fatalities and injured

**Accounting for a majority, the fatal accidents contain a high risk once they have occurred.**

The number of the fatalities and injured involved in the 18 accident cases was 41, with a breakdown of 24 fatalities (58.4%) and 17 injured (41.5%). The fact that the number of the fatalities accounted for a majority indicates that they contain a high fatality risk once they have occurred.

### ■ Lessons from the accident investigation cases ■

#### ◆ For working inside enclosed space

- Lesson 1. **Oxygen and gas concentration should be properly measured** before entering enclosed space.  
Lesson 2. Be aware of the details of such onboard work as may endanger the crew, establish safety check procedures during work as well as working procedures, and give them instructions on these procedures and ensure observance by them.

#### ◆ For handling tank washing water

- Lesson 3. In order to prevent mixing different types of tank washing water likely to cause a dangerous chemical reaction while recognizing that tank washing water includes cargo residue on board and bears similar properties as cargoes, it is necessary to identify in which case mixing tank washing waters is dangerous, such as by making a chemical interaction chart for dangerous types of cargo when mixed while referring to procedures for handling dangerous goods or material safety data sheet (MSDS). This should be fully disseminated to the crew. It is also necessary to fully disseminate the method of tank washing water treatment and slop tank usage to the crew in the form of a manual in order to ensure that they observe such procedures at all times.  
Lesson 4. In case a toxic substance like hydrogen sulfide gas is generated by chemical reaction while transporting tank washing water without checking the condition inside a slop tank, the manhole hatch covers of the slop tank should not be opened, and crew members staying near the discharge port of the slop tank's exhaust pipe should evacuate to the windward side of the discharge port of the exhaust pipe while those staying near the accommodation space should evacuate without delay to the closed accommodation sections.

### A word from Director for Analysis, Recommendation and Opinion

Considering most of the fatal and injury accidents caused by oxygen deficiency or gas poisoning occurring on chemical tankers are due to “failure to measure oxygen or gas concentration”, as explained in this digest, it should be noted that one of the most important safety actions that should be taken first is to implement the measurement properly without delay.

Since accidents occurring due to oxygen deficiency or gas poisoning can be prevented by measuring oxygen or gas concentration or using a gas detector in advance, it is earnestly desired to implement these safety actions appropriately without fail.

Your comments are most welcome

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(Starting from September, 2013)