General and Professional Education
3/2018 pp. 39-44
ISSN 2084-1469
DOI: 10.26325/genpr.2018.3.6

SAFETY ON-BOARD A SHIP VS KNOWLEDGE OF THE CHEMICAL PROCESSES DISCUSSED AT THE LEVEL OF HIGH SCHOOL

Agnieszka Kalbarczyk-Jedynak
Dorota Stochła
Ewelina Kostecka
Akademia Morsa w Szczecinie
Wydział Mechaniczny
ul. Wały Chrobrego 1-2
70-500 Szczecin
e-mail: a.kalbaczyk@am.szczecin.pl
e-mail: d.stochla@am.szczecin.pl
e-mail: e.kostecka@am.szczecin.pl

Abstract: Despite the fact that the IMSBC Code provides a precise stipulation of the possibilities of threats to human life and clearly describes requirements regarding the transport of hazardous substances, the number of marine casualties caused by hazardous substances used on-board ships or by substances transported by them is not diminishing. Studies conducted by the Marine Accident Investigators' International Forum (MAIIF) demonstrate that causes of marine casualties frequently include: departures from established procedures, ignorance, lack of identification and proper marking of hazardous areas on-board a ship, instinctive and emotional nature of rescue activities unsupported by adequate knowledge and exercises. In the article an attempt was made at combining the state of knowledge of chemistry among the students of the first years of the Maritime University in Szczecin with the causes of marine casualties resulting from a human factor.

Keywords: safety on-board a ship, chemical processes, education, accident on the ship.

Introduction

Safety on a ship is often associated with lack of accidents. A marine casualty is defined by the Act on the State Commission for Investigating Marine Casualties of 31 August 2012 [1]. The act also provides a definition of a serious marine casualty and a very serious marine casualty, as well as that of a marine incident. The shared feature of all of these terms entails unintended damage to human health, damage to a ship or port infrastructure or damage inflicted on the natural environment. Each year the State Commission for Investigating Marine Casualties presents a report on the analyses of marine casualties and incidents. Marine casualties are affected by mechanical, organizational, human as well as external factors, e.g. the weather. Contrary to what one might expect, it is not the weather that has the greatest impact on maritime casualties. On the basis of the reports of the State Commission for Investigating Marine Casualties from the period of 2013-2016, a conclusion may be drawn that next to the mechanical factor, it is the human factor that constitutes a significant cause of maritime casualties. In 2015, out of 55 reported maritime casualties and incidents, as many as 33 were caused by the human factor. The situation for 2016 was quite similar. An opinion prevails that the unfavourable water conditions are most frequently responsible for all maritime casualties. Contrary to expectations, it is not the weather that has the greatest impact on maritime casualties. Analysing the reports of the State Commission for Investigating Marine Casualties, one may conclude that the human factor is their significant cause [2, 3].

Causes of maritime casualties

Obviously, the most frequent causes of casualties are the results of errors in manoeuvring and errors in navigation. A relatively large number of casualties occur under the influence of unfavourable weather conditions, be it due to a main engine failure or main engine auxiliary blower failure. However, the human factor also has an impact on the occurring situations, what is stressed by the Commission – establishing body - in their report. The Commission reveals that out of 55 reported marine casualties and incidents in 2015, as many as 33 were caused by the human factor (Fig. 1).

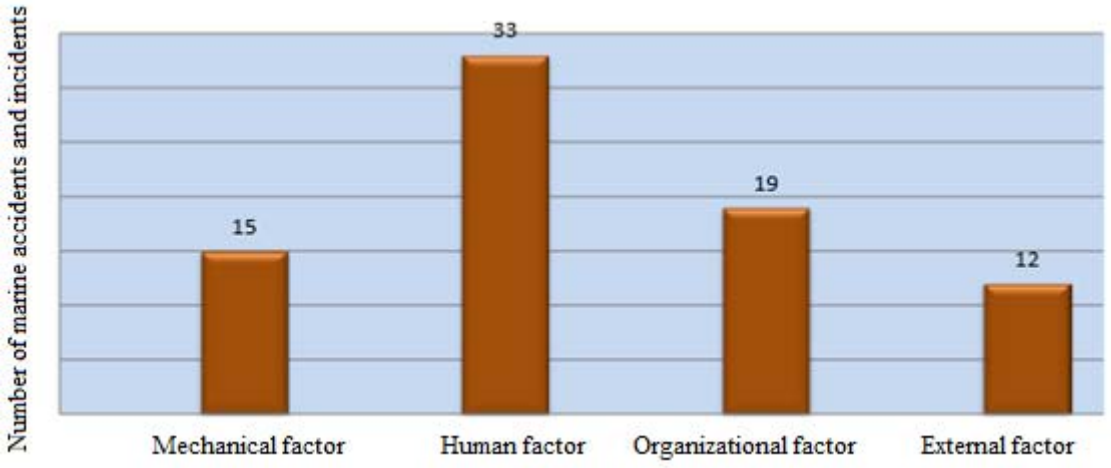

Fig. 1. Factors contributing to marine casualties [3].

The diagram below (Fig. 2.) presents the causes of all the casualties and incidents that the Commission for Investigating Marine Casualties handled in 2015. [3]
The human factor must be understood as the character traits that crew members demonstrate, i.e.: skills, abilities, knowledge resulting from experience and training, mental resilience, emotional state, crew's behaviour during a casualty [4]. Ignorance of various chemical processes often contributes to the occurrence of dangerous situations on a ship. Ignorance of the processes taking place on-board may lead, as the practice shows, to damage to health or even to the death of crew members. Upon a close examination of the report made available by the Commission for Investigating Marine Casualties from recent years, it becomes evident that the number of marine casualties and incidents caused by the human factor is rising systematically (Fig. 3.).

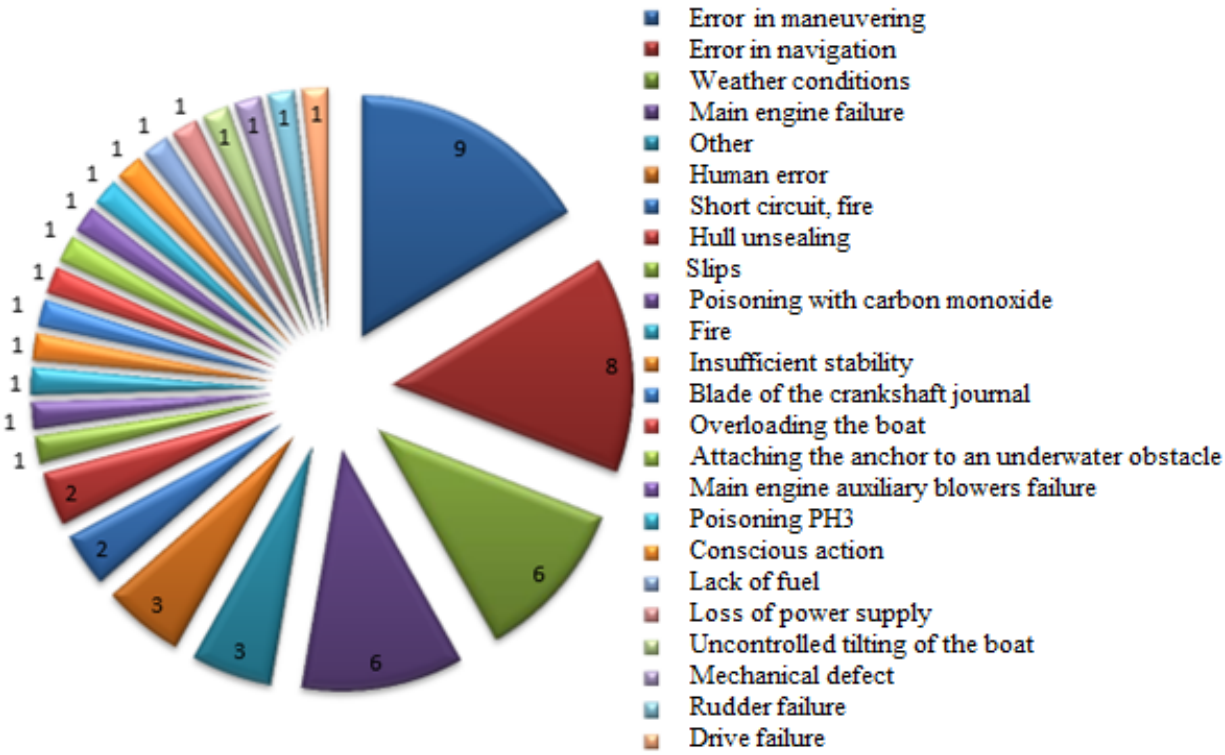

Fig. 2 Causes of marine casualties in the period of one year [3].

Fig. 3. Factors contributing to marine casualties in the period from 2013 to 2016 [5].

The London P&I Club defines the element of human error in marine casualties as procedural deficits, excessive self-confidence, instinctive and emotional acts displayed instead of knowledge and proper training [6].

When analysing maritime casualties from the period of 2013-2016, one may confidently claim that many calamities could be relatively easily prevented. All that needs to be done is reaching to the knowledge acquired at high school and at university. The material that the students of the Maritime University must learn includes the questions related to basic physical and chemical processes, including oxidation and reduction reactions, as well as issues related to the use of fuels. Classic examples of marine casualties in the above-mentioned period, i.e. 2013-2016, in which the main causative element was the human factor, are as follows:

-15.05.2013: M/V Ju Da; poisoning with gases from transported soya meal; loss of consciousness and a head injury of the cargo controller, who was not a crew member;

16.08.2013; Miss Alicja; a fire caused by an omission to switch on engine chamber ventilation after taking in fuel – the effect was a complete burn-down of a motor yacht and of verticals rubber fender beam on dolphins and steel spans between breakwater dolphins, burning off of paint coating;

- 28.04.2015: Corina, poisoning with carbon (II) monoxide resulting in the death of one crew member, and four other people giving aid to the accident victim, who were poisoned with carbon monoxide coming from the cargo of pellets.

- 25.09.2015: Nefryt - fatal phosphorus hydride (PH_3) poisoning, a substance used for shea nuts fumigation; poisoning of 17 crew members, 2 of whom died.

- 22.07.2016: KOŁ-288 fishing boat – hydrogen sulphide poisoning of eight people.

All those dangerous situations could have been avoided. Three cases, i.e.: M/V Ju Da, Corina, Koł-288, are situations that took place in ships' cargo holds or in adjacent rooms. In the case of M/V Ju Da soya meal poisoning took place, which, as a result of oxidation, caused a serious drop in oxygen amount in the companionway to the ship's cargo hold. Eventually, one of the cargo controllers, who was not part of that ship's crew, lost consciousness, and fell down from the height of 1.5 m to a lower-laying platform. None of the cargo controllers, who arrived to the ship in order to collect a sample of soya bean, measured oxygen concentration before entering the cargo hold. Failure to undertake such activities arose from ignorance of both oxidation and reduction processes of an organic cargo and the consequences resulting from them, as well as from failure to observe proper procedures concerning an entry to an enclosed space on a ship. In the case of "Corina" general cargo vessel one crew member died in a stowage room and four other people got poisoned with carbon monoxide during resuscitation. Here also the main cause was ignorance. A seaman failed to predict that since wooden pellet is stored in a cargo hold, it may reduce oxygen amount in the cargo hold as a result of oxidation and at the same time it may create carbon (II) monoxide in its place. That is why he did not follow the procedure for entering an enclosed space on board a ship. He failed to check oxygen and carbon dioxide levels in the room directly adjacent to the cargo hold. The result was an instant loss of consciousness and consequently death of the victim. Unloading fish from KOŁ-288 fishing boat had equally tragic consequences. Before unloading was commenced, sea water was poured into the cargo hold with the stored fish in order to give the cargo liquidity. The unloading was performed with a pump. The worker operating the sucking pipe lost consciousness falling face down into the water with fish. As a result of conducted rescue operation, seven other people were subject to poisoning. Once more, ignorance was the cause of casualty. As a result of fish decomposition hydrogen sulphide appears – a gas which in this case settled at the bottom of the cargo hold and partially dissolved in water. Ship operation crew was not aware of the possibility that a toxic substances may occur. Eventually, the operation crew inadvertently got themselves exposed to direct contact with hydrogen sulphide. Unawareness of being in the presence of a toxic substance is also characteristic of yet another

situation. In the case of Nefryt - general cargo vessel 17 people were poisoned, two of them fatally. The cause was poisoning with phosphorus hydride (PH_3). That compound was generated in a chemical reaction of aluminium phosphide with water. The reaction occurs very slowly. The period of initiation of the chemical reaction is approximately one hour. On account of the above, the use of preparations containing PH_3 may be carried out without the use of airways protection. However, release of phosphorus hydride may last as long as 72 hours. At the same time, the released gas is odour-free and colourless. Thus, it is difficult to realize without a proper measurement device whether the gas is still being released. Additionally, some leaks were detected in a ventilation duct running in the cargo hold casing in which fumigation was carried out. The above-mentioned leaks emerged as a result of corrosion of ventilation system elements. Gas leaks caused effective and systematic poisoning of the crew members while they were resting in their bunks. Symptoms of phosphorus hydride poisoning resembled food poisoning. When the cause of that poisoning was established, two of the crew members had already been dead. The presented situations share one common cause – ignorance. Lack of basic information on biochemical and biophysical processes entail casualties that were catastrophic in scale. Obviously, the fact that in all of these cases safety procedures were not observed was not without its own significance. In the case of "Nefryt" - general cargo vessel the ship's captain failed to fulfil the recommendations of the International Maritime Organization known as "Code of Safe and Efficient Maritime Fumigation". It is not a binding legal document, but knowing that a chemical substance is being sprayed, the biochemical risks of which are unknown to the entire crew, the meaning required steps included checking the leakproofness of the cargo hold and measuring gas concentration at least every 8 hours. Similarly, on-board "Corina" and M/V "Ju Da" the levels of oxygen and carbon monoxide needed to be checked in the rooms adjacent to the ships' cargo holds. This is a necessary measure if there is a suspicion that the material kept at the cargo hold might be oxidized. The oxidation process of vegetables, cereals, wood, forest products and iron is always associated with a decrease of oxygen levels in the air. Often toxic gases, such as carbon monoxide, hydrogen sulphide and others are created as a result. The afore-mentioned hydrogen sulphide was the cause of poisoning of eight people on KOŁ-288 fishing boat. At the same time, it must be borne in mind that the first two individuals fainted in the course of performing their work, but the next six people did so while giving aid to the previously injured and no one thought that a toxic gas of relatively high concentration appeared at the surface of floating fish. The gas remained on the surface of floating fish at the bottom of the cargo hold. Next crew members, not realizing the presence of hydrogen sulphide, instinctively went down to the cargo hold. Each instance of going down to the cargo hold resulted in the crew member fainting. The fishing cutter's crew once again demonstrated lack of elementary knowledge of basic chemistry and at the same time failed to observe the obligation of following proper procedures. Instead of solid knowledge the crew was guided by their instinct to bring aid, which, though commendable, proved to be ineffective. Evidently, ships' cargo holds are often a place where maritime casualties and incidents occur, and elementary knowledge of biochemistry is necessary. However, human errors contributing to dangerous situations on board a ship can also be attributed to lack of knowledge of how to safely handle fuels and oil products. A very serious maritime casualty of "Miss Alicja" motor yacht could serve as a good example. While passing the port channel in Gdańsk Nowy Port the yacht burst into flames. The cause of the casualty involved the omission to switch on manual ventilation. Even though the information regarding that requirement was placed on a plate next to the switch, none of the individuals on-board the motor yacht followed the instructions featured on it. It was evidently due to the ignorance and lack of knowledge of how to properly handle oil products. The last of the presented situations did not involve professional seamen.

Student survey analysis

A question then arises how students are able to handle such situations. Although it cannot be verified in practice, questions from the field of chemistry were asked to a group of 80 students of the first year of the Maritime University in Szczecin. The questions were framed in such a way so as to verify whether the students surveyed remember selected pieces of information from junior and senior high school and whether they are capable of translating that knowledge into practical situations that they may encounter in their future profession. The survey was meant to determine what the general level of student's knowledge is. The survey contained eight simple test questions. Each question was accompanied by five answers.

1. Certain bulk cargoes may cause a decrease of oxygen level in a cargo hold. Identify what cargoes those may be:
a) vegetables and cereals
b) wood and forest products
c) ferrous metals
d) a, b, c answers are correct
e) the above products do not decrease oxygen concentration, since they do not react with oxygen.
2. Certain bulk cargoes, e.g.: pellet, may oxidize, causing:
a) a decrease of oxygen level in a cargo hold
b) generation of toxic gases
c) spontaneous ignition
d) a, b, c answers are correct
e) it is not possible
3. Certain processes cause a decrease of oxygen levels in an enclosed space:
a) welding, cutting, soldering

b) rusting
c) paint drying
d) bacteria activity
e) all of the answers are correct
4. What chemical process may contribute to a person asphyxiating, if they stay in an enclosed space on-board a ship, e.g. in a humid cargo hold?
a) iron corrosion
b) iron reduction
c) high air humidity
d) a, b, c answers are correct
e) a, b, c answers are incorrect
5. How should an enclosed space be ventilated, if there is probability of gases which may cause poisoning in humans being present there?
a) with oxygen – it will cause a quick lung oxygenation in the person entering such a room
b) with nitrogen – because it is an inert gas
c) with air
d) with carbon dioxide in order for it to displace other combustible gases
e) first we ventilate the room with carbon dioxide and then with pure oxygen
6. Which gases accumulate at the floor level?
a) hydrogen sulphide
b) carbon (II) monoxide
c) methane
d) ammonia
e) all of the answers are correct
7. If an unconscious person is found in an enclosed room with poor ventilation, one first needs to:
a) start resuscitation immediately
b) move the unconscious person to another place with good ventilation and only then start resuscitation
c) notify rescue services and wait for professional help
d) not to undertake any actions;
e) all of the answers are incorrect
8. Solvents such as kerosene, petrol, or paint removing substances are dangerous, because:
a) in contact with the skin they penetrate into the system 10 times more strongly than by inhalation
b) in contact with the skin they penetrate into the system 10 times less strongly than by inhalation
c) they cause poisoning, which may bring about vertigo, drowsiness, headaches, coma or even death
d) a and c answers are correct
e) b and c answers are correct.
The percentage of correct answers is presented in Table 1.

Tab. 1. Answers obtained in the survey.

Answer number	Correct answers [%]	Incorrect answers [%]
1	20	80
2	35	65
3	46	54
4	13	87
5	93	7
6	79	21
7	35	65
8	75	25

The questions numbered one through three and question six aim to verify what information students remember from their third and fourth stage of education (junior and senior high school or technical senior high school). Those issues are not directly discussed in chemistry classes. However, they are featured in the chemistry curriculum at the fourth stage of education (senior high school and technical senior high school) at basic level, be it when food (question 1) or medication are discussed, and at the third stage of education (questions three and six). Furthermore, question one is meant to lead students to a correct answer in the second question. It verifies how successful students doing the survey are in reading with comprehension. Simultaneously, the issues featured in all of the questions are significant from the point of view of ship's safety. As demonstrated by the reports of the State Commission for Investigating Marine Casualties, ships' crew members are not always aware of the possibility of high density gases accumulating, i.e. gases accumulating in the lowest parts of a given room. In the end, individuals resuscitating frequently faint, since they carry out the procedure directly in the same location in which they found the injured individual, not caring that they themselves are breathing noxious gas that caused loss of consciousness of another person. As demonstrated by the Table 1, students are aware of the existence of "heavy" gases, but they fail to translate that knowledge into practical applications.
At the same time, first-year students do not yet know the procedures to be followed in life threatening situations and are not able to foresee on their own the proper course of conduct in difficult situations. Furthermore, it appears that first-year students do not always manage to answer questions that arise from previously asked questions, even though they have already given the right answers. From the answers given to question seven it transpires that the driving force for the behaviour demonstrated in dangerous situations are emotions and not solid knowledge or knowledge of procedures of conduct. Even though some people were aware of the

presence of heavy gases, they still attempted to resuscitate injured accident victims at the location in which there was great likelihood of noxious substances accumulating at the floor level. Question No 4, concerning the process of corrosion, poses the greatest difficulty to students. This was due to the fact that they had not encountered the issue at the high school level of their education. At the same time, the individuals surveyed are unable to link the previous answers sufficiently to provide a correct answer regarding corrosion in poorly ventilated rooms. The process is common knowledge among experienced seamen. They know how important it is not to enter enclosed and humid rooms, where there is a suspicion of existing corrosion centres, without observing proper procedure, particularly, if such rooms have not been used for a long time. It may result in hypoxia, or even death of a person who is not properly prepared, since the process of corrosion causes a decrease of oxygen concentration in the air.

Conslusions

In the face of danger, solid knowledge and observance of proper procedures is vital. Spontaneous and unorganized rescue activities may prove to be fatal, as they did on-board "KOL-288", where both the crew members of "KOŁ-288" as well as KGPR's workers demonstrated ignorance of the fact that a cargo of fish in a hold may start decomposing in a short period of time. The effect may be a release of harmful substances. Ignorance of the proper protocol to be followed in dangerous situations and failure to respect the procedures as well as following one's instinct instead of applying well founded knowledge may contribute to a growing scale of damage. That is what occurred on-board Miss Alicja, where, due to the use of improper means during fire-fighting operations, a small fire caused serious damage to the elements of seawall construction and fittings along with substantial material losses. The ability to translate the acquired knowledge into new situations is also of importance. This aspect is evidently omitted at every stage of education. Thus, further attention must be paid in the course of youth education to that particular ability. In light of the invoked facts, one may conclude with absolute certainty that ship's safety and the safety of its crew are decidedly determined by solid knowledge and its application in practice. The need of repeating trainings and renewing licences appears to be a crucial component in a seaman's work at every stage of their career. Lack of fundamental knowledge of chemistry is a frequent cause of accidents on ships. And ignorance may cost the lives of many people. Considering the above, particular attention needs to be paid to the proper teaching of chemistry classes, in order to sensitize students to the fact that awareness of basic principles of chemistry may translate into work safety on-board a ship.

References

1. Ustawa z 31 sierpnia 2012 o Państwowej Komisji Badania Wypadków Morskich, Dziennik Ustaw z 2012 poz. 1068, Poland, 2012.
2. Roczna analiza WIM 2013, http://pkbwm.gov.pl/images/uchwaly_raporty/Roczna_analiza_WIM_2013_1.pdf, (access 20.03.2018).
3. Roczna analiza WIM 2015, http://pkbwm.gov.pl/images/sampledata/analizy/Analiza_roczna_2015.pdf, (access 20.03.2018).
4. Dziula, P., Jurdziński, M., Kołowrocki, K., Soszczyńska, J., Modelowane bezpieczeństwa morskich systemów I procesów transportowych, Prace Wydziału Nawigacyjnego Akademii Morskiej w Gdyni, nr 22, Gdynia, 2008.
5. Roczna analiza WIM 2016, http://pkbwm.gov.pl/images/sampledata/analizy/Analiza_roczna_2016.pdf, (access 20.03.2018).
6. P&I Club, http://www.ukpandi.com/loss-prevention/article/593-8-08-enclosed-space-entry-worldwide-842, (access 20.03.2018).