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Articles

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Environmental impact of mishandlings on tankers

Abstract

Sea transport of liquid substances (petroleum and its derivatives) is done with the use of vessels called tankers. Their incorrect operation constitutes a great threat to the natural environment of maritime areas. Neglect of individual operations or failure to observe guidelines in many cases lead to oil spills the consequences of which are frequently irreversible and pose a threat to environmental safety.

This article analyses the threats engendered by improper operation of oil tankers and describes how the operations necessary in transport of liquid substances with the use of tankers should be performed. It is an important issue since elimination of the abovementioned threats at the same time favours the efforts aimed at the highest possible degree of safety of marine natural environment (or more broadly ecological safety).

The article also attempts to answer the following questions: *Is the majority of disasters involving tankers caused by a human factor? Are the disasters rather caused by political factors and armed conflicts?*

The answer to those questions may form a basis for further research aimed at raising the level of marine safety.

Keywords: tanker, environmental safety, ecological safety, marine safety, transport of liquids, crude oil

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Introduction

Oily liquid substances become dispersed on the surface of water very quickly. Negative effects of a leak are evident several minutes afterwards. Such leaks cause, *inter alia*, ecological damage, death of sea animals or financial losses. After a spill the marine ecosystem remains upset, and sometimes it becomes devastated.

The issues concerning marine safety are rarely encountered in Polish studies, more frequently in foreign ones, though they are mainly considered in the context of threats caused by adverse weather conditions or littering of water reservoirs and the adjacent areas.

Incorrect operation of oil tankers constitutes an enormous threat to the environment – especially seas. Petroleum products and crude oil are most frequently transported by tankers. They are characterized by large density and weight. Crude oil forms a barrier to oxygen and solar rays.

A well-insulated and equipped tanker reduces the possibility of a leak. The operational requirements concerning the construction and equipment of tankers are contained in Annex I of MARPOL Convention. Special emphasis is placed on the discharge of transported goods since this operation causes most of the pollutions getting into the sea. Good training of ship and terminal crews also prevents routine errors. The article will expound on these topics.

Threats caused by improper operation of tankers

Tankers are surface vessels capable of transporting liquid loads.[1] Sometimes the term *oiler* is used is used for *oil tankers*. Tankers are used mainly for the transport of petroleum and its derivatives. In case of a leakage of such substances the aquatic ecosystem becomes gradually upset.[2]

The contemporary dangers of tragic consequences arising from incorrect operation of tankers are leaks caused by an explosion, collisions of tankers with other vessels or stranding. However, a threat may arise at any time of the operation of a tanker, even during cleaning, sampling, probing or loading operations. According to the authors of the publication *Ropa naftowa w transporcie morskim (Petroleum in sea transport)* out of 38 oil leaks – 11 were caused by stranding, 11 by collisions, 8 by fire and collisions, and 8 by construction defects of the hull.[3]

Enormous quantities of petroleum get into the sea as a result of collisions of tankers, though the largest quantities of crude oil leak out into the water upon extraction.[4] Nevertheless, tanker leaks continue to constitute a great threat to the safety of marine environment.

Tankers used for transport of combustible liquids are considered to be the most dangerous type of vessels. In the majority of cases their damage starts an ecological disaster.

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1 Wiewióra, Wesołek, Puchalski (2007): 19.

2 https://www.gospodarz.pl/encyklopedia-rolnicza/r/ropa-naftowa.html, [access: 02.01.2020].

3 Wiewióra, Wesołek, Puchalski (2007): 123.

4 https://histmag.org/Nie-tylko-Exxon-Valdez-czyli-jak-ropa-trafia-do-morza-8746, [access: 02.01.2020].

Fires and explosions have been one of the greatest threats occurring on tankers since they started to be manufactured. The "black" month was December 1969. Three major explosions occurred in only one week:[5] *Margessa*, *Mactra* and *King Haakon VII*. It is interesting to note that until then fifty explosions had occurred which had killed as many as two hundred fifty crew members.

It has been disclosed that the cause of the three accidents was probably static electricity which is generated during high-pressure washing.

An explosion, otherwise called a chemical burst, is a violent chemical reaction during which large quantities of gases and vapours are released. When a fire starts, it is not the liquid that is burning but its vapours which are so hot that they evaporate from the liquid. This happens when the mixture of hydrocarbon vapour and air become so concentrated that it becomes combustible. Therefore, the lower (LEL) and upper (UEL) explosion limits are distinguished. It the concentration of vapours is below LEL no combustion can take place because the excess of air will absorb the heat generated in the initial phase triggering the incident. On the other hand, UEL is the highest concentration of vapours of combustible materials in air at which combustion is possible under the impact of the trigger. If the concentration of vapours exceeds UEL – no fire will take place.[6]

Each component of the transported mixture has its LEL and UEL. When insert gas is introduced to the mixture of hydrocarbon vapours and air, its flammability limits will be narrowed (LEL will increase and UEL decrease). Alongside

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5 Wiewióra, Wesołek, Puchalski (2007): 123.

6 Ibidem: 124.

growing concentration of inert gas, the gap between LEL and UEL will continue narrowing creating a flammable space. The greatest risk of entering the flammable area is generated by incorrect thinning with air or inert gas. The person performing this operation should be properly trained and possess the know-how when and how the thinner is to be used correctly.[7]

A serious step towards a disaster is also spontaneous combustion. It may be differently called the initiation of burning through slow but even warming of the combustible mixture in its entire mass. No external stimulus contributes to this process. To contain spontaneous combustion temperature of the flash point should be controlled. It is the lowest temperature at which liquid fuel can vaporize to form an ignitable mixture in ambient air. There are two types of flash point: in an open and closed crucible. The former is higher than the latter by about 6˚C, which is connected with hydrocarbon vapours in the open crucible method. However, the closed crucible methods is more commonly used.[8]

Carrying liquids over on open sea space always involves a fire hazard. However, flammability of each liquid is different and that is why over the year many liquid flammability classifications have been developed. Classification of dangerous goods is contained in the International Maritime Dangerous Goods Code (IMDG). There are three classes which are further divided into sub-classes. Crude oil as well as petroleum products are included in Class 3 – Flammable liquids. This means that they are most easily combustible liquid loads.

7 Ibidem: 127.
8 Ibidem: 128.

The majority of them are also volatile which also increases the possibility of a hazard during their transport.[9]

The dangers resulting from mishandling of a tanker may be innumerable, though most frequently they are crashes (as in the case of Atlantic Empress and Aegean Captain)[10], earlier mentioned technical problems during washing, sampling, probing, loading and unloading of goods, tank ventilation and any single operation connected with a tanker. Any mistakes and flaws are the first step to an ecological disaster; therefore, it is extremely important to perform each operation caring for all details.

A large source of water pollution is also docking of vessels, bilge water and fuel as well as accidents of vessels carrying dry loads.[11]

As commercial vessels tankers are also in danger of terrorist attacks. Petroleum and its products constitute one of major loads the aggressors desire to capture. Tankers practically have no proper safeguards and are unprepared to fend off a terrorist attack. Owing to a small number of the crew and high flammability of petroleum products tankers are not equipped with firearms (even for self-defence or as a deterrent). The additional features encouraging terrorists to attack is the autonomy and independence of vessels from supplies from land as well as their mobility and communications equipment. The cargo carried by a vessel may become an object of negotiations since it is not only valuable itself but may also be used as an explosive.[12]

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[9] Ibidem: 129.

[10] http://eszkola.pl/wos/katastrofy-tankowcow-7001.html, [access: 02.01.2020].

[11] Włodarski (2001): 55.

[12] Szulczewski (2007): 31.

Oil Record Book

Each tanker with a displacement above 150 BRT (gross register tons) should have an Oil Record Book (ORB) on board. It is used for recording each operation involving pure crude oil, its derivatives and mixtures. Operations are divided into those performed in the engine room and loading/ballasting operations. Book records are coded as provided for in the MARPOL Convention. Each recorded information should be dated and signed by the office responsible for its performance. The officer should also initial each page of the Book.[13]

Part I of the ORB (Machinery space operations) includes the following records:[14] ballasting or cleaning of oil fuel tanks, discharge of dirty ballast or cleaning water from oil fuel tanks, collection and disposal of oil residues from fuel tanks, discharge of bilge water from machinery spaces.

In Part II, cargo / ballast operations are recorded, namely[15]: loading of oil cargo, internal transfer of oil cargo during voyage, unloading of oil cargo, ballasting of cargo tanks and dedicated clean ballast tanks (does not apply to SBT – segregated ballast tanks), cleaning of cargo tanks including crude oil washing, discharge of ballast except from segregated ballast tanks, discharge of water from slop tanks, closing of all applicable valves or similar devices after slop tank discharge operations, closing of valves necessary for isolation of dedicated clean ballast tanks from cargo and stripping lines after slop tank discharge operations, disposal of residues.

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13 Ibidem: 64.
14 Ibidem: 65.
15 Ibidem.

Sometimes, in the case of a hazard to life or damage of a vessel, an emergency or other fortuitous event cargo must be discharged into the sea. Each such event should be recorded in the Book and the reason for the disposal of cargo should be stated.

Records should be entered on an ongoing basis and in clear hand. It must be at all times ready for making it available for inspection by the competent authorities. It must be kept on board of the vessel for three years from the time of the last entry.[16]

Hazard prevention and avoidance

In terms of safeguards tankers specializing in the carriage of crude oil and petroleum products are divided into two groups. The first includes vessels without an inert gas system (removed on new oil tankers of DWT 20000 and larger), and the other one vessels equipped with an insert gas system. In the first group, the most hazardous operations are as follows:[17]

- loading,
- unloading,
- tank ventilation (a safe process of thinning inner atmosphere in the tank with air),
- tank washing.

During the above mentioned operations the inner tank atmosphere may enter the so-called explosive area. The major factor is time and space the explosive mixture is contained in.

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16 Ibidem.

17 Wiewióra, Wesołek, Puchalski (2007): 129.

In this case, utmost care must be maintained when the tank is being washed. It is important how much time will elapse from tank washing to its degassing. Several hours after unloading a homogeneous explosive or close to explosive atmosphere is formed within the tank. The rest remains in the hands of specialists, their care as well as the type of cargo and explosive area. Alas, many times in history explosions have occurred on tankers during this very procedure.[18] In this connection, the review of the SOLAS convention[19] (regulations 60, 61, 62) introduced the requirement of equipping tankers with an inert gas system.[20]

Tankers equipped with an inert gas system are safer. The only hazards they face are associated with human error. At all times during their operation oxygen concentration is lower than the limit by 11.5% by volume, which given correct operation prevents entering into the explosive area.[21]

The application of an inert gas system is correct prevention which is aimed at eliminating all possible hazards or at least minimize them. The unloading operation may serve as an example. The combination of the unloading process with simultaneous feeding of inert gas leads to changes in the composition of the atmosphere so that it is far from the combustible zone. The same goes for any other process, e.g. washing or ballasting. Introduction of inert gas maintains the atmosphere at a safe distance from the explosive area.[22]

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18 Ibidem.

19 *Międzynarodowa konwencja o bezpieczeństwie życia na morzu z 1974* (Journal of Laws 1984 no. 61 item 318).

20 Wiewióra, Wesołek, Puchalski (2007): 123.

21 Ibidem: 130.

22 Ibidem: 131.

Ventilation and degassing is required only when there is a need for human presence in the tank, e.g. for repair or inspection. Inert gas should be also introduce before degassing in order to thin the atmosphere and reduce the concentration of hydrocarbon vapours. It is important as in case of degassing with air the atmosphere will enter the explosive zone.[23]

Four states of the atmosphere occur during washing:[24]

- inert atmosphere – accompanies introduction of inert gas, incapable of combustion, oxygen concentration is reduced (it may not exceed 8% by volume),
- uncontrolled atmosphere – atmosphere with any presumed composition,
- overly poor atmosphere – owing to deliberate reduction of the concentration of hydrocarbon vapours below LEL it is unable to combust. It occurs when the concentration of hydrocarbon vapours is lower than 50% LEL.
- overly rich atmosphere – is neither capable of combustion owing to the deliberate increase of the concentration of hydrocarbon vapours above UEL. For volatile products (including petroleum products) this atmosphere is assumed to occur when hydrocarbon concentration exceeds 15% by volume.

In order to maintain the highest possible level of safety before the tank is washed in inert atmosphere it should be ventilated with inert gas to obtain hydrocarbon concentration equal to 50% UEL. The correct measurement is made with special thermoconductive devices based on dependence

[23] Ibidem.
[24] Ibidem.

between electrical resistance and thermal conductivity of gasses.[25]

In the course of the tank washing procedure inert gas should be fed all the time in such quantity that would block air entering the tank. What is important is that oxygen concentration at half the height of the tank and at a distance of one metre from the deck should be less than 8% by volume. When this value is exceeded, washing should be stopped immediately and then oxygen concentration in the tank atmosphere should be reduced to below 8%. Each compartment of the tank should be measured separately and the correct pressure of inert gas should be maintained – it should be higher than ambient pressure. Should underpressure develop in the tank, the washing procedure should also be interrupted and pressure should be raised.[26]

Washing in an uncontrolled atmosphere should be performed basing on many principles. First of all, all existing sources of combustion should be neutralized. Also the number of washers (used simultaneously) should be reduced to four or three (depending on their efficiency). Then conductivity of washing hoses should be carefully examined and they have to be correctly connected before the machines are put into the tank. When the machines are in the tank hoses must not be separated (they may be loosened in order to drain water but should be tied again). People involved in tank washing should also remember that closed circuits should not be used so as to avoid washing with oiled water (it raises static electricity); likewise no chemical additives and water hotter than 60˚C should be used (in certain case it is necessary

[25] Ibidem: 132.
[26] Ibidem: 133.

but then washing should be done in an overly poor or inert atmosphere). Under no circumstances it is allowed to feed vapour into the tank and it should be all the time dehumidified. In case any slop water does appear, washing should be stopped and the tank dried out. When any objects are inserted or when probing the procedure of washing in an overly poor atmosphere should be followed.[27]

Washing in an overly poor atmosphere is the most difficult operation with the largest number of rules. Just like in the case of washing in an uncontrolled atmosphere the tank must not be washed in a closed circuit. On the other hand, washing in a open circuit is possible only on land (in compliance with the MARPOL convention). Washing in an overly poor atmosphere should be started with flashing the bottom of the tanks and removing residues, and then flashing of pipes and cargo pumps. Out of concern for the natural environment of marine areas slop water should be collected in residue tanks. Some vessels are equipped with a universal ventilation system. On such vessels, the tank that is being washed should be separated so as to prevent the flow of hydrocarbon vapours. The entire tank should be ventilated so that the hydrocarbon vapour concentration drops below 10% LEL. In order to ensure correct measurement, samples should be collected at several heights. The composition of the atmosphere should be checked throughout washing. The alert threshold occurs when the concentration of hydrocarbon vapours exceeds 50% LEL. In such case washing should be interrupted immediately and ventilation should be continued until the concentration drops to 20% LEL.[28]

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27 Ibidem: 135.

28 Ibidem: 133.

An important role is played by washer type. If mobiles washing machines are used hoses should be checked regularly for any obstructions. Hoses must be connected before they are entered into the Itank. In this case chemical additives may be used, though only when the water for washing is no hotter than 60˚C. Probing or inserting objects into the tank may be done only with the use of probing pipes. Each metal object inserted into the tank must stay there grounded for five hours after the end of washing (if ventilation is used this time is one hour). It is prohibited to insert into the tank any synthetic fibres and metal devices on electric cables.[29]

Only persons with specialist training are authorized to do washing in an overly rich atmosphere. This type of washing is not done frequently because it requires generation of an overly rich atmosphere. During such washing a drop in the concentration of vapours as a result of leakage should be reckoned with. When the concentration of hydrocarbon vapours falls below 15% by volume washing should be stopped immediately (for crude oil).[30]

The procedure of washing tanks on tankers is very complex. Only the post essential elements have been presented above. In reality, the process is very complicated. Therefore, there is high possibility of *human error* which may lead to irreversible consequences. The washing process has been explained in detail in the publication *Mycie i czyszczenie zbiorników ładunkowych na zbiornikowcach (Washing and cleaning of cargo tanks on tankers)*.[31]

Apart from washing, another hazard generating operation is the exchange of gases in tanks. This involves earlier

[29] Ibidem: 134.
[30] Ibidem: 133.
[31] Wiewióra (1994).

mentioned ventilation, inerting and degassing. The earlier mentioned ventilation means thinning of the tank atmosphere with air. Degassing is the complete removal of all gases from the tank and filling it with air in order to ensure safe entry. Inerting is the removal of hydrocarbon vapours with inert gas.[32]

In order to perform safe ventilation before cargo is accepted on board without the inert gas system it is necessary to prepare the atmosphere properly. Its hydrocarbon concentration must be lower than 40% LEL. At inspections the concentration should amount to less than 1% UEL i and the tank should be all the time ventilated effectively.[33]

The types of ventilation in tanks prepared for cold and hot operations are different. In a tank prepared for cold operations the concentration of hydrocarbon vapours should amount to less than 1% UEL. It is necessary to control residues and sediments so that they do not cause a rise of this concentration. The tank should be all the time ventilated. Before entering the tank it is necessary to check oxygen concentration, which should amount to 21%. When the vessel is at the wharf it is necessary to get a permission for ventilation from a representative of port authorities. In a tank prepared for hot operations the concentration of hydrocarbon vapours should also amount to less than 1% UEL. Any residues and sediments should be removed within the radius of ten metres from the site where the operations are performed. Hydrocarbon concentration should be constantly checked and there should be an appropriately trained firefighter present on site. All pipelines have to be cut off and

[32] Wiewióra, Wesołek, Puchalski (2007): 136.
[33] Ibidem.

the neighbouring tanks should be degassed, ventilated or even flooded with water. All the neighbouring bulk tanks should be kept under control. No hydrocarbons and toxic substances must get into them. High temperature can cause a penetration of heat through the bulkhead so that the adjacent space must be filled with water of fuel above the adopted level. It may be degassed as well. Due to the fact that high-temperature operations involve a greater risk of hazard it is more complicated to get a permission than in the case of "cold" operations. Work may be started only when check lists have been filled and a permission has been obtained, and if the vessel is at the wharf it is also necessary to obtain a permission of a representative of port authorities.[34]

There are two general methods of the exchange of gases. The first one involved mixing (thinning). It consists in feeding a gas from the outside and mixing it with the original atmosphere in the tank. The gas must be fed with the speed of 10–45 m/sec so that it gets mixed with the gas within the tank. The other method involves displacement. This method also consists in feeding a gas into the tank but it must displace the gas originally contained therein. The feeding speed does not exceed 2 m/sec so as to prevent mixing.[35]

In order to secure an appropriate level of safety during each of the above mentioned operations samples must be collected regularly at several heights and places in the tank so as to obtain a complete measurement and the effect of the operation. When sampling a mixture of air and inert gas special care must be observed as the mixture may turn out to be explosive.[36]

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34 Ibidem: 137.

35 Ibidem.

36 Ibidem: 138.

One of major preventive procedures is measurement. Measurements are performed all the time and in every circumstances. Thus it is possible to determine quickly and accurately the quantitative composition of various gaseous mixtures. Physical, chemical and physical-chemical methods are used. Measurement are performed with diverse devices. In individual phases of tanker operation it is mandatory to perform measurements of the concentrations of:[37]

1. oxygen in tank atmosphere,
2. oxygen in inert gas,
3. hydrocarbon vapours in air below LEL,
4. hydrogen vapours in air at any concentration,
5. hydrogen vapours in inert gas,
6. hazardous and toxic substances in air in trace quantities.

The people who supervise the safety of operations on tankers would be well trained and watch against falling into the rut so that each operation be carried out skilfully and accurately. The correct performance of operations on tankers is, therefore, mostly dependent on the human factor, namely: the awareness of the crew of the subject of atmosphere in cargo tanks, knowledge about the functioning of the inert gas system, knowledge of static electricity, knowledge of fire precautions[38] as well as the application of this knowledge in practice.

[37] Ibidem: 146.
[38] Ibidem: 123.

Procedure in case of a spill

Spills constitute the greatest threat to the natural environment of maritime areas. Each, even the smallest spill must be reported immediately notwithstanding whether the reporting person is responsible for the spill or has merely noticed it. The captain of the vessel from which the leak comes is obliged to report the incident to the nearest coastal country. The report must provide the following information:[39] name of vessel, radio communication frequency or channel, type of vessel, name, address, telex and telephone number of vessel's owner, incident description, damage description, position, vessel's course and speed, quantity of spilled cargo, other cargo on board, efforts made to prevent water pollution.

Moreover, the captain should also report the events and changes connected with the spill on an ongoing basis. Additionally, he should also adopt measures in order not to expose the vessel and the crew to danger. In case of a petroleum spill it is necessary to do the following:[40]

1. shut off the pumps and close all valves in the system from which the spill occurred,
2. call the first mate,
3. notify the engine room crew and order them to feed water onto the deck,
4. prepare fire-fighting equipment,
5. notify the terminal,
6. promptly dry the spill on deck (with oil absorbents).

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39 Włodarski (2001): 65.

40 Ibidem.

In order to draw more attention to sea pollution, international conventions and legal acts of individual states (relating to spills on territorial waters) provide for penalties for persons responsible for contamination of marine environment. The penalty depends on vessel's deadweight and type of spill. The United State of America set one of the highest penalties in the world. The maximum fine amounts there to 250,000 US dollars of fifteen years in prison. Failure to inform about a spill is penalized with a fine of 10,000 US dollars or one year imprisonment. Apart from civil penalties, also penalties for vessels are imposed. The amount of the fine depends on tanker's deadweight. Additional reductions are granted is the vessel was in good technical condition and the spill was not the result of neglect and breach of regulations. Penalties for vessels amount to from US$2,000,000 to US$100,000,000. Because of such high penalties each owner of a vessel larger than 2000 BRT has to have *insurance against liability for damage caused by sea pollution by the authorities of the flag state.*[41]

In marine areas, apart from water also air may be polluted. It is exposed to pollution in particular during loading operations, ballasting, degassing with air and ventilation of tanks with inert gas. As a result of the above mentioned operations ventilators eliminate hazardous hydrocarbons and inert gas and releases them into free atmosphere.

It is possible to prevent air pollution. During loading gas from the tanks should be returned to the feedback line to the terminal installation. With ongoing measurement of pressure, during ballasting gas may be fed into cargo tanks which are then being unloaded. The detailed rules

[41] Ibidem: 67.

and regulations concerning air pollution may be found in Annex VI to the MARPOL convention and in local port regulations.[42]

Adverse effects of hazards

The majority of human errors end with a fire, explosion and then a leak of cargo onto open waters. Most damage is caused by incidents involving crude oil and petroleum products cargo. Toxicity of individual types of crude oil is diverse and depends on it composition and sensitivity of the exposed organisms. This derives from four mechanisms of toxicity. The leading mechanisms are called physical and pharmacological, the third one, slower, is called mutagenic and/or carcinogenic, and the fourth one involve photoactivation.[43]

The physical mechanism blocks nutrient access and thus impedes development of an organism. The pharmacological mechanism affects the physiology or development of an organism. The third mechanism is slower and in a lesser degree affects the genetic apparatus of an organism since it is limited to a specific group of hydrocarbons. The last mechanism of toxicity involves photoactivation of poorly soluble compounds with a larger molecular weight.[44]

Crude oil toxicity increases at lower temperatures. It happens because when temperature drops vaporization of toxic components decreases. The time for which toxic components prevail after a spill depends mostly on the presence of organisms adapted to biological degradation of toxic components in a given ecosystem as well as the condition favouring

42 Ibidem.
43 Surygała (2001): 37.
44 Ibidem.

biodegradation, namely suitable temperature, amount of oxygen, pH and nutrients. Sometime physical and chemical detoxification is used, though does not prove effective in every case. On the contrary – in certain situations upon removal of the causes of toxicity other equally hazardous substances are introduced. Toxicity assessment should be performed in the specific ecosystem and for specific organisms so that it covers all possible scenarios.[45]

The majority of negative consequences of oil spills can be observed immediately. Oil spreads very quickly on water surface, its lightest components vaporize while the heaviest ones fall down towards the bottom. Sea animals are the first to experience the negative effects of an oil spill. Apart from toxin poisoning an oil spill causes also mechanical harm. Thick oil glues feathers of birds and immobilizes them. It also takes away the possibility to get food by poisoning fish. Walruses and sea lions are also cut off from the possibility to catch food. Going deeper into the water fish, sea horses, sponges and all other organism living under water (including bacteria) are slowed down by thick oil, they have nothing to feed on, they become poisoned with chemicals contained in oil. Oil also glues leaves and roots of plants, which are unable to go through the process of photosynthesis. Moreover, oil does not let through air which results in the cut-off of oxygen. It also blocks sun rays. Animals, plants and bacteria, that is the entire ecosystem is dying and doomed to slow annihilation.

Oil remnant prevail in water areas for a long time. After the contamination is removed it will take a very long time for the new healthy ecosystem to be reconstructed. Sometimes

[45] Ibidem.

it is impossible (depending on the amount of the spill and site of the incident as well as sea organisms affected). What is more, crude oil and petroleum products destroy the colloidal structure of soil and substrata. They upset their primary, i.e. compactness, plasticity and viscosity, as well as secondary physical features, i.e. water, heat and air characteristics. Oil also causes loss of sorptive capabilities of soils, which leads to reduction of biological life underground.

It should not be forgotten that in terms of chemistry (toxicity of hydrocarbons) negative effects of a spill of oil and petroleum products will be felt also by man. Hydrocarbons are characterized by capability to penetrate live organisms and accumulate in them. It is worth noting that hydrocarbons may get into an organism through the skin and accumulate in fatty tissue. They can also penetrate a live organism orally and by inhalation. Hydrocarbons may be swallowed with food and inhaled during breathing. Hydrocarbons are easily soluble in fat thanks to which they quickly get into the nervous system and act as narcotics by paralysing central nervous system. Lipophilic hydrocarbon components from petroleum products penetrate cell membranes. Most of the metabolic process takes place in the liver and kidneys. In the course of metabolism toxins are oxidised producing alcohols (e.g. 2,5-Hexanedione), which sometimes have negative consequences for the organism. Epoxides derived from hydrocarbons may also have tragic consequences leading to gene mutations. They stop separation of chromosomes and distort the structure of nucleic acids and proteins. Some hydrocarbons from petroleum products are exhaled through lungs, while some are retained in fatty tissue. By accumulation in fatty tissue toxins devastate organs. The contaminated organism is susceptible to inflammation, degenerations, serum

exudations, etc. In case of drinking water contaminates with even a minute amount of petroleum blood haemoglobin decreases and the number of erythrocytes is reduced.[46] There are much more negative effects of oil spills and leaks of other chemicals.

Accidents involving tankers

Atlantic Empress was a crude oil tanker. It was built in 1974. It belonged to Greece. The accident involving Atlantic Empress could actually be called Atlantic Empress/Aegean Captain, because those two tankers took part in it. The accident has been recognized as the largest crude oil spill in history.

he accident took place on the Caribbean on 19 July 1979. Both vessels were fully loaded. Atlantic Empress had the capacity of 276 DWT, and Aegean Captain around 200 DWT. Around 7 pm. near the coast of the Tobago Island the two tankers collided. Atlantic Empress caught fire. The crew of 26 seamen were killed. The ship was burning down surrounded by crude oil.

Aegean Captain caught fire only in the bow section and the crew managed to contain further conflagration. The oil spill from that ship was insignificant.

However, the fire on Atlantic Empress did not cease. The burning tanker was towed away to open sea. The surrounding oil was also partially aflame. Two firefighting operations were carried out, but two explosions took place (23 and 24 July). The largest and most destructive explosion which enhanced the fire occurred on 29 July.

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[46] http://www.e-czytelnia.abrys.pl/wodociagi-kanalizacja/2007-1-263/raport-wod-kan-2150/zanieczyszczenie-wod-gruntowych-zwiazkami-ropopochodnymi-6881 [access: 03.01.2020].

The wreck started to sink on 2 August. Oil was seeping out into water faster and faster and the vessel was becoming lighter. Certain parts were still on fire inside the wreck. Finally, Atlantic Empress vanished behind a huge black cloud. On 3 August, only an oil pool of enormous dimensions was left behind on the surface.

As a result of that accident, which lasted for 2 weeks, 280,000 tons of crude oil was spilled into the sea. It is not known how much oil was burnt and how much dispersed on the sea. People had at the time lesser than today awareness about natural environment and the hazards involved in the transport of combustible liquids.[47]

Photograph 1. Atlantic Empress on fire

Source: http://www.counterspill.org/disaster/atlantic-empress-oil-spill [access: 08.01.2020].

[47] https://shipwrecklog.com/log/history/atlantic-empress/ [access: 08.01.2020].

Atlantic Empress lies on the bottom of the Caribbean Sea until now and is the largest wreck in history.[48]

Amoco Cadiz was a tanker built in 1974 in Cadiz. It belonged to Spain. Its capacity amounted to 233,700 DWT.

The largest marine accident on European waters took place on 16 March 1978. Amoco Cadiz was on its way from the Persian Gulf to Rotterdam. In the vicinity of the English Channel the vessel encountered a huge storm. Early in the morning one of the waves damaged the rudder and the vessel was stalled. The Pacific – a German tugboat which was called for help, arrived after three hours. The Pacific was feeding ropes but they burst because of the gale. A towline was successfully attached at 8:55 pm. However, at 9:04 pm the Amoco Cadiz hit a rock which ripped a hole in the ship. With the exception of the captain and first officer the crew left the ship. About 5 am the captain and the officer were evacuated. Several hours later Amoco Cadiz broke up in two and the cargo of 233,000 tons of crude oil was spilled into the sea.[49]

Amoco Cadiz is fourth on the list of largest oil spills in the world. The oil cargo formed a pool of 29 kilometres wide and 128 kilometres long. All in all, the area of 321 square kilometres was contaminated. Hundreds of thousands of sea birds nesting at the coast died.[50]

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[48] http://www.portalmarynarski.pl/najwieksze-katastrofy-tankowcow/ [access: 08.01.2020].

[49] Ibidem.

[50] https://search.alexanderstreet.com/preview/work/bibliographic_entity%7Cvideo_work%7C1792362 [access: 08.01.2020].

Photograph 2. Amoco Cadiz on fire

Source: http://www.larousse.fr/encyclopedie/images/Mar%C3%A9e_noire_Amoco_Cadiz_1978/1006248 [access: 08.01.2020].

Another ship owned by Amoco was **Haven** – a tanker of the capacity of 233,690 DWT. It was built in Spain but belonged to Cyprus. On 11 April 1991, the Haven was transporting 230,000 tons of crude oil to the Multego floating platform. It was situated seven miles from the cost of Genoa (Italy). Having unloaded 80,000 tons of oil the Haven was disconnected from the platform but the pumping continued. The cargo was pumped from two side holds to the central cargo tank. A fire broke out. First officer Donatos Lilis said: "I heard a very loud noise, like iron bars beating against each

other. Then there was an awful explosion."[51] The fire whose flames reached the height of even one hundred metres engulfed the tanker. There were several explosions which raptured the Haven. Five seamen were killed.

40,000 tons of oil poured into the sea. The first to respond was Italy. The appointed appropriate service to fight the fire and control spillage. Already on the following day the Haven's hull was towed to the coast. Attempts were made to prevent oil from spilling onto the Italian coast. Three days after the incident the remains of the Haven went under water.

For the next 12 years the Mediterranean coast of Italy and France was polluted, The total area of the spill was 20 kilometres. It was the largest contamination ever in the Mediterranean. The effects continue to be felt until today.

Photograph 3. Haven on fire

Source: https://www.alamy.com/stock-photo-disaster-of-haven-oil-tanker-went-up-in-flames-and-sunk-in-front-of-84289953.htmlaccident [access: 09.01.2020].

[51] http://portalmarynarski.pl/najwieksze-katastrofy-tankowcow/ [access: 08.01.2020].

Despite an excellent and quick rescue operation and emergency management until today the remains of hydrocarbons have been spilling out of the wreck which lies on the sea bottom, where also residual amounts of tar may be encountered. Interventions are made to decontaminate the wreck in order to prevent any possible leak of lubricants and oils, which are probable owing to corrosion and subsiding of the wreck's structure. These are the first operations of this type in the Mediterranean. The area where the Haven sunk is also constantly monitored.[52]

Exxon Valdez was a vessel which crashed in 1989 at the coast of Alaska. The oil spill amounted to 370,000 tons of oil, but the Alaskan environment is very specific. Exceptional species of animals and plants were killed,[53] including thousands of otters, seals and hundreds of thousands of seagulls.

On 23 March 2989, just before midnight, Exxon Valdez was going to circumnavigate icebergs which blocked its route to Los Angeles. It took place in the Prince William Sound. The ship carried 240,000,000 litres of cargo which had been loaded in the nearby Alaska port of Valdez.

Exxon Valdez was negotiating the hard to navigate sound. The tanker left the shipping lane and failed to return onto it. Four minutes after midnight the ship hit a rock. The sound was in this place much wider so the cause was not too little room. The cause was human error. At the time of the incident as well as just before it the ship was navigated only

[52] https://www.researchgate.net/publication/273991890_The_MC_Haven_oil_spill_Environmental_assessment_of_exposure_pathways_and_resource_injury [access: 09.01.2020].

[53] http://portalmarynarski.pl/najwieksze-katastrofy-tankowcow/ [access: 09.01.2020].

by the helmsman and third officer. The captain was taking a nap. An additional factor of human error on top of fatigue and sleep was consumption of alcohol.

Photograph 4. Huge Exxon Valdez

Source: http://www.maritime-executive.com/article/india-s-supreme-court-allows-exxon-valdez-into-shipbreaking-yard [access: 10.01.2020].

Within six hour over 20% of cargo leaked out of the tanker. The clean waters of the environs of Alaska became contaminated. This was the beginning of an ecological disaster. It is not known how much oil has remained in the water. Some of it was burnt using a fire-resistant ring, and the remain were collected.

Until 26 March 1989, everything was going according to the instructions and it was hoped that an ecological disaster would be prevented. Unfortunately, on that day a storm broke out in the Prince William Sound. There were solvents poured earlier on the surface of the water which were to help in removing the spill. The strong gale beat the mixture into

a foam which was dispersed alongside the Alaskan shore. Day after day oil was dispersed further into the sea. Finally, it reached 760 kilometres and 1900 kilometres of the shore were contaminated. Beaches were occupied by a mixture of oil and solvent. The disaster was exacerbated by spring tides which are characterized by considerable variability.

Rescue operations lasted for several months. Attempts were made to protect fish nursery areas and streams inhabited by salmon. Beaches were washed with high-pressure water. Initially hot water, which, however, killed the live organism which had already been weakened. Water temperature was considerably lowered, which also diminished effectiveness. Apart from people, also planes, boats and heavy machinery took part in the operation. About half of the spilled cargo was collected, though it did not stop ecological disaster. Sea birds dies in terrible agony with their feathers glued by oil. Otters and seals had their furs glued by oil. This reduced its insulation properties which led to death because of hypothermia. Moreover, animals were suffocated by oil and died because of poisoning. Invertebrates and seaweeds were also harmed by the spill as well as its cleaning.[54]

A special committee called the Exxon Valdez Oil Spill Trustee Council was appointed for the cleaning operation. In 2004, it published investigation results which showed what animal species were affected by the disaster. It was over thirty species. Some of them have not been restored until today (cormorants, seals, harlequin ducks, pigeon guillemots, Pacific herrings, various bird species). Traces of oil could be found on Alaskan beaches for years.

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[54] http://www.rp.pl/artykul/275010,275722_Zbrodnia__i_kara_Exxona.html?p=3 [access: 10.01.2020].

It is worth noting that the group established by the Exxon company – ExxonMobil assumed a position most convenient for its business. Already a few years after the incident it claimed that the ecosystem of the Prince William Sound had returned to the pre-disaster condition despite the fact that oil still remained on the beaches. Exxon has to pay a high compensation to the state budget as well as to the families affected by the contamination. The captain was sentenced to 11 years of community service during which he collected garbage and helped the homeless.[55]

The Exxon Valdez spill is classified 35th on the list of major tanker accidents.[56] However, looking at that spill it is obvious that is should be ranked much higher because of the enormous losses of unique species as well as many years' presence of the hazardous substances in the sound.

There have been many more disasters in the history of tankers. A major one is **Braer** which spilled about 88,000 tons of crude oil into the sea. Another major spill was caused by a tanked called **Prestige**, which contaminated the shores of Galicia by spilling 63 tons of oil. That disaster, however, resulted in the enactment of a regulation banning the use of single-hull tankers (for carrying liquid raw materials).[57]

Conclusion

As it has been explained above, the majority of shipping accidents involving oil tankers are caused by a human factor?

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[55] Ibidem.

[56] http://portalmarynarski.pl/najwieksze-katastrofy-tankowcow/ [access: 10.01.2020].

[57] Ibidem.

Transport of liquid substances involves a possibility of great threat to the natural environment of maritime areas.

The greatest damage to the natural marine environment is made by spills of liquid substances because they become directly mixed with water. They require immediate response. Oil vapour and the exuding toxicity of hydrocarbons bring about adverse consequences for the safety of natural environment.

Tanker accidents do not occur as often as accidents involving other means of transport, but even the smallest collision may constitute a great hazard for ecological safety.

It is a fact that oil and petroleum products are valuable raw materials for aggressors (terrorists, pirates). Not only because of its high price. A tanker filled with oil may be used by terrorists as an instrument of terror. Tankers are not sufficiently safeguarded against unexpected incidents.

The effects of spilling chemical substances into the sea last for a very long time. Frequently, it is impossible to eliminate them completely.

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