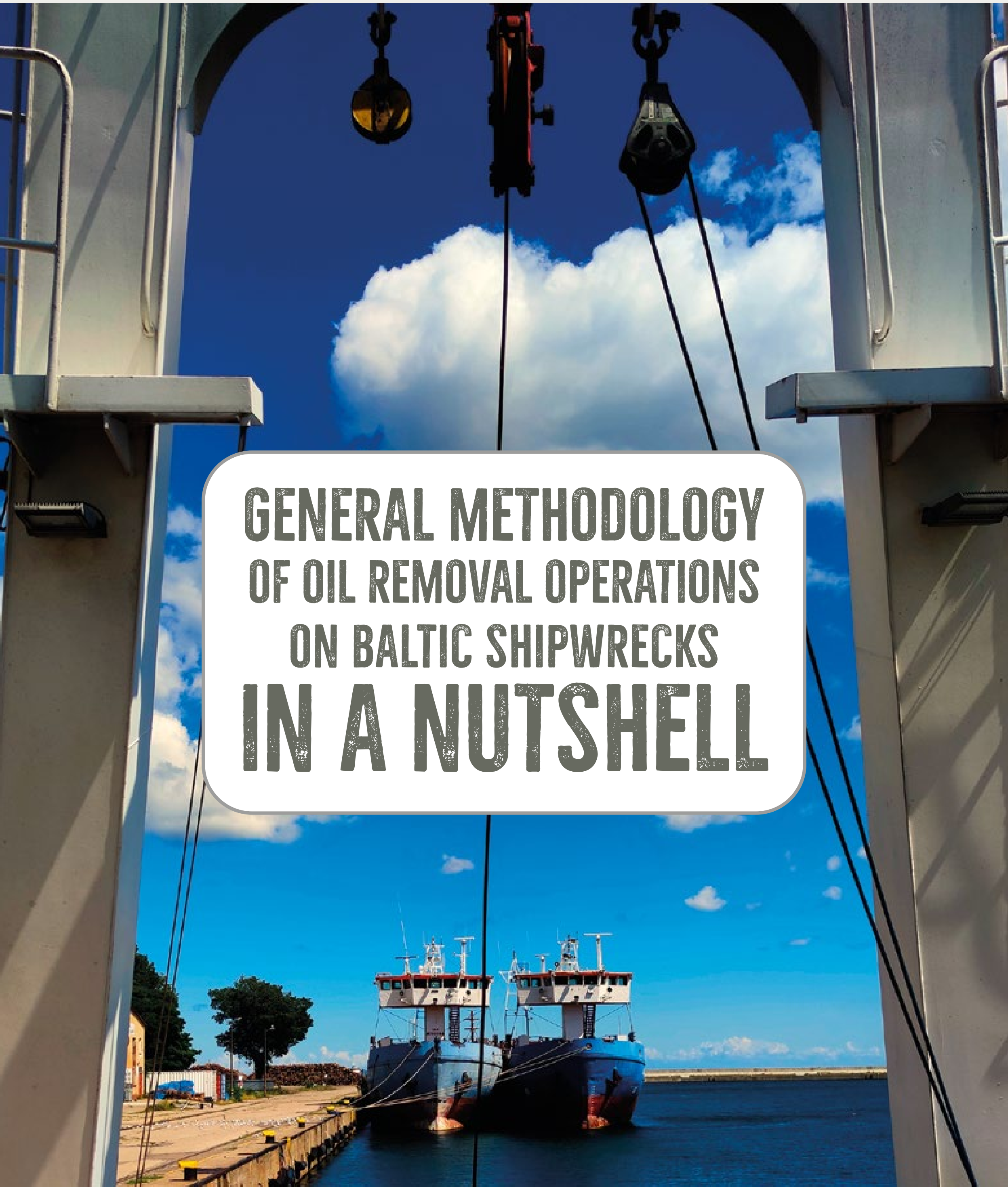
MARE

GENERAL METHODOLOGY OF OIL REMOVAL OPERATIONS ON BALTIC SHIPWRECKS IN A NUTSHELL



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The full version of the publication is available at www.fundacjamare.pl

GENERAL METHODOLOGY OF OIL REMOVAL OPERATIONS ON BALTIC SHIPWRECKS IN A NUTSHELL

The marine environment is an extremely complex system of inter-relations between water, sediments and water organisms. If an ecosystem functions properly, the balance between its components is preserved. However, this principle also works the other way around. One negatively affected component of the entity can directly affect all others, and in consequence the functioning of the whole system may be changed.

Leakages of oil and other hazardous chemical substances are one of the potential threats to the marine environment. Apart from the current accidents and disasters happening at sea, these leakages may also come out of shipwrecks located at the bottom of water bodies. According to the data held by the Naval Hydrographic Office in Gdynia, there are over 415 wrecks in the Polish exclusive economic zone, of which about 100 are located in the Gulf of Gdańsk. The greatest potential threat is posed by the wrecks that sunk mainly during the First and Second World War and later. We speak of "a potential threat" only because it is deferred in time. It does not mean that it is not real. There is a high risk that leakages will take place as a result of progressive corrosion of wrecks. It is difficult to determine when this will happen, but for sure, if it happens, a significant area surrounding the wreck, will be contaminated and that all living organisms will be affected.

Moreover, as a result of such event, people will also be impacted, primarily because of the costs associated with cleaning up such areas and the attempts to minimise environmental losses. Secondly, due to the degradation of the ecosystem and the resulting economic loses (e.g. for the tourism sector).

LEGAL FRAMEWORK

The 2007 Nairobi Wreck Removal Convention (NWRC) is currently one of the most important legal documents relating to the cleaning or removal of shipwrecks that may adversely affect the safety of life, goods and property at sea, as well as the marine environment. The NWRC is an international convention adopted in 2007 at the conference in Kenya and entered into force in 2015. To date, the NWRC has been ratified by 53 countries, which collectively cover approximately 76% of the world's maritime areas. So far, the convention has not been adopted by Poland.

The NWRC established detailed rules for dealing with wrecks, including: reporting, locating and marking wrecks (Articles 5, 7 and 8); criteria for determining whether a wreck is hazardous (Article 6); ways of removing wrecks and the rights and obligations in this regard (Article 9); owner liability for costs related to locating, marking and removing the wreck (Articles 10 and 11); compulsory insurance or other financial security requirements (Article 12) and rules for the settlement of disputes between states (Article 15).

In addition to the NWRC, **there are also a number of other international legal acts that indirectly define the rules for dealing with fuel spills from marine vessels**. The most important of them are: 1) the International Regulations for Preventing Collisions at Sea aka. COLREGs (1972), 2) the International Convention for the Prevention of Pollution from Ships aka. MARPOL 73/78 (in particular the provision relating to special areas), and 3) the International Convention for the Safety of Life at Sea aka. SOLAS (1974).

In the case of wrecks from the First and Second World War, as well as post-war wrecks, dating back to the period prior the adoption of NWCR and MARPOL regulations, it is not clearly defined who is responsible for cleaning the hazardous wrecks. Most interpretations of the existing legislation indicate that in the case of wrecks sunken prior to 2007, the responsibility for the damages is borne by the state in which territory the damage took place. In the case of the Polish legislation, the costs would be borne by the Maritime Administration. However, under the provisions adopted in 2007, the costs are borne by the party responsible for causing the damage (the Polluter pays principle).

METHODOLOGY OF OIL REMOVAL OPERATIONS ON BALTIC SHIPWRECKS

The term “**dangerous wreck**” should be understood as a wreck containing in its tanks (or any other enclosed space) fuel and/or other hazardous substances in quantities greater than 10 m^3. To be categorized as a dangerous to the environment, such a wreck must also be located less than 10 nautical miles from the coast that is a sand beach, a rocky beach or a cliff. Depending on such parameters as the amount of fuel, the distance from the coast and the type of the coastline, a concept of the risk degree has been introduced. A shipwreck containing from 10 to 500 m^3 of fuel, lying at a distance of 1 to 10 nautical miles from sandy, rocky or gravel beaches is classified as a wreck causing moderate or high risk. A wreck containing more than 500 m^3 of fuel and lying at a distance less than 1 nautical mile should be classified as a very dangerous wreck. **When classifying shipwrecks, apart from formal differentiation, other parameters such as the uniqueness of the site, where the wreck is located (e.g. closeness of natural reserves, protected areas of unique environmental value, presence of endangered fish and other marine or endemic species), as well as many other environmental aspects should be taken into account**.

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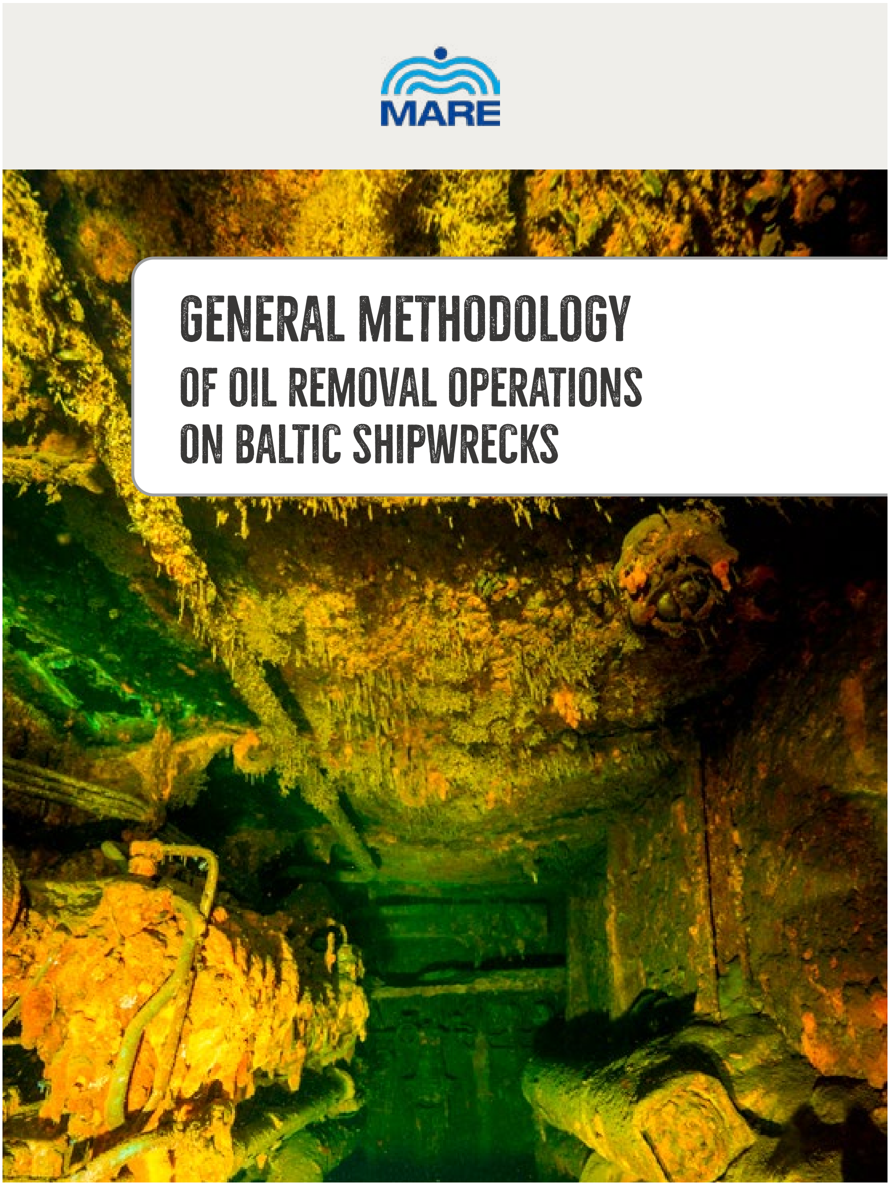
Awareness of environmental risks and damages caused by oil spills from wrecks has pushed many countries to undertake institutional measures aimed at studying and removing oil from wrecks. Many countries, among others the United States of America, have a separate, fixed budget and carry out systemic activities in this field. Every year, 2-3 wrecks selected out of 573 identified dangerous wrecks are cleaned. In the United Kingdom, a department of Salvage and Marine Operations (SALMO) functions under the Ministry of Defence and implements a Wreck Management Programme, which permits to study and clean between 2 to 5 wrecks every year out of more than 500 wrecks considered as potentially dangerous. Norway also carries out a Wreck Programme whereby 8 wrecks have been cleaned between 1994 and 2013 (out of 350 classified as dangerous, including 30 very dangerous ones). In the Baltic countries, such activities are carried out in Sweden and Finland. In Sweden, Chalmers University in Goteborg developed the VRAKA system that permits the Swedish Agency for Marine and Water Management to classify the wrecks, manage the risk and collect data. As a result, between 2 and 3 wrecks are cleaned every year (out of 316 wrecks, including 30 very dangerous ones). In Finland, the Environmental Institute (SYKE) conducts a comprehensive programme for studying and cleaning the wrecks, which also leads to cleaning of 2-3 wrecks per year, out of 420 dangerous wrecks, including 46 classified as very dangerous.

In Poland, between 1999 and2016, the Maritime Institute in Gdańsk carried out research on the threats posed by wrecks as part of the Finnish Review of Wrecks (on behalf of the Baltic Marine Environment Protection Commission aka. HELCOM). The project did not lead to cleaning of a single wreck, despite the risks posed by at least 4 wrecks in the Polish EEZ being documented. So far, there is no system aimed at solving the problem.

Many governmental, scientific and non-governmental institutions are interested in this problem. These include, in particular:

- the Maritime Administration, e.g. maritime offices administering, on behalf of the State, the areas along the Polish coast and responsible for the state of the marine environment,
- the Ministry of Climate and Environment, as well as the Ministry of Infrastructure, responsible for maintaining the proper state of the marine environment,
- universities and marine institutes (ex. The University of Gdańsk, Maritime Academy in Szczecin, Maritime Institute of the Maritime University in Gdynia, Sea Fisheries Institute and others) conducting different scientific projects to determine the quality of the marine environment, including water purity and potential threats (wrecks, conventional and chemical weapons, overfishing),
- non-governmental organisations such as the MARE Foundation, conducting environmental and educational projects in the field of marine conservation and supporting government activities aimed at improving the state of the Polish marine waters.

General Methodology of Oil Removal Operations on Baltic Shipwrecks published by the MARE Foundation as part of the project „*Reduction of the negative impact of oil spills from the Franken shipwreck*", financed by the Baltic Sea Conservation Foundation, is a proposal of a Wreck Management Plan for Poland and was created on the basis of programs already being implemented in Great Britain and Sweden. The full version of the document (available at www.fundacjamare.pl) presents an overview of the available wreck assessment methods and management strategies, and proposes an individual model adapted to Polish conditions. This brochure provides a brief overview of the key information covered by the methodology.



SHIPWRECK SURVEY METHODS

The procedure for cleaning up wrecks from oil is complex and multi-stage. One of the most important stages consists of conducting studies and gathering information on a given object. The acquired knowledge is needed to establish the subsequent research stages of the methodology, elaboration of a cleaning strategy and assessment of the costs of such undertaking, as well as the risk of uncontrolled fuel release.

It is crucial to determine the type of the vessel that is to be cleaned. This is a starting point for the decision process on what subsequent stages of data collection should be carried out. The next step is the identification of the actual and current conditions on the wrecks and in its surroundings, which should be carried out in a thoughtful, repeatable and reliable manner. Only the data obtained in such a way are considered to be qualitative and can be used in planning of the cleaning operations and risk assessment.

These methods can be used to clearly and repetitively describe the current state of the investigated wreck and its surroundings. The choice of the methods depends on several factors and thus the research should be carried out in the right order: from the most general studies - to more and more detailed ones, depending on the need to broaden the knowledge about given aspects of the analyzed object.

In order to determine all parameters relevant to the assessment of a wreck and the risks posed by it, the following actions should be undertaken:

1) **desk-based review** – including technical data, data on exploitation, descriptions and photographs of the ship and of the moment of sinking, transport documents, including records relating to the transport of explosives and dangerous materials, witness descriptions etc.;
2) **obtaining hydrographic data /navigational data**;
3) **conducting geophysical surveys** – bathymetric surveys, surveys with sidescan sonar, circulating sonar and acoustic camera, or with acoustic sub-bottom profiler (SBP), determining metal object distribution at the seabed;
4) **geological exploration of the seabed** – collecting surface samples of bottom sediments, collecting core samples (usually 3 meter long), analysis of different bottom sediments;
5) **chemical tests of soil and near-bottom water** – chemical tests of samples, which should be collected taking into account the location of the wreck on the seabed, any depressions, the bottom topography, the directions of the bottom currents, as these factors influence the number of samples collected and place of sampling;
6) **biological analysis** – usually done using the samples of the bottom sediments taken for geological analysis. This matters in elaborating the sampling strategy; they reflect well the state of the environment, because the presence or lack of certain groups of organisms is indicative of the level of pollution in the area;
7) **ecotoxicological analysis** – these tests are a very important indicator of the level and range of the contamination, however, these tests are expensive and worth carrying out only in the event of the confirmed presence of contaminants;
8) **inspection carried out on the wreck using Remote Operated Vehicles (ROVs)** – permits to determine the actual state of the wreck, the degree of overage with bottom sediments, possible presence and amount of ghost nets, presence of weapons and explosives, precise monitoring of the surroundings of the wreck and making a photographic documentation;
9) **collecting the information on the surroundings of the wreck** – such as the intensity of navigation of small and large vessels, distance from the wreck to waterways and navigation routes, military activities around the wreck, strong storms, fishing activities with the use of trawl nets, etc.

METHODS FOR ESTIMATING THE RISK OF OIL SPILLS

The risk posed by wrecks lying on the seabed is determined by the likelihood of a fuel leak and its consequential environmental impact. The likelihood of oil release should be determined from historical records concerning the wreck, supplemented by wreck survey data that indicate the physical integrity of the wreck, particularly its tanks. The magnitude of environmental impact is estimated using oil spill models, taking into account hydrological factors in the given area. Environmental and sometimes also socio-economic receptors of different sensitivity are taken into account. The risk can be determined integrally for the entire ecosystem or for its different components, such as the beaches, water column, water surface and bottom sediments.

The International Convention on the Removal of Wrecks adopted in Nairobi (IMO, 2007) does not set the framework for systems used for risk assessment of potentially dangerous wrecks. However, a number of scientific publications were produced on this subject. Here are some of the methods of assessing the environmental risks caused by wrecks:

- **The Wreck Oil Removal Program** implemented in the United States by the National Oceanic and Atmospheric Administration NOAA uses scientifically justified approach to oil removal and minimising the costs and risk of contamination posed by sunken commercial ships (NOAA, 2009);
- **Potentially polluting wrecks in marine waters** by Michel et al. (2005) published in the framework of the IOCS (International Oil Spill Conference), presents guidelines of assessing the consequences and risk of oil release from wrecks potentially polluting the marine environment. The aim of the report is to identify the principles for objective analysis of shipwrecks, using a methodology describing potential risk related to oil release and to provide measures to solve the problem;
- **DEEPP Project** ("Development of European guidelines for Potentially Polluting shipwrecks") (Alcaro et al., 2007) aims at delivering criteria and guidelines for dealing with potential environmental risks posed by shipwrecks to European coastal states and national administrations;
- **Norwegian Pollution Control Authority – NPCA** has identified shipwrecks as a priority. The project for establishing a wreck database was carried out in three stages: registration, priority classification and establishment of required action in order to get full picture of shipwrecks along the Norwegian coast;

- **The South Pacific Regional Environment Program (SERP) under which the Pacific Ocean Pollution Prevention Programme** (PACPOL) was developed and is being carried out. The aim of the programme is to determine sea pollution caused by leakages from shipwrecks and to minimize the damage caused by shipwrecks from the Second World War (SPREP and SOPAC, 2002);
- **The Swedish model "VRAKA – Probabilistic risk assessment of shipwrecks"** prepared by a scientific team from the Chalmers University of Technology in Gothenburg, led by Hanna Landquist (2016). VRAKA assessment consists of two modules:
  - tools for estimating the probability of release of hazardous substances from shipwrecks,
  - methods of estimating the potential consequences of such an event.
- **The British risk assessment system called "Wreck assessment protocol – Environmental Desk Based Assessment"** (2016) developed by the scientific team from the Centre for Environment Fisheries & Agriculture Science CEFAS and implemented by the Ministry of Defence of the United Kingdom (MoD). The purpose of the protocol is to make a standardised risk assessment using the already available environmental data.

The last method seems to be the most appropriate for implementation in Poland, in the region of southern Baltic. It is relatively simple, and at the same time highly effective. It permits to assess the risk based on a three-step scale and to assess the confidence level in risk assessment results. This method takes into account two basic scenarios – an acute release and its impact on the environment, and a slow release and its long-term effect on the marine environment. It permits a relatively quick oil release risk assessment for different wrecks and their classification, but it does not allow to determine the changes of the risk level with time. Such predictions can however be made using the VRAKA method.

Likelihood of oil release

The likelihood of oil release is assessed based on many criteria. Their impact on the risk is not the same, therefore, in accordance with E-DBA assessment, each criterion is given a weighting. After weighing of each criterion, the likelihood of oil release is classified as low, medium or high. The scores are calculated according to the data in Table 1.

Table 1. **Assessment criteria for the assessment of likelihood for wrecks to release oil, the assessment including the weights applied and risk categories.** (Source: CEFAS Assessment Protocol Environmental Desk Based Assessment C6107)

Risk assessment criteria	Weighting of criteria	**Low** (Score of 1)	**Medium** (Score of 2)	**High** (Score of 3)
Vessel depth	2	Low >100 m	30-100 m	High <30 m
History of leaks	3	No known leaks	Unknown known or anecdotal evidence	Documented history of leaks
Integrity of wreck	2	Broken into more than three pieces	Broken into two or three pieces	Intact, in one piece or unknown
Age of vessel at time of sinking	1	<10 years	10-30 years	>30 years
Length of time vessel has been submerged	2	<50 years	50-90 years	>90 years
Method of storage	2	Specific bunker tank	In hold	On deck, drums, containers, crates
Type of incident causing sinking	1	Multi-ple torpedo detonations, multiple mines, severe explosion	Single torpedo, shellfire, single mine, rupture of hull, breaking in half, grounding on rocky shoreline or unknown	Foul weather, grounding on soft bottom, collision
Seabed type	2	Known to be stable seabed	Relatively stable or not known	Unstable and/or high degree of movement

Confidence scores are used to conduct an assessment of the wreck condition:

- **High** – the data and information used are timely, the best available, robust and the outputs are well supported by evidence. There is consensus amongst experts;
- **Medium** – the data and information is based on limited evidence or proxy information. There is a majority agreement between experts; but conflicting evidence/opposing views exist;
- **Low** – the data and information is limited and is not well supported by evidence. There is no clear agreement amongst experts.

Oil release modelling

The key factor to determine the impact of oil release on marine environment is the second step consisting of assessing the exposure of the marine environment and infrastructure to the released fuel. Three scenarios for oil release are considered the scenario of release. Three basic scenarios can be distinguished:

- slow, but chronic release of oil, up to 50 kg per day;
- acute release of the entire oil content from the largest tank within 24 hours (the is the most likely scenario);
- release of the entire oil content from the wreck within 24 hours (the scenario with the most negative impact).

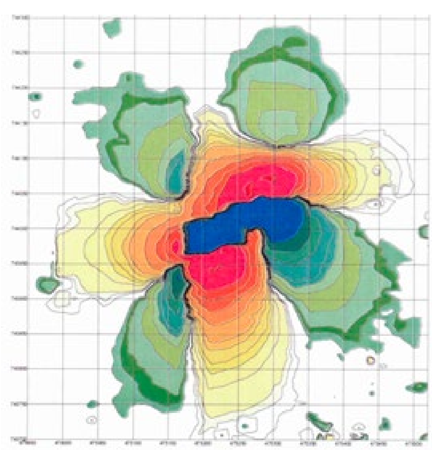
Modelling permits to track in advance how the oil will flow in the water column, on the surface and at the sea bottom, and therefore to assess the expected impact. In Poland, search and rescue service (SAR) uses the Swedish model, SeaTrack Web, but the choice of the models used throughout the world is very wide and results from the diversity of marine environments.

Center for Environment, Fisheries and Aquaculture Science (CEFAS) operating under the Ministry of Defence of Great Britain bases its calculations on the basis of two models:

1. **Dose-related Risk and Effects Assessment Model (DREAM)** – a model for slow but chronic release of oil;
2. **Acute oil release model MEMW** (*Marine Environmental Modelling Workbench*) together with the Oil Spill Contingency and Response (OSCAR) model.

Both of these models permit to calculate the contamination risk and in addition generate valuable information on the risk for different components of the environment, such as the shoreline, sea surface and water column. Furthermore, the E-BDA system permits to model the contamination of sediments around the wreck.

The maps are the final product of modelling and permit to visualise 1) the potential area at risk from oil release on the surface, 2) potential area at risk from contamination in water column, 3) the potential length of contaminated shoreline and 4) the potential area at risk of accumulation of oil heavier than water in the sediments.



Isolines created by the anomaly of the magnetic induction field, caused by the magnetic field around the S/S Stuttgart shipwreck - the area limited to the wreck itself.

Quantification of risk

The next step consists of an evaluation of negative impact of oil release on particularly sensitive receptors and marine infrastructure. Two groups of impacts, ecological and socio-economic, are considered. CEFAS uses a three-grade sensitivity scale for individual receptors: receptors sensitive to low, medium and high risk.

A final risk assessment qualifying the wreck as safe or hazardous for the environment is calculated based on the likelihood of the release and the risk to sensitive marine receptors. Each criteria is assigned a value of likelihood and risk from 1 to 3, based on a high/medium/low score. The main objective of the actions presented so far is to answer the following questions: "Does the wreck pose a threat" and "is it necessary to take action aimed at mitigating the risk of an oil spill?". To this end, it is recommended to carry out a detailed and more precise classification of the criteria of the overall risk assessment (Table 2).

Table 2. **Precise classification of the overall risk assessment.**

Criteria for the overall assessment of risk		
High risk	**Medium risk**	**Low risk**
There is a high potential for oil to be released. Detailed analysis is required to understand the severity of the threat to sensitive marine receptors.	The risk of oil being released is moderate. Further analysis is recommended to understand the severity of the threat to sensitive marine receptors.	The risk of oil being released is minimal. If the condition of a wreck changes a re-assessment is recommended to confirm risk.
Recommended actions		
Assessment has shown that there is a considerable threat to sensitive marine receptors, essential management actions will need to be considered.	The assessment has shown there is a threat to sensitive marine receptors, monitoring and that management may be required.	If the condition of a wreck changes a re-assessment is recommended to confirm risk. Monitoring may be required.

Risk assessment methodology for Polish wrecks

The E-DBA protocol created by CEFAS seems to be the most appropriate method to be adapted for the assessment of Polish wrecks in the Baltic waters. It does not assess how risk changes with time, which is possible using the VRAKA method, but it has a clear and simple structure. A Polish version of the E-BDA would provide an impartial assessment of risk and determine the most appropriate management strategy, thereby minimising conflict of interests with the maritime administration who would be consulted throughout the assessment process.

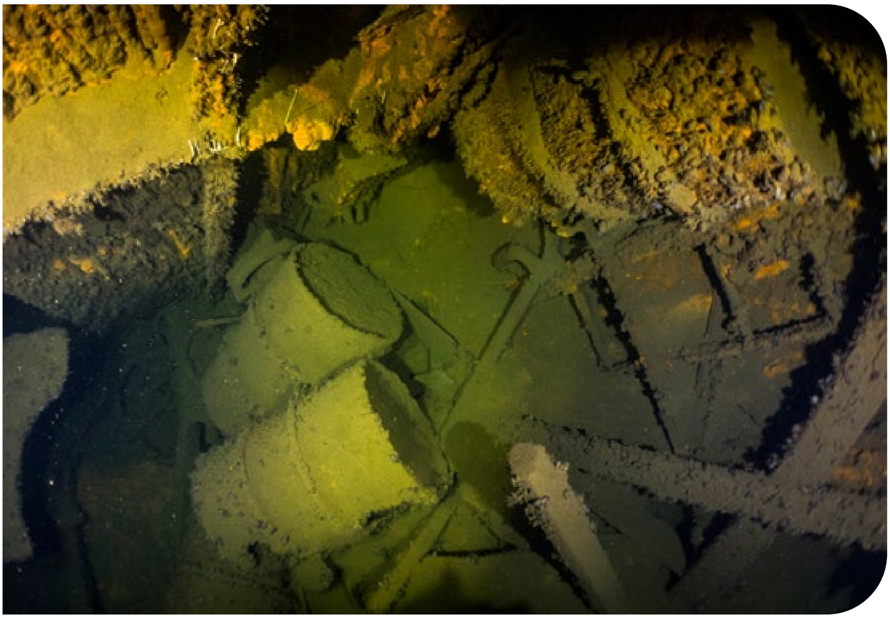
The methodology presented in the E-DBA protocol is based on the following principles:

1. **All wrecks should be subject to risk assessment, based on potential risk of contamination and presence of explosives, ammunition or other hazardous substances. The risk assessment should be based on the wreck database and supplemented by other reliable sources.**
2. **Based on the risk assessment, the wreck should be assigned to one of the four groups:**
   - **dangerous wrecks**, for which the risk cannot be tolerated and a wreck site survey is required to gather data for a more robust risk assessment;
   - **potentially dangerous wrecks**, for which the risk can be tolerated, but a wreck management plan is required;
   - **probably non-dangerous wrecks**, for which the risk can be tolerated, but the risk should be as low as possible;
   - **probably safe wrecks**, for which the risk can be tolerated and there is no need to demonstrate the risk status.

If there is no sufficient information to consider the wreck survey as reliable, then the wreck should be considered as dangerous or potentially dangerous and appropriate actions taken.

In a case where the on-site inspection and reassessment of the wreck show that the risk is unacceptably high and, most likely, it is impossible to manage it, intervention on the wreck is necessary. Its purpose is to minimize the risk of uncontrolled fuel leakage. To counteract this, it is necessary to develop a methodology for dealing with such a situation However, removing a potential risk from the wreck is a preferred measure of risk mitigation. After the intervention on the wreck, the risk assessment must be repeated, which means that in all cases where actions have taken place, the risk management plan must be re-drafted This should be done even if the risk has been minimised to an acceptable level.

AVAILABLE METHODS AND TECHNOLOGIES FOR REMOVING FUEL FROM THE SEABED AND REMEDIATING CONTAMINATED SEDIMENTS



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Remediation

As a result of the amendment to the Environmental Protection Law (the provision had been added through a revision of 11 July 2014, Journal of Laws of 2014, item 1101), the term "**disposal**" has been replaced by "**remediation**". This term is used in this study in relation to the measures aimed at removing or reducing the quantity, or controlling and limiting the spread, of hazardous substances in sea bed sediments and groundwater. The remediation is aimed at preventing the risk to human health and the environment, posed by the contaminated site, taking into account the current and future land use. The law also foresees that in justified cases, the process may consist of self-remediation, if it is to bring the greatest benefits for the environment. In practice, there are two basic options for recovering the contaminated seabed: *in situ* and *ex situ*.

1. *IN-SITU* METHODS*:*

Monitored natural recovery

The term monitored natural recovery (MNR) is defined by the *National Research Council* as a remediation to protect the environment from unacceptable exposures to contaminants on the basis of natural environmental processes (ITRC, 2014), i.e. natural self-cleansing of the sediments. This method consists of leaving the contaminated sediment in place to enable the following natural processes such as turning the contamination into less toxic form (e.g. biodegradation),binding the contamination closer to the sediment (e.g. sorption), capping contaminated sediments with a clean sediment (e.g. sedimentation), to take place).

Separating contaminated area with a fence

It is possible to stop the fuel spill on the seabed by placing a fence around the contaminated area. Such fence can be made of iron and steel elements combined into a waterproof wall, the so-called Larssen sheet piling. Most often, the fence is constructed in the form of a cofferdam, in order to separate the contamination source from its surroundings. Another solution is to surround the area with an embankment. Preserving such an embankment may be difficult in a more dynamic environment, where there is a risk of damage during storms. This method can only be used in shallow waters.

Solidification and stabilisation of contaminated sediment. Use of fly ash

This method is based on two processes, solidification and stabilisation (hardening) of sediments. Stabilisation is a chemical process that leads to the disposal of contaminants by converting them into less soluble, less mobile and less toxic forms. Solidification is a physical process, binding the contaminants with a binder. Binders include: the Portland cement, lime and fly ash from coal combustion and a mixture of these substances in different proportions. The best solution is to use fly ash, a product of coal combustion from power plants. Ash deposited on electrostatic filters is the size of dust, in a very shredded form. It has the capacity to swell and harden under the influence of water, which is easily absorbed. Such properties allow it to easily penetrate into gaps and rubble, creating a stable, non-settling sealing surface.

Bioremediation

Bioremediation consists of the use of microorganisms or their enzymes to decompose organic contaminants such as petroleum and petroleum products, aromatic hydrocarbons, benzene, toluene and xylene, PCB (polychlorinated biphenyls), PAH (polycyclic aromatic hydrocarbons), chlorinated phenols and several pesticides.

Capping the contaminated area

Capping consists of covering contaminated sediment with a layer of clean material to isolate the contaminated layers from the environment. There are three types of caps:

- conventional capping with sand or other natural materials put directly on the contaminated layer of sediments;
- reinforced capping with an additional layer of stones or backfill to provide protection against high velocity currents;
- composite capping composed of several layers of sand, stones and geotextile, providing better isolation of the contaminated area from the rest of the ecosystem.

Capping may also contain an active substance, such as organic carbon or other local modifications in order to slow down the flow of contaminants.

2. *EX-SITU* METHODS:

Removal of contaminated sediment by dredging

Removal of fuel and contaminated sediment by dredging is the most common method among the *ex situ* methods. This method differs from conventional dredging carried out for navigation purposes and is called *environmental dredging*. Special dredgers are used to remove contaminated sediment, which is then transported and processed outside of the place of original occurrence, reused or deposited. Heavily contaminated sediments require additional treatment before they can be deposited and are most often subjected to a stabilisation process. In some cases, fuel can be remediated by separating water and sediment through the decantation process.

Hot-tapping and pumping fuel residues from the wreck with a use of ROV

In a situation where fuel is trapped in the wreck's tanks, the most effective and modern method of retrieving the substance is with the use of the ROV robot and the hot-tapping technology. This technology had been initially operated by divers, but due to the high risk to their health, it became a common practice to use ROVs to remove oil from the wrecks at greater depths. The cleaning operation based on the ROV robot supporting the *hot-tapping* tool was first used in the case of the leakage from the Prestige ship, at a depth of 3500 m. This technology was also successfully used during operations carried out in the Baltic Sea region, e.g. on such wrecks as Park Victory, M/S Estonia, Brita Dan and Coolaroo.

Table 3. **Comparison of remediation methods.**

RECOMMENDATIONS	COSTS	ADVANTAGES	RESTRICTIONS
Monitored natural recovery			
Sensitive, unique ecosystems, relatively stable bottom sediments, contaminants are easily biodegradable or can be converted to lower toxicity forms, or their concentrations are low, in deep water bodies	Relatively low, mostly cover monitoring (approx. 1,3 $/m^3)	It does not disturb natural environment, no risk of disturbance of contaminated sediments and their dispersion, low costs, does not generate waste.	Biodegradation time is 5-30 years, secondary contamination is possible, possible exclusion of the area from fishing for a long period of time, biodegradation products may be toxic, lack of corrective measures may make society doubt the effectiveness of this method, lack of data from long-term surveys and lack of surveys proving long-term effectiveness of this method.
Separating contaminated area with a fence			
Small and shallow areas	This method is among the most costly ones: expensive material, transport, equipment.	Possibility to stop the horizontal oil spill on the seabed and leaving the contamination to biodegradation, possible separation of contaminants from water column, in favourable conditions possibility to dry the area and carry out remediation.	Costs, it does not stop the penetration of contaminants into the sediment, risk of release of contaminants in the water column during a storm, large restrictions with regards to the area of application
Solidification and stabilisation of contaminated sediment. Use of fly ash			
Technology used mostly in land, not used yet in the sea *in situ*, tested in a laboratory	The price of fly ash from carbon combustion: 15 $ - 40 $/t, high transport and processing costs,	It may lead to the transformation of contaminants into less toxic forms, environment friendly method, uses waste as raw material.	It does not remove contaminants but slows down their migration into the environment, big technological challenge, especially in the case of marine environment, lack of data on biological effects, data not sufficient to implement the method and calculate the costs.

RECOMMENDATIONS	COSTS	ADVANTAGES	RESTRICTIONS
Capping the contaminated area			
Capping is used in cases, where removal of the contamination would be too expensive and could cause further spread of contamination, also as a temporary measure and when natural recovery is too slow, to stop volatile and semi-volatile organic compounds, pesticides and heavy metals, possible to cover the contaminated area with concrete, together with the wreck.	Costs are mainly affected by its availability and transport costs, moderate costs, increases with modifications.	It physically isolates the contaminated sediment, reduces its direct contact with organisms which live inside the sediment and bioturbators, stabilises contaminated sediments, stops dispersion and migration to other areas, chemically isolates to reduce the flow of dissolved contaminants to water column, relatively uncomplicated method.	It requires long-term monitoring, a risk that after placing the first layer of the capping material, the sediments may be released to the water column, in some cases placing the cap may be difficult without disturbing the contaminants, to some extent disturbs and changes the habitats of benthos organisms.
Bioremediation			
It is recommended together with other methods.	Costs difficult to estimate, due to insufficient experience with the use of this method in the marine environment.	It is environment friendly, one of less harmful and invasive methods, potentially low costs, requires less equipment, contaminated sediment is cleaned *in situ*, no need to transport and disposal.	long time required for the biological degradation process, insufficient data to use the method in marine environment, introduction of nutrients and oxidising substances in the marine environment is complicated and may cause a release of contaminants, need for long term monitoring and analysis of bacteria content on the contaminated site.
Removal of contaminated sediment by dredging			
Used to remove contaminated sediments in the form of *hot spots* and to protect an area against spreading of contaminants, to move the secondary residual contamination	Depending in the dredger type:: mechanical dredger 2.10 $/m², hydraulic dredger 1.95 $/m², pneumatic dredger 1.40 4.00 $/m² + transport, storage, proces-sing and auxiliary technologies costs.	The fastest and most effective method, useful in case of vast contaminated areas, also in the case of oil that cannot be pumped, can be used in a dynamic environment.	Risk of significant resuspension of contaminants and loss of contaminants during transport, need for monitoring, very invasive to the environment, dredgers remove 20 cm of thickness of bottom sediment, costly and relatively complicated logistics due to the complex process.

COSTS OF OIL SPILL REMOVAL OPERATIONS

Each maritime accident resulting in the need to remove the toxic cargo or fuel residues from ship's tanks is different and it is difficult to estimate the costs of removing the contamination before the operation in carried out. Both the implementation of the operation and its costs may differ from the planned ones. Underestimation of the scale of the operation happens especially when the oil is being removed from an old wreck and there is no information on the amount of oil in the tanks, how it is distributed and what is the access to the tanks.

The United States Environmental Protection Agency (US EPA) published a guide that discusses in detail what elements should be taken into account during a feasibility study, when estimating the costs of a planned clean-up operation (U.S. EPA, 2000). The main elements include mobilisation, demobilisation, monitoring (including analyses and sampling), collection and separation of water, removal of the contaminated sediment and its storage, preparation of the capping material, in situ operations, ex-situ operations, transport and storage of contaminated sediment and elements related to professional technical services, design, planning, management and institutional inspections. The assessment of the factors influencing the costs of the operation are also presented in Table 3. The NOAA publication (2013) on risk assessment for potentially polluting wrecks presents the main factors that affect the assessment and removal of the oil. These factors include:

- oil type and properties (primarily viscosity);
- oil volume;
- water depth;
- bottom currents;
- sea state (eg. protected waters, open sea);
- weather conditions;
- environmental resources at risk (sensitive habitats);
- distance from the shore, distance from mobilisation place, logistical support;
- vessel configuration (eg. tank locations, ventilation and piping systems, location of tank baffles, general construction);
- vessel construction (eg. plate thickness, riveting, welding);
- vessel age (date of construction, modernisations, sinking);
- wreck condition (eg. broken sections, corrosion);

- wreck orientation (eg. upright, upside down);
- safety factors (eg. presence of munitions, hazardous materials, derelict fishing gear;
- other cargo (may still block access to tanks and void space);
- historical/cultural concerns (historical significance, war grave).

SUMMARY

Determining the necessary procedure to be followed while examining the impact of wrecks and the fuel they contain on the marine environment, the threats those wrecks pose to the environment, and how to mitigate the effects of these threats – is at present one of the most pressing challenges in the protection of the Southern Baltic. It should be an important task for scientific institutions dealing with the marine environment, as well as for the management bodies, responsible for marine areas, i.e. maritime administration at all levels.

A situation where, despite the classification of the wrecks as dangerous, appropriate measures to prevent the environmental disaster are not taken, is not acceptable. The consequences of an oil release from a wreck are large and should be sufficient to mobilise the relevant services to take action as soon as possible. The technologies available today help to avoid the damaging ecological and socio-economic effects that such events would cause. The proposals presented in the full version of this publication show what and how can be done to estimate the risk of the release of oil and other hazardous substances from wrecks lying on the seabed. The presented scheme of action permits to plan subsequent steps in the investigation and remediation process as well as to decide on the possible need to carry out the clean-up operations. The full version of the methodology, with a description of activities carried out in individual countries, is available at the MARE Foundation website (fundacjamare.pl).

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The extensive bibliography is available for download in the full version of the methodology at **www.fundacjamare.pl**.

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STOP
THE OIL SPILLAGE

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