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Black Sea SIERRA

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Complementary sustainable management plan of response
strategies to civil and military marine pollution

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Authors	INCDPM Team: Georgeta Tudor Ukr-SCES Team: Viktor Komorin ARCES Team: Alessandro Pernice & Melinda Terranova
Contributors	All partners: Institutul National De Cercetare-Dezvoltare Pentru Protectia Mediului Bucuresti (INCDPM) Institute of Oceanology Bas (IO-BAS) Ordu Universitesi (ORDU) Ukrainian Scientific Center of Ecology of the Sea (UkrSCES) Mircea cel Batran Naval Academy (MBNAR) Gheorghe Asachi Technical University of Iasi (TUIASI)

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CONSORTIUM MEMBERS



Coordinator

INSTITUTUL NATIONAL DE
CERCETARE-DEZVOLTARE PENTRU
PROTECTIA MEDIULUI BUCURESTI - INCDFM
Romania



P1

INSTITUTE OF OCEANOLOGY BAS - IO-BAS
Bulgaria



P2

E.M. ASSOCIAZIONE A.R.C.E.S. - ARCES
Italy



P3

ORDU UNIVERSITESI - ORDU
Türkiye



P4

UKRAINIAN SCIENTIFIC CENTRE
OF ECOLOGY OF THE SEA - UkrSCES
Ukraine



P5

ACADEMIA NAVALA MIRCEA
CEL BATRAN - MBNAR
Romania



P6

UNIVERSITATEA TEHNICA GHEORGHE
ASACHI DIN IASI - TUIASI
Romania

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Abbreviations and Acronyms

Abbreviation	Full form / explanation
ABADL	Dobrogea-Litoral Water Basin Administration (Romania)
ANAR	National Administration "Romanian Waters"
ANPM	National Environmental Protection Agency (Romania)
APMC	Constanța Maritime Ports Administration
ARBDD	Danube Delta Biosphere Reserve Administration
ARSVOM	Romanian Naval Search and Rescue Agency
BAT	Best Available Techniques
BSBD	Black Sea Basin Directorate (Bulgaria)
BSC	Black Sea Commission (Commission on the Protection of the Black Sea Against Pollution)
BSIMAP	Black Sea Integrated Monitoring and Assessment Programme
CINEA	European Climate, Infrastructure and Environment Executive Agency
CMEMS	Copernicus Marine Service
DEN-IZ	Integrated Marine Pollution Monitoring Programme (Türkiye)
EMFAF	European Maritime, Fisheries and Aquaculture Fund
EMODnet	European Marine Observation and Data Network
EMSA	European Maritime Safety Agency
EOD	Explosive Ordnance Disposal
EU	European Union
ExEA	Executive Environment Agency (Bulgaria)
GC-MS	Gas Chromatography–Mass Spectrometry
GIS	Geographic Information System
HELCOM	Baltic Marine Environment Protection Commission (Helsinki Commission)
HNS	Hazardous and Noxious Substances
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
IGSU	General Inspectorate for Emergency Situations (Romania)
ILC	International Law Commission
IMO	International Maritime Organization
INCDM	National Institute for Marine Research and Development "Grigore Antipa" (Constanța, Romania)
INCDPM	National Institute for Research and Development in Environmental Protection Bucharest (project coordinator)
IO-BAS	Institute of Oceanology, Bulgarian Academy of Sciences
MAR-ICE	Maritime Assistance and Rescue – International Chemical Environment network (EMSA hazardous-substance response network)
MARPOL	International Convention for the Prevention of Pollution from Ships

MBNAR	Mircea cel Bătrân Naval Academy (Romania)
MFF	Multiannual Financial Framework
MOEW	Ministry of Environment and Water (Bulgaria)
MSFD	Marine Strategy Framework Directive (2008/56/EC)
N ₂ O ₄	Nitrogen tetroxide
NATO	North Atlantic Treaty Organization
NDMA	N-nitrosodimethylamine
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
OSR	Oil Spill Response
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PETN	Pentaerythritol Tetranitrate
POLREP	Pollution Report (standardised IMO pollution-reporting format)
RDX	Research Department Explosive (cyclotrimethylenetrinitramine)
REMPEC	Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
RNA	Romanian Naval Authority
SAR	Synthetic Aperture Radar
SNMM	National Environmental Monitoring System (Romania)
TÜBİTAK MAM	Marmara Research Center of the Scientific and Technological Research Council of Türkiye
TNT	Trinitrotoluene
TUIASI	Gheorghe Asachi Technical University of Iași (Romania)
UDMH	Unsymmetrical Dimethylhydrazine
UkrSCES	Ukrainian Scientific Centre of Ecology of the Sea
UNCLOS	United Nations Convention on the Law of the Sea
USPA	State Enterprise "Ukrainian Sea Ports Authority"
UXO	Unexploded Ordnance
WFD	Water Framework Directive (2000/60/EC)
WGS84	World Geodetic System 1984 (coordinate reference system)
WP	Work Package

Executive Summary

This Complementary Sustainable Management Plan of Response Strategies to Civil and Military Marine Pollution is intended to support a more coordinated, practical and forward-looking response to marine pollution in the Black Sea region. It does not replace existing national or regional mechanisms, but complements them by bringing together scientific knowledge, institutional responsibilities, response practices and training needs into one common framework. The Plan is especially important in the current context, where traditional sources of pollution are increasingly combined with new risks linked to military activities and the consequences of armed conflict.

The Plan focuses on the northern, western and southern parts of the Black Sea, including coastal waters, river mouths, lagoons, estuaries and relevant transboundary areas. This geographical scope reflects the fact that marine pollution does not stop at administrative or national borders. Pollutants entering the sea from rivers, coastal cities, ports, industrial sites, shipping activities or conflict-affected areas can spread across the basin and affect shared ecosystems, coastal communities and economic activities in several countries.

The Black Sea is already exposed to long-standing civil pollution pressures, including municipal and industrial discharges, agricultural runoff, port activities, maritime transport, oil pollution, litter and eutrophication. At the same time, the region faces growing challenges from emerging contaminants, microplastics, hazardous substances, underwater noise and other complex pressures that are not always sufficiently covered by existing monitoring and response systems. In the northern part of the Black Sea, the armed conflict has added another layer of environmental risk, including pollution from damaged infrastructure, fuel releases, military debris, munitions, disturbed sediments and restricted access to affected areas. These problems are made more difficult by fragmented data flows, uneven technical capacity, limited interoperability between information systems and insufficient preparedness for combined civil and military pollution events.

The Plan therefore proposes a set of response-oriented measures aimed at improving prevention, preparedness, monitoring, early detection, emergency response, remediation, recovery and communication. It also identifies training needs for public authorities, scientific institutions, emergency responders and other stakeholders, particularly in relation to emerging pollutants, conflict-related contamination, risk assessment, data exchange and practical response procedures. By bringing these elements together, the Plan is expected to help decision-makers and stakeholders act in a more coordinated and evidence-based way, strengthen regional cooperation and improve the overall capacity of Black Sea countries to respond to both civil and military marine pollution.

2. Introduction

2.1 Background and rationale

The Black Sea is a semi-enclosed and environmentally sensitive regional sea. Because of its limited water exchange and strong influence from large river basins, pollution entering the Black Sea can persist, accumulate and spread across national boundaries. This makes the region particularly vulnerable to both long-term pollution pressures and sudden pollution events.

For decades, the Black Sea has been affected by a combination of civil sources of pollution. These include riverine inputs, municipal and industrial discharges, agricultural runoff, port activities, shipping, tourism, coastal development, oil pollution and marine litter. Many of these pressures do not act separately. They overlap in space and time, creating cumulative impacts on water quality, bottom sediments, marine organisms, habitats and coastal ecosystems.

Today, these long-standing pressures are accompanied by new and more complex risks. In the northern part of the Black Sea, the war has created additional environmental concerns. Damage to infrastructure, military activities, explosions, fires, fuel releases, sunken objects, munitions and disturbed sediments may introduce pollutants that are difficult to detect, quantify and manage. Some impacts are visible immediately, while others may remain hidden in sediments, biota or coastal habitats and appear only through long-term monitoring.

From a scientific and management perspective, there is a clear need for a practical framework that connects environmental evidence with management action. Existing systems already provide important knowledge and institutional experience, but they are often fragmented and not always adapted to combined civil and military pollution scenarios. This Plan is therefore proposed as a complementary instrument to help bring together scientific information, institutional responsibilities, response procedures and training needs in a more coherent way.

2.2 Purpose of the Plan

The purpose of this Plan is to provide a coherent framework for preparedness, response, remediation, training and transboundary cooperation in relation to civil and military marine pollution in the Black Sea region.

The Plan does not aim to replace existing legislation, monitoring programmes, emergency procedures or regional agreements. Its role is to complement them by identifying where existing mechanisms can be better connected, updated or

strengthened. In particular, it focuses on pollution situations that require cooperation between countries, institutions and sectors.

The Plan is intended to support decision-makers and technical experts in moving from separate pieces of information towards a more integrated understanding of pollution risks. It should help to identify vulnerable areas, clarify institutional roles, improve the use of monitoring data, support emergency response, and define practical training needs for those involved in marine pollution management.

Special attention is given to pollution linked to armed conflict. This is a relatively new and insufficiently systematised challenge for the Black Sea region. It requires not only additional scientific analysis, but also better preparedness, clearer communication channels and practical response tools.

2.3 Scope of the Plan

The Plan covers marine and coastal environments affected or potentially affected by civil and military pollution. Its scope includes marine waters, coastal zones, tributary river mouths, lagoons, estuaries, bottom sediments, biota, biodiversity receptors, coastal communities and the decision-making systems responsible for pollution management.

The Plan considers both routine and emergency pollution situations. It addresses chronic pollution from land-based and sea-based activities, as well as accidental and conflict-related pollution events. It also recognises that pollutants may move between different environmental compartments: from rivers to coastal waters, from water to sediments, from sediments to biota, and through food webs to sensitive biodiversity components.

In practical terms, the Plan covers:

- marine and coastal water pollution;
- pollution transported by tributary rivers;
- contamination of sediments and accumulation in biota;
- risks to biodiversity, habitats and ecosystem services;
- impacts on coastal communities and local economic activities;
- monitoring, assessment and data management;
- institutional coordination and decision-making;
- emergency response and remediation;

- training, awareness and capacity-building;
- transboundary cooperation and information exchange.

This broad scope is necessary because marine pollution is not only a chemical or technical issue. It is also a question of governance, preparedness, scientific interpretation and timely decision-making.

2.4 Target audience

This Plan is intended for institutions and stakeholders involved in preventing, assessing, managing or responding to marine pollution in the Black Sea region.

The main users include national and local authorities, environmental agencies, scientific institutions, monitoring organisations, laboratories, emergency services, civil protection bodies, port administrations, maritime safety actors, military-civil coordination bodies, coast guard and surveillance services, NGOs, coastal communities, educational institutions and international organisations.

The Plan is also relevant for policy-makers, project partners, technical experts and regional cooperation platforms working on marine environmental protection, pollution response, ecosystem resilience and environmental security.

2.5 Definitions and terminology

For the purposes of this Plan, key terms are used in a practical and management-oriented sense.

Civil marine pollution means pollution caused by non-military human activities. This includes municipal and industrial discharges, agricultural runoff, shipping, port operations, tourism, oil handling, waste disposal, coastal construction and other land-based or sea-based sources.

Military marine pollution means pollution directly or indirectly associated with military activities. This may include fuel and oil releases, damaged military equipment, naval operations, military debris, munitions, explosions, fires, sunken objects and other impacts linked to defence or combat-related activities.

Armed conflict-related contamination refers to pollution resulting from the consequences of armed conflict. It may originate from destroyed infrastructure, damaged industrial facilities, fuel storage sites, sunken vessels, munitions, disturbed sediments, fire residues or other conflict-related sources.

Emergency response means immediate coordinated actions taken after a pollution incident. These actions include assessing the situation, limiting the spread of pollutants, protecting people and the environment, informing responsible authorities and starting containment or mitigation measures.

Remediation refers to actions aimed at reducing, removing, containing or neutralising pollution and supporting environmental recovery where possible. Depending on the situation, remediation may involve technical solutions, management measures, nature-based approaches or a combination of these.

Monitoring means systematic collection, analysis and interpretation of information on the state of the marine environment, pollution levels, pollutant pathways, affected areas and possible impacts on ecosystems and human activities.

Hotspots are areas where pollution levels, ecological risks or vulnerability are higher than in surrounding areas. They may be associated with river mouths, ports, industrial zones, conflict-affected areas, accumulation zones or other specific sources of pressure.

Risk prioritisation means ranking pollution sources, areas or response needs according to their likely severity, probability, spatial extent, ecological consequences and urgency for management action.

Ecosystem resilience means the ability of marine and coastal ecosystems to absorb pressures, recover from disturbance and maintain their basic functions and services. In this Plan, strengthening resilience means reducing pollution risks, improving monitoring and response capacity, and supporting the recovery of affected ecosystems.

3. Methodological Basis of the Plan

3.1 Integration of WP5 activities

The methodological basis of this Plan follows the internal logic of Work Package 5. The Plan is not prepared as an isolated strategic document, but as the result of several connected analytical steps. Each of these steps contributes a specific part of the knowledge needed to build a realistic and useful management framework for responding to civil and military marine pollution in the Black Sea region.

The first step is the mapping of relevant authorities and organisations under T5.1. This provides the institutional background for the Plan. It helps to understand which actors are involved in marine pollution monitoring, assessment, emergency response, remediation, training, communication and decision-making. From a practical point of view, this is essential, because even the

best scientific data cannot support effective response if institutional roles, responsibilities and communication channels are unclear.

The second step is the analysis of existing information and training systems under T5.2. This part of the work shows what data sources, monitoring platforms, information systems, training programmes and capacity-building tools already exist in the Black Sea countries. For scientists and practitioners, this is a critical element. Marine pollution response depends on reliable information, comparable data, trained personnel and the ability to use available knowledge quickly during both routine and emergency situations. The analysis also helps to identify gaps, such as fragmented data flows, limited access to some information, uneven technical capacity and insufficient training on emerging or conflict-related pollutants.

The third step is the identification and systematisation of specific pollution types under T5.3. This task helps to clarify what kinds of pollution events the Plan should address. It distinguishes between long-term civil pollution pressures, accidental pollution events and pollution associated with military activities or armed conflict. It also considers possible sources, pathways, affected environmental compartments and risks for biodiversity, sediments, biota, coastal communities and decision-making systems. This is important because different pollution scenarios require different monitoring methods, response actions and management priorities.

Under T5.4, these three elements are brought together into one complementary sustainable management framework. In simple terms, T5.1 shows who is involved, T5.2 shows what information and capacities are available, and T5.3 shows what pollution risks and scenarios need to be managed. The role of T5.4 is to connect these findings and translate them into practical response strategies, coordination mechanisms, implementation measures and training priorities.

This approach allows the Plan to remain grounded in real institutional and scientific conditions rather than being only a general policy statement. It reflects the complexity of the Black Sea region, where pollution problems are often transboundary, data availability differs between countries, and response capacities are not always evenly developed. It also takes into account the additional challenges created by the war, where some pollution risks are new, difficult to assess and require closer cooperation between scientific institutions, authorities and operational response structures.

In this way, the Plan serves as a bridge between scientific assessment and practical management. It brings together evidence, institutional knowledge and response needs in order to support more coordinated, timely and informed action against civil and military marine pollution in the Black Sea.

3.2 Link with other work packages

The Plan is closely connected with the other technical and dissemination work packages of the Black Sea SIERRA project. Although it is developed under WP5, it is not limited to institutional or management analysis only. Its value depends on the ability to bring together scientific results, practical response tools and capacity-building activities produced across the project.

The results of WP2 provide the scientific basis for understanding the actual levels and types of marine pollution in the Black Sea region. WP2 focuses on the assessment of pollution in coastal zones, tributary river mouths, lagoons and other relevant areas affected by civil and military activities. These results help the Plan identify priority pollutants, affected areas, possible pollution pathways and the types of monitoring information that are needed for informed decision-making. In this sense, WP2 provides the Plan with evidence on what is present in the environment and where pollution pressures are most relevant.

The results of WP3 strengthen the ecological dimension of the Plan. WP3 focuses on bioaccumulation, biodiversity components threatened by pollution, spatial representation and modelling of pollutant distribution and dispersion. These outputs are important because management decisions should not be based only on the presence of pollutants in water or sediments, but also on their possible accumulation in organisms, their movement through the environment and their risks for marine ecosystems. WP3 therefore helps the Plan understand how pollution may affect biota, habitats and ecosystem vulnerability, and how risk prioritisation can be supported by modelling and spatial analysis.

The results of WP4 are directly linked to the response-oriented part of the Plan. WP4 addresses remedial measures, long-term reaction plans, monitoring approaches for armed conflict-related environmental pollution and practical solutions for reducing pollution impacts. Its outputs, including monitoring guidance and remedial solution concepts, provide the Plan with concrete elements for emergency response, remediation and recovery strategies. From a management perspective, WP4 helps answer the question what can be done after pollution is detected, especially in cases related to armed conflict, hot-spots or specific hazardous contaminants.

The results of WP6 support the communication, dissemination and training dimension of the Plan. WP6 is important for ensuring that the knowledge generated by the project does not remain only within the consortium, but reaches authorities, stakeholders, practitioners and the wider public. Dissemination materials, training courses, workshops and multilingual outputs will help translate the Plan into practical knowledge and support its wider use. WP6 therefore

contributes to capacity-building, awareness raising and uptake of the Plan by decision-makers and stakeholders.

Taken together, the links with WP2, WP3, WP4 and WP6 allow this Plan to function as an integrating management document. WP2 provides pollution assessment data; WP3 adds ecological interpretation, bioaccumulation and modelling; WP4 contributes response and remedial tools; and WP6 ensures that the results are communicated, taught and made accessible to relevant users. This connection between scientific evidence, practical response measures and training is essential for building a more coordinated and effective approach to civil and military marine pollution in the Black Sea region.

3.3 Sources of information

The Plan is based on different types of information, because marine pollution in the Black Sea cannot be understood through one source alone. The Plan combines measured data, official information, previous studies, institutional experience and expert judgement in order to provide a balanced and evidence-based assessment. This is especially important for pollution linked to armed conflict, where access to affected areas may be limited and some impacts are still difficult to document directly.

The first group of sources includes national reports and official documents from the participating Black Sea countries. These materials help to describe existing monitoring programmes, environmental assessments, legal frameworks, institutional responsibilities and national approaches to pollution management. They also show what each country already has in place and where additional support or coordination may be needed.

The second important source is monitoring data and environmental databases. These include national monitoring datasets, marine and coastal water quality data, information on sediments and biota, pollution databases, GIS-based tools and thematic datasets on nutrients, hazardous substances, oil pollution, marine litter, microplastics, underwater noise and other relevant pressures. These data help to identify trends, hotspots, vulnerable areas and possible pathways of pollutant transport.

The Plan also uses information from regional platforms and international data systems related to the Black Sea. These sources are important because many pollution problems are transboundary. Regional platforms help compare data between countries, support common assessments and make it easier to see the Black Sea as one connected ecosystem rather than as separate national coastal zones.

Scientific literature provides the broader analytical background. Peer-reviewed articles, technical reports, methodological papers and previous project outputs help explain how pollutants behave in the marine environment, how they accumulate in organisms, how risks can be assessed, and which monitoring or remediation approaches have already been tested. This allows the Plan to rely not only on available data, but also on established scientific knowledge.

A particularly important source for this Plan is the information collected through institutional questionnaires and partner contributions within WP5. These inputs help identify existing information systems, training programmes, responsible institutions, stakeholder roles and practical gaps. They are valuable because they reflect the real situation in each partner country, including national experience, limitations and specific needs.

The Plan also takes into account stakeholder consultations. Discussions with authorities, scientific institutions, environmental agencies, emergency services, NGOs, port-related actors and other stakeholders help to understand how pollution response works in practice. Such consultations are important because management plans must be useful not only on paper, but also in real situations where decisions need to be taken quickly and responsibilities must be clear.

In addition, the Plan draws on project deliverables and outputs from other work packages of Black Sea SIERRA. Results from pollution assessment, bioaccumulation studies, modelling, monitoring guidance, remedial measures, training materials and dissemination activities are used to build a more complete management framework. This helps ensure that the Plan reflects the scientific and practical results of the whole project, not only WP5.

Finally, the Plan relies on expert inputs from project partners and specialists in marine monitoring, pollution assessment, environmental risk analysis, remediation, data management and regional cooperation. Expert judgement is especially important where data are incomplete, monitoring is interrupted, or new pollution risks are still poorly understood.

Taken together, these sources provide the evidence base for the Plan. They allow to combine official information, monitoring data, scientific interpretation and practical experience. This makes the Plan more realistic and more useful for decision-makers and stakeholders who need to respond to civil and military marine pollution in the Black Sea region.

3.4 Analytical approach

The analytical approach of this Plan is based on the understanding that marine pollution management cannot rely on environmental data alone. The analytical approach considers not only pollutants and their impacts, but also the institutions, information systems, response capacities and practical conditions under which decisions are made. For this reason, the Plan combines scientific analysis with a management-oriented review of existing capacities and needs.

The first step is the mapping of actors involved in marine pollution prevention, monitoring and response. This includes public authorities, environmental agencies, scientific institutions, laboratories, emergency services, port administrations, maritime safety bodies, NGOs, coastal stakeholders and international organisations. This mapping helps to understand who is responsible for what, how institutions currently cooperate, and where coordination may need to be improved. In real pollution events, clear responsibilities and communication channels are often as important as technical data.

The second step is the review of existing information and training systems. This includes monitoring databases, information platforms, reporting tools, scientific data sources, training courses, workshops, manuals and capacity-building initiatives. The purpose is to understand what knowledge, tools and skills are already available in the Black Sea region, and whether they are sufficient for responding to both traditional pollution pressures and newer challenges, including conflict-related contamination.

The third step is the development of a pollution typology. This means grouping the main types of civil and military marine pollution according to their sources, pathways, affected environmental compartments and possible impacts. Such a typology helps distinguish between long-term pollution pressures, accidental events and pollution linked to armed conflict. It also helps to avoid treating all pollution events in the same way, since different situations require different monitoring methods, response actions and management priorities.

The fourth step is a gap analysis. At this stage, we identify what is missing or insufficient in the existing system. These gaps may relate to data availability, monitoring coverage, laboratory capacity, harmonisation of methods, access to affected areas, training, institutional coordination or emergency response procedures. This part of the analysis is especially important because the Plan should not only describe the current situation, but also indicate where improvement is most needed.

The fifth step is risk-based prioritisation. In practice, not all pollution problems can be addressed at the same time or with the same resources. Therefore, the Plan considers which risks should receive priority attention, taking into account their likely severity, spatial extent, persistence, ecological consequences, potential impact on coastal communities and the feasibility of response measures. This helps focus management efforts on the most urgent and significant problems.

The sixth step is strategy development. Based on the previous steps, the Plan proposes practical strategies for prevention, preparedness, monitoring, early detection, emergency response, remediation, recovery, communication and transboundary cooperation. These strategies are intended to be flexible enough for different national contexts, but still coherent enough to support a common regional approach.

The final step is implementation planning. This translates the proposed strategies into possible actions, responsible actors, timeframes, expected outputs and training needs. This is important because a management plan should be usable in practice, not only as a policy document. It should help authorities, scientists, emergency responders and other stakeholders understand what needs to be done, by whom and in what sequence.

Overall, the analytical approach moves from understanding the current situation to identifying practical ways forward. It asks several basic but important questions: who is involved, what information and capacities already exist, what pollution risks need to be addressed, where the main gaps are, and what actions can realistically improve preparedness and response. This allows the Plan to remain scientifically grounded while also being useful for decision-making and practical pollution management in the Black Sea region.

3.5 Limitations and uncertainty

This Plan is prepared in a complex and rapidly changing context. The Plan clearly distinguishes between findings supported by available evidence and areas where important uncertainties remain. This is especially relevant for the Black Sea today, where long-standing pollution pressures are now combined with wartime constraints and new environmental risks.

One of the main limitations is the presence of data gaps. Available information on marine pollution is not equally complete for all parts of the Black Sea. Some areas are covered by regular monitoring, while others are represented by fragmented, outdated or indirect data. In some cases, there is information on water quality, but much less information on sediments, biota, bioaccumulation

or long-term ecological effects. This limits our ability to assess all risks with the same level of confidence.

A second important limitation is restricted access to sea areas, particularly in the northern part of the Black Sea. Because of security risks, military activities and navigation restrictions, direct sampling and field observations may be limited or impossible in some areas. Under such conditions, scientists often have to combine different types of evidence, including data from accessible coastal zones and river mouths, remote sensing, modelling, historical information and expert judgement.

The war also creates broader practical constraints for monitoring and response. Field campaigns may be delayed or cancelled, infrastructure may be damaged, laboratory capacity may be reduced, and logistics may become more difficult. Safety risks for field teams also have to be taken into account. These factors affect not only data collection, but also the ability to verify pollution events quickly and to assess their environmental consequences directly.

Another limitation is that national monitoring systems differ between Black Sea countries. They may use different sampling frequencies, parameters, analytical methods, reporting formats, quality assurance procedures and data access rules. These differences are understandable, because each country has its own institutional and legal context, but they can make regional comparison and joint interpretation more difficult. For this reason, harmonisation and interoperability remain important needs for future cooperation.

There is also considerable uncertainty regarding new, emerging or poorly studied contaminants. This includes microplastics, transformation products, underwater noise, mixed contamination and pollutants associated with armed conflict. In many cases, their behaviour, persistence, toxicity and cumulative effects in the Black Sea environment are not yet fully understood. This is particularly true for contamination linked to damaged infrastructure, munitions, explosions, fires, fuel releases, sunken objects and disturbed sediments.

A further uncertainty concerns combined and cumulative impacts. Civil and military pollution pressures may overlap in the same areas and affect the same ecosystems. Long-term contamination from rivers, ports or coastal activities may interact with new inputs from conflict-related incidents or accidental releases. Understanding these combined effects requires long-term observations, modelling and interdisciplinary analysis, which are not always available.

For these reasons, the Plan should be understood as an adaptive management document. It is based on the best available information at the time of preparation, but it should be updated as new monitoring data, scientific results and practical experience become available. This is particularly important under

wartime and post-war conditions, when some environmental impacts may become visible only gradually.

At the same time, uncertainty should not be a reason for inaction. Where data are incomplete, the most responsible approach is to apply precaution, clearly document assumptions, improve monitoring, strengthen cooperation between institutions and use risk-based prioritisation. In this way, the Plan can remain scientifically sound, realistic and useful for decision-makers and stakeholders working to reduce the impacts of civil and military marine pollution in the Black Sea region.

4. Baseline Situation: Civil and Military Marine Pollution in the Black Sea

4.1 Civil pollution pressures

The Black Sea has been under pressure from civil sources of pollution for many decades. These pressures come from both land and sea, and they affect coastal waters, river mouths, lagoons, estuaries, bottom sediments, marine organisms and coastal ecosystems. Because the Black Sea is a semi-enclosed basin with limited water exchange, pollutants that enter the sea may remain in the system for a long time, accumulate in sediments or living organisms, and contribute to long-term ecological stress.

One of the main pathways of pollution is riverine input. Rivers bring into the Black Sea substances collected from large catchment areas, including nutrients, suspended matter, organic pollution, pesticides, heavy metals, petroleum hydrocarbons, plastics and other contaminants. River mouths are therefore especially important zones for monitoring, because they often show the connection between land-based activities and the condition of coastal marine waters.

Municipal wastewater is another important source of pressure, particularly near large coastal cities and tourist areas. Where wastewater treatment is insufficient, coastal waters may receive excess nutrients, organic matter, pathogens, pharmaceuticals, detergents and other household-related contaminants. These inputs can affect bathing water quality, stimulate eutrophication, reduce oxygen conditions and create additional stress for coastal habitats.

Industrial discharges also remain relevant in many parts of the Black Sea basin. Industrial areas located near the coast or within river catchments may contribute heavy metals, petroleum products, persistent organic pollutants, solvents and other hazardous substances. Even when current emissions are

reduced or controlled, historical contamination in sediments and industrial zones may continue to influence the marine environment for many years.

Agricultural runoff is mainly associated with nutrients, pesticides and suspended particles transported from agricultural land into rivers and then to the sea. High inputs of nitrogen and phosphorus can contribute to eutrophication and harmful algal blooms. Pesticides and other agrochemicals may also persist in the environment, accumulate in sediments or biota, and create risks for aquatic organisms.

Civil pollution is also connected with ports and shipping. Ports are essential for the regional economy, but they may generate pollution through cargo handling, dredging, fuel operations, ship maintenance, waste management problems and accidental spills. Shipping may add oil residues, bilge water, ballast water, antifouling substances, air emissions, underwater noise and litter. In busy coastal areas, these pressures often overlap with urban, industrial and riverine sources.

Tourism and coastal recreation create more seasonal but locally important pressures. During peak periods, coastal settlements and resort areas may face increased wastewater volumes, more litter, pressure on waste management systems, habitat disturbance and coastal development. These impacts may look small when considered separately, but together they can significantly affect sensitive coastal zones.

Oil and gas activities, including exploration, extraction, transport and storage, represent another source of potential risk. Operational discharges, accidental spills, petroleum hydrocarbons, seabed disturbance and risks related to terminals, pipelines and offshore infrastructure all need to be considered in pollution management and emergency preparedness.

Marine litter and microplastics are now among the most visible and persistent pollution problems. Litter enters the Black Sea through rivers, coastal settlements, tourism, fisheries, shipping and inadequate waste management. Plastic waste can gradually break down into microplastics, which may be ingested by marine organisms and enter food webs. Microplastics may also interact with other contaminants, which makes their assessment more complex.

From a scientific point of view, these civil pollution pressures should not be seen as separate problems. In many coastal areas, riverine inputs, wastewater, industrial activities, ports, shipping, tourism and agricultural runoff act together. Their cumulative effects may be more important than any single source alone. For this reason, civil marine pollution in the Black Sea requires integrated monitoring, comparison of data between countries, and management approaches

that take into account both individual sources and their combined impact on ecosystems.



Figure 1: *The image highlights pollution, with heavy emissions from factories contributing to air pollution and posing indirect risks to the marine environment. Source: Pixabay.*

4.2 Military and armed conflict-related pollution

Military and armed conflict-related pollution is one of the most difficult categories of pressure to assess in the Black Sea. Unlike many routine civil pollution sources, these impacts may occur suddenly, in unsafe or inaccessible areas, and may involve complex mixtures of substances that are not always included in regular monitoring programmes. This type of pollution should be assessed with particular care, because some effects are visible immediately, while others may remain hidden in sediments, biota or coastal habitats and appear only over time.

One important source is related to explosions and military activities in marine and coastal areas. Explosions can disturb bottom sediments, resuspend contaminants that were previously deposited, damage infrastructure and introduce residues of explosive materials into the environment. The scale of the impact depends on many factors, including the location, depth, type of material involved, hydrodynamic conditions and the sensitivity of nearby habitats.

Munitions and military debris are another serious concern. Unexploded ordnance, ammunition fragments, metal parts, damaged equipment and other mili-

tary residues may contain energetic compounds, heavy metals and other hazardous substances. If they remain in the water or sediments, they can gradually corrode and become a long-term source of contamination. At the same time, they create safety risks for sampling teams, divers, fishers and emergency responders, which makes monitoring and remediation much more complicated.

Fuel and oil spills are among the most visible consequences of conflict-related incidents. They may originate from damaged vessels, fuel storage facilities, port infrastructure, pipelines, vehicles or other equipment. Oil and petroleum products can spread quickly on the water surface, contaminate beaches and coastal habitats, affect birds and marine organisms, and accumulate in sediments. In semi-enclosed coastal areas, such pollution may persist and require coordinated containment, monitoring and recovery measures.

A major concern is also the damage to civilian infrastructure caused by military actions. When ports, industrial facilities, wastewater systems, energy infrastructure, storage tanks or transport networks are damaged, pollutants may enter rivers, coastal waters or directly the sea. These releases may include untreated wastewater, petroleum products, industrial chemicals, construction materials, metals and combustion residues. In such cases, the distinction between civil and military pollution becomes less clear, because military impacts may trigger pollution from civilian sources.

Sunken objects, such as vessels, vehicles, containers, military equipment or other debris, may also become long-term pollution sources. They can release fuels, oils, lubricants, paints, plastics, metals and other materials slowly over time. They may also disturb seabed habitats and create risks for navigation, fisheries and monitoring activities. From an environmental perspective, such objects should be considered not only as physical hazards, but also as potential sources of delayed chemical contamination.

Fire residues and combustion products are another possible pathway of pollution. Fires caused by attacks, explosions or infrastructure damage may produce soot, ash, petroleum-derived compounds, metals and other toxic substances. These materials can enter the marine environment through atmospheric deposition, surface runoff, rivers or direct release from damaged coastal facilities. Their composition is often complex, especially when different types of materials burn together.

Conflict-related pollution may also include heavy metals and hazardous substances released from munitions, damaged industrial sites, shipwrecks, port areas, fuel depots or disturbed sediments. Some of these substances can persist in the environment, accumulate in bottom sediments and enter food webs through

benthic organisms and fish. This is why monitoring should not be limited only to water samples, but should also consider sediments and biota where possible.

Another important pressure is underwater noise. Military activities, explosions, vessel movements and other conflict-related operations can generate intense sound in the marine environment. This may affect marine organisms, especially species that depend on sound for orientation, communication and feeding. In the Black Sea, this issue is particularly relevant for cetaceans and other sensitive species. However, underwater noise remains difficult to assess because it requires specialised equipment and can vary strongly in space and time.

From a scientific point of view, military and armed conflict-related pollution should be understood as a combined chemical, physical and acoustic pressure. It is rarely limited to one pollutant or one pathway. It may affect water, sediments, biota, habitats and coastal communities at the same time. It is also often associated with high uncertainty, because direct access to affected areas may be restricted and reliable baseline data may be limited.

For this reason, the Plan treats armed conflict-related pollution not only as an emergency issue, but also as a long-term environmental management challenge. It requires careful documentation, risk-based prioritisation, safe monitoring procedures, cooperation between scientists and authorities, and coordination with maritime, emergency and military-civil actors. Where direct measurements are not possible, remote sensing, modelling, historical data and expert judgement should be used carefully and transparently until field verification becomes feasible.

4.3 Emerging pollutants and new risks

Emerging pollutants are becoming an increasingly important issue for the Black Sea. Traditional monitoring programmes usually focus on well-known parameters, such as nutrients, petroleum hydrocarbons, heavy metals and selected hazardous substances. These indicators remain essential, but they no longer describe the full pollution picture. New substances, new combinations of pollutants and new pathways of contamination are appearing, while some of them are still not routinely monitored or are poorly studied in the Black Sea context.

One of the most visible examples is microplastic pollution. Microplastics enter the sea through rivers, wastewater, stormwater runoff, tourism, fisheries, shipping and the gradual breakdown of larger plastic litter. Because of their small size, they can be transported over long distances, accumulate in sediments and be ingested by marine organisms. From a scientific perspective, microplastics are important not only as particles themselves, but also because

they may interact with other contaminants and indicate broader problems in waste management and coastal pressure.

Pesticides also remain a concern, especially in areas influenced by agricultural runoff and riverine inputs. They may be transported from large catchment areas into coastal waters and affect plankton, benthic organisms, fish and other components of marine ecosystems. Their presence may vary seasonally, depending on agricultural practices, rainfall, river discharge and extreme weather events. In addition, some degradation products of pesticides may also be relevant, even when they are not included in regular monitoring programmes.

Pharmaceuticals and personal care products are another group of substances that require more attention. They can reach rivers and coastal waters through municipal wastewater and may include residues of medicines, antibiotics, hormones, disinfectants and household chemicals. Even at low concentrations, continuous exposure may affect aquatic organisms. Their presence also shows how strongly marine pollution is connected with wastewater treatment, urban systems and everyday human activity.

Persistent organic pollutants remain a long-term risk because they are stable, toxic and able to accumulate in sediments and living organisms. Some of these substances may no longer be widely used, but they can still be present in old sediments, contaminated areas or biological tissues. They may become relevant again when sediments are disturbed by storms, dredging, explosions, construction works or other physical impacts.

Algal toxins should also be considered among the new or increasing risks. Nutrient enrichment, warming, changes in river discharge and limited water exchange in coastal areas, lagoons and estuaries can create favourable conditions for harmful algal blooms. Some blooms may produce toxins that affect marine organisms, fisheries, aquaculture, bathing water quality and public health. For scientists and managers, this means that eutrophication should be assessed not only as a nutrient problem, but also as a possible trigger of biological and toxicological risks.

The armed conflict adds a further layer of uncertainty. Some substances released during military-related incidents may not have been monitored before in a systematic way. These may include residues of explosive materials, combustion products, fuel additives, corrosion products from military debris, contaminants from damaged industrial facilities, and substances released from sunken objects or disturbed sediments. In many cases, their composition and behaviour in the marine environment are still difficult to assess without targeted sampling and specialised laboratory analysis.

A major challenge is that emerging pollutants rarely occur alone. Microplastics, pesticides, pharmaceuticals, oil residues, metals, persistent organic pollutants and conflict-related contaminants may be present in the same area and may act together. Their combined effects are difficult to predict, especially when ecosystems are already under pressure from eutrophication, habitat disturbance, climate-related changes or chronic pollution.

For this reason, emerging pollutants and new risks should be treated as a priority for future monitoring and research. The list of monitored parameters needs to become more flexible, analytical capacity should be strengthened, and methods should be better harmonised between countries. This is particularly important for the Black Sea, where long-standing civil pollution pressures now overlap with new risks linked to war, damaged infrastructure and restricted access to affected areas.

From a management perspective, the most responsible approach is precautionary and adaptive. Where knowledge is incomplete, monitoring should be improved, assumptions should be clearly stated, and priority should be given to substances, areas and scenarios with the highest potential risk. This will help scientists, authorities and other stakeholders better understand emerging pollution threats and improve preparedness for both routine and crisis situations in the Black Sea region.

4.4 Environmental receptors and affected groups

Marine pollution in the Black Sea does not affect only seawater as a chemical medium. It reaches many parts of the ecosystem and, through them, also affects people and economic activities that depend on the sea. For this reason, it is important to look at pollution through the lens of environmental receptors — the components of the environment that receive, accumulate or respond to pollution.

The most immediate receptor is marine and coastal water. Water quality can change quickly after pollution enters the sea from rivers, wastewater discharges, ports, shipping, oil spills or conflict-related incidents. Changes in nutrients, oxygen conditions, turbidity, petroleum hydrocarbons, hazardous substances or microbial contamination can directly affect coastal ecosystems and human uses of the sea.

Bottom sediments are equally important. Many pollutants do not remain in the water column for long. Heavy metals, persistent organic pollutants, petroleum hydrocarbons, microplastics and other contaminants can settle and accumulate in sediments, especially near river mouths, ports, lagoons, estuaries

and low-energy coastal zones. Sediments can therefore tell a great deal about past pollution, but they can also become a secondary source of contamination if disturbed by storms, dredging, trawling, explosions or construction works.

Coastal habitats are among the most vulnerable receptors. Beaches, wetlands, lagoons, estuaries, shallow-water areas, seagrass habitats and rocky shores are often close to pollution sources and are highly important for biodiversity. These areas provide feeding, spawning, nursery and migration habitats for many species. Pollution can reduce habitat quality, change species composition and weaken the natural recovery capacity of coastal ecosystems.

At the base of the food web, plankton responds quickly to changes in environmental conditions. Excessive nutrient inputs can stimulate algal blooms, while toxic substances may affect plankton composition and productivity. Since plankton supports many other organisms, changes at this level can influence the wider marine food web.

Benthic communities are particularly useful for understanding longer-term pollution effects. These organisms live on or within sediments and are often exposed to contaminants that accumulate there. Changes in benthos can indicate organic enrichment, toxic contamination, oxygen deficiency or physical disturbance. For scientists, benthic organisms often provide a more stable signal of environmental stress than water samples taken at a single moment.

Fish are important both for the ecosystem and for people. They can be affected by polluted water, degraded habitats, reduced oxygen, contaminated food and accumulation of hazardous substances in tissues. Because fish are also used for human consumption, pollution may have consequences for fisheries, food safety and public confidence in seafood.

Molluscs, especially filter-feeding species such as mussels, are valuable indicators of pollution. They filter large volumes of water and can accumulate contaminants from suspended particles and dissolved substances. This makes them useful for monitoring bioaccumulation, but it also means that contamination may create risks for aquaculture, fisheries and human health.

Marine mammals, especially Black Sea cetaceans, are sensitive receptors of both chemical and physical pressures. They may be affected by underwater noise, oil pollution, hazardous substances, changes in prey availability, habitat disturbance and accidental interactions with human activities. Because they are long-lived and occupy higher levels of the food web, they can reflect broader ecosystem stress.

Birds, including seabirds and coastal birds, may be affected by oil pollution, litter, contaminated prey and degradation of coastal habitats. Wetlands, beach-

es and protected coastal areas are especially important for feeding, resting and migration. Pollution in these areas can therefore affect not only local species, but also migratory populations.

Protected areas require particular attention. Marine and coastal protected areas often include habitats and species of high ecological value. Pollution entering these areas can undermine conservation objectives and reduce ecosystem resilience. For this reason, protected areas should be considered priority zones for prevention, monitoring and rapid response.

The affected groups are not limited to ecosystems. Fisheries may be affected through reduced stocks, contamination of commercial species, restrictions on harvesting areas or loss of market confidence. Tourism may suffer from polluted beaches, visible litter, oil contamination, poor bathing water quality or negative public perception of coastal safety and environmental quality.

Finally, coastal communities are among the groups most directly connected with the consequences of marine pollution. They depend on the sea for livelihoods, food, recreation, health, cultural identity and local development. Pollution can affect public health, employment, income, quality of life and trust in environmental governance. In areas already affected by war or economic vulnerability, these impacts may become even more serious.

For this reason, the Plan considers environmental receptors and affected groups together. Pollution management should not stop at measuring contaminant concentrations. It should also ask what these concentrations mean for ecosystems, biodiversity, fisheries, tourism and people living along the coast. This broader view is essential for risk prioritisation, emergency response, remediation and long-term recovery in the Black Sea region.

4.5 Regional and transboundary dimensions

Marine pollution in the Black Sea has a clear regional and transboundary character. Even when pollution starts from a specific source — a river, port, city, industrial facility, vessel, coastal area or conflict-related incident — it does not necessarily stay there. Once pollutants enter the marine environment, they can move, transform, settle, accumulate or appear again in another place and at another time.

One of the main mechanisms is marine circulation. Currents can transport dissolved substances, suspended particles, oil residues, floating litter and microplastics over long distances. This means that pollution detected in one coastal area may partly originate from another part of the basin, and a pollution

event in one country may later affect waters, beaches, habitats or fishing grounds in another. In a semi-enclosed sea such as the Black Sea, this is especially important because water exchange is limited and pollutants may remain within the system for a long time.

River discharge is another key pathway. Rivers collect pollutants from large catchment areas, often crossing several countries before reaching the sea. Nutrients, pesticides, heavy metals, organic matter, plastics and other contaminants can therefore be transported from inland sources to river mouths, coastal waters, lagoons and estuaries. From a scientific and management perspective, this means that marine pollution cannot be separated from river basin processes.

Sediment transport also matters. Many pollutants attach to fine particles and settle in bottom sediments. These sediments may later be moved by storms, currents, dredging, trawling, construction works or explosions. As a result, contaminants can be redistributed or released back into the water column after being stored for years. This is particularly relevant near river mouths, ports, industrial areas and zones affected by military activity.

Pollution may also reach the sea through atmospheric deposition. Fires, explosions, industrial emissions, ship exhausts or fuel combustion can release particles and chemical substances into the air. These substances may then be deposited onto the sea surface, coastal areas or river catchments. In this way, the marine environment can be affected even when the original source is not directly in the water.

Maritime activities add another transboundary element. Ships, cargo routes, port operations, ballast water, bilge water, waste disposal, accidental spills and underwater noise are not confined to one national sector. Vessels move across jurisdictions, and pollution connected with maritime transport can affect several countries. This is why cooperation between maritime safety bodies, environmental authorities and port administrations is essential.

Pollution can also move through food webs. Contaminants may be taken up by plankton, benthic organisms, molluscs or fish and then transferred to higher trophic levels. Mobile species, including fish, birds and marine mammals, may carry or be exposed to pollutants far from the original source. This is especially important for persistent substances that can accumulate in organisms and remain in the ecosystem for a long time.

From a scientific and management perspective, these processes show that the Black Sea should be considered as one connected environmental system. National monitoring is necessary, but it cannot fully explain or manage pollution risks on its own. Comparable data, shared methods, regular information

exchange and joint interpretation are needed to understand where pollution comes from, how it moves and what risks it creates.

This is particularly important for combined civil and military pollution scenarios. A spill, damaged infrastructure, floating debris, disturbed contaminated sediments or conflict-related release may have consequences beyond the place where it first occurred. For this reason, the Plan places strong emphasis on regional cooperation, interoperable data systems, harmonised monitoring approaches and communication between scientific institutions, authorities and response actors across the Black Sea region.

5. Institutional and Governance Framework

5.1 Relevant authorities and organisations

Effective response to civil and military marine pollution in the Black Sea depends on the coordinated work of many institutions. No single organisation can cover the whole chain from pollution prevention to monitoring, emergency response, remediation and public communication. Marine pollution is a cross-sectoral problem, and this is especially clear when civil sources are combined with military or armed conflict-related impacts.

At the national level, environmental ministries and environmental agencies usually provide the main policy and regulatory framework. They are responsible for environmental protection, marine and water policy, pollution prevention, national monitoring programmes, reporting obligations and coordination with international environmental processes. Their role is to set priorities, define standards and ensure that marine pollution is addressed within broader environmental governance.

Environmental inspectorates and enforcement bodies are important for control and compliance. They inspect pollution sources, document violations, investigate incidents and support enforcement measures. In the context of war-related pollution, they may also contribute to documenting environmental damage and collecting evidence on pollution caused by damaged infrastructure, industrial sites or other affected facilities.

Scientific and research institutions provide the evidence needed for decision-making. They carry out monitoring, laboratory analysis, ecological assessment, modelling and interpretation of pollution data. Their role is particularly important when pollution sources are complex, when contaminants are new or poorly studied, or when direct access to affected areas is limited. Scientists also

help develop methodologies, monitoring guides, risk assessments and training materials.

Hydrometeorological and marine monitoring services provide information on weather, river discharge, currents, waves, water quality and other physical conditions that influence the movement and fate of pollutants. These data are essential for understanding how oil, litter, suspended matter or dissolved contaminants may spread through coastal and transboundary areas.

Emergency services and civil protection bodies are responsible for immediate action when pollution creates risks for people, infrastructure or the environment. Their work may include emergency coordination, safety measures, containment actions, field operations and communication with local authorities. In real incidents, their ability to act quickly depends on access to reliable information and clear links with environmental and scientific experts.

Maritime safety authorities, coast guard services and port administrations play a key role in preventing and responding to pollution from ships, ports and maritime activities. They are involved in vessel control, navigation safety, incident reporting, oil spill preparedness, port reception facilities, ballast and bilge water management, and response actions in port and coastal waters. Their role is especially important in areas with intensive shipping, port operations or off-shore infrastructure.

Local and regional authorities are often closest to the practical consequences of pollution. They deal with affected beaches, coastal infrastructure, tourism, waste management, public services and communication with local communities. When pollution reaches the shore, local authorities may be among the first to receive questions from residents, businesses and media. For this reason, they need clear information, practical guidance and good communication channels with national institutions.

Public health authorities become important when pollution may affect human health. This may concern bathing water quality, seafood safety, exposure to hazardous substances or pollution incidents near populated areas. Their assessments help define public warnings, temporary restrictions and communication with communities.

For military or conflict-related pollution, military-civil coordination bodies and defence-related actors may also be involved. Their role is sensitive but important. They may provide information on restricted or dangerous areas, support safe access planning, identify security risks, and help coordinate environmental actions in areas affected by military activity. Without this coordination, monitoring and remediation may be unsafe or impossible.

Non-governmental organisations, educational institutions and community groups also have an important role. They support public awareness, environmental education, beach monitoring, marine litter activities and communication with coastal communities. In some cases, they can help identify local pollution problems earlier than formal systems, especially where communities are directly exposed to coastal impacts.

At the regional and international level, Black Sea cooperation platforms, EU-related structures, maritime safety organisations and international environmental organisations support harmonisation, data exchange, training and trans-boundary cooperation. Their role is especially important because pollution in the Black Sea does not remain within national borders. Shared methods, comparable data and regular dialogue are necessary for a common understanding of risks.

From our perspective, the key issue is not only whether these institutions exist, but how well they work together. Monitoring data must reach decision-makers in time. Emergency responders need access to scientific support. Port and maritime authorities should be connected with environmental agencies. Local authorities need clear messages for the public. In this sense, institutional coordination is not an administrative detail; it is one of the core conditions for effective preparedness and response to civil and military marine pollution in the Black Sea.

A consolidated overview of the competent authorities, scientific institutions, operational response bodies and regional organisations relevant to the implementation of this Plan is provided in Annex 1 – Institutional and Information Framework. The Annex identifies their principal functions in monitoring, notification, emergency response, scientific support, remediation and trans-boundary cooperation.

5.2 Roles and responsibilities

A clear division of roles is essential for responding to civil and military marine pollution in the Black Sea. In practice, pollution response involves many institutions at the same time, and each of them sees only part of the problem. Effective management depends not only on reliable data, but also on whether the relevant institutions receive this information in time and are able to use it for decision-making.

Scientific institutions provide the evidence base. Their role is to monitor marine waters, sediments and biota, analyse samples, interpret results, identify pollution trends and hotspots, assess ecological risks and support modelling. They also help develop monitoring methods, risk assessment approaches and practical guidance. In situations linked to armed conflict, scientific institutions

are especially important because they can help distinguish between confirmed impacts, likely risks and uncertainties that still require further investigation.

Environmental authorities are responsible for the policy and regulatory framework. They define environmental priorities, coordinate national monitoring programmes, supervise implementation of environmental legislation and ensure reporting under national and international obligations. During pollution incidents, they should help coordinate environmental assessment, request expert support and ensure that response measures are consistent with ecosystem protection and public interest.

Emergency services and civil protection bodies have the key operational role when pollution creates an urgent risk. They are responsible for rapid mobilisation, safety measures, field coordination, containment actions where possible, and support to affected areas. Their work is especially important during oil spills, hazardous substance releases, coastal contamination events or other incidents where decisions must be taken quickly.

Maritime administrations and maritime safety bodies focus on pollution risks connected with navigation and maritime activities. Their responsibilities may include vessel control, maritime incident reporting, navigation safety, prevention of illegal discharges, response to ship-related pollution and cooperation with coast guard or surveillance services. They are central actors when pollution is linked to shipping, accidents at sea, ballast water, bilge water, oil operations or other sea-based sources.

Port authorities are responsible for prevention and response within ports and nearby waters. Their role includes safe port operations, waste reception facilities, oil spill preparedness, emergency procedures, control of fuel and cargo operations, and coordination with shipping companies, terminal operators and local responders. Ports are often located near cities and industrial zones, so they can also serve as important points for early detection and communication.

Military structures and military-civil coordination bodies become particularly relevant where pollution is connected with armed conflict, military activity, restricted zones, munitions, sunken objects or safety risks. Their role may include providing information on dangerous areas, supporting safe access planning, identifying military-related hazards and coordinating with civilian institutions. This is a sensitive but necessary part of response, because environmental monitoring or remediation cannot be carried out safely without understanding the security situation.

Local and regional authorities are often closest to the consequences of pollution. They deal with affected beaches, coastal infrastructure, local communities, waste collection, tourism, fisheries and public communication. When

pollution reaches the coast, local authorities are usually among the first to face questions from residents, businesses and media. They therefore need timely information from national authorities and scientific experts, as well as clear instructions on what should be communicated and what actions are needed.

International partners and regional organisations support the broader trans-boundary dimension. They can help with data exchange, harmonisation of methods, technical assistance, training, regional dialogue and alignment with international standards. Their role is important because pollution in the Black Sea often crosses borders, while monitoring and response capacities differ between countries.

These roles should not be understood as separate blocks. In real situations, they need to work together. Scientists need access to operational information. Emergency responders need scientific interpretation. Port and maritime authorities need to share incident data quickly. Local authorities need clear messages for the public. Military-civil coordination is needed when safety or access is uncertain. International partners can help connect national efforts into a regional response.

In this sense, the Plan promotes a coordinated model of responsibility: scientific institutions provide evidence; environmental authorities guide policy and assessment; emergency services act operationally; maritime and port authorities manage sea-based risks; military structures support safety in conflict-related contexts; local authorities connect response with communities; and international partners strengthen regional cooperation. This cooperation is what can turn separate institutional actions into a more effective response system for civil and military marine pollution in the Black Sea.

5.3 Existing coordination mechanisms

At the national level, coordination in Romania is formalized through the National Emergency Management System (Law no. 21/2004), which integrates the IGSU, the Romanian Naval Authority (RNA), the ANPM, the ARSVOM, the Border Police Coast Guard and the military naval forces. The Ministry of Environment, Waters and Forests coordinate the monitoring obligations under the Water Framework Directive (WFD, 2000/60/EC) and the Marine Strategy Framework Directive (MSFD, 2008/56/EC), ensuring that pollution data from environmental research institutes and the Dobrogea-Litoral Water Administration are integrated into national reporting.

At regional level, the Bucharest Convention (1992) and the Black Sea Commission provide the main framework for transboundary coordination. The Commission's pollution monitoring programme and the Black Sea-SCENE net-

work support data harmonisation between Bulgaria, Romania, Ukraine, Turkey and Georgia, providing a single virtual infrastructure where scientists can access historical data on water quality, biodiversity, but also satellite data (remote sensing). EMSA provides additional technical guidance and coordination of the intervention of the EU Member States on the Black Sea (Romania and Bulgaria), while bilateral agreements (e.g. Romania-Bulgaria and Romania-Ukraine) formalise joint intervention obligations for transboundary pollution incidents.

National environmental research councils, ministerial advisory committees, and project-based platforms like Black Sea SIERRA facilitate scientific-policy collaboration. However, formal collaboration between monitoring scientists and emergency response planners is lacking, especially for fresh armed conflict threats.

5.4 Governance gaps

The lack of legal norms for armed conflict pollution is the most significant governance gap. Romania, Bulgaria, and Turkey operate within EU environmental and maritime safety frameworks, but none has a national contingency plan for war-related marine contamination.

Limited data interoperability exists between countries. Romania, Bulgaria, Ukraine, and Turkey have different monitoring parameters, sample frequencies, laboratory methodologies, and reporting formats, making regional risk assessment and cooperative incident response tougher. Moreover, access to military-held environmental information (e.g. affected zones, sunken objects, explosive hazard areas in Ukrainian waters) is largely unavailable to civilian environmental authorities.

As part of its capacity-building and knowledge-transfer activities, ARCES conducted a comprehensive mapping and comparative analysis of existing EU projects addressing environmental monitoring, marine pollution, ecosystem resilience, and maritime governance in the Black Sea Basin. The objective was to identify transferable practices, methodological innovations, and opportunities for long-term coordination. The analysis included projects such as MARLITER, ANEMONE PLUS, BRIDGE-BS, DOORS, BS-SEOS, RESPONSE, EU4EMBLAS, BlueIN4BS, Black Sea SIERRA, IASON+, MicroDanger, RedMarLitter, EcoYou, HERO, LitOUTer, Blueing the Black Sea (BBSEA), MSP-GREEN, MARMAPS, and EMBLAS+. The findings reveal a remarkable convergence towards the development of common technical approaches aimed at strengthening regional environmental safety and governance.

A consistent finding emerging from the analysis is that standardisation has become a cross-cutting priority throughout the Black Sea research and innovation landscape. Although no single regional standardisation framework cur-

rently exists, a growing number of projects are independently developing complementary methodologies that collectively lay the foundations for a harmonised regional approach.

These efforts include the standardisation of environmental monitoring protocols, laboratory procedures, data collection and quality assurance methodologies, interoperable data-sharing platforms, common metadata standards, GIS-based information systems, digital twins, and AI-supported decision-support tools. At the same time, several initiatives are converging towards shared methodologies for environmental risk assessment, ecosystem vulnerability analysis, marine litter monitoring, conflict-related pollution assessment, and evidence-based decision-making.

Beyond their technical outputs, these projects demonstrate an increasing emphasis on harmonising governance practices and institutional cooperation. Many initiatives have developed policy recommendations, regional roadmaps, management plans, operational guidance, and capacity-building programmes designed to support the implementation of the Marine Strategy Framework Directive (MSFD), the Water Framework Directive (WFD), the Bucharest Convention, and the Black Sea Integrated Monitoring and Assessment Programme (BSIMAP). Collectively, these activities are fostering greater interoperability among national authorities, research organisations, and regional institutions while strengthening the science–policy interface.

The mapping exercise therefore indicates that the Black Sea Basin is undergoing a gradual transition from isolated project-based initiatives towards a more coherent regional ecosystem of shared methodologies, interoperable data infrastructures, and common operational practices. While these achievements have not yet been consolidated into a permanent regional standardisation framework, they provide a solid foundation upon which future initiatives can build. In this context, projects such as Black Sea SIERRA have the opportunity to capitalise on existing knowledge by integrating and operationalising these emerging standards into coordinated procedures for environmental monitoring, risk assessment, emergency preparedness, and long-term regional resilience.

5.5 Recommendations for governance improvement

Each Black Sea country should establish a National Marine Pollution Coordination Point with representatives from the environmental authority, marine safety body, emergency services, and scientific monitoring institution. It should be able to activate reaction procedures and communicate directly with neighboring state entities.

6. Existing Information and Training Systems

6.1 Information systems and databases

The Black Sea region is served by several national and regional information systems. In Romania, the National Environmental Monitoring System (SNMM) integrates data from ANPM, Dobrogea-Litoral Water Administration and IN-CDM “Grigore Antipa” Constanta, covering coastal water quality, river inputs, sediment chemistry and marine litter. The Danube Delta Biosphere Reserve Administration (ARBDD) maintains a dedicated ecological database for the delta-to-coastal transition area. At port level, the Constanța Maritime Ports Administration (APMC) holds incident records and water quality data for port areas.

At regional level, EMODNET (European Marine Observation and Data Network) provides access to bathymetry, sediment, chemistry and biological datasets for EU Black Sea waters and the Copernicus Marine Service (CMEMS) provides satellite-derived data on sea surface temperature, chlorophyll a, turbidity and surface currents, relevant for modelling pollution drift.

GIS tools are used operationally by EMSA (CleanSeaNet for satellite surveillance of oil spills) and at national level by environmental agencies for mapping pollution risk.

The key national and regional information systems, databases and operational data platforms referred to in this Chapter are summarised in Annex 1 – Institutional and Information Framework. The Annex specifies their ownership, geographical coverage, principal data types, accessibility and potential use for routine monitoring and emergency response.



Figure 2. The image represents the training and information systems in enhancing skills, and effective information management in the maritime sector. Source: Pexels.

6.2 Training systems and capacity-building tools

At the international level, EMSA (European Maritime Safety Agency) provides extensive training programmes for national authorities (including Member States and neighbouring countries) in areas such as oil pollution response (OSR), hazardous and noxious substances (HNS) and prevention of pollution from ships.

For the rapid exchange of information in the event of an incident, POLREP (Pollution Report) is the standardised pollution reporting format used internationally (recommended by the IMO) and within regional conventions (such as the Helsinki Convention or the Bonn Agreement).

EMSA supports the use of these standards through exercises, but its main operational tool for satellites is CleanSeaNet and for hazardous substances it collaborates with the MAR-ICE network. NATO and the Partnership for Peace framework include environmental security modules relevant to military-related marine pollution.

6.3 Critical analysis of existing systems

Effective chronic civil pollution monitoring systems exist. Environmental regulatory organizations, research institutions, and fisheries managers use them to monitor nutrients (nitrogen, phosphorus), dissolved oxygen, chlorophyll-a, heavy metals, petroleum hydrocarbons, and persistent organic pollutants in water, sediments, and biota.

Annual state-of-environment reports, WFD and MSFD assessment cycles, and national agency pollution risk maps enhance decision-making. EMSA's CleanSeaNet supports maritime response decisions with near-real-time satellite oil spill detection. The Bucharest Convention emergency reporting system (24-hour contact points) allows timely transboundary acute incident communication.

The critical limitation is that existing systems were designed before the large-scale armed conflict began in 2022. Explosive residues, energetic chemicals, military fuels (e.g. UDMH), munitions corrosion products, and sunken military vessel pollutants are not covered. These additional pollutant categories have not been consistently added to training programs. First responders and environmental authorities lack standardised processes for identifying, sampling, and evaluating conflict-related contamination.

6.4 Gaps and optimisation needs

The most urgent analytical gap concerns war-related contaminants. TNT, RDX, PETN, and their degradation products, UDMH and nitrogen tetroxide (N₂O₄) from rocket propellants, and corrosion products from munitions are absent from all national routine monitoring programs in the Black Sea region. Standard ICP-MS and GC-MS laboratory methods exist for these substances but are not routinely applied. Targeted method development and inter-laboratory validation are needed.

Underwater noise is monitored only sporadically. No continuous acoustic monitoring network exists in the Black Sea, yet the war has dramatically increased underwater noise from explosions, increasing risks for Black Sea dolphins. Bioaccumulation assessments for emerging pollutants (microplastics, PCBs from military equipment, pharmaceutical residues) are also missing from regional monitoring. Data interoperability between national systems requires metadata standardization, sample frequency harmonisation, and uniform data-sharing formats.

6.5 Contribution to the Management Plan

Three components of this Plan are shaped by the review of information and training systems. First, the monitoring gaps (explosive residues, underwater noise, military-origin microplastics, bioaccumulation of contaminants from conflict) define the priority parameters for the monitoring activity strategy in Section 9.2 (see below in this document) and inform the priority pollutants and indicators in Chapter 7.

The analysis of training gaps confirms the design choices of the Black Sea SIERRA complementary training curriculum (D6.1/D15): the curriculum fills specific gaps in legal knowledge (international humanitarian law, MSFD, MARPOL), contamination science (TNT/RDX behavior, heavy metal mobility, hydrocarbon toxicology), and practical response skills (safe field sampling, GIS mapping, crisis communication) that existing national programs do not.

The institutional roles and information resources identified through this analysis are operationalised in the consolidated tables presented in Annex 1.

7. Typology of Civil and Military Marine Pollution Events

7.1 Classification of pollution events

For this Plan, pollution events in the Black Sea are classified according to their source, duration, spatial scale, pathway and the type of response they require. This classification is not only a formal exercise. From a scientific and management point of view, it helps to understand what kind of pollution we are dealing with and what actions are realistic. A long-term input of nutrients from rivers, for example, requires a very different response from an oil spill, a damaged port facility or contamination related to military activity.

Chronic pollution refers to long-term or repeated pollution pressures. These may come from municipal wastewater, industrial discharges, agricultural runoff, ports, shipping, tourism, riverine inputs or historically contaminated sediments. Chronic pollution often develops slowly and may not be immediately visible, but its cumulative effects can be significant. Over time, it can contribute to eutrophication, habitat degradation, bioaccumulation of hazardous substances and reduced ecosystem resilience.

Acute pollution incidents are sudden events that release pollutants over a short period of time. These include oil spills, chemical releases, ship accidents, fires, infrastructure failures, explosions or accidental discharges. Such events usually require rapid assessment, emergency response, containment measures and timely communication between authorities, scientists, emergency services and affected communities.

Diffuse pollution comes from many dispersed sources and is often difficult to trace to one exact origin. Agricultural runoff, urban stormwater, atmospheric deposition, litter transported by rivers and small-scale coastal activities are typical examples. Diffuse pollution is challenging because it cannot usually be solved by addressing one discharge point. It requires long-term prevention, better land-sea management and cooperation between sectors.

Point-source pollution originates from a clearly identifiable location. This may be a wastewater outlet, industrial discharge point, port facility, fuel terminal, damaged pipeline, ship, storage tank or accident site. In principle, point sources are easier to identify and control than diffuse sources. However, once pollutants enter the marine environment, their impacts may still spread through currents, waves, sediment transport, wind or river discharge.

Transboundary pollution events occur when pollution generated in one area or country affects another. In the Black Sea, this can happen through

marine currents, river discharge, floating litter, oil drift, sediment movement, atmospheric deposition or the movement of contaminated organisms through food webs. These events clearly show why pollution management in the Black Sea cannot be limited to national borders. They require information exchange, comparable monitoring methods and regional cooperation.

Mixed civil-military incidents are situations where civil and military pollution sources overlap. For example, military damage to a port, wastewater treatment plant, fuel depot, industrial site or transport infrastructure may re-release civilian pollutants into the environment. In other cases, an area already affected by chronic civil pollution may also receive additional contamination from explosions, damaged vessels, military debris or disturbed sediments. These mixed cases are especially difficult to assess because they combine environmental, technical and security-related dimensions.

Armed conflict-related contamination refers to pollution caused directly or indirectly by armed conflict. It may include residues of explosives, munitions, heavy metals, fuel and oil releases, fire residues, sunken objects, damaged infrastructure, hazardous substances and contaminants released from disturbed sediments. Such pollution is often associated with high uncertainty. Access to affected areas may be unsafe or restricted, baseline data may be incomplete, and the exact composition of released substances may not be known immediately.

In practice, these categories often overlap. A river mouth may be affected by long-term diffuse pollution and then also receive contaminants from an acute incident. A port area may combine point-source pollution, shipping-related pressures, historical sediment contamination and risks from damaged infrastructure. A conflict-affected coastal zone may contain both civil pollution sources and military-related hazards.

For this reason, the typology should be used as a practical working tool rather than a rigid classification. It helps identify which response is most appropriate. Chronic and diffuse pollution require prevention, monitoring and long-term management. Acute and point-source incidents require rapid response and containment. Transboundary events require cooperation and data exchange. Mixed civil-military and armed conflict-related cases require additional safety planning, careful scientific interpretation and coordination between environmental, maritime, emergency and military-civil actors.

The classification is presented in an operational tabular format in Annex 2 – Integrated Pollution and Risk Assessment Framework, which links each pollution event type with its main sources, pathways, environmental and socio-economic receptors, priority indicators and recommended response measures.

7.2 Sources, pathways and receptors

For each pollution type, it is important to look at the full chain of impact: where the pollution comes from, how it moves, where it accumulates, and who or what may be affected. In the Black Sea, this chain is often complex. A pollutant may enter through a river, move into coastal waters, settle in sediments, be taken up by benthic organisms, and later appear in fish or other parts of the food web. For this reason, pollution should be assessed not only by its source, but also by its pathways and receptors.

Chronic pollution usually comes from long-term inputs such as municipal wastewater, industrial discharges, agricultural runoff, ports, shipping, tourism and riverine inflow. These pollutants are transported mainly through rivers, coastal discharges, stormwater, sedimentation, resuspension and food-web transfer. They affect coastal waters, lagoons, estuaries, bottom sediments and biota. The main receptors are plankton, benthos, molluscs, fish, coastal habitats, protected areas, fisheries, tourism and coastal communities. Because chronic pollution acts over long periods, its effects may be gradual but persistent, reducing the natural resilience of ecosystems.

Acute pollution incidents are linked to sudden events such as oil spills, chemical releases, ship accidents, damaged pipelines, fires, explosions or failures of infrastructure. In these cases, pollutants may spread quickly through surface drift, currents, waves, wind and direct coastal runoff. The first affected compartments are often the water surface, water column and shoreline, but sediments and coastal habitats may also be impacted. Birds, fish, molluscs, marine mammals, beaches, ports, fisheries, tourism facilities and nearby communities can be affected very quickly. These situations require rapid assessment and response, because the scale of impact may change within hours or days.

Diffuse pollution comes from many dispersed sources rather than from one clear discharge point. Typical sources include agricultural land, urban areas, stormwater runoff, small settlements, atmospheric deposition, litter leakage and multiple small-scale coastal activities. Its pathways are often indirect: rivers, drainage systems, surface runoff, groundwater, wind transport and gradual accumulation in coastal areas. It may affect marine waters, estuaries, lagoons, sediments and biological communities. Receptors include plankton, benthic organisms, shellfish, fish, wetlands, coastal vegetation, fisheries and public health. This type of pollution is difficult to manage because responsibility is spread across many sectors and locations.

Point-source pollution originates from a specific and identifiable place, such as a wastewater outlet, industrial discharge point, port facility, ship, fuel terminal, damaged tank, pipeline or accident site. Its pathways may include

direct discharge, plume dispersion, surface drift, sedimentation and later resuspension of contaminated particles. The affected compartments depend on the substance released, but may include water, sediments, shoreline areas and organisms living near the source. Receptors may include benthos, molluscs, fish, bathing waters, aquaculture areas, port workers, coastal users and local communities. Point sources are often easier to trace than diffuse sources, but their impacts can still extend well beyond the original location.

Transboundary pollution events occur when pollution moves from one jurisdiction to another. Sources may include large rivers, offshore spills, maritime transport, floating litter, atmospheric emissions, contaminated sediments or pollution events in another coastal area. Pathways include regional currents, river discharge, sediment transport, atmospheric deposition, vessel movement and biological transfer through migratory species or food webs. These events may affect open waters, coastal zones, beaches, sediments and living organisms in more than one country. Receptors include shared fish stocks, marine mammals, seabirds, protected areas, fisheries, tourism and coastal communities. Such cases clearly show why regional cooperation and comparable monitoring data are essential for the Black Sea.

Mixed civil–military incidents are especially complex because civilian and military sources overlap. For example, military damage to a port, wastewater treatment plant, fuel depot, industrial site, ship, pipeline or energy infrastructure may release civilian pollutants into the marine environment. At the same time, explosions or military operations may disturb already contaminated sediments. Pathways may include direct release into water, river transport, surface runoff, coastal drift, smoke, atmospheric deposition and sediment resuspension. Affected compartments include water, sediments, shoreline habitats, biota and built coastal infrastructure. Receptors may include benthos, fish, molluscs, birds, marine mammals, protected areas, emergency responders, port workers, local residents, fisheries and tourism. These incidents require not only environmental expertise, but also safety planning and coordination with security-related actors.

Armed conflict-related contamination may originate from explosions, munitions, military debris, sunken vessels or equipment, fuel and oil releases, damaged infrastructure, fires, hazardous materials and disturbed sediments. Its pathways may include dissolution, corrosion, leaching, sediment resuspension, surface drift, currents, atmospheric deposition and bioaccumulation. It can affect water, bottom sediments, coastal habitats, biota and, in some cases, the atmosphere through smoke and combustion products. Receptors include benthic organisms, fish, molluscs, cetaceans, birds, protected areas, fisheries, coastal communities, monitoring teams and emergency re-

sponders. This type of contamination is often associated with high uncertainty, because affected areas may be unsafe to access and some substances may not be part of routine monitoring programmes.

Across all these pollution types, several common patterns can be seen. Water is usually the first receiving environment, but sediments often become the long-term storage place for persistent contaminants. Biota may then accumulate pollutants and transfer them through food webs. Coastal habitats, fisheries, tourism and local communities may be affected directly or indirectly, depending on the type of pollutant, duration of exposure and local environmental conditions.

For practical management, each pollution event should therefore be assessed through four connected questions: what is the likely source, how can the pollution move, which environmental compartments may be affected, and which ecological or socio-economic receptors are at risk. This approach helps connect scientific assessment with real decisions on monitoring, risk prioritisation, emergency response and remediation.

7.3 Priority pollutants and indicators

For practical monitoring and management, the Plan should use a set of priority pollutants and indicators that can show not only whether pollution is present, but also where it may come from, how it behaves in the environment, and what risks it may create for ecosystems and people. This list should remain flexible, because the pollution situation in the Black Sea is changing, especially with emerging contaminants and armed conflict-related risks

Nutrients remain one of the basic groups of indicators. Nitrogen and phosphorus compounds, together with dissolved oxygen, chlorophyll-a, water transparency and organic matter, help to understand eutrophication processes and the influence of riverine inputs, wastewater and agricultural runoff. These indicators are especially important near river mouths, lagoons, estuaries, coastal cities and areas where algal blooms occur.

Organic pollutants are also a priority because many of them are toxic, persistent and able to accumulate in sediments and living organisms. This group may include persistent organic pollutants, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, phenols, surfactants and other hazardous organic compounds. Their presence is important not only as a sign of contamination, but also as a possible long-term risk for marine food webs.

Petroleum hydrocarbons should be monitored as a key indicator of pollution from shipping, ports, oil handling, fuel depots, offshore activities, damaged vessels and conflict-related incidents. Oil residues, total petroleum hydrocarbons and specific hydrocarbon fractions can help identify both recent spills and older contamination. This group is particularly relevant for port areas, shipping routes, coastal infrastructure, sunken objects and zones affected by accidental or military-related releases.

Heavy metals are important indicators of industrial, urban, port-related and military-associated contamination. Metals such as mercury, cadmium, lead, copper, zinc, nickel, chromium and arsenic may persist in the environment and accumulate in sediments and biota. For this reason, they should not be assessed only in water samples, but also in bottom sediments, molluscs, fish and other relevant organisms.

Pesticides are closely linked to agricultural runoff and riverine inputs. Both currently used pesticides, legacy pesticides and their degradation products may reach coastal waters through rivers and drainage systems. Their concentrations may change seasonally, depending on agricultural activities, rainfall and river discharge. This makes sampling design especially important in river mouths, estuaries, lagoons and coastal zones influenced by agricultural catchments.

Microplastics should be treated both as a pollutant and as an indicator of wider waste management problems. Their abundance, size, shape, polymer type and distribution in water, sediments and biota can provide useful information on sources and pathways. Microplastics are persistent, widely distributed and may interact with other contaminants, which makes them important for both monitoring and risk assessment.

For armed conflict-related pollution, particular attention should be given to **explosive residues and military-related substances**. These may include residues of explosive compounds, energetic materials, propellants, corrosion products from munitions, fuel additives and substances associated with damaged military equipment or sunken objects. Many of these substances are not routinely included in standard marine monitoring programmes, so targeted methods and specialised laboratory capacity may be needed.

Underwater noise should also be considered a priority indicator, although it is not a chemical pollutant. Noise from explosions, military activities, intensive shipping, construction or other operations can affect marine organisms, especially species that rely on sound for orientation, communication and feeding. In the Black Sea, this is particularly relevant for cetaceans. Monitoring

should consider sound levels, frequency, duration and spatial distribution of acoustic pressure.

Finally, **biological indicators** are essential for understanding what pollution actually means for the ecosystem. These may include phytoplankton composition, harmful algal blooms, benthic community structure, bioaccumulation in molluscs and fish, biomarkers of exposure or effect, fish health, habitat condition and the status of sensitive or protected species. Chemical measurements can show the presence of pollutants, but biological indicators help show whether the ecosystem is responding to them.

In practical terms, these indicators should be considered across three main environmental compartments: **water, sediments and biota**. Water samples help detect recent or ongoing pollution. Sediments show longer-term accumulation and possible secondary sources of contamination. Biota provides information on exposure, bioaccumulation and ecological effects.

Therefore, the priority indicator set should combine traditional parameters with newer and more specific ones. Nutrients, metals, hydrocarbons and organic pollutants remain essential, but they should be complemented by microplastics, pesticides, explosive residues, underwater noise and biological indicators. This broader approach will make the Plan more useful for both routine pollution assessment and response to new civil, military and mixed pollution scenarios in the Black Sea region.

The proposed minimum set of pollutants and indicators, together with the relevant environmental compartments, monitoring purpose and indicative analytical requirements, is provided in Annex 2 – Integrated Pollution and Risk Assessment Framework.

7.4 Risk hierarchy

For this Plan, the risk hierarchy is used to understand which pollution problems should receive priority attention. In the Black Sea, there are many different pressures, and they cannot all be addressed with the same urgency, methods or resources. The Plan requires a transparent approach to distinguish between risks that require immediate action, risks that need systematic monitoring, and risks that should remain under observation because the available information is still limited.

The hierarchy should be based on several criteria considered together. No single criterion is enough. A pollutant may be highly toxic but remain very localised. Another may be less toxic but persistent, mobile and able to affect large

areas. For this reason, the assessment should take into account toxicity, persistence, mobility, exposure, spatial extent, transboundary potential, biodiversity impact and socio-economic relevance.

Toxicity is one of the first criteria. Substances that can seriously affect marine organisms, ecosystems or human health should be treated as a higher priority. This includes some heavy metals, petroleum compounds, persistent organic pollutants, algal toxins, hazardous chemicals and military-related substances. Toxicity becomes especially important when pollution may affect bathing waters, seafood safety, protected areas or sensitive species.

Persistence shows how long a pollutant can remain in the environment. Some substances do not disappear quickly. They may stay in sediments, accumulate in organisms or continue to create risks long after the original release. Heavy metals, persistent organic pollutants, some petroleum residues, microplastics and certain conflict-related contaminants are examples of pollutants that may require long-term attention.

Mobility is also important. Pollutants that can move easily through water, suspended particles, sediments, air or food webs may affect areas far from the original source. Oil slicks, floating litter, dissolved substances, contaminated sediments and pollutants transported by rivers or currents can spread across coastal and transboundary areas. This makes them more difficult to manage and increases the need for early detection.

Exposure determines whether a pollutant becomes a real ecological or human risk. The same concentration may have different implications depending on where it occurs and who or what is exposed. Pollution near a fishery, bathing beach, protected area, river mouth, port or populated coastal zone may require higher priority than similar pollution in a less sensitive area.

Spatial extent helps distinguish between local hotspots and wider regional pressures. A small area with very high contamination may need urgent local action. At the same time, a lower but widespread pressure, such as eutrophication or microplastic pollution, may require long-term regional measures. Both situations are important, but they need different management responses.

Transboundary potential is a key criterion for the Black Sea. Pollutants may cross borders through currents, river discharge, floating debris, sediment transport, atmospheric deposition, maritime activities or food webs. When pollution can affect more than one country, it should receive higher attention in regional planning, because response requires data exchange, compatible monitoring methods and cooperation between institutions.

Biodiversity impact should be considered when pollution affects sensitive habitats, protected areas, spawning and nursery grounds, benthic communities, molluscs, fish, birds or marine mammals. Risks are higher when pollution can damage ecosystem functions, reduce resilience or affect species that are important for conservation and ecological balance.

Socio-economic relevance reflects the consequences for people and local economies. Pollution that affects fisheries, aquaculture, tourism, public health, beaches, ports, coastal infrastructure or local livelihoods should be considered a high management concern. This is particularly important for coastal communities where environmental degradation can directly affect income, employment and quality of life.

Based on these criteria, risks can be grouped into three broad levels.

High-priority risks are those with high toxicity, strong persistence, wide mobility, significant exposure of sensitive receptors, transboundary potential, serious biodiversity impact or clear socio-economic consequences. Examples may include large oil spills, hazardous chemical releases, contamination of fishery areas, pollution of protected habitats, armed conflict-related releases involving fuel or munitions, and severe eutrophication leading to harmful algal blooms.

Medium-priority risks include pollution pressures that are important but more localised, partly manageable or not yet fully confirmed as causing major ecological damage. Examples may include local contamination near ports, moderate sediment pollution, seasonal pesticide inputs, smaller petroleum releases, local microplastic accumulation or emerging pollutants detected at levels that require continued monitoring.

Watch-list risks include new, poorly studied or insufficiently documented pressures. These may not yet justify immediate large-scale response, but they should not be ignored. This category is especially relevant for substances that are not routinely monitored, emerging contaminants, low-level chronic pressures and possible conflict-related pollutants where evidence is still incomplete.

The hierarchy should remain adaptive. New monitoring data, modelling results, field observations or stakeholder information may change the level of risk. This is especially important under wartime and post-war conditions, where some impacts may only become visible later, access to affected areas may improve gradually, and previously unknown contaminants may be identified.

In practical terms, the risk hierarchy helps answer three questions: what needs urgent response, what requires systematic monitoring and prevention, and what should remain under scientific observation until more evidence is available. This

makes the Plan more useful for transparent, evidence-based and realistic decision-making in relation to civil and military marine pollution in the Black Sea.

For practical application, the risk criteria described above are converted into a semi-quantitative assessment matrix in Annex 2. The matrix supports transparent prioritisation based on hazard, likelihood, persistence, mobility, spatial extent, transboundary potential, ecosystem impact, socio-economic consequences and the level of uncertainty.

7.5 Scenario-based approach

A scenario-based approach is useful because pollution events in the Black Sea are rarely simple. In reality, one area can be affected at the same time by chronic pollution, a sudden incident, riverine inputs, port activity and, in some cases, military or conflict-related impacts. From a scientific perspective therefore need to think not only in terms of individual pollutants, but also in terms of realistic situations in which authorities and stakeholders may need to act.

The scenarios below are not meant to be rigid categories. They are practical examples that can help structure preparedness, monitoring, communication and response.

Oil spill scenario

An oil spill may occur as a result of a ship accident, port operation, damaged vessel, fuel depot failure, offshore activity, pipeline damage or conflict-related incident. In such a situation, the first questions are simple but urgent: where is the oil, how much has been released, where is it moving, and which areas are at risk?

Monitoring should combine visual observations, satellite or drone information where available, drift modelling, and sampling of water, shoreline material and sediments. Particular attention should be given to birds, fish, molluscs, beaches, protected areas and coastal communities. Response may include containment, recovery, shoreline protection, waste collection, public warnings and post-incident monitoring.

Chemical contamination scenario

Chemical contamination may come from industrial discharges, damaged storage facilities, transport accidents, wastewater failures, port incidents or conflict-damaged infrastructure. The difficulty here is that the exact substance

is not always known at the beginning. This creates uncertainty about toxicity, mobility and possible risks for people and ecosystems.

The response should start with source identification, safety assessment and targeted sampling. Water, sediments and biota may need to be analysed, and in some cases runoff or air-related pathways should also be considered. Priority should be given to substances that are toxic, persistent, mobile or likely to affect fisheries, public health, protected habitats or recreational waters.

Munitions-related pollution scenario

Munitions-related pollution is a particularly sensitive scenario. It may be linked to unexploded ordnance, ammunition residues, military debris, sunken objects or explosion sites. In this case, environmental assessment cannot be separated from safety. No sampling or field activity should be planned without proper risk assessment and coordination with competent security or military-civil authorities.

Possible pollutants include explosive residues, energetic compounds, heavy metals, corrosion products and associated fuel or oil contamination. Monitoring should focus mainly on sediments, near-bottom waters and biota in areas where contamination may accumulate. Because this type of pollution is not always included in routine monitoring, specialised expertise and careful documentation of uncertainty are needed.

Harmful algal bloom scenario

A harmful algal bloom may develop when high nutrient inputs combine with warm temperatures, calm weather, limited water exchange or changes in river discharge. Early signs may include water discoloration, reduced transparency, oxygen depletion, fish mortality or concern about bathing water safety.

Monitoring should include phytoplankton composition, chlorophyll-a, nutrients, dissolved oxygen, temperature, salinity and, where relevant, algal toxins. Response may include intensified monitoring, public information, temporary restrictions on bathing or shellfish harvesting, and investigation of nutrient sources. This scenario is especially relevant for lagoons, estuaries, coastal bays and river-influenced areas.

Riverine pollution pulse scenario

A riverine pollution pulse may occur after heavy rainfall, floods, dam-related events, industrial accidents within a catchment, agricultural runoff peaks or

wastewater releases. In such cases, the river becomes the main pathway transferring pollution from inland areas to the sea.

Pollutants may include nutrients, suspended matter, pesticides, heavy metals, organic pollution, litter and other contaminants. Monitoring should focus on river mouths, plume dispersion, salinity gradients, turbidity, nutrients, hazardous substances and sediment deposition zones. This scenario clearly shows that marine pollution management must be connected with river basin monitoring and inland environmental information.

Port accident scenario

A port accident may involve a fuel spill, chemical leakage, cargo loss, fire, explosion, ship collision, dredging-related disturbance or failure of waste management systems. Ports are complex areas where many risks are concentrated in a relatively small space: ships, cargo, fuel, infrastructure, workers, nearby communities and sensitive coastal waters.

Response should include rapid notification, identification of the substances involved, containment where possible, protection of workers and local residents, and coordination between port authorities, maritime administrations, environmental agencies and emergency services. Monitoring should cover harbour waters, sediments, nearby beaches and possible pollutant movement outside the port area.

Conflict-related coastal contamination scenario

Conflict-related coastal contamination may result from damaged infrastructure, military activity, explosions, fires, fuel releases, debris, sunken objects, disturbed sediments or restricted access to affected coastal zones. This is often the most complex scenario because environmental risks are combined with safety, security and access limitations.

In such cases, monitoring may need to combine field sampling where possible, remote sensing, modelling, historical information and expert interpretation. Priority should be given to hotspots near damaged infrastructure, ports, industrial areas, river mouths, protected areas and populated coastal zones. Response should include careful documentation of impacts, risk prioritisation, coordination with security actors and planning for delayed field assessment when direct access becomes possible.

Across all scenarios, several common steps are needed: early detection, source identification, safety assessment, monitoring of relevant environmental

compartments, risk communication, coordination between responsible institutions and follow-up assessment after the immediate event. The difference between scenarios lies in the type of pollutant, speed of spread, affected receptors, safety conditions and required response measures.

For this Plan, the scenario-based approach helps translate scientific knowledge into practical preparedness. It allows institutions to think in advance about what information is needed, who should be involved, which areas are most vulnerable and how decisions should be made when time is limited. This is particularly important for the Black Sea, where civil pollution pressures and conflict-related risks may occur separately, but also in combination.

When applying these scenarios, users should consult Annex 2 – Integrated Pollution and Risk Assessment Framework to select the relevant event category, monitoring indicators, risk criteria and initial management priority. The framework is intended as a decision-support tool and should be complemented by case-specific monitoring data and expert judgement.

8. Strategic Objectives of the Management Plan

Objective 1 – Strengthen preparedness and response capacity

This objective includes preparatory planning for active response. It includes the establishment or update of National Marine Pollution Coordination Points in each Black Sea country, the development of practical response protocols for acute incidents involving oil, hazardous substances, and conflict-related contaminants. Emphasis will be placed on training at least two response specialists for each partner country per year and conducting annual multi-agency simulation exercises, including civil-military scenarios regarding pollution sources. Success is determined by trained personnel, tested protocols, and functional coordination contacts.

Objective 2 – Improve monitoring and early detection

This objective requires expanding monitoring beyond the parameters covered by current national programmes. Incorporating explosive residues, energetic compounds, and military-related heavy metals into routine sediment and biota sampling in conflict-proximate areas; deploying or expanding underwater acoustic monitoring to detect unusual noise events; and using satellite (Copernicus Marine Service (CMEMS), CleanSeaNet) and drone data to identify surface

oil, floating litter, and plume behavior in near-real time are priority actions. Acute and cumulative pollution's ecological and socio-economic impacts can be mitigated by early diagnosis.

Objective 3 – Harmonise assessment and response methodologies

Harmonisation is needed for a meaningful regional risk assessment and shared response. To achieve this goal, (i) agreeing on a minimum set of common indicators for nutrients, heavy metals, petroleum hydrocarbons, persistent organic pollutants, microplastics, and explosive residues; (ii) adopting metadata standards compatible with EMODNET, MSFD, and the Bucharest Convention; (iii) organizing inter-laboratory calibration to align analytical quality; and (iv) developing common GIS data layers for mapping.

Objective 4 – Support evidence-based decision-making

The use of evidence-based decision-making hinges on the translation of scientific monitoring data into usable information. This objective is addressed through: (i) production of regularly updated pollution risk maps identifying high, medium and watch-list risk areas, consistent with the risk hierarchy in Chapter 7.4; (ii) preparation of concise technical briefs for environmental authorities, port administrations and emergency services following significant pollution incidents or new monitoring results; (iii) development of validated scenario-based response toolkits aligned with the scenarios described in Chapter 7.5; and (iv) documentation of lessons learned after all documented incidents. Communicating uncertainty clearly (see Chapter 13.4) is essential to making good judgements when information is lacking.

Objective 5 – Strengthen regional cooperation

The transboundary character of marine contamination demonstrated in Chapters 4.5 and 10 makes pursuing regional collaboration a scientific and a governance requirement. This objective includes: (i) the establishment or reinforcement of formal data exchange channels between Romania, Bulgaria, Ukraine and Turkey including 24-hour emergency notification procedures; (ii) the organisation of at least one joint field exercise per project cycle involving partners from more than one country; (iii) sharing of training materials, risk maps and response protocols through the project consortium platform; and (iv) engage-

ment with the Black Sea Commission, EMSA and relevant regional and international organisations to align the Plan with existing conventions and reporting obligations. Particular stress is laid on support to Ukraine to sustain environmental monitoring capabilities under conditions of war.

Objective 6 – Link monitoring, remediation and training

This integrated goal links science and practice. It requires (i) a structured mechanism by which new monitoring data (updated hotspot maps, new contaminant detections, post-incident assessments) are systematically reviewed and used to update response protocols; (ii) regular revision of the training curricula (D6.1) based on exercises and real incidents; and (iii) coordination between scientific institutions responsible for monitoring (INCDPM, IO-BAS, ORDU, UkrSCES) and training providers (MBNAR, TUIASI).

9. Response Strategies

9.1 Prevention and preparedness strategy

At a minimum, the following elements should be established and maintained: (i) a georeferenced inventory of pollution-sensitive areas (protected marine and coastal zones, fishery areas, bathing waters, Ramsar sites, Natura 2000 sites, river mouths and lagoons) for each partner country, with defined priority response zones; (ii) a continuously updated list of priority pollutants based on the indicator set described in Chapter 7.3, reviewed annually in light of new monitoring data and emerging threats; (iii) a baseline monitoring schedule for water, sediments and biota at hotspot and reference stations, enabling detection of statistically significant change within one monitoring cycle; (iv) hazard inventories listing significant pollution sources (ports, industrial sites, shipping routes, offshore infrastructure, conflict-affected areas) ranked according to the risk hierarchy in Chapter 7.4; and (v) pre-agreed communication channels between national coordination points, scientific monitoring institutions, emergency services and regional bodies, tested at least annually through desk exercises or drills. Review and update preparedness strategies following major pollution incidents and every two years.

9.2 Monitoring and assessment strategy

Regular monitoring is based on a level system. The common indicator set in Chapter 10.2 is used to sample nutrients, dissolved oxygen, turbidity, petroleum

hydrocarbons, heavy metals, and microplastics at fixed coastal and offshore stations. Sediment samples are collected annually at hotspot stations near ports, river mouths, lagoons, and conflict-contaminated areas to analyse for heavy metals, persistent organic pollutants, petroleum hydrocarbons, and explosive residues in high-risk areas. MSFD requires biota sampling (molluscs, fish muscle, fish liver) to determine bioaccumulation and ecological state.

Crisis monitoring begins after a major pollution occurrence or emergency alerting network notice. It entails intensive sampling at the affected site and probable downstream locations and priority pollutant class analysis within 24-48 hours, if laboratory capacity allows. When direct access is risky or limited, satellite products (CMEMS chlorophyll-a, CleanSeaNet SAR oil detection, Sentinel-2 turbidity images) and drone surveys enable rapid spatial evaluation.

Risk and vulnerability levels in the GIS maps are updated with monitoring data. Underwater noise is monitored using calibrated hydrophones or ship-mounted acoustic recorders in key cetacean habitats and shipping routes, in accordance with Descriptor 11 of the Marine Strategy Framework Directive (MSFD) and the standards of the SIERRA project in the Black Sea.

9.3 Emergency response strategy

When pollution is detected or reported, the following steps are taken: (i) One-hour notification to the National Marine Pollution Coordination Point, which activates the relevant response chain (environmental authority, maritime safety body, emergency services, port administration) and sends a cross-border alert for transboundary effects; (ii) Rapid first evaluation within 2-4 hours utilising remote sensing data (CleanSeaNet, Copernicus), hydrodynamic drift modelling, and the risk inventory to estimate spatial extent, likely pollutants, and priority receptors at risk; (iii) Deploying field response teams equipped with appropriate sampling equipment, protective gear (tailored to potential chemical or explosion hazards), and communication devices; (iv) Emergency sampling of water, sediment surfaces, and biota at the incident site and in potentially affected areas, accompanied by chain-of-custody documentation for all samples; and (v) Coordinated containment measures. (vi) Informing the public in plain language through predefined channels (official press releases, social media alerts, notices regarding bathing water and fishing), acknowledging uncertainty; (vii) Continuous documentation of activities, decisions, and data in the national incident registry; (viii) Formal post-action evaluation within 30 days to identify lessons learned and improve processes. SafeSeaNet, as an EMSA technical tool that reflects operational reality, functions as a rapid alert and monitoring system in case of marine pollution, providing authorities with real-time

data on the position of ships and dangerous goods to efficiently coordinate the emergency response.

These steps are translated into an operational sequence in Annex 3 – Marine Pollution Response Protocol. The protocol provides indicative timeframes, responsible actors, required records and specific safety provisions for incidents involving unexploded ordnance, explosive residues, damaged military infrastructure or other conflict-related hazards.

9.4 Remediation and recovery strategy

EU environmental legislation uses best available methods (BAT) to determine remediation strategies. Containment booms, skimmers, beach cleaning equipment, oiled wildlife response, and scientifically justified dispersants in open ocean are effective for oil and petroleum disasters. Chemical contamination is treated by adsorption, neutralisation, leachate containment, excavation, and off-site disposal.

In-situ stabilization and cover can be used in cases of sediment contamination (heavy metals, persistent organic pollutants, explosive residues) when physical disturbance poses a greater risk than leaving the sediments in place. Partner universities should identify transportable remediation units (mobile laboratories) in advance to enable rapid deployment of operations. Shoreline cleanup should be coordinated with local authorities and carried out by trained volunteers under professional supervision, when this can be done safely.

For at least 24 months after the incident, affected sites should monitor benthic community recovery, bioaccumulation in molluscs and fish, and habitat status. Set recovery goals against pre-incident or reference station baselines. Conflict-related contamination requires safe access planning and demining clearance by military or civil EOD authority before in-water remediation.

9.5 Communication and public information strategy

Effective communication is essential to marine pollution response. Three audiences and formats are identified by the communication strategy. For the public and coastal communities: clear, timely alerts via official websites, social media, local radio, and press, using simple language, avoiding jargon, and explicitly stating what is known, uncertain, and what actions to take (e.g., avoid swimming, do not eat local shellfish). For sector stakeholders within 24 hours following a confirmed significant occurrence, responsible authorities advise

stakeholders (fishers, aquaculture operators, tourism firms, NGOs) and provide regular updates.

Fact-based technical notes on the pollutant, detected concentrations, risk assessments relative to thresholds (OSPAR, environmental quality standards under the Marine Strategy Framework Directive), affected area, and recommended management measures for technical and policy audiences.

9.6 Data management and reporting strategy

All monitoring and response data collected under this Plan must be quality assured using HELCOM, OSPAR, and MSFD guidelines. Certified reference material results, technique detection limits, blank values, and repeat coefficients of variation must accompany laboratory data. Field sampling records must include GPS, date, depth, sampler type, preservation method, chain-of-custody, and analyst identification.

Data on parameter codes, units of measurement, quality indicators, and platform identifiers are stored in national databases. For parameters covered by the Bucharest Convention and the Marine Strategy Framework Directive (MSFD), this data is transmitted to regional and EU reporting platforms within the established deadlines. A common minimum data set (nutrients, heavy metals, petroleum hydrocarbons, microplastics, and, where applicable, explosive residues) is shared among partner countries through the data exchange mechanism defined in Chapter 10.2, using open formats (CSV, NetCDF, or GeoJSON).

The mandatory and recommended metadata fields for this exchange are specified in Annex 4 – Minimum Regional Data Exchange Template. The template covers incident identification, sampling location and time, environmental compartment, analytical results, methods, detection limits, quality flags, chain-of-custody information, responsible institutions and data-access restrictions.

Only material that compromises security or military-civil safety activities is confidential. Metadata acknowledges the restriction and its broad nature, but non-sensitive aggregated environmental results are transmitted as normal. Once security no longer applies, all limitations are evaluated and lifted.

9.7 Contributions of EU Projects to Sustainable Marine Management

The mapping analysis conducted by ARCES revealed a significant contribution of several EU-funded initiatives to the objectives of D5.2 – Complementary Sustainable Management Plan of Response Strategies to Civil and Military Marine Pollution. While previous mapping activities primarily identified projects supporting environmental monitoring, data harmonisation, governance frameworks, and emergency preparedness, this analysis highlights complementary initiatives that contribute to the sustainability dimensions of marine pollution management, including prevention, mitigation, remediation, ecosystem recovery, and long-term environmental resilience. These findings demonstrate that sustainable response strategies should not be limited to immediate containment and operational interventions but should also integrate preventive measures, restoration approaches, and circular recovery pathways.

The analysis identified pollution prevention as a fundamental component of sustainable marine pollution management. Projects such as WISE-WASTE, BlackNETs, GREENFISH, ALGAWA, and BSB-CIRCLECON demonstrate how improved waste management practices, circular economy solutions, and pollution reduction measures can decrease the pressures affecting marine and coastal ecosystems. These approaches are particularly relevant for D5.2, as the Complementary Sustainable Management Plan aims to incorporate preventive strategies alongside emergency response procedures. By reducing the quantity of pollutants entering marine environments, such initiatives contribute to strengthening ecosystem resilience and reducing the potential impacts of accidental, cumulative, or conflict-related pollution events.

The ARCES mapping also highlighted the relevance of circular economy approaches as a component of environmental resilience and post-pollution recovery. Several identified projects demonstrate opportunities for transforming waste streams into valuable resources, including the recovery of abandoned fishing gear through BlackNETs, the valorisation of fish-processing residues through GREENFISH, the conversion of plastic waste into energy carriers through TRESOILPower2X, and the use of macroalgae-based systems for wastewater treatment and biomass production through ALGAWA. Although these initiatives are not designed as emergency response mechanisms, they provide valuable examples of how sustainable remediation strategies can move beyond containment and disposal towards resource recovery, environmental restoration, and circular management approaches.

Furthermore, the mapping exercise identified the growing importance of nature-based solutions and ecosystem-based remediation approaches. The

ALGAWA project represents a relevant example, demonstrating the potential of macroalgae biofiltration systems to remove nutrients and contaminants from polluted waters while simultaneously generating valuable biomass. These approaches provide important insights for D5.2 by demonstrating that sustainable pollution response strategies should combine conventional technological solutions with ecosystem-based methods, including biological treatment systems, phytoremediation, and the enhancement of natural recovery processes. Such approaches are consistent with European ecosystem-based management principles and support a more integrated approach to marine environmental protection.

The analysis further demonstrated that sustainable marine pollution management requires a complete recovery cycle, extending from prevention and detection to response, remediation, ecological restoration, and circular resource recovery. Initiatives addressing the removal of ghost fishing gear (Black-NETs), improvement of water quality (ALGAWA), reduction of plastic pollution (WISE-WASTE), and valorisation of organic waste streams (GREENFISH) illustrate the importance of integrating long-term restoration objectives into pollution management strategies. This lifecycle perspective complements the operational response framework of Black Sea SIERRA by providing additional practices for strengthening ecosystem recovery and resilience after pollution events.

In addition, the ARCES mapping identified that long-term environmental security depends not only on technological solutions but also on capacity building, stakeholder engagement, and behavioural change. The analysed projects promote professional training, public awareness, citizen participation, sustainable fisheries practices, improved municipal waste management, institutional cooperation, and circular economy approaches. These elements reinforce a key principle for D5.2: effective response capacity requires not only appropriate technologies and operational procedures, but also institutional preparedness, stakeholder coordination, and environmental awareness.

Finally, the identified initiatives demonstrate strong alignment with broader European strategic priorities, including the EU Mission: Restore our Ocean and Waters by 2030, the European Green Deal, the Circular Economy Action Plan, and sustainable Blue Economy objectives. This alignment is particularly relevant for positioning Black Sea SIERRA within the wider European transition towards resilient, climate-neutral, and circular coastal and marine management approaches.

Overall, the mapping analysis conducted by ARCES provides the sustainability and recovery dimension of the D5.2 Complementary Sustainable Management Plan. The results show that EU-funded projects are increasingly mov-

ing beyond traditional pollution control approaches towards integrated management models combining pollution prevention, resource efficiency, nature-based remediation, ecosystem restoration, circular economy principles, and stakeholder engagement. These practices represent valuable inputs for D5.2, ensuring that response strategies to civil and military marine pollution extend beyond immediate emergency actions and contribute to the long-term environmental resilience and sustainable recovery of the Black Sea Basin.

10. Transboundary Cooperation Framework

10.1 Regional cooperation principles

Black Sea regional cooperation has six operational principles. First, shared environmental responsibility: cross-border contamination requires the state of origin and impacted governments to work together on assessment and response. Second, timely notification: partners must notify neighbouring coastal nations of pollution incidents with possible transboundary consequences within 4 hours of confirmation utilising the Bucharest Convention emergency contact network and EMSA reporting channels. Third, data compatibility: technique descriptions and quality indicators suitable for independent evaluation must accompany any monitoring data transferred between countries. Data incompatible with the minimal common indicator set should be flagged, not concealed. Fourth, reciprocal aid: partner countries offer technical, analytical, and logistical assistance to a country with a pollution problem beyond its unilateral response capacity. Fifth, transparency and scientific integrity: shared assessments must distinguish confirmed findings from model outputs and expert opinions. Sixth, respect for national mandates: collaboration supports but does not supersede national jurisdictions, laws, or security.

10.2 Data exchange and interoperability

The minimum common dataset for regular exchange includes nutrients (total nitrogen, total phosphorus, nitrate, ammonium), dissolved oxygen, chlorophyll-a, transparency (Secchi depth), petroleum total hydrocarbons, PAH, heavy metals, persistent organic pollutants, and microplastics. Bioaccumulation in mussels and fish, phytoplankton composition and biomass, and benthic macrofauna indices are biological markers.

CSV or NetCDF data georeferenced in WGS84 (EPSG:4326) must include station ID, collection date and time, depth, parameter code (CF standard or SDN BODC P01), unit, method code, quality flag (SEADATANET QC scale), and

responsible institution. Pollution hotspot maps, vulnerability maps, monitoring station networks, protected area limits, port perimeters, and declassified conflict-affected zone boundaries are shared in GeoJSON or Shapefile format. Annual interlaboratory validations for priority chemical parameters and national dataset comparisons at shared boundary stations are used. Routine data is exchanged semi-annually and crisis data promptly.

All regular and incident-related exchanges should use the structure provided in Annex 4 – Minimum Regional Data Exchange Template. Where a required field cannot be completed, the field should remain visible and be marked as “not available”, “not applicable” or “restricted”, rather than being omitted. This will improve comparability, transparency and automated processing of data received from different institutions and countries.

10.3 Cooperation between countries

Romania and Bulgaria are EU member states and are required to comply with the requirements of the Marine Strategy Framework Directive (MSFD) and the Water Framework Directive (WFD), while Turkey and Ukraine are voluntarily aligning themselves with these standards, thereby ensuring a common regulatory framework. Turkey is a Contracting Party to the Bucharest Convention (1992) and participates in the Black Sea Commission monitoring system, which offers regional legal basis for cooperation. The Plan promotes coordinated measures with Turkey through Bucharest Convention monitoring criteria, minimum common indicator set data exchange (Chapter 10.2), regional exercises, and expert meetings. National environmental standards for coastal and marine water quality in Turkey should converge with MSFD indicator thresholds as a best practice reference, without imposing duties beyond the Bucharest Convention framework. Ukraine is not an EU member, but the EU-Ukraine Association Agreement (2014) and Bucharest Convention bind it to European environmental norms. The Plan expressly supports remote sensing, modelling, and analysis of accessible coastal stations where direct field access is restricted to satisfy Ukraine’s wartime monitoring constraints.

10.4 Joint exercises and stakeholder dialogue

At the regional level, joint exercises should be organized at least twice a year. The first should be a theoretical national coordination exercise to evaluate decision-making, communication, and data-sharing protocols for a defined scenario (e.g., an oil spill from a battle-damaged ship drifting from Ukrainian to

Romanian waters). The second should be a field exercise to test sample collection under difficult conditions, the interlaboratory exchange of split samples, and communication in crisis situations.

Annual expert meetings among scientific monitoring institutions should analyze new monitoring results, update risk maps, and propose adjustments to the common minimum set of indicators. The results should include a brief annual summary report, distributed to all relevant authorities and made available to the public. These exercises also serve as capacity-building events for young researchers and response personnel, improving the practical effectiveness of the framework over time.

10.5 Link with regional conventions and initiatives

This Plan is designed to complement, not duplicate, existing regional and international frameworks governing marine environmental protection in the Black Sea. The primary legal baseline for transboundary cooperation is the Convention on the Protection of the Black Sea Against Pollution (Bucharest Convention, 1992) and the work of the Black Sea Commission (BSC). The Plan's minimum common indicator set (Chapter 10.2) is directly aligned with the BSC's Pollution Monitoring Programme parameters, and the transboundary notification procedures (Chapter 10.1) are designed to be fully compatible with the BSC's 24-hour emergency contact network. All monitoring data generated under this Plan that falls within the scope of the Bucharest Convention is intended for submission to the BSC through national focal points.

For the EU Member States in the consortium (Romania and Bulgaria), the plan supports compliance with the Marine Strategy Framework Directive (MSFD, 2008/56/EC) and the Water Framework Directive (WFD, 2000/60/EC). The monitoring strategy (Chapter 9.2) and the minimum set of common indicators are structured to align with the assessments of the MSFD descriptors: descriptor 5 (eutrophication), descriptor 8 (contaminants), descriptor 9 (contaminants in seafood), descriptor 10 (marine litter), and descriptor 11 (underwater noise). The operational tools of the European Maritime Safety Agency (EMSA) are explicitly integrated into the plan: CleanSeaNet satellite surveillance is mentioned for the detection of oil spills and surface pollution (Chapter 9.2), SafeSeaNet supports vessel traffic and incident reporting (Chapter 9.3), and the EMSA training framework underpins the capacity-building component (Chapter 11). The Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), administered under the auspices of the IMO (REMPEC), provides additional regional frameworks for training in the field of response and marine environmental protection.

The objectives of the marine ecosystem conservation and restoration plan are consistent with the EU Green Deal, the 2030 Biodiversity Strategy, and the mission to “Restore our oceans and waters by 2030.” As “Mission Ocean” and the implementation cycle of the revised Marine Strategy Framework Directive (MSFD) mature, the plan will align with EU instruments on underwater noise, marine litter, and integrated ocean monitoring.

Also, this Plan uses international norms. The International Law Commission (ILC) Principles on the Protection of the Environment in Relation to Armed Conflicts (2022) and the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (1976) govern conflict-related marine pollution.

11. Capacity Building and Training

11.1 Training needs assessment

Based on Chapters 5 and 6’s governance and information system analysis and Chapter 7’s pollution incident typology, the structured training needs assessment found the following priority gaps. Environmental authorities and decision-makers must understand war-related maritime contaminants, their monitoring methodologies, and legal implications; evaluate combined civil-military pollution risk assessments; and communicate uncertainties to the public and decision-makers. Scientists must use validated methods for explosive residues (TNT, RDX, PETN) and military heavy metals in sediments and biota matrices, underwater acoustic monitoring and interpretation, satellite and drone data for rapid pollution assessment, and interlaboratory quality assurance for the minimum common set of indicators. Safe sampling in conflict-affected or chemically hazardous areas, activation and usage of the transboundary notification network, oil and chemical spill containment, and practical and field exercises for emergency responders and coastguards. Recognition of early warnings, rights and obligations under national environmental legislation, and communication with responsible authorities during a pollution incident for local authorities, fishermen, aquaculture operators, and NGOs.

11.2 Link with complementary training curricula

This Management Plan establishes the scientific, institutional and operational framework for civil and military marine pollution response. It defines the typology of risks, the monitoring approach, intervention strategies, cooperation principles and governance requirements. The complementary training pro-

grams within the Black Sea SIERRA project translate each of these elements of the framework into structured, learner-centred educational modules.

11.3 Proposed training modules

The training curriculum developed under Task T5.5 of the Black Sea SIERRA project (D15/D6.1, TUIASI & MBNAR, 2026) comprises fourteen topics organized around three complementary competence directions: blue economy and ecosystem sustainability, legal governance and conflict-related contamination, and technical-operational monitoring. The topics were selected based on a demand-driven methodology, which integrated the partners' needs analysis (T5.1–T5.3), the gap analysis documented in Chapter 6, and the specific expertise of each institution in the consortium.

Competence related to legal governance and contamination due to conflict includes: the legal framework for the protection of the Blue Economy, including UNCLOS (articles 192–194), MARPOL (analysis of military exceptions), Bucharest Convention, MSFD (2008/56/EC), Additional Protocol I (articles 35 and 55), ILC Principles on the Protection of the Environment in Relation to Armed Conflict (2022) and the legislative gap matrix; marine contaminants related to war, including the chemistry and ecotoxicology of explosive residues (TNT, RDX and their anoxic reduction products 2-ADNT, 4-ADNT, 2,4-DANT), rocket propellants (UDMH, NDMA), heavy metals of military origin (Pb, Cd, Hg, As, Cu, Zn, Sb, Sr, W, Cr, Ni, Fe), PCBs, dioxins and military microplastics; underwater noise pollution caused by modern warfare techniques, including acoustic signatures of AUV/UUV vehicles and marine drones; and assessment of environmental damage caused by munitions, sunken objects and war activities. Bioindicator species used across all technical modules include *Mytilus galloprovincialis*, *Rapana venosa*, and *Pontogammarus maeoticus*, the last of which is introduced as a novel bioindicator for military-origin contaminants. Leading topics are led by the MBNAR team.

11.4 Training formats

The training curriculum is delivered through a combination of formats selected to address the diversity of target groups (Chapter 11.1) and practical constraints in the four Black Sea partner countries. Face-to-face training courses will be held in each partner country (Romania, Bulgaria, Ukraine, Turkey), as specified in the Black Sea SIERRA project proposal and in the final deliverable D6.1. The content days combine lecture-based training for legal, scientific and govern-

ance topics with interactive methods, including Mentimeter surveys, Educaplay exercises and Google Forms assessments, allowing for real-time assessment of participants' understanding and adaptation of the teaching pace. PowerPoint presentations, educational videos and structured case studies are used to support content delivery on all topics.

Blended and online delivery are used to complement in-person courses and support participants who cannot attend in person. Self-paced online modules cover the legal-governance track and selected sustainability topics, enabling multilingual access for practitioners across the region. Two regional science-policy workshops hosted by INCDPM (COO) gather representatives from all four partner countries together with EU stakeholders and policymakers to present project results and consolidate cooperative commitments. All training materials remain available online after the project lifecycle, hosted on the INCDPM project portal (<https://www.incdpm.org>), ensuring continued access for authorities, researchers, and educators beyond the funding period.

11.5 Evaluation of training effectiveness

Training effectiveness is assessed through a three-level framework specified in D15 (T5.5): L1 — a knowledge quiz administered before and after each session to measure learning gain; L2 — a scenario-based case study adapted to the participant's target-group profile (national authority, researcher, or naval/coast guard operator) to assess applied competence; and L3 — a reflective feedback sheet providing evidence-based input for continuous curriculum improvement. Google Forms is used as the primary data-collection tool across all three levels. Results are reviewed by the delivering institutions (TUIASI, MBNAR) after each training event and used to update content for subsequent courses.

12. Implementation Plan

12.1 Recommended actions

Action	Description	Responsible actors	Timeframe	Expected output
Mapping of response authorities	Update national and regional lists of bodies responsible for monitoring, response and remediation.	Project partners; competent authorities	Short-term	Institutional map and contact list
Harmonisation of monitoring indicators	Define a minimum set of pollutants, parameters and metadata for civil and military pollution assessment.	Scientific institutions; laboratories	Short-term	Common indicator list
Development of response protocols	Prepare practical procedures for rapid assessment, sampling, reporting and coordination during pollution incidents.	Authorities; response services; scientific experts	Medium-term	Response protocol package
Training programme implementation	Conduct national and regional training based on the complementary curricula and management plan.	WP5/WP6 partners; trainers	Medium-term	Trained specialists and training reports
Regional data exchange mechanism	Establish an interoperable format and routine for sharing monitoring and incident data.	Consortium; data managers; authorities	Medium-term	Shared data framework
Periodic review of the Plan	Review the Plan after major incidents, new monitoring results or institutional changes.	Plan owners; stakeholders	Long-term	Updated Plan and lessons learned

Translate the strategies into specific actions with responsible actors, time-frames, outputs and indicators.

The implementation of these actions should make direct use of the operational tools included in the Annexes: the institutional and information framework in Annex 1, the pollution and risk assessment framework in Annex 2, the response protocol in Annex 3, and the regional data exchange template in Annex 4.

12.2 Short-term measures

Short-term measures (0-12 months) include (i) institutional mapping of all relevant national authorities and organisations responsible for marine pollution monitoring, response, and remediation in each partner country using the TUIASI Romania institutional database and equivalent exercises for Bulgaria, Ukraine, and Turkey; and (ii) compiling a baseline dataset using existing national monitoring databases and D2.2 results.

12.3 Medium-term measures

Medium-term measures (12-30 months) include (i) harmonising priority parameter monitoring methods through inter-laboratory exercises at partner institutions; (ii) developing and publishing georeferenced pollution hotspot maps and vulnerability maps for the northern, western, and southern Black Sea zones using Chapter 7.4's combined monitoring datasets and risk hierarchy; and (iii) delivering the full training program. (iv) conducting two multi-agency simulation exercises (one tabletop, one partial field exercise) to test emergency response protocols; (v) piloting the data exchange mechanism with a structured trial of the minimum common dataset exchange between at least three partner countries; and (vi) developing validated explosive residue analysis laboratory methods at two or more partners.

12.4 Long-term measures

Long-term measures (30-36 months and beyond) include (i) formal endorsement of the Plan by national environmental authorities and its presentation to the Black Sea Commission for consideration as a contribution to the Black Sea Integrated Monitoring and Assessment Programme (BSIMAP); (ii) integration of the minimum common indicator set, including explosive residues and underwater noise, into the next review cycle of national WFD and MSFD monitoring

programmes, as described in Chapter 14.2; (iii) transfer of the operational tools developed under this Plan (Annexes 1-4, the response protocol and the data exchange template) to designated National Marine Pollution Coordination Points for routine use beyond the project's duration; (iv) establishment of a recurring, self-financed cycle of joint exercises and expert meetings (Chapter 10.4) that does not depend on project funding; (v) a full review of the Plan every three years, or sooner following a major incident, new scientific evidence or institutional change, in line with the updating procedure in Chapter 13.3; and (vi) use of the Plan's risk maps and identified gaps (Chapter 6.4) to support new funding proposals and investment in laboratory and monitoring capacity, as outlined in Chapter 14.4.

12.5 Resource requirements

The effective implementation of this Plan requires the following categories of resources. Human resources: at each partner institution, a minimum of one designated Marine Pollution Plan Coordinator, with time reserved for Plan-related activities; one or two trained scientific staff members per partner institution, qualified in the complete minimum set of common indicators; and at least one trained communications officer per national coordination point, responsible for communicating with the public and stakeholders during incidents. Training resources: facilities, equipment and printed or digital materials for delivering the three competence tracks of the training curriculum (D15/T5.5); on-line delivery infrastructure for e-learning components.

13. Monitoring, Evaluation and Updating of the Plan

13.1 Implementation indicators

The implementation of the Plan should be followed through a set of clear and practical indicators. These indicators should not be seen only as formal reporting requirements. Their main purpose is to help to understand whether the Plan is actually being used, whether cooperation is improving, and whether the response capacity in the Black Sea region is becoming stronger.

The following indicators may be used:

- number of specialists trained in marine pollution monitoring, emergency response, remediation and conflict-related contamination;
- number of institutions actively involved in the implementation or use of the Plan;

- number of national or regional datasets updated, shared or integrated into information systems;
- number of pollution risk maps, hotspot maps or vulnerability maps prepared or revised;
- number of response protocols, guidance documents or practical procedures developed and tested;
- number of simulation exercises, workshops or training events organised;
- number of documented pollution incidents, including civil, military and mixed civil-military cases;
- number of stakeholder consultations or coordination meetings held;
- number of cases where scientific data were used to support management decisions;
- number of public communication materials, technical notes or policy briefs prepared;
- number of identified gaps addressed through new monitoring, training or coordination measures.

From a scientific and practical perspective, it is important to monitor not only the number of documents or events produced, but also whether they are useful in real situations. For example, it matters whether institutions exchange data more efficiently, whether response protocols are tested, whether risk maps are updated, and whether trained specialists can apply their knowledge during actual pollution events.

13.2 Evaluation mechanism

The Plan should be evaluated periodically to understand whether it remains relevant, realistic and useful. Pollution risks in the Black Sea are not static. They change with environmental conditions, human activities, new monitoring results, institutional reforms and, in the current context, the consequences of war.

The evaluation mechanism should include a regular review of progress. This may be carried out annually or at another agreed interval. The review should consider which actions have been implemented, which datasets have been updated, what training activities have taken place, which institutions have been involved, and what pollution incidents have been documented.

It is also important to collect feedback from stakeholders. Authorities, scientific institutions, emergency services, port and maritime actors, local admin-

istrations, NGOs and other users of the Plan can provide practical comments on what works well and what remains difficult. This feedback is valuable because a management plan must be useful not only in theory, but also in real operational conditions.

After significant pollution events, the Plan should include a process for documenting lessons learned. This applies to oil spills, chemical contamination, harmful algal blooms, port accidents, riverine pollution pulses and conflict-related incidents. After such events, responsible institutions should review what information was available, what decisions were taken, what delays occurred, which actors were involved, and what should be improved in future response.

Quality assurance is also essential. Data, maps, assessments and recommendations used under the Plan should be checked for reliability, consistency and transparency. Methods should be documented, sources should be clear, and measured evidence should be distinguished from modelling results, assumptions or expert judgement.

Progress should be reported in a concise and useful form. Reporting should not only list completed activities, but should also identify remaining gaps, new risks, practical problems and recommendations for the next stage. In this way, evaluation becomes a tool for learning and improvement, rather than a purely administrative exercise.

13.3 Updating procedure

The Plan should be treated as a living document. It should be revised when new information or new circumstances make revision necessary. This is especially important for the Black Sea, where pollution risks, monitoring possibilities and institutional conditions may change quickly.

The Plan should be updated after major pollution events, such as large oil spills, hazardous chemical releases, severe algal blooms, port accidents, damage to coastal or industrial infrastructure, conflict-related contamination or incidents affecting protected areas, fisheries, tourism or coastal communities.

It should also be revised when new scientific evidence becomes available. This may include new information on emerging contaminants, microplastics, explosive residues, underwater noise, bioaccumulation, ecological effects, pollutant transport, sediment contamination or remediation options.

Changes in legislation, policies or regional agreements should also be reflected in the Plan. If national rules, EU requirements or regional procedures are

revised, the Plan should be adjusted so that it remains consistent with the current governance framework.

New monitoring results may also require updates. Revised datasets, new risk maps, improved modelling outputs, new hotspot information or new data from sediments and biota may change priorities and recommended response measures.

The Plan should also be updated when institutional responsibilities change. If new authorities are created, mandates are transferred, emergency procedures are revised or new coordination mechanisms are introduced, the relevant sections of the Plan should be corrected.

A practical updating procedure may include the following steps:

- identification of the reason for revision;
- collection of new scientific, institutional or operational information;
- expert review of the affected sections;
- consultation with relevant stakeholders;
- preparation of updated text, tables or maps;
- approval or endorsement by the responsible body;
- dissemination of the revised version to all relevant users.

This procedure should be simple enough to be applied in practice, but structured enough to ensure that updates are scientifically sound and institutionally accepted.

13.4 Management of uncertainty

Uncertainty is unavoidable in marine pollution assessment. This is particularly true for the Black Sea today, where monitoring may be limited by security risks, access restrictions, damaged infrastructure and the appearance of new or poorly studied contaminants. Uncertainty should not be hidden. It should be clearly described and used responsibly in decision-making.

All major assessments should identify data gaps. These may include missing monitoring data, limited spatial coverage, absence of sediment or biota samples, insufficient laboratory capacity, inaccessible areas or lack of information on emerging and conflict-related pollutants.

Where possible, uncertainty should be expressed through confidence levels or uncertainty ranges. For example, maps, risk assessments and modelling re-

sults should indicate whether conclusions are based on direct measurements, limited observations, remote sensing, modelling, historical information or expert judgement.

The Plan should also document key assumptions. This is important when direct data are not available and interpretation depends on indirect evidence. Assumptions may relate to pollution sources, transport pathways, exposure duration, affected receptors or the expected behaviour of substances in water, sediments or biota.

The main limitations should also be stated openly. These may include restricted access to sea areas, wartime constraints, safety risks for field teams, differences between national monitoring systems, lack of harmonised methods, or uncertainty about substances released during conflict-related incidents.

Where uncertainty is high but the possible consequences are serious, the Plan should apply a precautionary approach. This means that lack of complete data should not prevent reasonable protective action. In such cases, priority should be given to additional monitoring, protection of sensitive areas, temporary restrictions where needed, transparent communication and follow-up assessment.

From our perspective, managing uncertainty is not a weakness of the Plan. It is part of responsible scientific and management practice. By clearly documenting data gaps, assumptions, limitations and confidence levels, the Plan can remain transparent, adaptive and useful for authorities, scientists and stakeholders working to respond to civil and military marine pollution in the Black Sea.

14. Sustainability and Long-Term Use

14.1 Use after the project lifetime

Instead of a project product, this Plan is a living reference. Three methods guarantee its use when the Black Sea SIERRA project (end September 2026) ends. First, the document is operationally self-contained: each chapter provides enough explanatory and scientific context for a new environmental officer or regional cooperation body to understand and apply the recommended procedures without project-internal documents. Second, the Plan expressly links to regional frameworks (Bucharest Convention, MSFD, IMO-REMPEC, EMSA) that will continue after the project, keeping it relevant in an ongoing governance environment. Third, Chapter 13.3's updating system allows relevant national entities to revise the Plan as new data, incidents, legislation, or scientific results emerge, keeping it scientifically and practically current.

14.2 Integration into national and regional frameworks

Each Black Sea partner country should formalise the Plan into at least three national frameworks. The minimal common indicator set of this Plan, including explosive residues in priority conflict-proximate areas, should be added to national marine and coastal monitoring programs under the WFD and MSFD in the next program review cycle. Second, national marine pollution contingency plans (updated under the Bucharest Convention) should use this Plan's response strategies (Chapter 9), scenarios (Chapter 7.5), and transboundary notification procedures (Chapter 10) to model civil-military combined pollution events. Third, port state control, vessel traffic management, and Coast Guard risk assessment should use the Plan's hotspot maps and vulnerability assessments.

14.3 Maintenance of information systems and training materials

Recommended maintenance schedule: (i) The National Marine Pollution Focal Point in each country reviews and updates the institutional contact list biannually, checks it against official sources and shares it with all partner institutions. Following the routine monitoring cycle and annual data exchange described in Chapter 10.2, the monitoring databases and GIS layers (hotspot maps, vulnerability maps, minimum common data set) are updated annually; (iii) The institutions delivering this program (TUIASI, MBNAR) annually review the three competency lines of the training curriculum (D15/T5.5, Chapter 11.3), incorporating new monitoring results, updated legal instruments and feedback from the L1-L3 training evaluations. The updated versions are published on the websites of the partner institutions and, where possible, on the Black Sea Commission information portal. And a full review of the Plan would be required every three years (Chapter 13.3) or after a major event, institutional change, or new scientific evidence that significantly alters its recommendations.

14.4 Opportunities for future projects

This Plan provides a documented and evidence-based justification for future project proposals and investment applications. Its risk maps and governance gap analysis define specific, spatially based priorities that can be formulated as objectives in subsequent calls for funding for European research, climate and environment or in bilateral development cooperation instruments. The remaining analytical gaps identified in Chapter 6.4 (explosive residue monitoring, underwater acoustic networks, bioaccumulation surveillance for military con-

taminants) represent concrete scientific and technical objectives for future research and innovation projects.

Pilot actions for the assessment of conflict-related contamination in Ukraine's coastal waters, collaborative acoustic monitoring exercises, and mobile remediation unit testing can be established in scope and cost using this Plan's techniques. The Black Sea SIERRA consortium's institutional network and Chapter 11's educated professionals supply human capital for these future operations. The laboratory infrastructure investments in Chapter 12.5 can be justified against this Plan's analytical requirements and suggested in national research institutions' capital investment budgets or as co-financing components of future EU-funded initiatives. The operational workflows, data-sharing protocols, and risk models developed under the plan can be formally handed over to the Black Sea Commission (Commission on the Protection of the Black Sea Against Pollution) or integrated into ongoing and future EU programmes established under the 2028–2034 Multiannual Financial Framework (MFF), including Horizon Europe and future territorial cooperation initiatives in the Black Sea region, ensuring their long-term use and sustainability.

15. Conclusions and Recommendations

15.1 Main conclusions

The Black Sea is unusually vulnerable to long-standing civic pollution pressures and a new, acute risk from the 2022-armed conflict. D2.2 report shows that eutrophication, heavy metal contamination, petroleum hydrocarbons, microplastics, and persistent organic pollutants impair basin coastal waters, sediments, and biota (ORDU, 2026). The fighting has also delivered poorly characterised pollutants (explosive residues, military-origin heavy metals, fuel leaks, corrosion products from submerged objects) into an area with limited monitoring capacity and access.

The D15/T5.5 supplemental training program (TUIASI & MBNAR, 2026) covers the knowledge and ability gaps indicated. It uses a three-level assessment methodology (L1–L3) to measure learning gain and assist continuous development for blue economy and sustainability, legal-governance and conflict-related pollution, and technical-operational monitoring. The curriculum and Plan establish a coherent, evidence-based framework for integrated Black Sea civil and military marine pollution response.

15.2 Key recommendations

The plan’s key recommendations are the following:

- From a governance perspective, it is proposed that national marine pollution coordination centers—with explicit civil-military coordination functions—be established in each Black Sea littoral state, and that protocols addressing conflict-induced pollution be included in national emergency plans.
- From a monitoring perspective, it is recommended to add explosive remnants and underwater noise to the minimum common set of indicators, to upgrade the laboratories of partner institutions, and to maintain harmonized monitoring of stations in critical areas. Emergency preparedness through annual inter-agency simulations, safe operations in conflict zones, and a post-incident approach based on lessons learned.
- From a remediation perspective, they recommend the prior identification of mobile remediation resources, the integration of unexploded ordnance (EOD) disposal planning into cleanup operations near the conflict zone, and monitoring of ecological recovery 24 months after the incident.
- Regarding sustainability, the Plan should be presented to the Black Sea Commission and national environmental authorities.

15.3 Final statement

Due to the changing of Black Sea environment, this Plan should be updated often. New toxins are discovered, access to conflict-affected areas may change, monitoring technology improve, institutional arrangements change, and the international legal framework for environmental protection in armed conflicts is continually being developed. Unupdated plans lose scientific and operational value quickly.

The document lists national environmental authorities and Black Sea SIER-RA consortium scientific partners (INCDPM, IO-BAS, ORDU, UkrSCES, MBNAR, TUIASI) as Plan maintainers and updaters. Their commitment to the Plan beyond project money contributes to Black Sea environmental security.

Indicative Implementation Matrix

The table below lists this Plan’s primary implementation actions, including its responsible partners, timeframes, intended outputs, and key performance indi-

cator (KPI). It aids operational planning by national coordination points and project partners and Plan implementation monitoring as outlined in Chapter 13.

Action	Description	Responsible partners	Timeframe	Expected output	KPI
National Coordination Points	Identification of national civil-military coordination contact points for marine pollution response	Environmental ministries; maritime safety bodies; navy forces project partners	Short-term	Formal contact list; tested notification protocol	Contact list operational in all 4 countries
Minimum common indicator set	Agree and publish agreed parameter list, methods and metadata standard for cross-country data exchange	INCDPM; IO-BAS; ORDU; UkrSCES; TUIASI	Short-term	Published indicator set and metadata standard	Endorsed by all consortium partners
Explosive residue monitoring	Develop and validate methods for TNT, RDX, PETN and metabolites identification in sediment and biota; pilot sampling at conflict-proximate stations	UkrSCES; INCDPM; ORDU; IO-BAS	Medium-term)	Validated method at ≥2 labs; pilot dataset	Method validated; ≥1 pilot survey completed
Training programme delivery	Providing the three-track training curriculum (D15/T5.5): blue economy, legal-governance/ conflict contaminants, technical-operational monitoring to authorities, scientists, responders and stakeholders in all partner countries	MBNAR; TUIASI; INCDPM; IO-BAS; ORDU; UkrSCES	Medium-term	≥20 trained specialists per country; training reports	≥80 trained; post-training assessment score improvement ≥25%

Action	Description	Responsible partners	Timeframe	Expected output	KPI
Pollution hotspot and vulnerability maps	Produce and publish georeferenced GIS maps of high-priority and watch-list pollution zones for N, W and S Black Sea	INCDPM; IO-BAS; ORDU; UkrSCES; TUIASI	Medium-term	Published GIS maps; endorsed by competent authorities	Maps available for all 4 countries; updated annually
Simulation exercises	Annual multi-agency, simulated and/ or field exercises testing combined civil-military pollution scenarios.	National Coordination Points; Navy forces; IGSU; RNA; project partners	Annual	Exercise reports; updated response protocols	≥1 exercise/year; lessons learned documented

Annexes

Annex 1. Institutional and Information Framework

Consolidated overview of relevant authorities, organisations, information systems, databases and operational data platforms.

Annex 2. Integrated Pollution and Risk Assessment Framework

Consolidated typology of civil, military and conflict-related pollution events, priority pollutants and indicators, and the proposed risk assessment matrix.

Annex 3. Marine Pollution Response Protocol

Operational template for detection, notification, assessment, safe sampling, containment, communication and post-incident review.

Annex 4. Minimum Regional Data Exchange Template

Standardised structure for the exchange of routine monitoring and pollution-incident data between participating institutions and countries.

ANNEX 1. INSTITUTIONAL AND INFORMATION FRAMEWORK

Purpose. This annex identifies the minimum institutional and information architecture needed to connect environmental policy, monitoring, maritime safety, emergency response, scientific assessment and regional data exchange. The table deliberately uses institutional or functional contacts rather than personal names because personal contact details change frequently.

Table 1.1. Core authorities, operational bodies and scientific support organisations

Country / level	Organisation	Primary role under the Plan
Regional	Commission on the Protection of the Black Sea Against Pollution (Black Sea Commission / BSC Permanent Secretariat)	Regional cooperation under the Bucharest Convention; BSIMAP coordination; regional information exchange; support to joint action in accidental pollution cases.
Regional / EU support	European Maritime Safety Agency (EMSA)	Satellite oil-spill detection through CleanSeaNet; technical, training and response support available to participating coastal States.
Romania	Ministry of Environment, Waters and Forests (MMAP)	National environmental and water policy; marine strategy; coordination of environmental monitoring, reporting and emergency governance within its mandate.
Romania	National Administration "Romanian Waters" (ANAR) and Dobrogea-Litoral Water Basin Administration (ABADL)	Water management, coastal-water monitoring, river-basin and coastal management planning, data provision and technical implementation.
Romania	Romanian Naval Authority (RNA)	Ship and port-state control; implementation of maritime conventions; prevention of ship-source pollution; maritime incident and pollution-response functions within national law.
Romania	National Institute for Marine Research and Development "Grigore Antipa" (INCDM)	Marine monitoring, research, ecological assessment, MSFD-related scientific support and technical advice.
Bulgaria	Ministry of Environment and Water (MOEW)	National environmental policy; marine strategy; coordination of marine-water management and international environmental obligations.
Bulgaria	Black Sea Basin Directorate (BSBD)	River-basin and coastal-water planning, monitoring coordination, assessment and management of the Black Sea Basin District.
Bulgaria	Executive Environment Agency (ExEA)	Administration of the National Environmental Monitoring System; data management, assessment and reporting, including water monitoring.
Bulgaria	Maritime Administration Executive Agency	Maritime safety, ship-source pollution prevention, inspections and implementation of international maritime requirements.

	Operational scope	Official public source / general contact
	All Black Sea Contracting Parties.	blacksea-commission.org [4]
	European and participating coastal States; service access through designated national authorities.	emsa.europa.eu [7]
	National; Romanian coastal and marine waters.	mmediu.ro [11]
	Danube Delta, Dobrogea, coastal waters and associated river basins.	rowater.ro; dobrogea-litoral.rowater.ro [12]
	Romanian ports, territorial waters and national maritime jurisdiction.	portal.rna.ro [13]
	Romanian Black Sea waters and regional research cooperation.	rmri.ro; project documentation [1]
	National; Bulgarian Black Sea marine waters.	moew.government.bg [14]
	Eastern Bulgaria, coastal waters and Black Sea Basin District.	bsbd.org [15]
	National monitoring and reporting.	eea.government.bg [16]
	Bulgarian ports, territorial sea and maritime transport.	marad.bg; national authority websites

Country / level	Organisation	Primary role under the Plan
Bulgaria	Institute of Oceanology - Bulgarian Academy of Sciences (IO-BAS)	Marine research, monitoring, modelling, laboratory analysis and scientific support to the project and competent authorities.
Türkiye	Ministry of Environment, Urbanization and Climate Change - General Directorate of Environmental Management / relevant marine units	Marine environmental policy; pollution prevention; marine litter and environmental management; approval and coordination of relevant response plans under national law.
Türkiye	Directorate General for Maritime Affairs / National Maritime Safety structures	Maritime safety, ship-source pollution prevention, emergency-response regulation, national maritime safety and pollution-response training.
Türkiye	TÜBİTAK Marmara Research Center (TÜBİTAK MAM)	Integrated marine pollution monitoring (DEN-İZ), marine research, laboratory and modelling support.
Türkiye	Ordu University (ORDU)	Project scientific partner; monitoring, research, sampling and regional academic support.
Ukraine	Ministry of Economy and Environment of Ukraine / water and marine policy functions	National policy in environmental protection, water and marine policy, international cooperation and coordination of subordinate or related environmental bodies.
Ukraine	State Environmental Inspectorate of Ukraine and South-Western District Inspectorate	State environmental supervision and control; incident documentation; crisis inspections and sampling in accessible coastal areas.
Ukraine	State Enterprise "Ukrainian Sea Ports Authority" (USPA), including Odesa Branch	Environmental safety within port territories and waters; pollution prevention, localisation and clean-up; port contingency planning and operational drills.
Ukraine	Ukrainian Scientific Centre of Ecology of the Sea (UkrSCES)	Marine environmental monitoring, laboratory analysis, ecological assessment, modelling, databases, regional reporting and scientific support during pollution incidents.

	Operational scope	Official public source / general contact
	Bulgarian and regional Black Sea.	io-bas.bg; project documentation [1]
	National marine and coastal waters.	csb.gov.tr [17]
	Turkish maritime jurisdiction, ports and Turkish Straits.	maritime.uab.gov.tr [18]
	All Turkish seas, including the Black Sea.	mam.tubitak.gov.tr [19]
	Southern Black Sea and project activities.	odu.edu.tr; project documentation [1]
	National; Ukrainian marine and coastal waters.	me.gov.ua [8]
	National; South-Western district includes Odesa and Mykolaiv areas.	dei.gov.ua; sw.dei.gov.ua [9]
	Ukrainian seaports and port waters within the functions of each branch.	uspa.gov.ua; odesa.uspa.gov.ua [10]
	Ukrainian Black Sea and regional data cooperation.	sea.gov.ua; blackseadb.org [1], [20]

Table 1.2. *Key information systems and data services*

System / service	Owner / operator	Main data or function
Black Sea Environmental Data Platform (BS e-DataPlatform)	UkrSCES; developed through EMBLAS with EU/ UNDP support	Multi-source Black Sea environmental observations and assessment-relevant parameters, including chemical and biological data.
Black Sea Water Quality Database (WQDB)	UkrSCES	Searchable marine water-quality observations and supporting metadata.
Black Sea Integrated Monitoring and Assessment Programme (BSIMAP) / Black Sea Information resources	Black Sea Commission and Contracting Parties	Regional monitoring principles, harmonisation, assessment, QA/QC and reporting architecture.
EMODnet Chemistry	European Marine Observation and Data Network	Eutrophication, ocean acidification, contaminants and marine litter datasets and products.
EMODnet Biology	European Marine Observation and Data Network	Marine species occurrence and biological datasets from European providers.
Copernicus Marine Service - Black Sea Monitoring and Forecasting Centre	Copernicus Marine Service	Analysis and forecasts of Black Sea physical and biogeochemical conditions based on models, satellite and in-situ data.
CleanSeaNet	European Maritime Safety Agency	Near-real-time satellite detection of possible oil pollution and vessels; spill monitoring during emergencies.
Romanian water-management and Dobrogea-Litoral information resources	ANAR / ABADL	River-basin, coastal-water, monitoring and management-plan information.
Bulgarian National Environmental Monitoring System - Water subsystem	MOEW / Executive Environment Agency with basin directorates	National monitoring networks, water-quality information, assessment and reporting.
Integrated Marine Pollution Monitoring Programme (DEN-IZ)	Ministry of Environment, Urbanization and Climate Change; coordinated scientifically by TÜBİTAK MAM	Integrated monitoring of Turkish marine and coastal waters using ecosystem-based approaches.

	Coverage / access	Use under the Plan	Source
	Black Sea basin; public web interface, subject to dataset-specific access.	Historical baseline, regional comparison, indicator assessment, data discovery.	blackseadb.org [20]
	Black Sea; online searchable interface.	Baseline comparison, trend review and supporting evidence for incident assessment.	database.blackseadb.org [20]
	All Black Sea countries; programme and resources publicly documented, detailed reporting through national mechanisms.	Regional alignment, common assessment logic and reporting to BSC.	blacksea-commission.org [4]
	European sea basins including Black Sea; open data portal.	Regional baseline, data gap analysis, validation and map preparation.	emodnet.ec.europa.eu/en/chemistry [5]
	European sea basins including Black Sea; open data portal.	Biodiversity receptors, protected or sensitive species context, biological assessment.	emodnet.ec.europa.eu/en/biology
	Black Sea; open products subject to user registration and licence.	Drift context, currents, waves, sea state, chlorophyll, turbidity and event interpretation.	marine.copernicus.eu [6]
	Service for participating States through designated national users; selected public documentation.	Early detection and tracking of oil slicks; support to national surveillance and response.	emsa.europa.eu [7]
	Romanian territory and coastal waters; public reports and national systems.	National baseline, coastal-water status and Romanian implementation context.	rowater.ro; dobrogea-litoral.rowater.ro [12]
	Bulgaria; public reports plus competent-authority systems.	National monitoring evidence and regional data contribution.	eea.government.bg [16]
	All Turkish seas including Black Sea; programme results and institutional outputs.	Southern Black Sea baseline and harmonisation with project monitoring.	mam.tubitak.gov.tr [19]

Table 1.3. Minimum institutional activation logic

Trigger	Lead function	
Routine monitoring or gradual deterioration	Environmental / marine monitoring authority	
Suspected ship-source or port pollution	Maritime / port authority under national law	
Large acute spill or hazardous substance release	National emergency / maritime pollution coordination function	
Conflict-related or UXO-associated contamination	Competent national security/EOD and civil authority	
Potential transboundary effect	National competent contact point	

	Supporting functions	Minimum output
	Scientific institutions, laboratories, basin authorities, data managers	Validated monitoring record; trend or hotspot assessment; management recommendation.
	Environmental authority, emergency services, laboratory/scientific support	Incident registration; verification; containment decision; POLREP or national report where applicable.
	Environmental authority, maritime authority, civil protection, ports, scientific teams	Activated response chain; safety perimeter; rapid assessment; response action log; public information.
	Environmental authority, maritime services, scientific teams, local authorities	Safety clearance or access restriction; remote assessment; approved sampling plan; documented uncertainty.
	Black Sea Commission arrangements, neighbouring countries, scientific modelling and data services	Rapid cross-border notification; shared situation report; agreed data and map exchange.

ANNEX 2. INTEGRATED POLLUTION AND RISK ASSESSMENT FRAMEWORK

Purpose. This annex provides a single workflow for classifying pollution events, selecting monitoring indicators and assigning a transparent screening priority. It is designed for preliminary management decisions and does not replace substance-specific ecological or human-health risk assessment.

Table 2.1. Typology of civil, military and mixed marine pollution events

Event type	Working definition	Typical sources
Chronic pollution	Long-term or repeated input that produces cumulative pressure.	Municipal and industrial discharges; agriculture; river loads; ports; shipping; historically contaminated sites.
Acute / emergency pollution	Sudden release over a short period with potential for rapid spread or severe local impact.	Ship accidents, oil or chemical spills, fires, damaged storage, infrastructure failure, explosions.
Diffuse pollution	Input from multiple dispersed sources that cannot be attributed to one discharge point.	Agricultural runoff, urban drainage, atmospheric deposition, litter leakage and small-scale coastal activities.
Point-source pollution	Release from a clearly identifiable site or facility.	Industrial outlet, wastewater discharge, port terminal, pipeline, tank, ship, depot or damaged facility.
Transboundary pollution	Pollution likely to cross or already crossing national jurisdiction.	Large rivers, offshore spills, atmospheric transport, floating litter, regional currents or migrating biota.
Mixed civil-military pollution	Civil pollution released or intensified by military action, or overlap of pre-existing civil pressure with conflict-related hazards.	Damage to ports, wastewater plants, industrial sites, fuel depots, vessels, pipelines or waste infrastructure.
Armed conflict-related contamination	Direct or indirect pollution associated with armed conflict or military activities.	Explosive residues, propellants, fuels, fires, munitions corrosion, military debris, sunken objects and disturbed sediments.

	Main pathways	Priority receptors	Management response
	Rivers, outfalls, atmospheric deposition, sedimentation, resuspension and food-web transfer.	Coastal habitats, plankton, benthos, molluscs, fish, ecosystem services and coastal communities.	Source reduction, routine monitoring, trend analysis, measures at river-basin and coastal-management level.
	Surface drift, currents, waves, wind, direct runoff, plume dispersion and shoreline deposition.	Birds, mammals, fish, beaches, ports, protected areas, fisheries, tourism and public health.	Immediate notification, rapid assessment, containment where safe, sampling, public warning and clean-up.
	River networks, surface runoff, groundwater, wind and gradual accumulation.	Estuaries, lagoons, plankton, benthos, shellfish, wetlands and coastal users.	Catchment-level prevention, monitoring of source proxies, land-sea coordination and long-term measures.
	Direct discharge, local plume, surface drift, sedimentation and later resuspension.	Local water and sediment, benthos, bathing areas, port users and nearby communities.	Source localisation, stop or contain release, targeted sampling, enforcement and remediation.
	Currents, river discharge, wind, sediment transport, vessel movement and food webs.	Shared fish stocks, cetaceans, protected areas, beaches and coastal economies in more than one country.	Rapid notification, common situation picture, comparable data, shared modelling and coordinated monitoring.
	Combined chemical, physical and operational pathways; restricted access may delay verification.	All environmental compartments, infrastructure, responders and coastal populations.	Civil-military coordination, safety screening, remote sensing, specialised sampling and transparent uncertainty reporting.
	Atmospheric fallout, dissolution, corrosion, sediment resuspension, leaching and food-web transfer.	Benthic habitats, sediments, fish, molluscs, cetaceans, responders and users of affected coastal areas.	Security/EOD assessment first; remote monitoring; targeted analytical methods; restricted access; long-term surveillance.

Table 2.2. *Minimum priority pollutants, pressures and indicators*

Group	Parameters / indicators	Matrix
Hydrography and event context	Temperature, salinity, depth, currents, waves, turbidity, suspended solids, river discharge and meteorological conditions.	Water column; remote sensing; model fields.
Eutrophication	Total nitrogen and phosphorus; nitrate, nitrite, ammonium, phosphate, silicate; dissolved oxygen; chlorophyll-a; transparency; phytoplankton biomass and harmful blooms.	Water; optionally sediment nutrient flux and biota response.
Petroleum hydrocarbons	Total petroleum hydrocarbons; oil and grease; PAH profile; selected biomarkers and weathering indices.	Water, surface films, shoreline material, sediment and biota.
Metals and metalloids	Hg, Cd, Pb, Cu, Zn, Ni, Cr, As; additional Sb, W, Sr and other elements when military origin is suspected.	Dissolved/particulate water, sediment and biota.
Persistent and hazardous organic contaminants	PCBs, organochlorine pesticides, dioxin-like compounds, phenols, surfactants and other priority substances selected by source inventory.	Water, sediment and biota.
Current-use pesticides and pharmaceuticals	Selected pesticides, metabolites, antibiotics, pharmaceuticals and endocrine-active substances based on catchment and source information.	Water, sediment and biota where relevant.
Marine litter and microplastics	Beach litter counts; floating and seafloor litter; microplastic abundance, size, shape and polymer type.	Shoreline, water, sediment and biota.
Explosive residues and energetic compounds	TNT, RDX, PETN and relevant transformation products; other compounds selected after source and safety assessment.	Water, porewater, sediment and biota.
Propellants, combustion and fire-related chemicals	UDMH/NDMA where relevant; fuel additives; combustion products; fire residues and source-specific hazardous chemicals.	Water, sediment, deposition material and biota as justified.

	Suggested methods	Assessment reference	Specific relevance
	CTD and field sensors; turbidity meters; satellite products; hydrodynamic modelling.	National monitoring methods; Copernicus Marine products; project QA/QC.	Controls transport, dilution, sediment resuspension and sampling design.
	Spectrophotometry/auto-analyser; oxygen sensors or titration; fluorometry/HPLC; microscopy and validated molecular tools where appropriate.	MSFD Descriptor 5, WFD where applicable, BSIMAP and national standards.	Chronic riverine and wastewater pressure; algal blooms; hypoxia and ecosystem resilience.
	GC-FID/GC-MS; fluorescence screening; gravimetry only where suitable; source-fingerprinting methods.	National EQS/standards; MSFD Descriptor 8; BSC guidance; incident-specific baseline.	Shipping, ports, fuel storage, damaged vessels and conflict-related fuel releases.
	ICP-MS/ICP-OES; mercury analyser; validated digestion and certified reference materials.	EU/national EQS and sediment/biota guidance where applicable; BSIMAP; site background.	Industrial and port pressure, munitions corrosion, debris and disturbed sediments.
	GC-MS/MS, LC-MS/MS and validated targeted screening.	National and EU priority-substance requirements; MSFD Descriptor 8; food-safety standards when relevant.	Long-term accumulation, bioaccumulation, damaged electrical or industrial equipment.
	LC-MS/MS or GC-MS/MS; passive sampling as a supplementary tool.	National watch lists, WFD-related lists where applicable, project screening priorities.	Diffuse catchment inputs, wastewater and combined civil pressures.
	Standardised visual surveys; microscopy; FTIR/Raman polymer identification; QA blank controls.	MSFD Descriptor 10; EMODnet/BSC-compatible classifications; national protocols.	Persistent diffuse pollution and potential military-origin fragments or fibres.
	HPLC-UV/LC-MS/MS or GC-MS methods validated for the target matrix; strict field blanks and chain of custody.	No single universal Black Sea EQS: use validated detection limits, ecotoxicological screening values, reference sites and documented uncertainty.	Munitions, detonations, military debris and restricted sites; requires EOD/safety clearance.
	Targeted LC-MS/MS/GC-MS; non-target screening may support identification but must be confirmed by targeted methods.	Incident-specific source inventory, national hazardous-substance rules and laboratory validation.	Damaged storage, missiles/rockets, fires and unknown mixed releases.

Group	Parameters / indicators	Matrix
Underwater noise	Continuous sound level; impulsive events; frequency, duration and spatial distribution; cetacean observations and strandings as contextual evidence.	Acoustic records and biological observations.
Biological effects and ecosystem status	Phytoplankton composition; benthic indices; biomarkers; bioaccumulation in mussels/ fish; fish health; habitat condition; sensitive/protected species status.	Biota and habitat.

Table 2.3. Proposed screening score for management prioritisation

Criterion	Score 1 – Low
1. Hazard / toxicity	Low known hazard at observed or plausible exposure.
2. Persistence / secondary release	Short-lived; rapid natural attenuation; little accumulation.
3. Likelihood / exposure	Release unconfirmed or receptors unlikely to be exposed.
4. Spatial extent	Very local and contained.
5. Transboundary potential	No credible cross-border transport pathway.
6. Receptor sensitivity	Low-sensitivity setting; limited ecological or human use.
7. Socio-economic consequences	Minor disruption and low clean-up cost.
8. Response complexity	Routine methods and safe access available.

Priority bands. Sum the eight criterion scores: 8-12 = Watch-list; 13-18 = Medium priority; 19-24 = High priority. Record confidence separately as High, Medium or Low

	Suggested methods	Assessment reference	Specific relevance
	Calibrated hydrophones; passive acoustic monitoring; event logs; modelling and standardised cetacean observation.	MSFD Descriptor 11 and national/regional monitoring approaches.	Explosions, military operations, intensive shipping, construction and unmanned systems.
	Taxonomic methods; tissue chemistry; biomarker assays; habitat surveys; eDNA as complementary evidence where validated.	MSFD Descriptors 1, 4, 6, 8 and 9; BSIMAP and national programmes.	Connects contaminant presence with ecological effect and recovery.

	Score 2 - Moderate	Score 3 - High
	Moderate hazard or uncertainty about toxicity.	Severe acute/chronic toxicity, carcinogenicity, reproductive toxicity, or life-safety hazard.
	Persists seasonally or may accumulate locally.	Persistent for years; bioaccumulative; sediment reservoir or recurring secondary release likely.
	Release plausible/confirmed but exposure limited or intermittent.	Confirmed release with ongoing or likely substantial exposure.
	Local coastal or subregional footprint.	Large, expanding, basin-connected or difficult-to-bound footprint.
	Possible transport under specific conditions.	Likely or observed cross-border transport.
	Some sensitive habitats, species or users.	Protected habitats/species, spawning areas, seafood, bathing water, densely used coast or critical infrastructure.
	Temporary restrictions or moderate operational/economic impact.	Major impact on health, fisheries, tourism, ports, livelihoods or essential services.
	Specialised methods, coordination or equipment needed.	Restricted/unsafe access, UXO/security risk, unknown mixture, scarce laboratory capacity or major multi-agency response.

Table 2.4. *Illustrative application of the screening tool (not a site-specific risk assessment)*

Illustrative scenario	H	P	L	S	T	R	E	C	Total	
Fresh petroleum spill in a busy port with shoreline drift	3	2	3	2	2	3	3	2	20	
Suspected explosive residues in sediment near a restricted military area	3	3	2	1	1	3	2	3	18	
Large nutrient-rich river plume with hypoxia and bloom indicators	2	2	3	3	3	3	3	2	21	
Repeated high-intensity impulsive underwater noise near cetacean habitat	3	1	3	2	2	3	2	2	18	
Contaminated sediment acting as a secondary source after infrastructure damage	3	3	2	2	2	3	2	3	20	

Abbreviations in Table 2.4: H - hazard; P - persistence; L - likelihood/exposure; S - spatial extent; T - transboundary potential; R - receptor sensitivity; E - socio-economic consequences; C - response complexity.

Table 2.5. *Minimum assessment record*

Field	
Assessment ID	
Date/time and assessor	
Event classification	
Evidence used	
Priority indicators	
Criterion scores	
Priority and confidence	
Immediate actions	
Uncertainties	
Review date	

	Initial priority	Confidence / qualification
	High	Medium-High; confirm volume, product and trajectory.
	Medium	Low until verified; safety/UXO override may make response Critical.
	High	Medium; combine field data, satellite and river discharge.
	Medium	Medium; upgrade if mortality/injury or large spatial exposure is confirmed.
	High	Low-Medium; verify sediment chemistry and resuspension potential.

Required content
Unique identifier linked to incident or monitoring dataset.
UTC date/time, institution and responsible role.
One or more types from Table 2.1; overlapping categories may be selected.
Field observations, laboratory data, satellite products, modelling, official reports and expert judgement, each clearly distinguished.
Selected parameters from Table 2.2 with matrix, method and applicable benchmark.
Eight scores from Table 2.3 with one-sentence justification for each.
Watch-list / Medium / High / Emergency-Critical plus High / Medium / Low confidence.
Notification, access restrictions, further sampling, containment, communication or transboundary exchange.
Missing data, restricted access, analytical limitations, source ambiguity and alternative explanations.
Time or condition for reassessment, including receipt of laboratory or modelling results.

ANNEX 3. MARINE POLLUTION RESPONSE PROTOCOL

Purpose. This protocol is a common planning template for civil, military and mixed pollution incidents. National legal procedures, safety rules and competent-authority decisions prevail. Timeframes are planning targets and may be shortened or extended according to the scale, access and safety conditions.

Table 3.1. Common response sequence

Stage	Target timeframe	Core actions	
1. Detection and initial notification	Immediately; target within 1 hour	Register report; identify location, time, reporter, visible extent and suspected source; preserve photos, video and original messages; alert relevant national authority.	
2. Activation and coordination	Target within 2 hours	Activate competent national coordination chain; appoint incident coordinator and scientific lead; determine whether POLREP or other cross-border notification is required.	
3. Rapid situation and risk assessment	Target within 2-4 hours	Compile satellite, model, weather, current, vessel/port and visual information; classify event; identify likely pollutants and receptors; apply preliminary risk screen.	
4. Safety decision and field plan	Before any deployment	Conduct task-specific risk assessment; determine PPE, exclusion zones, vessel/shore access, decontamination, communications and emergency withdrawal.	
5. Verification and sampling	Target 4-12 hours when safe and feasible	Verify event; collect water, sediment, shoreline material and/or biota samples using controls, replicates and reference stations; document chain of custody.	
6. Containment, protection and clean-up	Target 6-48 hours; continue as needed	Stop source where possible; deploy booms/skimmers/sorbents or other approved techniques; protect sensitive sites; manage recovered waste; document decisions and effectiveness.	
7. Public and stakeholder communication	First message target within 12 hours; updates as needed	Issue clear official information: what is known, uncertain, affected area, restrictions and public actions; brief fishers, tourism, ports, NGOs and local communities.	
8. Ongoing monitoring and recovery	From first response through recovery	Track spread, concentrations, ecological effects and clean-up performance; define recovery targets and monitoring duration; revise restrictions based on evidence.	
9. Post-incident review and reporting	Target final review within 30 days; long-term reports later	Evaluate effectiveness, costs, exposure, environmental consequences, communication and coordination; identify lessons; update plans, contact lists, methods and training.	

Lead / supporting functions	Required records and outputs	Conflict-related safeguards
Operator, port/maritime authority, environmental inspectorate, local authority or research institution according to how the event is detected.	Initial Notification Form; incident ID; map point/polygon; photo log; initial source and hazard statement.	Do not approach suspicious objects; record possible UXO, active hostilities, mines, debris, chemical or fire hazards.
National environmental/ maritime/emergency coordination function; ports; scientific and local authorities.	Activation record; contact log; roles; reporting schedule; initial transboundary decision.	Include military/security or EOD representation when access, objects or sources may be conflict-related.
Scientific institution with competent authorities and operational services.	Rapid Situation Report; preliminary map; risk score and confidence; recommended protective actions.	Use remote assessment where access is restricted; distinguish confirmed facts from assumptions and intelligence-sensitive information.
Operational safety lead; EOD/ security authority where needed; field-team leader and laboratory.	Approved Site Safety Plan; sampling plan; team list; equipment checklist; access clearance.	No sampling in suspected mined/UXO areas without formal clearance or authorised specialist support.
Accredited/competent scientific or regulatory teams; port or maritime support.	Field sheets; GPS; photos; sample IDs; preservation details; Chain of Custody; laboratory request.	Use non-contact or remote methods first where appropriate; avoid disturbing munitions or contaminated sediment.
Emergency services, port/ maritime authority, polluter/ operator, waste contractors, environmental authority.	Operational log; equipment and waste records; effectiveness observations; updated map; safety incidents.	Dispersants, in-situ treatment, sediment disturbance or salvage require competent-authority approval and safety assessment.
Designated communication lead with competent authorities and scientific review.	Public statement; stakeholder notice; Q&A; update schedule; record of corrected information.	Do not release security-sensitive details; explain why some data or areas cannot be disclosed.
Environmental authority, scientific institutions, laboratories, local authorities and sectoral bodies.	Monitoring programme; trend plots; recovery indicators; decision record for lifting restrictions.	Long-term sediment, biota and habitat surveillance may be required after conflict-related releases.
National coordination function with all participating bodies.	Final incident report; lessons learned; updated risk matrix; data package; corrective action plan.	Record access constraints, evidence limitations and needs for future demining, monitoring or research.

Table 3.2. *Initial Notification Form - minimum fields*

Field	Entry requirement
Incident ID	Country/organisation code + date + sequential number.
Date and time	UTC preferred; record local time and time zone if UTC conversion is not immediately available.
Reporter	Name or role, organisation, phone/email; anonymous report status where applicable.
Location	Latitude/longitude in WGS84, named location, port/river/shore segment and estimated affected polygon.
Detection method	Visual, satellite alert, sensor, laboratory result, public report, vessel/port report or other.
Observed characteristics	Colour, odour, sheen, foam, debris, dead or distressed organisms, fire/ smoke, sound event, shoreline deposition.
Suspected source	Vessel, port facility, river, industrial site, damaged infrastructure, unknown, or conflict-related source.
Suspected substance	Oil/fuel, chemical/HNS, sewage, nutrients, litter, explosive/energetic compound, sediment, unknown mixture.
Immediate hazards	Fire/explosion, toxic vapour, UXO/mines, unstable structure, navigation hazard, biological hazard, security restriction.
Weather and sea state	Wind, waves, current, visibility and precipitation if available.
Immediate actions taken	Source stopped, area isolated, port operation changed, public access restricted, boom deployed, sampling initiated.
Attachments	Photographs, videos, satellite product, sketch/map, witness statement, vessel/port record.
Notifications made	Authorities, time, contact method and reference number; POLREP/ transboundary status.

Table 3.3. *Rapid Situation Report - required sections*

Section	Minimum content
1. Executive status	Incident ID; current status; operational period; lead authority; priority level and confidence.
2. What is confirmed	Confirmed source, substance, location, affected area, observations and validated results.
3. What is assumed or unknown	Alternative sources, unverified reports, missing data and access/ analytical limitations.
4. Forecast	Expected movement and affected receptors using currents, wind, waves and modelling; forecast validity period.
5. Safety	Exclusion zones, UXO/security information, PPE, access status and responder risks.
6. Actions completed	Notifications, sampling, containment, clean-up, restrictions and communication.
7. Actions next	Operational priorities for the next 6, 12 and 24 hours; responsible body for each action.
8. Transboundary status	Countries potentially affected, notifications sent, shared data and requests for assistance.
9. Data annex	Map, observation table, sample list, modelling products, photographs and source documents.

Table 3.4. *Decision rules for selected response options*

Option	Use when	Do not use / additional approval needed when
Containment booms and skimmers	Floating petroleum or recoverable surface pollutant can be safely contained and sea state permits.	Unsafe sea state, navigation/ security risk, explosive hazard, substance incompatible with equipment or containment increases exposure.
Sorbents	Small/localised surface contamination or shoreline residues; waste recovery is organised.	Large uncontrolled spill without recovery capacity; sorbent could disperse, create waste hazard or interfere with wildlife.
Dispersants	Only where legally authorised and a net environmental benefit analysis supports use.	Shallow/sensitive waters, unknown substance, insufficient mixing, human exposure concern or no competent-authority approval.
Shoreline clean-up	Pollutant has stranded or is likely to strand and safe access/waste management are available.	Mines/UXO, unstable infrastructure, active hostilities, sensitive habitat damage from clean-up, or no waste route.
Sediment capping / in-situ stabilisation	Contaminated sediment poses ongoing risk and disturbance/ removal would create greater release; site-specific design supports the option.	Navigation, habitat, security or hydrodynamic conditions make the measure ineffective; no long-term monitoring plan.
Dredging / removal	Source removal is feasible and safer than leaving sediment in place; disposal route and permits exist.	Disturbance may mobilise contaminants or explosives; no safe disposal; habitat damage outweighs benefit.
Remote sensing and modelling	Direct access is delayed/restricted or rapid spatial information is needed.	Never as the sole proof of substance identity; field or laboratory confirmation is still needed when safe and feasible.

ANNEX 4. MINIMUM REGIONAL DATA EXCHANGE TEMPLATE

Purpose. This annex defines the minimum fields and rules needed to exchange routine and crisis monitoring data among project partners and competent authorities. The template can be implemented in CSV for tabular records, NetCDF for gridded/model or structured oceanographic data, and GeoJSON for spatial features. WGS84 coordinates and controlled parameter vocabularies are recommended.

Table 4.1. Minimum metadata and data dictionary

Field name	Definition / rule	Format / controlled value
record_id	Unique identifier for one result record.	Text; globally unique within shared dataset.
incident_id	Identifier linking data to a pollution incident; blank for routine monitoring.	Text.
dataset_version	Version of the submitted package.	Semantic or date version.
country	Country responsible for the record.	ISO 3166-1 alpha-2.
responsible_institution	Institution owning or validating the record.	Official name; optionally EDMO code.
contact_role	Functional contact, not necessarily a personal name.	Role + institutional email.
station_id	Persistent sampling or observation station identifier.	Text; national/project code.
station_name	Human-readable location name.	Text.
latitude	Latitude of sampling/ observation.	Decimal degrees, WGS84; north positive.
longitude	Longitude of sampling/ observation.	Decimal degrees, WGS84; east positive.
geometry	Point, line or polygon when spatial extent is exchanged.	GeoJSON geometry or link to spatial file.
datetime_utc	Sampling/observation date and time in UTC.	ISO 8601: YYYY-MM-DDThh:mm:ssZ.
time_precision	Precision or uncertainty of time.	second / minute / hour / day / estimated.
platform_type	Platform used for observation.	shore, vessel, buoy, satellite, aircraft, drone, model, laboratory.
platform_id	Name or identifier of vessel, buoy, satellite product or model.	Text; use standard platform ID where available.
depth_m	Sampling/measurement depth below sea surface.	Numeric metres; 0 for surface where appropriate.
bottom_depth_m	Water depth at station.	Numeric metres.

	Requirement	Example
	Mandatory	UA_UKRS_20260728_001_TPH
	Conditional	UA-ODS-2026-017
	Mandatory	1.0
	Mandatory	UA
	Mandatory	UkrSCES
	Mandatory	Data manager; data@institution.xx
	Mandatory	UA_CW5_03
	Recommended	Odesa coastal station 3
	Mandatory	46.43125
	Mandatory	30.77640
	Conditional	POLYGON(...)
	Mandatory	2026-07-28T08:30:00Z
	Recommended	minute
	Mandatory	vessel
	Recommended	Patrol F-7
	Conditional	0.5
	Recommended	12.0

Field name	Definition / rule	Format / controlled value	
environmental_matrix	Material or compartment analysed.	water, dissolved, particulate, sediment, porewater, biota, shoreline material, air/deposition, acoustic.	
sample_id	Identifier on sample bottle/ container and chain of custody.	Text.	
sample_type	Sampling design qualifier.	grab, composite, replicate, blank, reference, passive sampler, in-situ, remote observation.	
parameter_name	Human-readable parameter.	Text.	
parameter_code_scheme	Vocabulary used for parameter code.	BODC P01 / CF standard name / national / project.	
parameter_code	Controlled parameter identifier.	Valid code in declared scheme.	
result_value	Reported numeric value.	Decimal; do not place qualifiers in numeric field.	
unit	Unit matching parameter and matrix.	Controlled unit vocabulary where possible.	
result_qualifier	Qualifier for non-detect or censored data.	=, <, >, not_detected, estimated.	
detection_limit	Method detection/reporting limit in the same unit.	Numeric.	
analytical_method	Method name/code and instrument.	Text plus method reference/version.	
laboratory	Laboratory performing analysis.	Official name.	
accreditation_status	Accreditation and scope relevance.	ISO/IEC 17025 accredited / validated non-accredited / research screening.	
qc_flag	Quality status of individual value.	SeaDataNet-compatible flag from Table 4.2.	
measurement_uncertainty	Expanded uncertainty or other documented uncertainty.	Numeric + unit or percent + coverage factor.	
replicate_id	Links replicate measurements.	Text.	
preservation	Preservation, storage temperature and holding-time information.	Text/code.	
chain_of_custody_ref	Reference to signed chain-of-custody record.	Text or document URI.	
source_document	Report, satellite product, model run or field sheet supporting record.	Citation, filename or URI.	
validation_status	Status of institutional validation.	draft, technically_checked, validated, superseded.	
confidentiality	Data-access category.	open, restricted, security_sensitive, embargoed_until_date.	
restriction_reason	Reason and review date for restricted information.	Text; do not disclose sensitive detail in open metadata.	
comments	Essential interpretation notes only.	Text.	

	Requirement	Example
	Mandatory	water
	Conditional	UA260728-W03-01
	Mandatory	grab
	Mandatory	Total petroleum hydrocarbons
	Mandatory	BODC P01
	Mandatory where available	Project code TPH_WATER if no approved P01 mapping
	Mandatory unless non-detect reported separately	0.043
	Mandatory	mg/L
	Mandatory	=
	Mandatory for laboratory chemistry	0.005
	Mandatory	GC-FID, validated laboratory SOP CH-07
	Conditional	UkrSCES laboratory
	Mandatory	ISO/IEC 17025 - within scope
	Mandatory	1
	Recommended	15%, k=2
	Conditional	REP-A
	Conditional	Amber glass; 4 C; analysed within SOP holding time
	Conditional	COC-UA-2026-017
	Recommended	Field sheet FS-UA-017-01
	Mandatory	validated
	Mandatory	open
	Conditional	Security-sensitive location; review 2027-01-31
	Optional	Light surface sheen observed; no shoreline impact at sampling time.

Table 4.2. Recommended SeaDataNet-compatible quality flags

Flag	Meaning	Use
0	No quality control	Initial status before any documented QC.
1	Good value	Passed relevant automatic and expert checks; consistent with method and context.
2	Probably good value	Likely valid but confirmation or additional checks are pending.
3	Probably bad value	Suspect result; should normally be excluded from assessment unless justified.
4	Bad value	Invalid result; retain only for traceability, not for assessment.
5	Changed value	Original value has been corrected; preserve audit trail.
6	Value below detection	Report detection limit and qualifier; do not substitute zero.
7	Value in excess / above range	Instrument or method range exceeded; report lower bound and follow-up action.
8	Interpolated value	Derived by interpolation; not a direct observation.
9	Missing value	No value available.
A	Value phenomenon uncertain	Observed phenomenon or value is uncertain and requires expert review.

Table 4.3. Exchange formats, timing and minimum validation

Data type	Preferred format	Exchange timing	Minimum validation before release
Routine station and laboratory records	UTF-8 CSV plus data dictionary; optional SeaDataNet/EMODnet-compatible export.	At least semi-annually; sooner for project milestones.	Coordinates, dates, units, parameter codes, detection limits, QC flags, duplicates and institutional validation.
Crisis observations and rapid laboratory results	CSV or secure structured form; accompanying map in GeoJSON/PDF.	As soon as technically checked; version updates when validated results replace preliminary data.	Incident ID, source, time, coordinate, qualifier, confidence, confidentiality and clear preliminary/ validated status.
Model and gridded products	NetCDF using CF conventions; supporting metadata and model configuration reference.	With each operational forecast or agreed product cycle.	Time/space coordinates, units, model version, forcing, validation status and uncertainty/ limitations.

Data type	Preferred format	Exchange timing	Minimum validation before release
Hotspot, vulnerability and incident geometries	GeoJSON preferred; Shapefile only with complete sidecar files; PDF for visual communication only.	During incident updates and at least annual map review.	WGS84 CRS, layer date, source data, method, legend, classification and restriction status.
Images and remote-sensing products	Original/authorised image or service link plus georeferenced derived product where licensing permits.	Near real time for response; archived with final report.	Acquisition time, sensor/product, processing level, confidence and national validation status.

Table 4.4. *Fictitious example showing how one result is encoded*

Field	Example value
record_id	UA_UKRS_20260728_001_TPH
incident_id	UA-ODS-2026-017
dataset_version	1.0
country / institution	UA / UkrSCES
station_id / name	UA_CW5_03 / Odesa coastal station 3
coordinates	46.43125 N; 30.77640 E; WGS84
datetime_utc	2026-07-28T08:30:00Z
platform / depth	vessel - Patrol F-7 / 0.5 m
matrix / sample	water / UA260728-W03-01 / grab
parameter	Total petroleum hydrocarbons
code scheme / code	Project code / TPH_WATER pending controlled-vocabulary mapping
result	0.043 mg/L; qualifier =
detection limit	0.005 mg/L
method	GC-FID, laboratory SOP CH-07
accreditation / QC	ISO/IEC 17025 within scope / QC flag 1
validation / access	validated / open
comment	Fictitious example only; not an actual monitoring result.

Data integrity: The example in Table 4.4 is intentionally fictitious and must not be interpreted as an observed concentration or incident record.

Table 4.5. *Minimum file-package structure*

File / folder	Contents
README.txt or README.pdf	Dataset title, incident/project context, owner, contact role, version, licence/access restrictions and citation.
data.csv	One row per result record using Table 4.1 fields.
data_dictionary.csv	Field definitions, code lists, units and mandatory/conditional status.
stations.geojson	Sampling stations and incident geometries in WGS84.
methods/	Laboratory and field method references, QA/QC summary and accreditation scope information.
chain_of_custody/	Restricted or controlled copies of chain-of-custody records where exchange is legally permitted.
maps/	Situation, hotspot or vulnerability maps with legends and source notes.
change_log.txt	Version history, corrections, superseded records and responsible validator.

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- [6] Copernicus Marine Service - Black Sea Monitoring and Forecasting Centre and Black Sea products. marine.copernicus.eu/
- [7] European Maritime Safety Agency - CleanSeaNet and oil-pollution response services. www.emsa.europa.eu/csn-menu.html
- [8] Ministry of Economy and Environment of Ukraine - official website and water/marine policy functions. me.gov.ua/?lang=en-UA
- [9] State Environmental Inspectorate of Ukraine and South-Western District Inspectorate. www.dei.gov.ua/
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- [12] National Administration "Romanian Waters" and Dobrogea-Litoral Water Basin Administration. rowater.ro/
- [13] Romanian Naval Authority - ship inspection, pollution prevention and response information. portal.rna.ro/
- [14] Bulgarian Ministry of Environment and Water - Marine Environment. www.moew.government.bg/en/water/marine-environment/
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