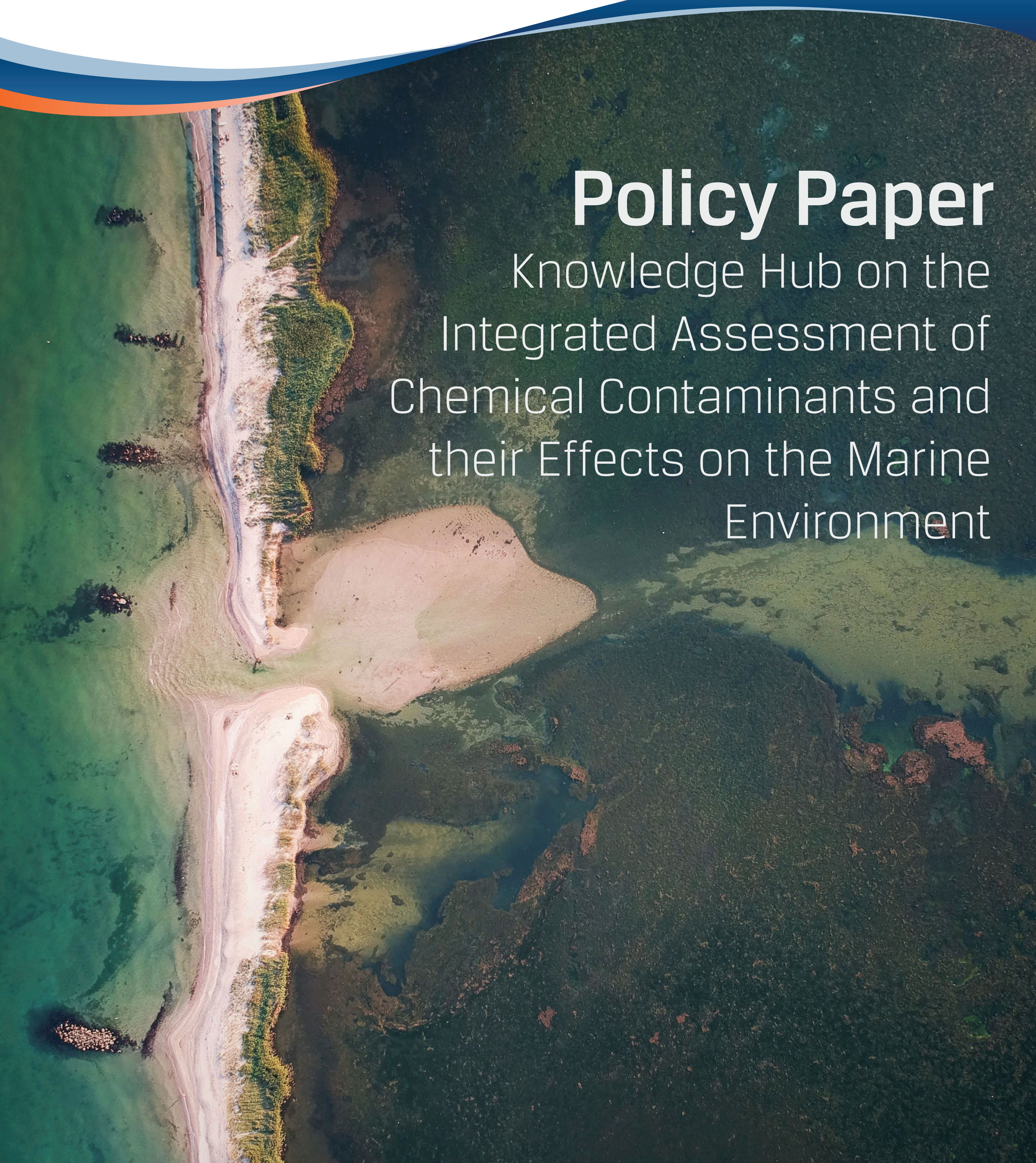
Policy Paper

Knowledge Hub on the Integrated Assessment of Chemical Contaminants and their Effects on the Marine Environment



Contributions:

Lillicrap, Adam (coordinator), Norwegian Institute of Water Research (NIVA), Norway
Katsiadaki, Ioanna (co-coordinator), Center for Environment Fisheries and Aquaculture Science (CEFAS), U.K.
Bellas, Juan, Spanish Institute of Oceanography (IEO), Spain
Brockmeyer, Berit, Federal Maritime and Hydrographic Agency (BSH), Germany
Brooks, Steven, Norwegian Institute for Water Research (NIVA), Norway
Burgeot, Thierry, Department of Biological Resources and Environment Biogeochemistry and Ecotoxicology Unit, IFREMER, France
Chacón Campollo, Esther, Spanish Foundation for Science and Technology (FECYT), State Research Agency (AEI), Ministry for Science and Innovation, Spain
De Witte, Bavo, Flanders Research Institute for Agriculture, Fisheries and Food Animal Sciences Unit – Aquatic Environment and Quality (ILVO), Belgium
Deudero, Salud, Spanish Institute of Oceanography (IEO), Spain
Giani, Michele, National Institute of Oceanography and Applied Geophysics (OGS), Italy
Giorgi, Giordano, Higher Institute for Protection and Environmental Research (ISPRA), Italy
Hanke, Georg, European Commission, Joint Research Centre (JRC), Ispra, Italy
Lee Behrens, Hanna, Research Council of Norway (RCN), Norway
Maggi, Chiara, Higher Institute for Protection and Environmental Research (ISPRA), Italy
Mauffret, Aourell, Department of Biological Resources and Environment Biogeochemistry and Ecotoxicology Unit, IFREMER, France
Parmentier, Koen, Royal Belgian Institute of Natural Sciences · Operational Directorate Natural Environment (RBINS), Belgium
Parts, Laine, Estonian Environmental Research Centre (EKUK), Estonia
Roose Patrick, Royal Belgian Institute of Natural Sciences · Operational Directorate Natural Environment (RBINS), Belgium
Schulz-Bull, Detlef, Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Germany
Tornero, Victoria, European Commission, Joint Research Centre (JRC), Ispra, Italy
Trujillo Quintela, Abraham, Spanish Foundation for Science and Technology (FECYT), State Research Agency (AEI), Ministry for Science and Innovation, Spain
Ureta Maeso, Jorge, Ministry for the Ecological Transition and the Demographical Challenge, Spain
Vethaak, Dick, Deltares, Unit Marine and Coastal Systems / VU University, Department Environment and Health, Netherlands

Publication editing:

Willem De Moor, Lavinia Giulia Pomarico, Tom Redd and Isabelle Schulz

Suggested reference:

JPI Oceans (2021) Policy Paper Knowledge Hub on the Integrated Assessment of Chemical Contaminants and their Effects on the Marine Environment, Brussels.

Photo credit frontpage:

Roman Skrypnyk on Unsplash

Copyright:

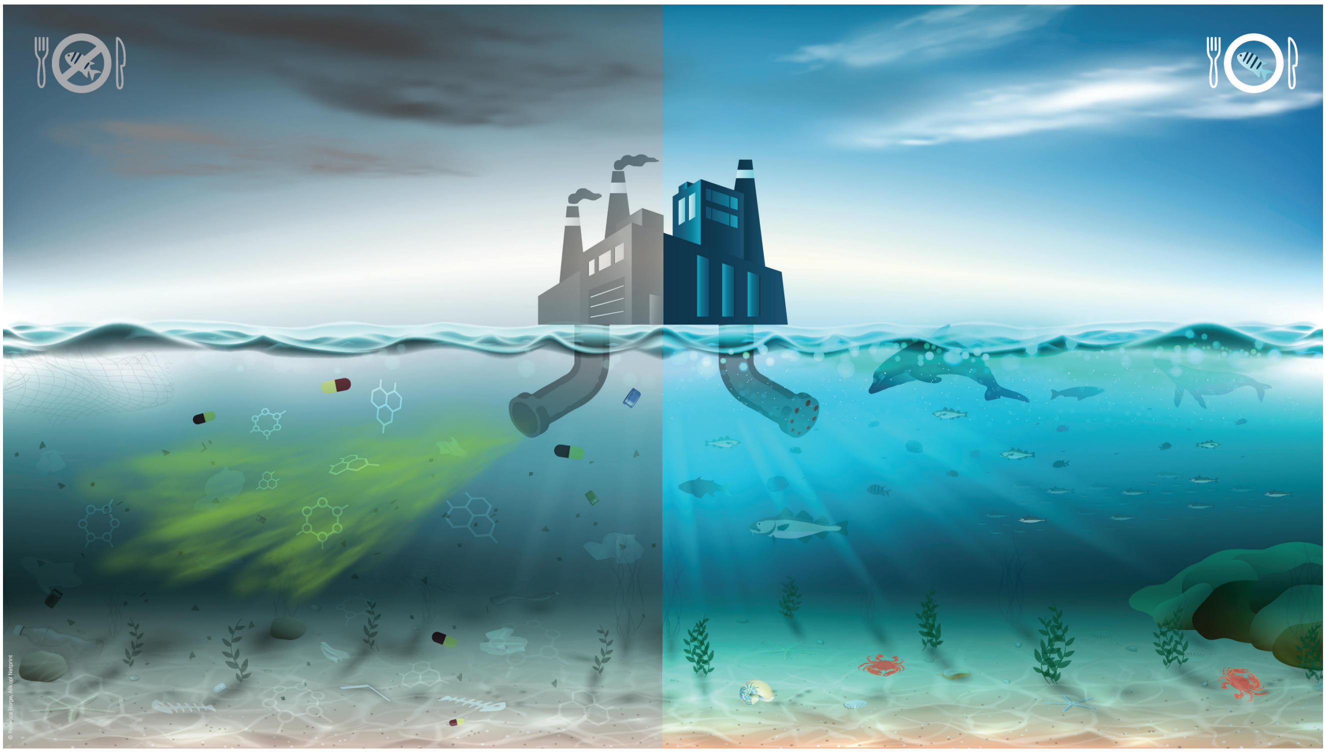
JPI Oceans Knowledge Hub on the Integrated Assessment of Chemical Contaminants and their Effects on the Marine Environment

Background

In a time of environmental awareness, spurred on by the possibility that our world is threatened by climate change, it is important to remember that there are other anthropogenic pressures, which are also essential for addressing the protection of the marine and coastal environment. Pollution is a global, complex issue that contributes to biodiversity loss and poor environmental health and comes from the production and release of many of the synthetic chemicals that we use in our daily lives. Chemical contaminants are often underrepresented as a major contributor of environmental deterioration.

The Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans) established in 2018 the JPI Oceans Knowledge Hub on the integrated assessment of chemical contaminants and their effects on the marine environment. The purpose of the Knowledge Hub was to provide recommendations on how to improve the methodological basis for marine chemical status assessment.

The work has resulted in the following policy paper which focuses on improving the efficiency and implementation of integrated assessment methodology of effects of chemicals of emerging concern. Substantial additional knowledge of biological effects is needed to achieve Good Environmental Status (GES) of our oceans and coastal areas. The Knowledge Hub is represented by highly skilled scientists and policy makers, appointed by the JPI Oceans Management Board, to ensure that the recommendations provided are useful for policy making.



Decades of pollution have severely degraded the condition of marine ecosystems. Restoring and protecting the oceans is one of the urgent and defining tasks of our time © Rebecca Borge, Alkopi NetPrint.

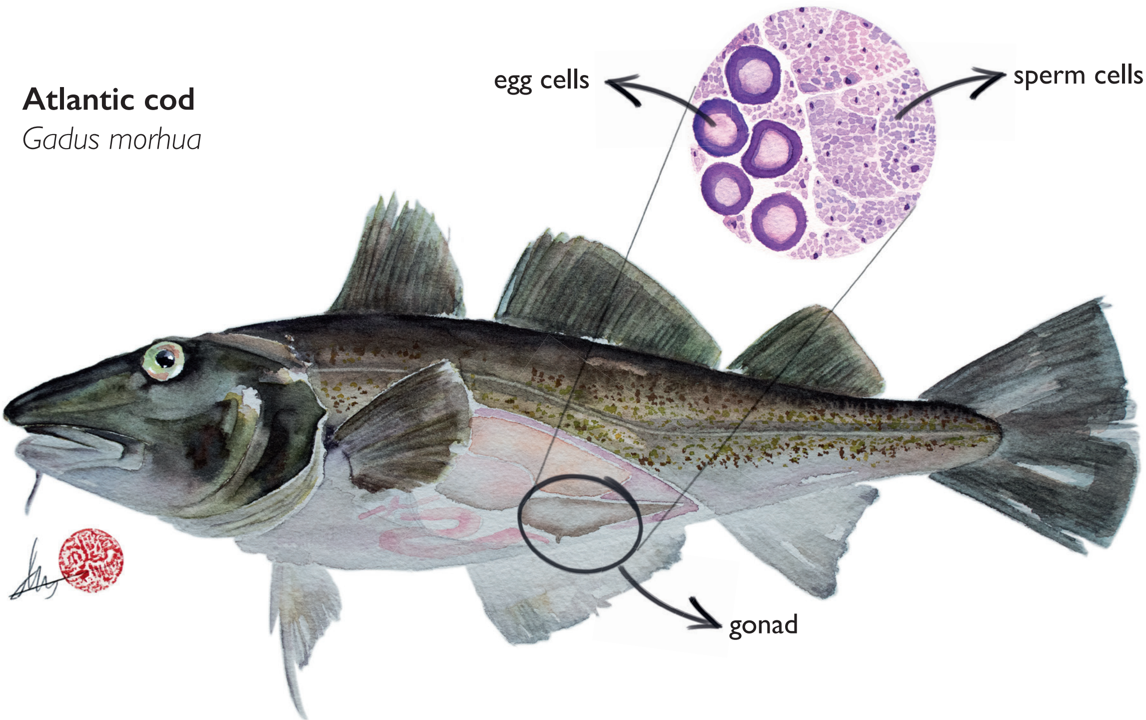
The topic of concern

An example of a chemical which caused major ecological issues in coastal ecosystems is the antifouling agent tributyltin (TBT). This chemical disrupts key physiological pathways across all taxonomic groups, but importantly, TBT exposure results in imposex in female snails leading to infertility, population declines and even extinction in some locations. Consequently, the use of TBT was regulated in certain countries from the late 1980s and banned globally for use as an antifoulant from 2008. The global ban on the use of TBT has led to subsequent recovery of snail populations, and monitoring studies have shown that the prevalence of imposex is now decreasing at previously impacted sites. Only after the TBT ban, it was discovered that other coastal organisms including crustaceans and fish are also developmentally affected by low concentrations of TBT. This fact highlights the risk of missing key toxicological features by the battery of tests used in standard environmental toxicity assessment.

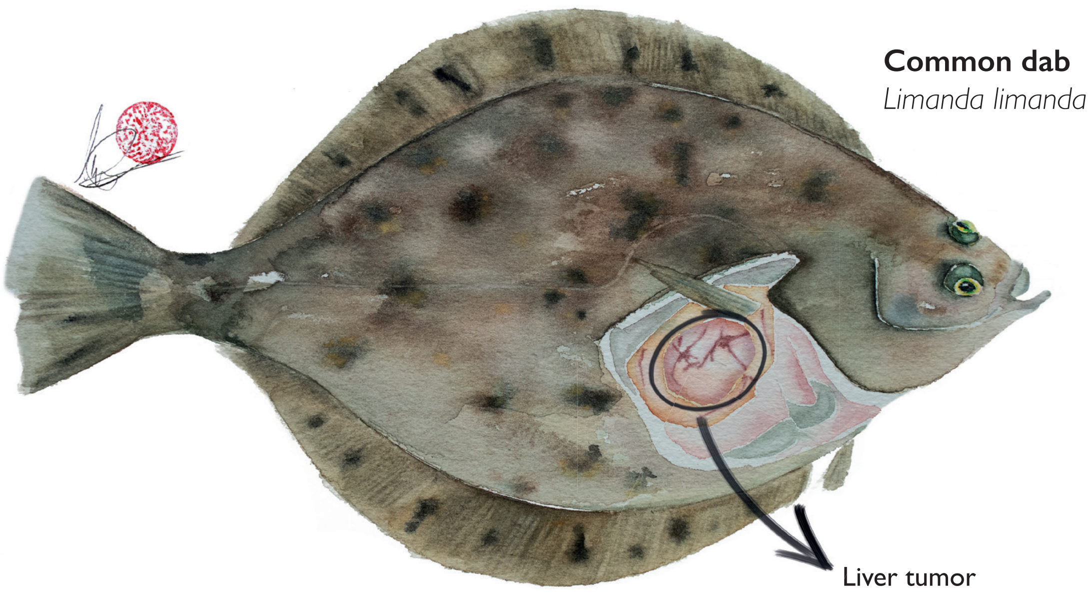
Another example of ecological damage from chemicals, is the reproductive disfunction in marine mammals caused by Polychlorinated Biphenyls (PCBs). Due to their high trophic level position, cetaceans act as sentinel organisms in the marine food web for chemicals which are persistent and bioaccumulative.

Samples collected under the UK Cetaceans Stranding Investigation Programmes (CSIP) have provided valuable information about chemicals of concern in the marine environment. During the necropsies of the cetaceans analysed in CSIP, data showed that the health status of the animals were correlated with the observed chemical concentrations in the tissues. Numerous studies were conducted looking at levels and trends of emerging contaminants, including flame retardants and perfluorinated substances which were detected in harbour porpoises. In addition, higher trophic level species, such as bottlenose dolphins and killer whales, were found to contain levels of PCBs likely to impact the immunological and reproductive health of the organisms.

It is estimated that almost 80% of the world effluents are being discharged directly without treatment into the sea. With continued use and discharge, chemicals that do not biodegrade easily, generally tend to increase in concentrations in the environment. Confounding this is



Atlantic cod (*Gadus morhua*) is an iconic species for most North Atlantic countries. The prevalence of intersex (gonads where both male and female gametes are present), although low, does not naturally occur in cod. Suspected chemicals involved in this abnormality include endocrine disrupting chemicals. Image © courtesy of Nicolas Sánchez & Susanne Schorr.



The flatfish species dab (*Limanda limanda*) is one of the sentinel species for offshore marine monitoring. At certain sites in the North and Irish Seas, the prevalence of liver tumors can exceed 20%. Suspected chemicals as causative agents include Polyaromatic Hydrocarbons (PAHs). Image © courtesy of Nicolas Sánchez & Susanne Schorr.

when persistent chemicals also have properties which make them prone to bioaccumulate in the tissues of marine organisms. Some bioaccumulative chemicals can also biomagnify up the food chain which means that their concentration in top predators (such as marine mammals as shown by CSIP previously) can be significantly higher than those at the lower end of the food web.

This biomagnification also presents an issue for public health, given that both capture fisheries and aquaculture-produced seafood often contain high levels of chemical contaminants. Some substances which are extremely persistent but are not very bioaccumulative, can be relatively soluble and therefore extremely mobile in the marine environment. With estimated half-lifes of many thousands of years, they will be an environmental problem for many generations to come.

The term "chemicals of emerging concern" (CECs) is increasingly used to designate chemicals that might be a threat to the environment but have only recently been identified as a cause for concern. CECs cover a wide range of chemicals including plant protection products, pharmaceuticals, veterinary medicines, personal care products, antifoulants, warfare agents, biocides, hormones and hormone-like substances.

Although some CECs may lead to acute aquatic toxicity (e.g. death), they can also cause significant ecological damage at low or very low environmental concentrations via sublethal effects (i.e., reproductive toxicity, reduced fecundity, developmental toxicity or endocrine disruption). CECs could hinder the EU objective of obtaining GES in the marine environment.

Current approaches to monitor/assess the effects/hazards of marine environmental contaminants

Standardized ecotoxicity bioassays are required for determining the hazards that chemicals pose to the environment and have to be performed according to internationally agreed guidelines (e.g. OECD) or standards (e.g. ISO). Many of the ecotoxicity bioassays were developed for freshwater organisms. Data from these studies are used to determine the concentration of a substance which may cause an effect and can be expressed as an EC50 (the median concentration causing an effect) or as a low and no observed effect concentration (LOEC and NOEC). To account for the vast biodiversity in the marine environment, an assessment factor is applied to the lowest effect concentration or NOEC to derive the predicted no effect concentration (PNEC). These data are subsequently compared to predicted or measured environmental concentrations to determine whether there is a risk to the environment (i.e., are environmental levels of the substance below, close or higher than the PNEC).

The problem with the current battery of bioassays is that many of these tests are crude in design (i.e., does an organism live or die?), do not reflect real world complexities and give little information on sublethal effects of chemicals which may extend over long periods (such as imposex or reduced fecundity). Consequently, biological effects assessments are also important to understand the real environmental hazards of different chemicals, particularly in the marine environment and are an essential tool for prioritizing chemicals of emerging concern. In addition to the inclusion of biological effects methods in marine monitoring programmes, more effort is needed for the development and implementation of regulatory accepted tests which are suitable to assess chemical hazards in the marine environment.

OSPAR (Convention for the protection of the marine environment of the North-East Atlantic) and ICES (International Council for the Exploration of the Sea) started to develop an integrated chemical-biological effect framework in 2005, and some of the available methods are presented in Figures 1 and 2. The implementation of the Marine Strategy Framework Directive (MSFD) and adoption of the holistic ecosystem approach in 2008 was an important driver in getting these biological effects assessments implemented into monitoring programs. The OSPAR/ICES integrated chemical-biological effect framework, also embraced by HELCOM (Baltic Marine Environment Protection Commission– Helsinki Commission) and MEDPOL (Pollution monitoring and assessment programme- Mediterranean region), aimed at quantifying both the presence and effects of known and unknown contaminants, and in 2012 was proposed as being suitable for the assessment of GES in the MSFD. Due to the lack of cost-effective integrated methodologies and guidance on interpreting monitoring data, in addition to technical, political and budget constraints, the criterion related to biological effects monitoring in the MSFD was changed from being mandatory (Commission Decision 2010/477/ EU, criterion 8.2) to voluntary (secondary criterion D8C2, Commission Decision 2017/848/EU). This means that Member States (MS) do not need to conduct biological effects assessments of hazardous chemicals in the marine environment to be in compliance with the MSFD. As a consequence, the number of MS that are implementing biological effects assessments in their monitoring programmes is limited, or MS simply may not have reported the data due to the lack of harmonized approaches to assess GES. The Joint Research Centre (JRC) has reviewed the latest MS's submissions for MSFD

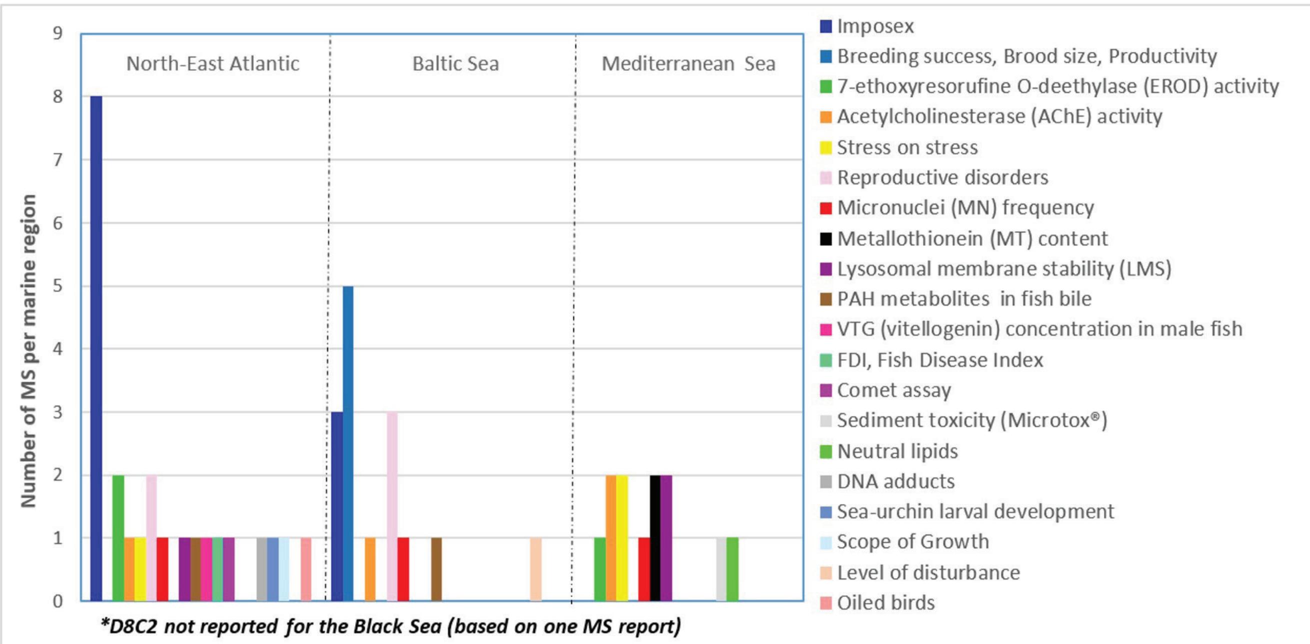


Figure 1. Overview of different biological effects assessments and frequency of use by different Member States (MS) in Europe (Tornero et al., 2021) Results based on reports from 21 out of 22 coastal EU MS.

(2012-2018 assessment cycle) to analyse comparability between countries and marine regions and provide recommendations for improving assessment approaches in view of reaching/maintaining GES in the EU. The analysis, in relation to MSFD Descriptor 8 Criterion 2 (D8C2), shows that approximately half of the MS have reported on this criterion (Figure 1) (Tornero et al., 2021). However, apart

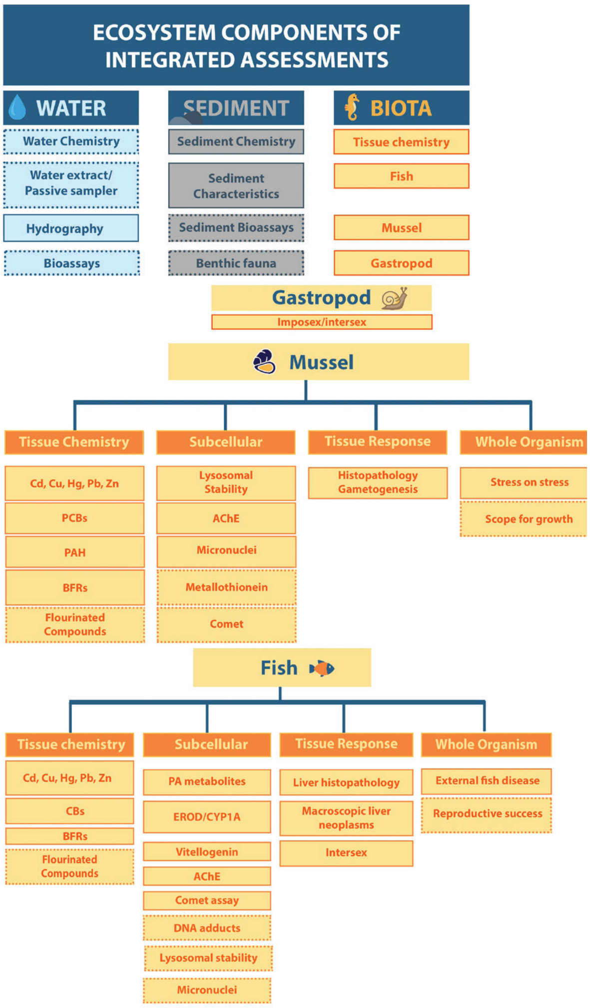


Figure 2. The main components of the OSPAR/ICES integrated monitoring framework for chemical and biological effects in water, sediment and biota. Biological effects assessment in fish and mussels and imposex/intersex measured in gastropods. Core methods –solid lines, additional methods – dashed lines (adapted from Vethaak et al., 2017. Mar. Environ. Res. 124: 11-20). AChE – acetylcholine esterase, PCB – polychlorinated biphenyls, PAH – Polyaromatic hydrocarbons, BFR – Brominated flame retardants, CB – chlorinated biphenyls, EROD - ethoxyresorufin-O- deethylase, CYP1A - cytochrome P450 1A.

from imposex in the North-East Atlantic and white-tailed sea eagle reproduction parameters in the Baltic Sea, there is high variability in the number of biological effect methods reported by different MS (Figure 1). This, along with the lack of data interpretation for GES, is an important deficiency and should be addressed to ensure that the EU and other geographical regions are able to meet the target for GES.

Inconsistencies between different directives/legislations

Inconsistencies can occur between the different legislations such as with the Water Framework Directive (WFD) and the MSFD. This includes the interpretation of the geographical extent of each of the directives as implemented by different MS. The range of application of the WFD is not restricted to just freshwater, but also covers the coastal and transitional waters. In coastal areas, the WFD is in force up to one nautical mile from the territorial baseline of a MS to ensure Good Ecological Status[1] and up to 12 nautical miles for Good Chemical Status. The overlap between the MSFD and WFD in coastal zones can lead to difficulties in harmonized assessments, particularly due to the different ecosystem approaches between the two directives. The WFD has established the concentration of certain pollutants (Environmental Quality Standards (EQS)) which should not be exceeded to obtain a Good Chemical Status of a water body. The WFD classification procedure is based on "one out all out" (OOAO) principle, where the worst status determines the final status of the water body. Whereas the WFD uses OOAO principle, no specific rule has been proposed for the MSFD, allowing MS to adopt different criteria for assessing environmental quality status.

The EU Directive 2013/39/EU on priority substances has a new mechanism for providing reliable information on the monitoring of emerging substances that can potentially harm the European aquatic environment. This new tool, called Watch List, monitors the presence of compounds for which the mechanism of damage to the aquatic ecosystem and human health are still unclear. The list of the substances to be monitored in marine environments is under constant revision. However, for CECs to be included in this list, it is necessary to understand the risks they may pose on marine organisms. An early identification system of the chemicals which are likely to cause irreversible and

1 GES is defined by the WFD as "Good Ecological Status" and by the MSFD as "Good Environmental Status".

potentially catastrophic effects to marine organisms is clearly needed to avoid legacy pollutant issues such as those detailed previously about TBT and PCBs.

The chemical specific risk-based paradigm, which informs monitoring and assessment of environmental contaminants, does not apply well to the many thousands of chemicals (new and existing) that enter the marine environment. This emphasises the need for novel approaches, focusing on the effects of both legacy chemicals and CECs.

New fit for purpose, transferable methodologies, that are consistent with an integrated approach, have the potential to streamline monitoring efforts and resources and provide an early warning system for chemical impacts. These methodologies should also assist MS in implementing relevant directives, namely the MSFD and WFD.

For any new integrated chemical effects assessment approach to be implemented within regulatory frameworks, such as the MSFD or the WFD, the test/ assay needs to be standardised. This is to ensure that the assay/ test is reliable, robust and relevant. It is important to note that the time taken to standardise any new integrated approach can be considerable and a means to reduce the duration, from demonstration of readiness to international validation, is clearly needed.

A tiered approach is recommended, which not only focuses on contaminant data, but combines current regular monitoring, based on contaminant concentrations and related ecotoxicity data, with a set of biological effect data that can be evaluated by assessment criteria. At regions or areas where primary assessment criteria are exceeded, a more profound investigation could be applied, combining a larger set of biological effect assessments with non-target chemical screening approaches. The integration of different measurements on chemical concentrations and biological effects will lead to an improved assessment status and will enhance the ability to identify new groups of CECs or substances sharing similar modes of action that may impact GES. Toxicity profiling using a bioanalysis (a battery of in vitro and in vivo assays) combined with passive sampling, routine chemical analyses, and, if needed, Effect-Directed Analysis (EDA), has been shown to be a promising technique for hazard and risk assessment of known and unknown chemicals in fresh water (e.g. as shown in the EU SOLUTIONS project). In parallel, such an approach has been developed for marine sediments using a tiered screening approach that include non-targeted chemical monitoring, and when needed, at higher tiers, components of/or the full OSPAR/ICES integrated framework (Vethaak et al., 2017) (Figure 2) . These tiered approaches could be linked with the SIMONI (Smart Integrated Monitoring) approach which is a novel bioanalytical strategy for water quality assessment, potentially to be applied in regular water quality monitoring programs under the WFD and might be worth further exploration for the marine environment.

Recommendations

Based on the information described above, the Knowledge Hub has developed a set of recommendations for further work in improving and implementing the Integrated Approaches to Testing and Assessment (IATA) methodologies.

To apply biological effects assessment in the marine environment, it is important to differentiate their application. Biological effects assessment can be used to identify priority compounds which may be the highest cause for concern (Recommendations 1-3), and also to inform monitoring programmes to aid in evaluating GES (Recommendations 4-7). The recommendations developed by the JPI Oceans Knowledge Hub on the integrated assessment of chemical contaminants and their effects on the marine environment are as follows:

1. Existing and new biological effects assessments should be used to help provide guidance on which chemicals of emerging concern (CECs) should be prioritized for monitoring in the marine environment. New methods need to be developed for evaluating specific effects of CECs in marine environments, particularly for marine sediments since this environmental compartment is poorly represented by current standardised bioassays.

2. Regulatory authorities should use data from alternative validated methods, assuming that the tests are performed and reported to a high level of quality. Standardisation of new methods should be encouraged and International validation should be promoted by competent authorities to ensure rapid acceptance within organisations such as ISO and OECD.

3. Methods for identification of non-target pollutants/CECs need to be improved and more stringent restrictions need to be applied by European regulatory authorities on CECs from entering the marine environment.

4. There is a need for transparency and commitment regarding monitoring data and assessment methodologies applied within different MS. Monitoring data should be freely available and accessed through a central portal (e.g. ICES data centre, EMODnet, EEA etc.), facilitating data exchange and interoperability of databases. Threshold values, including Environmental Quality Standards (EQS) for CECs, need to be better harmonized across MS and be relevant for the marine environment.

5. For CECs that show enhanced toxicity, an integrated toxicity regime with relevant chronic endpoints should be carried out on a variety of species, especially at crucial (potentially more sensitive) life stages, in order to minimise the risk of overlooking sensitive organisms.

6. Since CECs enter transitional waters, coastal regions and open oceans, both the WFD and MSFD are applicable for the evaluation of CEC levels and their effects in the marine environment. However, there is a need for better harmonization between the MSFD and WFD monitoring/assessment frameworks, and Member States need to adopt a common policy on the interpretation of the directives to avoid conflicting assessments.

7. An Integrated Approach to Testing and Assessment (IATA), combining both chemical contaminant and biological effect data, should become mandatory in marine monitoring programmes. An integrated approach will aid Member States evaluating whether Good Environmental Status is both achieved and maintained in the marine environment. To support Member States in understanding and applying integrated effects assessments in a tiered approach, an internationally accepted guidance document, adopted by different supranational agreements is required.

Concluding remarks

Pollution is a global issue and comes from the production and release of many of the synthetic chemicals used in our daily lives.

The JPI Oceans Knowledge Hub for integrated effects assessments of chemical contaminants has in this policy paper provided a set of recommendations to meet the challenges we face today in understanding the integrated effects of pollutants in our marine and coastal environment.

The key recommendation of the Knowledge Hub is to develop and implement an integrated approach for assessing chemicals of emerging concern and their effects on the marine environment. Inspired by the United Nations Decade of Ocean Science for Sustainable Development it is time to collectively put effort into restoring and protecting the environment, regardless of the price and complexity of the system. A shared effort is needed and to be successful must be carried out in close cooperation between expert scientists and policy makers, nationally as well as on a European and international level.

List of abbreviations

AChE	Acetylcholine esterase
BFR	Brominated flame retardants
CB	Chlorinated biphenyls
CEC	Chemicals of emerging concern
CSIP	Cetaceans stranding investigation programmes
CYP1A	Cytochrome P450 1A
EC50	Half maximal effective concentration
EDA	Effect-Directed Analysis
EEA	The European Economic Area
e.g.	exempli gratia
EMODnet	The European Marine Observation and Data Network
EU	European Union
EQS	Environmental Quality Standards
EROD	Ethoxyresorufin-O-deethylase
GES	Good Environmental Status
HELCOM	Baltic Marine Environment Protection Commission – Helsinki Commission
IATA	Integrated Approach to Testing and Assessment
ICES	International Council for the Exploration of the Sea
ISO	International Organization for Standardization
i.e.	id est
JPI Oceans	Joint Programming Initiative Healthy and Productive Seas and Oceans
JRC	Joint Research Centre
LOEC	Low observed effect concentration
MEDPOL	Pollution monitoring and assessment programme - Mediterranean region
MSFD	Marine Strategy Framework Directive
MS	Member States
NOEC	No observed effect concentration
OECD	Organization for Economic Co-operation and Development
OOAO	One out all out
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PAH	Polyaromatic hydrocarbons
PBT	Persistent, bioaccumulative and toxic
PCB	Polychlorinated Biphenyl
PNEC	Predicted no effect concentration
SIMONI	Smart Integrated Monitoring
TBT	Tributyltin
WFD	Water Framework Directive

JPI Oceans AISBL | Company number: 0691.970.779 | Rue du Trône 4
1000 Brussels | Belgium
Tel. +32 (0)2 626 16 60 | info@jpi-oceans.eu
www.jpi-oceans.eu