Harmonization and Networking for contaminant assessment in the Ionian and Adriatic Seas

Deliverable T2.3.1 – Guidelines on common data visualization products

Work Package T2 - Data collection and definition of common data outputs focused on contamination

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1. Introduction

The Adriatic and Ionian Seas are crucial for the blue growth of both EU and non-EU coastal states. However, increased human use of the marine and coastal space may threaten marine ecosystems through several kind of physical, chemical and biological disturbances and through contamination by hazardous substances. In particular, the overall expansion in maritime transport, the increasing coastal urbanization and the foreseen enlargement in offshore oil and gas extraction in the ADRION region pose serious risks of pollution from hazardous substances for several coastal countries. In order to promote the sustainable use of the seas, the Marine Strategy Framework Directive and the Protocols for the Protection of the Mediterranean Sea against Pollution of the Barcelona Convention require EU Member States and UNEP/MAP Contracting Parties to take measures to maintain or achieve Good Environmental Status (GES) in the European seas by 2020 (European Commission 2008/56/EC, MSFD). Member States sharing a marine region or sub-region should cooperate to assure a coherent approach to environmental monitoring, good environmental status definition and assessment.

2. Legal background

Taking into account the Integrated Monitoring and assessment programme of the Mediterranean Sea and Coast and related assessment criteria (IMAP, 2016) and the Marine Strategy Framework Directive of the European Union (MSFD, 2008), Good Environmental Status (GES) is defined according to eleven qualitative descriptors (according to MSFD) or to, almost overlapping, eleven ecological objectives (EO, according to UNEP/MAP):

1. Biodiversity (quality and occurrence of habitats and the distribution and abundance of species) (overlapping with EO1).
2. Non-indigenous species (overlapping with EO2).
3. Populations of all commercially exploited fish and shellfish (overlapping with EO3).
4. Marine food webs and their components (overlapping with EO4).
5. Human-induced eutrophication (overlapping with EO5).
6. Seafloor integrity (overlapping with EO6).
7. Hydrographical conditions (overlapping with EO7).

8. Concentrations of contaminants (overlapping with EO9: Contaminants cause no significant impact on coastal ad marine ecosystems and human health).
9. Contaminants in fish and other seafood (overlapping with EO9: Contaminants cause no significant impact on coastal ad marine ecosystems and human health).
10. Marine litter (overlapping with EO10).
11. Energy introduction, including underwater noise (overlapping with EO11).

UNEP/MAP has defined additional Ecological Objective, which does not overlap with MSFD descriptors. This is Ecological Objective EO8 - Coastal ecosystems and landscapes. For good environmental status, natural dynamics of coastal areas should be maintained and coastal ecosystems and landscapes should be preserved.

Descriptor 8 of the MSFD describes protection against pollution of marine waters by chemical contaminants.

In particular, with regard to Descriptor 8, the ecosystem - based approach focuses on the concentration of contaminants in the different matrixes, but also denotes that pollution effects need to be considered at various biological levels of organization: "Concentrations of contaminants are at levels not giving rise to pollution effects"

Descriptor 8 (MSFD) has been further developed by Commission Decision 2017/848 laying down criteria and methodological standards on good environmental status of marine waters:

The criteria elements considered are:

- Substances: under different consideration based on spatial criteria. For coastal and territorial waters, contaminants for which an environmental quality standard is established, river basin specific Pollutants and additional substances which may give rise to pollution effects. Beyond territorial waters, contaminants considered for coastal and territorial area where these still may give rise to pollution effects.
- Relevant species and habitats at risk from contaminants.
- Acute pollution events.

The criteria for the assessment of the above mentioned elements are:

- Concentrations of contaminants do not exceed legally established **threshold** values.

- The health of species and the condition of habitats are not affected by pollutants.
- The extent and effects of acute pollution events are reduced and eliminated if possible.

Descriptor 8: Concentration of contaminants

Criteria elements	Criteria	Methodological standards
Contaminants in a matrix with EQS	Concentrations do not exceed EQS Threshold Values	a) For each contaminant whether the threshold values set have been achieved b) The proportion of contaminants assessed which have achieved the threshold values, indicate substances behaving like ubiquitous persistent, bioaccumulative and toxic substances (uPBTs)
Contaminants in a matrix with no EQS	Concentrations do not exceed Threshold Values established by Member States through regional or sub-regional cooperation. *For RBSPs regional cooperation is already in place by WFD WG except for Med Sea*	
River Basin Specific Pollutants (RBSPs)		
Additional contaminants which may give rise to pollution effects in the region or subregion		

Table 1: Outline of the implementation for Descriptor 8

Descriptor 8: acute pollution events

Criteria elements	Criteria	Methodological standards
Significant acute pollution events involving polluting substances, as defined in Article 2(2) of Directive 2005/35/EC of the European Parliament and of the Council, including crude oil and similar compounds.	**D8C3 — Primary:** The spatial extent and duration of significant acute pollution events are minimised.	a) an estimate of the total spatial extent of significant acute pollution events and their distribution and total duration for each year.
Species of the species groups, as listed under Table 1 of Part II, and benthic broad habitat types, as listed under Table 2 of Part II.	**D8C4 — Secondary:** The adverse effects of significant acute pollution events on the health of species and on the condition of habitats (such as their species composition and relative abundance) are minimised and, where possible, eliminated.	a) an estimate of the abundance of each species that is adversely affected; b) an estimate of the extent of each broad habitat type that is adversely affected.

Table 2: Outline of the implementation for acute pollution events

The EEA marine thematic indicator on hazardous substances in marine organisms (MAR001) addresses the key policy question: *Are the concentrations and trends of hazardous substances in marine organisms acceptable*? This indicator describes the levels and trends in European seas of hazardous substances concentrations in marine biota. The indicator is based on the assessment of seven substances (sub-indicators): cadmium, lead, mercury, DDT, lindane, HCB and PCBs (Tsangaris et al., 2014).

It is noticeable that MSFD has provided a wide and rather unspecific framework for the protection of the marine environment. The Regional Sea Conventions and Action Plans are the world's only legal framework for protecting the oceans and seas at the regional level. They are cooperation structures which aim to protect the marine environment and bring together Member States and neighbouring countries that share marine waters. Comparability and harmonization respecting the particularities of each marine region must be assured in a sustainable management of the oceans. Therefore, Regional Sea Conventions experience and work is essential in this context. They have been monitoring and managing the geographical areas under their jurisdiction, for many years. At present, they are working with the objective of achieving the GES by 2020 as stated in the Marine Framework Directive. Both HELCOM and OSPAR have developed aggregated assessment methodologies. UNEP

MAP has followed OSPAR's methodology using Mediterranean data from UNEP/MAP MED POL database to perform the assessment (Tab. 2).

HELCOM	OSPAR	UNEP MAP
• Monitoring and assessment strategy revised 2013 • Monitoring manual "Combine" revised 2015 • Core indicators to measure progress towards GES and Baltic Sea Action Plan Objectives (HBCDD, Cd, Pb, Hg, PFOS, PBDE, Cs-137) • Helcom data portal. Updated 2016 monitoring stations focused on MSFD. No data available yet • By now data focused in sediment and biota. • Traffic light schema for visualization	• OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2021 (updated 2016) • CEMP guidelines for coordinated monitoring for hazardous substances (OSPAR Agreement 2016-04) • List of Chemicals for Priority Action (Revised 2013) • Monitoring only in sediment and biota • Long-term background series for some substances • ICES data centre serves for data handling, management and storage • Traffic light schema for visualization	• Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria (IMAP), 2016-2021 • Integrated monitoring and assessment guidance (updated 2016) • Common indicators and key contaminants to asses trends and progress towards GES • Follow Ospar methodologies to establish assessment criteria • No public Information data system

Table 3: Comparison between Regional Sea Convention approaches

UNEP/MAP has agreed on common indicators for hazardous substances addressed by Ecological Objective 9: Contaminants cause no significant impact on coastal and marine ecosystems and human health of the Ecosystem Approach.

Assessment of environmental status is carried out comparing contaminant levels against background thresholds (BACs) (UNEP/MAP, 2016a). However, accurate environmental assessment criteria (EACs) defining acceptable or non-acceptable environmental chemical status in the Mediterranean Sea from an environmental perspective have not been determined yet, and the current approach relies on threshold adopted by UNEP/MAP, 2016a (based on European policy for biota: EC/EU 1881/2006 and 629/2008 Directives for maximum levels for certain contaminants in foodstuffs, and US Effects Range Low - ERL values sediment toxicological criteria) for sediments (Table 4).

Trace metal	[a]Mussel (MG) µg/kg d.w.			[b]Mussel µg/kg d.w.	[c]Fish (MB) µg/kg d.w.[f]			Sediment µg/kg d.w.		
	BC	Med BAC	EC	BAC	BC	Med BAC	(EC)	BC	[e]Med BAC	ERL
Cd	725	1088	5000	1000	4	8/16[d]	207	-	150	1200
Hg	125	188	2500	170	296	600	4150	-	45	150
Pb	2500	3800	7500	1000	279	558	1245	-	30000	46700

[a] preliminary data for the NW Mediterranean (Spain);
[b] additional BAC data provided by Lebanon for *Brachidontes variabilis* species;
[c] preliminary data for the NW Mediterranean (Spain);
[d] earlier estimation wet weight;
[e] estimated from sediment cores (UNEP(DEPI)/MED WG.365/Inf.8, 2011);
[f] a dry/wet ratio of 20 should be used to convert units for MG (f.w. units = d.w. units / 5)

Table 4: IMAP Assessment Criteria for Heavy Metals and other existing assessment criteria.

In this framework, HarmoNIA aims to propose harmonized rules and guidelines for the analysis and visualization of data on marine contaminants, thus to support the practical implementation of cross-border environmental status assessment and strategic assessment.

3. Objective

Visualization is a useful tool to gather datasets and produce practical and understandable information for many stakeholders and decision makers (Fig. 1). Transmitting data effectively is as important as monitoring and data management.

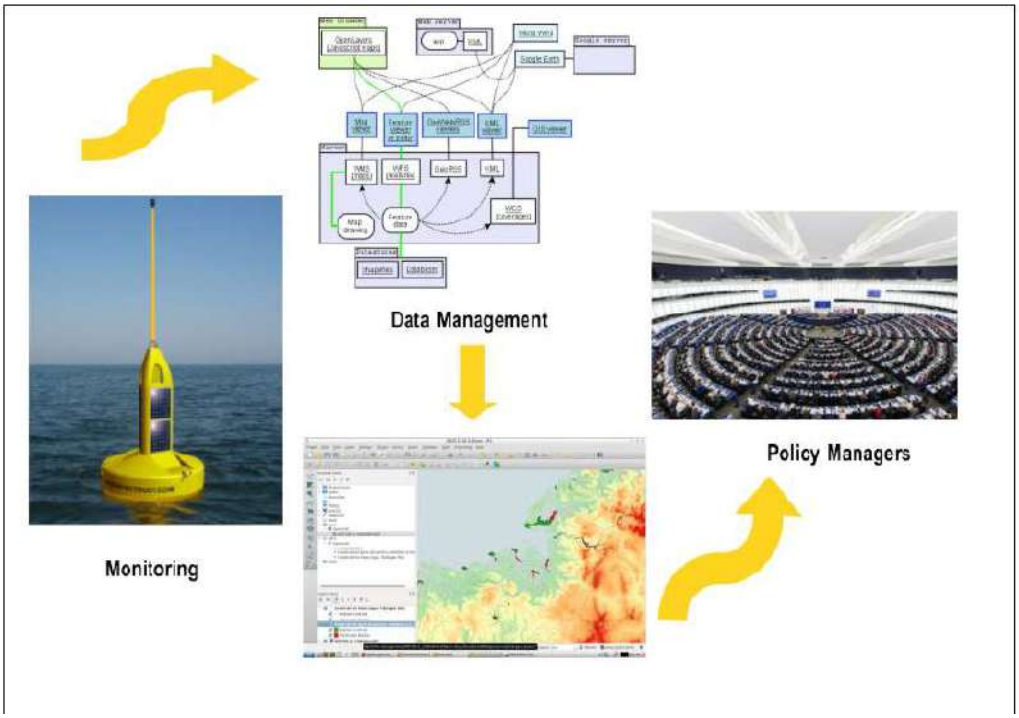

Figure 1: From environmental monitoring to decision making

The visualization of contaminant levels in the marine environment can be a useful instrument to facilitate the evaluation of the environmental status, according to a common and harmonized approach. Several methods and tools have been proposed to assess where concentrations of hazardous substances in the marine environment are at levels which may pose an unacceptable risk to the environment and its living resources (OSPAR, 2009; Lyons et al., 2017).

A review of the instruments currently used within the ADRION region to visualize contaminant level has been performed (Annex: HarmoNIA Data Products Inventory). Based on this review, an inventory of data visualization products commonly found for the assessment of contaminants in the Adriatic – Ionian seas is available. Best practices from Regional Sea Conventions in other areas (eg. OSPAR, HELCOM) have been additionally included. To address current lack of harmonization, the inventory

of data visualization products has been shared and discussed among HarmoNIA network, to select the most useful examples which will be adopted to display contaminant levels for the ADRION region.

According to the best examples, HarmoNIA proposes guidelines to:

- articulate a synthetic and scientifically meaningful way to analyse and represent data
- illustrate spatial variability and temporal trends of the given chemical parameters
- define data products specifically relevant for the MSFD

Upon agreement with data providers, part of the gathered data sets will be used, in selected key areas, to create examples of common data outputs useful for management of contamination at transnational scale. Partners in charge of environmental monitoring and assessment have shared their procedures of data aggregation for chemical status assessment and have contributed to the inventory of data visualization products used in the different countries. On the other hand, partners mainly involved in scientific research have provided experience in the field of statistical analysis and have, thus, provided an additional complementary information useful to identify best practices.

Capitalization from previous projects and synergy with similar initiatives (eg. IRIS-SES, EMODnet Chemistry, SeaDataCloud, …) provides added value to the task, increasing the knowledge and improving the quality of the support to the MSFD assessment.

The collected information is used to define common guidelines for the Adriatic - Ionian region for the visualization of data on contaminants, required to assist the harmonized implementation of MSFD in the area.

Taking into account IMAP and MSFD requirements, data visualizations must provide information on:

Thresholds: To allow assessing that: “Level of pollution is below a determined threshold defined for the area and species” it is useful to visualize thresholds (when available).

Trends: To allow assessing that “Concentration of priority contaminants is kept within acceptable limits and does not increase”.

4. Needs: temporal and spatial scales

According to Article 3.5 of the MSFD, good environmental status of MS marine waters shall be determined at the level of the marine region or sub-region.

Assessments need to be done at spatial scales that are ecologically significant to provide information on the environmental status, which is relevant to ecosystem-based management. The assessments have to support management of the human activities and pressures in the marine environment, in order to achieve GES in line with the ecosystem-based approach.

These evaluations are carried out to estimate: the (change of) **environmental status**, the **impact of human activities** and the **effect of policy measures**.

Member States should express the extent to which good environmental status is being achieved as:

- the proportion of their marine waters over which the threshold values have been achieved

or

- the proportion of criteria elements (species, contaminants, etc.) that have achieved the threshold values.

When assessing the status of their marine waters in accordance with article 17(2)(a) of the MSFD, Member States should express any change in status as **improving**, **stable** or **deteriorating** compared to the previous reporting period, in view of the often slow response of the marine environment to change.

Consequently, monitoring data must provide information on spatial and temporal variability and trends in concentration. The objective is to verify progress towards good environmental status and to evaluate if pollution is progressively being phased out, i.e. the presence of contaminants in the marine environment and their biological effects are kept within acceptable limits, so as to ensure that there are no significant impacts on or risk to the marine environment.

Aggregation inevitably causes loss of information, but information requirements can differ, depending on the purpose. Environmental assessments address different information needs and different spatial scales, from small spatial scales, needed for management measures, up to assessments at level of (sub)regions to follow policy implementation (Prins et al., 2014).

Geographic assessment and reporting scales have to be chosen in such a way that assessments provide the right information to the process of policy implementation and management of marine areas, and at the same time, must take into account

ecological considerations (eg. hydrodynamics, biogeography, habitat distributions). For descriptors 5, 8 and 9 with clearly localized sources of pollution, hydrodynamic play an important role.

Spatial scale

For all descriptors, the spatial scale of assessment and reporting of environmental status are of major importance. The scale may be different among the descriptors as the affected environmental compartments may differ. It will be important that the scale allows the observation of the functioning of ecosystems at the level where it might be compromised. Upscaling to larger areas might then show the extent of that problem (Law et al., 2010). While certain aspects of GES under Descriptor 8 are being affected at very large scales, as e.g. the pollution by long range transport of persistent pollutants, other impacts occur at a more local scale.

With regard to descriptor 8, products should facilitate the **identification of sites below or above EQS thresholds** (Fig 2).

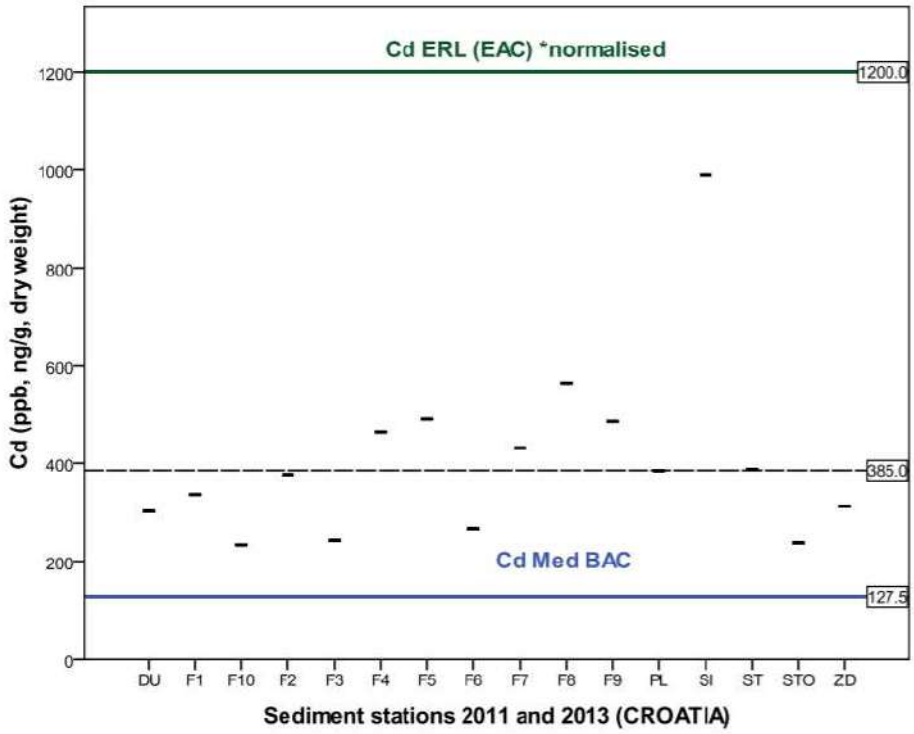

*Figure 2: Example from UNEP(DEPI)/MED, 2016: Cadmium data for 2011-2013. The dashed line represents the median and the Med BAC (*background thresholds for Mediterran*) and EAC (*environmental assessment criteria*) are also presented for reference.*

The visualization should allow comparison of the concentration of contaminants between sites (spatial distribution), highlighting areas with high concentrations of contaminants that are of concern (Fig. 3).

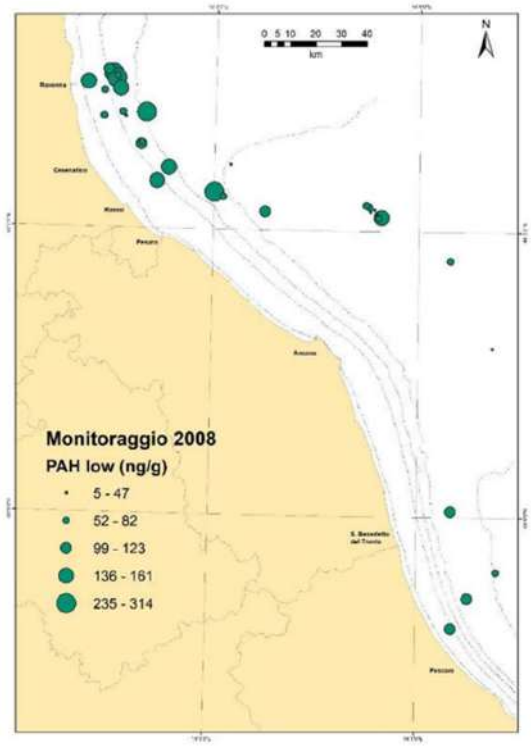

Figure 3: Spatial distribution of concentration on contaminants in surface sediment (ISPRA).

One important point to take into account is the spatial coverage of monitoring stations and their associated metadata to evaluate the quantity of available data and the reliability of the assessments. Metadata from the monitoring stations can be visualized in order to provide information adressed to cover needs from different users or stakeholders: monitored matrix, group of substances, monitoring frequency.

In the Mediterranean region, for the assessments, three types of monitoring stations have been considered by MEDPOL: Hotspots, Coastal and Reference (Fig. 4).

- **Hotspots**: "Point sources on the coast which potentially affect human health, ecosystems, biodiversity, sustainability or the economy in a significant manner. They are the main points where high levels of pollution loads originating from domestic or industrial sources are being discharged".

- **Coastal**: "Defined coastal areas where the coastal marine environment is subject to pollution from one or more point or diffuse sources on the coast which potentially affect human health in a significant manner, ecosystems, biodiversity, sustainability or the economy".
- **Reference**: Reference condition or state (sometimes referred to as background levels); concentrations of certain substances that would be expected in "pristine" or "remote" sites, based on the available monitoring data (such as Reference Areas/Stations).

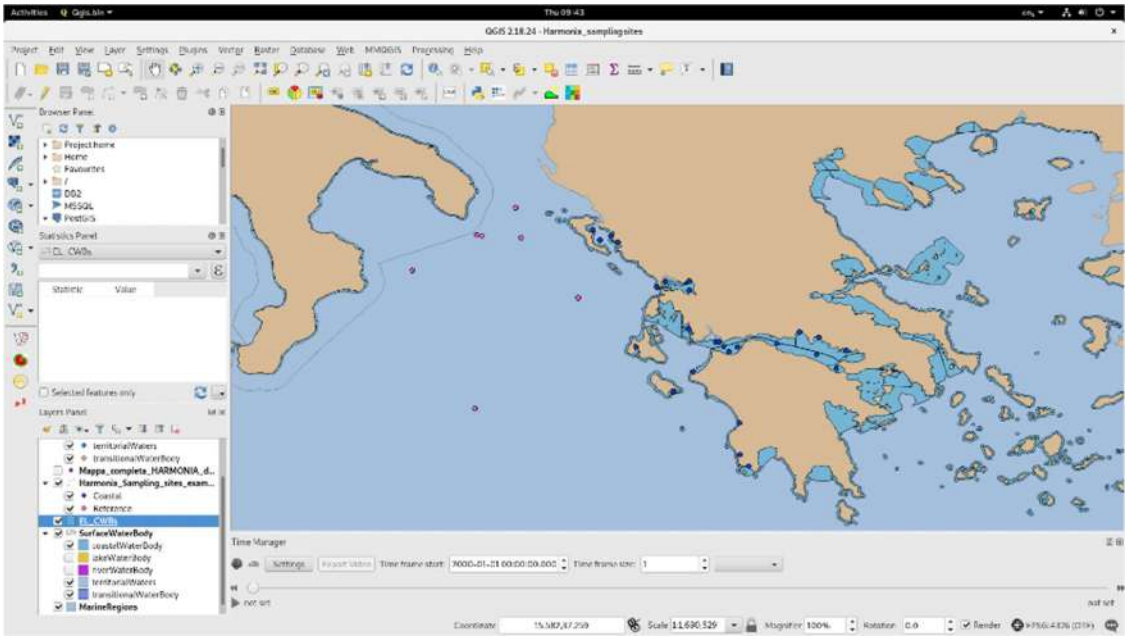

Figure 4: Example of coastal and reference monitoring stations in the Adrion Region (Greece)

Temporal scale

For the purpose of the MSFD, Member States shall keep up to date their marine strategies. The review of these instruments should be done every six years after their initial assessment.

However, as it was mentioned before, assessment scales must be selected taking into account ecological elements and the slow response of the marine environment to change.

"Spatially extensive multi-decadal time series add value by providing a regional perspective with which to interpret local ecological changes over long time scales. This is particularly relevant for the MSFD, which requires a regional sea-scale approach to marine management and monitoring" (McQuatters-Gollop, 2012)

Time scales and spatial scales of assessments are closely related, and the choice for a specific time scale may have consequences for the spatial scale. In practice, it will be difficult to decide on appropriate spatial scales without considering the temporal scales at the same time (Prins et al., 2014).

At regional level, for the Mediterranean, two basic types of monitoring are identified within the framework of MEDPOL, compliance and trend monitoring (UNEP(DEC)/MED WG.282/Inf.5/Rev.1, 2006).

Compliance monitoring is defined as the collection of data through surveillance programs to verify that the regulatory conditions for a given activity are being achieved.

Trend monitoring is defined as repeated measurements of concentrations or effects over a period of time to detect possible changes with time and also with space. Sediment monitoring is usually handled within trend monitoring activities, being an integral part of the monitoring system established for hot spots and coastal waters.

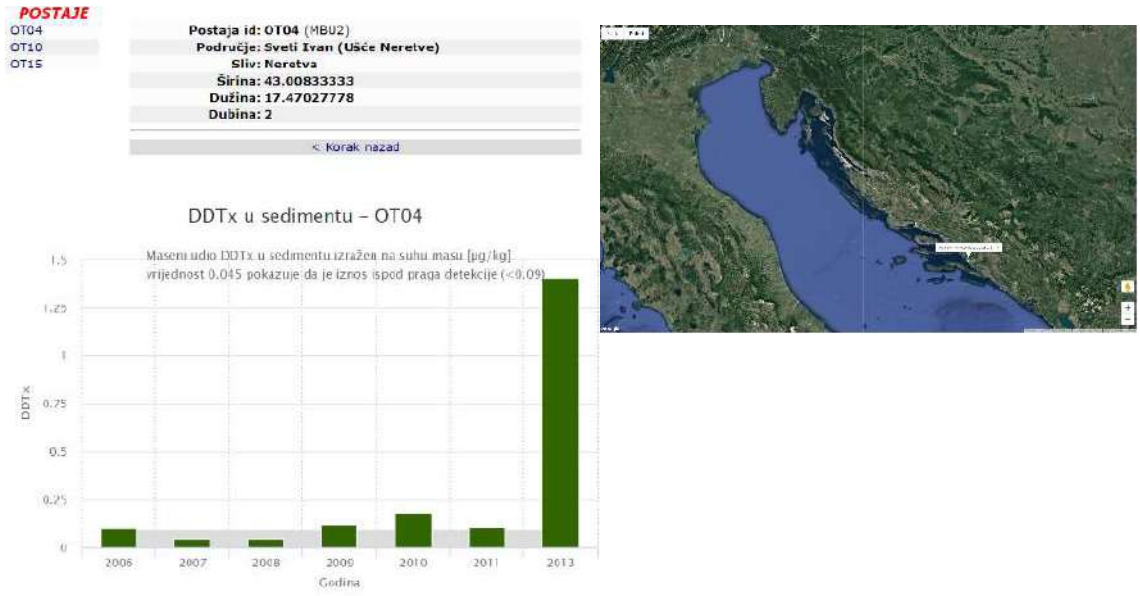

Figure 5: DDTx in sediment trend for one station in Croatia. The grey area represents the Limit of Detection of the chemical variable.

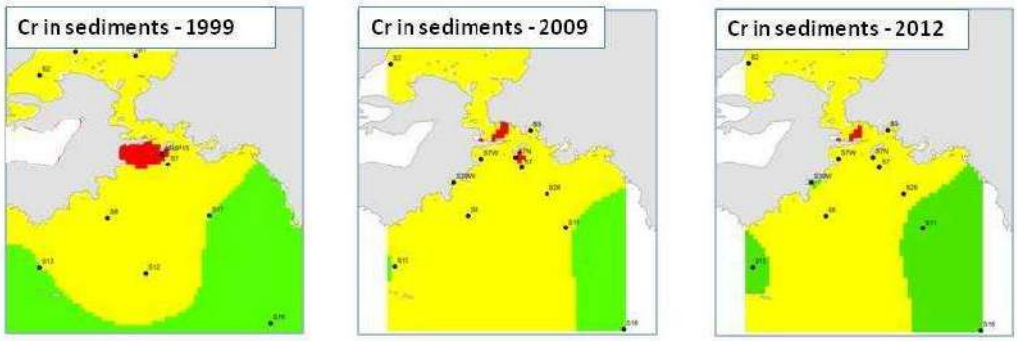

Figure 6: Contaminants in sediment toolset run for the Greek coast - Saronikos Gulf

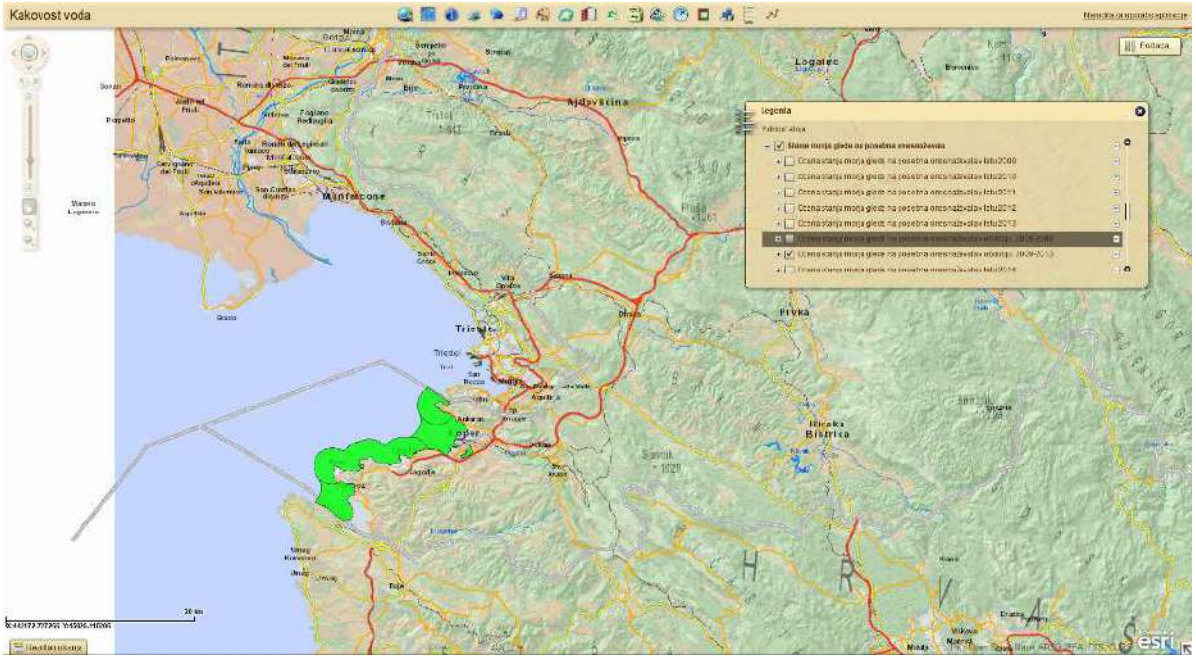

Figure 7: Interactive maps presenting the status of Slovenian coastal water bodies according to the concentration of national relevant substances (ARSO)

5. Statistics used

In the framework of analysis of temporal trends and level of chemical contaminants, UNEP/MAP MEDPOL used following statistics (UNEP(DEPI)/MED WG.427, 2016):

For the **level assessments**, medians, interquartile ranges (IQR), concentration ranges and lower and upper quartiles (Box-and-Whisker plots) for each chemical

have been calculated in order to characterise the populations and to identify the extreme values and outliers (including also the arithmetic mean for reference).

For **trend analysis**, work within OSPAR Convention has proposed three trend detection methods all at once with the idea to take the benefits of all methods, because there is not only one statistical method which always offers the best analysis of the environmental monitoring datasets. Each one has its own capabilities and underlying assumptions. The three methods (Mann-Kendall, linear regression and LOWESS smoother) are amongst the most commonly used in this field. The priority is given from the simplest to the more complex method. The non-parametric Mann-Kendall is the most robust to outliers, but in case of a linear trend, the linear regression has more statistical power. The smoother algorithms are used to detect non-linear trends (UNEP(DEPI)/MED WG.427, 2016).

The last Quality Status Report of the Mediterranean (Mediterranean QSR, 2017) reports that the method for the assessment has been undertaken by evaluating the latest and available MED POL datasets of levels of chemical contaminants against set environmental criteria (for different matrices) at a regional scale. The assessment methodology is based on the calculation of the percentages of stations (units) with levels below or above the BACs and above ECs and ERLs, and plotted spatially (Fig. 8).

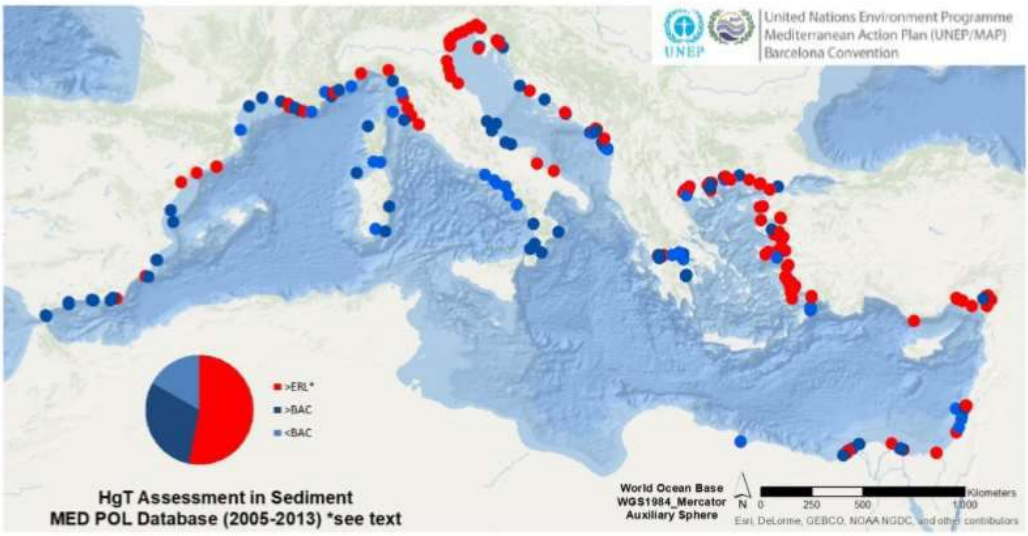

Figure 8: Example from Mediterranean QSR 2017: Regional Mercury levels assessment against ERL [1]criteria in sediment for the Mediterranean Sea

[1] ERL: Effects Range-Low values developed by the United States Environmental Protection Agency (US EPA) for assessing the ecological significance of sediment concentrations. ERL is the lower tenth percentile of the data set of concentrations in sediments, which were associated with biological effects. Adverse effects on organisms are rarely observed when concentrations fall below the ERL value.

6. Analytical Quality

Analytical Quality assurance is a fundamental pre-requisite for the assessment of the status of chemical contamination and information of data QA is essential to allow comparison among different datasets.
As availability of good quality data on contaminants is still a bottleneck for large scale environmental status assessment, some compromises and some approaches have been proposed in order not to discard possibly useful data. If limited information of QA exists, data were given analytical weights according to the available QA information within OSPAR's Coordinated Environmental Monitoring Programme (CEMP) (OSPAR, 2008). A similar approach proposed by Nicholson & Fryer (2002) was to use the available QA information to categorise the analytical quality of data as *Good, Poor, Unknown* and *Unacceptable* and allocate statistical weights $1 > W_{poor} > W_{unknown} > 0$ accordingly. The approach is simple and intuitively appealing, however, the choice of statistical weights is arbitrary.

Taking into account work done in the framework of EMODnet Chemistry Phase III, it is proposed to display concentrations of chemical substances with regard of analytical Limit of Quantification (LOQ) or to Limit of Detection (LOD), when available, in order to provide information on "fitness for use for environmental quality assessment" (Giorgi et al., 2018 http://www.emodnet-chemistry.eu/repository/EMDChem-ProposalForContaminant-Maps_V4.pdf).

Minimum performance criteria for methods of analysis to be applied when monitoring water status, sediment and biota, as well as rules for demonstrating the quality of analytical results, are determined in COMMISSION DIRECTIVE 2009/90/EC, laying down technical specifications for chemical analysis and monitoring of water status. Member States shall ensure that all methods of analysis, including laboratory, field and on-line methods, used for the purposes of chemical monitoring programmes are validated and documented in accordance with EN ISO/IEC-17025 standard or other equivalent standards accepted at international level. Minimum performance criteria for all methods of analysis applied should be based on an uncertainty of measurement of 50 % or below (k = 2) estimated at the level of relevant environmental quality standards and a limit of quantification equal or below a value of 30 % of the relevant environmental quality standards.

7. Categories of products proposed

Taking into account the requirements previously described, the information collected within HarmoNIA partnership (Annex: HarmoNIA Data Products Inventory) and the need of user-friendly data visualization, following products are proposed to achieve a harmonized visualization approach for spatial distribution and temporal trend of selected marine contaminants in the ADRION region:

Spatial distribution of data and stations with different visualizations pointing out several important aspects regarding the sampling points or the measurements (using different symbologies in the maps and/or graphics will be realized. To allow visualization of concentration of chemical substances in the monitored stations, station maps with point size proportional to concentration and/or bar charts will be produced (ex. Fig. 3).

Temporal trends will be visualized with bar charts, which will be available per station/group of stations (ex. Fig. 5).

Annual **median** concentrations will be displayed, and products will also display threshold levels, when available, for the different matrices (eg. EQS, EAC, ERL, EC). Lastly, when sufficient information is available, products will display data below and above Limit of Quantification (LOQ) or Limit of Detection (LOD).

These proposed products will be available through OGC Web Map Services (WMS) and Web Feature Services (WFS) for visualization (and downloading) of the data.

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Romano, S., Langone, L., Frignani, M., Albertazzi, S., Focaccia, P., Bellucci, L. G., & Ravaioli, M. (2013). Historical pattern and mass balance of trace metals in sediments of the northwestern Adriatic Sea Shelf. Marine pollution bulletin, 76(1-2), 32-41.

Tsangaris C., Stolte W., Kaartokalio H., Iona A., van der Meulen M., Simboura N. (2014). Development of a shared data and information system between the EU

and the Regional Sea Conventions. Deltares, Proposal under Framework contract No ENV.D2/FRA/2012/0019

UNEP(DEPI)/MED WG.427/Inf. 4 2016 Marine Pollution Monitoring Regional Data Base and Reporting, MED POL Database Gaps and Related Quality Assurance Issues. Temporal Trends and Levels Analysis for Chemical Contaminants from the MED POL Database

UNEP/MAP 2016a. Decision IG.22/7 - Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria. COP19, Athens, Greece. United Nations Environment Programme, Mediterranean Action Plan, Athens

UNEP/MAP 2016b. Decision IG.22/7 - Integrated Monitoring and Assessment Programme (IMAP) of the Mediterranean Sea and Coast and Related Assessment Criteria. COP19, Athens, Greece. United Nations Environment Programme, Mediterranean Action Plan, Athens

Webster L., Fryer R., Davies I., Gubbins M., Roose P., Moffat C. 2010 Environmental status assessment of contaminant concentrations in sediment and biota – Assessment criteria and data integration. ICES CM 2010/F:10

Annex: Questionnaire on data products

Harmonization and Networking for contaminant assessment in the Ionian and Adriatic Seas

Questionnaire on data products - Annex to Deliverable T2.3.1

Work Package T2 - Data collection and definition of common data outputs focused on contamination

Coordinators:
M.E. Molina Jack, Lipizer M. – OGS

Contributors:
M. Giani – OGS, G. Giorgi – ISPRA, D. Ivankovic - IOF, C. Zeri, S. Iona - HCMR, M. Fafandjel - RBI, D. Joksimovic, A. Castelli, Milena Mitric – UoM-IMBK, M. Dobnikar Tehovnik, M. Poje, M. Velikonja – ARSO, R. Bakiu - AUT

January 2018

Index

1. Introduction

The following Questionnaire has been circulated within HarmoNIA partnership in order to collect information and experience needed to define best practices for visualization of data on contaminant concentrations in the marine environment, to facilitate evaluation of environmental status.

2. Questionnaire

2.1. Can you share your experience in visualization of spatial distribution of contaminant concentration:

(If yes, please provide examples such as plots in scientific papers, plots in reports, link to website, ... that can help to gather information within HarmoNIA.)

PP1- OGS, Italy

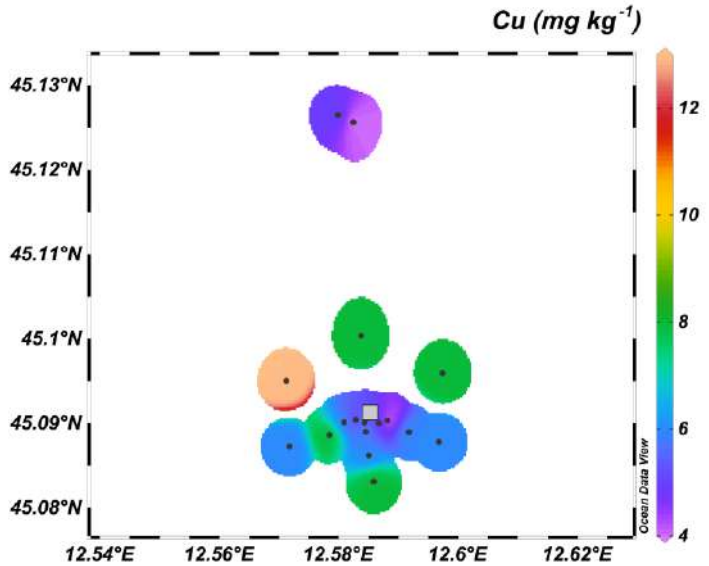


Figure 1. Spatial distribution of copper (mg kg^{-1} d.wt.) in surface sediments around an offshore platform (grey square symbol).

Spatial distribution maps of trace metals (example in Fig. 1) were produced using Ocean Data View with a colour scale differentiating the different levels of the target metal in the sediment.

PP2 - ISPRA, Italy
seawater Yes

sediment	Yes
biota	Yes

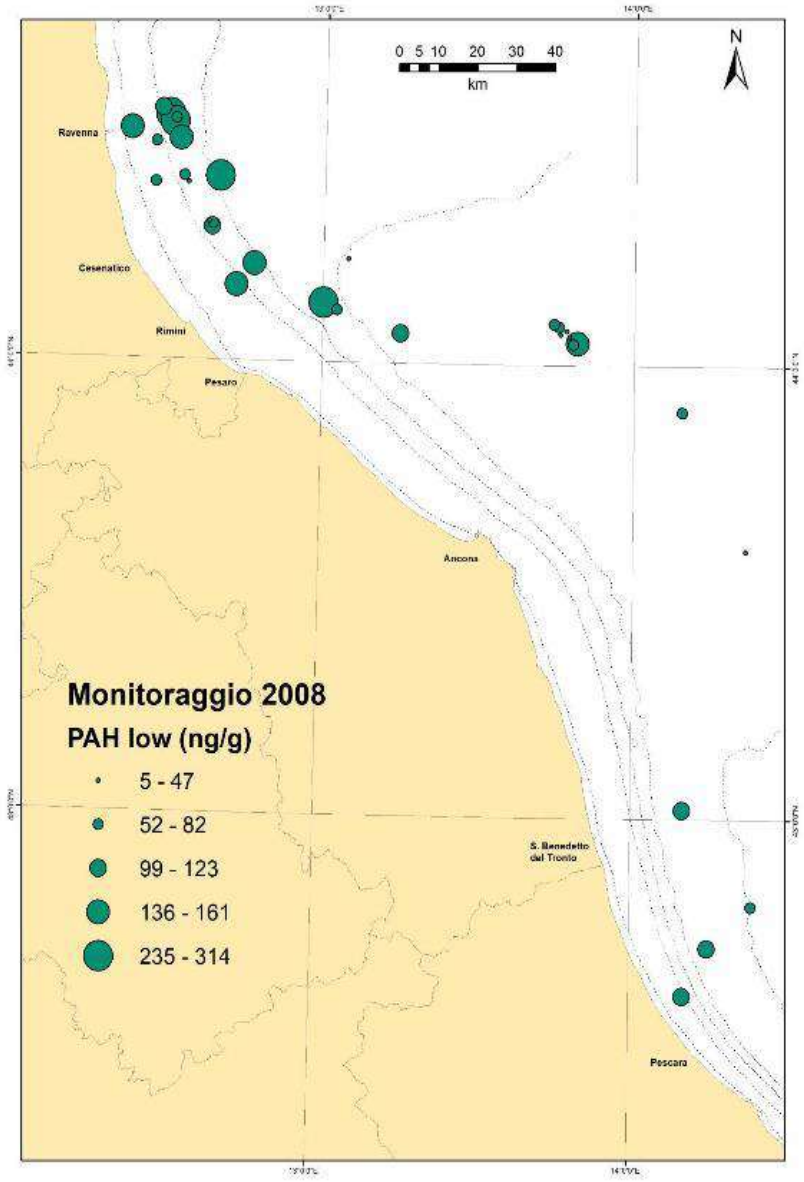


Figure 2. PAH lmw (low molecular weight): average of the three superficial level samples within a distance of 50 m from each platform.

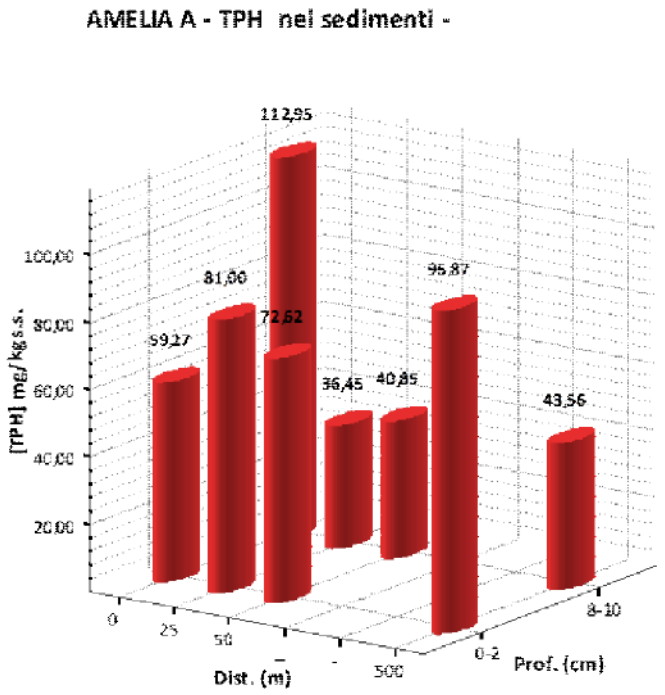


Figure 3. TPH (mg/kg) in "Amelia A" platform - Estate 2008. Stations along a transect from platform to 500 m distance.

In addition, PP2 coordinates the definition and preparation of maps on contaminant, within EMODnet Chemistry initiative, with the aim to display data spatial distribution, evaluate data quality and fitness for use for MSFD environmental quality assessment. In order to provide information on "fitness for use for environmental quality assessment", products will display data below and above Limit of Quantification (LOQ), data with LOQ above or below 30 percent of EQSD threshold values, data below and above EQSD threshold values, as well as will provide information on matrix.

PP3 - IOF, Croatia

seawater NO data in seawater
sediment State of marine environment, aquaculture and fisheries indicators database
biota State of marine environment, aquaculture and fisheries indicators database

PP4 - HCMR, Greece

seawater yes
sediment yes
biota yes

HCMR Experience within EMODnet Chemistry Project

HCMR is partner in EMODnet Chemistry Project. More specifically is responsible for the data aggregation and DIVA products (horizontal concertation maps) preparation for the region of the Mediterranean Sea. Spatial distribution maps describing the geographical coverage of the aggregated data collections prior to the DIVA analysis are prepared with the use of ODV software tool, an example is shown in Fig. 4 (a) below.

After the data products preparation, for their visualizations and do their downloading, it is used the OceanBrowser Viewing service (http://ec.oceanbrowser.net/emodnet/), developed and maintained by University of Liege. The service provides horizontal and vertical sections as shown in Fig. 4 (b)

In addition, partner Deltares has developed additional WPS visualisation services for the aggregated data collections which generate fully dynamic plots of the data at a selected location as time series or as profiles. More specifically there are generated:

- Plots of time series and profiles of selected parameters from data sets of selected stations
- Maps of regional data collections displaying spatial resolution in time and intensity of data availability for selected parameters

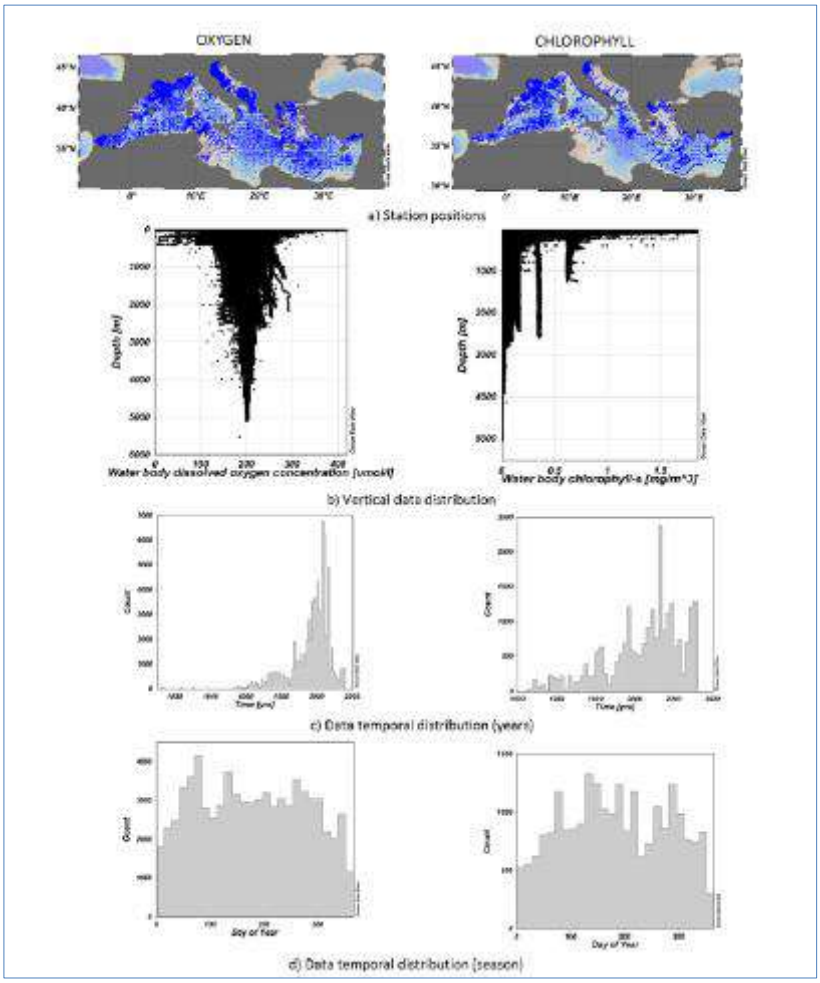
More details can be found the final report of EMODnet Chemical phase 2, 30/11/2016

Other HCMR experience:

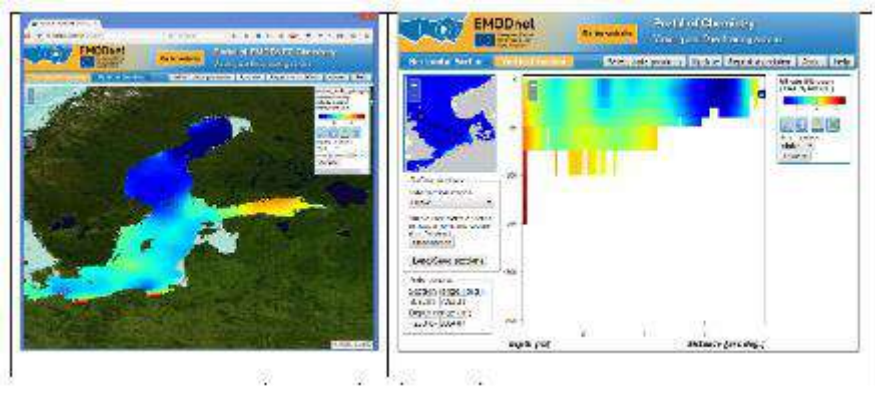
GIS toolboxes has been developed to assess the Environmental Status (ES) related to Contaminants (Descriptors 8, and 9) within the scope of IRES-SES Project. The concept was to provide a set of simple but intelligent tools, to support scientists as well policy makers, managers, stake-holders and in general people who are not experts on these issues (eutrophication and contaminants). It should also have been developed as a state-of-the-Art taking into consideration all the latest developments under the MSFD monitoring requirements (e.g. WG DIKE, ATKINS data base, scoring of indicators, monitoring gaps, etc) with the strategic aim to be a tool for the monitoring requirements of MSFD. It was essential to be able to use the product-tools in both Mediterranean (Western & Eastern) and Black Sea.

The product - tools have initially developed as a desktop toolbox for ArcGIS version 10.2.x. and contain a set of customized commands that allow users to create grids of the relevant indices from an input biochemical point dataset in a common excel file format. The names of these toolboxes are "Contaminants in sediments" , and "Contaminants in biota". The materials which have been used are Model Builder Module of ArcGIS and ArcGIS Toolboxes (Geoprocessing, Spatial Analyst etc). The minimum software requirements are the user to have a licensed copy of the ArcGIS 10.2.x platform, as well as the Spatial Analyst extension. There are no other

minimum hardware requirements than those suggested by ESRI for the ArcGIS 10.2.x platform with the Spatial Analyst extension.
A general deficiency in generating a GIS tool for contaminants (D8-D9) has been identified. The literature does not provide any widely accepted policy on the assessment of pollution in waters, sediments and seafood. Therefore, the data for the case study areas (Saronikos Gulf, Mediterranean coast of Spain, Danube River Delta) have been collected and organized in terms of station-coordinates-parameter in Excel files. The thresholds on various contaminants have been listed and a GIS application for the analysis and visualization of pollution status according to ERL-ERM (Long, 1995), Directive 2006/44/EC and EC REGULATION No 1881/2006, national legislation and experts judgment. These values can also be modified by the user according to his experience or the current status of the threshold definition based on national or European decisions. Two main categories of contaminants are considered, PAHs and Metals (Cd, Hg, Cu, Pb, Zn) in Sediment, Seawater and Seafood. The toolbox for PAHs in Sediment has already been developed (Figures 5).
At this point the tool has been developed for Spain, Greece and Romania, i.e. the countries who provided input data during IRIS-SES project; marine boundaries for those countries have been embedded in the tool. The future development of the tool, beyond the scope of IRIS-SES, will comprise the rest of the countries and the Web version of the toolbox. This version will be implemented through web geoprocessing services WGS in ArcGIS Server Platform. In addition, the connection of the tools with established databases will permit their use without initial user input data.

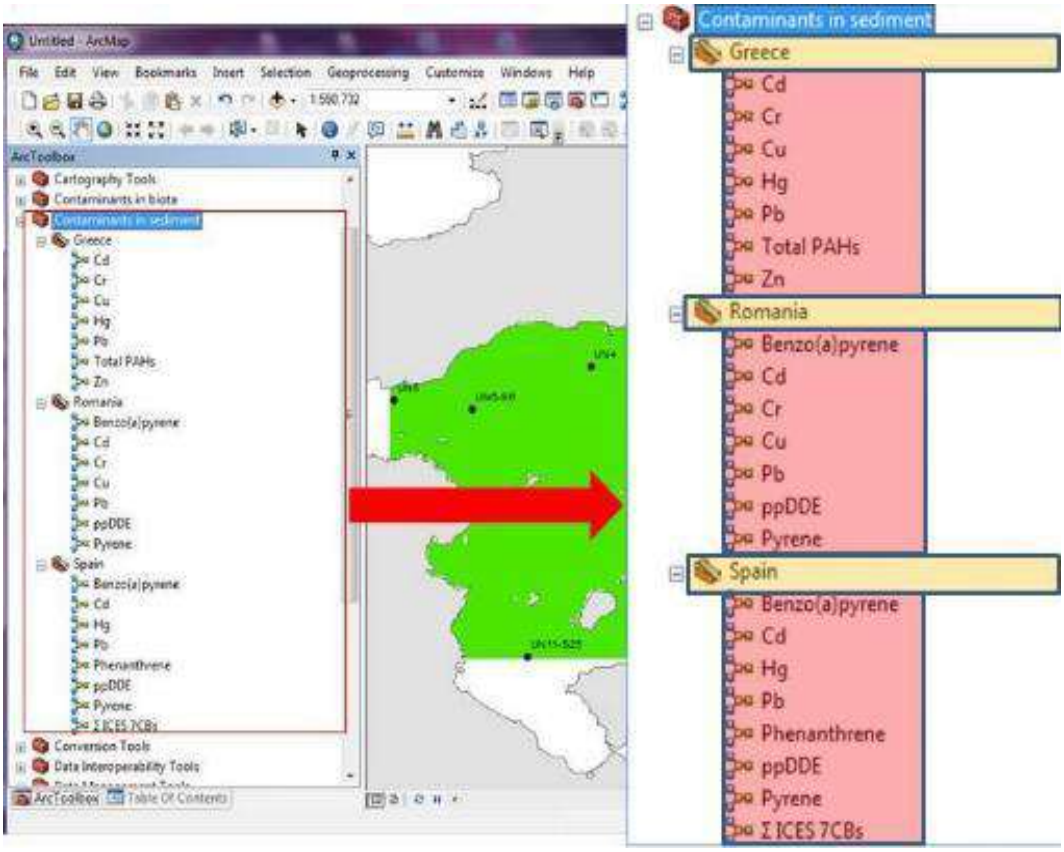


(a)

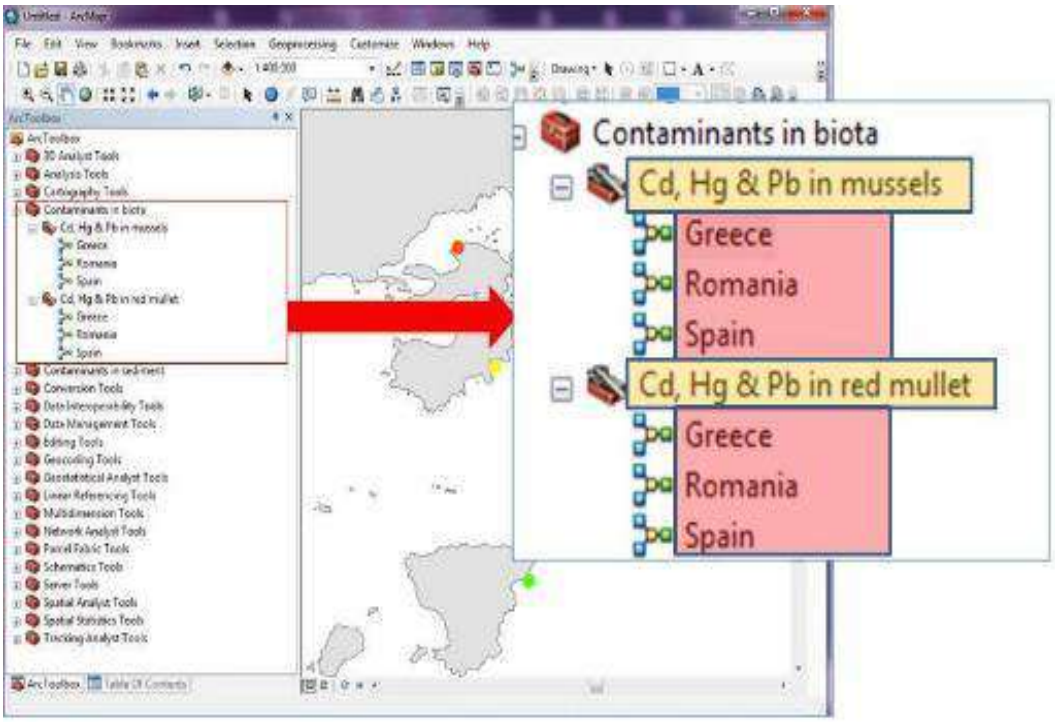


(b)

Figure 4. (a) Example of spatial and temporal distributions of aggregated data collection prior to DIVA analysis, (b) horizontal and vertical sections of data products (excerpt from EMODnet Chemical phase 2 final report-v2, 30/11/2016)



(a)



(b)

Figure 5. Contaminants in (a) sediment and (b) biota: GIS Toolbox structure

PP6 – IRB, Croatia

biota yes (Fig 6)

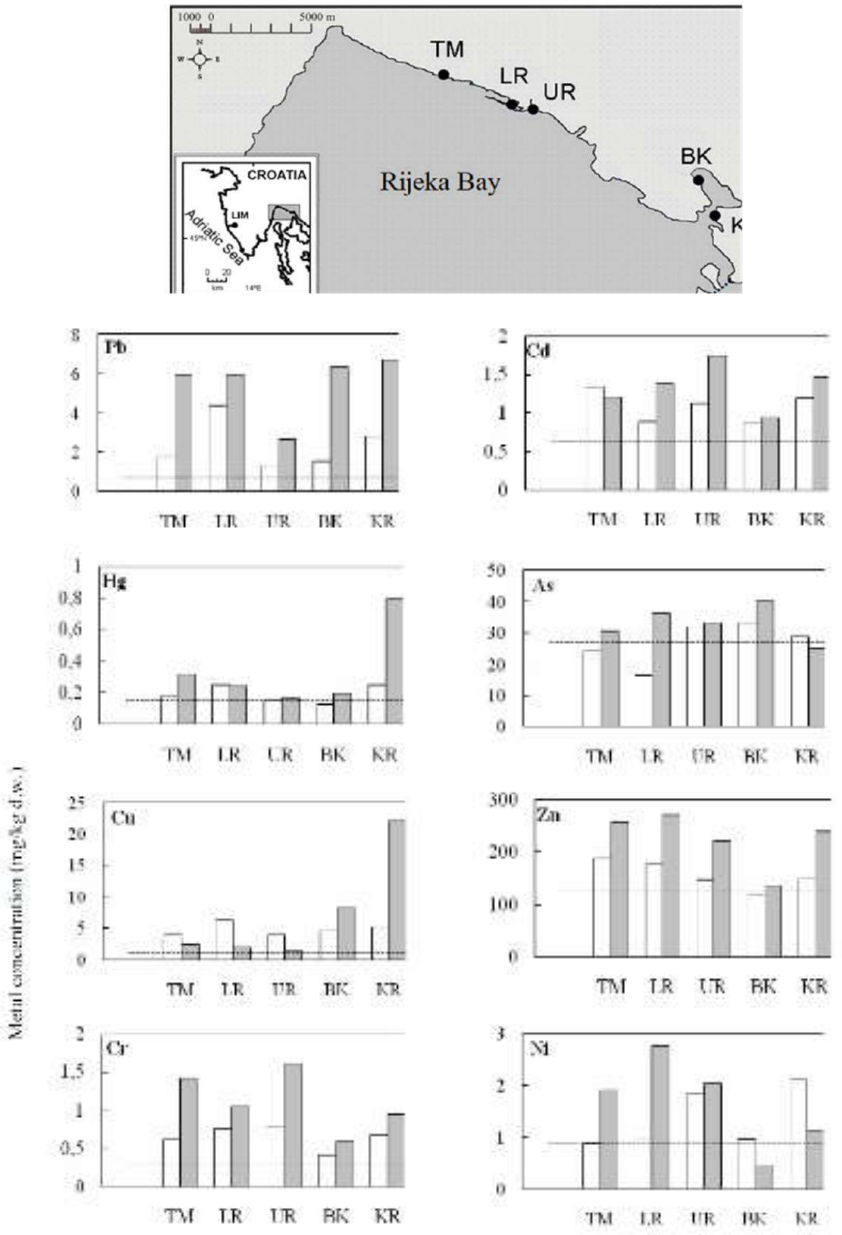
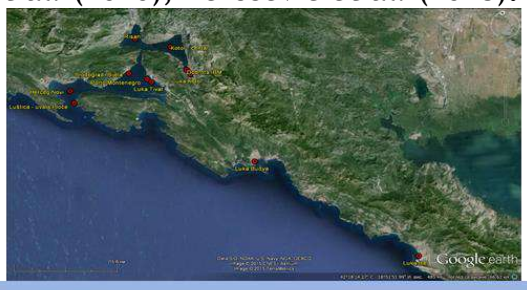


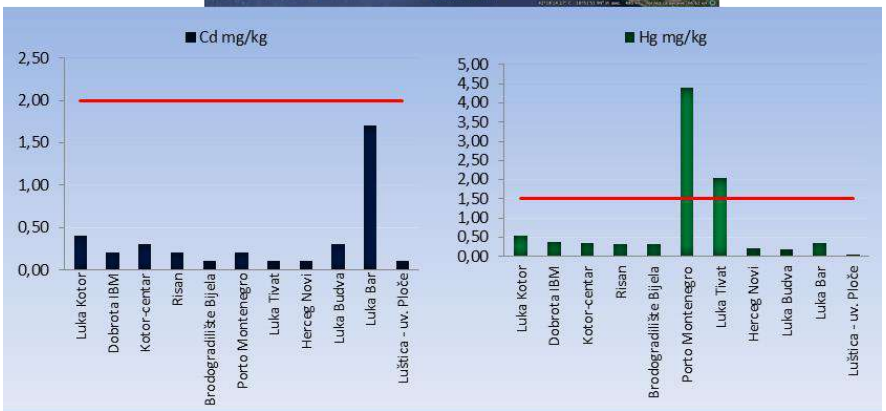
Figure 6. Concentration of metals (mg/kg dry weight in the soft tissue of caged (white) and resident (grey) mussels from Rijeka Bay). The dotted horizontal line indicates concentration of respective metal in control mussels from site Lim.

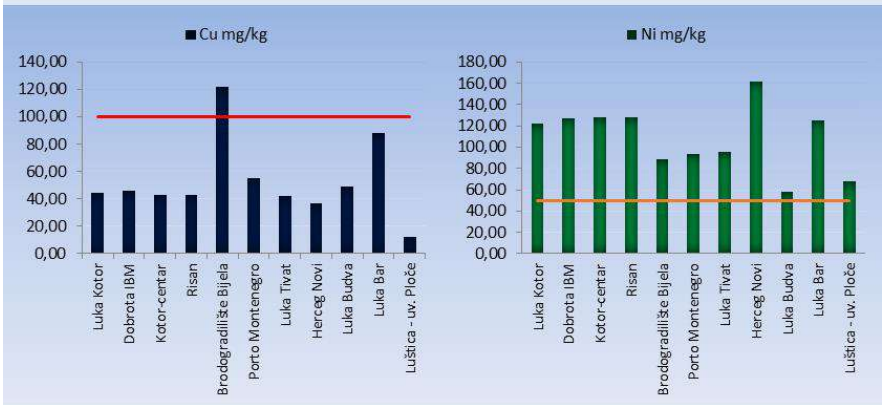
PP7 – UoM-IMBK, Montenegro

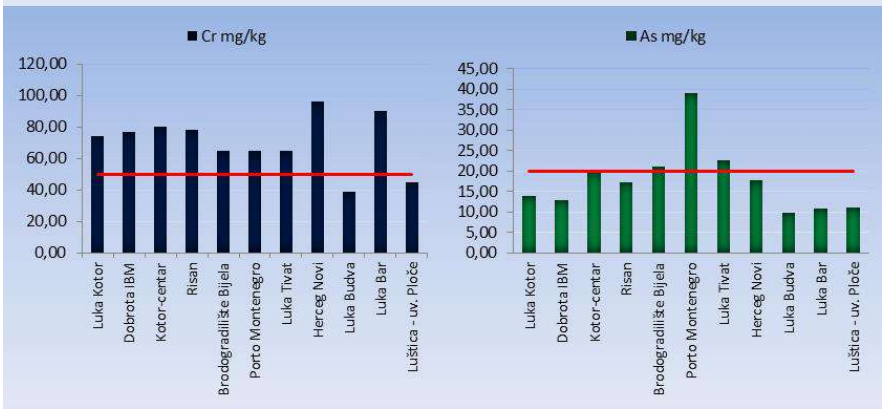
UoM-IMBK shares experience on Montenegro National Monitoring of the environment - EPA Montenegro on visualization of spatial distribution of contaminants in surface sediment, with comparison with MAC (Maximum Allowable Concentrations) according to „Rulebook on permitted amounts of

hazardous and harmful substances in soil and methods of interrogating" (Official Gazette, 18/97) (Fig. 7).
Furthermore, examples of spatial distribution of some contaminant data (biota, sediment) are presented in the following scientific papers: Tanaskovski et al. (2016); Perosevic et al. (2018).









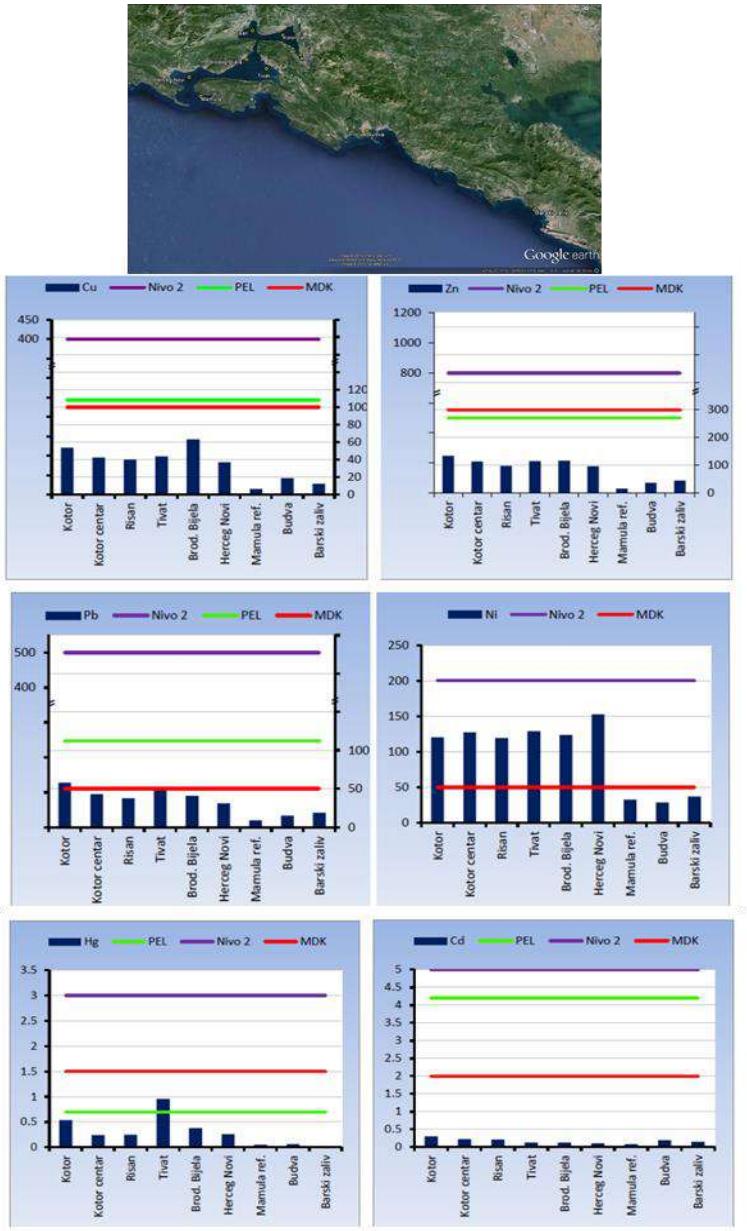


Figure 7. Concentration in mg/kg of Cd, Hg, Cu, Ni, Cr and As in surface sediment samples at 11 locations (indicted on the map) along the Montenegrin coast. The red line is MAC of the analysed element according the „Rulebook on permitted amounts of hazardous and harmful substances in soil and methods of interrogating" (Official Gazette, 18/97). Data from National Monitoring of the environment - EPA Montenegro 2014 (upper plots). Concentration in mg/kg of Cu, Zn, Pb, Ni, Hg and Cd in surface sediment samples at 9 locations along the Montenegrin coast (indicated on the map). The red line is MAC of the analysed element according the „Rulebook on permitted amounts of hazardous and harmful substances in soil and methods of interrogating" (Official Gazette, 18/97). The National Monitoring of the environment - EPA Montenegro 2015.

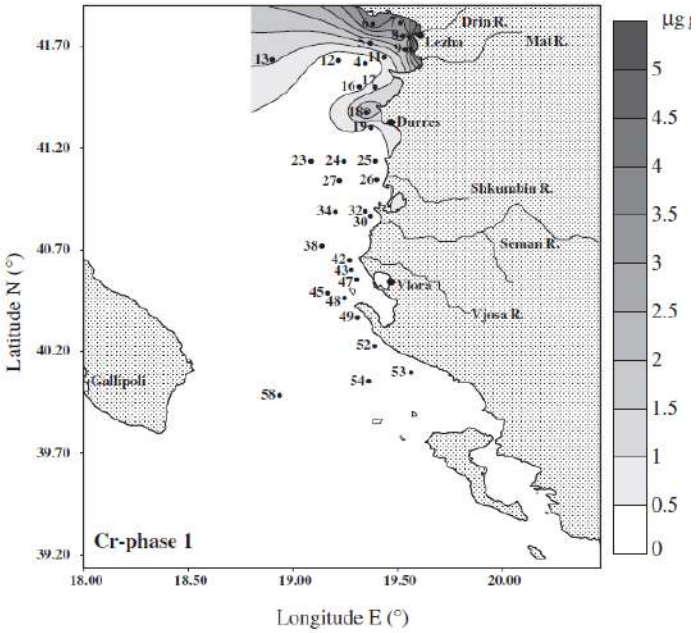
PP9 – ARSO, Slovenia

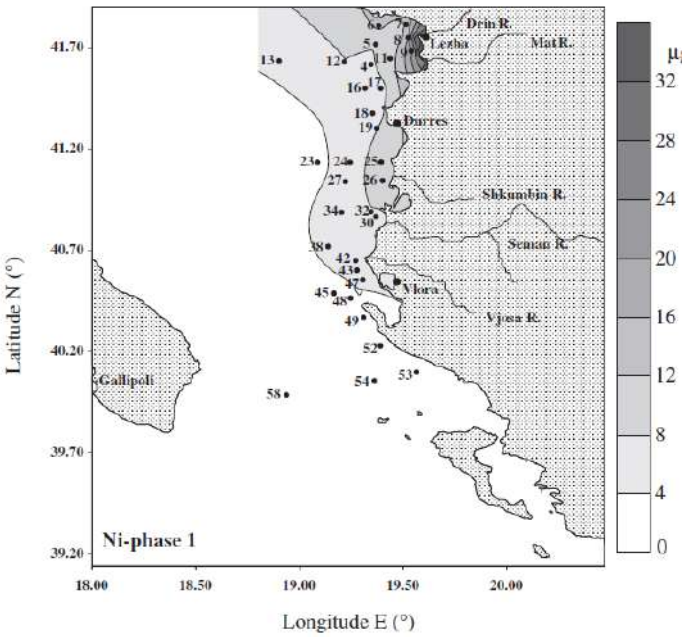
seawater yes
sediment yes
biota yes

- Interactive maps, presenting chemical and ecological status of water bodies; individual year or river basin management period can be chosen: http://gis.arso.gov.si/apigis/povrsinskevode/
- The status in individual year is presented as sampling point, but the status for RBM period is extrapolated to the water body.Maps in River Basin Management Plan: http://www.mop.gov.si/fileadmin/mop.gov.si/pageuploads/podrocja/voda/nuv_II/13_2_OCENA_KEM_ST_REKE.pdf http://www.mop.gov.si/fileadmin/mop.gov.si/pageuploads/podrocja/voda/nuv_II/13_3_OCENA_KEM_ST_REKE_HG.pdf
- Environmental Indicators – chemical and ecological status of marine water bodies http://kazalci.arso.gov.si/?data=indicator&ind_id=365
- Maps in annual reports: http://www.arso.gov.si/vode/morje/
- Eurowaternet Slovenia – digital information about water in Slovenia http://nfp-si.eionet.europa.eu/Dokumenti/GIS/voda/

PP10 – AUT, Albania

seawater yes
sediment yes
biota yes


Drin R.
Lezha
Mat R.
Durres
Shkumbin R.
Seman R.
Vlora
Vjosa R.
Gallipoli
Cr-phase 1
Latitude N (°)
Longitude E (°)
41.70
41.20
40.70
40.20
39.70
39.20
18.00
18.50
19.00
19.50
20.00
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


Drin R.
Lezha
Mat R.
Durres
Shkumbin R.
Seman R.
Vlora
Vjosa R.
Gallipoli
Ni-phase 1
Latitude N (°)
Longitude E (°)
41.70
41.20
40.70
40.20
39.70
39.20
18.00
18.50
19.00
19.50
20.00
32
28
24
20
16
12
8
4
0

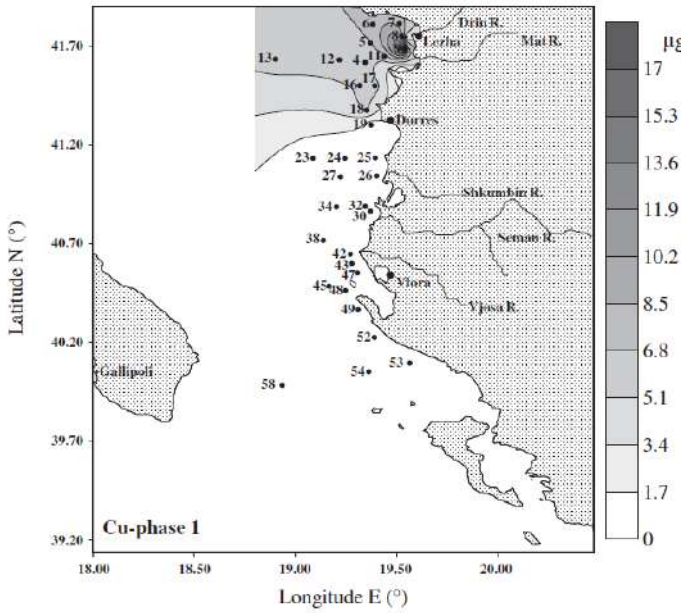
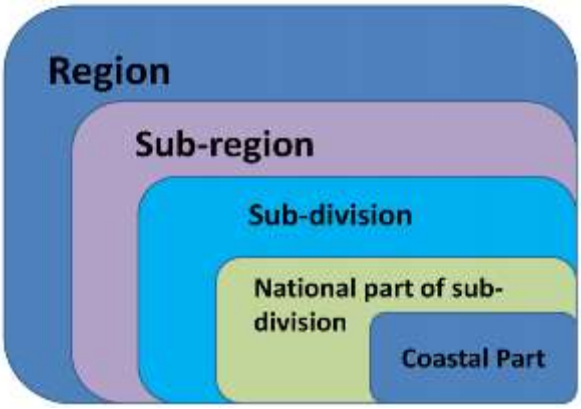


Figure 8. Spatial distribution of Cr, Ni and Cu in labile phase (phase 1) in Lezhe, Durres, Kavaje and Vlore (Rivaro et al., 2007)

- Maps in annual reports:
  http://akm.gov.al/cil%C3%ABsia-e-mjedisit.html#raporte_publikime
- European Environment Albania – digital information about water in Albania:
  https://www.eea.europa.eu/countries-and-regions/albania

2.2. What is the spatial scale of data aggregation?



PP2 – ISPRA, Italy
Sub-division (North and Central Adriatic Sea)

PP3 – IOF, Croatia
National part of subdivision

PP4 – HCMR, Greece
Region, National part of sub-division

PP6 – IRB, Croatia
Coastal. Example: Perić et al., (2012) fresenius Environmental Bulletin 21, 9a, 2785-2794

PP7 – UoM-IMBK, Montenegro
region, coastal part

PP9 – ARSO; Slovenia
Coastal+transitional+territorial / national water bodies

PP10 – AUT; Albania
Coastal+transitional+bathingwaters / national water bodies

2.3. Can you share your experience in visualization of temporal variability of contaminant concentrations:

(If yes, please provide examples such as plots in scientific papers, plots in reports, link to website, ... that can help to gather information within HarmoNIA.)

PP2 – ISPRA, Italy

seawater	Yes
sediment	Yes
biota	Yes

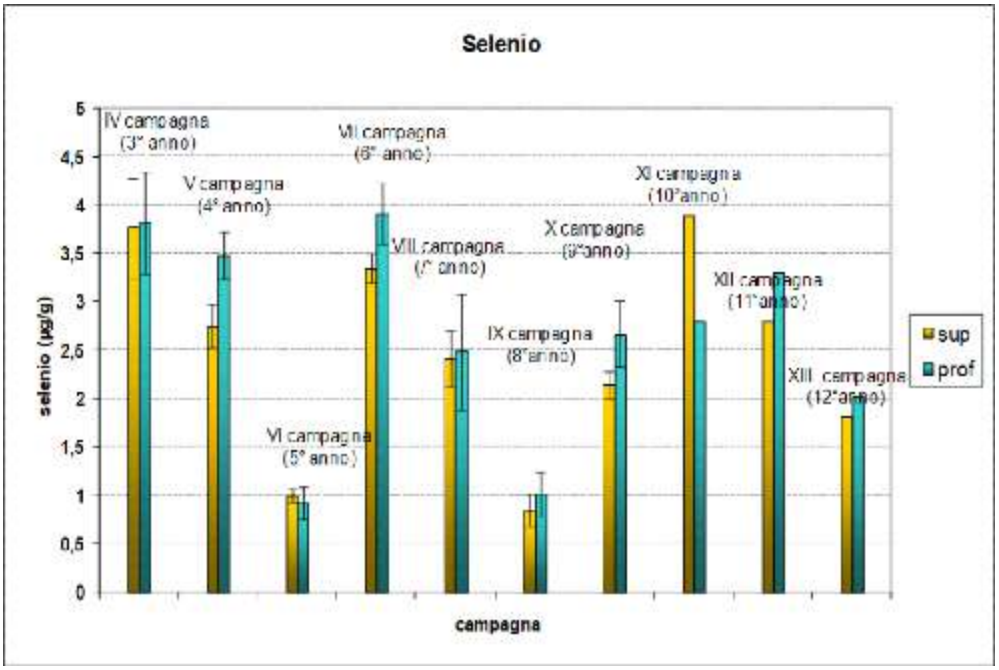


Figure 9. Average concentration (µg/g) of Selenium in mussels (Mytilus galloprovincialis) for a platform. Samples collected by triplicate.

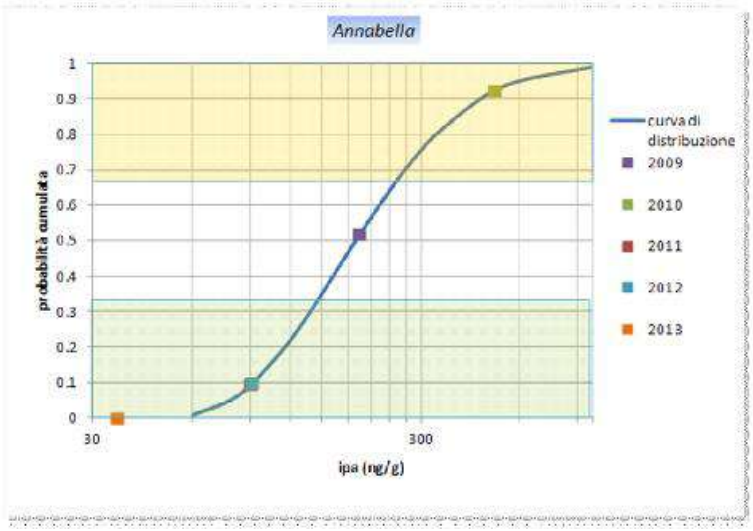


Figure 10. Cumulative probability distribution (Johnson, 1949) of PAH concentration from 2009 to 2013 (blue line). Mean PAH concentration (µg/g) in mussels (Mytilus galloprovincialis) for a platform (coloured square). Samples collected by triplicate.

PP3- IOF, Croatia

seawater NO data in seawater

sediment State of marine environment, aquaculture and fisheries indicators database

biota State of marine environment, aquaculture and fisheries indicators database

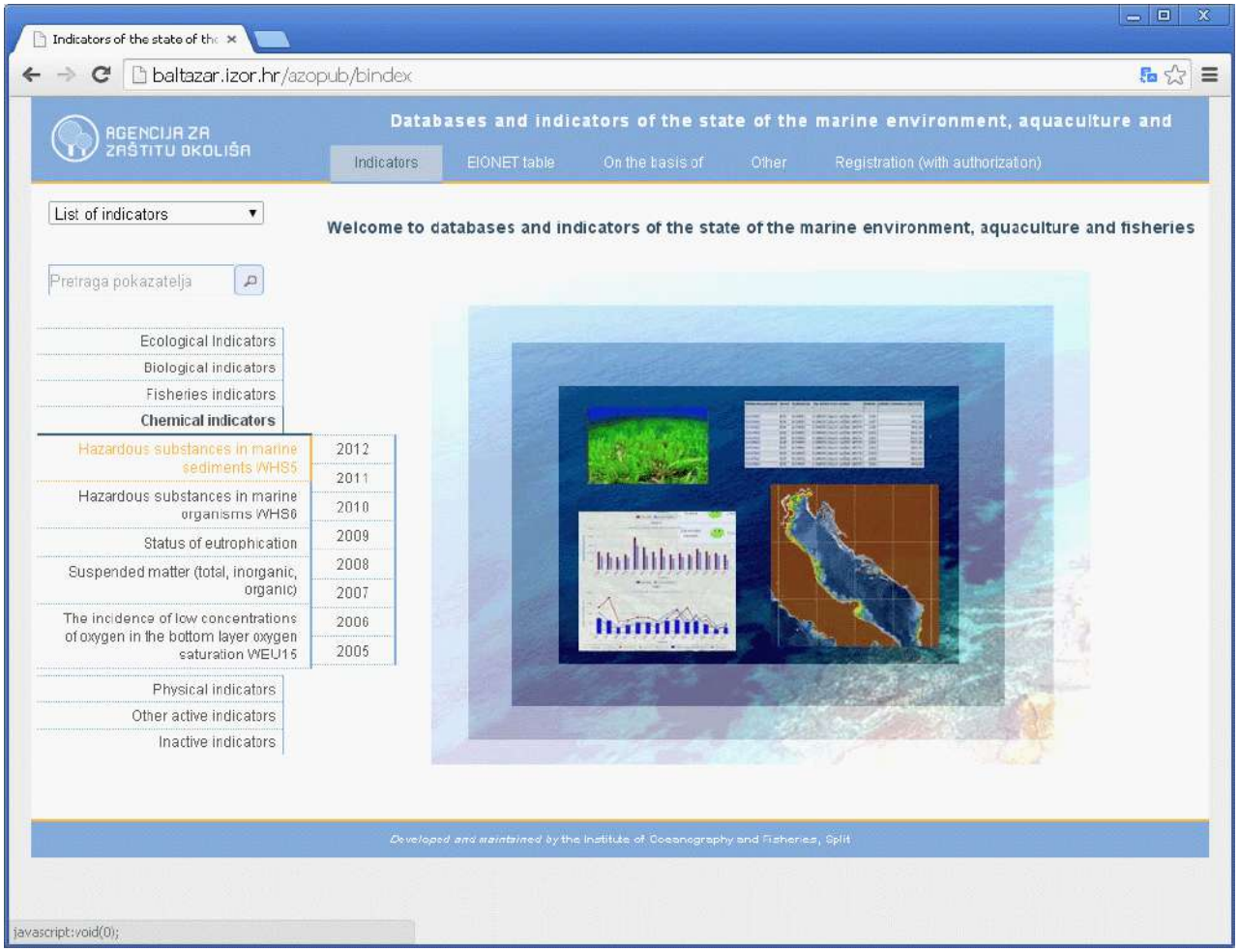


Figure 11. Screen shot of translated web application (originally in Croatian) http://www.izor.hr/azo

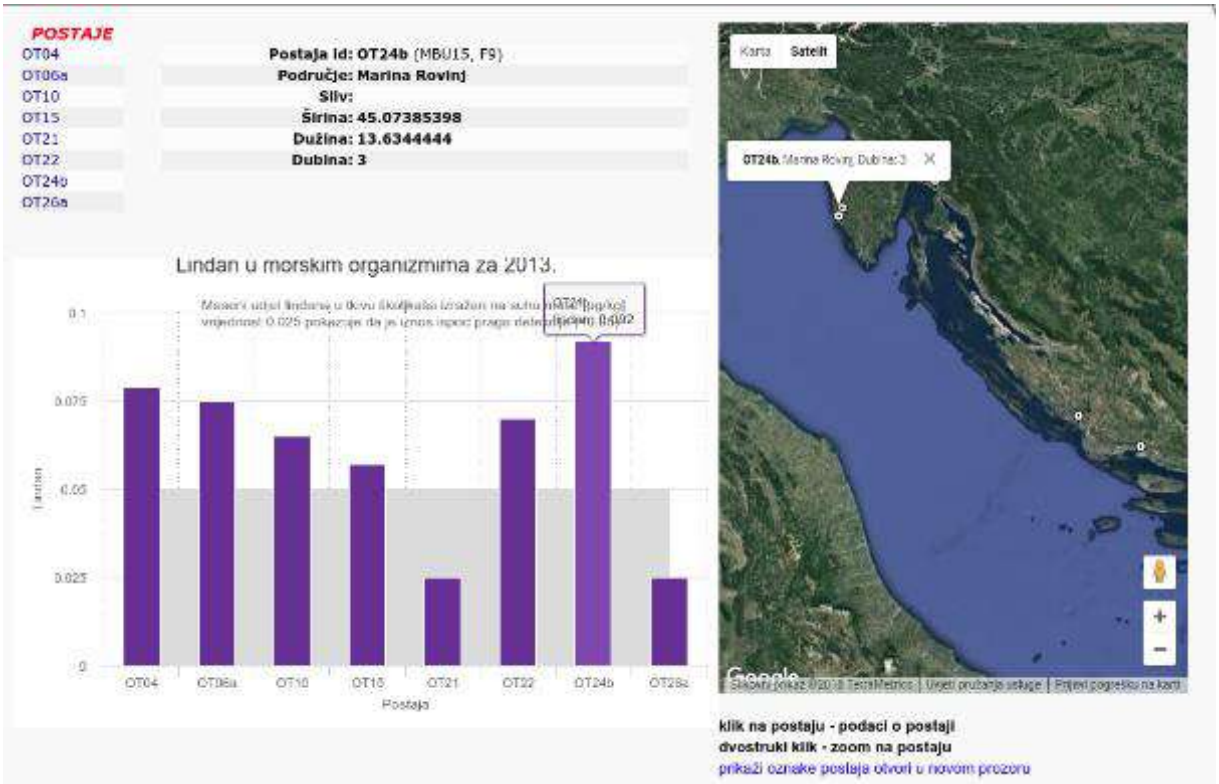


Figure 12. Lindan in biota year 2013. Grey area indicates detection limit (values under detection limit are represented with half detection limit value). Graph is paired with map: click on bar on the graph marks location of station on the map.

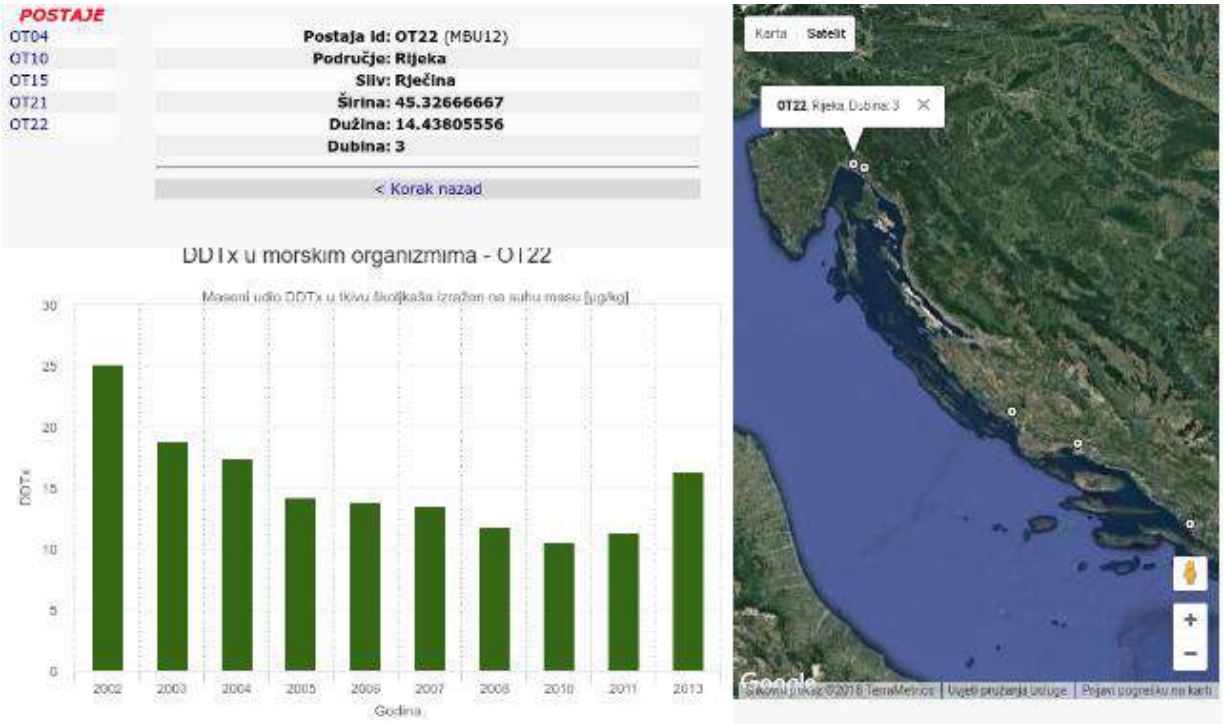


Figure 13. DDTx in biota trend for one station

PP4 – HCMR; Greece

seawater	yes
sediment	yes
biota	yes

HCMR Experience within EMODnet Chemistry Project

Within EMODnet Project, temporal variability of contaminant concentration is illustrated with two ways:

- ODV software tool for the analysis and visualization plots of time series and vertical profiles of selected parameters from the aggregated data collections of selected stations
- Web Processing Services (WPS) for visualization plots of time series and vertical profiles of selected parameters from the aggregated data collections of selected stations (Figure 14)
- OGC Web Map Services (WMS) and Web Feature Services (WFS) (e.g the Ocean Browser viewing service) for visualization (and downloading) of the data products. The data products have been prepared by the aggregates and validated data collections.

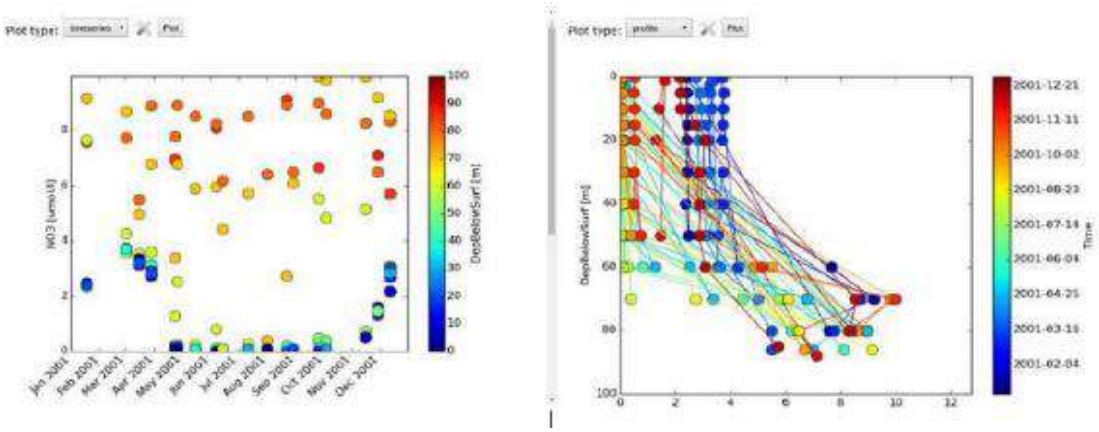


Figure 14. Time series and vertical profiles at selected location (from EMODnet Chemical phase 2 final report-v2, 30/11/2016)

HCMR experience within of IRES-SES Project

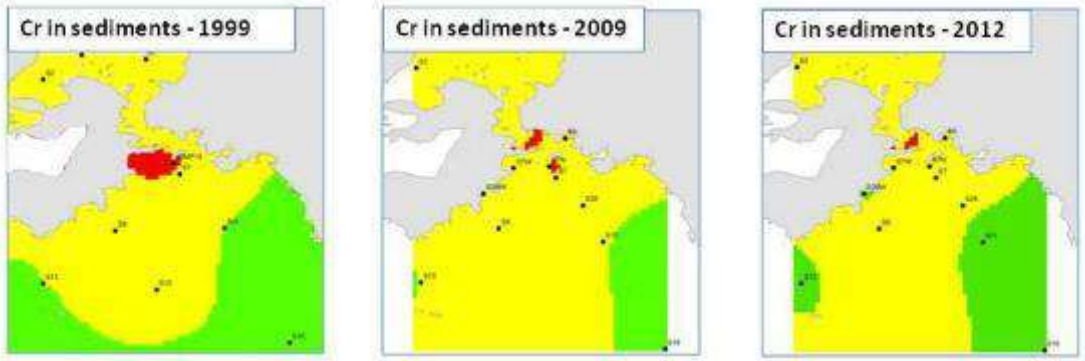


Figure 15. Contaminants in sediment toolset run for the Greek coast - Saronikos Gulf.

PP7 – UoM-IMBK; Montenegro

seawater	data will be the part of Emodnet Chemistry3 project data system
sediment	data will be the part of Emodnet Chemistry3 project data system
biota	data will be the part of Emodnet Chemistry3 project data system

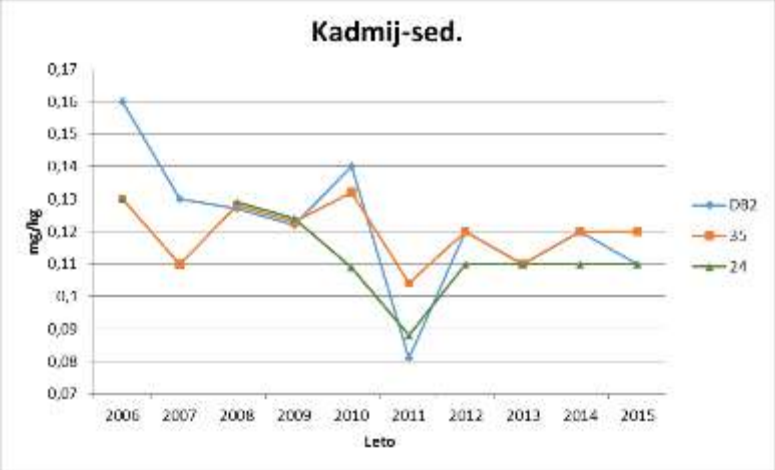
If yes, please provide examples such as plots in scientific papers, plots in reports, link to website, ... that can help to gather information within HarmoNIA.

PP7: The data will be available via data services at : http://www.emodnet-chemistry.eu

PP9 – ARSO, Slovenia

seawater	yes
sediment	yes
biota	yes

- Graphs in the annual reports
  http://www.arso.gov.si/vode/morje/



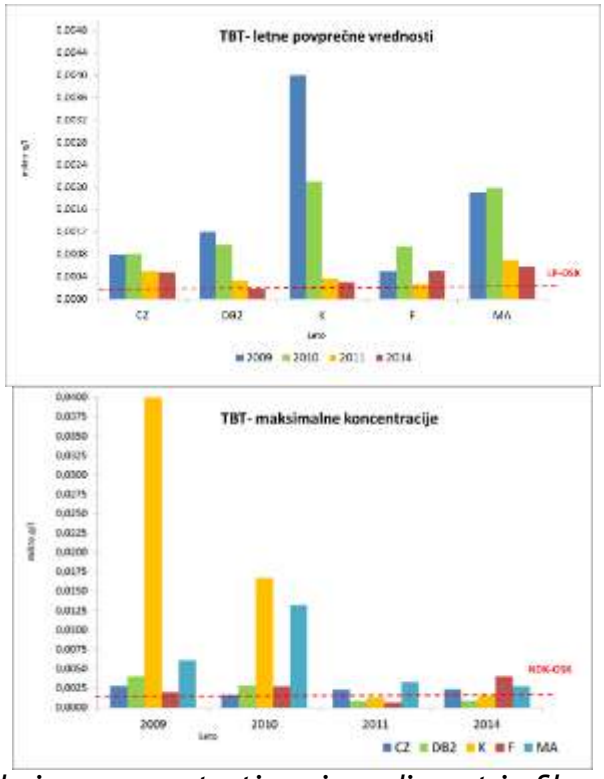


Figure 16. Cadmium concentrations in sediment in Slovene coastal and territorial waters from year 2006 to 2015; annual average concentrations and maximum annual concentrations of tributyltin compounds in water in Slovene coastal and territorial waters from year 2009 to 2014

- Interactive maps, as already mentioned in point 1, presenting chemical and ecological status of water bodies; individual year or river basin management period can be chosen: http://gis.arso.gov.si/apigis/povrsinskevode/

The status in individual year is presented as sampling point, but the status for RBM period is extrapolated to the water body.

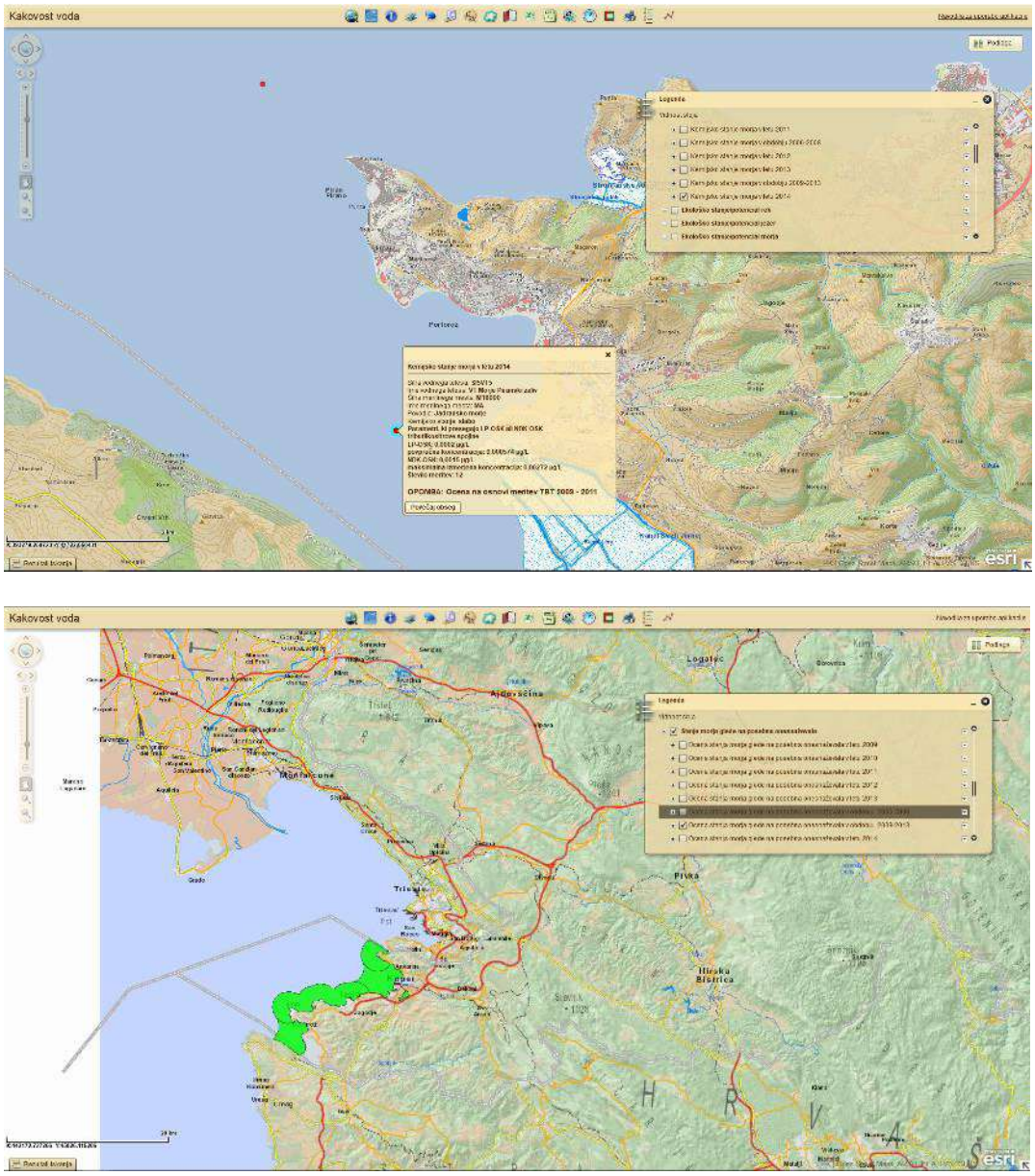


Figure 17. GIS examples of annual chemical status assessment (upper picture) and status of coastal water bodies according to the concentration of national relevant substances *for river basin management plan in Slovenia (picture below)*

PP10 - AUT, Albania

seawater	yes
sediment	yes
biota	yes

Figure 18. Monitoring activities by MED POL programme (MED POL National Coordinators Meeting '05 - Agenda 8.3)

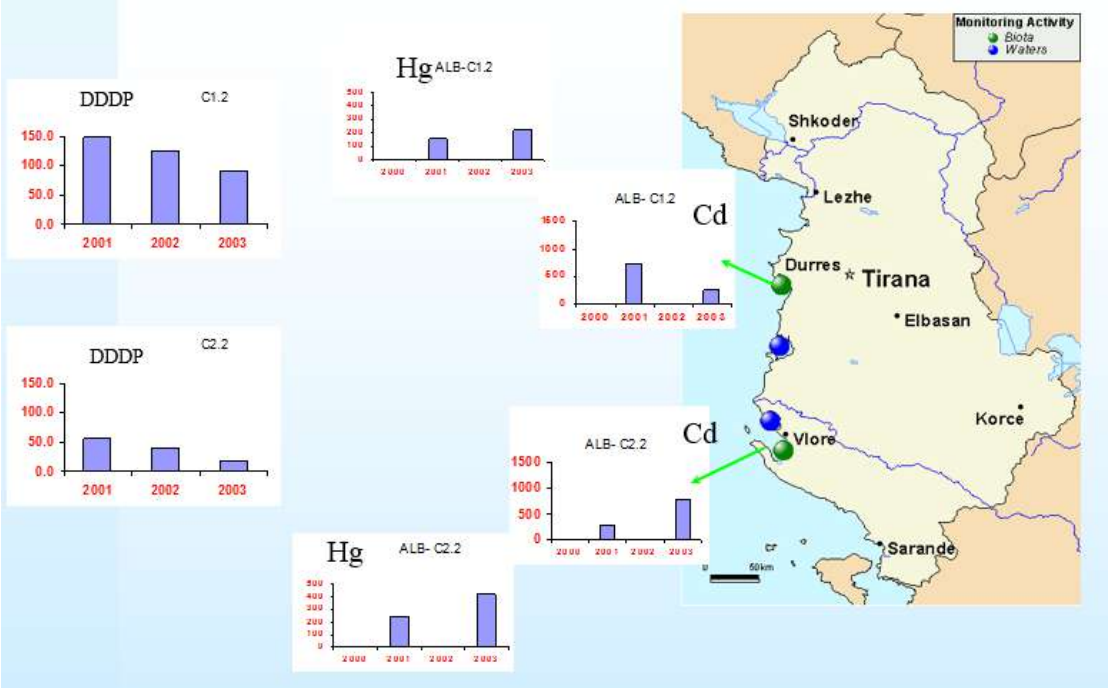


Figure 19. Monitoring activities by MED POL programme from 2000 to 2003 (MED POL National Coordinators Meeting '05 - Agenda 8.3)

2.4. What kind of analysis (statistics used) do you use to identify spatial distribution?

PP2 – ISPRA, Italy
Concentration per sampling station (because the sampling frequency in the Production Water Monitoring Program is one per year); or median year concentration per sampling station if I want analyse a spatial and temporal trend.

View Example: Fig. 2 and Fig. 3. (ISPRA)

PP3 – IOF, Croatia
Eg. annual median concentration per sampling station; interpolated maps; ...

Yearly average per sampling station, represented on graph with bars

PP4 – HCMR, Greece

HCMR experience within of IRES-SES Project

The materials which have been used are Model Builder Module of ArcGIS and ArcGIS Toolboxes (Geoprocessing, Spatial Analyst etc).

PP6 – IRB, Croatia
Average per sampling station. RBI research data are subjected to different statistical analyses depending on the purpose of the study.

PP7 – UoM-IMBK, Montenegro
More about producing interpolated maps for contaminants within the Emodnet Chemistry 3 project could be found on http://www.emodnet-chemistry.eu/products/generation and in the "Proposal for generating dedicated maps on contaminants", available at:
http://www.emodnet-chemistry.eu/documents/projectdocuments

PP9 – ARSO; Slovenia
For priority substances, we use annual average concentration per sampling station.

PP10 – AUT; Albania
For priority substances, generally are used annual average concentration per sampling station (including the standard deviation).

2.5. What scale of temporal aggregation do you use to identify temporal variability?

PP2 – ISPRA, Italy
Mean concentration for each sample

PP3 – IOF, Croatia
Yearly average per sampling station, represented on graph with bars

PP4 – HCMR, Greece
ODV software tool and its station temporal selection criteria

PP6 – IRB, Croatia
RBI research data are subjected to different statistical analyses depending on the purpose of the study.

PP7 – UoM-IMBK, Montenegro
http://www.emodnet-chemistry.eu/products/generation

PP9 – ARSO, Slovenia
Single data or annual average concentration in individual year, represented in graphs. For spatial distribution, we interpolate sampling point to water body.

PP10 – AUT, Albania
Yearly average per sampling station, represented on graph with bars

Partner	Spatial distribution	Temporal trend
PP1	Single sample	Single sample
PP2	Annual median	Annual mean
PP3	Annual median/mean	Annual mean
PP4	Single sample	Annual median/mean
PP6	Annual mean, range	Annual mean
PP7	Other	Other
PP9	Annual mean	Annual mean
PP10	Annual mean	Annual mean
UNEP/MAP, 2016	*medians, IQR, range*	
OSPAR-CEMP, 2008	*medians, quartile*	
MSFD, TG 8 Report		*Annual mean*

Table 1: Synthesis of statistics used for data aggregation used for spatial distribution and temporal trends.

2.6. How are data processed (spatial and temporal aggregation)

PP2 – ISPRA, Italy
Spatial data are usually processed at local and sub-division level aggregation (Fig. 1 and Fig. 2). Temporal aggregation is by year interval.

PP3 – IOF, Croatia
Data are processed inside relational database. Aggregation is done as yearly average and stored in separate indicators table. Online interface for defining graphs are developed inside indicators database

PP4 – HCMR, Greece

DIVA interpolation tool allows spatial and temporal aggregation of data from different sources.

Within IRES-SES Project:
Figure 16 shows the flow charts for some substances as they are structured in the ArcGIS Model Builder Module within IRES-SES Project.

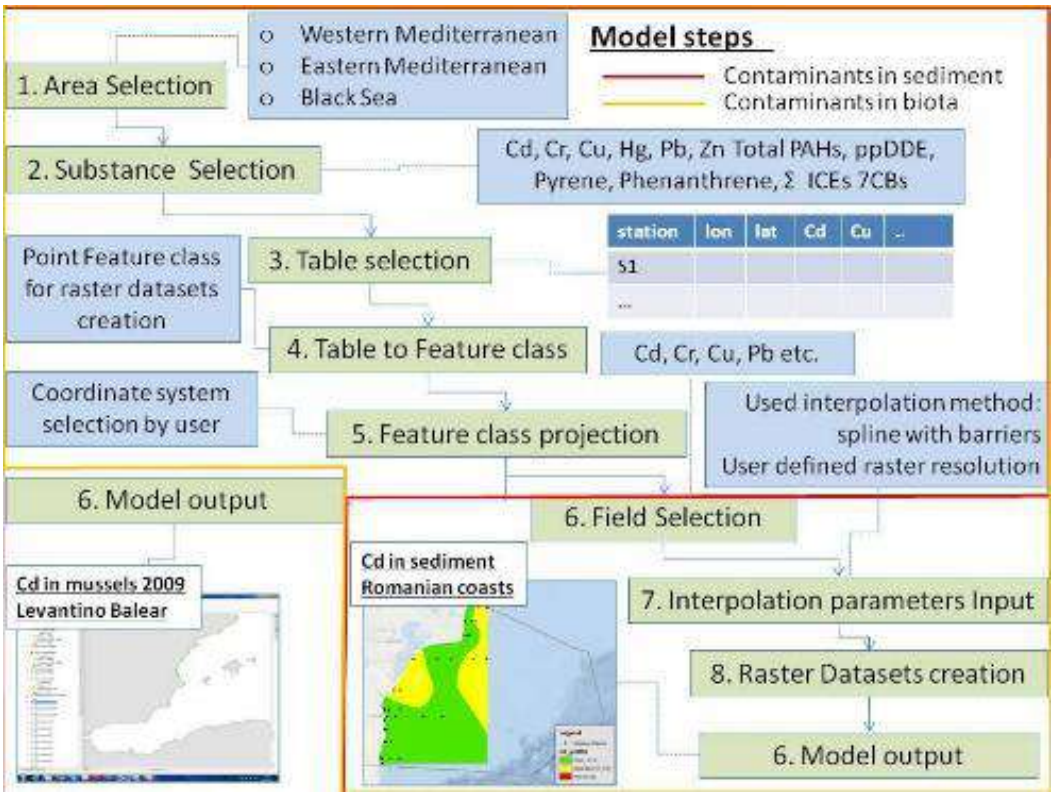


Figure 20. Contaminants Toolboxes Workflow Schema

PP6 – IRB, Croatia
RBI research data are subjected to different statistical analyses depending on the purpose of the study.

PP7 – UoM-IMBK, Montenegro
The ODV software is used by regional groups in EMODnet Chemistry for quality checking, validation and aggregation of the chemistry data sets. More about aggregation of contaminant parameters in this project could be found in "Proposal for generating dedicated maps on contaminants" and "Second Phase - EMODnet Chemistry Rules for aggregation and visualization of data on contaminants", both available at:
http://www.emodnet-chemistry.eu/documents/projectdocuments

PP9 – ARSO, Slovenia
ARSO has a special tool developed for the purpose of chemical status assessment (calculation of average annual concentration and maximum allowable concentration, comparison with AA-EQS and MAC-EQS).

PP10 – AUT, Albania
Data are processed inside relational database. Aggregation is done as yearly average and stored in separate indicators table. Online interface for defining graphs are developed inside indicators database

Partner	Spatial aggregation	Temporal aggregation
PP1	none	Year interval
PP2	Local and sub-division	Year interval
PP3	National part of sub-division	Year interval
PP4	National part of sub-division	Year interval
PP6	Coastal	other
PP7	Coastal	other
PP9	Coastal+transitional+territorial/national	Year interval
PP10	Coastal+transitional /national	Year interval

Table 2: Synthesis of information on Data aggregation.

2.7. Other comments:

PP3 – IOF, Croatia
General remark:
Linux CentOS server OS, Oracle database, Automatic Storage Management, Oracle application server, Google maps API, High charts javascript graphs, Short response time, Highest usage peak 1000+ users in one minute time.

Other types of data visualisations on Internet are also developed and used, but not for contaminant data.

Figure 21. Example of Carlit index visualisation using Geoserver

PP6 – IRB, Croatia

General remark: ALL contaminants data on processing related to Croatian national monitoring is done in IOF Split, RBI sends raw data.

RBI research data are subjected to different statistical analyses depending on the purpose of the study. Except descriptive statistics it includes inferential data analyses both univariate (ANOVA,..) and multivariate (PCA, ..)

PP9 – ARSO, Slovenia

On ARSO web page there is Environmental Atlas (Figure 18) with important environmental data such as monitoring points, protected areas, Natura 2000, Corine Land Cover, urban wastewater treatment plants, industry,..

http://gis.arso.gov.si/atlasokolja/profile.aspx?id=Atlas_Okolja_AXL@ARSO&culture=en-US

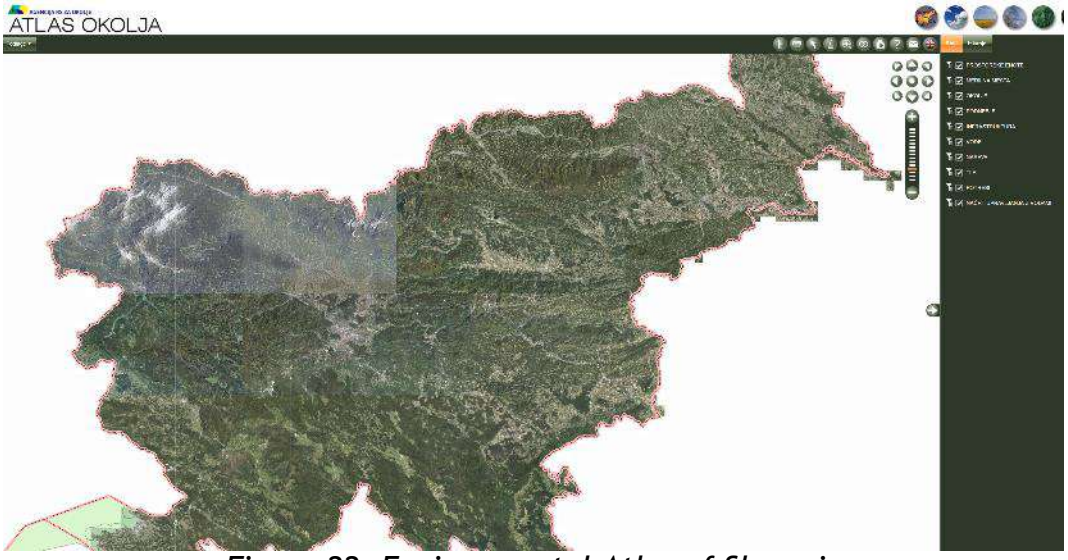


Figure 22. Environmental Atlas of Slovenia

PP10 – AUT, Albania

The State of Environment Report (SoER) is prepared every year by the National Environmental Agency (NEA) and is a legal obligation. The environmental indicators used in the Report are based on the data provided mainly by the monitoring of environmental indicators and from information and data provided basically by NEA and other public research and monitoring institutions at the national level. The SoER shows the state of the main environmental indicators for air, water, biodiversity, soil, climate change, forests etc and is based mainly on the Driving Forces-Pressures-State-Impacts-Responses (DPSIR) framework.

Indicators which can not be covered and monitored by the NEA are obtained from the following bodies:

- Various ministries;
- Other public institutions;
- Research and scientific institutes contracted by NEA.

The publication of environmental monitoring data aims to raise public awareness on the state of environment at local and national level. It offers reliable information concerning critical issues, risks, and pressures, which should be under continuous monitoring and supervision.

The SoER provides information on the state of the main environmental indicators, their trend by giving recommendations and proposing the necessary legislative measures and acts needed to be drafted by policymakers.

The monitoring of urban air quality is focused on indicators for: PM10, PM2.5, O , NO , SO , CO and Benzene. Based on the data assessment from the period 2011 to 2013 in Tirana, a decrease of 20-30% has been observed at the concentration level of PM10 and PM2.5. This is due to improvements made in infrastructure and to several legislative measures undertaken regarding the standardization of used cars and vehicles.

At the national level the concentration of CO and Benzene are at levels within the EU standards. Groundwater monitoring is made on the main watershed basins for chemical parameters, NO, NO, NH, HCO, Cl, SO, Na, Ca, Mg, K, Fe, dissolved oxygen, conductivity and hazardous substances. The level of chemical parameters monitored are within the allowed limits. Groundwater in Albania are classified as freshwater and have neutral and weak alkalinity, and strong average hardness. Content is within the maximum allowed values. The quality of bathing water is focused on the main beaches of Albania for the following microbiological indexes: *Enteroccoccus intestinalis* (IE), fecal Coliform probably *Escherichia coli* including sanitary inspection. The classification is based on the WHO/UNEP-UE criteria. According to the assessment made nearly 60% of the coastal bathing water stations in 2013 were classified within the A and B categories (A being excellent quality and B good quality).

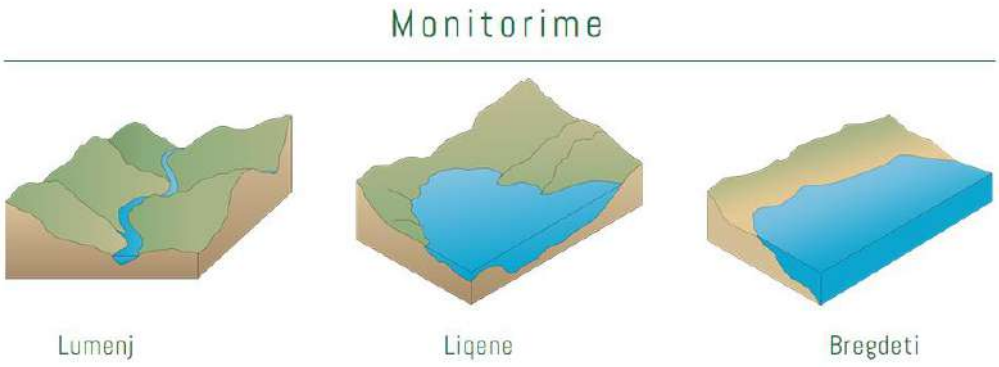


Figure 23. State of Environment Report (http://akm.gov.al/cil%C3%ABsia-e-mjedisit.html#raporte_publikime)

2.8. Other examples from scientific literature (preliminary and not exhaustive analysis):

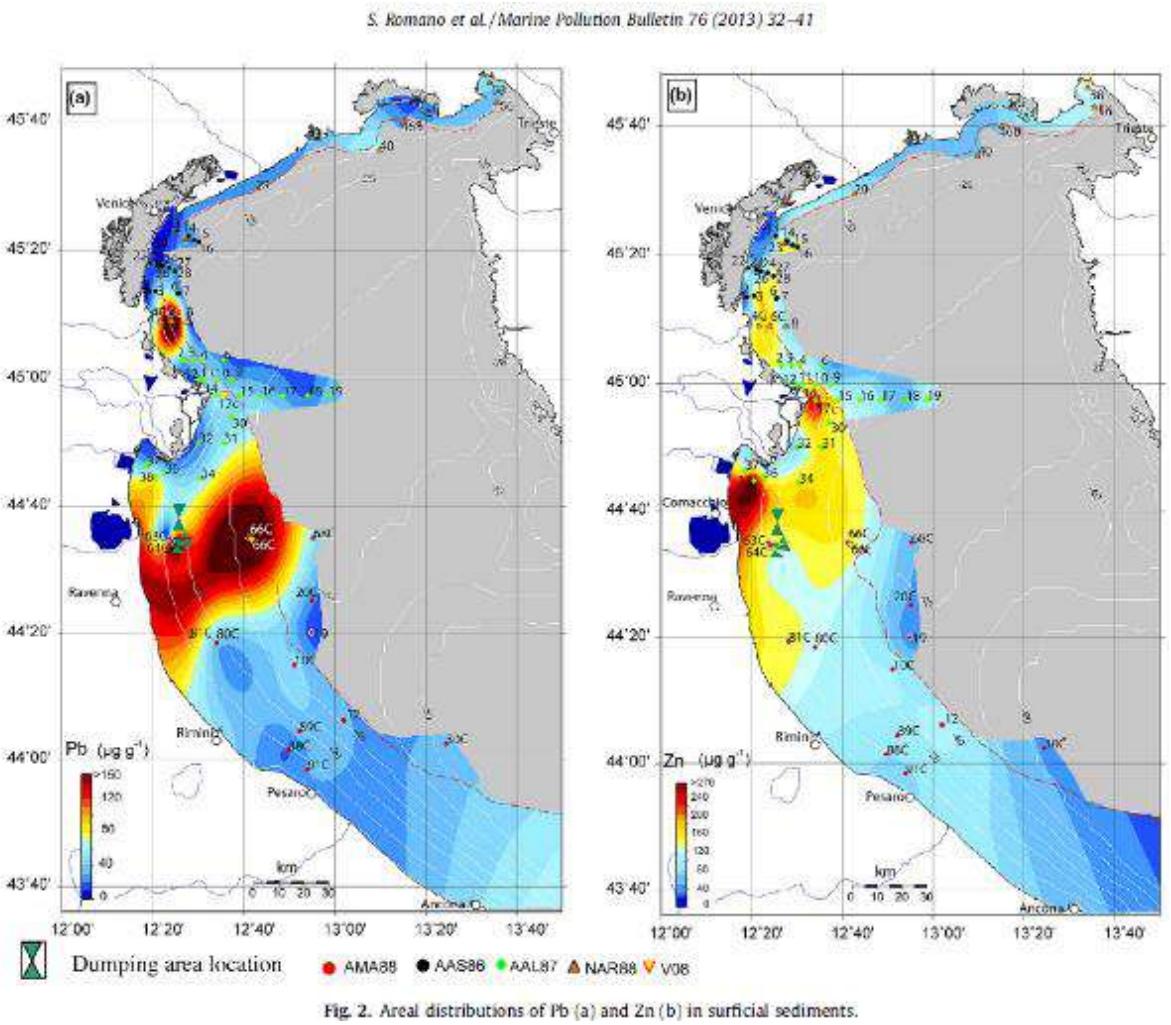


Figure 24. Spatial distribution, from: Romano et al. 2013

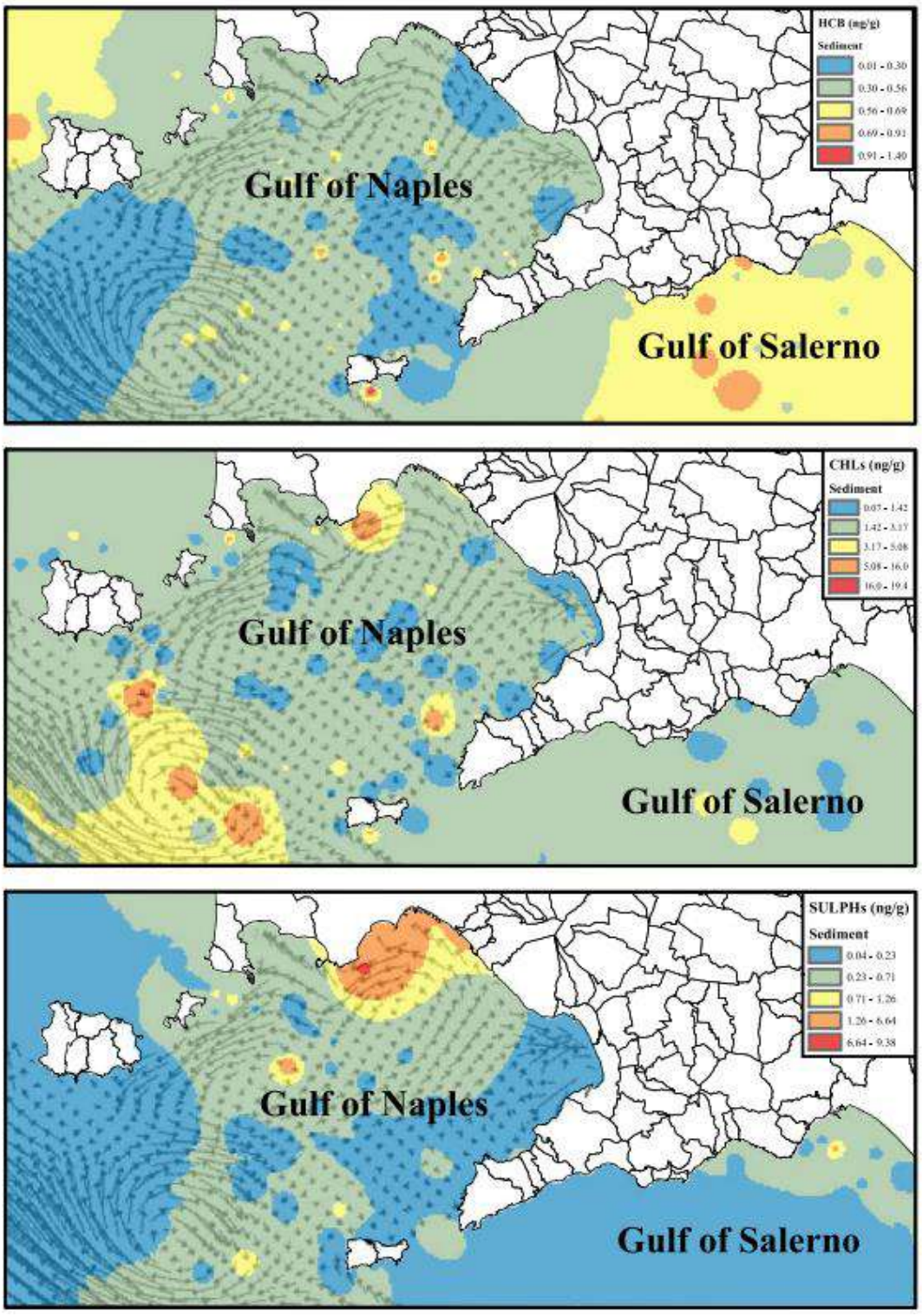
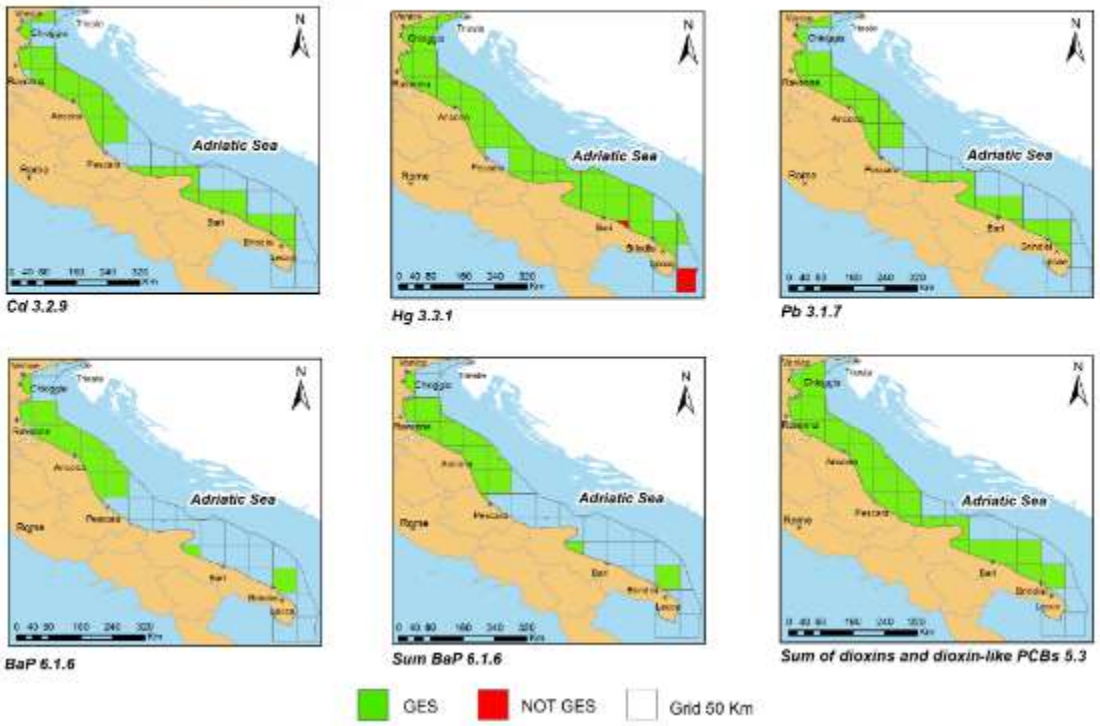


Figure 25. Example of spatial distribution: Depth – averaged currents on map application to spatial distribution of DDTs, HCHs, HCB, CHLs and SULPHs in sediments from the gulf of Naples and Salerno (taken from: Qu et al., 2017).

Environmental Quality of Italian Marine Water by Means of Marine Strategy Framework Directive (MSFD) Descriptor 9

Figure 2

Results on Metals, PAH and Dioxins/Dioxin-like PCBs in Adriatic Sea Subregion (AS).



doi: https://doi.org/10.1371/journal.pone.0106463.g002

Figure 26. Spatial distribution, from: Maggi et al., 2014

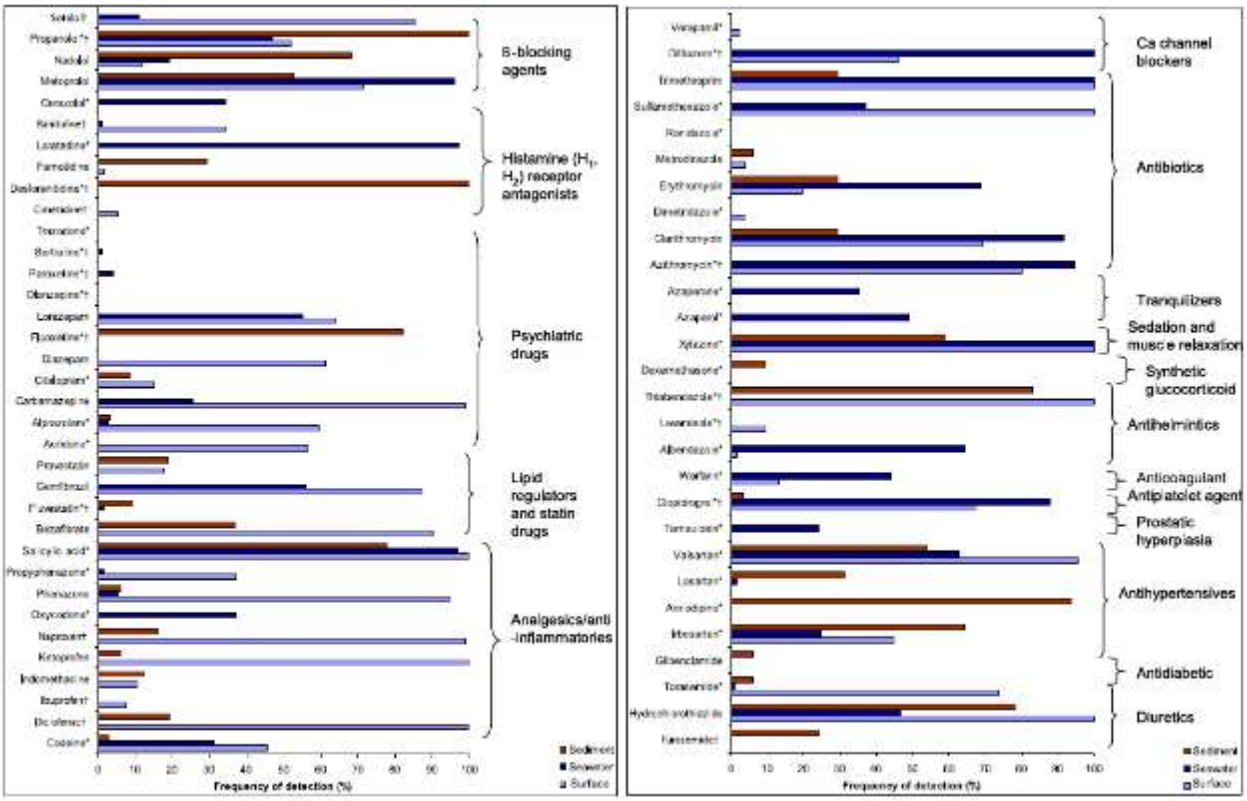


Fig. 2. Frequency of detection (% of total samples) in seawater, sediment and surface water (weekly input through El Albujón watercourse, Moreno-González et al. (2014). Compounds marked with asterisk were not included in Jelić et al. (2009). Compounds marked with a cross did not meet any of our quality control criteria and data shown is just qualitative.

Figure 27. Frequency (temporal) of detection, from: Moreno-González et al., 2014.

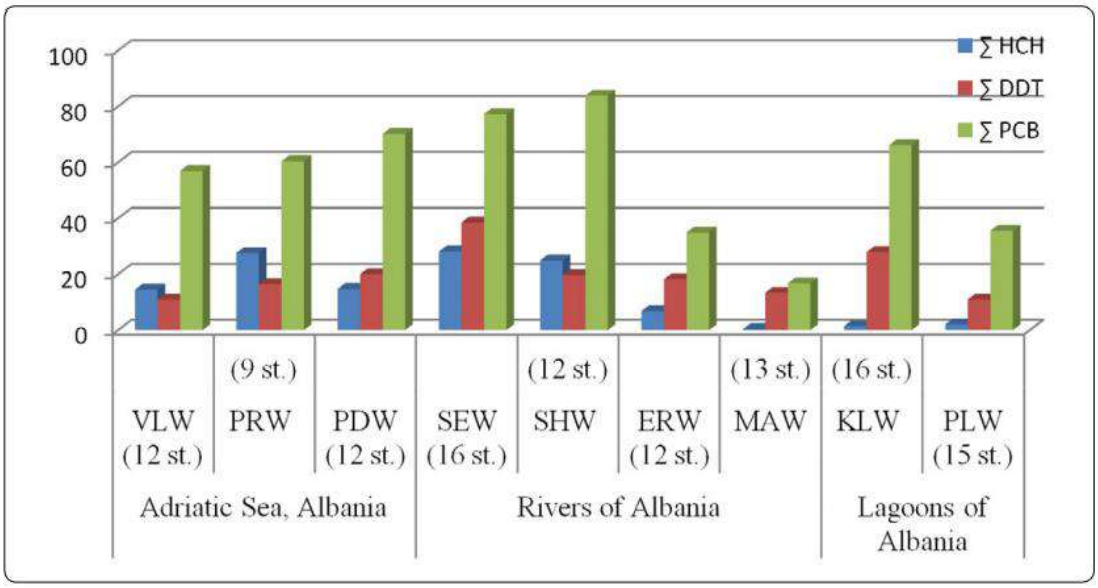


Figure 28. Total of HCHs, DDTs and PCB markers in water samples Ecosystems (Nuro et al. 2018)

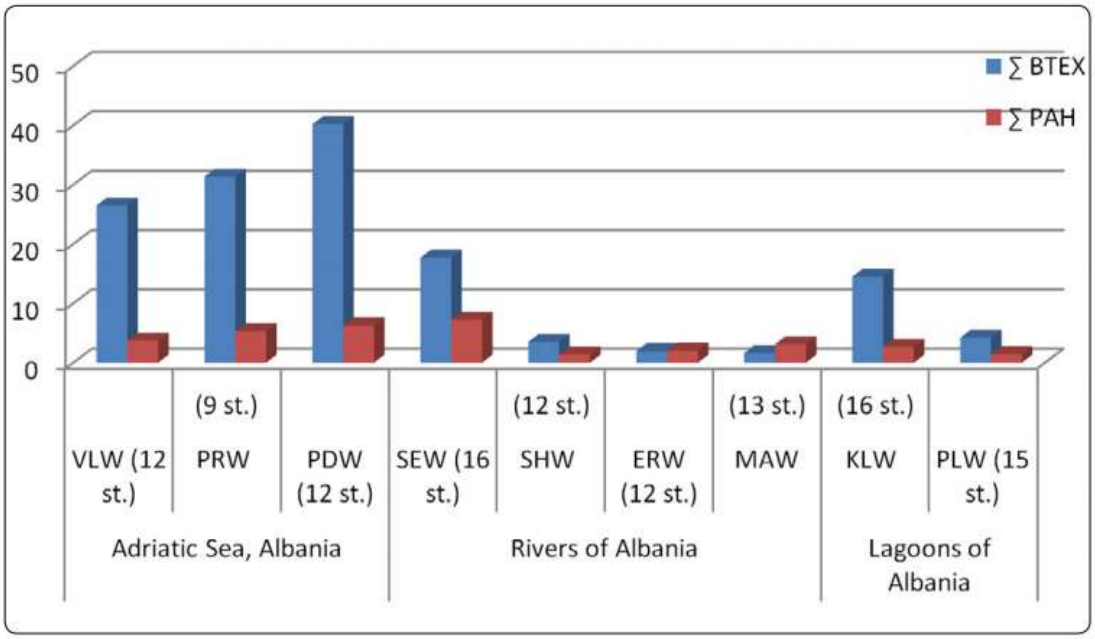


Figure 29. Total of PAHs and BTEX in water samples ecosystems (Nuro et al. 2018)

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