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

Deliverable T3.1.3 - Oil spill dispersion and extension of mixing zone maps

Work Package T3 - Case study of contaminant dispersion

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September 2019

How to cite: D. Melaku Canu, V. Bandelj, C. Laurent, S. Querin, C. Solidoro – OGS, G. Giorgi, L. Manfra - ISPRA 2020 WPT3 HarmoNIA Deliverable T3.1.3 - Oil spill dispersion and extension of mixing zone maps doi: 10.6092/feb2152b-c62e-4ae8-8502-0b12e6980f7b

1. Objective

The aim of the activity was the production of oil spill density maps of oil spill dispersion scenario.

These objectives have been reached through the implementation of 4 scenario simulations of:

1) Surface oil spill from the main routes of oil tankers in the Adriatic Sea;
2) Surface oil spill from a tanker accident in the Gulf of Trieste (I);
3) Surface oil spill from a tanker accident in the Bay of Split (HR);
4) Surface oil spill from an oil platform during discharge operations with FSO.
5) Numerical dispersion Produced Formation Water from offshore oil and gas extraction platforms in the Adriatic Sea.

2. Approach

The oil spill simulations have been carried out by applying the oil spill model OILTRANS (Berry et al., 2012) and the oil transport model, the lagrangian LTRANS v.Zlev model (Laurent et al., 2019) to a set of meteo-marine conditions: wind fields and current fields produced with the MIT General Circulation Model (Querin et al., 2016, Querin et al., 2013). The simulations are run on the model domains presented in the Deliverable 3.1.2: the Adriatic-Ionian region with a horizontal resolution of 1/32° (~3.4 × 2.4 km), the Gulf of Trieste and of the Bay of Split at the high resolution of 1/320°, the Gulf of Patras at the resolution of 1/128°. The wind forcing was provided by the meteorological forcing fields produced by the 2016 version of the Regional Climate Modeling system RegCM4, which was developed at the Abdus Salam International Centre for Theoretical Physics (ICTP) and described by Giorgi et al. (2012).
The statistical approach proposed by Melaku Canu et al., 2015 was applied by performing, for each domain, a set of 357 oil spill releases, one per each day of the year, followed for the next 10 days, up to the end of the year. The results were therefore aggregated in order to provide oil density maps, mediated over the year of simulation, representing the oil density at each site, at 240 time intervals (one per hour) for ten days after the spill.
These results give the indication of the probability of the hazard of oil pollution related to an oil spilled from the selected points, considering the average meto-marine conditions of each area, during 10 consecutive days after the spill.
Examples of the results are presented in section 3, with the color maps, showing the average (yearly) qualitative contamination hazard index, from low (blue) to high (red). The maps can be interpreted as the probability to find the oil (after fixed times after the spill) at the sea surface **surface** oil, eventually

emulsificated), below surface (**dispersed oil**) in the water column, **beached** along the coasts.

3. Synthesis of work done – example of results

The simulations were done by setting the oil spill from the chosen points, and following its transformation and dispersion during the following ten days. Each simulation consisted in the release of a certain number of particles corresponding to the release of 3000 m3 of Arabian light oil each.

Specificities of this oil were taken from the database available on the web:

http://www.etc-cte.ec.gc.ca/databases/oilproperties/pdf/WEB_Arabian_Light.pdf.

We choose the Arabian crude light oil type, that is among the most common crude oil transported by the Tankers in the Mediterranean waters, which was parameterised in the model as described in Table 1.

The evaporation was computed in the model using the Fingas (1999) formulation, given by:

$$\%Ev = (C_B + C_T T) \ln(t) \qquad \text{Eq. 1}$$

where T is temperature, t is time, C_B C_T are constants, that for the Arabian light oil are, respectively, 2.52 and 0.037.

For each domain of the simulations 2,3 and 5, 357 oil spill modelling simulations were run, setting an oil spill per each day of the year. For simulation 1 the oil spills were released every 7 days from 840 points along the tranker routes, for a total of 43920 simulations. Every simulation was computed by simulating the weathering (spreading, evaporation, dispersion in the water column, emulsification) and transportation for the following 10 days. Transports and oil degradation are therefore dependent on the meteo-marine conditions encountered by the particle during the simulation, and therefore ary with the day of release. Whenever a particle arrives at less than 100 m from the coast, or reaches the open boundary of the water basin, it stops (but its weathering continues).

OIL PROPERTIES	
API	**33.4**
Dynamic viscosity	**14 cP at 15°C**
asphaltenes	**3%**
resin content:	**6%**
saturated contents	**51%**
aromatics	**39%**

Table 1. Oil properties
http://www.mckinseyenergyinsights.com/resources/refinery-reference-desk/arab-light-crude/

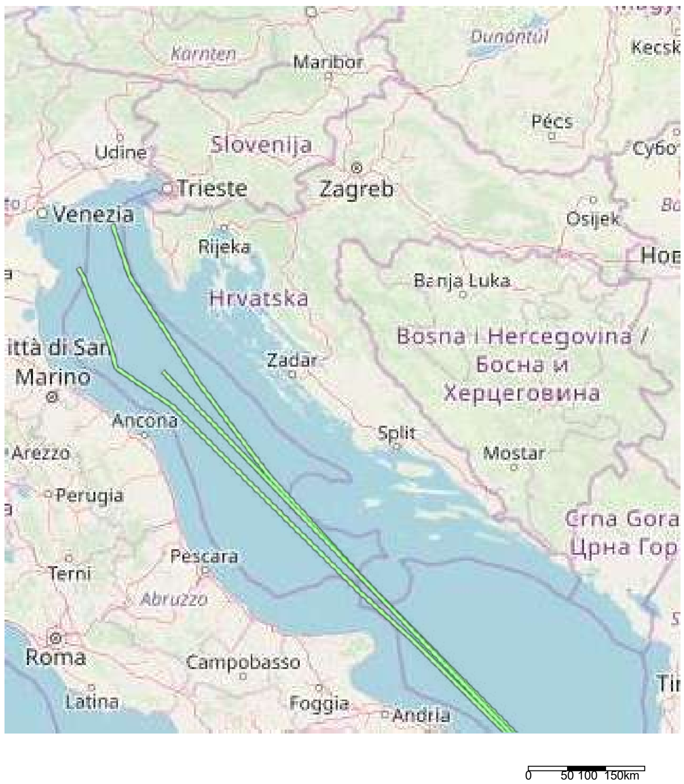


Fig. 1. Main marine traffic routes source: http://data.adriplan.eu/layers/geonode:bs_motorway_sea_ln

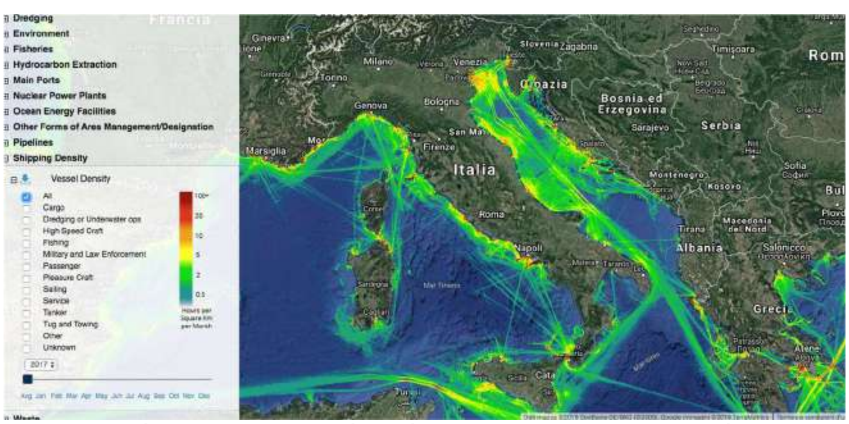


Fig. 2. Shipping vessel density. Source: https://www.emodnet-humanactivities.eu/view-data.php

Adriatic/Ionian Sea

The simulations were performed for the shipping route (Fig. 3) setting the oil spill from 840 chosen points, as represented Fig.3, and following its transformation and dispersion during the following seven days. Each simulation consisted in the release of 200 particles, weighted by a weight proportional to the traffic density shown in Fig. 3. In this way, the hazard index can be stimated in m3 of released oil times the traffic density (hours/km^2/months

The data uploaded in the Geoportal are in ASCII format. The dataset contains 30 text files, one for each day after the spill, for ten consecutive days, for:

1) oil at surface;
2) oil dispersed in the water column;
3) oil slicked at the coast.

The surface oil and the dispersed oil in the water column after 1 day (24 h) after the spill, are presented in figures 4 and 5.

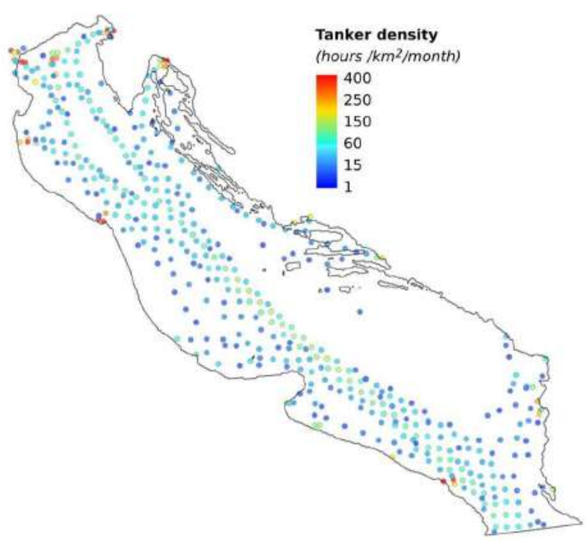


Fig. 3. Oil spill release points, with weighted tanker density, for the **shipping route scenario**.

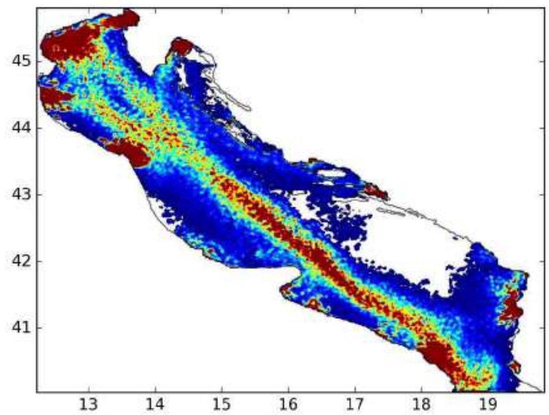


Fig. 4. Surface oil spill density maps after 24 hours for the **shipping route scenario**. (blue, low hazard index, red high hazard index).

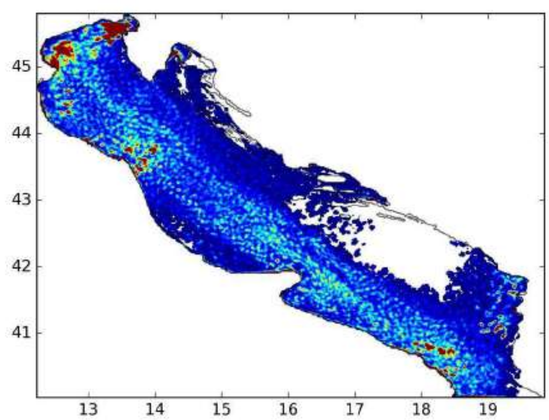


Fig. 5. Oil dispersed in the water column 24 hours for the **shipping route scenario.** (blue, low hazard index, red high hazard index).

Gulf of Trieste (I)

The simulations were performed for the Gulf of Trieste, (Figure 5), setting the oil spill from the chosen point (Lat: 45.6264, Lon:13.6996) , and following its transformation and dispersion during the following ten days. Each simulation consisted in the release of 1000 particles, corresponding to the release of 3000 m3.

The data uploaded in the Geoportal are in ASCII format. The dataset contains 30 text files, one for each day after the spill, for ten consecutive days, for:

1) oil at surface;
2) oil dispersed in the water column;
3) oil slicked at the coast.

The surface oil, the dispersed oil in the water column, and the slicked oil at the coast after 1 day (24 h) after the spill, are presented in figure 7.

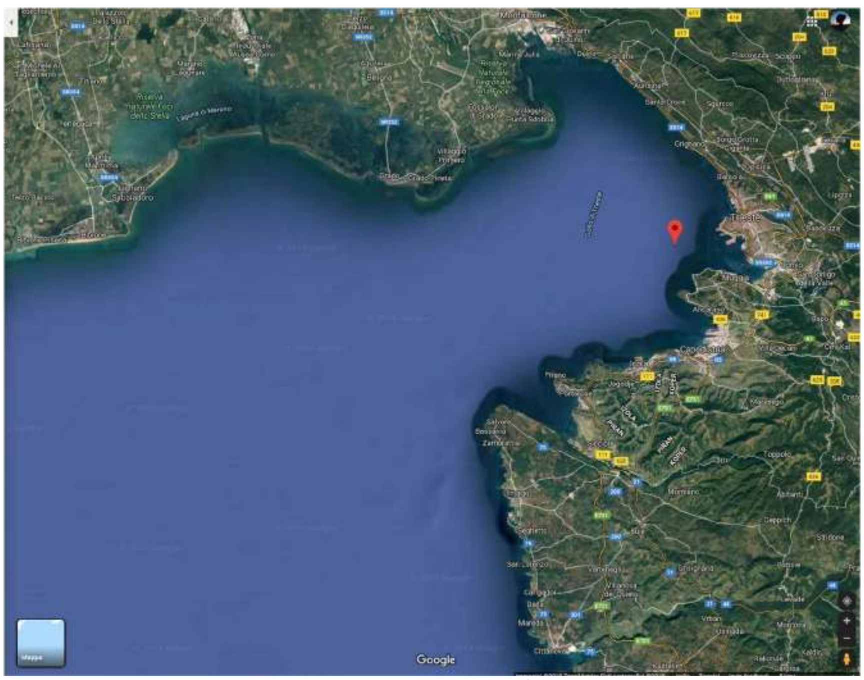


Fig. 6 Oil spill release point for the **Gulf of Trieste scenario**

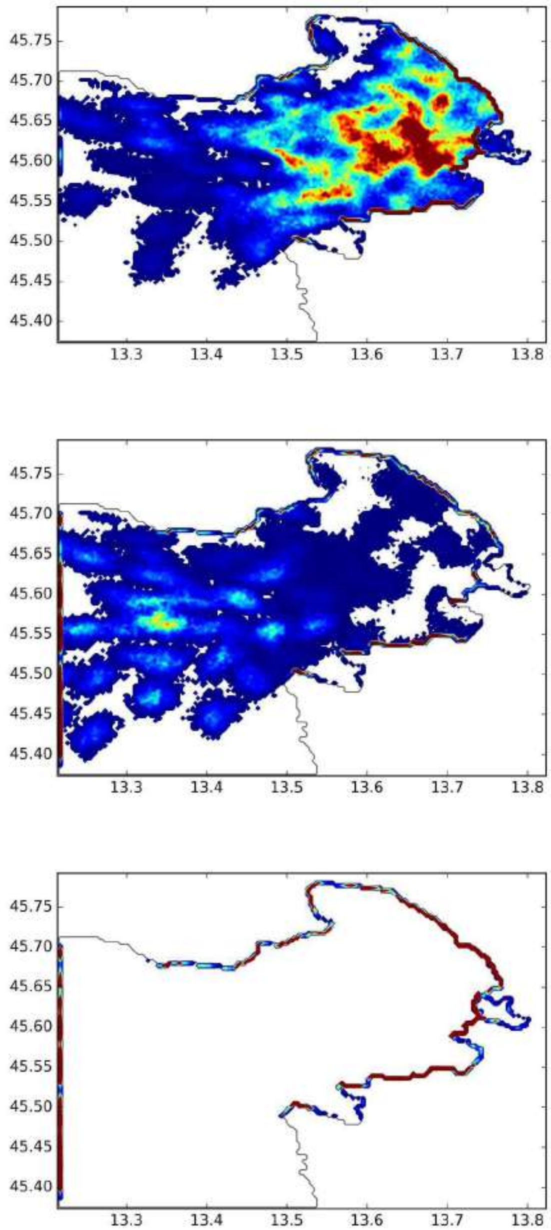


Fig. 7 Oil spill in the **Gulf of Trieste scenario**, after 24 hours: top: surface oil, center: dispersed oil, down: beached oil. (blue, low hazard index, red high hazard index).

Bay of Split (HR)
The simulations were performed for the Bay of Split, (Figure 8), setting the oil spill from the chosen point (Lat=43.521796, Lon=16.385317) and following its transformation and dispersion during the following ten days. Each simulation consisted in the release of 1000 particles, corresponding to the release of 3000 m3.

The data uploaded in the Geoportal are in ASCII format. The dataset contains 30 text files, one for each day after the spill, for ten consecutive days, for:

1) oil at surface;
2) oil dispersed in the water column;
3) oil slicked at the coast.

The surface oil, the dispersed oil in the water column, and the slicked oil at the coast after 1 day (24 h) after the spill, are presented in figures 9.

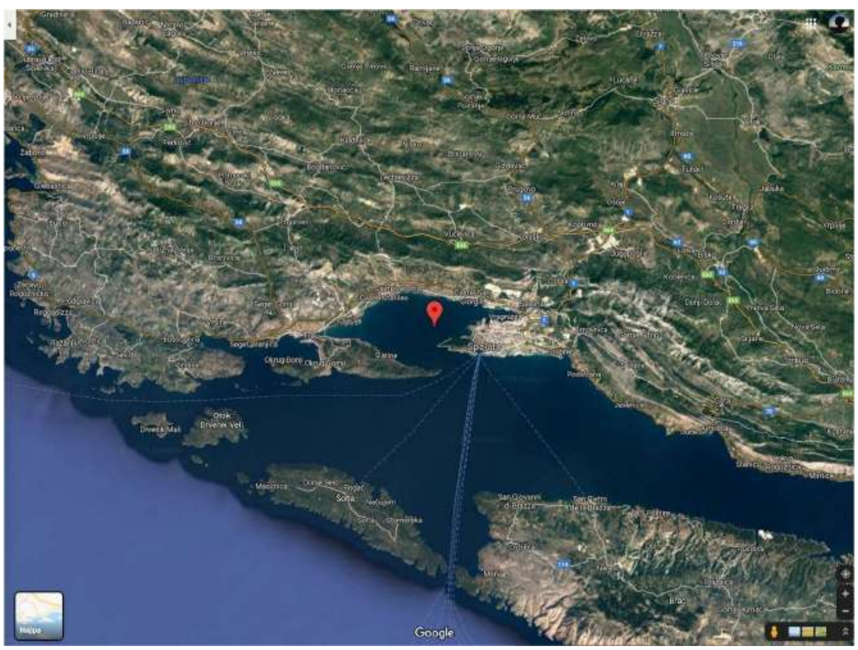
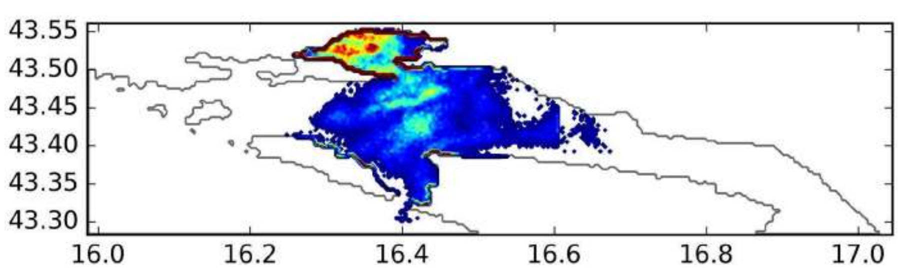


Fig. 8. Oil spill release point for the **Gulf of Split scenario**



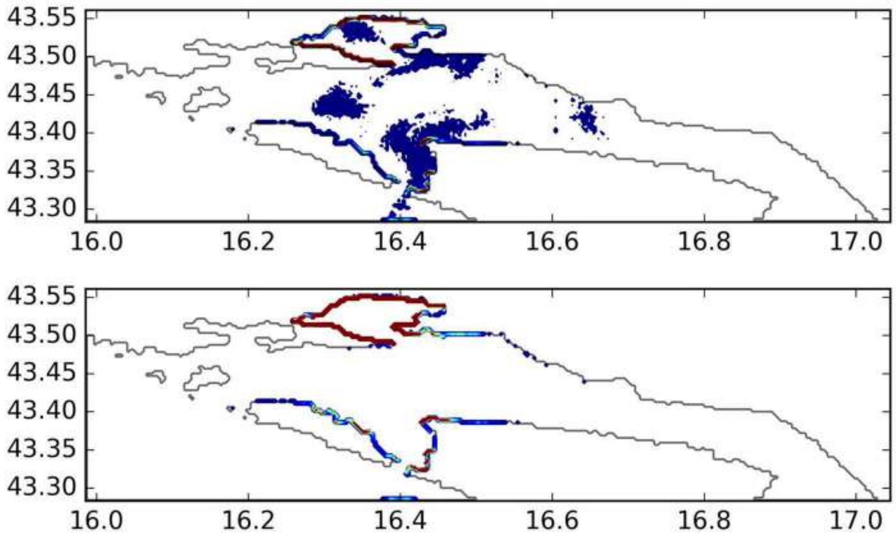


Fig. 9. Oil spill in the **Gulf of Split scenario**, after 24 hours: top: surface oil, center: dispersed oil, down: beached oil. (blue, low hazard index, red high hazard index).

Gulf of Patras (GR)

The simulations were performed for the Gulf of Patras, (Figure 10), setting the oil spill from the chosen point (Lat=38.241007, Lon=20.867395) and following its transformation and dispersion during the following ten days. Each simulation consisted in the release of 1000 particles, corresponding to the release of 3000 m3.

The data uploaded in the Geoportal are in ASCII format. The dataset contains 30 text files, one for each day after the spill, for ten consecutive days, for:

1) oil at surface;
2) oil dispersed in the water column;
3) oil slicked at the coast.

The surface oil, the dispersed oil in the water column, and the slicked oil at the coast after 1 day (24 h) after the spill, are presented in figure 11.

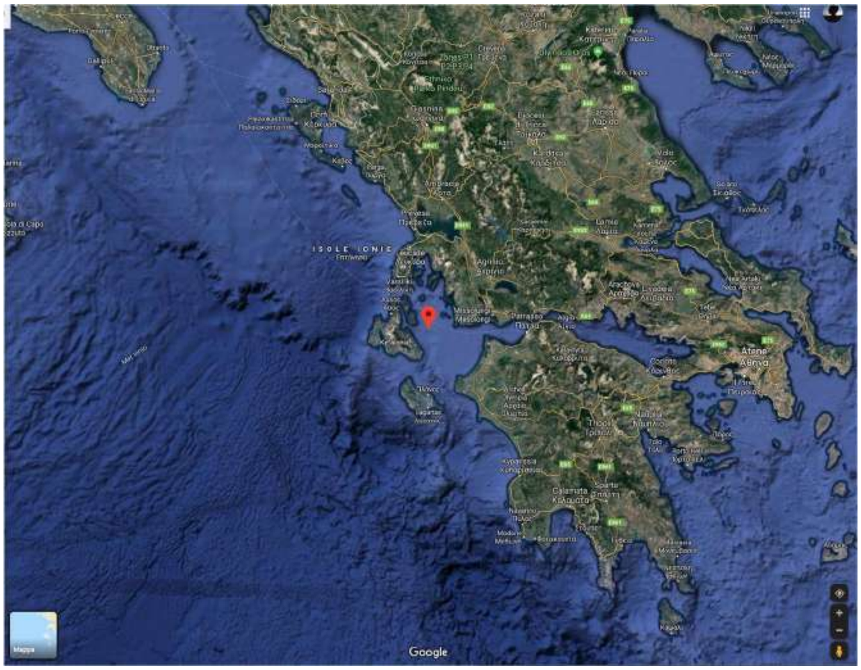
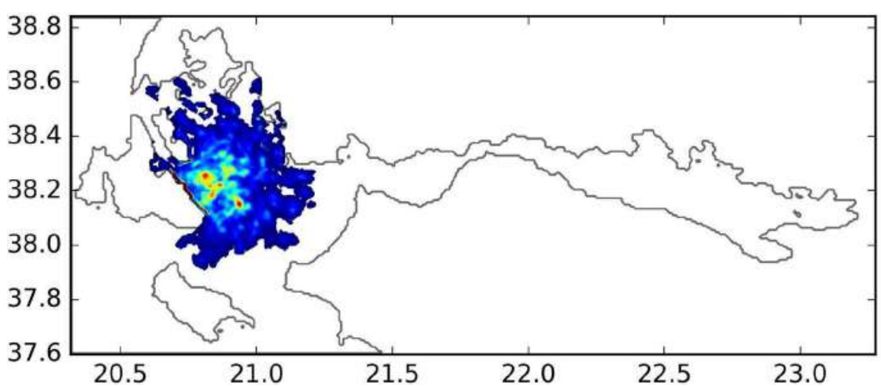


Fig. 10 Oil spill release point for the Gulf of Patras scenario



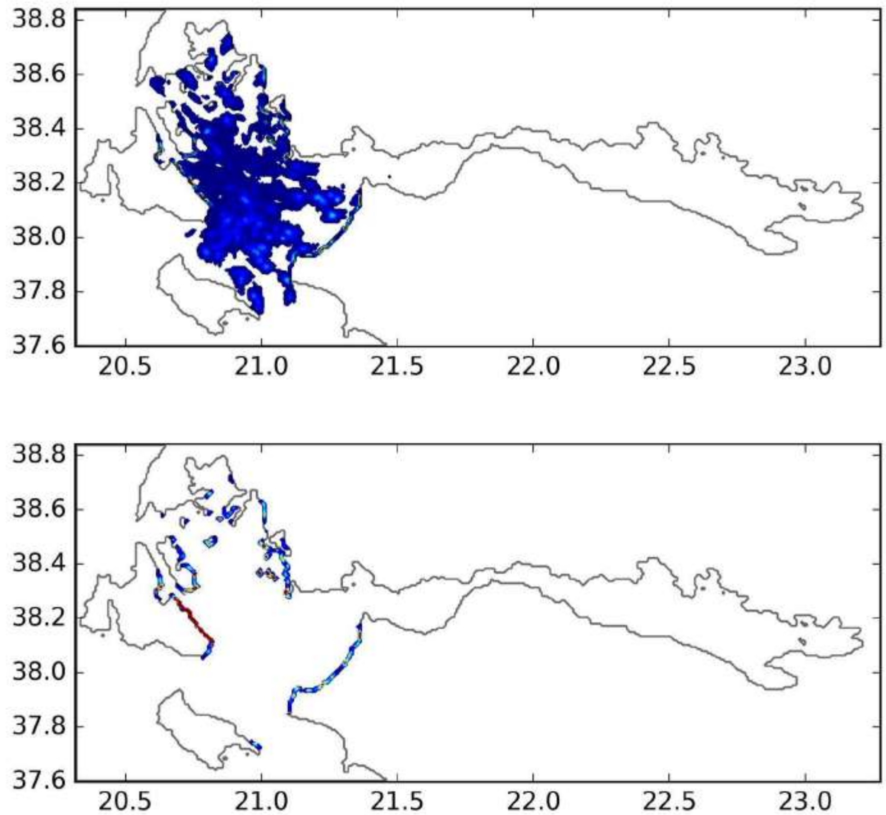


Fig. 11. Oil spill in the **Gulf of Patras scenario**, after 24 hours: top: surface oil, center: dispersed oil, down: beached oil. (blue, low hazard index, red high hazard index).

Disposal of Produced Formation Water from offshore oil and gas extraction platforms in the Adriatic Sea

In order to consolidate a transnational common approach to assess contaminant dispersion and thereof contribute to the definition of a shared strategy for the evaluation of the risk due to contaminant dispersion from different sources of pollution, discharges of produced formation water have also to be taken into account.

In fact, the wide range of potential impacts of offshore oil and gas activities requires specific management measures and crucial impacts may derive from offshore installations that physically disturb seabed habitats, cause atmospheric emissions, noise, discharge cuttings piles and produced formation water (PFW) (OSPAR, 2009; Manfra et al, 2010; Manfra and Maggi, 2012). Origin, characterization and disposal of PFW represent a key issue to assess contaminant dispersion due to offshore platforms.

The PFW is a by-product of oil and gas extraction, which to date represents the largest volume waste from the production phase of the offshore oil and gas facilities, constituting approximately 80 % of the wastes and residuals yield from natural oil and gas production operations (McCormack et al., 2001, Berry, 2005). The PFW is usually a saline water that may contain a number of potential contaminants such as heavy metals, hydrocarbons, phenols, ammonia, radionuclides and chemicals (demulsifiers and corrosion inhibitors) added at times during the operation of the well (OGP, 2005; Scott et al., 2007). The concentrations of these compounds are tipically high when compared to the receiving environment (Manfra et al., 2007).

The disposal of PFW is carried out through the reinjection into the reservoir, the transport onshore or the discharge into the ocean. After the release into the sea, PFW undergoes several different processes such as dilution into the ambient fluid, evaporation and biodegradation, volatilization towards the atmosphere and settling at the bottom.

The impact of PFW discharges on the marine environment strictly depends on the characteristics of the effluent and the receiving ambient fluid. In order to assess the potential effects and risks for marine ecosystems it is of the utmost importance to schedule specific monitoring plans.

Monitoring programmes have been developed worldwide in all the areas (e.g. North Sea, Gulf of Mexico, Adriatic Sea) characterised by an intense oil and gas extraction and production activity. These monitoring programmes are mainly aimed at: establishing the environmental background level before the PFW discharge; identifying spatial and temporal evolution of physical, chemical and biological parameters during the PFW discharge; assessing mitigation measures and defining guidelines supporting regulations and decisions. The complex dispersion processes which determines the fate of the effluents discharged into the marine environment makes it difficult to assess the behaviour of the PFW only by means of field observations (Cianelli et al., 2011).

Therefore, these need be integrated with application of numerical dispersion models to simulate transport and fate process determining the dilution of PFW in the sea water, namely the mixing of the effluent with the ambient fluid (e.g. Baumgartner et al., 1994). Such a dispersion process occurs in two phases: a rapid initial (near-field) mixing phase taking place immediately after the release within the first tens of meters from the discharge point, and the subsequent far-field passive dispersal phase that evolves at larger distance over time scales of hours or days.

The results of three works of Cianelli et al. (2008, 2009, 2013) focused on the Adriatic Sea are summarized. In these studies, a numerical model (UM3 Three-dimensional Updated Merge) was applied to simulate the temporal and spatial distribution of the PFW plume discharged from offshore gas platforms in the Adriatic Sea, identifying the main environmental factors affecting plume behaviour.

UM3 is a mathematical Lagrangian model commonly used by US EPA for marine discharges and available in the software application Visual Plumes (e.g. Frick et al., 2004). It uses as initial conditions the measured data on currents and density profiles of the receiving water column as well as the measured PFW concentrations and flow and the outfall pipe geometrical features. This model allows to consider the diameter, the orientation of the port and the depth of discharge as further outfall features which may affect the effluent velocity and the plume trajectory. The numerical output provides the following wastefield characteristics at the border of the near field: the average dilution factor, the plume rise height, thickness and diameter, the length of the near field and the initial mixing time. In order to simulate the PFW plume performance under a range of environmental and discharge conditions, the model is initialized with several field data collected during the monitoring surveys; UM3 addresses this issue allowing the use of time series data as input parameters. Ambient properties such as currents velocity and stratification conditions also affect the rate of dilution thus determining the concentration of contaminants in the receiving waters. The ambient salinity and temperature influence the plume buoyancy determining the equilibrium density of the plume in the water column. UM3 has proven to provide the best simulation of the initial dilution and length of near field zone.

As indicated in Fig. 12, Cianelli et al. (2008, 2009, 2013) results are summarized as follows:

- In high stability conditions of water column (summer) the simulations showed low dilution due to the limited extent of the initial mixing zone of the PFW plume, whereas during winter the weak stratification sustained the dilution of the plume over a wide zone of the water column.
- The highest PFW concentrations, within the nearfield zone, are found with strong stratification and low current velocity. Discharging higher volumes of PFW during the winter period could be a good practice, as it would promote the dilution in the near-field.

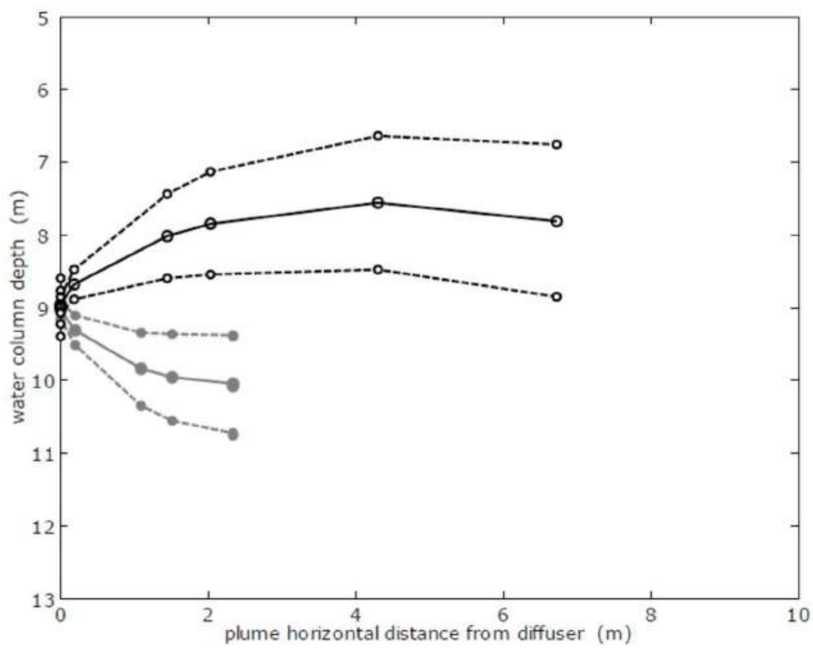


Fig. 12. The vertical section of the plume vs, the horizontal distance from the releasing point in summer (grey lines) and winter (black lines) conditions. The solid line represents the centreline of the plume, the dashed lines represent the plume boundaries.

Such results may play a crucial role in a "prevention first" policy and represent an important tool in the design of a decision-making action to protect the marine ecosystems from the impacts of the offshore platform operations.

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

Screening and bibliographic research on the oil spill risk index and on oil spill modelling and related parameters.
- Annex to Deliverable T3.1.3

Work Package T3 – Case study of contaminant dispersion

Contributors:
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September 2018

1. Objective

The objective of the first 6 months of work was the preparation of the working tools for the analysis of dispersion of oil spills, and the contribution to the identification of the oil spill risk index. These objectives have been reached by developing different activities, such as modelling tests, and desk based data search.

1. Revision of oil spill models

The revision of the oil spill risk models and of their processes (represented in figure 4) has been started, making comparisons with different, and parameterizations (Fig. 5). In particular, comparisons between MedslikII and OILTRANS have been performed, and the OILTRANS module has been tested.

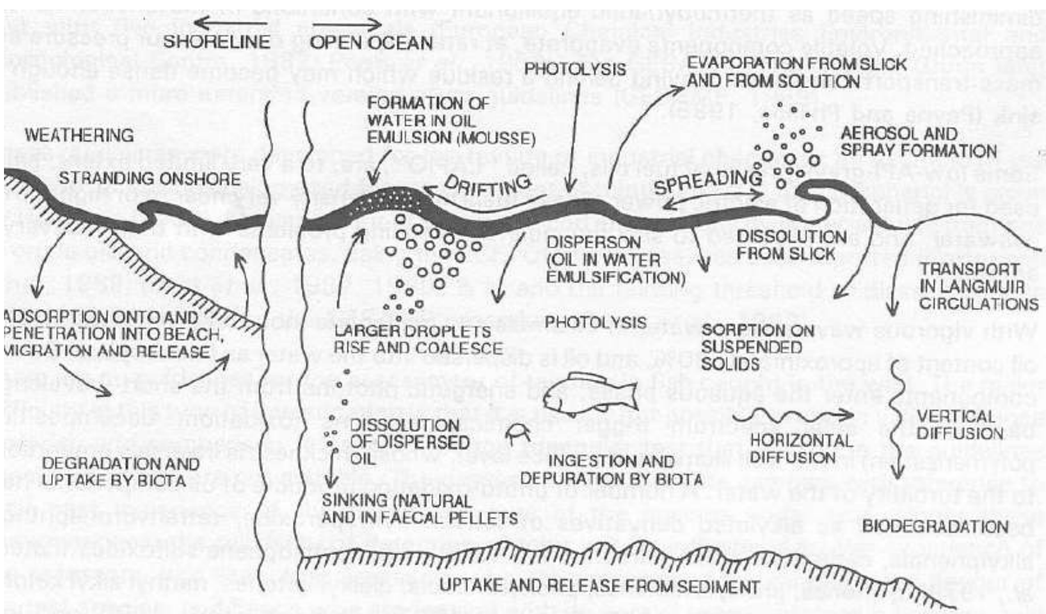

Fig. 1. Oil in sea water: dynamics and processes.

Processes presently modeled by examples of referenced oil or inert drift modeling systems

	ADIOS	GNOME	OILMAP / SARMAP / OILMAPWEB	OSCAR	MOTHY	POSEIDON OSM	MEDSLIK	MEDSLIK II	SEATRACK WEB	OILTRANS	BSHmod.L	SLROSM	OD3D + LEEWAY	GulfSpill	MOHID	OILTRANS mod
Advection	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Diffusion	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Wind drift	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Stokes drift	-	-	-	+	+	+	-	+	+	+	+	-	+	-	+	+
Floating objects	-	-	+	-	+	-	+	+	+	-	+	-	+	-	+	-
Backtracking	-	-	+	-	+	-	+	-	+	-	-	-	-	-	+	+
Stranding	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Spreading	+	-	+	+	+	+	-	-	+	+	+	+	-	+	+	+
Evaporation	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Emulsification	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Natural Dispersion	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Vertical Movement	-	-	+	+	+	+	-	-	+	-	+		+	-	+	-
Dissolution	-	-	+	+	-	-	-	-	-	-	-	-	-	-	+	-
Sedimentation	-	-	-	+	+	+	+	+	+	-	+	-	-	-	+	-
	ADIOS	GNOME	OILMAP / SARMAP / OILMAPWEB	OSCAR	MOTHY	POSEIDON OSM	MEDSLIK	MEDSLIK II	SEATRACK WEB	OILTRANS	BSHmod.L	SLROSM	OD3D + LEEWAY	GulfSpill	MOHID	OILTRANS mod

Fig. 2. Oil spill models and their processes.

2. Identification of oil spill risk indexes

The screening and bibliographic research on the oil spill risk index has been started, focusing on the risk index introduce in the Italian regulations with the DLGS 145, 18/8/2015. (Fig.6)


LINEE GUIDA
PER LA REDAZIONE
DELLA RELAZIONE SUI GRANDI RISCHI
E LA VALUTAZIONE DEL RISCHIO
IN ACCORDO
AL DLGS. N.145 DEL 18 AGOSTO 2015

2.3. CRITERIO DI ACCETTABILITÀ PER IL RISCHIO AMBIENTALE

In letteratura a livello internazionale non sono disponibili criteri consolidati e ben strutturati per la valutazione dell'accettabilità del rischio ambientale. Nella sezione che segue si riporta una metodologia che si ritiene idonea per la verifica ai sensi del D.Lgs. 145/2015.

2.3.1. CRITERI DI ACCETTABILITA' RACCOMANDATI PER IL RISCHIO AMBIENTALE PER L'APPLICAZIONE DEL D.LGS.145/2015

I criteri di accettabilità per il rischio ambientale devono tenere in considerazione diversi parametri tra cui la probabilità che si verifichi un incidente ambientale grave, la severità del danno e la risposta dell'ambiente. Inoltre deve essere ben definito come tali valori sono stati individuati e quali assunzioni siano state fatte.

Partendo dall'analisi del Decreto, si definisce incidente ambientale grave un incidente che provoca, o rischia verosimilmente di provocare un significativo danno ambientale così come definito dal D.Lgs. 3 aprile 2006 n.152, compreso il deterioramento provocato alle acque marine, come definite dal D.Lgs. 13 ottobre 2010, n.190.

Con danno ambientale si intende qualsiasi deterioramento significativo e misurabile, diretto o indiretto, di una risorsa naturale o dell'utilità assicurata da quest'ultima.

Ai sensi della direttiva 2004/35/CE, costituisce danno ambientale il deterioramento, in confronto alle condizioni originarie, provocato:

COMITATO PER LA SICUREZZA DELLE OPERAZIONI A MARE
Linee Guida per la redazione della Relazione Grandi Rischi e la valutazione del rischio in accordo al D.Lgs. 145/2015 –
Allegato 3: Criteri di accettabilità del rischio

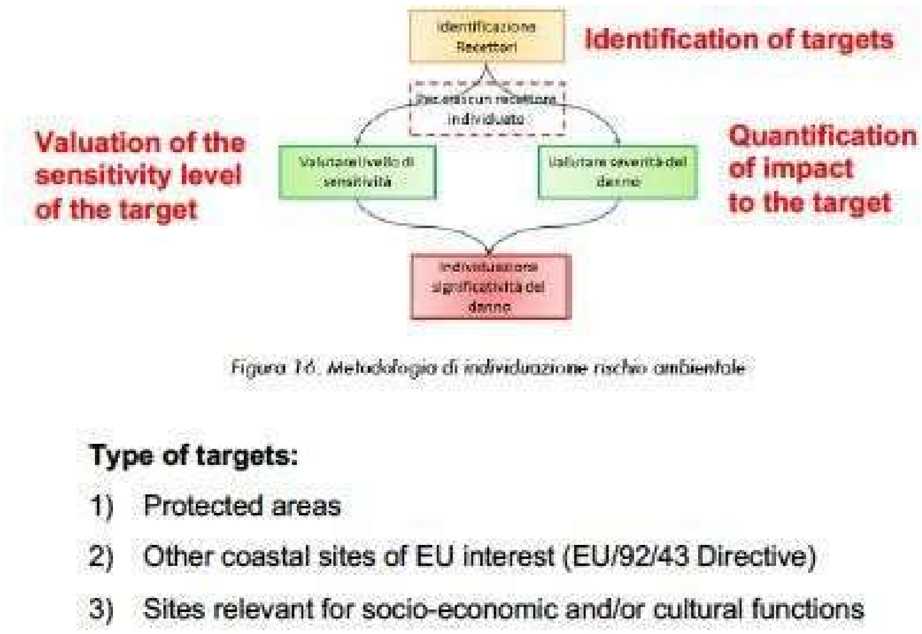

Fig. 3. Identification of oil spill risk index.

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