Venezia 2021

Programma di ricerca scientifica per una laguna "regolata"

Linea 2.1

Qualità del sedimento lagunare a supporto della sua gestione sostenibile

D2.1.1.2

Inventario delle conoscenze disponibili

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Sommario

La gestione dei sedimenti all'interno della laguna di Venezia, con la costruzione delle strutture morfologiche necessarie al contenimento dell'erosione e al mantenimento delle caratteristiche intertidali della laguna, è cruciale. Il problema principale nel processo pianificatorio consiste nel valutare il corretto riutilizzo dei sedimenti dragati, mantenendo la qualità e la biodiversità complessiva dell'ecosistema lagunare e dei servizi ecosistemici che esso fornisce, quali quelli legati alle attività produttive (ad es. allevamento di molluschi bivalvi).

In questo contesto, è in corso la revisione della normativa applicata in Laguna (il cosiddetto "Protocollo Fanghi" del 1993) da cui dipendono le scelte gestionali relative alla movimentazione del sedimento. La comunità scientifica è in grado di offrire un valido supporto alla nuova classificazione attraverso una serie di approfondimenti che permettono una corretta valutazione della qualità dei sedimenti, attraverso l'integrazione di diverse tipologie di indagine che valutino la reale mobilità e biodisponibilità degli inquinanti del sedimento di fondo.

Inoltre, sarà necessario considerare e valutare gli effetti che la messa in esercizio del MOSE potrà avere sulle dinamiche sedimentarie, sulla qualità del sedimento, sugli organismi e sulle attività produttive legate alla molluschicoltura.

Attraverso l'integrazione di diverse tipologie di indagini sperimentali e modellistiche, la linea 2.1 ha come obiettivo fondamentale l'ottenimento di informazioni necessarie a supportare una gestione sostenibile dei sedimenti. A questo fine verranno ampliate le conoscenze sulla qualità del sedimento, sulle dinamiche che la determinano e influenzano, nonché sull'interazione con gli organismi lagunari.

La linea di ricerca, costituita da diverse indagini strettamente integrate tra loro, è strutturata in quattro workpackages:

WP2.1.1 "Inventario delle informazioni disponibili e determinazione dei valori di fondo";

WP2.1.2 "Valutazione della qualità dei sedimenti per fini gestionali legati alla loro movimentazione";

WP2.1.3 "Studio del sedimento lagunare come sorgente secondaria di contaminazione";

WP2.1.4 "Valutazione degli impatti della messa in funzione del MOSE sulla produttività delle aree di molluschicoltura della laguna di Venezia".

L'obiettivo della Deliverable 2.1.1.2 "Inventario delle conoscenze disponibili", pianificata nel WP2.1.1, Task2.1.1.1 "Inventario delle informazioni disponibili sulla qualità del sedimento e delle acque della laguna di Venezia" per il mese 4 (fine febbraio 2019), e successivamente prorogata al mese 6 al fine di permettere il completamento dei lavori, è quello di fornire un'analisi critica delle informazioni disponibili, dalla letteratura e da autorità ed istituti rilevanti, su i) i valori di fondo dei contaminanti inorganici nella laguna di Venezia; ii) la qualità delle acque e dei sedimenti superficiali e profondi; iii) il ruolo del sedimento come sorgente secondaria di contaminazione. Sulla base di questa analisi sono state identificate le lacune di conoscenza che verranno affrontate rispettivamente nei WP2.1.1, WP2.1.2 e 4, e WP2.1.3 e che hanno guidato e guideranno la pianificazione dettagliata delle attività sperimentali nei quattro WP (Deliverable 2.1.1.3 "Design sperimentale").

A tal fine la stessa è strutturata in cinque capitoli. Il primo fornisce una breve introduzione alla deliverable. Il Capitolo 2 presenta i metodi utilizzati per raccogliere le informazioni disponibili, ed è seguito da tre capitoli nei quali le informazioni raccolte sono analizzate in maniera critica al fine di evidenziare punti di forza e lacune di conoscenza relativamente ai temi di ricerca della linea 2.1: Capitolo 3 "Sediment natural background" (WP2.1.1), Capitolo 4 "Sediment as secondary source of contamination" (WP2.1.3), Capitolo 5 "Sediment and water quality" (WP2.1.2 and 4). Seguono infine delle brevi conclusioni.

Per quanto riguarda il tema "Sediment natural background", come riportato nel Capitolo 3, sono stati esaminati sia la letteratura scientifica che i progetti esistenti per presentare, da un lato, una panoramica delle metodologie esistenti utilizzate per distinguere le concentrazioni di fondo naturale dagli input

antropogenici per diversi contaminanti inorganici e, dall'altro, i valori di fondo disponibili, determinati da studi precedenti condotti per i sedimenti della laguna di Venezia. Dopo aver introdotto il concetto di valore di fondo, nel Capitolo 3 vengono descritte le metodologie usate per discernere tra concentrazioni di fondo naturali e antropiche. Nello specifico, vengono discussi vantaggi e svantaggi delle metodologie di indagine, distinguendo tra metodologie empiriche e statistiche. Infine, si conclude indicando l'opportunità di aggiornare i valori di fondo esistenti (Task 2.1.1.2) soprattutto in ragione di un possibile cambiamento delle condizioni ambientali (es. TOC, Fe, Al), e di andarli a comparare con i valori regionali nei suoli, nonché con i valori ricavati da carote profonde in canali navigabili (WP2.1.2) per evidenziare il potenziale contributo delle acque sotterranee.

Per quanto riguarda il tema "Sediment as secondary source of contamination", come riportato nel Capitolo 4, si è proceduto con la revisione della letteratura scientifica disponibile su due argomenti specifici. Per il primo, relativo ai processi all'interfaccia acqua-sedimento, sono stati raccolti ed analizzati i lavori più rilevanti e sono state evidenziate delle lacune di conoscenza (che saranno colmate nella T2.1.3.1) relative alle dinamiche (abbondanza) e alla diversità dei batteri e al loro collegamento con i flussi bentici (inclusi i flussi diffusivi). Per il secondo argomento si è proceduto in maniera analoga e le lacune evidenziate, relative alla relazione tra le proprietà della frazione fine/ultrafine dei sedimenti e il suo effetto tossicologico per gli organismi acquatici, richiederanno lo sviluppo e l'applicazione di un nuovo approccio sperimentale nella T2.1.3.2.

Infine, per quanto riguarda il tema "Sediment and water quality", nel Capitolo 5 la conoscenza esistente rispetto alla valutazione della qualità dei sedimenti e dell'acqua nella laguna di Venezia è stata descritta in quattro paragrafi distinti. Il primo paragrafo introduce l'approccio "Weight of Evidence" (WoE) come metodologia per valutare la qualità dell'acqua e del sedimento attraverso le cosiddette "linee di evidenza" (LoE) e illustra se e come questo approccio sia stato implementato nei progetti di ricerca condotti sulla laguna di Venezia negli ultimi 20 anni dalle autorità e dagli enti locali. I paragrafi successivi approfondiscono le conoscenze disponibili relative alle cinque LoE che si considereranno in Venezia2021: chimica; ecotossicologia mediante bioassay, trascrittomica e biomarcatori; biaccumulo, quest'ultima focalizzandosi sull'analisi degli strumenti modellisitici ad oggi applicati alla laguna di Venezia.

Table of content

1 Introduction

Sediment management in the lagoon of Venice, including the construction of morphological structures necessary to control erosion and to maintain the intertidal nature of the lagoon, is of crucial importance. The main problem related to the planning process is the evaluation of a proper reuse of dredged sediments, preserving the quality and the overall biodiversity of the lagoon ecosystem and of the ecosystem services that it provides, such as those linked to productive activities (e.g. shellfish farming).

In this context, the current legislation that regulates the management of dredged sediments in the lagoon (the so-called "Protocollo Fanghi", 1993) is undergoing revision. The scientific community is able to provide a valuable support for the new classification of dredged materials, through a series of in-depth analyses aimed at a correct evaluation of sediment quality. This will be accomplished through the integration of different methods of investigation, capable to evaluate the actual mobility and bioavailability of sediment contaminants.

Moreover, it will be necessary to take into account and evaluate the effects that the commissioning of the MOSE system might have on sediment dynamics and quality, on organisms and on productive activities related to shellfish farming.

Through the integration of different methodologies for both experimental and modelling research, the primary objective of line 2.1 is to obtain the necessary information to support a sustainable management of sediments. To this end, this research line is expected to achieve a deeper knowledge on sediment quality, on the dynamics that determine and influence quality itself, as well as on sediment interaction with lagoon organisms.

The research line is structured into the following four workpackages (WPs):

WP2.1.1 "Inventario delle informazioni disponibili e determinazione dei valori di fondo";

WP2.1.2 "Valutazione della qualità dei sedimenti per fini gestionali legati alla loro movimentazione";

WP2.1.3 "Studio del sedimento lagunare come sorgente secondaria di contaminazione";

WP2.1.4 "Valutazione degli impatti della messa in funzione del MOSE sulla produttivita delle aree di molluschicoltura della laguna di Venezia".

The goal of Deliverable 2.1.1.2 "Inventario delle conoscenze disponibili", planned in WP2.1.1, Task2.1.1.1 "Inventario delle informazioni disponibili sulla qualità del sedimento e delle acque della laguna di Venezia" by month 4 (end of February 2019), and later postponed to month 6 to allow its completion, is to provide a critical review of the available information, from the literature and from relevant authorities and institutes, about i) background values of inorganic contaminants in the lagoon of Venice; ii) the quality of water, surface sediments and bottom sediments; iii) the role of sediment as a secondary source of contamination. Accordingly, relevant knowledge gaps are identified. Such gaps will be addressed in WP2.1.1, WP2.1.2 and 4, and WP2.1.3, respectively, and will guide the detailed planning of experimental activities of WP2.1.2-3-4 in Deliverable 2.1.1.3 "Design sperimentale".

To this end the deliverable is structured into five chapters. The first one provides a brief introduction to the deliverable. Chapter 2 is dedicated to present the methods adopted for the collection of available information, and is followed by three chapters in which the available information is critically analysed with the aim to highlight strengths and knowledge gaps in view of the three research areas addressed in line 2.1: Sediment natural background (WP2.1.1), Sediment as secondary source of contamination (WP2.1.3), Sediment and water quality (WP2.1.2 and 4), respectively. Then, a short conclusion section follows.

2 Search criteria and inventory of available sources

This chapter briefly reports the search criteria and methods adopted to collect available information from both relevant authorities and institutes (paragraph 2.1) and the scientific literature (paragraph 2.2). Results are then presented and discussed in Chapters 3 to 5.

2.1 Projects relevant to the lagoon of Venice developed by local authorities and institutes

A specific search of information focused solely on reviewing projects relevant to the lagoon of Venice developed by local authorities and institutes. The activity was carried out in order to obtain an overview of the studies focusing on the quality of water, surface sediments and deep sediments in the lagoon of Venice, on sediments natural background and on the role of sediment as a secondary source of contamination.

The main output of the described activity is Table A-1, reported as Annex, containing the detailed description of 14 scientific projects covering roughly a time span between 1998 (Mappatura) and 2017 (MODUS).

All selected 14 projects concentrate on research and monitoring of the number of biological, chemical and physical parameters and processes (e.g. rates of erosion and sedimentation or radionuclide fluxes at the sediment/water interface) which can be used to describe quality of sediments and water in the lagoon.

The main factors taken into account during selection process were availability of original data and reports containing objectives, methodologies, analysis and discussion of the results.

The final table (Table A-1 reported as Annex) was populated with relevant information categorised into 11 topics: *Project* (*Progetto*, abbreviated name), *Title (Titolo)*, *Responsible authority/institute (Competenza)*, *Objectives (Obiettivi)*, *Timing (Tempistica)*, *Monitoring/Research* (*Attività monitoraggio/ricerca*, main focus of the project), *Bio-physico-chemical parameters and processes* (*Parametri e processi bio-fisico-chimici*, list of studied variables and processes), *Sediments* (*Sedimenti*, details methodology applied to study sediment compartment), *Water* (*Acqua*, details methodology applied to study water compartment), *Human health* (*Salute umana*, details any information regarding human health risks or exposures to contaminants), *Relevance to line 2.1 objectives* (*Rilevanza per obiettivi linea di ricerca 2.1*, classifies projects according to their relevance to the three research area of 2.1: i) sediment natural background, ii) sediment as secondary source of contamination, iii) sediment and water quality). Finally, the last column reports the *bibliographic reference* (*riferimento bibliografico*) used to fill in the row for the specific project.

The retrieved list of projects and source references is the following:

1. **Mappatura** (MAV-CVN, 1999)
2. **Orizzonte 2023, LINEA A, LINEA B, LINEA C, LINEA D, LINEE EA-EE, LINEA F** (MAV-CVN, 1999)
3. **DRAIN** (MAV-CVN, 2004)
4. **MELa1 - studio ARTISTA, MELa2, MELa3, MELa3 - DPSIR 2005** (MAV-CVN, 2004)
5. **ICSEL A, ICSEL C** (MAV-CVN, 2005)
6. **CORILA Linea 3.08** (CORILA, 2004)
7. **CORILA Linea 3.11** (CORILA, 2004)
8. **ISAP** (MAV-CVN, 2004)
9. **SIOSED** (MAV-CVN, 2005)
10. **MAPVE-1,2** (MAV-CVN, 2007)
11. **HICSED** (MAV-CVN, 2011)
12. **QSEV** (MAV-CVN, 2011)
13. **MODUS** (MAV-CVN, 2018)
14. **TRESSE** (UNIVE, 2015)

A number of MAV-CVN research and monitoring projects were developed in the past to address quality of the lagoon ecosystem. The past projects developed before MAPPATURA (1999), which were not considered in the analysis due to lack of data and therefore not included in the Table A-1, are listed below:

- Studio A.3.1: Campagne di misure chimico-fisiche in laguna – 1^ fase, in cui è stato valutato lo stato trofico in un arco annuale con 6 campagne di rilevamento e 15 stazioni in laguna centrale (1984 – 1985);
- Studio A.3.2: Campagne di misure integrative per la determinazione dello stato qualitativo dell'ecosistema lagunare (acque, sedimenti, organismi) con 27 stazioni su tutta l'area lagunare (1986-1988);
- Studio A.3.3./1.3.2: Distribuzione delle concentrazioni di inquinanti e delle velocità di corrente in diverse sezioni alle bocche di porto (1987-1988);
- Studio A.3.4/1.3.3: Integrazione degli elementi conoscitivi relativi agli apporti di inquinanti in laguna attraverso il censimento degli apporti in laguna di origine civile, industriale, agricola, portuale ed atmosferica. (1986-1990);
- Studio A.3.9 /1.3.9: Rapporto sullo stato attuale dell'ecosistema lagunare (1988-1990);
- Studi A.3.16 I^ e II^ fase: Composizione delle comunità biologiche connesse con le modifiche morfologiche della laguna (1990-1991 e 1991-1992);
- Studio sui processi Biogeochimici in laguna, I fase;
- Studio A.3.21 – Indagini a supporto degli interventi per l'arresto del degrado nella laguna di Venezia – Studio sui processi Biogeochimici in laguna, II fase (1993-1994);
- Verifica sperimentale di tecniche di arresto ed inversione del degrado della laguna - intervento in Palude della rosa (1993-1995);
- Studi, monitoraggi ed attività speciali eseguiti nell'ambito degli interventi per l'arresto del degrado connesso alla proliferazione delle macroalghe in laguna di Venezia (1989-1999);
- Progetto integrato Rii, Comune di Venezia, (1994-2003)

2.2 Scientific literature

The collection of available information from scientific literature was structured according to the following topics, relevant for research activities in line 2.1: i) Sediment natural background; ii) Sediment as secondary source of contamination, focusing on the "Processes at the water-sediment interface" and the "Ultrafine fraction of sediment"; iii) Sediment and water quality with a focus on "Tools for ecotoxicity assessment" and "Modelling tools". Accordingly, for each topic a short paragraph describing the search criteria and methods adopted to collect available information is reported below.

<u>Sediment natural background</u>

Sediment natural background was investigated by some monitoring and research projects (see last column in Table A-1).

Additional references on this topic was gathered through literature search in January 2019 on Scopus and other databases, by using the following keywords: 'threshold value', 'baseline concentration', 'background baseline', 'baseline marker', 'ambient background', 'natural baseload' and 'background value', 'Venice', 'Sediments', 'Sediment Quality Guidlines'.

The obtained results are reported and discussed in Chapter 3.

Processes at the water-sediment interface

Within the general framework of the sediment as a secondary source of contamination in the Venice lagoon, the role of the water-sediment interface has been addressed in a piecemeal fashion by some monitoring and research projects (Table A-1).

Additional references on the water-sediment interface in the Venice lagoon was gathered through literature search in January 2019 on Scopus and other databases, by using the following keywords: 'Bacteria', 'Archaea', water-sediment', 'DOC', 'porewater', 'benthic chamber', 'nutrients', 'contaminants', 'grain-size analysis', 'activity', 'oxygen', 'respiration', 'abundance', 'metagenomics', 'amplicons', 'fish'.

In addition, the following author names were used to refine the search*:* Zonta, Cassin, Gieskes, Pretto, Baldi, Quero.

The obtained results are reported in Table 4-1, that is presented and discussed in paragraph 4.1 of this deliverable.

Ultrafine fraction of sediment

The role of sediment as a secondary source of contamination in the lagoon of Venice has been considered in some of the research projects and monitoring activities carried out by local authorities and institutions, listed in Table A-1. These investigations examined the processes of sediment resuspension, transport and deposition in the lagoon environment, with some of them focusing more specifically on the fate and ecotoxicological effects of sediment-associated contaminants. Most information that will be discussed in paragraph 4.1 was therefore obtained from the related technical reports and peer reviewed scientific journals.

Additional literature (Table 4.2) was gathered through a literature search in January 2019 on Scopus and Google Scholar, by using appropriate keywords, both as single words and phrases ('Venice', 'lagoon', 'sediment', 'resuspension', 'suspended', 'particles', 'particulate', 'fine', 'ultrafine', 'fraction', 'grain-size', 'texture', 'contaminant', 'contamination'), as well as by using known author names (e.g. Sfriso, Zonta, Molinaroli).

When containing relevant knowledge, and to obtain more exhaustive information about what we refer to as the "ultrafine" fraction of suspended sediments (<4 μm), the review included also investigations dealing with suspended particulate matter in the water column and studies that investigated sedimentary dynamics mostly in relation to lagoon morphology.

The obtained results are reported in Table 4.2, that is presented and discussed in paragraph 4.2 of this deliverable. Relevant literature about toxicity testing related to suspended sediments has been also identified from the sources presented in Chapter 5, Table 5.5.

Tools for ecotoxicity assessment

As concern ecotoxicity data, the literature review conducted in January 2019 has been focused on studies concerning toxicity testing, bioaccumulation, biomarker and transcriptomics, performed in the lagoon of Venice, including both field studies and laboratory analyses. Search engines exploited for the review were Scopus and Web of Science; keywords used for screening the documents were: 'sediment toxicity', 'toxicity testing', 'bioaccumulation', 'transcriptomics', 'biomarker' and 'ecotoxicology', coupled with the key search parameter "Venice lagoon".

The data returned by the search engines were pooled, checked for duplicate entries, screened to eliminate references dealing only with sediment or water chemistry, and then merged with data provided by a previous overview of ecotoxicological studies performed in the Venice lagoon by Losso and Volpi Ghirardini (2010).

This review process allowed to retrieve 110 peer reviewed papers, covering a period from 1982 up to 2019, which are reported in Table A-2.

Since in Venezia 2021, line 2.1, ecotoxicity assessment will be performed by integrating the following Lines of Evidence (LoEs): Ecotoxicological bioassays, Trascriptomics, Biomarkers, and Bioaccumulation, the collected literature has been classified according to these types of tools (see last column in Table A-2). Moreover, since research activities in line 2.1 will mainly focus on the first three LoEs (while Bioaccumulation LoE, although taken into account to complete the ecotoxicity assessment, will not be deeply investigated through innovative experimental approaches), the analysis of the collected information reported in Chapter 5 is focused on ecotoxicological bioassays (sub-paragraph 5.3.1), genomic assays (sub-paragraph 5.3.2) and biomarkers (sub-paragraph 5.3.3).

Modelling tools

To review environmental models developed and/or applied in the Venice lagoon, a literature search was performed on January 2019 in Scopus. This search was also aimed at providing a complete overview on the research carried out so far on modelling activities related to pollution in the lagoon of Venice, to complete the picture outlined in Table A-1. Keywords applied in the search were 'Veni*', 'lagoon', 'model*'; the period of interest was 1999-2019, as this is the reference period of the monitoring projects funded in the Venice lagoon (see Table A-1). 141 hints resulted as original research and review papers. The main interest of the review was to find out which are the model applications available in the lagoon of Venice concerning different aspects of water and sediment pollution, in order to better plan future activities in Venezia2021. Of the identified papers around one third was dedicated to model applications related to chemicals behaviour in water and sediment.

Of these, several papers were reporting geostatistical analysis, decision-related modelling or PM2.5 and PM10 atmospheric modelling and were not considered further for the aim of this deliverable. The relevant publications are reported in Table 5.7 in paragraph 5.4, where the model application, the contaminants of interest and the objective of the study are reported and discussed. Also, where a link to the projects listed under Table A-1 was declared in the papers, it is outlined in the table and in the discussion.

3 Sediment natural background

As anticipated in Chapter 2, both literature and projects were scrutinised in order to present on the one hand an overview of existing methodologies employed to distinguish natural background concentrations from anthropogenic inputs for several common contaminants, mostly microelements, and on the other hand ranges of natural background values already established for the sediments of the lagoon of Venice.

3.1 Review of available information on sediment natural background

It is often an important question whether concentration of a chemical, especially a priority substance, is at or is approaching background levels for naturally occurring substances or remains close to zero for man-made chemicals. The natural background can be defined as the concentration of the contaminant at a pristine or remote site based on contemporary or historical data (OSPAR Commission, 2009). Another term used in relation to sediment contamination is anthropogenic enrichment that is the current concentration of a substance which exceeds natural background levels: it indicates the magnitude of human-induced change (Guerzoni et al., 2007). Knowledge about background concentration and its variability can be of use in the assessment of anthropogenic contributions to the overall level of pollution (Chapman, 2007), legal issues such as setting up concentration limits (Apitz et al., 2007) or estimation of vertical extent of contamination (Degetto et al., 2005). In the specific case of the lagoon of Venice, natural background values can be used as important criteria helping in designing management strategy of dredged materials and in morphological reconstruction (Apitz et al., 2007b).

There is a number of methodologies used to differentiate between anthropogenic and naturally occurring concentrations. They can be divided into two categories: empirical and statistical techniques.

Empirical methods often require finding a reference site unaffected by anthropogenic inputs (Geiselbrecht et al., 2019). Several methods have been developed based on: i) global averages of metal concentration in upper crust and marine shale, ii) pristine areas which requires identification of uncontaminated areas, iii) the use of catchment geology, soils, shales and fluvial sediments (Giandon, 2015) and iv) sediment core data. Comparison between concentration of chemical in contaminated site and reference site requires often a correction for grain size and/or organic carbon.

Statistical methods aim at differentiation of the initial observed chemical concentration data into natural and anthropogenic subsets and establishing a threshold dividing the two groups. Among exercised statistical methods in establishing natural concentrations are cumulative frequency, modal analysis or outlier testing (Matschullat et al., 2000). More techniques used in deriving background values were reviewed by Birch (2017); these are regression techniques, cluster/factor analysis, multi-fractal analysis, maximum likelihood mixture estimation, population clustering, gradient method, sorption hypothesis and specific surface area methods. Most of the statistical techniques require data to be normally, or log-normally distributed. This is however often a requirement difficult to meet, due to various processes affecting distribution of substance concentration, leading to anomalies in observed data. Detection of such anomalies is frequently performed throughout identification of outliers (Reimann et al., 2005). Characterisation and removal of outliers, that is concentration levels above natural background, is often used as a basis of various statistical methods. The statistical procedure for removal of outlier and application of multiple regression analysis was demonstrated by Apitz et al. (2009) on Venice Lagoon sediments for the most recent deposits in order to separate natural and anthropogenic levels of the microelements and calculate ranges of natural background concentrations.

Background values are sometimes used to derive Sediment Quality Guidelines (SQGs) (Kwok et al., 2014), however neither background nor enrichment metric take into account, or imply, biological effects or toxicity (Chapman and Wang, 2001). As background concentrations reflect the pristine condition, these values should be lower than SQGs, except in cases of mineralised catchments and excessive atmospheric pollution (Birch, 2017). Although these two metrics (background and enrichment) are based on different methodologies and criteria, they are often confounded and are even aggregated into a single value, or indicator, e.g. the Pollution Load Index (Caeiro et al., 2005) which combines enrichment and SQGs. Another example is Priority Index, which aggregates three indices: the Pollution Load Index, the Ecological Risk Index and the Geo-accumulation Index (Kabir et al., 2011).

Examples of studies where estimation of natural background values in the lagoon of Venice is described along with the estimated concentration ranges are the following:

1) Prediction of the natural background concentrations of microelements using multiple linear regressions on a dataset obtained by radiochronological dating and statistical methods (Apitz et al., 2009);

Element (mg/kg)	Range
Hg	<0.02 - 0.3
Cd	0.1 - 1.2
Pb	5 - 50
As	5 - 35
Cr	4 - 80
Cu	5 - 40
Ni	5 - 45
Zn	40 - 130

2) Geochemical normalization. Ambient contaminant levels or background natural levels, or a combination of both, can be separated from site-specific anthropogenic inputs by normalizing to or plotting against sediment characteristics that tend to indicate natural metal-rich particles (e.g., Fe, Al) or fine-grained particles (e.g., Fe, Al, %fines, %organic carbon) (Lucchini et al., 2001);

Element (mg/kg)	Core B*		Core F		Core D	
	AVE[1]	SD[2]	AVE	SD	AVE	SD
Cu	23.3	0.6	26.4	1.5	31.2	1.8
Zn	70.7	4.8	82.6	6.8	79.7	5.2
Pb	12.1	2.2	19.7	6	20.2	3.6
Cu/Al	4.3	0.6	4.4	0.5	5.6	0.8
Zn/Al	13.1	0.4	13.6	1.3	14.2	0.8
Pb/Al	2.3	0.5	3.1	0.8	3.6	0.6

**Core B, northern lagoon; Core F, central northern lagoon; Core D, central lagoon.*

[1] AVE = average

[2] SD = standard deviation

3) Reconstructing the inventories and fluxes of pollutants in the sediments and evaluation of the homogeneity of the entire sedimentary system based on radiochemical survey of airborne radionuclides (Degetto et al., 2005, 1999);

Element (ppm)	Core 1*	Core 2	Core 3
Cr	nd	18-30	nd
Ni	34-38	nd	Nd
Cu	11-13	2-4	9-12
Zn	82-89	60-62	69-74
As	nd	nd	11-12
Cd	nd	nd	0.6-0.7
Hg	nd	0.1-0.3	0.5-0.6
Pb	25.29	12-13	23-25

**Core 1, the Cona Marsh (side NE); Core 2, the area south of ''S.Giacomo in paludo''; Core 3, the area close to Venice, south side.*

4) Statistical analysis of the distribution of As and Cr in geological strata in relation to the granulometric characteristics of the sediments affected by the widening of the Malamocco-Marghera channel project (APV, 2014);

Element (mg/kg)	Average	SD	MIN	MAX	SUM*
As	14.6	14.2	2.1	150	7235.3
Cr	15.4	12.6	4.7	180	7658.6

**54 core samples*

5) Organic contaminants background (pre-industrial) values derived from dated cores collected inside lagoon and city channels (Guerzoni et al., 2007).

Substance	Background concentration
PCB (µg/kg dw)	1
PCDD/Fs (µg/kg dw)	0.03
2,3,7,8-TCDD equivalent (I-TE) (ng/kg dw)	0.5
HCB (µg/kg dw)	0.1

Overall, on the one hand empirically derived background values can be significantly affected by local geological mineralisation making a single background for regional assessments problematic. On the other hand statistical techniques applied to distinguish background values are adversely affected by multiple distribution modality and require large data sets. In the first case the use of sediment cores seems to be most attractive when assessing background concentration, providing that sedimentary deposits are homogeneous (Degetto et al., 2005, Frignani et al., 2001a, 2001b). Additionally, the technique allows for dated record of contamination.

Subsequent developments could be considered in updating background concentration of the relevant chemicals (Task 2.1.1.2). Estimation of the background concentrations for the watershed, and comparison between regional background values in soils and those present in lagoon sediments could be included. Calculation of background concentration in function of various variables such as TOC, Fe, Al, which already exist in the literature, however need an update due to changing environmental conditions. Moreover normalisation of background values using the updated environmental variables would be of interest.

Additionally, knowledge gained from the new measurements of elements in deep sediments from the navigation channels (planned in WP2.1.2) would have an impact on the understanding of the vertical distribution of metal(loids) concentration; this also would elucidate potential contribution of elements from polluted groundwaters.

4 Sediment as secondary source of contamination

In line 2.1, the investigation of sediment as secondary source of contamination includes two specific in-depth analyses: i) a study about the processes at the water-sediment interface with the aim to deepen the knowledge (also in relation to the commissioning of MOSE system), about the role of sediment as a secondary source of contamination and as modifying factor for food web; and ii) a study about the ultrafine fraction of sediment (below 4 µm) with the aim to understand its role in in the overall quality of the aquatic compartment. Accordingly, the review of available information addressed these two topics separately, as presented in paragraphs 4.1 and 4.2 below.

4.1 Processes at the water-sediment interface

As anticipated in Chapter 2, most of the information was gathered from final technical reports of monitoring and reserach projects (reported in Table A-1) and scientific literature. Mostly grain-size analysis, organic matter and contaminant concentrations and sediment dynamic (erosion vs deposition) have been measured. Few data are available on dissolved organic carbon (DOC), oxygen and nutrient benthic fluxes, microbial (Bacteria and Archaea) dynamics and diversity in the water-sediment interface (Table 4.1).

Table 4.1: Relevant literature for the topic “processes at the water-sediment interface”.

Reference	Title	Sampling period	Location of sampling sites	Related topic
Chapman et al., 2008	Benthic fluxes of copper, complexing ligands and thiol compounds in shallow lagoon waters.	Oct., May	Tresse, Campalto	Benthic fluxes
Turetta et al., 2005	Benthic fluxes of trace metals in the lagoon of Venice	June	Tresse, Campalto	Benthic fluxes
Cassin et al., 2018	PAH and PCB contamination in the sediments of the Venice Lagoon (Italy) before the installation of the MOSE flood defence works.	Early year	380 stations entire lagoon	Contaminants
Gieskes et al., 2015	Anthropogenic contaminants in Venice Lagoon sediments and their pore fluids: Results from the SIOSED Projec	Over a long period: 2005-2007	Central basin, city of Venice	Contaminants
Guédron et al., 2012	Tidal cycling of mercury and methylmercury between sediments and water column in the Venice Lagoon (Italy).	Two sampling campaigns Oct.-Nov. 2008, Sept. 2009	By Torcello and Burnano	Contaminants
Zonta et al., 2007	Sediment chemical contamination of a shallow water area close to the industrial zone of Porto Marghera (Venice Lagoon, Italy)	May	Tresse	Contaminants
Han et al., 2007	Biogeochemical factors affecting mercury methylation in sediments of the Venice Lagoon, Italy.	June	Central basin, city of Venice and Palude della Rosa	Contaminants

Reference	Title	Sampling period	Location of sampling sites	Related topic
Frignani et al., 2004	Accumulation of polychlorinated biphenyls in sediments of the Venice Lagoon and the industrial area of Porto Marghera	May, Feb., Jan., Mar. (1996-1998)	Central basin and focus on Marghera	Contaminants
Fattore et al., 1996	Sterols in sediment samples from Venice Lagoon, Italy.		Dese, City of Venice, Chioggia and Adriatic Sea	Contaminants
Zonta et al., 2018	Sediment texture and metal contamination in the Venice Lagoon (Italy): a snapshot before the installation of the MOSE system.	Early year	380 stations entire lagoon	Grain-size and contaminants
Frignani, et al., 1997	Metal fluxes to the sediments of the northern Venice Lagoon.	Feb.-Mar.	Campalto-Cona	Metal fluxes
Quero et al., 2017	Seasonal rather than spatial variability drives planktonic and benthic bacterial diversity in a microtidal lagoon and the adjacent open sea	Mar., May, Oct., Feb.	Marghera (3), City of Venice (2), Adriatic Sea (4)	Microbial diversity (NGS 16S amplicons)
Perini et al., 2015	Distribution of Escherichia coli in a coastal lagoon (Venice, Italy): Temporal patterns, genetic diversity and the role of tidal forcing	Nov., Jan., Aug.	City of Venice (2)	Microbial diversity (*E. coli* by RAPD)
Borin et al., 2009	Biodiversity of prokaryotic communities in sediments of different sub-basins of the Venice lagoon	May	Entire lagoon (9 stations)	Microbial diversity (ARISA,clone libraries)
Pretto 2008	Microbes and mercury biogeochemical cycle in the Venice lagoon.	Over a long period: 2005-2007	Central basin, city of Venice	Microbial diversity (ARISA, clone libraries)
Svesson et al., 2000	Nitrogen cycling in sediments of the Lagoon of Venice, Italy	April	North central basin (Dese-Lido)	Microbial fluxes
Masiol et al., 2014	Interannual heavy element and nutrient concentration trends in the top sediments of Venice Lagoon (Italy)	June	Central lagoon (23 stations)	Nutrients
Martin et al., 1995	Significance of Colloids in the Biogeochemical Cycling of Organic Carbon and Trace Metals in the Venice Lagoon (Italy)	July	North basin (Lido-Palude Rosa, 7 stations)	Organic matter

The critical review of the collected literature from the point of view of the water-sediment interface showed that there is a lack of data on bacteria dynamics (abundance) and diversity especially by metagenomic approaches. Most of the data available on microbial functioning and diversity published have been collected in stations located in the sub-basin within Marghera, North sub-basin and the City of Venice thus not covering the entire Venice lagoon. Furthermore, there is a lack of coupling between the benthic fluxes, including diffusive fluxes, and bacteria dynamics and diversity.

In order to fill these knowledge gaps, the proposed activity of the task 2.1.3.1 will investigate:

1) Bacteria and Archaea diversity in 5 stations within 3 different sub-basins (sub-basin C, sub-basin L, sub-basin T, Zonta et al. 2018) by next-generation sequencing technology namely metagenomics coupled with analysis on bacteria abundance. Thus, extending the coverage of microbial diversity and potential functional genes related to contaminants, pathogenicity and antibiotic resistance in the Venice lagoon;

2) Benthic and diffusive fluxes (dissolved organic carbon and nutrients) will be measured and will be coupled with metagenomic data in order to characterized the microbial communities responsible to the activities within the biogeochemical cycles of carbon and nutrients at the water-sediment interface;

3) Grain-size, organic matter content of the sediment (sampled in 2.1.3.1) and heavy metal concentration will be coupled with the fluxes and diversity data to understand the potential functional response of the bacterial and archaeal resident communities and how this varies in time and space.

4.2 Ultrafine fraction of sediment

The processes of sediment resuspension, transport and redistribution have been and continue to be extensively studied in the lagoon of Venice, with the aim to evaluate their influence on both the lagoon morphology and the contamination level.

As anticipated in Chapter 2, information about the role played in these processes by the fine fraction of sediments has been obtained from both technical reports of monitoring and research projects (Table A-1) and from the scientific literature reported in Table 4.2.

Table 4.2. Relevant literature for the topic “ultrafine fraction of sediment”.

Publication	Sampling period (related project in Table A-1)	Location of sampling sites	Matrices	Parameters
Zonta et al, 2018	2008 (QSEV)	Whole lagoon 380 sites	Sediment (50-cm cores, 5 sections)	Grain-size (d<16 μm, d 16-63 μm, d>63 μm; d< 31 μm) Metals TOC, OC, IC
Cassin et al, 2018	2008 (QSEV)	Whole lagoon 380 sites	Sediment (10-cm cores, 2 sections)	PAH, PCBs Grain-size (from Zonta et al, 2018) TOC, OC, IC
Sfriso et al., 2014	2003-2005	Central lagoon 2 sites (S. Guliano, Fusina)	Surface sediment SPM (traps) R. philippinarum (transplanted)	PCDD/Fs, PCBs Grain size (<63 μm) Corg
Molinaroli et al., 2013	2008 1976-78	PortoMarghera 26 sites	Surface sediment	Grain-size (d<8 μm; d 8-63 μm; d>63 μm) Metals (Hg, Zn)

Publication	Sampling period (related project in Table A-1)	Location of sampling sites	Matrices	Parameters
Molinaroli et al., 2009	2002 1976-78	Whole lagoon 2002: 140 sites 1976-78: 162 sites	Surface sediment	Grain-size (d<8 µm; d 8-63 µm; d>63 µm) Grain-size (d 2-22; d 22-63; d 63-105 µm; d>105 µm)
Sfriso et al., 2008	2003-2005	Central lagoon 2 sites (S. Guliano, Fusina)	Surface sediment SPM (traps) R. philippinarum (transplanted)	Metals Grain size (<63 µm) Corg
R Zonta, et al., 2005	1999	Dese river (drainage basin)	Water SPM	Water: SPM, metals (total and dissolved), nutrients SPM: grain-size distribution
Sfriso et al., 2005	1998-99 1989-90	Central lagoon 4 sites (S. Guliano, Fusina, Sacca Sessola, Alberoni)	Sediment SPM (traps)	SPM rates Grain size (<63 µm)
Argese et al. 1997	1995	Inner channels of Venice	Surface sediment SPM (traps)	Metals Grain-size
Sfriso et al., 1995	1989-1990	Central lagoon (S. Guliano, Sacca Sessola, Alberoni)	Sediment SPM (traps)	Metals pH, Eh, P, N
Martin et al., 1995	1992	Central-Northern lagoon 7 sites, along a salinity gradient from Bocca di Lido to Silone channel	Water (fractionated) -	Metals Corg
Sfriso et al., 1991	Not reported	Whole lagoon 5 sites	Sediment cores Resuspended matter (RM) (portable resuspending device)	RM amounts Grain size (<63 µm) Ptot, Ntot, Corg

It is well known that the fine fraction of sediments may undergo resuspension processes more easily than the coarser one, and that fine-grained particles, due to their specific properties, are likely to play a major role as carrier of contaminants of different origins. The preferential association of some metals and POPs with fine suspended particles has been observed in different studies carried out in shallow areas of the lagoon (Sfriso et al. 2008, 2014) and in the drainage basin (Zonta et al., 2005)

However, the analysis of the collected literature revealed the lack of a comprehensive evaluation of the role played by the fine fraction of both bottom and resuspended sediments, especially in terms of its contribution to sediment toxicity. The main limitations that emerged may be summarized as follows:

- Resuspended sediments, collected by traps mostly in the central basin of the lagoon, have been the subject of a number of studies (Argese et al., 1997; Sfriso et al., 1991; 1995; 2005; 2008; 2014), some of which examined also the relationships between chemical contaminationand content of fine particles. However, these studies took into account only the fraction < 63 μm as a whole, except for thestudy by Argese et al. (1997), carried out in the inner channels of the city of Venice;

- Studies that carried out a detailed determination of grain-size distribution, whether they included (Zonta et al., 2018; Cassin et al., 2018; Molinaroli et al., 2013) or not (Molinaroli et al., 2009) the determination of contaminant concentrations, examined only bottom sediments;

- For both bottom and resuspended sediments, the analytical determination of contaminant concentrations was always performed on whole samples. No division into size fractions was carried out prior to analysis, and the relationships between contaminant concentrations and grain size were generally evaluated through statistical methods;

- None of the examined studies took into account the finest fraction (<4 μm), apart from one study that examined the colloidal fraction in water samples and determined its metal and organic carbon content (Martin et al., 1995);

- The available literature sources did not provide evidence of ecotoxicity testing of resuspended sediment or suspended particulate matter collected in the lagoon. Ecotoxicological assays were carried out mostly on laboratory-derived suspended sediments and on elutriates (see Chapter 5, Table 5.5); these matrices, however, were not usually characterized in terms of grain-size distribution, morphology and behaviour in the water column of suspended particles.

To address the knowledge gaps that emerged from the literature review, the activities of Task 2.1.3.2 are intended to develop and apply a novel experimental approach, with the aim to elucidate the relationship between the properties of the fine/ultrafine fraction of sediments and its toxic effects towards aquatic organisms. The study of the ultrafine fraction of resuspended sediments will therefore require the development and optimization of suitable procedures, since standardized methods are not available, and the literature covering this topic is scarce and scarsely pertinent.

5 Sediment and water quality

This chapter briefly describe the state of knowledge of the sediment and water quality assessment in the lagoon of Venice. Paragraph 5.1 introduces the Weight of Evidence (WoE) approach as a methodology to assess the sediment and water quality through “lines of evidence (LoE)” and presents how this approach was implemented in the reasearch projects carried out by local authorities and institutes over the last 20 years on the lagoon of Venice. Then, paragraphs 5.2, 5.3.1, 5.3.2 and 5.3.3 focus on the investigation of Chemistry, Ecotoxicological bioassays, Trascriptomics and Biomarkers LoE, respectively. Finally, paragraph 5.4 reviews the literature regarding the modelling of pollutants (nutrients, heavy metals and organic compounds) with a focus on modelling tools supporting the Bioaccumulation LoE.

5.1 Assessment of sediment and water quality

The evaluation of sediment quality is of fundamental importance in the management of the Venice lagoon, considering the essential role it plays in the lagoon environment. Indeed, the sediment continuously exchanges energy and matter with the water column, through processes of sedimentation, resuspension and erosion of clasts and organic matter and with the interaction on interstitial waters, which is populated by microorganisms that contribute to fundamental biogeochemical cycles with biological processes. All these processes influence the distribution of organic and inorganic contaminants between water and sediment and thus, determine the possible exposure of biological communities to pollutants, starting from benthic organisms living in direct contact with the sediment, including species of economic relevance for the activities of aquaculture in the lagoon.

Since the 90’s, the environment of the Venice lagoon was widely monitored and studied by the scientific community to investigate the environmental risk generated from various stressors, including pollutants (in particular persistent, toxic and bioaccumulative chemicals) (Benedetti et al., 2012). Different type of assessment approaches were applied, including extensive monitoring of chemical pollutants and other stressors (e.g. nutrients), ecotoxicological testing using different target species and endpoints, ecological investigations on several biological groups (e.g. fish, macroinvertebrates, phanerogams).

As result, it has been demonstrated that the chemical characterization of the sediment alone is not sufficient to predict the ecotoxicological effects and bioaccumulation processes connected with the transfer of chemical substances from sediment to organisms. With the aim of overcoming an assessment approach based on individual experimental evidence, and in line with the approaches proposed at international level for the evaluation of sediment quality, the Weight-of-Evidence approach (WoE) was proposed and applied to the Venice lagoon sediment (Benedetti et al., 2012; Burton et al., 2002; Chapman et al., 2002). The WoE approach is based on the integration of multiple "Lines of Evidence" (LoE), i.e. results from different fields of investigation such as chemistry, ecotoxicology, ecology, bioaccumulation. Specifically developed for the sediment quality assessment, the Sediment Quality Triad approach (Chapman, 1990; Chapman and Anderson, 2005; Ghirardini et al., 1999; Long and Chapman, 1985)) is based on the integration of i) chemical data (concentration of contaminants in the sediment and their bioavailability), ii) ecotoxicological data (results of ecotoxicological tests carried out on samples of the sediment examined) and iii) ecological data (analysis of the composition of macrobenthic communities in order to evaluate possible alterations), which together contribute to develop an integrated quality judgment on the sediment under investigation. WoE methods are also applied for the assessment of water quality, as indicated by the European Water Framework Directive (2000/60/CE), which requires Member States to evaluate and classify the ecological status of water bodies by integrating different quality elements (i.e., Biological, Physico-chemical, and Hydromorphological) (Benedetti et al., 2012).

In this deliverable, the state of knowledge regarding the quality of water and sediment compartments in the lagoon of Venice have been reviewed. More specifically, knowledge and data obtained within projects carried out by local authorities and research institutes over the last 20 years (reported in Table A-1) have been futher analysed and structured in Table 5.1[(3)], in order to highlight relevant methodological approaches and knowledge gaps in this field. [3]

[3] The project ORIZZONTE2023 linea F is not included in this table because it is not relevant for the discussion on sediment and water quality.

Table 5.1. Research projects focused on the quality of water and sediment compartments in the lagoon of Venice carried out over the last 20 years. For each project, the assessed Lines of Evidence are reported.

	General information on the project				Target /Matrix						Class of contaminants				Line of Evidence					
Project	**Start date**	**End date**	**Area of investigation**	**Output tipology**	**Atmosphere**	**Surface sediments**	**Deep sediments**	**Water**	**Biota**	**Humans**	**Nutrients**	**Heavy metals**	**Organic compounds**	**Radionuclides**	**Chemistry**	**Physico-chemistry**	**Ecotoxicology**	**Ecology**	**Bioaccumulation**	**Scientific literature**
Mappatura	1997	1999	Shallow waters;	Management; Knowledge inventory/update; Monitoring;		x	x		x		x	x	x		x	x		x	x	Micheletti et. al., 2004; Bertazzon et.al., 2006; Micheletti et. al., 2007; Micheletti et. al., 2008;
Orizzonte 2023, LINEA A	1998	1999	Mainland;	Monitoring;	x							x	x		x	x				
Orizzonte 2023, LINEA B	1998	1998	Shallow waters;	Knowledge inventory/update; Monitoring;		x	x					x	x		x	x				
Orizzonte 2023, LINEA C	1998	1998	Channels; Saltmarsh; Shallow waters;	Monitoring;		x	x				x		x		x	x				Rossini et. al., 2001; Guerzoni et. al., 2004; Adriano et. al., 2005; Degetto et. al., 2005; Guerzoni et. al., 2005; Gerino et. al., 2007; Bellucci et. al., 2013
Orizzonte 2023, LINEA D	1998	1998	Shallow waters;	Knowledge inventory/update; Monitoring;	x	x		x	x		x	x			x	x			x	
Orizzonte 2023, LINEE EA-EE	1998	1999	Channels; Saltmarsh; Shallow waters;	Risk assessment; Sampling methods;Modelling; Monitoring;		x			x	x		x	x		x	x	x	x	x	
DRAIN	1998	2000	Tributaries (rivers);	Monitoring;	x			x				x	x		x	x				Bettiol et. al., 2005; Collavini et. al., 2005; Marcomini A., 2005; Zonta et. al., 2005;
MELa1 - studio ARTISTA	2001	2005	Shallow waters;	Modelling; Monitoring;		x		x	x		x	x	x		x		x		x	Carrer et al., 2005; Solidoro et al., 2004;

	General information on the project				Target /Matrix						Class of contaminants				Line of Evidence					
Project	**Start date**	**End date**	**Area of investigation**	**Output tipology**	**Atmosphere**	**Surface sediments**	**Deep sediments**	**Water**	**Biota**	**Humans**	**Nutrients**	**Heavy metals**	**Organic compounds**	**Radionuclides**	**Chemistry**	**Physico-chemistry**	**Ecotoxicology**	**Ecology**	**Bioaccumulation**	**Scientific literature**
ICSEL A	2003	2006	Channels; Shallow waters;	Knowledge inventory/update; Management;Monitoring;		x	x		x			x	x		x	x	x			Apitz et al., 2007; Moschino et. al., 2012; Picone et. al., 2016;
ICSEL C	2003	2006	Channels; Open sea; Shallow waters;	Management; Sampling methods; Monitoring;		x		x	x			x	x		x	x	x		x	
MELa2	2004	2004	Channels; Mainland; Saltmarsh; Shallow waters;	Knowledge inventory/update; Monitoring;				x	x		x	x	x		x	x		x		Parolini et al., 2010
MELa3	2004	2005	Channels; Mainland; Saltmarsh; Shallow waters;	Knowledge inventory/update; Monitoring;				x	x			x	x		x	x				Parolini et al., 2010
CORILA - PROGRAMMA DI RICERCA 2004-2006 - Linea 3.8	2004	2006	Shallow waters;	Knowledge inventory/update; Modelling; Monitoring;		x		x	x		x	x	x	x	x	x	x	x	x	Nesto et. al., 2007; Nesto et. al., 2010; Sommerfreund et. al., 2010 (1); Sommerfreund et. al., 2010 (2)
CORILA - PROGRAMMA DI RICERCA 2004-2006 - LINEA 3.11	2004	2006	Channels; Shallow waters;	Sampling methods; Modelling;		x	x		x		x	x	x		x	x	x	x	x	Christian Micheletti et al., 2007; Micheletti et al., 2011
ISAP	2004	2007	Channels; Mainland; Shallow waters;	Monitoring;		x	x	x	x			x	x		x		x	x	x	
MELa3 - DPSIR 2005	2005	2005	Channels; Mainland; Saltmarsh; Shallow waters;	Knowledge inventory/update;		x		x	x						x	x	x			Pastres and Solidoro, 2012
SIOSED	2005	2007	Channels; Shallow waters;	Management; Monitoring;		x	x		x						x	x	x	x	x	Gieskes et. al., 2013; Gieskes et. al., 2015;

	General information on the project				Target /Matrix						Class of contaminants				Line of Evidence					
Project	**Start date**	**End date**	**Area of investigation**	**Output tipology**	**Atmosphere**	**Surface sediments**	**Deep sediments**	**Water**	**Biota**	**Humans**	**Nutrients**	**Heavy metals**	**Organic compounds**	**Radionuclides**	**Chemistry**	**Physico-chemistry**	**Ecotoxicology**	**Ecology**	**Bioaccumulation**	**Scientific literature**
MAPVE-1,2	2007	2009	Channels; Shallow waters;	Monitoring;		x	x		x						x	x	x		x	Zonta et. al., 2007
HICSED	2008	2008	Channels; Shallow waters;	Management; Knowledge inventory/update; Sampling methods;		x			x						x	x	x		x	Benedetti et. al., 2012; Picone et. al., 2018;
QSEV	2008	2008	Shallow waters;	Knowledge inventory/update; Monitoring;		x	x								x	x				Cassin et. al., 2018; Zonta et. al., 2018;
MODUS	2011	2017	Channels; Shallow waters;	Management; Knowledge inventory/update; Monitoring;		x			x						x	x	x	x	x	
TRESSE	2015	2016	Channels; Shallow waters;	Monitoring;		x	x		x						x		x	x	x	

The information in Table 5.1 is organized in five main sections (i.e. General information on the project; Target/matrix; Class of contaminants; Line of Evidence; Scientific literature), each of them reporting relevant data mined from the 14 projects in Table A-1, in order to have a general overview of the studies conducted on the lagoon of Venice and to compare their objectives and results. The first section, "General information on the project", reports project name, starting and end date (year) of the project and its final aim/outcomes (e.g., "Management" for projects aiming to develop management strategies based on collected data, or "Modelling" for projects focused on the development of a physical or mathematical model. Most of the projects are usually addressing more than one objective). The section "Target/matrix" identifies the investigated environmental compartments among atmosphere, sediments (deep and surface), water, biota and humans. The third section, called "Class of contaminants", reports the classes of contaminants investigated in the project: nutrients, heavy metals, organic compounds and radionuclides. The section "Line of Evidence" reports which LoE(s) were investigated by the specific study: Chemistry (i.e. chemical concentrations), Physico-chemistry (e.g. temperature, pH), Ecotoxicology (e.g. LD_{50}, LC_{50}), Ecology (e.g. indexes of diversity and abundance), and Bioaccumulation (e.g. indexes of bioaccumulation and/or biomagnification). Finally, the last section ("Scientific literature") lists the peer-reviewed papers published in scientific journals as outcome of each project.

As shown in Table 5.1, most of the projects focused on the monitoring and knowledge inventory of contamination in order to update the information collected in previous studies or to expand the investigation to different areas, habitats, organisms or new contaminants in the lagoon. Few of the 14 projects focused on or included modelling activities (i.e. ORIZZONTE 2023 EA-EE, MELa 1 – studio ARTISTA, DPSIR, CORILA 3.8) and fewer aimed at developing new sampling methodologies (i.e. HICSED; ICESEL C, CORILA 3.11). Only the sub-project ORIZZONTE 2023 EA -EE had risk assessment as main objective.

The main target of the investigation was, often, the sediment compartment, with a special attention to surface sediments. In addition, biota and water compartments were also frequently investigated. In few projects, atmosphere (i.e. in 2023 A+D and DRAIN) and human targets (i.e. in the risk assessment within the project ORIZZONTE 2023 EA-EE) where also addressed.

Regarding the investigated "classes of contaminants", heavy metals and organic compounds were addressed by almost all the projects, while nutrients were addressed only by eight of them. Finally, two projects (i.e. ORIZZONTE 2023 C and QSEV) investigated the presences of radionuclides in the lagoon environment.

Regarding the water matrix, many studies focused on the concentration of nutrients as well as inorganic and organic contaminants in the water column, their interaction with the sediment matrix and their availability to the biota. Starting from the project "ORIZZONTE 2023 – linea D" (1998 - Eutrophication and pollution of water and sediments in the central part of the Venice lagoon) other studies considered the water quality in their investigations: "MELa 1-2-3" (starting from 2001), "ICSEL C"(2003), "CORILA 3.8" (2004), "ISAP" (2004). In addition, the project "DRAIN" (1998) investigated the pollution loads from the water bodies of the drainage basin to the Venice lagoon and used it to determine the total budget of the pollution sources in the lagoon. As a general conclusion, the seasonal, spatial and temporal variability of water quality in the lagoon of Venice is very marked. For example, there are differences in the distribution of nutrients, due to the location of the sources (e.g. fluvial mouths and industrial areas) and the tidal circulation (MELa 1; DRAIN). However, the data on total dissolved metals show a general homogeneity of concentrations in the different lagoon areas which seems little or not influenced by the seasonal evolution of the lagoon, by the tidal circulation or by meteo-climatic variability but only from the point sources. Organic contaminants (i.e. PCDD/F, PCB, HCB, IPA) show, in general, higher concentrations in the central lagoon areas due to the relevant presence of particulate matter with chemical characteristics similar to the sediment in those areas (MELa 1 – studio ARTISTA; Mela 3). Moreover, it is evident how, in addition to the differences between industrial canals of Porto Marghera and the area immediately in front, the influence of industrial pollution extends up to the areas of Lake Teneri and Fusina (ISAP).

Regarding the sediment matrix, starting from the project "Mappatura dell'inquinamento dei fondali lagunari (MAV-CVN, 1999)", which was the first survey extensively investigating surface sediment contamination (140 sampling sites in the whole lagoon), numerous projects aimed to understand sediment-related processes, the state of their contamination and the ecological implications for the lagoon ecosystems. Among these projects, we can mention: “Progetto 2023” (1998-1999); “MELa1” (2000-2003, including the ARTISTA study on trophic networks, sediment pollution and toxicity); “ICSEL” (2003-2006); “ISAP” (2006); “HICSED” (2008)”; “QSEV” (Quality of the sediments of the Venice lagoon, 2008); “MAPVE1” and “MAPVE2” (2007-2009); and “MODUS” (starting from 2010). These studies mainly focused on the characterization of the surface sediments (i.e. the first 15-20 cm) of shallow water areas, where the exchanges with the water column and the interaction with the biota occur. In some cases, the investigations included also the sampling of sediment cores that, through radio-dating techniques, allowed to reconstruct the historical contamination trends of organic and inorganic compounds. Identified trends were often correlated with the intensity and type of industrial activities carried out in the lagoon Marcomini et al., 1999; (Frignani et al., 2005, 2001). In addition, “ISAP” project focused on investigating the sediments (and waters) contamination of both industrial canals and shallow areas in front of Porto Marghera industrial area, while "Progetto Integrato Rii" (listed at paragraph 2.1), which started in 1994 and ended in 2003, aimed to chemically characterize the sediments of the channels of Venice historical center. However, it should be noted that so far there have been no specific research projects investigating sediment quality in navigation channels, which must be periodically dredged to ensure the passage of boats. Such sediments must always undergo chemical characterization by the Venice Port Authority before dredging, in order to decide where to dispose them according to “Protocollo Fanghi” (1993) hovewer, a comprehensive assessment of these informations with the results of past research studies is still lacking. The research on sediments was mainly performed on the shallow water areas because of the abundance of biota, while in the navigation channels, given the low environmental interest, the artificiality of the system and the scarce presence of biota, few studies were carried out. Most of the investigations on deep sediments (ISAP; MAPVE-1,2; QSEV) were carried out through the extraction of sediment cores in shallow water areas (1 m of water depth on average, with a drilling depth between 60 cm and 2 m). Other cores were extracted from a depth up to 12 meters (intercepting groundwater layers) to investigate the possibility to dig new navigation channels in shallow water areas (ISAP, TRESSE). A third type of cores was extracted from navigation channels (large navigable channels could approach 20 meters of depth with respect to the water surface), around 10 -12 m below the sediment floor, to chemically characterize the sediment and decide about its disposal destination after dredging according to “Protocollo Fanghi” provisions (ISAP,TRESSE). Therefore, under a management perspective and in the light of the large quantities of sedimented material that are mobilized, investigations focused on the surface and deep sediments of navigable channels should be prioritized in order to fill the existing knowledge gap in those areas.

As far as sediment quality is concerned, from the cited 14 projects it emerges that the highest pollutants’ concentrations in sediments are reached in correspondence with the sources of contaminants in the lagoon, i.e. the mouths of some tributaries of the drainage basin, the industrial area of Porto Marghera and the inhabited centers of Venice and Chioggia. For example, the area close to Porto Marghera refineries is identified as hot spot of contamination for some metals (in particular Hg and Cd) and organic compounds (IPA, HCB) by many projects (ORIZZONTE 2023 linee C, D; MELa 2; MELa 3; ICSEL A; CORILA linea 3.8; MODUS;). In particular, mercury is more widespread in the central-northern lagoon, while cadmium is found at highest concentrations in the central lagoon and in the southern lagoon, as well as close to the urban centers of Venice and Chioggia. This is obviously not only due to the sources of contaminants but also to natural background levels as well as processes such as sediments transport and tide streams. Another area characterized by widespread contamination is in the proximity of the Tronchetto Island, where the concentrations of metals are clearly lower than the peaks detected in the samples close to the refineries, but the presence of other organic and organometallic contaminants is evident (MAPVE 2). Moving away from the industrial area, a clear decreasing trend in contamination of sediments was identified for all the considered main contaminants (MAPVE 2).

Focusing on the quality of deeper sediments, industrial channels show concentrations of any kind of pollutants significantly higher than those found in the lagoon shallow areas (i.e. the area of the old stretch of the Vittorio Emanuele III Canal, dating back to the 1970s and now buried, is particularly contaminated), while the lagoon channels exhibit levels of contamination very similar to those of the shallow waters, characterized by contaminants of industrial origin (ISAP; MAPVE -1,2; QSED). Overall, the chemical investigations carried out on the lagoon sediments in shallow water areas highlight lower concentrations of some metals in the surface layers compared to the deeper ones. This difference is certainly due in large part to the lower content in fine textural component and the large presence of organic matter in deeper sediments, which constitute the sites of preferential association for pollutants. Conversely, for organic compounds a higher concentration is detected in the surface layers (0 – 50 cm) with a decreasing gradient along the vertical profile (50 – 200 cm) (MAPVE 2). In the channels it is possible to undeline a major homogeneity among the vertical layers for both heavy metals and organic compounds (MAPVE 2).

The significant contamination of the lagoon sediments is also confirmed by comparing the measured chemical concentrations with regulatory thresholds. According to projects' results (HICSED; MAPVE 1-2; QSEV), the sediments of the Venice lagoon fall mainly in three classes of contamination out of the four identified by "Protocollo Fanghi" (1993): Class A (30%) – no contamination, Class B (63%) - low contamination and Class C (7%) – moderate contamination (HICSED; QSEV). The sediments classified as C are located almost exclusively in the central-northern basin of the lagoon, in the area between the historic center and the industrial area of Porto Marghera. Few sediments of worst quality (> C) are located in Darsena della Rana.

As it is clear from the above description, the preferred method (i.e. Line of Evidence) used to assess the quality of Venice lagoon is the measurement of pollutants' concentration (i.e. Chemistry LoE) in water and sediment, followed by the measurement of relevant physico-chemical parameters (i.e. Physico-chemistry LoE). Ecotoxicological test started to be carried out mainly from year 2001 (i.e. ORIZZONTE 2023, MELa 1 – Artista) (Losso and Ghirardini, 2010), followed by the investigation of Ecological and Bioaccumulation LoE. In only 5 out of 14 projects, i.e. "ORIZZONTE 2023, linee EA-EE" (1998-1999), "CORILA programma di ricerca 2004-2006, linee 3.8 e 3.11" (2004-2006), "SIOSED" (2005-2007) and "MODUS" (2011-2017), all the five LoE were considered for the assessment of sediment and water quality.

Bioaccumulation analysis provide an information on pollutant compounds not detectable from sediments and reproduce the availability of contaminants within the trophic chain (Losso and Ghirardini, 2010). Among ecotoxicological investigations, biomarkers are biochemical, physiological or behavioural variations in a tissue, in a biological fluid or in the whole organism (as individual or as population) due to exposure to chemicals (Losso and Ghirardini, 2010). Bioaccumulation and biomarkers investigations carried out in mussels and fish since 2000 revealed a general improvement in the environmental quality of the central area of the Venice Lagoon compared to what was reported by other studies carried out during the 1990s (MAPPATURA; ORIZZONTE 2023; MELa 1 - Artista; CORILA 2006; ICSEL). The obtained results concur to indicate a medium level of contamination, both for metals and for organic pollutants. In addition, ecotoxicological bioassays carried out on polluted sediments and/or interstitial waters indicate that the surface sediments (0-50 cm) of industrial channels present a greater toxicity compared to the shallow waters of the other lagoon areas; in fact, only 15% of industrial channels are non-toxic, compared to 77% of the lagoon inland areas tested in previous investigations (ISAP). Overall, the Ecotoxicological LoE, as investigated in several projects, highlighthed the relationship between ecotoxicity and classification of sediments according to chemical concentrations (i.e. Protocollo Fanghi (1993)): ecotoxicity of Class A sediments is substantially not significant while Class B and C sediments can produce a variable toxicity that could be not significant (low) to very high. This provided a general confirmation of the fact that the assessment of sediment quality based solely on chemical concentrations provides only a partial view of the water body quality; therefore the adoption of a Weight of Evidence approach is highly recommended.

More details regarding the evidence provided by chemical and ecotoxicological experimental investigations as well as modelling activities performed in the last 20 years in the lagoon of Venice are provided in the following paragraphs.

5.2 Chemistry line of evidence

According to a literature search carried out in the main databases, about 250 papers on trace elements and organic pollutants in sediments and water of the lagoon of Venice have been published in peer reviewed journals. The first papers were published in the ‘80s (Donazzolo et al., 1981; Pavoni et al., 1987a, Pavoni et al 1987b) and the most recent ones in 2017-2018 (Morabito et al., 2017; Teatini et al., 2017; Zonta et al., 2018; Cassin et al., 2018). Part of these papers are related to the projects and monitoring plans reported in Table A-1, while others are from previous or different research activities.

The most relevant literature is reported in Tables 5.2.1 and 5.2.2 for organic pollutants and trace elements, respectively. In both tables, the column “year” indicates the sampling period, while the last column provides information about the presence in these studies of sampling stations in navigable channels. Moreover, Table 5.2.2 shows which studies report data about trace element speciation, termed as “geospeciation” for sediments and “speciation” for water.

Several organic pollutants were studied in water and sediments of the Venice Lagoon (Table 5.2.1). Most studies examined the following classes of compounds:

- PCBs (Pavoni et al., 1987b; Raccanelli et al., 1989; Pavoni et al., 1990; Moret et al., 2001; Frignani et al., 2001a; Fava et al., 2003; Frignani et al., 2005; Secco et al., 2005; Moret et al., 2005; Manodori et al., 2006; Guerzoni et al., 2007, Micheletti et al., 2007, Zonta et al., 2007; Parolini et al., 2010; Cassin et al., 2018),
- PAHs (Pavoni et al., 1987b; La Rocca et al., 1996; Salizzato et al., 1997; Wetzel and Van Vleet, 2003; Manodori et al., 2006, Zonta et al., 2007, Parolini et al., 2010; Cassin et al., 2018)
- PCDDs, PCDFs, PBDDs and PBDEs (Fattore et al., 1997; Bellucci et al., 2000; Raccanelli et al., 2000; Frignani et al., 2001b; Frignani et al., 2005; Micheletti et al., 2007; Raccanelli et al., 2009).

Table 5.2.1. Relevant literature about organic pollutants in sediments and water of the Venice Lagoon.

Reference	Sampling sites	Year	Matrix	Pollutants	Navigable channels
Bellucci et al., 2000	18 sites in the canals of the industrial area and 4 sites in the lagoon	1996-1998	Surface sediment	PCDDs, PCDFs	Yes (industrial canals)
Cassin et al., 2018	380 sites all over the lagoon	2008	Surface sediment (0-10 cm)	PCBs, PAHs	No
Fattore et al., 1997	6 sites: Chioggia, Canal Grande, Cona Marsh, Adriatic Sea, Sacca Sessola, Porto Marghera	1992, 1994	Surface sediment (0-10 cm)	PCDDs, PCDFs, PCBs, PAHs, LABs,	Yes (Canal Grande)
Fava et al., 2003	Porto Marghera	2001	Surface sediment (0-20 cm)	PCBs	No
Frignani et al., 2001a	18 sites in the canals of the industrial area and 6 sites in the lagoon	1996-1998	Surface sediment	PCBs	Yes (industrial canals)
Frignani et al., 2001b	5 sites in canals of the industrial area; 2 sites in the central lagoon	1996-1998	Core sediment (0-35 cm)	PCDDs, PCDFs	Yes (industrial canals)
Frignani et al., 2005	3 sites, 2 in the industrial area and 1 in the northern part of the lagoon	1998	Core sediment (0-60 cm)	PCBs, PCDDs, PCDFs, HCB	Yes (Canale San Giuliano)
Guerzoni et al., 2007	4 areas where clams are farmed/harvested (northern, central and southern lagoon; industrial area)	2001-2002	Surface sediment (0-10 cm)	PCDDs, PCDFs, PCBs, HCB	No
La Rocca et al., 1996	5 sites: Petta di Bo, sacca Sessola, Dese river mouth, Canal Grande, Porto Marghera industrial area	1995	Surface sediment	PAHs	Yes (Canal Grande)
Moret et al., 2001	5 sites: Dese river mouth, Marghera industrial area, Canal Grande, Sacca Sessola, Chioggia	1994	Surface sediment (0-20 cm)	PCBs	Yes (Canal Grande)

Reference	Sampling sites	Year	Matrix	Pollutants	Navigable channels
Parolini et al., 2010	8 sites: Dese, Campalto, Palude del Monte, Porto Marghera, San Servolo, Fusina, Ca' Roman and Valle di Brenta,	2007	Surface sediment (0-5 cm)	PCBs, PAHs, DDTs, HCHs, HCB	No
Pavoni et al. 1987b	1 site (2 km from the industrial area of Porto Marghera, towards Venice)	1982	Core sediment (0-50 cm)	PCBs, DDTs, PAHs	No
Pavoni et al., 1990	1 site (Lido)	1985-1986	Surface sediment (0-3 cm)	PCBs	No
Raccanelli et al., 1989	5 sites (whole lagoon, areas with different conditions and input sources)	1986-1987	Surface sediment (0-5 cm)	PCBs	No
Salizzato et al., 1997	16 sites in the central lagoon, including inner canals of Venice	1994	Surface sediment	AHs, PCBs, PAHs, chlorinated pesticides	Yes (urban canals)
Secco et al., 2005	25 sampling sites in the central lagoon	1987, 1993, 1998	Surface sediment (0-5 cm)	PCBs, chlorinated pesticides, PAHs	No
Wetzel and Van Vleet, 2003	8 sites, city of Venice (interior canals, partially enclosed canals, open-water locations)	1995, 1998	Surface sediment (all sites, 0-5 cm); core sediment (2 sites, 0-45 cm)	TPHs, PAHs	Yes (urban canals)
Zonta et al., 2007	51 sites in a shallow-water area extending from the industrial area toward the city of Venice	2005	Surface sediment (0-10 cm)	PAHs, PCBs	No
Guerzoni et al., 2007	15 sites all over the lagoon	2001-2002	Water	PCDDs, PCDFs PCBs, HCB	No
Manodori et al., 2006a	2 sites (Sacca Sessola and area between Tessera and Murano)	2001, 2003	Water	PCBs, PAHs	No

Reference	Sampling sites	Year	Matrix	Pollutants	Navigable channels
Moret et al., 2005	7 sites in the Venice Lagoon: Lazzaretto Vecchio, Grand Canal, Malamocco-Marghera channel, San Giorgio in Alga, Carbonera, San Felice, Adriatic Sea	2001	Water	PCBs	Yes (1 site)
Raccanelli et al., 1989	5 sites (whole lagoon, areas with different conditions and input sources)	1986-1987	Water	PCBs	No
Raccanelli et al., 2009	21 sites in the lagoon	2009	Water	PCBs, PCDDs, PCDFs, HCB	No

As shown in table 5.2.2, among trace elements Al, Ag, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Zn were studied in sediments, whereas Ag, Al, As, Cd, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Sb, U, V and Zn were studied in water.

Table 5.2.2. Relevant literature about trace elements in sediments and water of the Venice Lagoon.

Reference	Sampling sites	Year	Matrix	Trace elements	Geospeciation	Navigable channels
Argese and Bettiol 2001	Palude di Cona, Giudecca, Malamocco inlet (8 sites)	1994	Surface sediment (0-5 cm)	Cr, Cu, Fe, Mn, Ni, Pb, Zn	Yes	No
Argese et al., 2003	3 sites in the South Industrial Canal, Porto Marghera	1999	Surface sediment (0-5 cm)	Cr, Cu, Fe, Mn, Ni, Pb, Zn	Yes	Yes
Basu and Molinaroli, 1994	163 sites all over the lagoon	1976-78	Surface sediment	Cd, Co, Cu, Cr, Fe, Ni, Hg, Pb, Zn	No	No
Bianchi et al., 1998	5 sites: Palude di Cona, Palude Fondello, Sacca Sessola, Porto Marghera, Venezia	1994	Surface sediment (0-15 cm)	As, Cd, Cr, Cu, Ni, Hg, Pb, Zn	No	No

Reference	Sampling sites	Year	Matrix	Trace elements	Geospeciation	Navigable channels
Bellucci et al., 2002	18 sites in the lagoon and 9 sites in the canals of the industrial area of Porto Marghera	1996	Surface sediment (0-5 cm)	As, Cd, Hg, Pb, Zn	No	Yes
Bellucci et al., 2005	18 sites in the central and southern basins of the lagoon	1992	Core sediment (0-65 cm)	Al, Fe, Ca, K, Mg, Mn, Si, Ti, Pb, Zn, Cu, Ni, Cr, ^{210}Pb, ^{137}Cs	No	No
Bellucci et al., 2010	Industrial area (4 sites in the canals and 1 site in the lagoon just ouside)	1996, 1997, 1998	Core sediment (0-40 cm)	Ag, As, Ba, Cd, Hg, Pb, and Zn a	No	Yes
Bernardello et al., 2006	25 sites all over the Venice Lagoon	1987, 1993, 1998	Surface sediment (0-5 cm)	Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn	No	No
Berto et al., 2012	27 sampling sites in the southern Venice Lagoon (of which 11 in channels)	2003	Surface sediment (0-3 cm)	Cr, Cu, Fe, Pb, Zn	No	Yes
Corami et al., 2011a	2 sites in the Venice Lagoon: Sacca Sessola, Campalto	2010	Surface sediment (0-5 cm)	Cd, Cu, Hg, Pb, Zn	Yes	No
Corami et al., 2014	Sacca Sessola and Palude di Cona	2013	Surface sediment (0-5 cm)	Al, As, Cd, Cu, Fe, Hg, Mg, Mn, Ni, Pb, Sb, Tl, Zn.	Yes	No

Reference	Sampling sites	Year	Matrix	Trace elements	Geospeciation	Navigable channels
Corami F. et al., Submitted to Environmental Science and Pollution Research	Area from Canale Vittorio Emanuele to Malamocco-Marghera Channel, in front of Tresse island	2015	Core sediment (0-10 m)	Be, V, Cr, Cu, Zn, Ni, As, Se, Sb, Cd, Hg, Pb	Yes	Yes (2 sites in Canale Vittorio Emanuele)
Frignani et al., 1997	18 sites in the northern part of the Venice Lagoon	1992	Core sediment (0-65 cm)	Cd, Cr, Cu, Hg, Mn, Ni, Pb, Zn.	No	No
Martin et al., 1994	Palude della Rosa	1992	Surface sediment (0-20 cm)	Al, Cd, Cu, Fe, Mn, Ni, Pb, Zn	No	No
Masiol et al., 2014	25 sites in the central lagoon	2003	Surface sediment (0-5 cm)	As, Cd, Co, Cr, Cu, Fe, Hg, Ni, Pb, Zn	No	No
Pavoni et al., 1987a	2 sites (area between industrial area of Porto Marghera and Venice city center)	1982	Core sediment (0-50 cm)	Cd, Co, Cr, Cu, Fe, Hg, Ni, Pb, Zn	No	No
Scarponi et al., 1998	Marghera, Dese mouth, Sacca Sessola, Petta di Bò, Canal Grande	1992	Surface sediment	Al, Fe, Cd, Cr, Cu, Pb, Ni, Mn, Zn, Hg, Se	Yes (not for Hg and Se)	Yes (Canal Grande)
Teatini et al., 2017	Area from Canale Vittorio Emanuele to Malamocco-Marghera Channel, in front of Tresse island	2015	Core sediment (0-10 m)	Cr	Yes	Yes (2 sites in Canale Vittorio Emanuele)
Turetta et al., 2005	Porto Marghera (Tresse) and Campalto	2002-2003	Core sediment (0-30 cm)	Al, As, Cd, Cu, Fe, Mn, Mo, Sb, U, V and Zn	No	No

Reference	Sampling sites	Year	Matrix	Trace elements	Geospeciation	Navigable channels
Zonta et al., 2007	51 sites in a shallow-water area extending from the industrial area toward the city of Venice	2005	Surface sediment (0-10 cm)	Ag, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn	No	No
Zonta et al., 2018	380 sites all over the Lagoon	2008	Core sediment (0-50 cm)	Al, As, Cu, Cr, Fe, Hg, Mn, Ni, Pb, Zn	No	No
Bloom et al., 2004	26 sites all over the lagoon	2001-2003	Water	Hg	Yes (Hg and CH_3Hg)	Yes
Cairns et al., 2008	canals close to Santa Marta, Venice Lagoon	2008	Water	Hg	Yes (Hg and CH_3Hg)	Yes
Cescon et al., 2000	5 sites: Palude di Cona, Palude Fondello, Chioggia, Sacca Sessola, Venezia	2000	Water	Cd, Cu, Pb	Yes (ASV-labile fraction and concentration of ligands for Cu, Cd and Pb)	No
Martin et al., 1994	7 sites located along the salinity gradient from Porto di Lido entrance to Silone channel	1992	Water	Cd, Cu, Fe, Ni, Pb, Zn	Yes (metal fraction chelated by DOM)	Yes (Lido inlet, Silone)
Morabito et al., 2017	Campalto, Chioggia, Dese, city of Venice, Mazzorbo, Marghera, Murano, Punta della Salute, Sacca Sessola, San Giorgio in Alga, Tresse, Adriatic Sea,	from 1992 to 2006	Water	Cd, Cu, Pb	Yes (ASV-labile fraction and concentration of ligands for Cu, Cd and Pb)	No

Reference	Sampling sites	Year	Matrix	Trace elements	Geospeciation	Navigable channels
Scarponi et al., 1998	Marghera, Dese mouth, Sacca Sessola, Petta di Bò, Canal Grande	1992	Water	Al, As, Cd, Cu, Cr, Pb; Mn, Ni, Se, Fe, Sn, Ba	Yes (ASV-labile fraction and concentration of ligands for Cu, Cd and Pb)	Yes (Canal Grande)
Turetta et al., 2004	Central part of the lagoon near the industrial area of Marghera	2002 - 2003	Water (experiment with benthic chambers)	Al, Ag, As, Cd, Co, Cr, Cu, Fe, Mn, Mo, Pb, Sb, U, V, Zn	No	No
Turetta et al., 2005	Porto Marghera (Tresse) and Campalto	2002 - 2003	Subsurface and bottom waters (benthic chamber experiments)	Al, As, Cd, Cu, Fe, Mn, Mo, Sb, U, V and Zn	No	No

As can be seen in Tables 5.2.1 and 5.2.2, organic pollutants and trace elements were mostly analyzed in surface sediments (0-20 cm) and most sampling stations were located in shallow water areas of the lagoon. Very few investigations regarded the sediments of navigable channels, apart from those carried out in the industrial canals of Porto Marghera and in the urban canals of Venice. Different studies examined sediment cores of varying depths, but chemical contamination in very deep layers (up to 10 meters) was studied only in Teatini et al. (2017) and in Corami et al. (submitted), related to the TRESSE project.

According to the literature concerning organic pollutants (Table 5.2.1), the concentrations of PCBs and PCDDs/PCDFs were significantly higher in sediments of the industrial canals of Porto Marghera, compared to lagoon sediments (Bellucci et al. 2000, Frignani et al. 2001a and 2001b). In addition, the analysis of PCDD/PCDF homologue profiles in dated sediment cores allowed to identify the possible sources and temporal evolution of contamination, which was of both industrial and civil origin (Frignani 2001b). The authors of these studies concluded that the very polluted sediments of the industrial canals were relatively immobile, but that they could represent a potential risk for the lagoon environment when episodically resuspended by dredging operations or passage of ships.

Sediments showed high organic pollutants' levels not only in the industrial area, but also in the canals of the city of Venice, such as the Canal Grande (La Rocca et al. 1996, Fattore et al 1997). This was ascribed to the presence of different local sources, i.e. untreated domestic waste waters for linear alkylbenzenes (LABs), motor boat traffic and combustion from motor boat engines for PAHs, PCBs, PCDDs and PCDFs (Fattore et al. 1997). Wetzel and Van Vleet (2003) showed that the concentrations of total petroleum hydrocarbon (TPH) and PAHs were higher in the interior canals of the city with limited flushing capacities, but that they declined from 1995 up to 1998, probably due to the dredging activities started in 1994.

Among the most recent studies, Parolini et al. (2010) highlighted the presence of high levels of DDTs in the northern basin, while Zonta et al. (2007) found a moderate contamination level of PCBs and PAHs in the area in front of the industrial zone, with concentrations more than an order of magnitude lower than those reported for the Porto Marghera and Venice canals. The study by Cassin et al. (2018), in the framework of the QSEV project, provided a detailed picture of PCBs and PAHs distribution in the upper layer of sediments of the whole lagoon in 2008 (380 sampling sites). These authors showed that the concentrations found for these contaminants were not likely to represent a risk to the biota, though according to the current guidelines for disposal after dredging (Protocollo Fanghi, 1993), sediments should be considered moderately polluted in 5.8 and 19% of sampling sites for PAH and PCB concentrations, respectively. The location of these sites is in the proximity of the industrial area, inhabited islands, harbours and mouths of lagoon's tributaries.

According to the reference collected, analyzing organic pollutants in sediments, especially in those of channels and canals, is still relevant for a better comprehension of the environmental threats. Although PCBs have been banned and are not produced anymore, sediments can be still a source for these pollutants. The same holds for other organic pollutants like PAHs, which are tracers for biomass burning, fossil fuels, domestic heating and urban traffic, and dioxins and furans, which are tracers of industrial contamination and combustion processes.

Furthermore, the progress in analytical chemistry in the last decade may allow for the detection of lower concentrations of most organic pollutants, thus possibly providing updated data for previously undetected compounds.

As can be seen for trace elements in Table 5.2.2, in general most studies and monitoring plans assessed their total concentrations in surface sediments. Some investigations evaluated also the temporal evolution of contamination through the examination of sediment cores, while only few studies determined trace element partitioning in sediments by means of sequential extraction procedures. As in the case of organic pollutants, very few studies included navigable channels/canals, except for the canals of the industrial area and of the city of Venice.

Studies carried out in different areas of the lagoon have shown that the contamination by trace elements was higher in the sediments of the central and northern-basins, where the concentrations of organic pollutants were high as well. The highest concentrations were found in the canals and in the proximity of the industrial area of Porto Marghera, in shallow water areas on the landward side and in the canals of Venice (Bellucci et al., 2002; Turetta et al., 2005; Bellucci et al., 2005; Bellucci et al., 2010; Frignani et al. 1997; Basu and Molinaroli, 1994).

Different studies carried out from the late 70s to the 90s pointed out the role played by the industrial activities carried out at Porto Marghera as a source of trace elements. Basu and Molinaroli (1994), who modelled the distribution of nine toxic metals in surface sediments sampled in 1976-1978 in 163 stations in the lagoon, identified Porto Marghera and the industrial zone as an area of high metal contamination. Pavoni et al. (1987a) estimated background total concentrations of trace elements by analyzing the deeper portions of sediment cores and highlighted that contamination in the area between the city of Venice and the industrial zone of the Porto Marghera was mainly due to the industrial activities. Research carried out in the framework of the "Sistema Lagunare Veneziano" project confirmed that total concentrations of all the analyzed major and trace elements were above background levels and that the industrial area was the most contaminated one (Bianchi et al. 1998). On the other hand, by studying sediment cores in 18 sites of the northern part of the Venice Lagoon, Frignani et al. (1997) found high levels of metal contamination also in the Palude di Cona area and in the Dese river.

Studying the sediments of the canals of the industrial area, Bellucci et al. (2002) showed that they were the most important potential source of toxic metals to the lagoon environment, due to occasional sediment resuspension. These findings were confirmed in other studies by the same authors (Bellucci et al. 2005; 2010). Bernardello et al. (2006) showed that, despite the decline of inputs, Porto Marghera was still the main source of contamination of the Venice Lagoon, but they observed a redistribution of trace elements, with the highest decrease along the inner border of the Lagoon. These changes were ascribed to sedimentation disturbance, related to intense clam harvesting, and to the transport of the fine fraction of sediments out of the Lagoon into the sea.

Trace element redistribution was examined or observed also in other studies. Benthic chamber experiments showed that trace elements can be remobilised from the sediment to the water column by resuspension and/or sub-oxygenation of water, and that mobility is influenced by the environmental characteristics of the investigated sites or by seasonality (Turetta et al. 2005). A study carried out in the area close to Chioggia identified the sediments of dockyards, harbours and marinas as a local source of trace elements, but highlighted also that sediment resuspension due to dredging activities and Manila clam harvesting in the central lagoon could facilitate the transport and spreading of contaminants in the southern basin (Berto et al. 2012). Masiol et al. (2014) highlighted that, although the industrial activities related to contamination by Hg and Cd have been discontinued, these elements are redistributed throughout the lagoon. They suggest that in the late 1990s the effects of sediment resuspension caused by clam harvesting favoured the increase and redistribution of contaminants in the lagoon; however, they observed that in the following years this process probably determined a ‘‘dilution’’ of concentrations across a wider area and loss to the sea.

The most recent and detailed picture of contamination by trace metals in the lagoon was provided by the QSEV project in 2008, which examined sediment cores in 380 sites in the whole lagoon (Zonta et al. 2018). In this study the spatial distribution of trace element concentrations was related to the proximity to contaminant sources, to sediment grain-size distribution and to lagoon hydrodynamics. Shallow water areas near freshwater inputs, areas close to the industrial zone of Porto Marghera, and a small zone near the city of Chioggia were identified as the main pollutant accumulation sites. They also showed that trace elements of partly anthopogenic origin, such as Cu, Hg, Pb, Zn, increased up to the subsurface sediment layers (5-10 and/or 10-20 cm) as an effect of increasing pollutant inputs until a certain time in the past.

In a comprehensive study, Scarponi et al. (1998) showed a link between the different classes of chemical contaminants detected in water and the different polluting inputs (industrial, agricultural, urban) to which the Venice Lagoon is subject and between the speciation of trace elements in the sediment and its toxicity.

As already mentioned, the majority of studies that investigated trace elements contamination in sediments and waters of the lagoon examined total concentrations. Conversely, as can be seen in Table 5.2.2, speciation has been included only in few studies.

Total concentration of trace elements has been defined as a “face value”, because the analysis of total concentration of trace elements does not give any information on their bioaccessibility, bioavailability and mobility (Technical Guidance 27 European Union, 2011). Different guidance documents of the EU within the Waten Framework Directive highlight the important role payed by pollutant bioavailability and the importance of metal speciation (Technical Guidance 25 European Union, 2010; Technical Guidance 27 European Union, 2011). Hence, studying the speciation of trace elements may be crucial to evaluate the threat posed by polluted sediments and waters.

Speciation refers to the chemical forms of trace elements in the environment; each form may have a different bioaccessibility, bioavailability and mobility. Bioaccessibility refers to the concentration of a given element that is available in the environment and that can then interact with contact surfaces of organisms, and is potentially available to be absorbed and adsorbed. Indeed, the bioaccessible concentration refers to the exchangeable concentration of a given element through physical, chemical and biological processes. Bioavailability is expressed as the fraction of a given element which an organism is exposed to under defined conditions and within a specified period, that is how much of the bioaccessible concentration is effectively absorbed onto, into and across biological membranes. (Fairbrother et al., 2007). Mobility of a given element depends upon different variables, such as pH, redox potential, temperature, oxygen concentration, etc.; in relation with a change of one or more of these variables, elements can become bioaccessible and hence bioavailable (Fairbrother et al., 2007; Morillo et al., 2007).

In this context, sequential extraction procedures (SEP) are tools of significant help to assess the mobility, bioavailability and bioaccessibility of sediment-bound trace elements. These analytical methods are designed to provide the distribution of trace elements among operationally defined fractions (Tessier et al., 1979, Fairbrother et al., 2007), which we may refer to as “geospeciation”. Different extraction schemes have been developed, which differ for the number of extraction steps and the extractiong solutions used.

Geospeciation was studied via SEP in few researches on the sediments of the Venice Lagoon, as shown in Table 5.2.2. Partitioning of trace elements in the different fractions assessed by SEP depended on the trace element studied and on the composition of sediments as well (Argese and Bettiol, 2001. Argese et al. 2003, Corami et al., 2009, Corami et al., 2011a). However geospeciation was poorly studied in sediment cores or in navigable canals and channels, especially those which need to be dredged to guarantee navigation.

Teatini et al. (2017) and Corami et al. (submitted) recently applied a four-step SEP to 10-m long sediment cores,divided into 1-m long sections, with the purpose of estimating the bioavailabity, bioaccessibility and mobility of trace elements in case of dredging. According to the adopted SEP scheme, trace elements were portioned in the following fractions: a) bioaccessible and labile fraction, composed by the readily exchangeable fraction and the exchangeable fraction, which is bound to carbonates, and both are bioaccessible and bioavailable to the biota; b) acid reducible, bound to Fe/Mn oxy-hydroxides fraction, which is not directly bioaccessible, but it is mobilizable; c) oxidizable fraction, bound to organic matter and sulphide, which is not directly bioaccessible and less mobilizable than F2; d) residual fraction, which is the last fraction extracted; it may be defined inert fraction, since it is not mobilizable and bioaccessible, and the concentration of trace elements in this fraction can be considered as the contribution from natural sources. They showed that the bioaccessible fraction and the two mobile fractions for many trace elements, including Cd, Cr and the most toxic Hg, increased along the depth of the cores, although the total concentration of these elements decreased along the depth of the core.

Thus, studying geospeciation in sediments of channels and canals of the lagoon that could be dredged to maintain navigation is necessary not only to understand the contamination along the depth, but also to evaluate the bioaccessibility, bioavailability and mobility of trace elements in sediments and the possible impact of their disposal in receiving sites.

Speciation in water has been entered in the latest amendments of the European Directive 2000/60 CE (i.e. 2008/105 CE, 2013/39 CE) and of Italian laws in force (e.g. D lgs. 172/2015) (Corami et al., 2014, Morabito et al., 2018). As regards the sediments, the limits imposed by the laws in force (Corami et al., 2014, Morabito et al., 2018), including the limits in Protocollo Fanghi (which is in force for the Venice Lagoon) are based on values of total concentrations of inorganic and organic pollutants, thus not supporting the understanding of the cause (pollutant concentration) – effect (toxicity) relationship. However it should be highlighted that the study of speciation was mentioned and demanded in Protocollo Fanghi (Corami et al., 2014).

Thus, with a view of a better comprehension of the cause-effect relationship and to support the interpretation of results provided by the Weight of Evidence-based procedure for ecological risk assessment developed and applied in Task 2.1.2.7, studying geospeciation of trace elements on sediments of navigable canals and channels becomes crucial, in order to support planning dredging operations, sediments handling and management more efficiently.

References for the methods to be employed for the study of geospeciation and for the assessment of organic pollutants are presented in table 5.2.3.

Table 5.2.3. References for the methods which will be employed for the analyses of sediments from navigable channels; in this table both reference for POPs analyses and SEP are reported.

Authors	Reference Title	Matrices
Argese E., Bettiol C., 2001 Toxicological and Environmental Chemistry	Heavy metal partitioning in sediments from the Lagoon of Venice (Italy)	Surface sediments
Argese E. et al. 2003 Annali di Chimica	Speciation of heavy metals in sediments of the lagoon of Venice collected in the industrial area.	Surface Sediments
Corami F., Rigo C., Cairns W.R.L (2008-2010) Ministero delle Infrastrutture e dei Trasporti, Magistrato alle acque-Ispettorato generale per la Laguna di Venezia, Marano e Grado e per l'attuazione della legge per la salvaguardia di Venezia	Linea 3.4 Biodisponibilità e biotossicità dei contaminanti lagunari ed evoluzione normativa, Programma di Ricerca 2008-2010, La Laguna di Venezia nel Quadro dei Cambiamenti Climatici, delle Misure di Mitigazione ed Adattamento e dell'Evoluzione degli Usi del Territorio	Surface Sediments
Corami F et al., 2009 Int. Congress The Centenary Padova	Remediation and Bioremediation of Dredged Polluted Sediments of the Venice Lagoon, Italy: An Environmental-friendly approach	Surface Sediments
Corami F., Morabito E., Gambaro A., Cescon P., Libralato G., Picone M., Volpi Ghirardini A., Barbante C. Submitted to Environmental Science and Pollution Research	Geospeciation, Toxicological Evaluation and Hazard Assessment of Trace Elements in the Superficial and Deep Sediments.	Surface and deep sediments of navigable channels
Moret et al., 2005 Chemosphere	Determination of polychlorobiphenyls in Venice Lagoon sediments	Surface sediments
Teatini P. et al.2017 Hydrol. Earth Syst. Sci	Hydrogeological effects of dredging navigable canals through lagoon shallows. A case study in Venice	Surface and deep sediments of navigable channels

5.3 Ecotoxicological assessment

As anticipated in Chapter 2, the review process of ecotoxicity data allowed to retrieve 110 peer reviewed papers, covering a period from 1982 up to 2019, which are reported in Table A-2.

Since in line 2.1 research activities will mainly focus on toxicity bioassays, genomic assays and biomarkes, the analysis of the collected information focused on these three ecotoxicity assessment tools, as reported in sub-paragraphs 5.3.1, 5.3.2 and 5.3.3 respectively.

5.3.1 The use of toxicity bioassays for the assessment of sediment and water quality in the Venice Lagoon (Ecotoxicological bioassays Line of Evidence)

Twenty-three out of the 110 papers concerning ecotoxicology retrieved from the literature review are related to the application of toxicity tests (Table 5.5). Bioassays have been extensively used in the Lagoon of Venice with the aims to (Losso and Ghirardini, 2010):

- Document the extent of bioavailable contamination in channels and shallows;
- Serve as a tool for monitoring the state of the environment, as concern the quantification of the toxic effects due to exposure to contaminants;
- Quantify adverse effects from disposal of dredged material;
- Estimate possible adverse effects of treated wastewaters.

In most of the ecotoxicological studies involving toxicity bioassays, the focus was on sediment quality, whilst studies on overlying water are very scarce (ICSEL project, algal growth test with *Dunaliella tertiolecta*; data not published in peer-reviewed articles). Different matrices were exploited for characterization of sediment toxicity: whole-sediment (WS), sediment-water interface (SWI), suspended sediment (SS), elutriate (EL), and porewater (PW).

Whole-sediment toxicity test are among the most ecologically relevant testing procedures available for assessing sediment toxicity, since they allow to assess effects due to exposure to both sediment-bound and dissolved chemicals, via food/sediment ingestion, dermal contact and diffusion through respiratory tissues. Whole sediment tests in the Lagoon of Venice involved almost exclusively the use of infaunal amphipods as bioindicators (Bona et al., 2000; Picone et al., 2008, 2016, 2018a; Benedetti et al., 2012), and mortality after acute exposure (10 days) as endpoint. Only the work of Picone et al. (2018) explored chronic toxicity of whole-sediment, using growth rates as endpoint, whilst all the other studies focused on acute lethal effects. Whole-sediment, acute toxicity tests with amphipods are also part of the suite of bioassays applied in most of the monitoring projects promoted by the Provveditorato alle Opere Pubbliche, including ICSEL, SIOSED, HICSED, MaPVE-1 and MaPVE-2, MODUS (see Table A-1).

Sediment-water interface tests with copepods (Acartia tonsa) were only recently introduced as assays complementary to sediment tests (Picone et al., 2018b); these procedures allow for the identification of medium-term, sub-lethal effects on larval development due to contaminants occurring in the sediment and that may be released in the water column as results of changes in the redox conditions or mineralization of organic matter.

Suspended sediment is a laboratory-derived matrix, obtained by mixing whole-sediment and diluent (3.5% NaCl or phosphate buffer) at a given ration, using a magnetic stirrer. Suspended sediment coupled with the Microtox® Solid-Phase test, was by far the solid-phase matrix more used in the Lagoon of Venice (Salizzato et al. 1998; Volpi Ghirardini et al. 1998, 1999; Bona et al. 2000; Libralato et al. 2008) and has been implemented in monitoring programmes and projects since 2003, with project Orizzonte 2023. For this matrix, only short-term effects have been exploited, since Microtox® Solid-Phase Test is a procedure designed for measuring effects on bacterial bioluminescence after a period of exposure ranging from 5 to 30 minutes.

Elutriate is probably the more exploited matrix for the assessment of sediment quality in the Lagoon. Elutriates are obtained by vigorous shaking of sediment with seawater, according to a pre-determined rate (1:4 or 1:20, sediment to water ratio). This procedure is intended to simulate the release of water-soluble contaminants occurring during sediment dredging, resuspension and movement in aquatic environments; thus, this matrix provides information on the possible effects that may be exerted towards sensitive biological components of the water column, including gametes, embryos and larvae of benthic and pelagic species (Losso and Volpi Ghirardini, 2010). Large datasets are available both concerning acute (sperm-cell toxicity test) and sub-chronic toxicity (embryotoxicity test) for elutriates extracted from sediments of the Venice Lagoon. In particular, gametes and embryos of the sea urchins *Paracentrotus lividus* and embryos of the bivalves *Crassostrea gigas* and *Mytilus galloprovincialis* are the biological indicators mostly used, both in the monitoring programmes (Orizzonte 2023, ICSEL, SIOSED, HICSED, MAPVE and MODUS) and also in the research projects (Volpi Ghirardini et al. 1999, 2003, 2005a,b; Marin et al. 2001; Losso et al. 2004, 2007; Arizzi Novelli et al. 2006; Libralato et al. 2008).

Porewater, separated by the solid phase by centrifugation, provides information on the dissolved chemicals, not bound to acid-volatile sulphides, Fe and Mn oxy-hydroxides and organic matter. This matrix is often reported as the main route of exposure for sediment dwelling organisms, even if its use is often criticised because of the lack of ecological relevance (namely, sediment dwelling organisms are never directly exposed to porewater) and the artefacts that may be introduced in the sample during the extraction procedure (i.e. centrifugation, squeezing and use of peepers). As elutriate, it allows testing effects towards sensitive water column organisms, including gametes, embryos and larvae of benthic and pelagic species (Losso and Volpi Ghirardini, 2010); nevertheless, it has been less used in monitoring and research as compared with elutriates, also for the relatively high concentrations of ammonia and sulphides that may characterize porewater extracted through centrifugation (ammonia) or using peepers (ammonia and sulphides) and can significantly affect larval development in sea urchins and bivalves (Losso et al. 2004, 2007; Picone et al. 2009). Sperm-cell test with *P. lividus* and embryotoxicity test with *C. gigas* are the bioassays recognized as best choice for testing acute and sub-chronic toxicity of porewaters in the Venice Lagoon (Losso et al. 2010).

In general, in the Venice Lagoon toxicity tests have been used mostly to identify short-term lethal effects on aquatic organisms (acute toxicity) and short-medium term effects on early-life stages (sub-chronic toxicity). Large databases are available from monitoring activities and research programmes for test such as Microtox® Solid-Phase Test, sperm-cell test with *P. lividus*, embryotoxicity test with *P. lividus*, *M. galloprovincialis* and *C. gigas*, and lethality tests with amphipods (*Leptocheirus plumulosus, Corophium orientale, C. volutator, Monocorophium insidiosum*).

Experimental design, investigated sites, sampling seasons and sediment depth differed considerably among studies reported in Table A-1, making it difficult to identify tendencies and gradients. Anyhow, the following general trends have been observed:

1. acute toxicity, both toward amphipods and sea urchin sperm-cells, is generally absent. Acute effects have been occasionally observed in surface sediments of shallow areas where high ammonia concentration characterizes porewater and elutriates (Pili, San Giuliano, Chioggia), or in deeper sediments collected in channels and in the area of Porto Marghera;
2. sub-chronic toxicity towards embryos and larvae has been evidenced in several areas of the lagoon, but in general there is a gradient of effects, with decreasing toxicity from the industrial area toward the sea-inlets;
3. major sub-chronic effects have been observed in sites characterized by higher anthropogenic pressure, such as the industrial area, but also in shallows in the inner lagoon, where confounding factors and environmental condition may be less favourable to the settlement of the larvae (Palude della Rosa, Valle Millecampi, Lago Lanzoni);
4. impairments in larval development in sea urchins, bivalves and copepods were linked to anthropogenic sources of contamination in the industrial area and to ammonia and sulphur compounds both in the industrial area and in the shallows/channels of the open lagoon.

Literature review allowed also to evidence that tests aimed at identifying chronic sub-lethal effects, such as growth rate impairments, behavioural abnormalities and retarded sexual maturity are generally overlooked, although 1) chronic exposure to contaminants is a more frequent condition in natural environments than to acute exposure, 2) moderately contaminated sediments are more common than highly contaminated sediments (also in the Lagoon) and 3) sub-lethal effects may have greater ecological significance than acute effects. The few data available (Picone et al. 2018b) evidenced that in low to moderate contaminated sediments, growth rates of amphipods may be significantly impaired as compared with a reference condition (native sediment, collected in the Venice Lagoon).

Sediments of channels and channels, targets of Venice 2021 project, were mostly studied in the framework of monitoring programmes promoted by Provveditorato alle Opere Pubbliche, as ICSEL, ISAP and MAPVE. As concern ICSEL, only surface (0-15 cm depth) and sub-surface (30-45 cm depth) sediments collected in channels of the open lagoon were analysed using a suite of acute and sub-chronic toxicity tests (amphipod mortality, sperm-cell and embryotoxicity tests with *P. lividus*). Acute toxicity has been observed in a few sites, both in surface and sub-surface samples, whilst sub-chronic effects were spread throughout the Lagoon, also in areas far from the industrial district. In contrast, Perizia ISAP and projects MAPVE focused mainly on sediments collected within the industrial area (ISAP) or in the channels of the area between the city of Venice and the industrial district (MAPVe1 and MAPVe2); in both cases the 0-50 cm depth layer was investigated, but due to the location of the sampling sites the results of toxicity testing have a low significance for the whole ecosystem. In any case, as compared with shallows, toxicity tests evidenced not only sub-chronic toxicity towards sea urchin and bivalve larvae (severe effects widespread in the area), but also acute effects towards bacteria and amphipods, both in the industrial area and in Canale Vittorio Emanuele II, Canale San Secondo, Canale di Fusina and Canale Contorta Sant'Angelo.

None of the previous studies explored the 0-100 cm depth layer.

Table 5.5. Papers published in peer-reviewed journals dealing with sediment toxicity testing in Venice Lagoon. Acronyms for matrices are as follows: WS = whole sediment; SS = suspended sediment; SWI = sediment-water interphase; EL = elutriate; PW = porewater.

Reference	Title	Matrices	Species	Endpoint
Salizzato et al. 1998	Sensitivity limits and EC50 values of the *Vibrio fischeri* test for organic micropollutants in natural and spiked extracts from sediments	SS	*Aliivibrio fischeri*	Bioluminescence inhibition
Volpi Ghirardini et al. 1998	Microtox® solid-phase bioassay in sediment toxicity assessment	SS	*Aliivibrio fischeri*	Bioluminescence inhibition
Volpi Ghirardini et al. 1999	An integrated approach to sediment quality assessment: the Venetian lagoon as a case study	SS, EL, PW	*Aliivibrio fischeri* (SS, EL, PW) *Paracentrotus lividus* (EL)	Bioluminescence inhibition (*A. fischeri*) Fecundation (*P. lividus*)
Bona et al. 2000	An integrated approach to assess the benthic quality after sediment capping in Venice lagoon	SS	*Aliivibrio fischeri* *Leptocheirus plumulosus*	Bioluminescence inhibition (*A. fischeri*) Survival (*L. plumulosus*)
Marin et al. 2001	Sediment elutriate toxicity testing with embryos of sea urchin (*Paracentrotus lividus*)	EL	*Paracentrotus lividus*	Larval development
Arizzi Novelli et al. 2003	Toxicity of heavy metals using sperm cell and embryo toxicity bioassays with *Paracentrotus lividus* (echinodermata: Echinoidea): Comparisons with exposure concentrations in the Lagoon of Venice, Italy	EL	*Paracentrotus lividus*	Fecundation Larval development
Volpi Ghirardini et al. 2003	Sea urchin toxicity bioassays for sediment quality assessment in the Lagoon of Venice (Italy)	EL	*Paracentrotus lividus*	Fecundation Larval development
Losso et al. 2004a	Sulfide as a confounding factor in toxicity tests with the sea urchin *Paracentrotus lividus*	PW	*Paracentrotus lividus*	Fecundation
Losso et al. 2004b	Evaluation of surficial sediment toxicity and sediment physico-chemical characteristics of representative sites in the Lagoon of Venice (Italy)	EL	*Paracentrotus lividus*	Fecundation Larval development
Volpi Ghirardini et al. 2005a	Sediment toxicity assessment in the Lagoon of Venice (Italy) using *Paracentrotus lividus* (Echinodermata: Echinoidea) fertilization and embryo bioassays	EL	*Paracentrotus lividus*	Fecundation Larval development
Volpi Ghirardini et al. 2005b	*Mytilus galloprovincialis* as bioindicator in embryotoxicity testing to evaluate sediment quality in the lagoon of Venice (Italy)	EL	*Mytilus galloprovincialis*	Larval development
Arizzi Novelli et al. 2006	Is the 1:4 elutriation ratio reliable? Ecotoxicological comparison of four different sediment:water proportions	EL	*Paracentrotus lividus* *Mytilus galloprovincialis*	Fecundation (*P. lividus*) Larval development (*P. lividus, M. galloprovincialis*)
Losso et al. 2007a	Potential role of sulfide and ammonia as confounding factors in elutriate toxicity bioassays with early life stages of sea urchins and bivalves	EL	*Paracentrotus lividus* *Crassostrea gigas*	Fecundation (*P. lividus*) Larval development (*P. lividus, C. gigas*)

Reference	Title	Matrices	Species	Endpoint
Losso et al. 2007b	Developing toxicity scores for embryotoxicity tests on elutriates with the sea urchin *Paracentrotus lividus*, the oyster *Crassostrea gigas*, and the mussel *Mytilus galloprovincialis*	EL	*Paracentrotus lividus* *Crassostrea gigas* *Mytilus galloprovincialis*	Larval development
Libralato et al. 2008	Ecotoxicological evaluation of industrial port of Venice (Italy) sediment samples after a decontamination treatment	SS, EL	*Aliivibrio fischeri* (SS) *Crassostrea gigas* (EL)	Bioluminescence inhibition (*A. fischeri*) Larval development (*C. gigas*)
Picone et al. 2008	Evaluation of *Corophium orientale* as bioindicator for Venice Lagoon: Sensitivity assessment and toxicity-score proposal	WS	*Corophium orientale*	Survival
Losso et al. 2009	Porewater as a matrix in toxicity bioassays with sea urchins and bivalves: Evaluation of applicability to the Venice lagoon (Italy)	PW	*Paracentrotus lividus* *Crassostrea gigas* *Mytilus galloprovincialis*	Fecundation (*P. lividus*) Larval development (*P. lividus, M. galloprovincialis, C. gigas*)
Picone et al. 2009	Sequential toxicity identification evaluation (TIE) for characterizing toxicity of Venice Lagoon sediments: Comparison of two different approaches	PW	*Paracentrotus lividus* *Crassostrea gigas* *Mytilus galloprovincialis*	Fecundation (*P. lividus*) Larval development (*M. galloprovincialis, C. gigas*)
Benedetti et al. 2012	A multidisciplinary weight of evidence approach for classifying polluted sediments: Integrating sediment chemistry, bioavailability, biomarkers responses and bioassays	WS, SS, EL, SWI	*Aliivibrio fischeri* (SS) *Corophium orientale* (WS) *Tigriopus fulvus* (EL) *Paracentritus lividus* (EL) *Crassostrea gigas* (EL) *Acartia tonsa* (SWI)	Bioluminescence inhibition (*A. fischeri*) Survival (*C. orientale, T. fulvus*) Fecundation (*P. lividus*) Larval development (*C. gigas, A. tonsa*) Larval growth (*T. fulvus*)
Gomiero et al. 2013	The use of protozoa in ecotoxicology: Application of multiple endpoint tests of the ciliate *E. crassus* for the evaluation of sediment quality in coastal marine ecosystems	WS	*Euplotes crassipes*	Survival Replication rate
Picone et al. 2016	Assessment of sediment toxicity in the Lagoon of Venice (Italy) using a multi-species set of bioassays	WS, EL	*Corophium volutator* (WS) *Paracentrotus lividus* (EL) *Crassostrea gigas* (EL)	Survival (*C. volutator*) Larval development (*P. lividus, C. gigas*) Fecundation (*P. lividus*)
Picone et al. 2018a	Testing lagoonal sediments with early life stages of the copepod *Acartia tonsa* (Dana): An approach to assess sediment toxicity in the Venice Lagoon	SWI	*Acartia tonsa*	Larval development
Picone et al. 2018b	Assessment of whole-sediment chronic toxicity using sub-lethal endpoints with *Monocorophium insidiosum*	WS	*Monocorophium insidiosum*	Growth rate

5.3.2 Genomic resources for the environmental risk assessment of the Venice lagoon (Trascriptomics Line of Evidence)

The development of new resources to evaluate the environmental status is becoming increasingly important representing a key challenge for ocean and coastal management. Transcriptome profiling has benefited from technological improvements and has become more efficient and economically affordable for a wide range of species, thus overcoming the initial concerns about its high costs. Currently, the employment of transcriptomic techniques, such as RNAseq, in aquatic toxicology may allow the identification of early biomarkers of exposure and the definition of Mode Of Action (MOA) or gene patterns associated to chemicals or environmental stressors.

The development of high-throughput transcriptomic techniques, which allow expression profiling of thousands of genes, has made it possible to rapidly and simultaneously assess biological responses to chemical stressors on a whole-genome scale. Additionally, whole-transcriptome profiles can serve as an unprecedented source of biomarkers for pollutant exposure. Recent studies (reported in Table 5.6) have demonstrated the potential of applying a toxicogenomic approach in marine animals within the Venice lagoon (Venier et al. 2006; Milan et al. 2011; Milan et al. 2013; Milan et al. 2015). Toxicogenomic studies have only been conducted in shellfish in general and, more specifically, in bivalves in the last several years, despite the great potential of these animals to be utilized as biological indicators of water pollution within the Venice lagoon. The potential use of this novel tool was evaluated in a first study by analyzing the tissue-specific gene transcription profiles of mussels exposed to chemical mixtures in laboratory and in their natural environment within the Venice lagoon (Malamocco, Lido, Porto Marghera) (Venier et al. 2006). The results obtained allowed a distinction between mussels living in the Venice lagoon (Italy) at the petrochemical district and mussels close to the open sea.

Recently, the employment of transcriptomics in aquatic toxicology has led to increasing initiatives proposing to integrate ecotoxicogenomics in the evaluation of marine ecosystem health. The Manila clam *Ruditapes philippinarum*, representing an important commercial species within the Venice lagoon, may constitute an excellent species to evaluate the effects of complex mixtures of industrial and urban effluents on aquatic organisms. To date, few studies have been performed to identify Manila clam gene expression profiles related to different environmental conditions and ecological status. In a first study, clams were collected in different seasons at four locations within the Venice Lagoon characterized by different anthropogenic impact. The sampling sites were characterized by a range of pollutant concentrations and included Porto Marghera. Pooled soft tissues were subjected to mass spectroscopy analysis to measure the concentrations of PCDDs/PCDFs/PCBs-DL, PCBs, PBDEs, HCB and PAHs, and pooled digestive gland samples were used for gene expression profiling through DNA microarray. While seasonal variation was found to be responsible for the largest proportion of transcriptional changes, significance analysis of microarrays quantitative correlation analysis identified 162 transcripts that were correlated with at least one class of chemicals measured in the samples from the four different sampling sites. In addition, a minimal set of seven genes that correctly assigned samples collected in the restricted polluted area (Porto Marghera), independent of the season in which they were collected, has been identified. Overall, through an integrated approach combining transcriptomics and chemical analyses of the Manila clam, this study provided a global picture of how Manila clams respond to complex mixtures of xenobiotics and their interplay with other biotic and abiotic factors. In addition, gene expression signatures for different classes of chemicals and a set of robust biomarkers of exposure to these chemicals have been also identified (Milan et al. 2011; Milan et al. 2013).

However, several technical issues still need to be addressed before introducing genomics as a reliable tool in regulatory ecotoxicology. Currently, the main challenges that must be addressed for a successful implementation of genomics in regulatory ecotoxicology are i) the standardization of data collection and analysis; ii) the definition of transcriptional features/perturbations reflecting the response to specific environmental conditions, and the establishment of thresholds associated to "non-significant" and "adverse" responses; iii) the identification of links between molecular and biochemical responses and adverse alterations in survival, development, and reproduction; iv) increasing exchange of information between scientists and end-users, such as government policy, nongovernment organizations and environmental regulators.

Table 5.6. Genomic studies performed for the environmental risk assessment of the Venice lagoon.

Reference	Title	TOOLS/METHODS	Species	Investigated sites	Sampling season	Chemical analysis
Venier P. et al. 2006	Development of mussel mRNA profiling: Can gene expression trends reveal coastal water pollution?	Transcriptomics CDNA microarray	*Mytilus galloprovincialis*	Malamocco, Lido, Porto Marghera	Early summer 2015	none
Milan M. et al 2011	Transcriptome sequencing and microarray development for the Manila clam, *Ruditapes philippinarum*: Genomic tools for environmental monitoring	Transcriptomics DNA microarray	*Ruditapes philippinarum*	Porto Marghera, Alberoni	Autumn 2009	none
Milan M. et al. 2013	Exploring the effects of seasonality and chemical pollution on the hepatopancreas transcriptome of the Manila clam	Transcriptomics DNA microarray	*Ruditapes philippinarum*	Porto Marghera, Alberoni, Chioggia, Sant'erasmo	June, September, December, April 2009	PCDDs/PCDFs/PCBs-DL, PCBs, PBDEs, HCB and PAHs in clam whole bodies
Milan M. et al. 2015	Transcriptomic resources for environmental risk assessment: A case study in the Venice lagoon	Transcriptomics DNA microarray	*Ruditapes philippinarum*	Porto Marghera, Chioggia, Colmata	January/February 2011	PCDDs/PCDFs/PCBs-DL, PCBs, PBDEs, HCB and PAHs in clam whole bodies
Milan M. et al. 2018	Microbiota and environmental stress: how pollution affects microbial communities in Manila clams	16S microbiota analyses	*Ruditapes philippinarum*	Porto Marghera, Alberoni, Chioggia, Sant'erasmo, Colmata	June, September, December, April 2009, January/February 2011	none

In this context, in a second study (Milan et al. 2015) the potential role of genomics to assist environmental monitoring was investigated through the definition of reliable gene expression markers associated to chemical contamination in Manila clams, and their subsequent employment for the classification of Venice lagoon areas. This study addresses key issues to evaluate the future outlooks of genomics in the environmental monitoring and risk assessment, paving the way to the potential for genomic tools to be incorporated in a multi-disciplinary approach for environmental monitoring and risk assessment.

Given the crucial role of microbiota in environmental interactions, genomic analyses focusing on host-microbiota interactions should certainly be considered in the investigation of the adaptive mechanisms to environmental stress. Recently, several studies suggested that microbiota associated to digestive tract is a key player that must be considered to assess the toxicity of environmental contaminants. Bacteria-dependent metabolism of xenobiotics may indeed modulate the host toxicity. Conversely, environmental variables (including pollution) may alter the microbial community and/or its metabolic activity leading to host physiological alterations that may contribute to their toxicity. A recent study (Milan et al. 2018) characterized for the first time through 16S rRNA gene amplicon sequencing the hepatopancreas microbiota composition of the Manila clam, *Ruditapes philippinarum* collected in Venice lagoon area subject to different anthropogenic pressures. Seasonal and geographic differences in clam microbiotas were explored and linked to host response to chemical stress identified in a previous study at the transcriptome level, establishing potential interactions among hosts, microbes, and environmental parameters. The obtained results showed the recurrent presence of putatively detoxifying bacterial taxa in PM clams during winter and over-representation of several metabolic pathways involved in xenobiotic degradation, which suggested the potential for host-microbial synergistic detoxifying actions. On the other, opportunistic taxa might take advantage of the host, whose physiological status is significantly compromised by chronic exposure to industrial chemicals (Milan et al. 2018).

Venezia 2021 will allow to assess for the first time the potential sediments toxicity through controlled exposures, reducing the confounding effects due to environmental parameters (e.g. temperature, salinity) and to the potential adaptation of natural populations to specific environmental conditions. In addition, genomic data generated within Venezia 2021 will serve as a proof of concept for the integration of "genomic tools" in environmental risk assessment models based on multidisciplinary investigations. To this end, genomic data will be elaborated through weighted criteria and finally integrated in a quantitative model with those from other types of analysis (lines of evidence, LOEs), such as sediment chemistry, bioavailability, and cellular biomarkers [. The development of such "genomic" LOEs will be included into the structure of a Weight of Evidence (WOE) approach, that is considered a key component of ERA procedures, according to recent European Directives, which requires member states to evaluate and classify the ecological status of water bodies integrating different quality elements.

5.3.3 Biochemical and cellular analyses for the assessment of sediment and water quality in the Venice Lagoon (Biomarkers Line of Evidence)

As shown in Table A-2, a multibiomarker approach was previously used to assess the effects of different environmental conditions in clams or mussels collected in various sites of the Lagoon of Venice differently influenced by both anthropogenic impact and natural conditions. Biomarkers, defined as quantitative measures of changes at differing biological levels indicative of exposure to stressors, have been proposed as sensitive early warning signals in environmental quality assessment.

For example, in the study of Matozzo et al. (2012) (Table A-2), clams (*R. philippinarum*) were monthly collected from March 2009 to February 2010 in two sites of the Lagoon of Venice differently influenced by both anthropogenic impact and natural conditions: a seaward site (Punta Sabbioni, PS), close to the Lagoon inlet of Lido, characterised by high hydrodynamism and influenced by intense passage of ships, and a landward site (Canale Dese, CD) characterized by low hydrodynamism and influenced by both riverine inputs and agricultural waste waters. Various biomarkers were measured at cellular, tissue and organism level: total haemocyte count, pinocytotic and haemolymph lysozyme activities, gill acetylcholinesterase activity (AChE), superoxide dismutase and catalase activities in both gills and digestive gland, condition index and survival-in-air. Water temperature, pH and salinity values and total chlorophyll concentrations were measured. In addition, grain size, organic matter content, and concentrations of p,p'-DDT (dichlorodiphenyltrichloroethane) and its 5 homologues, 4 HCHs (hexachlorocyclohexanes), 13 PBDEs (polybrominated diphenyl ethers), 13 PCBs (polychlorinated biphenyls) and 18 PAHs (polycyclic aromatic hydrocarbons) were seasonally measured in surface sediments of the two sampling sites. Immunomarkers, as well as AChE activity, highlighted an overall better condition for clams from PS, whereas a different response was provided by the biomarkers measured at organism level, condition index increasing and survival-in-air decreasing in PS clams. No marked differences in sediment contamination levels (except for PAHs) were observed between CD and PS. Overall, results of that study demonstrated that biomarkers measured allowed to discriminate the two sampling sites.

In another study (Matozzo et al., 2010) (Table A-2), a multibiomarker approach was used to assess effects of environmental contaminants in the clam *R. philippinarum* from 8 sites of the Lagoon (Campalto, Marghera, Palude del Monte, Valle di Brenta, Ca Roman, San Servolo, Fusina and Canale Dese). The following biomarkers were measured: total haemocyte count and lysozyme activity in cell-free haemolymph as immunomarkers, acetylcholinesterase activity in gills as a biomarker of exposure to neurotoxic compounds, vitellogenin-like protein levels in both digestive gland and cell-free haemolymph as a biomarker of exposure to estrogenic compounds, and survival-in-air widely used to evaluate general stress conditions in clams. In addition, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), 1,1,1-Trichloro-2,2-bis(p-chlorophenyl)ethane (p,p'-DDT) and its breakdown products (DDE, DDD), hexachlorobenzene (HCB) and hexachlorocyclohexane (HCH) were measured in clams. Results demonstrated that the integrated approach between biomarkers and chemical analyses in *R. philippinarum* is a useful tool in biomonitoring the Lagoon of Venice.

In general, previously conducted biochemical and cellular analyses (Table A-2) focused on monitoring of natural populations or active biomonitoring through transplantation experiments. However, such approaches cannot be applied for the investigation of deep sediments (as those dredged from navigation canals addressed in WP2.1.2). Therefore, in the frame of WP2.1.2 a novel approach will be adopted using laboratory controlled exposure of animals to sampled sediments, analogously to what planned in Ecotoxicological bioassays and Trascriptomics LoE.

5.4 Modelling (focus on Bioaccumulation Line of Evidence)

The literature performed in Scopus with keywords "Veni*", "lagoon", "model*", resulted in 141 hints as original research and review papers. Of the identified papers, around one third was dedicated to model applications related to chemicals behaviour in water and sediment. Of these, several papers were reporting geostatistical analysis, decision-related modelling or PM2.5 and PM10 atmospheric modelling and were not considered further for the aim of this deliverable. 32 publications were identified as relevant and reported in Table 5.7. In 10 publications nutrients behaviour in the lagoon is concerned, in 11 publications focus is on metals behaviour and 15 publications take into consideration organic pollutants (selected congeners of PCBs, PCDD, PCDFs, PAHs). Some of the papers take into account different pollutant classes. In Table 5.7 information on the type of model applied, the aim of the application and the chemicals of interest, as well as the funding, when indicated in the reviewed papers, are reported. When data from the local projects are applied, it is also highlighted under the column "Funding/Data".

Six publications focus on the development and application of bioaccumulation modelling. Carrer et al. (Carrer et al., 2000) proposed an ecotoxicological food web model for estimating the bioaccumulation of PCDDs and PCDFs and comparison with measured concentrations in *Tapes philippinarum*, *Mytilus edulis*, *Scardinius eritrophtalamus*, where the model was quite successful in predicting concentrations in invertebrate species, but was less precise in the prediction of bioaccumulation in fish, thus showing that more data would be needed to implement the model parametrisation for the fish species. Micheletti et al. (Micheletti et al., 2004) and Bertazzon et al. (Bertazzon et al., 2006) focus on the estimation of ecological risk on the basis of bioaccumulation potential for metals and sum of PCBs congeners in *Tapes philippinarum*. A different approach was applied in Ciavatta et al. (Ciavatta et al., 2009), where a food web bioaccumulation model was applied with a focus on uncertainty associated to model parameterisation to *Tapes philippinarum* and in the top fish predator *Zosterissesor ophiocephalus* of lindane and PCBs 15, 101 and 194. Giubilato et al. (Giubilato et al., 2016) and Radomyski et al. (Radomyski et al., 2016) applied Merlin Expo, a library of environmental and biological fate models to dynamically simulate bioaccumulation of dioxins and PCB congeners along the food web for the species *Tapes philippinarum*, *Carcinus mediterraneus, Chelon labrosus* and *Zosterissessor ophiocephalus.* Moreover, simulated concentrations in edible species were used, together with age-dependent food intake rates, to reconstruct human internal exposure for local population subgroups.

Environmental fate models have been also developed and applied to the case study area to selected metals (Cu, Pb), OCDD and OCDF and PCB 180 (Sommerfreund et al., 2010; Sommerfreund et al., 2010) and for PCB and PCDF congeners (Dalla Valle et al., 2003).

Some of the reported research develops on data generated by the local projects reported in Table A-1, specifically data from ARTISTA were applied in Carrer et al. (Carrer et al., 2000) and data from Corila 2nd program were applied in Sommerfreund et al. (J. K. Sommerfreund et al., 2010). Data generated in Mappatura were applied in Micheletti et al. (Micheletti et al., 2004), while Pastres et al. (Pastres and Solidoro, 2012) applied data from MELa. CORILA was supporting also the development of the biogeochemical model by Botter et al. (Botter et al., 2006). More recently, Teatini et al. (Teatini et al., 2017a) developed on the SOLVE project, consisting on the creation of a GIS based system collecting data on different lagoon variables, from hydrodynamics to chemicals concentrations.

According to the evidence collected from the literature, in the WP 2.1.2 concerning the application of predictive bioaccumulation models, we plan to extend the studies performed so far through the application of Merlin Expo to a broader class of pollutants in *Tapes philippinarum*, and to predict the biomagnification and bioaccumulation in the lagoon foodweb. Emphasis will be dedicated to the role of different exposure pathways to the bioaccumulation in key species.

Table 5.7. List of publications on chemicals modelling in the lagoon of Venice, in the period 1999-2019.

Reference	Model type	Aim	Chemicals	Funding/Data
Pesce et al., 2018	SWAT and AQUATox	Assess climate-related hazard taking into consideration nutrients concentrations	Nutrients	GLOCOM (FP7)
Teatini et al., 2017a	Water flux, contaminant exchange (metals) in sediments dredging. Multi-model approach	Quantify leaking from the industrial area into the lagoon of anthropogenic pollutants	Metals (As, Cd, Cu, Cr, Hg, Pb, Se)	SOLVE
Radomyski et al., 2016	Bioaccumulation model	Probabilistic assessment of the ecological and human exposure to selected pollutants in the Lagoon of Venice	PCB 126 2,3,7,8-TCDD	FP7 4FUN
Giubilato et al., 2016	Bioaccumulation model	Application of an exposure model to account for bioaccumulation and biomagnification of pollutants concentrations along the foodweb and humans	PCB 126 2,3,7,8-TCDD	FP7 4FUN
Guédron et al., 2016	Biogeochemical model	Estimate partitioning of Hg with the dissolved organic carbon	total mercury (THg) and monomethylmercury (MMHg)	NA
Brito et al., 2012	Biogeochemical model	Climate change impacts on the microphytobenthos in the Lagoon	N and chlorophyll	NA
Pastres and Solidoro, 2012	Biogeochemical model	Coupling of monitoring data and mathematical models in assessing the ecological status of the Lagoon of Venice by focussing on the budgets of N and P on the metabolism of the ecosystem, to predict and prevent anoxic events	N and P	Data from MELa

Reference	Model type	Aim	Chemicals	Funding/Data
Benedetti et al., 2012	Software assisted weight of evidence (woe) to evaluate sediment hazard	Assess the environmental hazard of selected pollutants in the sediments of the Lagoon of Venice by applying a woe model, combining pollutants sediments concentrations, bioaccumulation in Anguilla anguilla, a set of tests on biomarkers and a set of standardized ecotoxicological bioassays.	Cd, Cu, Zn polycyclic aromatic hydrocarbons	NA
Ciavatta and Pastres, 2011	Biogeochemical model	Apply the Dynamic Harmonic Regression model to investigate interannual changes in the trend and seasonality of biogeochemical variables monitored in coastal areas	ammonia, nitrate, orthophosphate and chlorophyll	NA
Sommerfreund et al., 2010	Fate and transport model	Fate model	Cu, Pb, OCDD/F and PCB-180	CORILA II
Solidoro et al., 2010	Biogeochemical model	Impacts of changes in temporal precipitation patterns on the biogeochemical properties of the lagoon of Venice		SESAME Project FP6
Carpani and Giupponi, 2010	Conceptual Modelling and Bayesian Networks	Assess the effectiveness of agri-environmental policy measures adopted by the Veneto Region to reduce diffuse water pollution of agricultural origin	N	NA
Libralato and Solidoro, 2009	Trophic level dynamics-biogeochemical cycles	integration in which two models are not coupled by using the output of first model as a forcing of the second model and vice versa	Nutrients	NA
Ostoich et al., 2009	DPSIR model	Definition of environmental quality standards according to the WFD	Priority pollutants	NA

Reference	Model type	Aim	Chemicals	Funding/Data
Cossarini et al., 2009	Biogeochemical model	investigate the seasonal ecosystem dynamics of the Lagoon of Venice and provide guidance on the monitoring and management of the Lagoon, combining a rich data set with a physical-biogeochemical numerical estuary-coastal model	Nutrients	NA
Ciavatta et al., 2009	Bioaccumulation model	Uncertainty analysis and bioaccumulation in two species in the Vencie lagoon	POPs	NA
Sfriso et al., 2009	Indices validation through the macrophyte assemblages and biogeochemical values	Assessment of the ecological status of the Lagoon of Venice	nutrient and pollutant (metals, Polychloro-Dibenzo-Dioxins/Furans, Polycyclic Aromatic Hydrocarbons, Pesticides and Polychlorinated Biphenils) concentrations in surface sediments	NITIDA program (MIUR)
Cossarini et al., 2008	Biogeochemical cycles and dynamic and statistical models	Determining the effect of climate cariables on the biogeochemical cycles	Nutrients	NA
Salon et al., 2008	Regional climate model	Assess the impact of climate change on biogeochemical cycles in the Venice lagoon		NA
Rampazzo et al., 2008	Statistical analysis	Influence of glass factory on air quality in Venice Lagoon	eight major elements (Al, Ti, Ca, Mg, Na, K, Fe, Mn), 20 minor and trace elements (Li, V, Cr, Co, Ni, Cu, Zn, Ga, As, Se, Rb, Sr, Ru, Rh, Cd, Sb, Ba, Ce, Pt, Pb) and four PAHs (BaA, BbF, BkF, BaP)	

Reference	Model type	Aim	Chemicals	Funding/Data
Garcia-Solsona et al., 2008	Mass balance model	Determine Radium excess in the Venice lagoon and its sources	Radium isotopes	partially supported by the Réseau Interdisciplinaire Méditerranéen (RIM) project
Dalla Valle et al., 2007	Fate and transport model	Climate change effect on the fate of pollutants	PCB and PCDD/F congeners	CMCC
Bertazzon et al., 2006	Bioaccumulation model	Integration of geostatistics and multivariate spatial regression to compute efficient spatial regression parameters and to characterize exposure at under-sampled locations	organic and inorganic micropollutants	NA
Botter et al., 2006	Geomorphological scheme of the hydrological response coupled with suitable Lagrangian transport models (mass-response functions) applied in a Montecarlo framework	Study spatial and temporal variability of nitrogen sources of agricultural origin and the effects of the relative timing and intensity of the forcing rainfall fields on the ensuing nitrate leaching	NA	CORILA
Carrer et al., 2005	Bidimensional model	Build an ecotoxicological model	polychlorinated dibenzo-dioxins/polychlorinated dibenzo-furans (PCDD/F), polychlorinated biphenyls (PCBs), heavy metals	Data from ARTISTA, MELa1
Busetti et al., 2005	Linear regression	Prediction of removal efficiency of a waste treatment plant	Metals Al, Ag, As, B, Ba, Cd, Cr, Fe, Mn, Hg, Ni, Pb, Cu, V, and Zn	NA

Reference	Model type	Aim	Chemicals	Funding/Data
Micheletti et al., 2004	Bioaccumulation model	Ecological risk assessment	inorganic pollutants (e.g., arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc) and organic pollutants (e.g., polychlorobiphenyls),	Mappatura
Critto et al., 2005	PCA and statistical analysis	Exposure scenario	Metals; total PAHs, total PCBs, HCB	NA
Džeroski, 2001	Machine learning methods in ecological modelling	Review	Chemicals	NA
Zharova et al., 2001	Biomass model	Predict Zostera marina growth	NA	NA
Wenning et al., 2000	Wildlife exposure models	Screening ecological risk assessment	Dioxins and dibenzofurans	NA
Carrer et al., 2000	Trophic network model and ecotoxicological food web model	Compute exposure concentrations	Dioxins and dibenzofurans	NA

Conclusions

This deliverable provides a critical review of the available information, from the literature and from relevant authorities and institutes, about i) background values of inorganic contaminants in the lagoon of Venice; ii) the quality of water, surface sediments and bottom sediments; iii) the role of sediment as a secondary source of contamination, with the aim to identify relevant knowledge gaps to be addressed in WP2.1.1, WP2.1.2, WP2.1.3 and WP2.1.4 (see Description of Activities (DoA) of Venezia 2021).

As only deviation from the DoA, the submission of this deliverable was postponed by two months (from month 4 to month 6) to complete the analysis of the large number of project reports and scientific papers produced in the last 20 years of investigations in the lagoon of Venice for the topics of concern in line 2.1.

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Annexes

TABLE A-1 – Overview of the research projects relevant to the lagoon of Venice developed by local authorities and institutes. Informations are categorised into 11 topics: *Project* (*Progetto*, abbreviated name), *Title (Titolo)*, *Responsible (Competenza)*, *Objectives (Obiettivi)*, *Timing (Tempistica)*, *Monitoring/Research* (*Attività monitoraggio/ricerca*, main focus of the project), *Bio-physico-chemical parameters and processes* (*parametri e processi bio-fisico-chimici*, list of studied variables and processes), *Sediments* (*Sedimenti*, details methodology applied to study sediment compartment), *Water* (*Acqua*, details methodology applied to study water compartment), *Human health* (*Salute umana*, details any information regarding human health risks or exposures to contaminants), *Relevant to line 2.1 objectives* (*Rilevanza per obiettivi linea di ricerca 2.1*, classifies projects according to their relevance to the three research area of 2.1: i) sediment natural background, ii) sediment as secondary source of contamination, iii) sediment and water quality). Finally, the last column reports the *bibliographic reference* (*riferimento bibliografico*) used to fill in the row for the specific project.

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAG GIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFIC O
Mappatura	"MAPPATURA DELL'INQUINAMENTO DEI FONDALI LAGUNARI"	Magistrato alle Acque di Venezia-Consorzio Venezia Nuova	Fornire indicazioni utili a supportare le decisioni relative allo smaltimento del sedimento, esso ha permesso di conseguire una prima valutazione del grado di contaminazione dell'intera laguna sulla base della presenza di gran parte degli inquinanti accumulabili nel sedimento	17.3.1997 - 30.7.1999	Le attività di campo per il campionamento dei sedimenti e benthos sono state effettuate tal il 27.10.1997 e il 18.6.1998; sono state prelevate 140 carote di sedimento/terreno in 140 punti, da cui sono stati ottenuti 209 campioni. Tra il 26.1.1998 e il 2.7.1998 sono stati anche prelevati 52 campioni di organismi eduli	Metalli pesanti e composti organici, compresi PCDD e PCDF, IPA, PCB, pesticidi ed altri composti in tracce, di sedimenti ed organismi eduli	SEDIMENTI SUPERFICIALI: 99 campioni (15 cm), SEDIMENTI PROFONDI: 39 carote (2m), 2 carote (1m)	ORGANISMI MACROBENTONICI: I campionamenti di macrobenthos sono stati effettuati in 75 punti, ORGANISMI EDULI: 24 campioni di *Tapes philippinarum* (vongola), 9 campioni di *Carcinus mediterraneus* (granchio), 4 campioni di *Chelon labrosus* (cefalo), 7 campioni di *Mytilus galloprovincialis* (mitilo), 8 campioni di *Zosterissessor ophiocephalus* (gò)	-	-	***	MAV-CVN, 1999, Project MAPPATURA. Mappatura dell'inquinamento dei fondali lagunari. Final Report. Ministry of Public Works e Venice Water Authority e Consorzio Venezia Nuova, Venezia, p. 1300
Orizzonte 2023, LINEA A	"CONTRIBUTO DI FALL-OUT ATMOSFERICO ALLE IMMISSIONI IN LAGUNA"	Magistrato alle Acque di Venezia - Consorzio Venezia Nuova. Dott. S. Guerzoni (CNR- Istituto di Geologia Marina di Bologna) con la partecipazione dell'Università Ca' Foscari di Venezia, Dipartimento Scienze Ambientali,	Lo studio delle deposizioni atmosferiche mensili misurate nella Laguna di Venezia riguardanti i microinquinanti inorganici ed organici per valutare l'entità del contributo atmosferico all'apporto di contaminanti nell'area lagunare veneziana	7.1998 - 7.1999	Totale campioni n. 65. Sono stati utilizzati deposimetri BULK (raccoglitore passivo di deposizioni umide e secche) in quattro stazioni poste all'interno ed in prossimità della gronda lagunare. Stazione n.1: Centro Storico, 2: Laguna Nord, 3: Laguna Sud; 4: Zona Industriale. Il criterio di scelta dei siti si è basato sull'ipotesi di valutare il gradiente di carico di inquinanti inorganici e organici tra terra e laguna e tra Nord e Sud	Per ciascun campione sono stati analizzati diversi parametri chimico-fisici: pH, conducibilità, granulometria e mineralogia, e i campioni sono stati suddivisi in frazione solubile e insolubile. Su entrambe le frazioni di ogni campione sono stati analizzati elementi: Al, Ca, Na, K, Mg, Si, Mn, Fe, Zn, Ni, Cr, Cu, Pb, Cd, As, Hg, Ti, V, S, P, Se, Sb. Sulla sola frazione solubile è stata determinata la composizione di: Cl-, NO3-, SO4--, NH4+ e PO4--. Su una campione distinto (totale) sono stati analizzati i seguenti microinquinanti organici: IPA, PCB, HCB, POC, DDD+DDE, DDT, PCDD/F	-	-	-	-	*	MAV-CVN, 1999, Project ORIZZONTE 2023. Programma generale delle attività di approfondimento del quadro conoscitivo di riferimento per gli interventi ambientali, Venice

[4] * natural background,** sed-water interface,*** sed/water quality

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAG GIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFIC O
Orizzonte 2023, LINEA B	"LE CARATTERISTICHE RADIOCHIMICHE DEI SEDIMENTI RECENTI DELLA LAGUNA DI VENEZIA"	per il quale la Dott.ssa E. Molinaroli e il Dott. G. Rampazzo sono stati coordinatori delle attività di propria competenza	**Indagine B1:** indagine sulla omogeneità di accumulo dei sedimenti e tendenze evolutive del sistema, **Indagine B2:** inventario di inquinanti nei depositi sedimentari della laguna nord e determinazione dei flussi di inquinanti organici ed inorganici verificatisi nell'ultimo secolo	1998	• Campionamento B1 • Campionamento B2. + ricerca della precedente mappatura del contenuto di radionuclidi effettuata nel 1989	7-Be, 210-Pbns, 137-Cs, 137-CsChy e 137-CsWT (dati dal 1989), 40-K, 214-Pb, 214-Bi, 226-Ra		-	-	-	*	
Orizzonte 2023, LINEA C	"LO STUDIO DEI PROCESSI LEGATI ALLA DINAMICA DEL PARTICELLATO E DEI SEDIMENTI LAGUNARI"		Lo studio si è rivolto alla migliore definizione dell'apporto e dell'accumulo di inquinanti nei sedimenti e del ruolo che svolgono i processi di bioturbazione e risospensione nel trasporto e nella distribuzione del materiale sedimentario.	26.08.1998 - 14.10.1998	1) sedimentazione e accumulo di inquinanti nel sedimento, in 10 siti lagunari ed in 2 barene; 2) bioturbazione, in 4 siti e due tempi; 3) risospensione, in 2 siti lagunari	Sono state eseguite le seguenti analisi: 1) caratteristiche fisiche (contenuto d'acqua e densità secca, granulometria, suscettività magnetica e magnetizzazione rimanente), 2) costituenti principali (elementi maggiori, minerali, calcite e dolomite), 3) carbonio organico e azoto totale, 4) traccianti radioattivi (137-Cs, 210-Pb, 7-Be, 239-,240-Pu), 5) metalli pesanti, 6) microinquinanti organici (PCDD, PCDF, PCB, IPA, HCB e POC (Pesticidi Organo Clorurati))	Sono state campionate due barene in corrispondenza di Punta Fossei nella laguna sud e di Bondante nella parte Nord (M3 e M4). All'interno della zona industriale sono stati campionati i canali Brentella e San Giuliano (I1 e I2) e carote di sedimento in corrispondenza di otto siti (A, B, C, D, E, F, G e H) scelti in base alla loro rappresentatività di diversi ambienti deposizionali	-	-	-	**	
Orizzonte 2023, LINEA D	"L'EUTROFIZZAZIONE E L'INQUINAMENTO DELLE ACQUE E DEI SEDIMENTI NELLA PARTE CENTRALE DELLA LAGUNA DI VENEZIA"		L'attività D intende aggiornare ed integrare la serie storica dei dati acquisiti dal Dipartimento di Scienze Ambientali dell'Università di Venezia sul grado di trofia e di inquinamento della parte centrale della laguna di Venezia, compresa tra il Canale Malamocco-Marghera a Sud-Ovest e le Barene di Burano e Torcello a Nord-Est. + ricerca delle trasformazioni avvenute nel bacino centrale della laguna dall'inizio degli	1998	In questo lavoro si sono scelte quattro stazioni di campionamento dislocate in aree, rappresentative di differenti situazioni trofiche e del diverso livello di inquinamento presente nella laguna. Stazione A "Alberoni", Stazione B "Sacca Sessola", Stazione C "San Giuliano", Stazione D "Fusina". Il monitoraggio con cadenza mensile. Le matrici analizzate nel presente progetto campionate sono state cinque:	Metalli pesanti, microinquinanti organici (PCB, IPA, PCDD e PCDF). Temperatura, Salinità, Ossigeno disciolto, pH, Potenziale ossido-riduttivo, Trasparenza e trasmissione luce, Particolato filtrato, Fitoplancton, Macrofite nella colonna d'aqua e sedimenti	le concentrazioni dei nutrienti nei sedimenti e nel materiale particellato nelle quattro aree di studio del bacino in questione sono state determinate con frequenza mensile per un periodo annuale (12 campagne totali). primi 5 cm	Le biomasse algali e/o di fanerogame e macrofite Zostera, Ulva sono state determinate con frequenza mensile per un periodo annuale (12 campagne totali)	le concentrazioni dei nutrienti nella colonna d'acqua nelle quattro aree di studio del bacino in questione sono state determinate con frequenza mensile per un periodo annuale (12 campagne totali).	-	***	

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAGGIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFICO
			anni '90 ad oggi.		aria, acqua, sedimento, particellato, biomassa. Le concentrazioni di metalli pesanti sono state determinate ogni due mesi (6 campagne totali) mentre i microinquinanti organici (PCB, IPA, PCDD e PCDF) sono stati analizzati nel corso di una campagna invernale ed in una estiva (2 campagne totali) nei sedimenti, colonna d'aqua, nel particellato sedimentato, macrofiti. Questo lavoro documenta le trasformazioni avvenute nel bacino centrale della laguna dall'inizio degli anni '90 ad oggi.							
Orizzonte 2023, LINEE EA-EE	**E-A:** "IMPIEGO DI INDICATORI BIOLOGICI PER LA QUALITA' DEI SEDIMENTI NELLA LAGUNA DI VENEZIA"; **E-B:** "INDIVIDUAZIONE DI DANNO GENETICO IN ORGANISMI DELL'ECOSISTEMA LAGUNARE"; **E-C:** "VALUTAZIONE DEL TRASFERIMENTO DELLA CONTAMINAZIONE DELLA LAGUNA DI VENEZIA NELLA CATENA TROFICA E VALUTAZIONE DEL RISCHIO PER LA SALUTE UMANA"; **E-D:** "APPLICAZIONE DEL BIOMONITORAGGIO ATTIVO E DI BIOMARKERS NELLA VALUTAZIONE DEL RISCHIO TOSSICO IN LAGUNA DI VENEZIA"; **E-E:** "INDIVIDUAZIONE DI ANOMALIE GENOMICHE IN ORGANISMI		**E-A:** testare la sensibilità e la capacità discriminante di due saggi di tossicità (sulla fecondazione e sullo sviluppo larvale) con l'echinoide P. lividus nel valutare la tossicità dei sedimenti della laguna. **E-B:** l'indagine ha mirato al rilevamento del danno genetico in *Mytilus galloprovincialis*, mitilo Mediterraneo filtratore del livello intermareale, e *Zosterisessor ophiocephalus*, pesce-go' tipico dei fondali con sedimenti coperti da vegetazione; **E-C:** lo studio si è rivolto alla migliore definizione dell'apporto e dell'accumulo di inquinanti nei sedimenti e del ruolo che svolgono i processi di bioturbazione e risospensione nel trasporto e nella distribuzione del materiale sedimentario; **E-D:** verificare l'applicabilità e l'efficienza del biomonitoraggio attivo come strumento di valutazione di qualità ambientale, verificare l'efficienza di una serie di indici di stress in ambienti molto complessi e variabili, definire, mediante gli indici applicati e la qualità delle aree	1998/99	**E-A:** monitoraggio degli effetti tossici dei sedimenti della laguna; **E-B:** 5 siti entro i quali stabilire 2 campagne di studio (raccolta di organismi, analisi chimiche e biologiche) per l'individuazione di danno genetico (addotti al DNA e micronuclei) in pesci e molluschi potenzialmente esposti ad agenti inquinanti genotossici nell'area lagunare veneziana; **E-C:** Lo studio si è articolato in due fasi e attività complementari una di valutazione del rischio e una modellistica. Sono stati utilizzati, per l'elaborazione dell'informazione, i dati disponibili in letteratura, quelli prodotti nel corso del progetto da linee di ricerca inserite nell'ambito Orizzonte 2023 ed infine quelli provenienti dallo studio Mappatura dei Fondali Lagunari. Gli analiti presi in considerazione sono stati selezionati sulla base della loro dimostrata presenza negli organismi lagunari, per la loro rilevanza per la salute umana in accordo con gli studi del U.S.EPA Office of Water; **E-D:** biomarkers indice di stress fisiologico (MFO, enzimi antiossidanti, latenza e altezza dei tubuli digestivi); **E-E:** I	**E-A:** fecondazione e sviluppo larvale; **E-B:** è stata misurata la concentrazione di contaminanti rappresentativi sia inorganici (As, Cd, Cr, Hg, Ni, Pb, Sn) che organici (idrocarburi aromatici policiclici, PCBs ed altri composti clorurati di riferimento) (Su polpa di mitili), danno genetico (addotti al DNA e micronuclei) (mitilo Mediterraneo e pesce-go'); **E-C:** l'arsenico, le diossine ed i PCB-diossina simili; **E-D:** idrocarburi aromatici polinucleari (IPA) e policlorobifenili (PCB); **E-E:** il tasso di proliferazione cellulare, la quantità di addotti al DNA e di cellule micronucleate nei tessuti	**E-A:** 5 siti prescelti. 8 carote di diametro 5 cm e profondità 20 cm. sono state condotte due campagne, una a fine estate (agosto 1998) e una a fine inverno (marzo 1999).	**E-A:** Gli esperimenti sono stati condotti con entrambi i test (spermio ed embriotossicità) per tutte tre le repliche di elutriato ottenute per ogni stazione. Ogni esperimento è stato condotto in tre repliche sperimentali. Per il controllo di qualità dei dati sono stati impiegati controlli negativi (acqua artificiale di diluizione, sedimento naturale non inquinato), positivi (tossico di riferimento) e un bianco procedurale; **E-B:** Addotti al DNA di tipo aromatico sono stati analizzati mediante la tecnica di postmarcatura con 32P in campioni di tessuto branchiale di entrambe le specie (anche in fegato di pesce durante l'indagine preliminare condotta su 10 siti distinti) mentre la frequenza di micronuclei ed altre anomalie nucleari è stata analizzata per microscopia ottica in cellule di branchia ed emociti di singoli mitili; **E-C:** l'utilizzo dei dati ambientali disponibili e prodotti con varie finalità per la realizzazione di un sistema di valutazione e stima della distribuzione dei contaminanti secondo un modelle multicompartimentale e la successiva quantificazione dei rischi per i vari bersagli; **E-D:** *Mytilus galloprovincialis* provenienti da un impianto di allevamento in mare al	-	**E-C:** La costituzione di un modello di rischio per la salute pubblica applicabile alla popolazione residente nella Laguna Veneta. Le vie di esposizione individuate sono state definite in: assunzione di inquinanti da prodotti ittici locali; inalazione e di contaminanti	***	

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAGGIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFICO
	DELL'ECOSISTEMA LAGUNARE, PER MEZZO DELLA CITOFLUORIMETRIA IN FLUSSO"		monitorate; **E-E:** valutare il tasso di proliferazione cellulare ed eventualmente evidenziare ulteriori anomalie a livello genomico (aneuploidie e poliploidie diffuse, associate o meno a neoplasie, variazione più o meno ampia del contenuto di DNA cellulare) o citologico		prelievi dei tessuti da analizzare al citofluorimetro sono stati effettuati contestualmente ed in parallelo su mitili e ghiozzi gò provenienti dalle medesime 5 stazioni, campionate dalla Linea 3E-B in seconda campagna			largo dell'isola di Pellestrina, utilizzato come sito di controllo, sono state trasferite in cinque zone della Laguna di Venezia che presentano un diverso grado e tipo di inquinamento e lì mantenuti per sei settimane. L'esperimento di trapianto è stato condotto durante i mesi primaverili (aprile - maggio 1999); **E-E:** le alterazioni genomiche, legate alla quantità di DNA nucleare, in due tessuti del mitilo (*Mytilus galloprovincialis*) e del ghiozzo gò (*Zosterisessor ophiocephalus*)		atmosferici; assunzione di contaminanti del paniere alimentare.		
Orizzonte 2023, LINEA F	"ATTIVITÀ DI FORMAZIONE DEL QUADRO DELLE CONDIZIONI AMBIENTALI DELL'ECOSISTEMA LAGUNARE"		• **Integrazione della conoscenza vecchia e nuova prodotta** • Sintesi dei risultati prodotti dalle linee di ricerca A-E; • Individuare, raccogliere ed analizzare criticamente i dati e le conoscenze pregresse, con particolare riferimento alla qualità dell'ecosistema lagunare; • Identificare lo stato attuale del sistema lagunare, attraverso la razionalizzazione e integrare la più recente conoscenza resa disponibile dalle attività del Magistrato alle Acque e delle altre Amministrazioni che operano per la salvaguardia del sistema lagunare, secondo l'approccio DPSIR (Driving Forces, Pressures, State, Impact, Response) sviluppato ed adottato dall'Agenzia Europea per l'Ambiente (EEA) e definito; • Definire le specifiche per una strategia di monitoraggio in grado di seguire l'evoluzione del sistema lagunare e delle sue forzanti attraverso opportuni indicatori e di valutare la risposta del sistema agli interventi	1999	Acquisizione di informazioni degli studi pregressi e delle evidenze emerse dai nuovi progetti (2023 e Drain) per la calibrazione e l'affinamento dei modelli matematici, da utilizzarsi quali strumenti operativi di supporto alle decisioni. Le informazioni acquisite andranno ad alimentare ed aggiornare i modelli matematici sulla laguna (modelli idrodinamici, diffusivi, ecologici, morfodinamici)	l'integrazione della informazione disponibile	l'integrazione della informazione disponibile	l'integrazione della informazione disponibile	l'integrazione della informazione disponibile	l'integrazione della informazione disponibile	*, **, ***	

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAGGIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFICO
DRAIN	"DETERMINAZIONE DEGLI APPORTI DI INQUINANTI DAL BACINO SCOLANTE"	Magistrato alle Acque di Venezia- Consorzio Venezia Nuova. Thetis S.p.A. Responsabile Scientifico Dott. R. Zonta del CNR-ISDGM di Venezia	Fornire informazioni importanti sugli apporti di acqua dolce e di inquinanti alla laguna di Venezia provenienti dal bacino scolante e sulle loro modalità di trasferimento	1998 – 2000	Stima delle quantità di acqua, sedimenti ed inquinanti immessi in laguna dal bacino scolante	temperature, salinity, dissolved oxygen, pH, redox, potential, turbidity, Fe, Mn, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, organic micro-pollutants, including polycyclic aromatic hydrocarbons, (PAHs), dioxin-like polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB), organochlorine pesticides, triazine herbicides, polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), suspended particle matter (SPM) and organic carbon (POC and DOC)	-	-	Water samples were collected at two different depthsalong the vertical profile: 20 cm below the surface and 20 cm from the bottom annual freshwater with the objective to measure discharge into the Venice Lagoon and to estimate the related load of pollutants	-	***	MAV-CVN, 2005, DRAIN project. DeteRminatio n of pollutAnt INputs from the drainage basin into the Venice Lagoon, Venice
MELa1 - studio ARTISTA	"ANALISI DELLE RETI TROFICHE, INQUINAMENTO DEI SEDIMENTI E TOSSICITÀ AMBIENTALE"	Magistrato alle Acque di Venezia- Consorzio Venezia Nuova	Obiettivo di questa attività è la messa a punto di una serie di modelli in stato stazionario delle reti trofiche lagunari, finalizzata al loro utilizzo in accoppiamento con un modello ecotossicologico a scala lagunare, per la descrizione del trasferimento dei contaminanti tra le diverse matrici ambientali (abiotiche) e gli organismi. lo studio integra attività sperimentali ed uso di modelli matematici, con il supporto dell'esteso database esistente relativo alla contaminazione di acque – sedimenti – biota.	2001	La raccolta dei dati è stata condotta integrando le basi di dati già disponibili con dati di letteratura prodotti nell'ambito di studi ed indagini: sedimento, acque di colonna, acque interstiziali, particellato, biota.	Nell'ambito dello studio ARTISTA è stata inoltre raccolta una grossa mole di dati sulla ripartizione e sulla mobilità degli inquinanti, nonché sui flussi all'interfaccia acqua-sedimento, tutti questi dati sono stati utilizzati in varie fasi della messa a punto del modello ecotossicologico. Le indagini sperimentali in questione hanno preso in considerazione le sostanza nutrienti (C, N, P) nelle loro varie forme e una serie di contaminanti inorganici (metalli pesanti) ed organici; tra questi ultimi sono stati selezionati le diossine e i furani (PCDD/F), i policlorobifenili (PCB) e l'esaclorobenzene (HCB). Parametri di qualità delle acque di interesse specifico per la messa a punto dei modelli: solidi sospesi (TSS), carbonio organico particellato (POC), clorofilla-a e feopigmenti fitoplancton, microzooplancton (determinazione di lista tassonomica, densità, biovolumi, biomassa),mesozooplancton, macrofitobenthos, (macroalghe,fanerogame, epifiti delle fanerogame), meiozoobenthos macrozoobenthos (macrozoobenthos epifauna,	L'indagine sperimentale è stata articolata in due campagne, realizzate nei mesi di giugno e novembre 2001. Sono state effettuate misure e campionamenti in 10 stazioni di bassofondo. in ogni stazione sono state prelevate 2 o 3 carote per le misure su 3 livelli (0-1 cm, 6-7 cm e 14-15 cm)	Le indagini sulle reti trofiche sono state svolte in cinque stazioni di bassofondo lagunare. Queste stazioni appartengono tutte alla rete di trenta stazioni di monitoraggio periodico della qualità delle acque lagunari del programma MELa1. Nelle stazioni in questione sono state sono state condotte tre campagne nel corso del 2001: - "campagna invernale" o "campagna di gennaio" dal 25.01.01 al 06.02.01; - "campagna primaverile" o "campagna di maggio" dal 27.04.01 al 07.05.01; - "campagna estiva" o "campagna di agosto" dal 21.08.01 al 28.08.01.	Le campagne di campionamento campionamento di acqua in prossimità dell'interfaccia acqua-sedimento si sono svolte nei giorni 26-27 giugno e 20-21 novembre.	-	***	MAV-CVN, 2004, Project MELa. Attività di Monitoraggio Ambientale della Laguna di Venezia – Esecutivo del 1° stralcio triennale (2000-2003). 4993538-REL-T097.0

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAGGIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFICO
						macrozoobenthos endofauna), necton						
ICSEL A	"INTEGRAZIONE DELLE CONOSCENZE SULL'ECOSISTEMA LAGUNARE"	Magistrato alle Acque di Venezia-Consorzio Venezia Nuova	Approfondimento delle conoscenze sullo stato di contaminazione dei sedimenti lagunari per l'ottimizzazione delle loro strategie di gestione	2003-06	Sono state eseguite alcune indagini sperimentali ed è stata eseguita un'ampia ricerca bibliografica per la raccolta e organizzazione dei dati prodotti da studi ed indagini eseguiti sia dal MAV-CVN che da vari Enti ed Istituzioni: • Valutazione integrata dello stato qualitativo attuale dei sedimenti lagunari superficiali • Evoluzione temporale dell'inquinamento antropico dei sedimenti • Stato dei sedimenti lagunari rispetto ad altri ambienti di transizione e marini costieri a diverso grado di antropizzazione • Analisi dei benchmark (livelli di riferimento) utilizzati internazionalmente per valutare i sedimenti • Relazioni fra lo stato dei sedimenti e la qualità dell'ecosistema • Valutazione ecotossicologica dello stato dei sedimenti dei canali lagunari	Metalli totali, metalli SEM, AVS, PCB, PCDD/F, IPA, HC(<12, >12C), POC, HCB, Ammoniaca, Solfuri. Ecotox, biomarkers, danno genetico, bioacc	Le indagini sperimentali sono state eseguite sullo strato superficiale (0-15 cm) del sedimento prelevato da 20 stazioni, su 10 delle quali è stato analizzato anche lo strato profondo (tra 30 e 45 cm)	20 stazioni riportate in un arco temporale compreso tra l'8 settembre e il 20 ottobre 2003. Sono stati effettuati generalmente in 4 stazioni al giorno, una volta alla settimana. Test tossicologici con Vibrio fisheri - Microtox® , con Paracentrotus lividus e con Corophium orientale	-	-	***	MAV-CVN, 2005, Project ICSEL. Programma generale delle attività di approfondimento del quadro conoscitivo di riferimento per gli interventi ambientali – secondo stralcio-Studio ICSEL. ICS-REL-T068.0 Vol. I/VI, Venice
ICSEL C	"INTEGRAZIONE DELLE CONOSCENZE SULL'ECOSISTEMA LAGUNARE"	Magistrato alle Acque di Venezia-Consorzio Venezia Nuova	Valutazione sperimentale del rischio ecologico dovuto all'inquinamento delle acque e dei sedimenti della laguna di Venezia	2003-06	Integrazione tra approccio tradizionale di tipo chimico e approccio di tipo ecotossicologico: • bioaccumulo di microinquinanti organici ed inorganici in molluschi bivalvi e pesci; • saggi di tossicità su acque; • saggi di tossicità su sedimenti; • indici di stress o biomarkers.	carbonio organico (TOC), granulometria, metalli totali: As, Cd, Cr, Cu, Hg, Pb, Ni, Zn, Simultaneously extracted metals (SEM) - As, Cd, Cr, Cu, Hg, Pb, Ni, Zn - e solfuri acidi volatili (AVS), zolfo elementare, policloro bifenili (PCB), esaclorobenzene (HCB), idrocarburi policlici aromatici (IPA), pesticidi organoclorurati (POC), idrocarburi <C12 e >C12, policlorodibenzodiossine (PCDD) e policlorodibenzofurani (PCDF), Mortalità, Fecondazione, Sviluppo embrionale,	Caratterizzazione chimico-fisica di 30 siti	• un saggio acuto su sedimento tal quale con anfipodi (Corophium sp.); • un saggio acuto su sedimento risospeso con batteri bioluminescenti (*Vibrio fischeri*); • due saggi (un acuto ed un subcronico) su elutriati con l'echinoide *Paracentrotus lividus*. Caratterizzazione tossicologica di 30 siti, 20 campioni analizzati nel corso del 1° anno di monitoraggio (dato singolo) e 10 campioni ripetuti nel corso del triennio di monitoraggio (dato medio dei tre anni). 10 siti utilizzando una batteria estesa di biomarker su due specie di bivalvi	Caratterizzazione ecotossicological' esecuzione di un saggio di laboratorio, ha interessato nel corso del 1° anno 15 siti.	-	***	

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAGGIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFICO
						Bioluminescenza, Crescita cellulare, Biomarkers, Bioaccumulo		(*Mytilus galloprovincialis* e *Tapes philippinarum*) ed una specie di pesce gobide (*Zosterisessor ophiocephalus*). Bioaccumulo in organismi nativi e trapiantati				
MELa2	**LINEA E:** "ESTENSIONE DELLE ATTIVITÀ DI MONITORAGGIO DELLA QUALITÀ DELLE ACQUE"	Magistrato alle Acque di Venezia-Consorzio Venezia Nuova	L'obiettivo di questa linea del Progetto MELa2 è quello di integrare le conoscenze ottenute dai programmi di monitoraggio MELa1 e MELa3 fornendo: dati sulla concentrazione di azoto totale e fosforo totale • Importanti informazioni sulla distribuzione dei microinquinanti organici sia nella frazione totale che in quella disciolta • Ottenere dati per la definizione della composizione quali-quantitativa della comunità fitoplanctonica in Laguna di Venezia	risultati relativi all'anno 2004 (terzo anno di attività) e la loro analisi comparata con i dati misurati nel biennio precedente (I° e II° anno del progetto)	• Le attività di campionamento relative al progetto Mela2 sono state svolte sempre in condizioni di marea di quadratura ed in concomitanza con le attività di monitoraggio MELa3 • Verificare la variabilità dei diversi macrodescrittori in funzione del ciclo di marea	• Azoto Totale (TN) e Fosforo Totale (TP); • Stima quali-quantitativa della comunità fitoplanctonica; • Principali microinquinanti organici: PCDD/F, HCB, IPA, PCB (totali e nella frazione disciolta).	-	Campioni superficiali, raccolti trimestralmente in concomitanza delle attività di monitoraggio della qualità delle acque MELa1	Le attività di campionamento relative al progetto Mela2 sono state svolte sempre in condizioni di marea di quadratura ed in concomitanza con le attività di monitoraggio MELa3. Sono state svolte una serie di campagne ad alta frequenza durante cicli mareali di sizigie	-	***	MAV-CVN, 2004, Project MELa. Attività di Monitoraggio Ambientale della Laguna di Venezia – Esecutivo del 1° stralcio triennale (2000-2003). 4993538-REL-T097.0
MELa3	**ATTIVITA' A:** CAMPAGNE PERIODICHE DI MISURA DELLA QUALITÀ DELL'ACQUA	Magistrato alle Acque di Venezia-Consorzio Venezia Nuova	• mantenere ed aggiornare la base conoscitiva costituita dai dati raccolti nel progetto "MELa1" e nei monitoraggi precedenti • monitorare le tendenze evolutive dello stato trofico e della contaminazione chimica delle acque lagunari • sviluppare ulteriormente la comprensione dei processi che regolano il funzionamento del sistema-Laguna	Attivita' A gennaio 2004 – dicembre 2005 (MELa 2001-2005)	Rete di campionamento pari a 30 in MELa1 e 23 in MELa3. Le attività di monitoraggio delle acque: • parametri chimico-fisici • parametri trofici • metalli in tracce.	• parametri chimico-fisici: temperatura, salinità, ossigeno disciolto, pH, potenziale redox, eH, ed alcalinità totale • parametri trofici: torbidità, clorofilla a, solidi sospesi totali (TSS), azoto disciolto in forma di ammonio (N_NH4) e in forma ossidata (N_NOx), azoto disciolto totale (TDN), azoto totale (TN), fosforo disciolto reattivo, (P_PO4), e disciolto totale (TDP), fosforo totale (TP), carbonio organico associato al particellato (POC), e totale (TOC) • metalli in tracce: arsenico, rame, mercurio, piombo, zinco, cadmio, cromo e nichel	-	Campionamento bi/quadrisettimanale	20 delle stazioni MELa3 costituiscono un sotto-insieme della rete adottata nel progetto MELa1. Frequenza del campionamento quadrisettimanale in MELa1 e almeno quadrisettimanale nella rete di monitoraggio MELa3.	-	***	MAV-CVN, 2004, Project MELa. Attività di Monitoraggio Ambientale della Laguna di Venezia – Esecutivo del 1° stralcio triennale (2000-2003). 4993538-REL-T097.0
CORILA - PROGRAMMA DI RICERCA 2004-2006 – Linea 3.8	LINEA 3.8: SPECIAZIONE, DISTRIBUZIONE, FLUSSI, BIOACCUMULO E TOSSICITÀ DEI PRINCIPALI	Responsabile scientifico: Dr. Mauro Frignani • Dipartimento di Scienze	• biodisponibilità degli inquinanti presenti nelle acque e nei sedimenti; • bioaccumulo e biomagnificazione; • coerenza dei limiti di concentrazione fissati per legge con l'esigenza	2004-2006	Oggetto della ricerca sperimentale: acqua, sedimento, particellato,sospeso, organismi. Quattro campionamenti a cadenza stagionale in corrispondenza di due siti della laguna centrale, Campalto e	microinquinanti organici (PCB ed IPA), metalli pesanti (Pb, Cd, Cr, Cu, Mn, Zn, Fe), DOC, biomarker di esposizione, bioaccumulo, bioturbazione	Sedimento superficiale, 4 campagne stagionali, primi 2 cm della carota di 10 e 20 cm	Bioaccumulo e la tossicità preso in considerazione: *H. diversicolor* e *P. cultrifera* (policheti), *M. galloprovincialis* (mitile) e *Z. ophiocephalus* (pesce). Bioturbazione: 1) molluschi bivalvi, 2) molluschi, 4) gasteropodi, 5)	4 campagne stagionali • Scambi acqua/sedimento e speciazione dei principali contaminanti in	-	**, ***	Consorzio per la Gestione del Centro di Coordinamento delle Attività di Ricerca inerenti il

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAGGIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFICO
	CONTAMINANTI NELLA LAGUNA DI VENEZIA: APPROCCIO SPERIMENTALE E MODELLISTICO	Ambientali-Università Ca' Foscari di Venezia • CNR-Istituto di Scienze Marine, sede di Bologna (ex Geologia Marina) • CNR-Istituto di Scienze Marine, sede di Venezia (ex Biologia del Mare) • Department of Geography, University of Toronto (CA) • Laboratoire d'Ecologie des Hydrosystèmes, Toulouse (FR)	di proteggere l'ambiente e permettere l'espletazione delle normali attività; • qualità attuale rispetto alle normative europee; • capacità di filtro del sistema; • scelta di bioindicatori; • nuove indicazioni sui valori di soglia e • confronto con le legislazioni a livello internazionale		Sacca Sessola			anellidi policheti, 6) tunicati, 7) echinodermi, 8) crostacei.	fase acquosa • Stima dei flussi di inquinanti inorganici all'interfaccia acqua/sedimento e laguna/mare			Sistema Lagunare di Venezia, PROGRAMMA DI RICERCA 2004-2006. SPECIAZIONE, DISTRIBUZIONE, FLUSSI, BIOACCUMULO E TOSSICITÀ DEI PRINCIPALI CONTAMINANTI NELLA LAGUNA DI VENEZIA: APPROCCIO SPERIMENTALE E MODELLISTICO. CORILA-RAPPORTO FINALE-LINEA 3.8
CORILA - PROGRAMMA DI RICERCA 2004-2006 - LINEA 3.11	INDICATORI E INDICI DI QUALITÀ AMBIENTALE PER LA LAGUNA DI VENEZIA	Responsabile scientifico: prof. Antonio Marcomini Coordinatore operativo: prof. Paolo Maria Bisol Dipartimento di Scienze Ambientali, Università Ca' Foscari Venezia Dipartimento di Chimica Fisica, Università Ca' Foscari Venezia CNR- Istituto di Scienze Marine (ISMAR) sezione di Venezia Dipartimento	Definizione di indici ed indicatori per la valutazione della qualità ambientale della laguna di Venezia, facendo riferimento all'approccio stabilito dalla Direttiva Quadro sulle acque del 2000.	2004-2006	Approccio integrato considerando misure di tipo biologico (biodiversità), tossicologico, e di esposizione a sostanze tossiche di sintesi e non di sintesi, così come ad agenti stressanti di tipo fisico.	Misura di parametri chimico-fisici (temperatura, salinità, pH, solidi disciolti totali, concentrazione di sedimenti in sospensione, contenuto di materia organica disciolta, carbonio organico disciolto). Misura dell'effeto di vernici antivegetative (TBT metacrilato; zinco piritione, zineb, endosulfan; sea-nine 211, diuron; zinco piritione, diuron, sea-nine 211; TCMS piridina, diuron)	Uso dei dai rilevati nel progetto "MAPPATURA" riferiti al sedimento superficiale (15 cm) di 139 siti in laguna. **-Per analisi del carbonio organico**: Campionamento di 140 stazioni nell' anno 2002 e di 54 stazioni nell'anno 2003 relative ad ambienti di velma/bassifondale. Eseguiti 5 campionamenti per ogni stazione relativi a sedimenti superficiali (0 - 5 cm).	**Studio della diversità genetica (biodiversità di primo livello) nel crostaceo decapode *Carcinus aestuarii:*** eseguiti 6 campionamenti (primavera 2005, primavera 2006) in tre siti e sono stati raccolti 179 esemplari. Effettuate le analisi per: i)stima della variabilità genetica e della distribuzione dei livelli di polimorfismo (indici di popolazione: percentuale loci polimorfi, numero medio di alleli, frequenze degli eterozigoti); ii) Stima del grado di suddivisione e delle relazioni fra popolazioni, verifica di pressioni selettive, isolamento ed influenza della deriva genetica; valutazione dell'erosione genetica. iii) Valutazione delle eventuali relazioni fra variabilità genetica e altri indicatori biologici. **Espressione dell'emocianina di esemplari di *Carcinus* aestuarii**: In tre siti, sono stati eseguiti due campionamenti (primavera) e raccolti 100 individui. Lo scopo è stato quello di analizzare il range di espressione e la			**, ***	Consorzio per la Gestione del Centro di Coordinamento delle Attività di Ricerca inerenti il Sistema Lagunare di Venezia, PROGRAMMA DI RICERCA 2004-2006. INDICATORI E INDICI DI QUALITÀ AMBIENTALE PER LA LAGUNA DI VENEZIA. CORILA-RAPPORTO FINALE-LINEA 3.11

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAGGIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFICO
		di Biologia, Università di Padova					Campionamento in zona intertidale, 18 stazioni (estate 2002 ed estate 2004), 3 campionamenti per ogni stazione relativi a sedimenti superfiviali (0 - 5 cm). **-Per lo sviluppo di un indici di tossicità dei sedimenti:** campionamento in 6 stazioni con carote di 20 cm.	variabilità dei patterns, in popolazioni della medesima specie correlabili a contesti ecologici diversi. **Produzione di nuove Expressed Sequence Tags in *M. galloprovincialis***: preparazione ed analisi dei campioni derivanti dai mitili trattati in laboratorio e dall'ambiente lagunare, elaborazione dei profili di espressione genica ed interpretazione dei risultati ottenuti. **Biomarcatori cellulari:** a) Esposizione di Zosterisessor ophiocephalus a livelli subacuti di Cd++; Esposizione di Mytilus a organostannici (TBT) disciolti in H20 ; **Alterazioni endocrine come indicatori delle condizioni ambientali**: induzione di proteine Vg-like, quali biomarker di esposizione, a composti ad attività xenoestroenici (4-nonilfenolo, NP; 17β-estradiolo, 2E) in laboratorio e in campo su due specie di molluschi bivalvi: *Tapes philippinarum Cerastoderma glaucum.* Campionamento di 100 individui per specie raccolti da sei siti con periodicità stagionale (gennaio e giugno 2005). **Asimmetrie fluttuanti come indicatori**: Misure di asimmetria fluttuante (FA), la deviazione casuale e non ereditabile dalla perfetta simmetria bilaterale in *Carcinus aestuarii.* **Evoluzione temporale e biotica delle comunità del macrofouling di substrato duro. Definizione e validazione di indici di stress e descrittori della biodiversità. Effetti di vernici antivegetative**: determinazione della biodiversità.				
ISAP	INDAGINE SUI SEDIMENTI E SULLE ACQUE DEI CANALI DI PORTO MARGHERA E DELLE AREE LAGUNARI ANTISTANTI	Magistrato alle Acque di Venezia- Consorzio Venezia Nuova.	Attività di campionamento di sedimenti lagunari e le relative caratterizzazioni chimico-fisiche, microbiologiche e mineralogiche condotte nell'ambito dell' "OP/346 - ISAP – Indagine sui sedimenti e sulle acque dei canali di Porto Marghera e delle aree lagunari	2004 - 2007	Le attività effettuate: - sondaggi e prelievo di campioni di sedimento - prove geotecniche di laboratorio - analisi chimiche e microbiologiche - indagini mineralogiche	Dai sondaggi effettuati in corrispondenza delle 239 stazioni sono stati complessivamente prelevati 1350 campioni di sedimento sui quali sono stati determinati, in campo, il pH e il potenziale redox. Sulla base delle informazioni contenute nel	Le prove geotecniche effettuate per la determinazione delle proprietà fisiche sui campioni sono le seguenti: - determinazione	Analisi di Bioaccumulo: al fine di valutare il grado di contaminazione ambientale e valutare la biodisponibilità di alcuni inquinanti presenti nella colonna d'acqua, ha previsto il prelievo e l'analisi di campioni di mitili (*Mytilus galloprovincialis*) presenti naturalmente all'interno dei canali	Le misure sono state effettuate da una imbarcazione dotata di sistema di GPS e di sonda multiparametrica per la raccolta dei profili dei		***	MAGISTRATO ALLE ACQUE – CONCESSIONARIO : CONSOSRZIO VENEZIA NUOVA – OP/346 ISAP – Indagine sui

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAGGIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFICO
			antistanti”			piano operativo di campionamento (individuazione dei campioni con relativa codifica ed analisi da effettuare per ognuno) sono stati selezionati un totale di 755 campioni da avviare ai laboratori per le determinazioni chimico-fisiche, ecotossicologiche e microbiologiche previste. Su un numero ridotto di campioni (20), prelevati in corrispondenza di livelli significativi, sono state inoltre condotte le analisi mineralogiche.	del contenuto naturale d’acqua wN - determinazione del peso specifico dei grani Gs - analisi granulometriche	industriali, sia di organismi della stessa specie provenienti da aree esterne al sito industriale e successivamente trapiantatiall’interno dei canali. Le analisi chimiche condotte sono state: Pesticidi organoclorurati, Policlorobifenili, Idrocarburi Policiclici Aromatici (IPA), Metalli ed elementi in trace, Composti organostannici, Diossine e Furani.	parametri chimico fisici in ogni punto di prelievo: profondità, pH, temperatura, conducibilità, salinità, OD %, OD ppm, clorofilla e torbidità. Sono state eseguite le analisi per la determinazione dei seguenti parametri: - Arsenico – Cadmio - Cromo totale – Mercurio – Nichel – Piombo – Rame – Zinco – Antimonio – Vanadio - Cianuri totali – VOC - Diossine (PCDD/PCDF) (su 35 campioni) - Policlorobifenile (PCB) - Idrocarburi Policiclici Aromatici (IPA) - Esaclorobenzene (HCB) - SVOC			sedimenti e sulle acque dei canali di Porto Marghera e delle aree lagunari antistanti – RAPPORTO FINALE, Marzo 2006
MELa3 - DPSIR 2005	“STATO DELL’ECOSISTEMA LAGUNARE VENEZIANO AGGIORNATO AL 2005, CON PROIEZIONI AL 2025”	Magistrato alle Acque di Venezia-Consorzio Venezia Nuova. Thetis S.p.A.	Contaminazione da microinquinanti e rischio per la salute umana e per l’ecosistema lagunare. Lo schema concettuale DPSIR è stato integrato con quello dell’Analisi di Rischio Ecologico e per la Salute Umana (ERA-HHRA)	2005	Fonti informative utilizzate per la construzione del database sulla contaminazione dei sedimentti lagunari: Mappatura, MELa 1, MELa 3, ICSEL A, ICSEL C, Progetto 2023, I Pili,	Acque: metalli disciolti e composti organici. Chimica dei sedimenti, ecotossicologia e biota.	l’integrazione della informazione disponibile nello schema concettuale DPSIR	l’integrazione della informazione disponibile nello schema concettuale DPSIR	l’integrazione della informazione disponibile nello schema concettuale DPSIR	l’integrazione della informazione disponibile nello schema concettuale DPSIR	**, ***	MAV-CVN, 2004, Project MELa. Attività di Monitoraggio Ambientale della Laguna di Venezia – Esecutivo del 1° stralcio triennale (2000-2003). 4993538-REL-T097.0

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAGGIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFICO
SIOSED	"VALUTAZIONE FINALE DELLA COMATIBILIÀ DEI SEDIMENTI LAGUNARI VENEZIANI PER INTERVENTI DI RECUPERO MORFOLOGICO"	Magistrato alle Acque di Venezia-Consorzio Venezia Nuova. Thetis in collaborazione con SCRIPPS Institution of Oceanography (SIO) di La Jolla, California, USA, l'Istituto di Scienze Marine del CNR di Venezia, l'Istituto Nazionale di Geofisica e Oceanografia di Trieste e la società SELC	Il progetto intende a determinare in via sperimentale gli effetti del riutilizzo dei più diffusi sedimenti della Laguna di Venezia fornendo elementi concreti per l'aggiornamento della normativa di settore che, attualmente, non consente il reimpiego dei sedimenti poco contaminati presenti nella maggior parte dell'area. Valutazione del rischio ambientale associato alla movimentazione di sedimenti di classe A (Protocollo Fanghi, 1993).	Da 2005, durava 27 mesi, si conclude con l'ultima campagna di monitoraggio prevista per luglio 2007	• Sperimentazioni e valutazioni integrate: **Biodisponibilità e tossicità dei sedimenti**, Geochimica dei sedimenti ed ecologia dei foraminiferi bentonici, Comunità bentoniche e ricolonizzazione di banchi sommersi e barene artificiali, Comunità microbiche dei sedimenti e comportamento biogeochimico del mercurio, Microrganismi patogeni nei sedimenti, Aspetti microbiologici nella colonna d'acqua ed all'interfaccia acqua-sedimento connessi ai processi di movimentazione (dragaggio e trapianto) dei sedimenti, L'impatto della chimica dei sedimenti sulla capacità di sopravvivenza e sulla fotofisiologia degli organismi microautotrofi nella laguna di Venezia, Aspetti idrodinamici connessi alla costruzione dei banchi artificiali ed effetti sul trasporto dei sedimenti; • Nel 2005 sono stati realizzati i banchi artificiali e le relative campagne di monitoraggio previste prima e dopo la costruzione degli stessi; • Sono stati considerati ed integrati i risultati di una serie di studi recenti ed in corso, svolti dal Magistrato alle Acque – Consorzio Venezia Nuova: MELa1/MELa3-attività di monitoraggio, MELa1-Studio ARTISTA, MELa2-attività monitoraggio, ICSEL.	I banchi artificiali sono stati costruiti con sedimenti di classe A in due aree di bassofondo, una in prossimità del canale di prelievo, caratterizzata da sedimenti di classe A e una lontana con fondale con sedimenti di classe B. E stata effetuata la stima dei livelli dei metalli (Hg, Cd, Pb, As, Cr, Cu, Ni, Zn); Idrocarburi totali; Idrocarburi policiclici aromatici totali; Policlorobifenili totali; Pesticidi organoclorurati totali in diverse matrici ambientali (sedimento, aqua/particellato sospeso e biota). La valutazione in campo e in laboratorio della biodisponibilità, bioaccumulo e biomagnificazione dei metalli in organismi nativi e ecotossicologia.	I dati sono stati acquisiti nel corso delle otto campagne distribuite nei diciotto mesi di monitoraggio dei banchi (dal mese di dicembre 2005 a maggio del 2007). I carotaggi sono stati effettuati per uno spessore di circa 70 cm e lo strato più superficiale, per uno spessore di circa 15 cm	La valutazione degli effetti è stata effettuata sia prima che dopo la movimentazione dei sedimenti attraverso determinazioni di bioaccumulo in organismi chiave della rete trofica e in ofiuridi bioluminescenti e l'utilizzo di test di tossicità. Ecotoxicologia: seguenti saggi con anfipodi, Microtox, di spermio- ed embriotossicità con echinodermi. Bioaccumulo: nei foraminiferi e ostracodi. Biomagnificazione. E' stato effettuato un biomonitoraggio integrato basato su più tecniche di misurazione di tipo biologico e chimico: bioaccumulo di inquinanti inorganici in policheti; bioaccumulo di inquinanti inorganici ed organici in organismi appartenenti ai diversi livelli della rete trofica; saggi di tossicità sui sedimenti. Gli effetti dei contaminanti ambientali sugli organismi sono stati valutati mediante i tradizionali saggi ecotossicologici e, parallelamente, applicando un nuovo saggio con l'ofiuride bioluminescente Amphipholis squamata, sia in esperimenti di trapianto in situ sia in condizioni controllate di laboratorio	Particellato sospeso, metalli	-	**, ***	MAV-CVN, Project SIOSED. Determinazione sperimentale degli effetti del riutilizzo dei più diffusi sedimenti della Laguna. REL-T025.0, Venice

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAGGIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFICO
MAPVE-1,2	• "INDAGINI E MONITORAGGI NELLE AREE LAGUNARI TRA VENEZIA E PORTO MARGHERA – 1° FASE (MAPVE-1)" • "DETERMINAZIONE DELLE CHARACTERISTICE DELLE MATRICI LAGUNARI NELLE AREE MAPVE 2 ED ULTERIORI APPROFONDIMENTI NELL'AREA MAPVE 1"	Magistrato alle Acque di Venezia-Consorzio Venezia Nuova, Istituto di Scienze Marine di Venezia (CNR-ISMAR), SELC	**MAPVE 1:** Caratterizzazione dello stato delle matrici ambientali (sedimento e biota) della zona compresa all'interno dei perimetri del Sito di Interesse Nazionale e dell'enclave vietato alla pesca posto a sud del Canale Vittorio Emanuele III, zona nel seguito indicata come "area MAPVE-1". Attività di monitoraggio per verificare gli effetti del prelievo della risorsa biologica (Tapes philippinarum) e l'efficacia dei sistemi di mitigazione adottati. **MAPVE 2:** Caratterizzazione ambientale dell'area MAPVE-2. Studi specialistici di carattere biologico/ecologico a supporto della progettazione nell'area MAPVE-1. L'area MAPVE-2 rappresenta la porzione di zona lagunare delimitata a sud dal canale Vittorio Emanuele III, ad est dalla darsena del Tronchetto, a nord dal canale di San Secondo (non compreso nell'area), ad ovest dalla macroisola dei petroli.	**MAPVE 1:** 2007; **MAPVE 2:** 2009	Caratterizzazione chimico-fisica e ecotossicologica dei sedimenti, Classificazione granulometrica dei sedimenti, Distribuzione spaziale della contaminazione nei bassifondi e nei canali, Profili verticali della contaminazione, Biomarkers e bioaccumulo negli organismi.	granulometria, densità e residuo a 105°C, pH ed Eh, nutrienti: N tot, P tot e TOC, Al, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, Fe, V, Co, Mn, metalli SEM, AVS, IPA totali, PCB totali, PCB dioxin like, PCDD/F, idrocarburi C > 12, sommatoria organostannici, POC e HCB.	**MAPVE 1:** Bassofondi: 0-25 cm, 25-50 cm, 50-75 cm; Canali: 100 cm, 200 cm. 268 carote (231 bassofondi e 37 canali). **MAPVE 2:** Bassifondi: 0-25 cm, 25-50 cm, 50-75 cm, 75-100 cm, 100-150 cm, 150-200 cm; Canali: 0-50 cm, 50-100 cm, 100-150 cm, 150-200 cm. 155 carote (120 bassofondi e 35 canali)	**MAPVE1:** Ecotossicologia: Sono stati utilizzati i seguenti saggi *Corophium orientale*, *Paracentrotus lividus*, *Mytilus galloprovincialis*, *Crassostrea gigas* (mortalità, spermiotossicità, embriotossicità). Sub-set di 80 campioni (14% del totale) prelevati nei bassifondi 0-25 cm e 50-75 cm e nei sedimenti superficiali dei canali (0-50 cm). Solo 2 campioni provenienti dai sedimenti 25-50 cm sono stati saggiati, entrambi provenienti da carote di 2 m. Bioaccumulo: *M. galloprovincialis* (Parti molli), *T. philippinarum* (Parti molli), *N. reticulatus* (Parti molli) 6 stazioni e 18 campioni per stazione e *Z. ophiocephalus*/*G. niger* (Filetto/Fegato) 3 stazioni e 9 campioni per stazione. Biomarkers: Z. ophiocephalus o Gobius niger, mitili. **MAPVE 2:** Ecotossicologia: sub-set di 53 campioni, pari al 14% del numero complessivo di campioni analizzati per la chimica. Inoltre, sono stati saggiati solamente campioni degli strati più superficiali (25 cm per i bassifondi e 50 cm per i canali). *Vibrio fischeri* su sedimento risospeso; mortalità a 10-gg con l'anfipode Corophium orientale; spermiotossicità con gameti dell'echinoide *Paracentrotus lividus*; embriotossicità con il bivalve *Mytilus galloprovincialis*; embriotossicità con il bivalve *Crassostrea gigas*. Bioaccumulo: tessuti molli di *M. galloprovincialis* in 9 stazioni, le parti molli do *T. philippinarum* in 46 stazioni.	-	-	*, ***	MAV-CVN, 2007, Project MAPVE. Indagini e monitoraggi nelle aree lagunari tra Venezia e Porto Marghera. 56554-REL-T007.0, Venice

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAGGIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFICO
HICSED	"INDIRIZZI PER LA FORMULAZIONE DI UN'ANALISI DI RISCHIO PER LA LAGUNA DI VENEZIA"	Magistrato alle Acque di Venezia-Consorzio Venezia Nuova.	• fornire indicazioni sulle metodologie analitiche e sui requisiti di qualità del dato chimico da adottare nell'ambito degli studi e misure sui sedimenti lagunari e nell'ambito di una possibile revisione del "Protocollo Fanghi del 1993"; • fornire una raccolta di informazioni sperimentali di tipo chimico ed ecotossicologico utili all'integrazione ed all'approfondimento delle conoscenze e valutazioni già disponibili sulla effettiva pericolosità della contaminazione dei sedimenti lagunari con l'utilizzo di criteri ecotossicologici; • impostare una "analisi di rischio" specifica per gli ecosistemi lagunari; • sperimentare tecniche di decontaminazione innovative per i sedimenti inquinati della Laguna di Venezia.	2008	Analisi chimiche ed ecotossicologiche	As, Cd, Cr, Cr (VI), Cu, Hg, Metil-Hg, Ni, Pb, Zn, V, Organostannici, IPA (Acenaftene, Antracene, Benzo(k)fluorantene, Benzo(b)fluorantene, Benzo(a)antracene, Benzo(a)pirene, Benzo(g,h,i)perilene, Crisene, Dibenzo(a,h)antracene, Fluorantene, Fluorene, Indeno(1,2,3cd)pirene, Naftalene, Fenantrene, Pirene), PCB, bassa risoluzione (28, 52, 101, 105, 118, 128, 138, 153, 156, Aldrin, Alfa esaclorocicloesano, Beta esaclorocicloesano, Gamma esaclorocicloesano, DDT, HCB, DDD, DDE, Dieldrin170,180, 209), PCDD/F, PCB "dioxin-like" (77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, 189)	Sono stati individuati 48 siti distribuiti in tutto il bacino lagunare, 0-15 cm (bassifondo e canali). L'attività di campionamento dei sedimenti è stata articolata in tre distinte campagne, ognuna delle quali ha previsto il prelievo dei campioni in 16 stazioni	48 campioni. • Diatomea marina (alga*) P. tricornutum* su fase liquida • Batterio *V. fischeri* su sedimento risospeso • Crostaceo anostraco A. franciscana su fase liquida • Crostaceo copepode *A. tonsa* su fase solida • Crostaceo arpacticoide *T. fulvus* su fase liquida • Crostaceo anfipode Corophium sp. su sedimento tal quale • Echinoide *P. lividus* su fase liquida • Bivalve *C. gigas* su fase liquida	-	-	***	MAV-CVN, 2011, Project HICSED. Indagini chimico-ecotossicologice. HICSED-REL-T005. 1, OP/409, Venice
QSEV	"QUALITÀ DEI SEDIMENTI DELLA LAGUNA DI VENEZIA"	Magistrato alle Acque di Venezia-Consorzio Venezia Nuova	• ottenere un quadro di riferimento aggiornato, più dettagliato rispetto al passato, sullo stato qualitativo dei sedimenti dei bassi fondali dell'intera laguna, con particolare riguardo ad alcuni settori dove il sistema appare più sensibile ad accumulare inquinanti; • evidenziare le variazioni della concentrazione degli inquinanti lungo il profilo verticale del sedimento e porle in relazione con le sorgenti ed i processi di trasporto e sedimentazione; • valutare le condizioni qualitative dei sedimenti lagunari, in riferimento alla normativa italiana e comunitaria, attraverso l'impiego di criteri empirici e/o statistici (SQGs) in uso nella comunità scientifica internazionale; • acquisire dati	Gennaio e Marzo 2008	Analisi della distribuzione dimensionale (granulometrie), concentrazione di metalli pesanti, materia organica e nutrienti, microinquinanti organici (IPA, PCB), analisi dei radionuclidi. Tutti i siti di prelievo appartengono ai bassi fondali lagunari Sviluppato dai precedenti progetti ICSEL e SIOSED	Al, As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn, naftalene, acenaftene, fluorene, fenantrene, antracene, fluorantene, pirene, benzo(a)antracene, crisene, benzo(b)fluorantene, benzo(k)fluorantene, benzo(a)pirene, dibenzo(a,h)antracene, benzo(g,h,i)perilene, PCB: congeneri 52, 101, 110, 118, 138, 153, 180, 137-Cs, 210-Pb, 7-Be, materia organica, carbonio totale e organico, azoto totale, fosforo totale.	380 siti bassi fondali. In ciascuno sito sono state prelevate 3 carote di lunghezza pari a 50 cm. Metalli 5 strati (0-5, 5-10, 10-20, 20-30, 30-50 cm), organici 2 strati (0-5, 5-10). 15 siti per l'indagine sui radionuclidi, una carota in totale, sono stati raccolti 315 campioni, carote di sedimento di lunghezza pari a 60 cm.	-	-	-	*, ***	MAV-CVN, 2011, Project QSEV. Qualità dei SEdimenti della laguna di Venezia. Indagine per l'aggiornamento e l'integrazione dei dati sulla qualità dei sedimenti lagunari. Rapporto Tecnico Finale, Venice

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAG GIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFIC O
			utili alle finalità gestionali e di controllo del MAV e di altri Enti									
MODUS	"MONITORAGGIO DEI CORPI IDRICI LAGUNARI A SUPPORTO DELLA LORO CLASSIFICAZIONE E GESTIONE (DIRETTIVA 2000/60/CE, DM 260/2010 E DIRETTIVA 2013/39/UE) - MODUS"	Magistrato alle Acque di Venezia-Consorzio Venezia Nuova	Prosecuzione del monitoraggio dello stato chimico dei corpi idrici lagunari e aggiornare la classificazione di stato chimico e di stato ecologico del Piano di Gestione. I Piani di Gestione, quali strumento di governo di tutti gli aspetti legati alla tutela dei corpi idrici, vanno aggiornati ogni 6 anni.	Continuamente dal 2011	Monitoraggio annuale delle sostanze prioritarie di acque, sedimenti (sedimenti superficiali, elutriato) e biota (ecotossicologia, bioaccumulo). 30 siti selezionati per il monitoraggio del 2016 costituiscono un sottoinsieme dei 36 siti monitorati nel 2012 che a loro volta costituiscono un sottoinsieme di stazioni comune a tutto il periodo di monitoraggio (2011-2015). Di questi 36 siti, sono state mantenuti le 19 stazioni appartenenti alla rete di monitoraggio delle acque, 5 stazioni aggiuntive alle 19 per l'esecuzione dei saggi nel 2015, tutte le stazioni sulle quali sono state eseguite le determinazioni di diossine, furani e PCB.	Sedimenti: Tabelle 2/A (14 sostanze), 2/B (8 sostanze), 3/B (4 sostanze) del D. Lgs 172/2015 + argento, rame, zinco, trifenilstagno, IPA totali e nichel, mobilità dei metalli nel sedimento: SEM/AVS; Elutriato: metalli totali, azoto ammoniacale e solfuri. Caratterizzazione granulometrica dei sedimenti (primi 5 cm superficiali). Ecotoss: mortalità a 10 gg con anfipodi della specie Corophium su sedimento, inibizione della bioluminescenza naturale di Vibrio fischeri su elutriato, sviluppo embrionale con il bivalve Crassostrea gigas su elutriato, crescita algale con la cloroficea unicellulare Dunaliella tertiolecta su elutriato. Bioacc: : benzo(a)pirene, DDT tot, difeniletere bromato, esaclorobenzene, esaclorobutadiene, fluorantene e mercurio (2015).	Primi 5 cm	Il monitoraggio annuale dei sedimenti (sedimento ed elutriato) attraverso la caratterizzazione chimica e l'effettuazione di saggi ecotossicologici Corophium, Vibrio fischeri, Crassostrea gigas, Dunaliella tertiolecta. Valutazione annuale dei livelli di bioaccumulo, considerando campioni di organismi di diversa tipologia (molluschi bivalvi e fauna ittica).	Determinazioni sui 30 campioni di elutriato estratti dai sedimenti di monitoraggio (2013-2015). Mentre le aque interstiziale (2011-12). Elutriati (Elutriati ed acque interstiziali possono differire anche significativamente nella loro composizione chimica).	-	***	MAV-CVN, 2018, Project MODUS. Monitoraggio dei corpi idrici lagunari a supporto della loro classificazione e gestione (Direttiva 2000/60/CE, DM 260/2010 e Direttiva 2013/39/UE) – MODUS 4° stralcio (2016-2017). 26122-REL-T025.0
TRESSE	"STATO AMBIENTALE DELLA LAGUNA DI VENEZIA ED ELEMENTI PER LA PIANIFICAZIONE SOSTENIBILE DELLE ATTIVITÀ PORTUALI"	Dipartimento di Scienze Ambientali, Informatica e Statistica Università Ca' Foscari Venezia	Caratterizzare nel dettaglio lo scenario ante-operam, ovvero lo scenario ambientale di riferimento nell'area potenzialmente interessata dall'escavo del nuovo canale secondo il tracciato Tresse Est/Tresse Nuovo.	2015 - 2016	L'indagine ambientale dell'area interessata dall'escavo del canale Tresse Nuovo è stata suddivisa in due componenti. La prima riguarda la valutazione dello stato chimico, eco-tossicologico, mineralogico ed ecologico di 4 stazioni localizzate in prossimità dell'inizio e della parte centrale del tracciato del nuovo canale, posizionandosi sia a nord che a sud del suddetto tracciato e ha incluso il	Sono state valutate la concentrazione totale di elementi in tracce e la concentrazione di diverse classi di inquinanti organici in campioni di sedimento e materiale particolato, campionati in corrispondenza di quattro trappole localizzate in prossimità del Canale "Tresse Est". In riferimento allo studio eco-biologico condotto dal prof. Pranovi (DAIS), campioni di	L'attività riguarda la caratterizzazione sedimentologica e mineralogica di 4 campioni di sedimento superficiali. Per ogni stazione è stato preparato un campione integrato costituito da 8				**; ***	STATO AMBIENTALE DELLA LAGUNA DI VENEZIA ED ELEMENTI PER LA PIANIFICAZIONE SOSTENIBILE DELLE ATTIVITÀ PORTUALI

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAGGIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFICO
					campionamento del sedimento superficiale, del particolato sospeso/risospeso (tramite trappole di sedimentazione) e del biota per approfondire le conoscenze sui processi chimici, fisici ed ecologici in atto nell'area. La seconda componente di indagine ha riguardato la caratterizzazione di 8 carote di sedimento (profondità 10 m) prelevate lungo il percorso del nuovo canale per quanto riguarda gli aspetti sedimentologici e mineralogici, chimici (inquinamento da contaminanti organici e inorganici in sedimento, acque interstiziali e nella colonna d'acqua soprastante) ed eco-tossicologici. L'obiettivo dell'analisi è stato la caratterizzazione dei sedimenti da movimentare per stabilire la loro classificazione secondo la normativa vigente, che ne determina la possibile destinazione d'uso dopo l'escavo.	biota, molluschi della specie Venerupis philippinarum (conosciuta anche come Tapes philippinarum), prelevati in siti limitrofi ai siti di campionamento delle carote profonde, sono stati analizzati per la valutazione della concentrazione totale di elementi in tracce e della concentrazione di contaminanti organici. Sono state monitorate anche le concentrazioni di alcuni contaminanti organici persistenti, come i policlorobifenili (PCB), gli idrocarburi policiclici aromatici (IPA), i pesticidi, le policlorodibenzo-p-diossine (PCDD) e i policlorodibenzofurani (PCDF). oltre alla concentrazione totale, per gli inquinanti organici sono state valutate le concentrazioni dei singoli congeneri, in particolare quelli ritenuti cancerogeni. Tutti i dati ottenuti dalle analisi del particolato, del sedimento risospeso (trappole) e del biota, sono stati attentamente elaborati e validati secondo i principi scientifici di validazione del dato.	carote della profondità 20 cm. Si evidenzia che manca totalmente la sabbia grossa, mentre la sabbia molto fine è la frazione prevalente tra le sabbie (media: 14 %), seguita dalla sabbia fine (13%). Tra le frazioni del silt quella prevalente è il silt medio (media: 19%), a seguire silt grosso (16%) e silt fine (16%). I risultati granulometrici del particolato sospeso: le frazioni sabbiose sono presenti in percentuali molto basse, la sabbia molto fine è la frazione prevalente tra le sabbie e si registra la percentuale più elevata nel sito AS_2 (media: 9%). Tra le frazioni del silt, il silt medio e il silt fine sono i più abbondanti e presentano la stessa percentuale nel sito AN_1 (media silt medio: 23%; media silt fine: 22%) e in TS_4 (media silt medio: 21%; media silt fine: 21%) Mentre nel sito AS_2 prevale il silt medio (media:					Presentazione dei risultati finali prodotti dal dipartimento DAIS all'interno della convenzione APV-CORILA - Dipartimento di Scienze Ambientali, Informatica e Statistica Università Ca' Foscari Venezia. 2015-2016

PROGETTO	TITOLO	COMPETENZA	OBIETTIVI	TEMPISTICA	ATTIVITA' MONITORAGGIO / RICERCA	PARAMETRI E PROCESSI BIO-FISICO-CHIMICI	SEDIMENTI	BIOTA	ACQUA	SALUTE UMANA	PER OBIETTIVI LINEA DI	RIFERIMENTO BIBLIOGRAFICO
							22%) e nel sito TN_3 è più elevato il valore medio del silt fine (21%). Le analisi mineralogiche sono state condotte sui 4 campioni di sedimento superficiale e i 12 campioni di particolato sospeso, allo scopo di individuare la composizione e l'origine geologica di tali sedimenti. I dati confermano che l'area studiata è particolarmente ricca di minerali silicatici rispetto a quelli carbonatici, infatti, quest'area della Laguna è stata interessata nel tempo dall'accumulo dei sedimenti trasportati dal fiume Brenta drenante aree prevalentemente a carattere igneo. Mentre non è particolarmente interessata dall'apporto di carbonati.					

TABLE A-2. Papers published in peer-reviewed journals dealing with ecotoxicology in Venice lagoon using different analytical tools.

Reference	**Title**	**Tools**
Nasci and Fossato, 1982	Studies on physiology of mussels and their ability in accumulating hydrocarbons and chlorinated hydrocarbons	Biomarker
Nasci et al., 1989	Hydrocarbon content and microsomal BPH and reductase activity in mussel, *Mytilus* sp., from the Venice area, north–east Italy	Biomarker
Sfriso et al., 1994	Gracilaria distribution, production and composition in the Lagoon of Venice	Bioaccumulation
Livingstone et al., 1995	Assessment of the impact of organic pollutants on goby (*Zosterisessor ophiocephalus*) and mussel (*Mytilus galloprovincialis*) from the Venice Lagoon, Italy: Biochemical studies	Biomarker
Lowe et al., 1995	Contaminant-induced lysosomal membrane damage in blood cells of mussels *Mytilus galloprovincialis* from the Venice Lagoon: an in vitro study	Biomarker
Sfriso et al., 1995	Heavy metals in sediments, SPM and phytozoobenthos of the lagoon of Venice	Bioaccumulation
Wootton et al., 1995	Evidence for the existence of cytochrome P450 gene families (CYP1A, 3A, 4A, 11A) and modulation of gene expression (CYP1A) in the mussel *Mytilus* spp	Biomarker
Favero et al., 1996	Metal accumulation in a biological indicator (*Ulva rigida*) from the lagoon of Venice (Italy).	Bioaccumulation
Venier et al., 1996	DNA adducts in *Mytilus galloprovincialis* and *Zosterisessor ophiocephalus* collected form pac-polluted and reference sites of the Venice lagoon	Biomarker
Widdows et al., 1997	Effects of pollution on the scope for growth of mussels (*Mytilus galloprovincialis*) from the Venice Lagoon, Italy	Biomarker, Bioaccumulation
Di Domenico et al., 1998	Priority microcontaminants in biota samples from the Venice lagoon: a selection of concentration data and elements of risk analysis	Bioaccumulation
Fossi et al., 1998	Mixed function oxidase induction in *Carcinus aestuarii*: field and experimental studies for the evaluation of toxicological risk due to Mediterranean contaminants	Biomarker
Jimenez et al., 1998	Congener Specific Analysis of Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans in Crabs and Sediments from the Venice and Orbetello Lagoons, Italy	Bioaccumulation
Nasci et al., 1998	Assessment of the impact of chemical pollutants on mussel, *Mytilus galloprovincialis*, from the Venice Lagoon, Italy	Biomarker, Bioaccumulation
Salizzato et al., 1998	Sensitivity limits and EC50 values of the *Vibrio fischeri* test for organic micropollutants in natural and spiked extracts from sediments	Ecotoxicological bioassays
Volpi Ghirardini et al., 1998	Microtox® solid-phase bioassay in sediment toxicity assessment	Ecotoxicological bioassays
Volpi Ghirardini et al., 1999	An integrated approach to sediment quality assessment: the Venetian lagoon as a case study	Ecotoxicological bioassays
Volpi Ghirardini et al., 1999	*H. diversicolor*, *N. succinea* and *P. cultrifera* (Polychaeta: Nereididae) as bioaccumulators of cadmium and zinc from sediments: preliminary results in the Venetian lagoon (Italy)	Bioaccumulation
Bona et al., 2000	An integrated approach to assess the benthic quality after sediment capping in Venice lagoon	Ecotoxicological bioassays

Reference	Title	Tools
Da Ros, et al., 2000	Biomarkers and Trace Metals in the Digestive Gland of Indigenous and Transplanted Mussels, *Mytilus galloprovincialis*, in Venice Lagoon, Italy	Biomarker
Nasci et al., 2000	Biochemical and histochemical responses to environmental contaminants in clam, *Tapes philippinarum*, transplanted to different polluted areas of Venice Lagoon, Italy	Biomarker, Bioaccumulation
Solé et al., 2000	Study of the biological impact of organic contaminants on mussels (*Mytilus galloprovincialis* L.) from the Venice Lagoon, Italy: responses of CYP1A-immunopositive protein and benzo(a)pyrene hydroxylase activity	Biomarker, Bioaccumulation
Marin et al., 2001	Sediment elutriate toxicity testing with embryos of sea urchin (*Paracentrotus lividus*)	Ecotoxicological bioassays
Viganò et al., 2001	Biomarkers of exposure and effect in flounder (*Platichthys flesus*) exposed to sediments of the Adriatic Sea	Biomarker
Caliceti et al., 2002	Heavy metal contamination in the seaweeds of the Venice lagoon	Bioaccumulation
Da Ros et al., 2002	Field application of lysosomal destabilisation indices in the mussel *Mytilus galloprovincialis*: biomonitoring and transplantation in the Lagoon of Venice (north–east Italy)	Biomarker
Dolcetti Venier P., 2002	Susceptibility to genetic damage and cell types in Mediterranean mussels	Biomarker
Franco et al., 2002	Ethoxyresorufin *O*-deethylase (EROD) activity and fluctuating asymmetry (FA) in *Zosterisessor ophiocephalus* (Teleostei, Gobiidae) as indicators of environmental stress in the Venice lagoon	Biomarker
Nasci et al., 2002	Field application of biochemical markers and a physiological index in the mussel, *Mytilus galloprovincialis*: transplantation and biomonitoring studies in the lagoon of Venice (NE Italy)	Biomarker
Bortoli et al., 2003	Butyltins and phenyltins in biota and sediments from the Lagoon of Venice	Bioaccumulation
Jia et al., 2003	210Pb and 210Po concentrations in the Venice lagoon ecosystem (Italy) and the potential radiological impact to the local public and environment	Bioaccumulation
Matozzo et al., 2003	Evaluation of 4-nonylphenol toxicity in the clam *Tapes philippinarum*	Ecotoxicological bioassays, Biomarker
Mauri and Baraldi, 2003	Heavy metal bioaccumulation in *Mytilus galloprovincialis*: A transplantation experiment in Venice Lagoon	Bioaccumulation
Arizzi Novelliet al., 2003	Toxicity of heavy metals using sperm cell and embryo toxicity bioassays with *Paracentrotus lividus* (echinodermata: Echinoidea): Comparisons with exposure concentrations in the Lagoon of Venice, Italy	Ecotoxicological bioassays
Pavoni et al., 2003	Organic micropollutants (PAHs, PCBs, pesticides) in seaweeds of the lagoon of Venice	Bioaccumulation
Venier et al., 2003	Characterisation of coastal sites by applying genetic and genotoxicity markers in *Mytilus galloprovincialis* and *Tapes philippinarum*.	Biomarker
Volpi Ghirardini et al., 2003	Sea urchin toxicity bioassays for sediment quality assessment in the Lagoon of Venice (Italy)	Ecotoxicological bioassays

Reference	Title	Tools
Camus et al.,2004	Total oxyradical scavenging capacity responses in *Mytilus galloprovincialis* transplanted into the Venice lagoon (Italy) to measure the biological impact of anthropogenic activities	Biomarker
Losso et al., 2004	Sulfide as a confounding factor in toxicity tests with the sea urchin *Paracentrotus lividus*	Ecotoxicological bioassays
Losso et al., 2004	Evaluation of surficial sediment toxicity and sediment physico-chemical characteristics of representative sites in the Lagoon of Venice (Italy)	Ecotoxicological bioassays
Nesto et al., 2004	Spatial and temporal variation of biomarkers in mussels (*Mytilus galloprovincialis*) from the Lagoon of Venice, Italy	Biomarker
Pellizzato et al., 2004	Concentrations of organotin compounds and imposex in the gastropod *Hexaplex trunculus* from the Lagoon of Venice	Biomarker, Bioaccumulation
Wetzel and Van Vleet, 2004	Accumulation and distribution of petroleum hydrocarbons found in mussels (*Mytilus galloprovincialis*) in the canals of Venice, Italy	Bioaccumulation
Argese et al., 2005	Distribution of arsenic compounds in *Mytilus galloprovincialis* of the Venice lagoon (Italy)	Bioaccumulation
Frangipane et al., 2005	Heavy metals in *Hediste diversicolor* (polychaeta: Nereididae) and salt marsh sediments from the lagoon of Venice (Italy)	Bioaccumulation
Matozzo et al., 2005	Acetylcholinesterase as a biomarker of exposure to neurotoxic compounds in the clam *Tapes philippinarum* from the Lagoon of Venice	Biomarker
Nesto and Da Ros, 2005	Cellular alterations in *Mytilus galloprovincialis* (LMK) and *Tapes philippinarum* (Adams and Reeve, 1850) as biomarkers of environmental stress: field studies in the Lagoon of Venice (Italy)	Biomarker
Pampanin et al., 2005	Susceptibility to oxidative stress of mussels (*Mytilus galloprovincialis*) in the Venice Lagoon (Italy)	Biomarker
Pampanin et al., 2005	Physiological measurements from native and transplanted mussel (*Mytilus galloprovincialis*) in the canals of Venice. Survival in air and condition index	Biomarker
Pampanin et al., 2005	Stress biomarkers and alkali-labile phosphate level in mussels (*Mytilus galloprovincialis*) collected in the urban area of Venice (Venice Lagoon, Italy)	Biomarker
Santovito et al., 2005	Antioxidant responses of the Mediterranean mussel, *Mytilus galloprovincialis*, to environmental variability of dissolved oxygen	Biomarker
Venier et al., 2005	Evidence of genetic damage in grass gobies and mussels from the Venice lagoon	Biomarker
Volpi Ghirardini et al., 2005	Sediment toxicity assessment in the Lagoon of Venice (Italy) using *Paracentrotus lividus* (Echinodermata: Echinoidea) fertilization and embryo bioassays	Ecotoxicological bioassays
Volpi Ghirardini et al., 2005	*Mytilus galloprovincialis* as bioindicator in embryotoxicity testing to evaluate sediment quality in the lagoon of Venice (Italy)	Ecotoxicological bioassays
Arizzi Novelli et al., 2006	Is the 1:4 elutriation ratio reliable? Ecotoxicological comparison of four different sediment:water proportions	Ecotoxicological bioassays
Bragato et al., 2006	Accumulation of nutrients and heavy metals in *Phragmites australis* (Cav.) Trin. ex Steudel and *Bolboschoenus maritimus* (L.) Palla in a constructed wetland of the Venice lagoon watershed	Bioaccumulation

Reference	Title	Tools
Garaventa et al., 2006	Imposex in *Hexaplex trunculus* at Some Sites on the North Mediterranean Coast as a Base-Line for Future Evaluation of the Effectiveness of the Total Ban on Organotin based Antifouling Paints	Biomarker
Maran et al., 2006	Organochlorine compounds (polychlorinated biphenyls and pesticides) and polycyclic aromatic hydrocarbons in populations of *Hexaplex trunculus* affected by imposex in the Lagoon of Venice, Italy	Biomarker, Bioaccumulation
Marin et al., 2006	Field validation of autometallographical black silver deposit (BSD) extent in three bivalve species from the Lagoon of Venice, Italy (*Mytilus galloprovincialis, Tapes philippinarum, Scapharca inaequivalvis*) for metal bioavailability assessment	Biomarker
Venier et al., 2006	Development of mussel mRNA profiling: Can gene expression trends reveal coastal water pollution?	Transcriptomics
Boscolo et al., 2007	Polychlorinated biphenyls in clams *Tapes philippinarum* cultured in the Venice Lagoon (Italy): Contamination levels and dietary exposure assessment	Bioaccumulation
Boscolo et al., 2007	Polycyclic aromatic hydrocarbons (PAHs) in transplanted Manila clams (*Tapes philippinarum*) from the Lagoon of Venice as assessed by PAHs/shell weight index: A preliminary study	Bioaccumulation
Canesi et al., 2007	Immunomodulation of *Mytilus* hemocytes by individual estrogenic chemicals and environmentally relevant mixtures of estrogens: In vitro and in vivo studies	Biomarker
Garaventa et al., 2007	Imposex and accumulation of organotin compounds in populations of *Hexaplex trunculus* (Gastropoda, Muricidae) from the Lagoon of Venice (Italy) and Istrian Coast (Croatia)	Biomarker, Bioaccumulation
Losso et al., 2007	Potential role of sulfide and ammonia as confounding factors in elutriate toxicity bioassays with early life stages of sea urchins and bivalves	Ecotoxicological bioassays
Losso et al., 2007	Developing toxicity scores for embryotoxicity tests on elutriates with the sea urchin *Paracentrotus lividus*, the oyster *Crassostrea gigas*, and the mussel *Mytilus galloprovincialis*	Ecotoxicological bioassays
Matozzo and Marin, 2007	First evidence of altered vitellogenin-like protein levels in clam *Tapes philippinarum* and in cockle *Cerastoderma glaucum* from the Lagoon of Venice	Biomarker
Monteduro et al., 2007	Contamination in *Mytilus galloprovincialis* by chlorinated hydrocarbons (PCBs and pesticides), PAHs and heavy metals in the lagoon of Venice.	Bioaccumulation
Nesto et al., 2007	Bioaccumulation and biomarker responses of trace metals and micro-organic pollutants in mussels and fish from the Lagoon of Venice, Italy	Biomarker, Bioaccumulation
Pavoni et al., 2007	Imposex levels and concentrations of organotin compounds (TBT and its metabolites) in *Nassarius nitidus* from the Lagoon of Venice	Biomarker, Bioaccumulation
Libralato et al., 2008	Ecotoxicological evaluation of industrial port of Venice (Italy) sediment samples after a decontamination treatment	Ecotoxicological bioassays
Picone et al., 2008	Evaluation of *Corophium orientale* as bioindicator for Venice Lagoon: Sensitivity assessment and toxicity-score proposal	Ecotoxicological bioassays
Raccanelli et al.,2008	On the detoxification of benthic bivalves contaminated by POPs: Insights from experimental and modelling approaches	Bioaccumulation
Sfriso et al., 2008	*Tapes philippinarum* seed exposure to metals in polluted areas of the Venice lagoon	Bioaccumulation

Reference	**Title**	**Tools**
Venier et al., 2008	DNA Adducts in *Mytilus Galloprovincialis* and *Zosterisessor Ophiocephalus* Collected from PAC-Polluted and Reference Sites of the Venice Lagoon	Biomarker
Losso et al., 2009	Porewater as a matrix in toxicity bioassays with sea urchins and bivalves: Evaluation of applicability to the Venice lagoon (Italy)	Ecotoxicological bioassays
Picone et al., 2009	Sequential toxicity identification evaluation (TIE) for characterizing toxicity of Venice Lagoon sediments: Comparison of two different approaches	Ecotoxicological bioassays
Zanon et al.,2009	Time trend of Butyl- and Phenyl-Tin contamination in organisms of the Lagoon of Venice (1999-2003)	Bioaccumulation
Losso and Volpi-Ghirardini, 2010	Overview of ecotoxicological studies performed in the Venice Lagoon (Italy)	Ecotoxicological bioassays
Losso et al., 2010	Integration of biological responses from a suite of bioassays for the Venice Lagoon (Italy) through sediment toxicity index - Part A: Development and comparison of two methodological approaches	Ecotoxicological bioassays
Matozzo et al., 2010	Biomarker responses and contamination levels in the clam *Ruditapes philippinarum* for biomonitoring the Lagoon of Venice (Italy)	Biomarker, Bioaccumulation
Moschino et al., 2010	Use of biomarkers to assess the welfare of the edible clam, *Ruditapes philippinarum*: may it be a tool for proving areas of origin?	Biomarker
Ricciardi et al., 2010	Biomarker responses and contamination levels in crabs (*Carcinus aestuarii*) from the Lagoon of Venice: An integrated approach in biomonitoring estuarine environments	Biomarker, Bioaccumulation
Han et al., 2011	Mercury concentration and monomethylmercury production in sediment: Effect of dredged sediment reuse on bioconcentration for ragworms	Bioaccumulation
Milan et al., 2011	Transcriptome sequencing and microarray development for the Manila clam, *Ruditapes philippinarum*: Genomic tools for environmental monitoring	Transcriptomics
Moschino et al., 2011	Biomonitoring approach with mussel *Mytilus galloprovincialis* (Lmk) and clam *Ruditapes philippinarum* (Adams and Reeve, 1850) in the Lagoon of Venice	Biomarker, Bioaccumulation
Moschino et al., 2011	Long-Term Effects of Fishing on Physiological Performance of the Manila Clam (*Ruditapes philippinarum*) in the Lagoon of Venice	Biomarker
Pascoli et al., 2011	Evaluation of oxidative stress biomarkers in *Zosterisessor ophiocephalus* from the Venice Lagoon, Italy	Biomarker
Benedetti et al., 2012	A multidisciplinary weight of evidence approach for classifying polluted sediments: Integrating sediment chemistry, bioavailability, biomarkers responses and bioassays	Biomarker, Bioaccumulation, Ecotoxicological bioassays
Berto et al., 2012	Tin free antifouling paints as potential contamination source of metals in sediments and gastropods of the southern Venice lagoon	Bioaccumulation
Matozzo Vet al., 2012	Biomarker responses in the clam Ruditapes philippinarum and contamination levels in sediments from seaward and landward sites in the Lagoon of Venice	Biomarker
Moschino et al., 2012	Assessing the significance of *Ruditapes philippinarum* as a sentinel for sediment pollution: bioaccumulation and biomarker responses	Biomarker

Reference	**Title**	**Tools**
Schiavon M et al., 2012	Accumulation of selenium in *Ulva* sp. and effects on morphology, ultrastructure and antioxidant enzymes and metabolites	Bioaccumulation
Gomiero et al., 2013	The use of protozoa in ecotoxicology: Application of multiple endpoint tests of the ciliate *E. crassus* for the evaluation of sediment quality in coastal marine ecosystems	Ecotoxicological bioassays
Milan et al.,2013	Exploring the effects of seasonality and chemical pollution on the hepatopancreas transcriptome of the Manila clam	Transcriptomics
Boscolo et al., 2014	Histopathology and stress biomarkers in the clam *Venerupis philippinarum* from the Venice Lagoon (Italy)	Biomarker
Dominik et al., 2014	Mercury in the food chain of the Lagoon of Venice, Italy	Bioaccumulation
Sfriso et al., 2014	PCDD/F and dioxin-like PCB bioaccumulation by Manila clam from polluted areas of Venice lagoon (Italy)	Bioaccumulation
Castellani et al., 2015	Monitoring programme for the chemical status of Venice Lagoon according to the European water framework directive (2000/60/CE)	Bioaccumulation
Milan et al., 2015	Transcriptomic resources for environmental risk assessment: A case study in the Venice lagoon	Transcriptomics
Matozzo et al., 2016	Does the antibiotic amoxicillin affect haemocyte parameters in non-target aquatic invertebrates? The clam *Ruditapes philippinarum* and the mussel *Mytilus galloprovincialis* as model organisms	Biomarker
Picone et al., 2016	Assessment of sediment toxicity in the Lagoon of Venice (Italy) using a multi-species set of bioassays	Ecotoxicological bioassays
Ademollo et al., 2017	Clam bioaccumulation of Alkylphenols and Polyciclic aromatic hydrocarbons in the Venice lagoon under different pressures	Bioaccumulation
Cacciatore et al., 2018	Imposex levels and butyltin compounds (BTs) in *Hexaplex trunculus* (Linnaeus, 1758) from the northern Adriatic Sea (Italy): Ecological risk assessment before and after the ban	Biomarker
Cacciatore et al., 2018	Imposex in *Nassarius nitidus* (Jeffreys, 1867) as a possible investigative tool to monitor butyltin contamination according to the Water Framework Directive: A case study in the Venice Lagoon (Italy)	Biomarker
Milan et al., 2018	Microbiota and environmental stress: how pollution affects microbial communities in Manila clams	Transcriptomics
Picone et al., 2018	Testing lagoonal sediments with early life stages of the copepod *Acartia tonsa* (Dana): An approach to assess sediment toxicity in the Venice Lagoon	Ecotoxicological bioassays
Picone et al., 2018	Assessment of whole-sediment chronic toxicity using sub-lethal endpoints with *Monocorophium insidiosum*	Ecotoxicological bioassays
Sfriso et al., 2018	Spatial distribution, bioaccumulation profiles and risk for consumption of edible bivalves: a comparison among razor clam, Manila clam and cockles in the Venice Lagoon	Bioaccumulation
Pauletto et al., 2019	Significance of the goby *Zosterisessor ophiocephalus* as a sentinel species for Venice Lagoon contamination: Combining biomarker responses and bioaccumulation	Biomarker, Bioaccumulation