The WoE approach applied to the sediments characterization to the lagoon environment: the Venice Lagoon case

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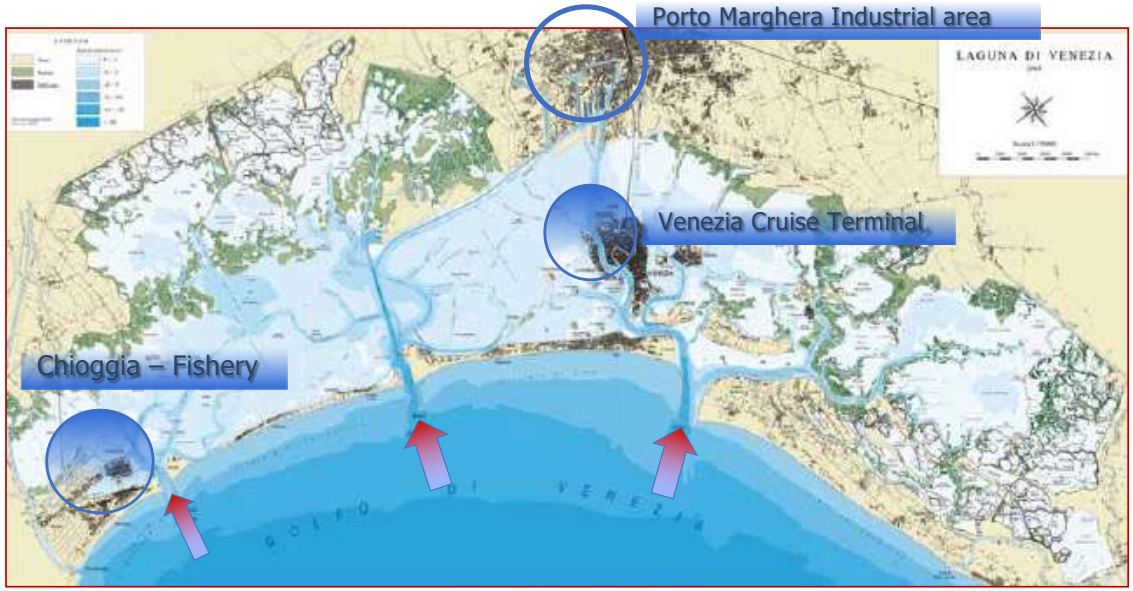
Summary

- The lagoon of Venice. Natural and anthrpogenic pressures
- The morphological degradation and the loss of sediments
- The management of sediment in the last decades. The 1993 protocol.
- The new regulaton and the WoE approach. The 22nd May 2023 Ministry Decree
- Further perspectives

The Venice lagoon 550 sq km. The largest brackish water body in the Mediterranean

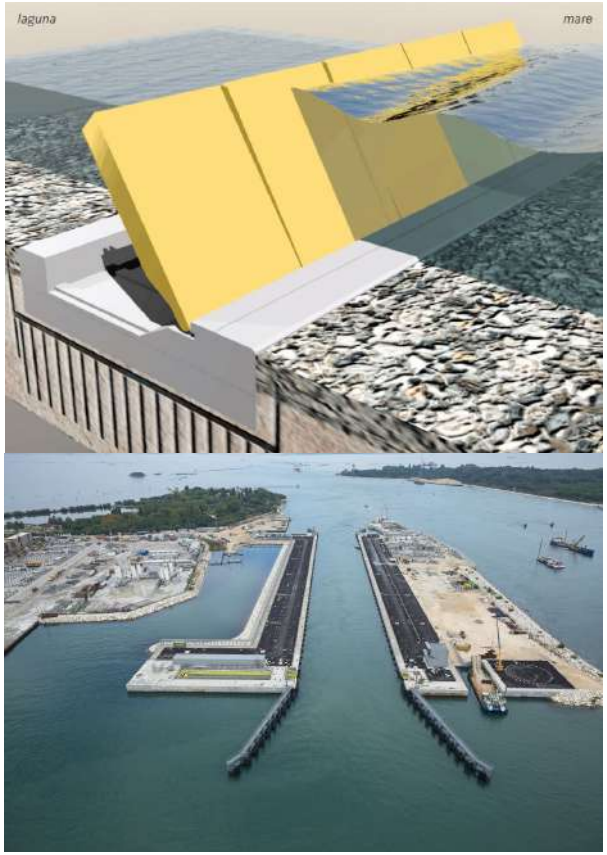
- Small islands, extensive tidal flats, salt marshes, fish farms and a complex tidal channels network;
- high heterogeneity in physical and biochemical habitat conditions
- 3 mt the averege water depth
- Semidiurnal astronimic tidal regime (1 mt max amplitude)
- 20 spring rivers discharge into the lagoon
- Watershed 2000 sq km



Port facilities

Fishery, Cruise terminal, Industrial area

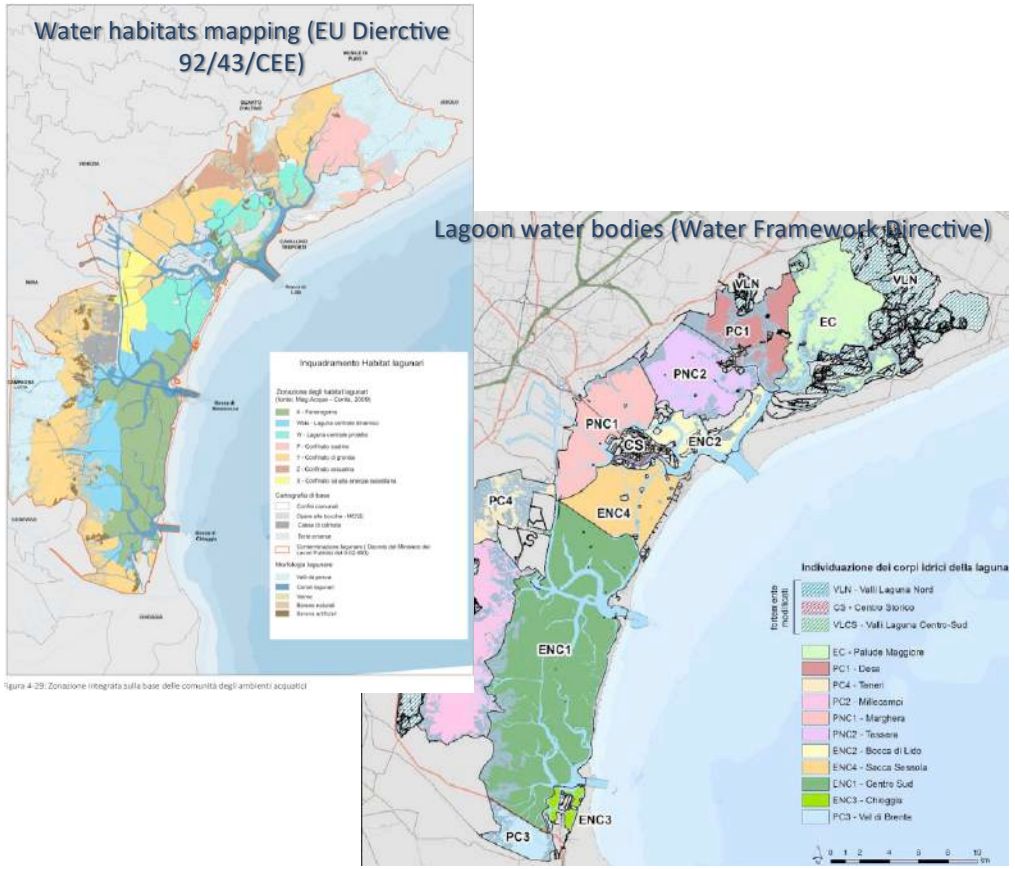
Coping with marine floods – The Mo.S.E. system



The lagoon of Venice. Natural and anthrpogenic pressures

Extreme weather conditions are included among the sources of a widespreaad alteration of the morphological status of the lagoon.

- Strong local winds blowing on water surface induce the surge of a remarkable wave motion (H_{wmax} = 2 mt into the lagoon)
- Wind waves are a the basis of relevant sediment suspension from the shallow water bottoms (tidal flats) and at the basis of the erosion of the salt marshes edges
- 600.000 m^3/y average estimation of total amount of eroded sediments
- Effects on the lagoon habitat status and on the water bodies ecological status



Source: Provveditorato OO.PP. Per il Veneto, Trentino Alto Adige, Friuli Venezia-Giulia. *Aggiornamento del piano per il recupero morfologico della laguna di Venezia*. Documento di Piano. Marzo 2021

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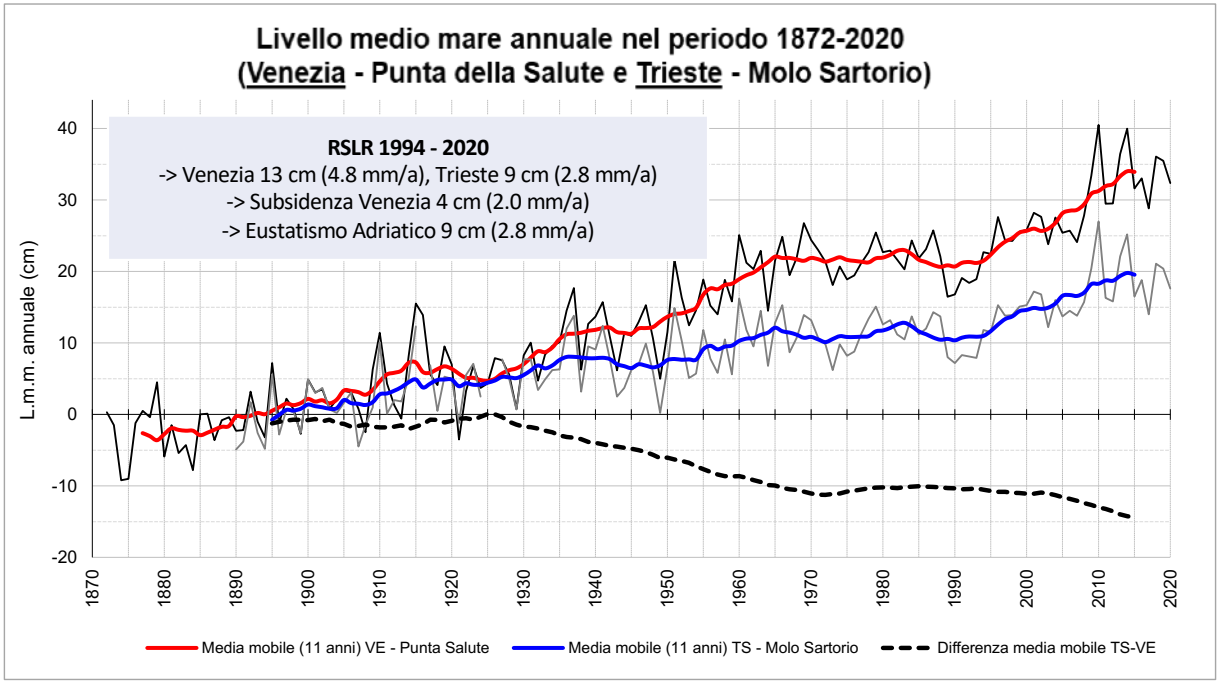
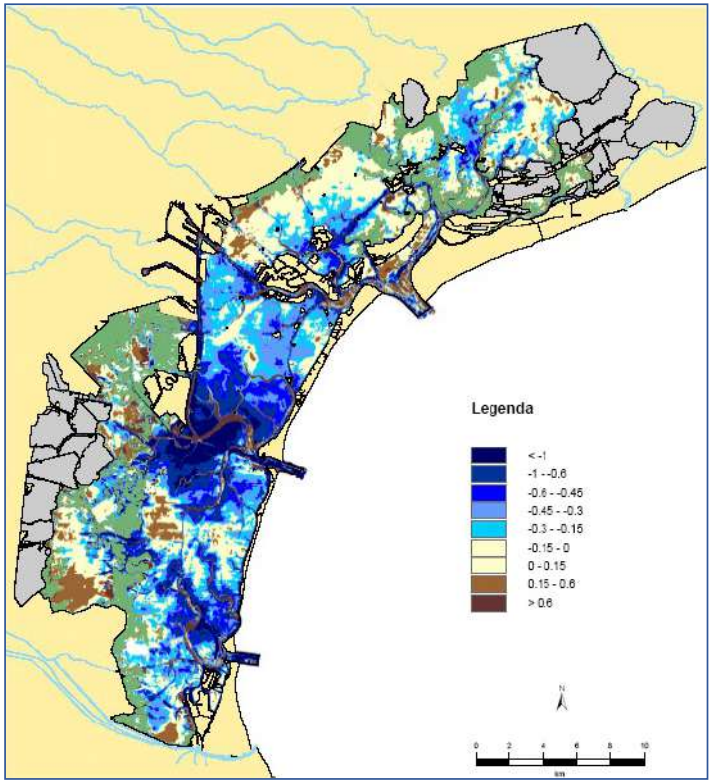
General sinking of shallow waters and Relative Sea Level Rise

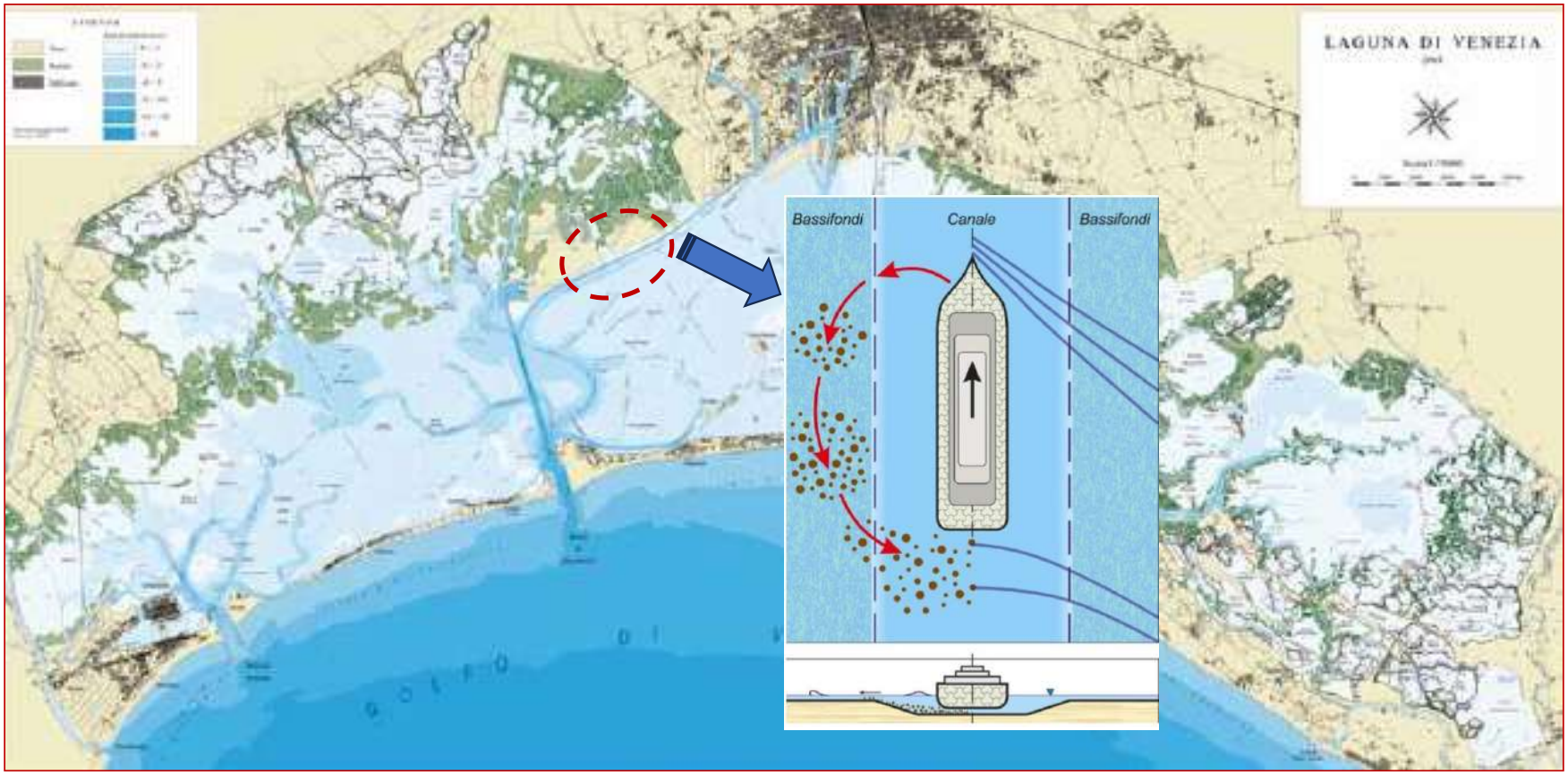




- Widespread erosion. Very strong at the center of the lagoon
- The loss of trasitional environmental features
- The lagoon seams becoming a bay

Source: Provveditorato OO.PP. Per il Veneto, Trentino Alto Adige, Friuli Venezia-Giulia. *Aggiornamento del piano per il recupero morfologico della laguna di Venezia*. Documento di Piano. Marzo 2021

The lagoon of Venice. Natural and anthrpogenic pressures



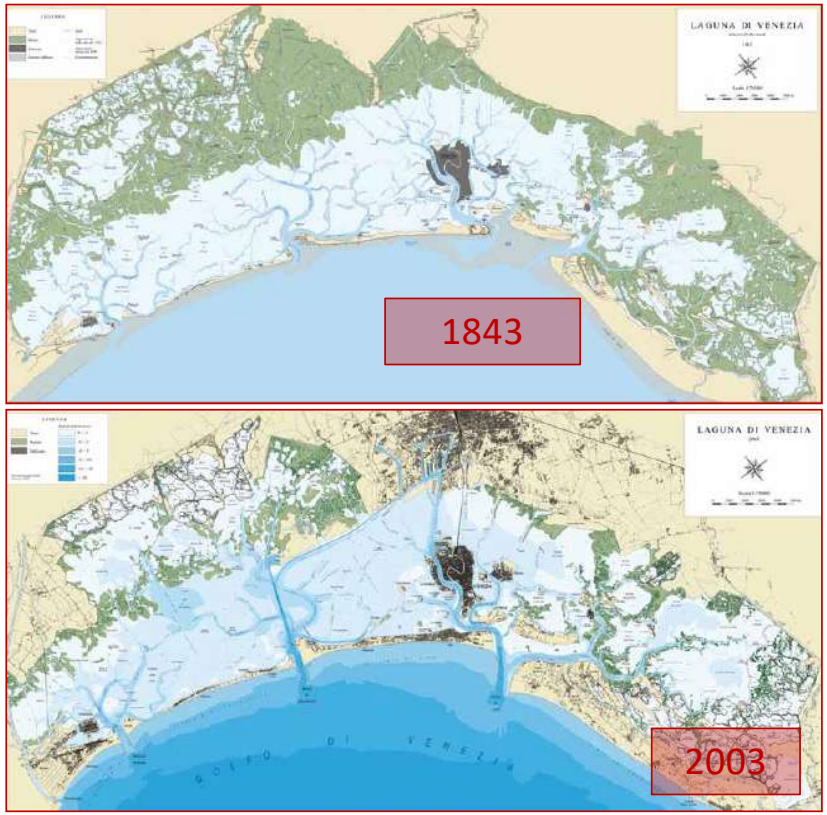
The morphological decay and the loss of sediments

Extreme events, RSLR and poor load of sediment from watershed at the basis of the morphological decay

- 1,4 x 10^6 cbm/y the amount of sediments for keeping the current lagoon morphological status according to the latest RSLR rate (4.8 mm/y)
- 8,0 x 10^6 cbm/y the amount of sediments requested to mantain the current lagoon morphological status according the worst IPCC Scenario (RPC 8.5)

Critical issues

- Availiability of large amounts of sediments
- Qualitative and phisical compatibility
- Environmental issues and cost-effectivness in the operations of displacement inside the lagoon



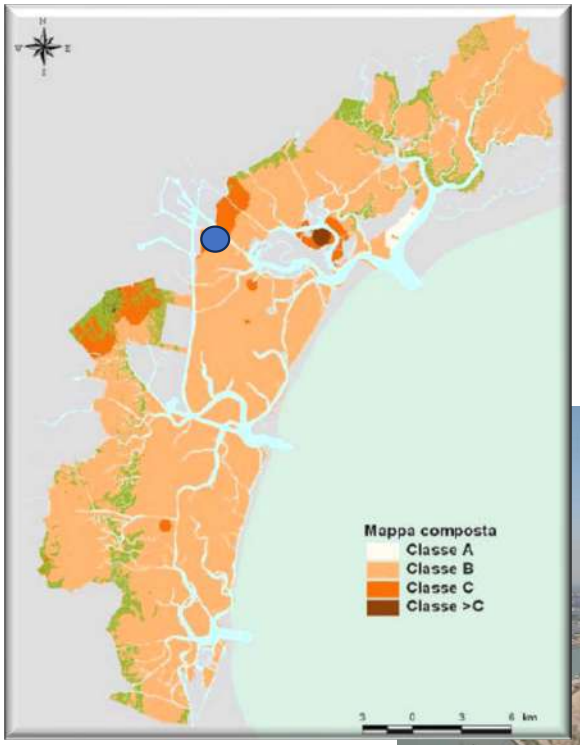
Source: Prof. L. D'Alpaos (DICEA, Università di Padova) – *L'evoluzione morfologica della laguna di Venezia attraverso la lettura di alcune mappe storiche e delle sue carte idrografiche*

The management of dredged sedments. The 1993 Protocol

ELEMENTI E COMPOSTI	CLASSE "A" (mg/kg)	CLASSE "B" (mg/kg)	CLASSE "C" (mg/kg)
Hg	0.5	2.0	10
Cd	1	5	20
Pb	45	100	500
As	15	25	50
Cr	20	100	500
Cu	40	50	400
Ni	45	50	150
Zn	200	400	3.000
Idrocarburi totali	30	500	4.000
IPA totali	1	10	20
PCB totali	0.01	0.2	2
Pesticidi org. clorurati	0.001	0.02	0.5

4 risk classes (threshold chemical concentration)

- A – Sediments for morfological restoration
- B - Island restoration. Permanent separation from water bodies and no flooding erosion risk (high tides)
- C – Widening/rising islands and permanent separation from water bodies by means deep foundations
- OVER C - Management as waste outside of the lagoon or into landfill waterproof area



Critical issues

- Most of sediments in Cl B
- Few chance to found new landfill area

Knowledge improvements and EU Directives

- Extention of the list of pollutant compounds with respect to the 1993 Protocol
- Standard Environmental Quality (SEQ) according to the WFD (water column, sediments and biota)
- The WoE approach in the field of marine sediments - The Environment Ministry Decree DM 173/2016

Parametro	Protocollo Fanghi 1993			DM 260/2010 Tab 2/A SQA-MA	DM 260/2010 Tab 3/B SQA-MA	DM 260/2010 Tab 3/A SQA-MA Biota	DLgs 172/2015 Tab 2/A SQA-MA	DLgs 172/2015 Tab 3/A SQA-MA	DLgs 172/2015 Tab 3/B SQA-MA	DLgs 172/2015 Tab 1/A SQA-MA Biota	DM 173/2016	
	A	B	C								L1	L2
Elementi in tracce				mg kg⁻¹ p.s.	mg kg⁻¹ p.s.	µg kg⁻¹ p.f.	mg kg⁻¹ p.s.	mg kg⁻¹ p.s.	mg kg-1 p.s.	mg kg-1 p.s.	mg kg⁻¹ p.s.	mg kg⁻¹ p.s.
Arsenico	15	25	50		12				12		12	20
Cadmio	1	5	20	0,3			0,3	0,3			0,3	0,80
Cromo	20	100	500		50				50		50	150
Cr VI					2				2		2	2
Rame	40	50	400								40	52
Mercurio	0,5	2	10	0,3		20	0,3	0,3		20	0,3	0,80
Nichel	45	50	150	30							30	75
Piombo	45	100	500	30			30	30			30	70
Zinco	200	400	3000								100	150
Contaminanti organici				µg kg⁻¹ p.s.	µg kg⁻¹ p.s.	µg kg⁻¹ p.s.	µg kg⁻¹ p.s.	µg kg⁻¹ p.s.	µg kg⁻¹ p.s.	µg kg⁻¹ p.s.	µg kg⁻¹ p.s.	µg kg⁻¹ p.s.
Composti organostannici				5 (tributil-stagno)			5 (tributil-stagno)	5 (tributil-stagno)			5	72
∑PCB	0,01	0,2	2		8				8		8	60
∑DDD	0,001	0,02	0,5	0,8			0,8	0,8			0,8	7,8
∑DDE	0,001	0,02	0,5	1,8			1,8	1,8			1,8	3,7
∑DDT	0,001	0,02	0,5	1			1	1		50* 100 **	1,0	4,8
Clordano	0,001	0,02	0,5								2,3	4,8
Aldrin	0,001	0,02	0,5	0,2			0,2	0,2			0,2	10
Dieldrin	0,001	0,02	0,5	0,2			0,2	0,2			0,7	4,3
Endrin	0,001	0,02	0,5								2,7	10
α-HCH	0,001	0,02	0,5	0,2			0,2	0,2			0,2	10
β-HCH	0,001	0,02	0,5	0,2			0,2	0,2			0,2	10
γ-HCH (Lindano)	0,001	0,02	0,5	0,2			0,2	0,2			0,2	1,0
Eptacloro epossido											0,6	2,7
HCB				0,4		10		0,4		10	0,4	50
Esaclorobutadiene						55				55		
Idrocarburi C>12	30	500	4000								ND	50000
∑IPA(16)	1	10	20		800						900	4000

Parametro	Protocollo Fanghi 1993			DM 260/2010 Tab 2/A SQA-MA	DM 260/2010 Tab 3/B SQA-MA	DM 260/2010 Tab 3/A SQA-MA Biota	DLgs 172/2015 Tab 2/A SQA-MA	DLgs 172/2015 Tab 3/A SQA-MA	DLgs 172/2015 Tab 3/B SQA-MA	DLgs 172/2015 Tab 1/A SQA-MA Biota	DM 173/2016	
Antracene				40			24	24			24	245
Benzo[a]antracene											75	500
Benzo[a]pirene				30				30		5	30	100
Benzo[b]fluoranlene				40				40			40	500
Benzo[k]fluoranlene				20				20			20	500
Benzo[g,h,i]perilene				55				55			55	100
Crisene											108	846
Indenopirene				70				70			70	100
Fenantrene											87	544
Fluorene											21	144
Fluoranlene				110				110		30	110	1494
Naftalene				35			35	35			35	391
Pirene											153	1398
∑T.E. PCDD,PCDF (Diossine e Furani) e PCB diossina simili					2,00E-03			2,00E-03		6,50E-03	2,00E-03	1,00E-02
PCDD/F												
PCB diossina simili												
Difenileteri bromurati										0,0085		
Dicofol										33		
Acido perfluorottansolfonico e suoi Sali (PFOS)										9,1		
Esabromociclododecano (HBCDD)										167		
Eptacloro ed eptacloro epossido										6,70E-03		

Source: A. Marcomini. *Per una gestione sostenibile del sedimento lagunare. Il contributo del DM 173/2016 alla valutazione della qualità del sedimento*. La trasparenza a salvaguardia di Venezia. Quaderni della laguna. Anno 0, vol. 0, 2017

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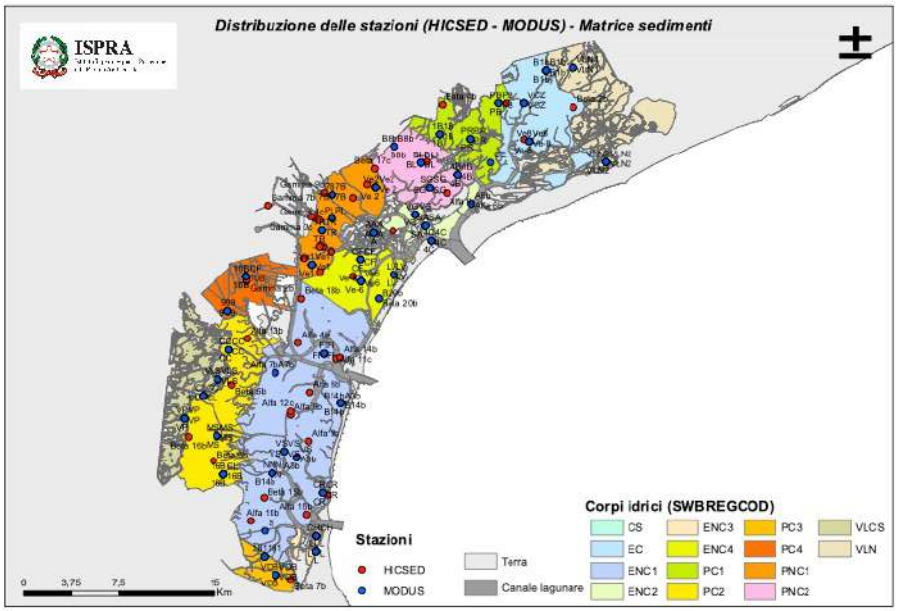
The WoE aproach. New chemical action levels in the lagoon of Venice

- Deep and wide scientific investigations on environmental risk with respect of a group of chemical stressors (perisistent , toxical, bioaccumulation) in the last decades
- Only chemical caracterization on sediments is not able to predict ecotoxicological and bioaccumulation effects
- Extended monitoring activities and new methodological approach (WoE by the integration of different lines of evidence)
- A series of specific projects (ICLSEL, SIOSED, HICSED) have pointed out that there is no scientific evidendence in the separation of class risk A and B
- Most of the class risk B sediments didn't show any statistical relevant toxicty with the respect of the main pollutant substances



New guidelines for the management of sediments in the lagoon of Venice

(Ministry Decree 22 maggio 2023 n° 86)

- Technical and operational details to follow for the environmental investigations on dredging site and desposit site (salt marshes, tidal flats)
- Environmental monitoring planning details (hydrodinamics, water column, turbidity, etc)
- Sediments quality assessment and new class risk allocation according a WoE criteria by mean the integration of chemical data and ecotoxicological data aimed at their reuse with respect the needs of conservation of the lagoon
- EU Environmental Directives Consistency (WFD, Waste Directive, Habitat & Birds Directives)
- Not worsening criteria as regard as the environamental conditions within the deposit site and within the water body.

The WoE approach – An adatpation of the marine sediments approach

The Environment Ministry Decree DM 173/2016

The sediment quality classes is assigned following the integration of chemical and ecotoxicological data using weighted criteria.

The chemical classification

Number, magnitude and tipology of pollutant exceeding 2 action levels specifically assessed for the lagoon envirnomet (L1loc, L2loc)

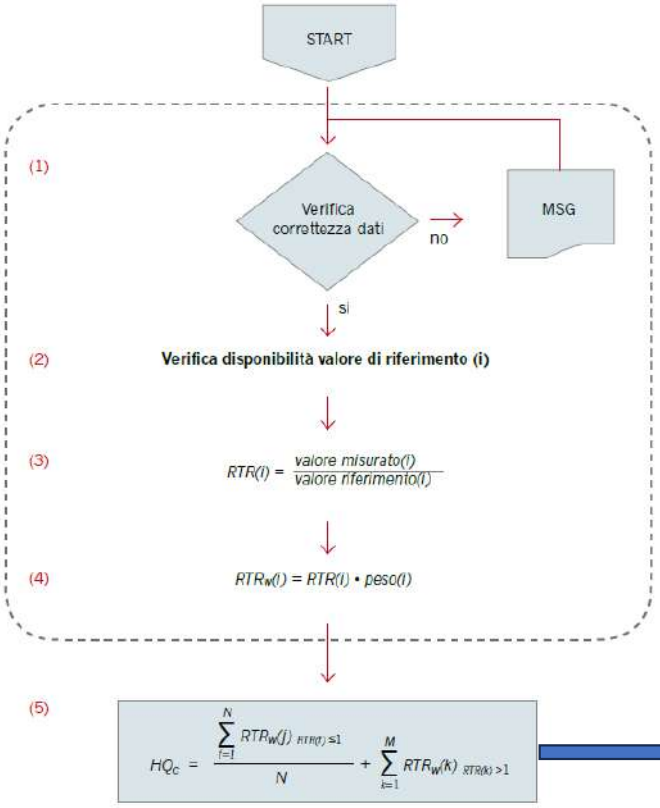
The indexing of ecotoxicological responses

Relevance of measured endpoints, tested matrix, time of exposure, magnitude and statistical difference of effects compared to specific thesholds of all the assays of the battery

Syntetic hazard indices for chemical and ecotoxicological data are provided

By means their integration a quality class can be assigned to the sediments.

Chemical Hazard Quotient (HQc)



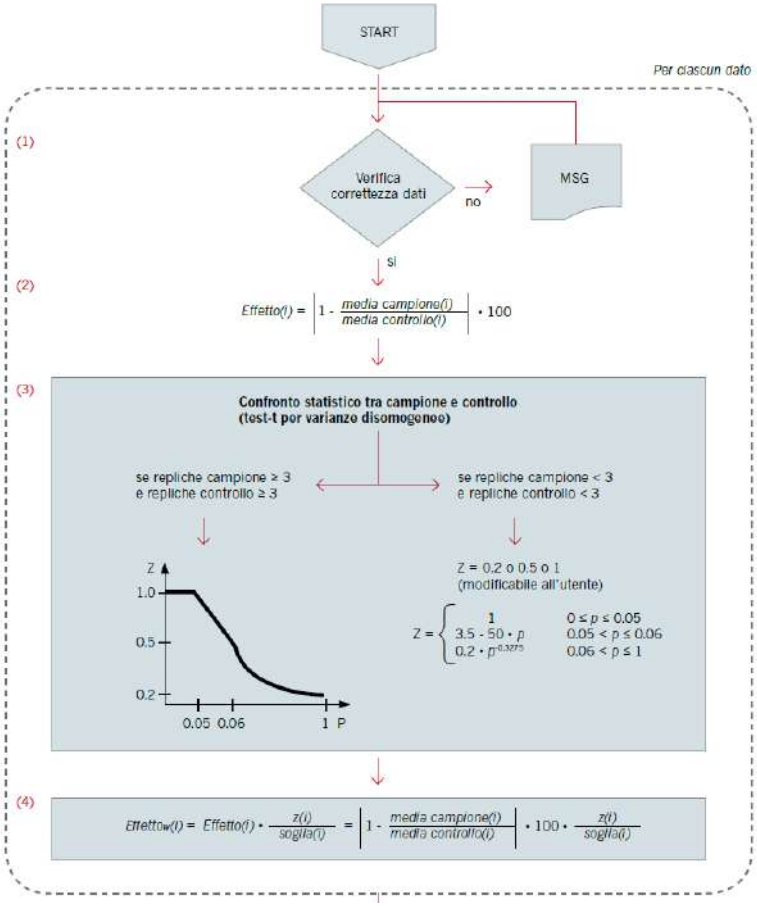
L1loc , L2loc adaptation

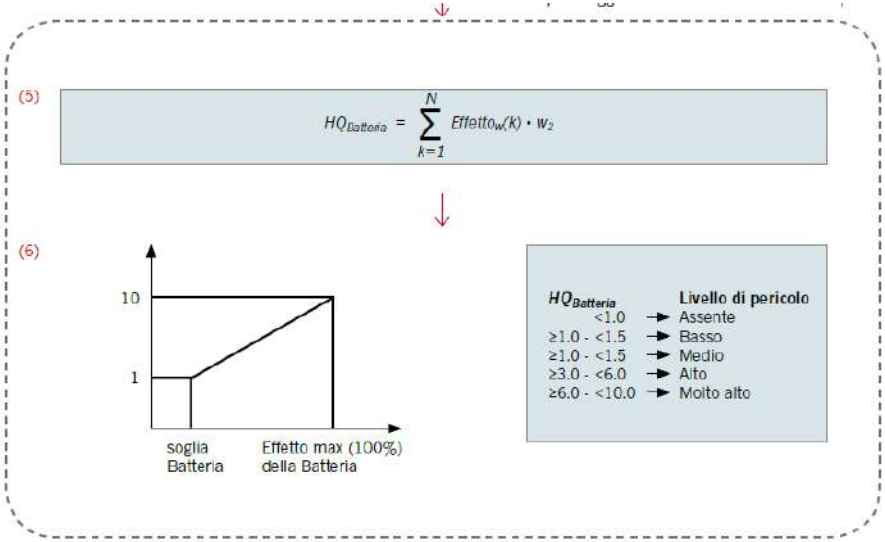
- 234 sediment samples
- 7124 chemical data (not omogeneosly distributet among the whole group of the pollutants)
- 892 biological text

HQc	Hazard class
0 - < 0,7	No hazard
0,7 – 1,3	Neglitable
1,3 – 2.6	Low
2,6 – 6.5	Medium
6.5 – 13,0	High
>= 13.0	Very high

GRUPPO A	U.M.	L1 (SQA)	L2 (PEL sito specifico)
As	mg/kg	12	19
Cd	mg/kg	0,3	1,4
Cu	mg/kg	40	62
Hg	mg/kg	0,3	1,2
Pb	mg/kg	30	50
Zn	mg/kg	100	274
Anthracene	µg/kg	24	79
Benzo_a_antracene	µg/kg	75	329
Benzo_a_pirene	µg/kg	30	199
Benzo_b_fluorantene	µg/kg	40	192
Benzo_k_fluorantene	µg/kg	20	133
Crisene	µg/kg	108	328
Benzo_g,h,i_perilene	µg/kg	55	180
Fluorantene	µg/kg	110	366
Fenantrene	µg/kg	87	245
Fluorene	µg/kg	21	66
Indeno_1,2,3_pirene	µg/kg	70	138
Pirene	µg/kg	153	836
IPAtot	µg/kg	900	1887
HCB	µg/kg	0,4	4,8
TBT	µg/kg	5	16
PCBtot	µg/kg	8	15
Diossine, furani e PCB Dioxin Like	µg/kg (T.E.)	0,002	0,02
GRUPPO B	U.M.	L1 (SQA)	L2 (PEL sito specific)
Cr	mg/kg	50	-
Ni	mg/kg	30	-
Naftalene	µg/kg	35	-
Cr VI	mg/kg	2,0	-
DDD	µg/kg	0,8	-
DDE	µg/kg	1,8	-
DDT	µg/kg	1,0	-
Clordano	µg/kg	2,3	-
Aldrin	µg/kg	0,2	-
Dieldrin	µg/kg	0,7	-
Endrin	µg/kg	2,7	-
α-HCH	µg/kg	0,2	-
β-HCH	µg/kg	0,2	-
γ-HCH	µg/kg	0,2	-
Eptacloro epossido	µg/kg	0,6	-
Idrocarburi C>12	µg/kg	-	-

Ecotoxicological Hazard Quotient (Hqecotox)





Quality risk classes and option for the management of sediments inside the lagoon of Venice

Risk class	Bioacc.	Ecotox	Chemical	Option of management
Alpha (surface layer < 0.5 mt)	[X] "average" ≤ D.Lgs. 172/15	-	[X] "media" ≤ SQA	No restrictions in the reuse for morphological restoration Monitoring planning according to new guidelines
Alpha (deep layers > 0,50 mt)		No hazard (HQ < 1)	[X] ≤ SQA + 20%	
Beta		No hazard/Low (HQ < 1,5)	HQ ($L2_{Loc}$) < 1 No hazard	Reuse for morphological restoration Not worsening the class risk of sediments in the deposit site and monitoring planning
Gamma		Medium (-1,5 ≤ HQ < 3)	HQ (L2Loc) ≤ Low	Reuse for morphological restoration with an ovelay of better quality sediments (no direct connection to the nearby water bodies)
Delta		High 3 ≤ HQ < 6	Low < HQ ($L2_{Loc}$) ≤ High	Permanent displacement in waterproof landfill area
Epsilon		Very High HQ ≥ 6	HQ($L2_{Loc}$) >High	

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Concluding remarks

- The new gudelines had arised relevant expetcations among the stakeholders
- Port facilities improvements
- Environmental issues for the sefeguarding of the lagoon
- A first implementation period (2 years) has been established in the perspective of acquaring new data, knowledge improvments, a better tailoring of the metodolgy and the probable upgrading action level values
- A general morphological restoration planning (PMLV) is already available and its upgrading is underway in the context of Environmental Strategic Assessment (Eu Directive)
- **A crucial issues of the PMLV is the identification of those strategic interventions (salt marches/tidal flats restoration) by means the sediments can be reused with respect of new guidelines of management**

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