VALUTAZIONI INTEGRATE NELLA DEFINIZIONE DELLA QUALITÀ AMBIENTALE: LINEE DI EVIDENZA, INDICI DI PERICOLO ED APPROCCIO ‘’WEIGHT OF EVIDENCE’’

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La cooperazione al cuore del Mediterraneo
La coopération au cœur de la Méditerranée

INTEGRATED MODELS FOR RISK ASSESSMENT

Chemical analyses

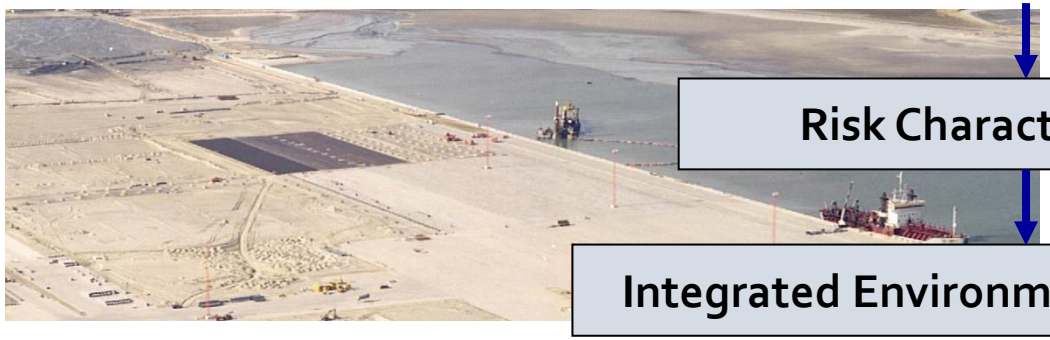
Bioavailability of chemicals

Ecotoxicological approach (biomarkers)

Toxicological Bioassays

Ecology (population, community, biodiversity..)

Human Health



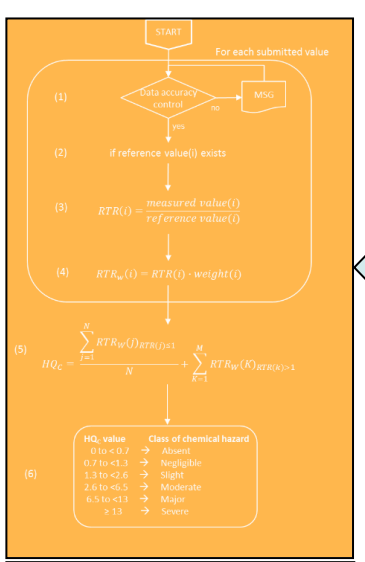
Risk Characterization

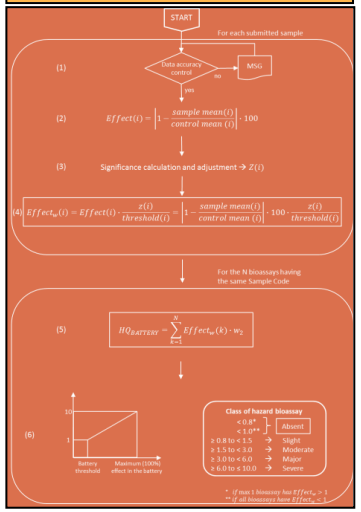
Integrated Environmental Management

CRITICAL ISSUES IN RISK ASSESSMENT

- Interpretation and significance of complex datasets of heterogeneous results
- Qualitative and quantitative evaluations: indices and scales development
- Integration of different typologies of data
- Synthetic risk characterization/communication

Quantitative risk assessment model on Weight of Evidence (WOE) approach





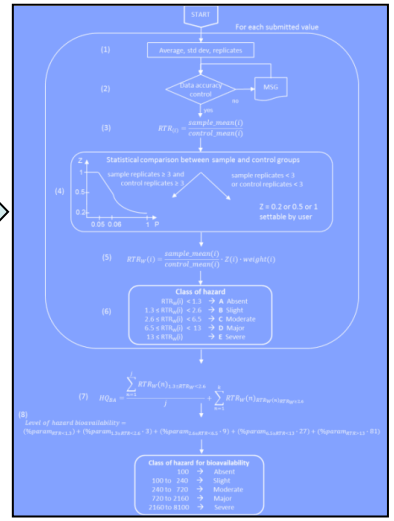
LOE 1 Chemical analyses

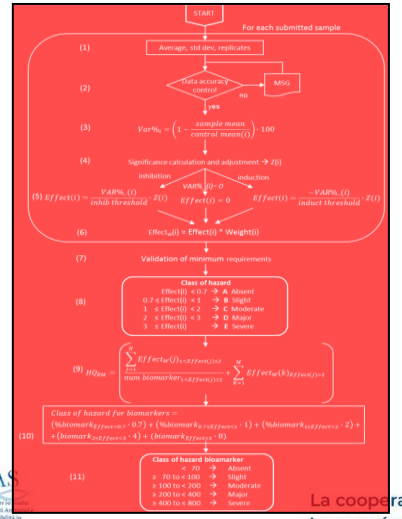
LOE 2 Bioavailability

LOE 4 Bioassays

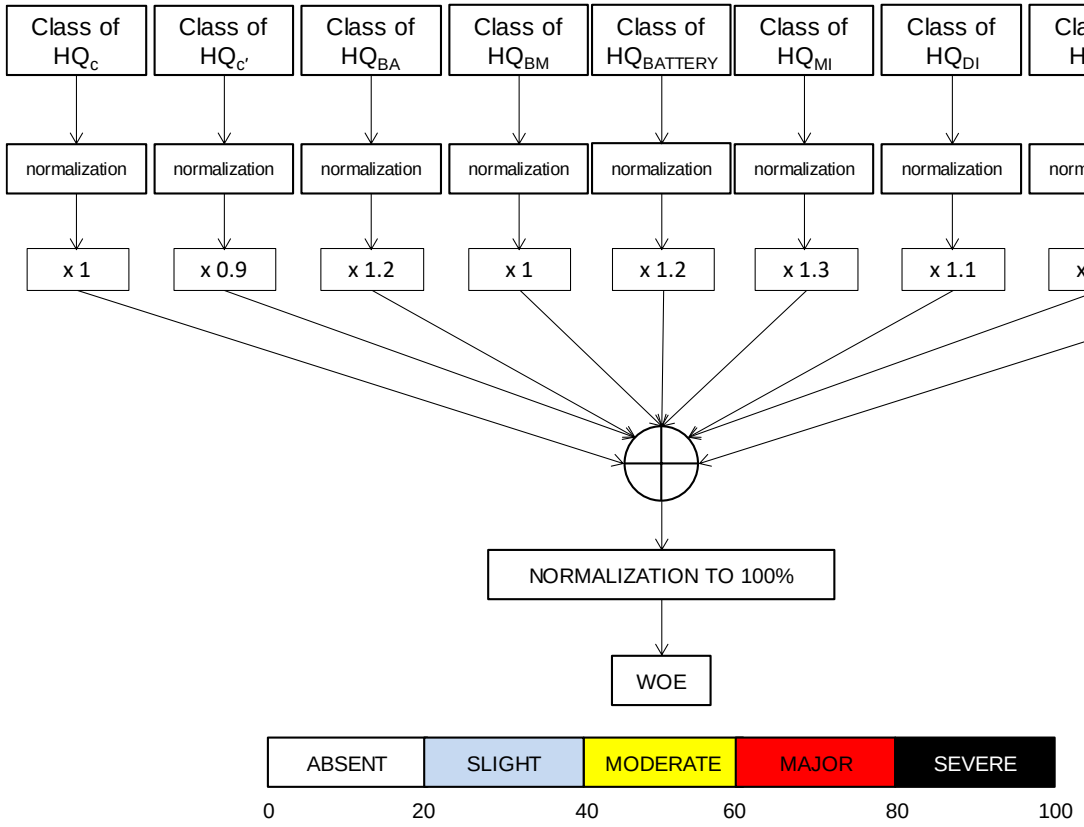
LOE 3 Biomarkers

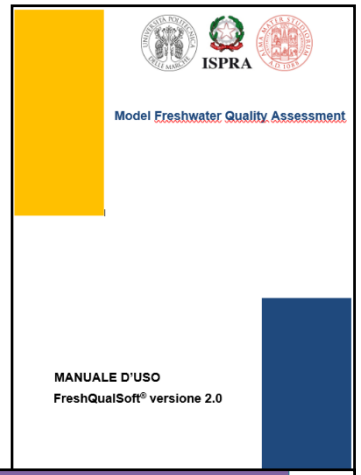
Integrated Risk Index using WOE approach

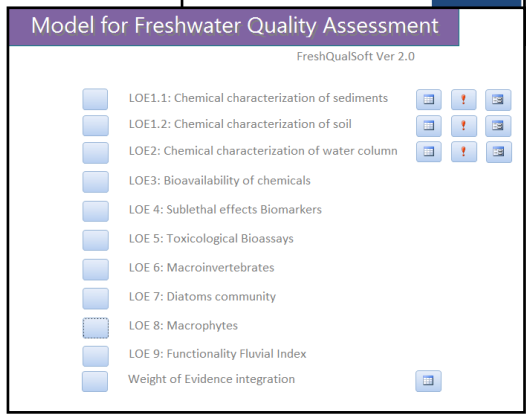




Validation of Weight of Evidence (WOE) model for freshwater environments

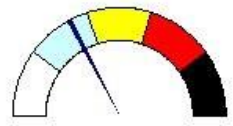






Weight of Evidence integration

Area	Cecina
Site	River Cecina
Chemical characterization of sediments	MAJOR
Chemical characterization of soil	
Chemical characterization of water column	MODERATE
Bioavailability of chemicals	SLIGHT
Sublethal effects Biomarkers	MODERATE
Toxicological Bioassays	ABSENT
Macroinvertebrates	MODERATE
Diatoms community	ABSENT
Macrophytes	ABSENT
Index of river functionality	MODERATE
Weight of Evidence integr	SLIGHT



frontiers in Marine Science

ORIGINAL RESEARCH
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Mussel Caging and the Weight of Evidence Approach in the Assessment of Chemical Contamination in Coastal Waters of Finland (Baltic Sea)

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TABLE 3 | Elaborations with levels of hazard assigned to the different LOEs and the final WOE.

Site	Chemical characterization	Bioavailability	Biomarkers	Benthic communities	Near-bottom oxygen	Eutrophication	Weight of Evidence integration
Kotka	HQ: 0.284 Absent -	HQ: 63.417 Major BaP–DBahA–BkF; PER	HQ: 4.229 Moderate CAT-GST	HQ: 67.174 Major	Absent	Major	MODERATE
Porvoo	HQ: 0.311 Absent -	HQ: 63.030 Major ANT–FLU; PER	HQ: 4.642 Moderate GST-LPO-CAT; GR	HQ: 46.078 Moderate	Slight	Major	MODERATE
Helsinki	HQ: 2.271 Slight 100% Zn	HQ: 14.842 Slight -;-	HQ: 2.517 Moderate -; GST	HQ: 31.326 Slight	Absent	Major	SLIGHT
Hanko	HQ: 0.28 Absent -	HQ: 29.925 Moderate -; 1-MetNAPH	HQ: 2.714 Moderate GR-GST; -	HQ: 46.377 Moderate	Absent	Moderate	SLIGHT
Parainen	HQ: 1.7 Slight 100% Zn	HQ: 59.329 Major BbF–BaP; PER	HQ: 2.008 Slight LPO;-	HQ: 48.291 Moderate	Absent	Major	MODERATE
Naantali	HQ: 2.829 Moderate 100% Zn	HQ: 80.710 Major FLU; PER–OSn	HQ: 2.402 Moderate GST-CAT; -	HQ: 49.020 Moderate	Absent	Major	MODERATE
Uusikaupunki	HQ: 1.566 Slight 100% Zn	HQ: 1.985 Slight -;-	HQ:2.42 Moderate CAT-GST; -	HQ: 9.520 Absent	Slight	Moderate	SLIGHT
Rauma	HQ: 6.18 Moderate 81.5% Zn	HQ: 64.589 Major -; PER–BaP	HQ: 2.125 Slight CAT; -	HQ: 33.676 Slight	Absent	Moderate	MODERATE
Pori	HQ: 0.293 Absent -	HQ: 0 Absent -;-	HQ: 0 Absent -;-	HQ: 50.986 Moderate	Absent	Slight	SLIGHT
Vaasa	HQ: 2.199 Slight 100% Zn	HQ: 4.296 Slight -;-	HQ: 1.0 Slight -;-	HQ: 59.938 Moderate	Absent	Slight	SLIGHT

Hazard Quotient (HQ) is provided for chemical characterization of seawater (showing the percentage of the parameter contributing most to the HQ), bioavailability (parameters showing major or severe effects), biomarkers (parameters showing moderate or major effects), and benthic communities

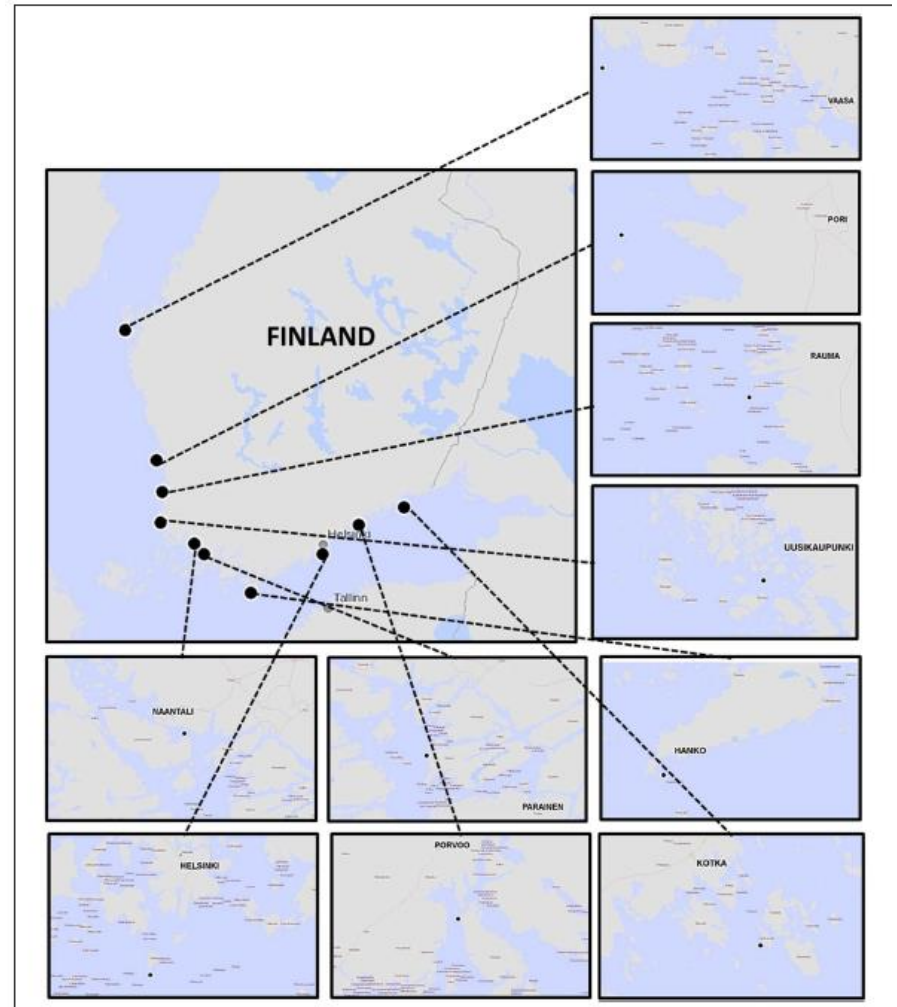
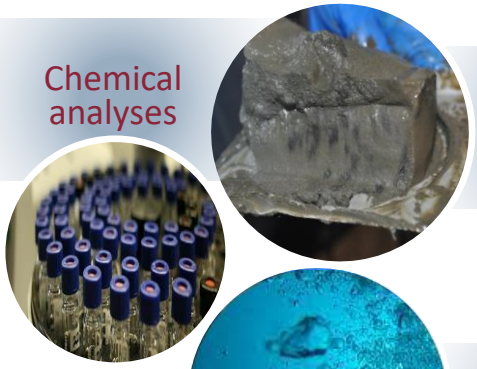
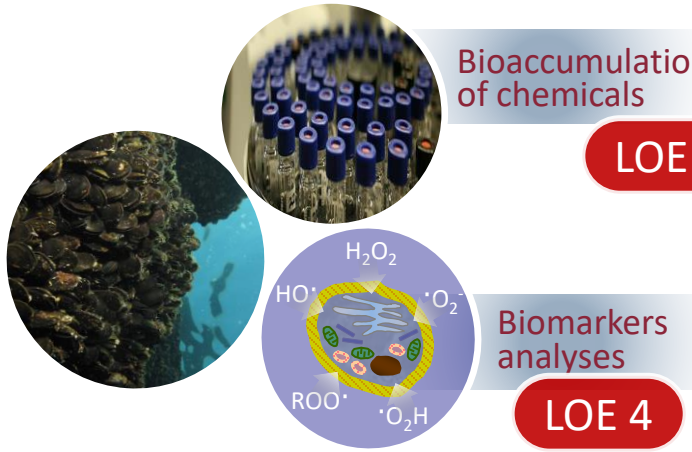
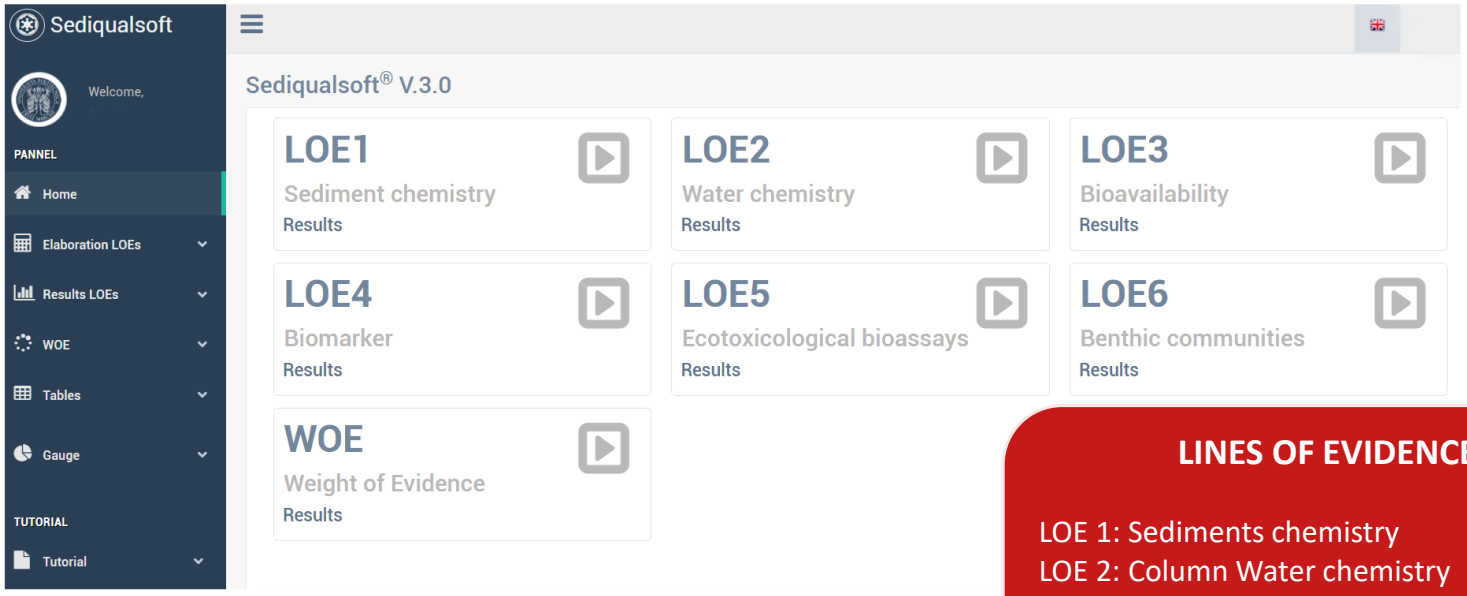


FIGURE 1 | Study sites along the coast of Finland. The black dot in each site map represent the exact site of the mussel cage.

Sediqualsoft: Geremia

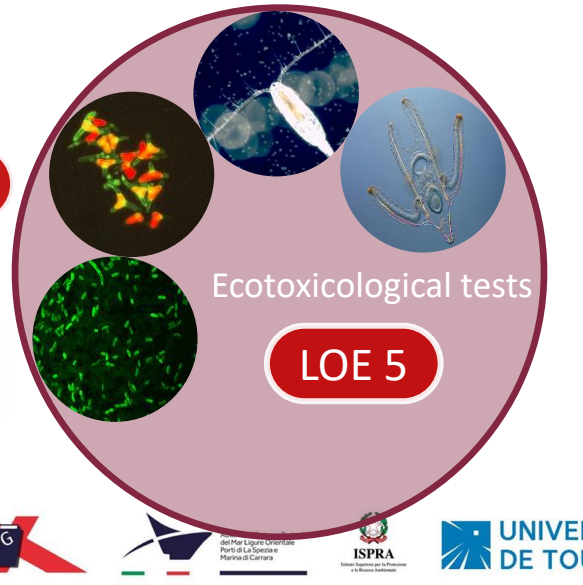






LINES OF EVIDENCE

LOE 1: Sediments chemistry
LOE 2: Column Water chemistry
LOE 3: Bioavailability on sentinel organisms
LOE 4: Biomarkers on sentinel organisms
LOE 5: Bioassays
LOE 6: Analyses of benthic communities



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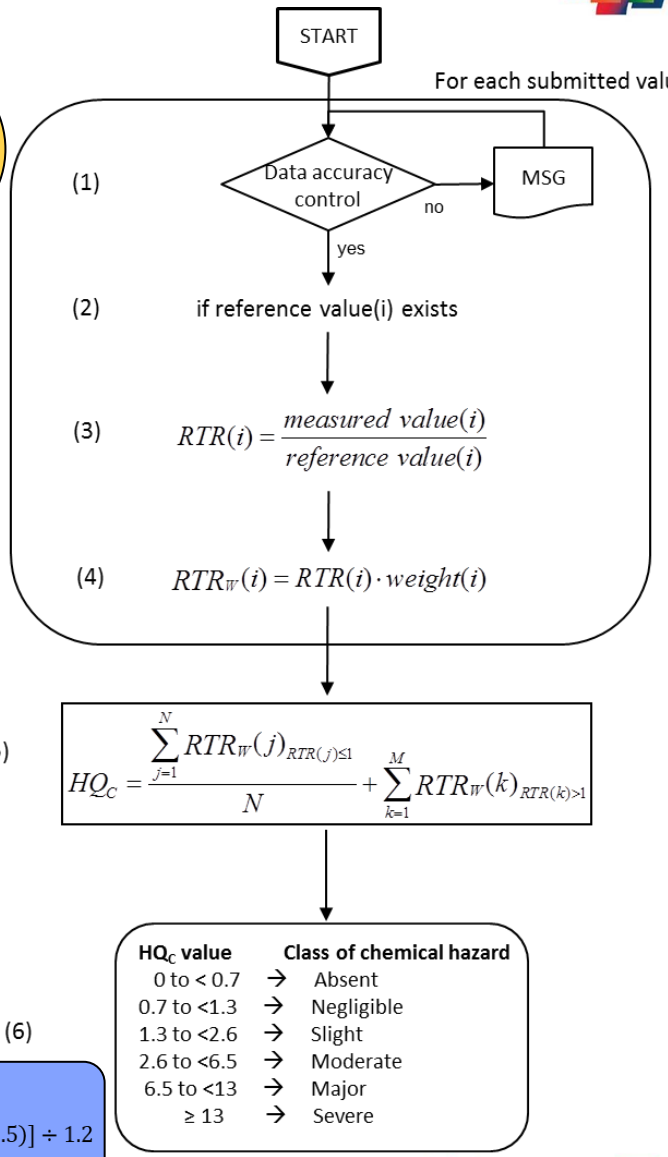
Flow chart and calculation of chemical HQ

LOE 1 Chemical Analyses (sediments)

LOE 2 Chemical Analyses (water column)



HQ_C value		Class of chemical hazard
0 to < 0.7	→	Absent
0.7 to <1.3	→	Negligible
1.3 to <2.6	→	Slight
2.6 to <6.5	→	Moderate
6.5 to <13	→	Major
≥ 13	→	Severe

- Calculation for each parameter concentration of the <u>Ratio To Reference</u>, RTR
- Correction for <u>typology of pollutants</u> (i.e. hazardous or priority), RTR*p*
- <u>Cumulative HQ</u> differently weights for parameters with RTR<1 and those with RTR>1
  - to discriminate even moderately polluted sites (close to reference values)
  - increase according to number and magnitude of exceeding parameters
  - not lowered by "not exceeding" parameters
- <u>Classification of HQ</u> in 1 of 5 classes of hazard (absent-negligible, slight, moderate, major, severe)

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LOE 1
Chemical Analyses (sediments)

Chemical analyses

	B	C	D	E	F	G	H	I	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1	Longitude	Area	Site	Date	Sampling code	Core code	Level code	Sample code	As	Ba	Be	Cd	Co	Cr tot	Cr VI	Cu	Fe	Hg	Me Hg	Mn	Ni	Pb	Sb
2	8,922483	Genova	Diga foranea imboccatura levante	13/12/2018	GR-GE-I-SE-01			GR-GE-I-SE-01	8,78078			0,74035		64,5955		32,9257	21523,9	0,18			43,9031	52,9487	
3	8,919	Genova	Porto antico	13/12/2018	GR-GE-I-SE-02			GR-GE-I-SE-02	5,6098			0,34246		80,1061		51,585	18479,5	0,46			46,3194	63,2455	
4	8,875117	Genova	Foce Polcevera	13/12/2018	GR-GE-I-SE-03			GR-GE-I-SE-03	10,4238			0,46893		149,192		84,5771	41556,8	0,23			127,04	63,0451	
5	8,933853	Genova	Diga foranea imboccatura levante	16/05/2019	GR-GE-II-SE-01			GR-GE-II-SE-01	8,03118			0,43679		59,1385		46,1169	21556,5	0,17			44,8172	74,3146	
6	8,921642	Genova	Porto antico	16/05/2019	GR-GE-II-SE-02			GR-GE-II-SE-02	13,9585			0,40952		77,7851		78,2099	18854,6	1,36			46,0034	92,1128	
7	8,874175	Genova	Foce Polcevera	16/05/2019	GR-GE-II-SE-03			GR-GE-II-SE-03	5,45135			0,37115		133,141		88,5697	40330,9	0,23			131,111	59,6732	
8	9,849547	La Spezia	Molo Fornelli	20/11/2017	MF1			MF1															
9	9,849579	La Spezia	Molo Fornelli	20/11/2017	MF2			MF2															
10	9,849583	La Spezia	Molo Fornelli	20/11/2017	MF3			MF3															
11	9,849546	La Spezia	Molo Fornelli	20/11/2017	MF4			MF4															
12	9,84578	La Spezia	Tra Molo garibaldi e Molo Fornelli	14/05/2019	GR-SP-II-SE-01			GR-SP-II-SE-01	23,7409			0,084		92,3921		62,7097		0,27349			59,1383	41,5757	

REFERENCE VALUES (Marine sediments)
L1 (DM 173/2016)
L2 (DM 173/2016)
ERL (Effect Range Low) (Long et al., 1995)
ERM (Effect Range Median) (Long et al., 1995)
TEL (Threshold Effect Level) (Mac Donald, 1994, Long et al. (1995)
PEL (Probable Effect Level) (Mac Donald, 1994, Long et al. (1995)
SQA (D. Lgs 172/2015),
SL/SQHV (ANZECC, 2009)
Column A, (Allegato 5, parte IV, Titolo V, D. Lgvo 152/2006)
Column B ("…")

EASY TO UPDATE WITH OTHER REFERENCES

159 analytes including Trace metals, aliphatic hydrocarbons, PAHs, PCBs, pesticides, organo-tin dioxins and dioxin-like compounds, aromatic solvents, halogenated, nitro-aromatics, phenols, aromatic ammine, …

LOE 2
Chemical Analyses (water column)

	CHEMICALS (µg L^{-1})	SQA	Weighting			
1	As	10	1	57	Diclorvos	0,01	1
2	Cd 1	0,08	1,3	58	Dimetoato	0,5	1
3	Cd 2	0,08	1,3	59	Diuron	0,2	1,1
4	Cd 3	0,09	1,3	60	Endosulfan	0,005	1,3
5	Cd 4	0,15	1,3	61	Eptaclor	0,005	1
6	Cd 5	0,25	1,3	62	Esaclorobenzene (HCB)	0,005	1,3
7	Cd		1,3	63	Esaclorobutadiene	0,05	1,3
8	Cr totale		1	64	Esaclorocicloesano	0,02	1,3
9	Hg	0,03	1,3	65	Fenitrotion	0,01	1
10	Ni	20	1,1	66	Fention	0,01	1
11	Pb	7,2	1,1	67	Fluorantene	0,1	1,1
12	1,1,1 Tricloroetano	10	1,1	68	Isoproturon	0,3	1,1
13	1,2 dichloroethane	10	1,1	69	Linuron	0,5	1
14	1,2 dichloromethane	20	1,1	70	Malation	0,01	1
15	1,2 Diclorobenzene	2	1	71	MCPA	0,5	1
16	1,3 Diclorobenzene	2	1	72	Mecoprop	0,5	1
17	1,4 Diclorobenzene	2	1	73	Metamidofos	0,5	1
18	1-Cloro-2-nitrobenzene	1	1	74	Mevinfos	0,01	1
19	1-Cloro-3-nitrobenzene	1	1	75	Naftalene	2,4	1,1
20	1-Cloro-4-nitrobenzene	1	1	76	Octilfenolo	0,1	1,1
21	2 Cloroanilina	1	1	77	Ometoato	0,5	1
22	2,4 D	0,5	1	78	Ossidemeton-metile	0,5	1
23	2,4,5 T	0,5	1	79	Paration etile	0,01	1
24	2,4,5-Triclorofenolo	1	1	80	Paration metile	0,01	1
25	2,4,6-Triclorofenolo	1	1	81	PCB-101	0,1	1
26	2,4-Diclorofenolo	1	1	82	PCB-118	0,1	1
27	2-Clorofenolo	4	1	83	PCB-126	0,1	1
28	2-Clorotoluene	1	1	84	PCB-128	0,1	1
29	3 Cloroanilina	2	1	85	PCB-138	0,1	1
30	3,4-Dicloroanilina	0,5	1	86	PCB-153	0,1	1
31	3-Clorofenolo	2	1	87	PCB-156	0,1	1
32	3-Clorotoluene	1	1	88	PCB-169	0,1	1
33	4 Cloroanilina	1	1	89	PCB-180	0,1	1
34	4-Clorofenolo	2	1	90	PCB-28	0,1	1
35	4-Clorotoluene	1	1	91	PCB-52	0,1	1
36	4-Nonilfenolo (Nonilfenolo)	0,3	1,3	92	PCB-77	0,1	1
37	Alachlor	0,3	1,1	93	PCB-81	0,1	1
38	Alcani, C10-C13, cloro	0,4	1,3	94	Pentaclorobenzene	0,007	1,3
39	Aldrin		1	95	Pentaclorofenolo	0,4	1,1
40	Antracene	0,1	1,3	96	pp DDT	0,01	1,1
41	Atrazina	0,6	1,1	97	S DDT	0,025	1,1
42	Azinfos etile	0,01	1	98	S PCB	1	1
43	Azinfos metile	0,01	1	99	S PCDD,PCDF,PCB diossina simili (TE-I)	0,1	1
44	Bentazone	0,5	1	100	Simazina	1	1,1
45	Benzene	10	1,1	101	TBT (Sn)	0,0002	1,3
46	Benzo(a)pirene	0,05	1,3	102	Terbutilazina	0,5	1
47	Benzo(b)fluorantene + Benzo(k)fluorantene	0,03	1,3	103	Tetracloroetilene	10	1,1
48	Benzo(g,h,i)perilene + Indeno(1,2,3,c,d)pirene	0,002	1,3	104	Tetracloruro di C	12	1,1
49	Brominated diphenyl ether	0,0005	1,1	105	Toluene	5	1
50	Chlorfenvinphos	0,1	1,1	106	Triclorobenzeni	0,4	1,1
51	Chlorpyriphos	0,03	1,1	107	Tricloroetilene	10	1,1
52	ciclodiene + Aldrin + Dieldrin + Endrin + Isodrin	0,01	1,1	108	Triclorometano	2,5	1,1
53	Clorobenzene	3	1	109	Trifenilstagno	0,0002	1
54	Cloronitrotolueni	1	1	110	Triflularin	0,03	1,1
55	Demeton	0,1	1	111	Xilene	5	1
56	Di(2-ethylhexyl)phthalate	1,3	1,1				

LOE 1
Chemical
Analyses
(sediments)

Sediments

NORMATIVES AND SEDIMENT QUALITY GUIDELINES

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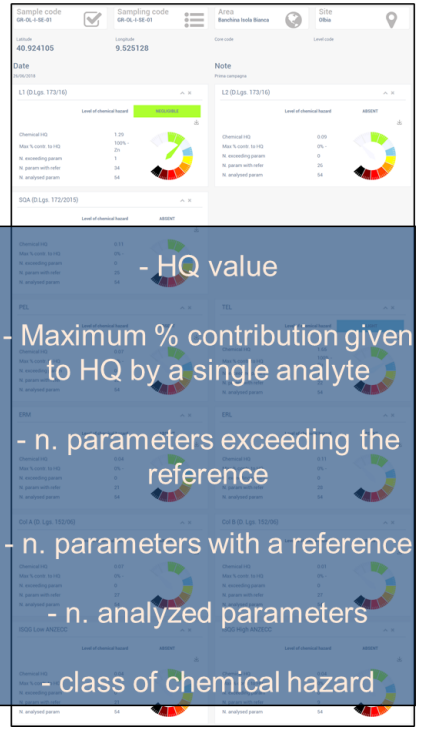


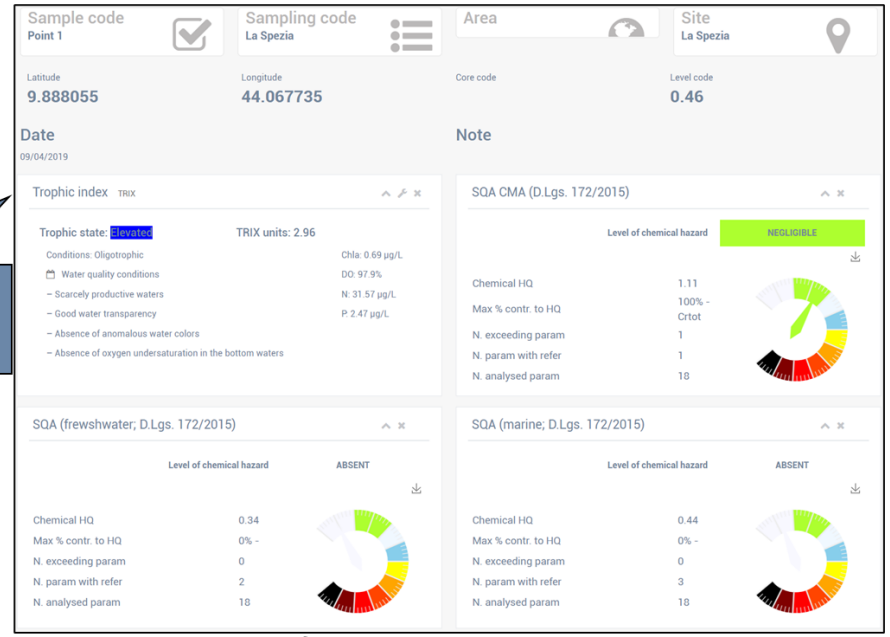
- HQ value
- Maximum % contribution given to HQ by a single analyte
- n. parameters exceeding the reference
- n. parameters with a reference
- n. analyzed parameters
- class of chemical hazard

Output of Chemical Module

UPDATE OTHER INDICES
(i.e. Trophic Index)

LOE 2
Chemical
Analyses
(water column)

Water column



NORMATIVES AND SEDIMENT QUALITY GUIDELINES

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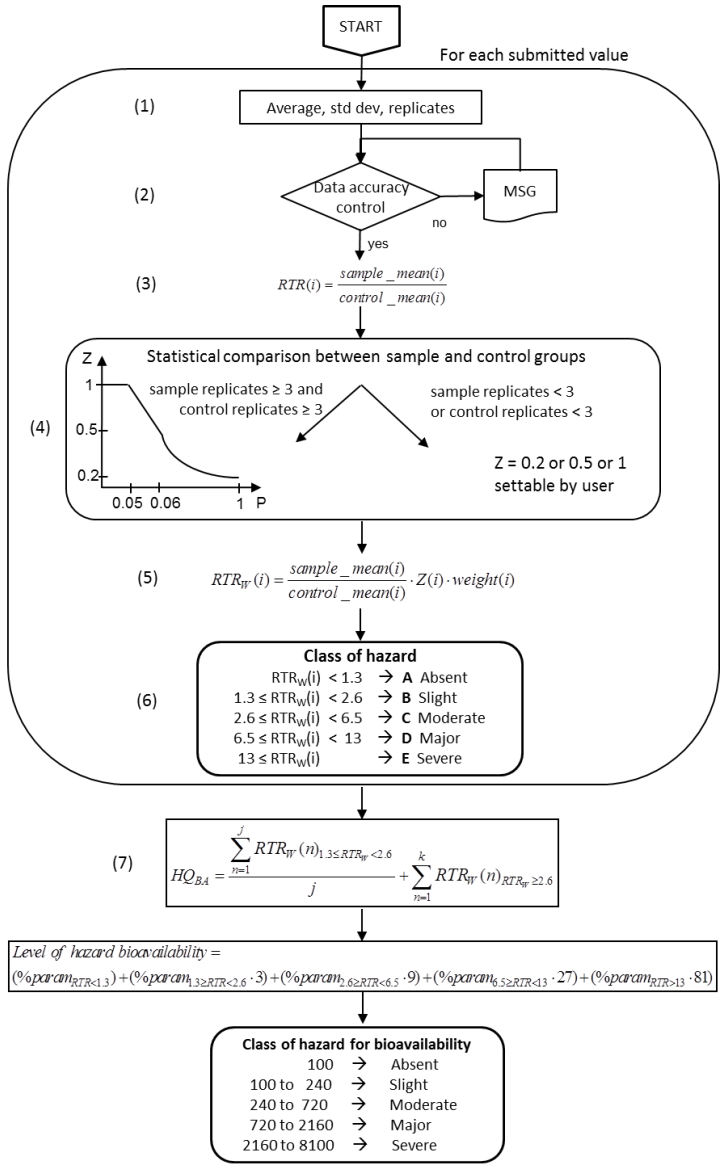
Flow chart and calculation of bioavailability HQ

LOE 3 Bioavailability



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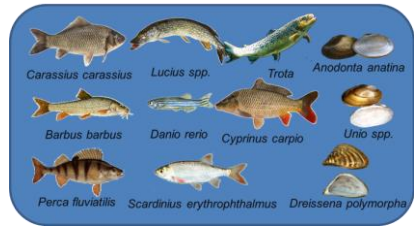
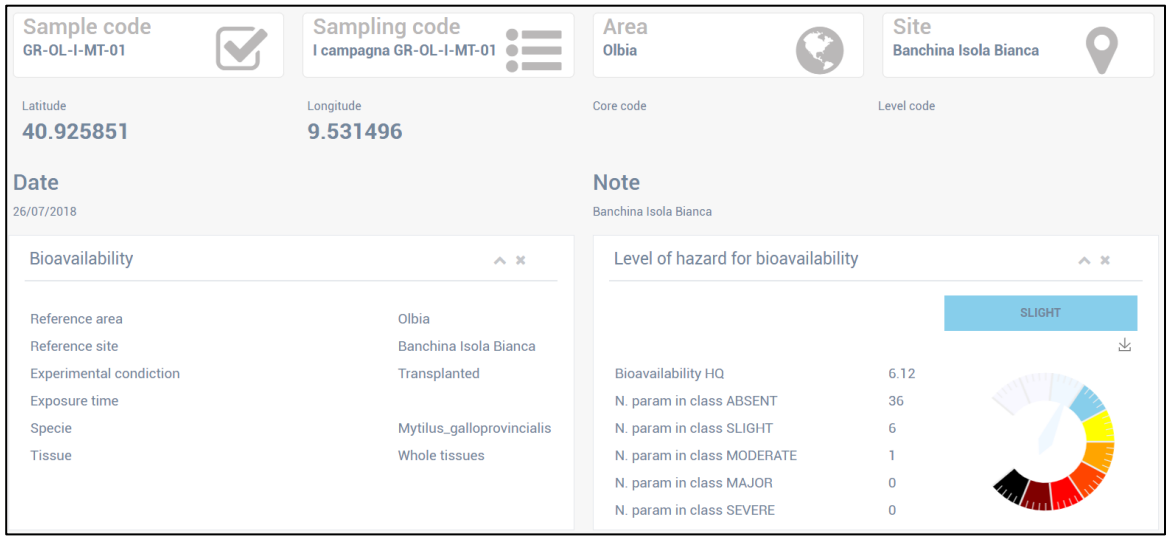
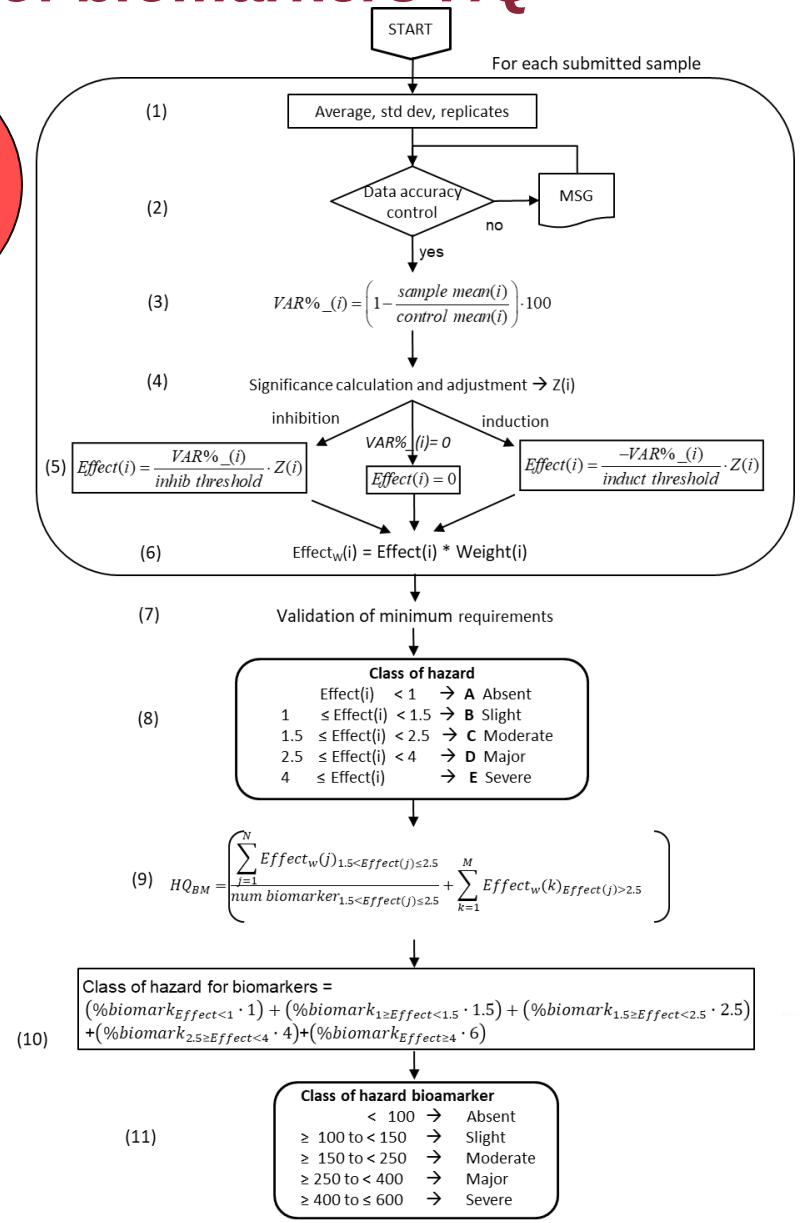


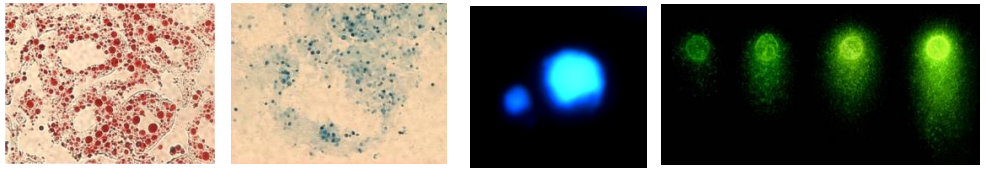
- Calculation for each parameter of <u>increased concentration</u>, corrected for <u>typology of pollutants</u> (i.e. hazardous or priority) and <u>statistical significance</u> (RTRw)
- Assignment of each parameter to 1 of 5 classes of effect (absent, slight, moderate, major, severe)
- The cumulative HQ <u>differently weights</u> these parameters according to the entity of variation (is not an average)
- Level of cumulative HQ is summarized by the % distribution of parameters in the classes of effect



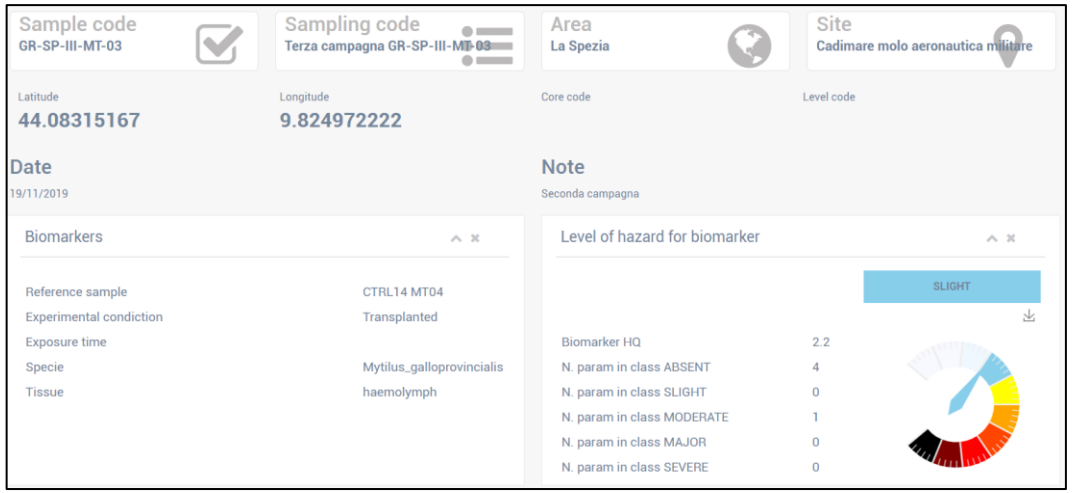
Flow chart and calculation of biomarkers HQ

LOE 4 Biomarkers





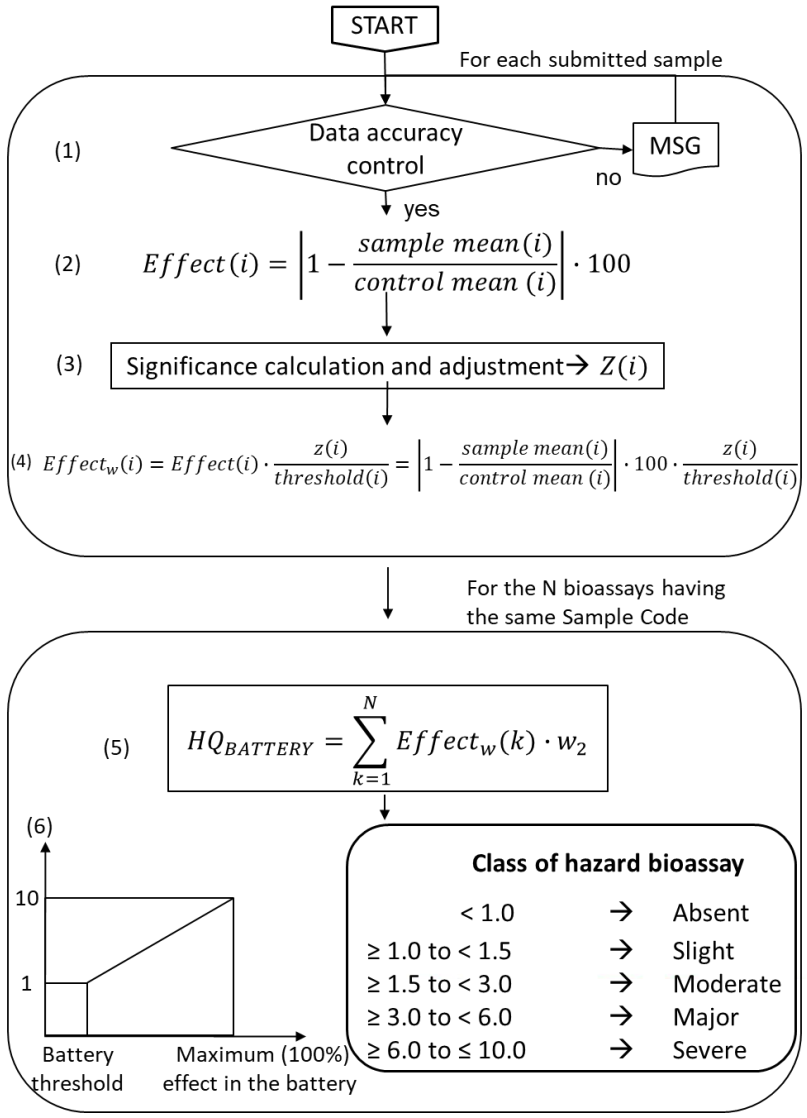
- For each biomarker, the variation is compared to Threshold, corrected for statistical significance and importance of biomarker (weight)
- **Assignment of each biomarker response to 1 of 5 classes of effect**
- Calculation and classification of cumulative HQ in a level of hazard according to % distribution of biomarkers in the 5 classes



Flow chart and calculation of bioassays HQ

LOE 5 Bioassays

- Species
- Matrix
- Endpoint
- Experimental conditions



- **Each bioassay has a <u>Weight</u> depending on the biological endpoint, and a <u>Threshold</u> based on tested matrix, time of exposure, hormesis**
- **Variation of each bioassay is compared to its Threshold, corrected for the <u>statistical significance</u> and the <u>weight</u> of the assay**
- **A <u>cumulative HQ</u> for the battery is calculated by the summation of each effect vs the threshold of the battery; <u>classification of the HQ</u> in 1 of 5 classes of hazard, absent, slight, moderate, major, severe (from less of the battery threshold to 100% of effects).**

Output Module bioassays

LOE 5 Bioassays

Single Bioassay Results

Level of hazard for bioassays

Sample code: GR-TL-II-SE-02 | Sampling code | Area: Tolone | Site: La Tour Royale

Latitude: 43.102303 | Longitude: 5.925276 | Core code | Level code

Date: 17/10/2019 | Note: II campagna

Single Bioassay Results: *Vibrio_fischeri*

Endpoint	Bioluminescence	Effect	337.36
Exposure time	Acute	Effect Z	337.36
Matrix	Centrifuged sediment	Weighed Effect	0
Control mean	123.86	Specific HQ	0
Control Std Dev	5.63	Specific HQ norm (1:10)	0
Control Rep	3	Specific HQ threshold (10%)	1.44
Exposed mean	28.32	Specific HQ max (100%)	5.76
Exposed Std Dev	1.74		
Exposed Rep	2		

Single Bioassay Results: *Phaeodactylum_tricornutum*

Endpoint	Algal Growth	Effect	151.65
Exposure time	Chronic	Effect Z	151.65
Matrix	Elutriate	Weighed Effect	1.25
Control mean	420000	Specific HQ	1.29
Control Std Dev	13229	Specific HQ norm (1:10)	1.25
Control Rep	3	Specific HQ threshold (10%)	1.03
Exposed mean	677500	Specific HQ max (100%)	10.29
Exposed Std Dev	58790		
Exposed Rep	3		

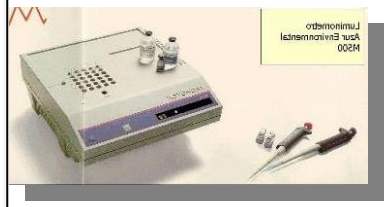
Single Bioassay Results: *Paracentrotus_lividus*

Endpoint	development	Effect	14.01
Exposure time	Chronic	Effect Z	14.01
Matrix	Elutriate	Weighed Effect	0.93
Control mean	85.67	Specific HQ	0.87
Control Std Dev	0.58	Specific HQ norm (1:10)	0.93
Control Rep	3	Specific HQ threshold (10%)	0.93
Exposed mean	73.67	Specific HQ max (100%)	6.21
Exposed Std Dev	0.58		
Exposed Rep	3		

Level of hazard for bioassays

ABSENT

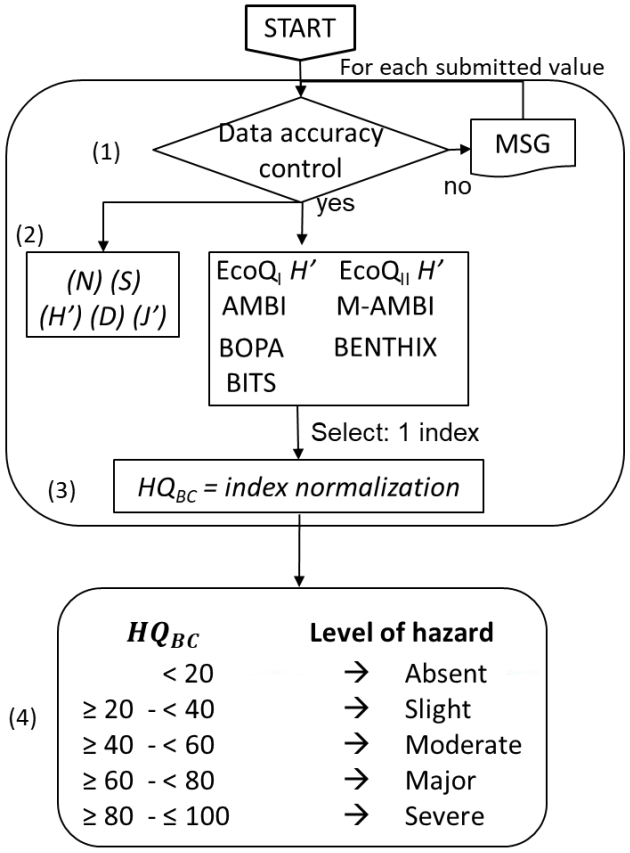
HQ Battery (Scale 1:10)	0.6
N. Bioassays	3
HQ Battery	2.16
Battery HQ threshold	3.4
Battery HQ max	22.26
% elutriate	100

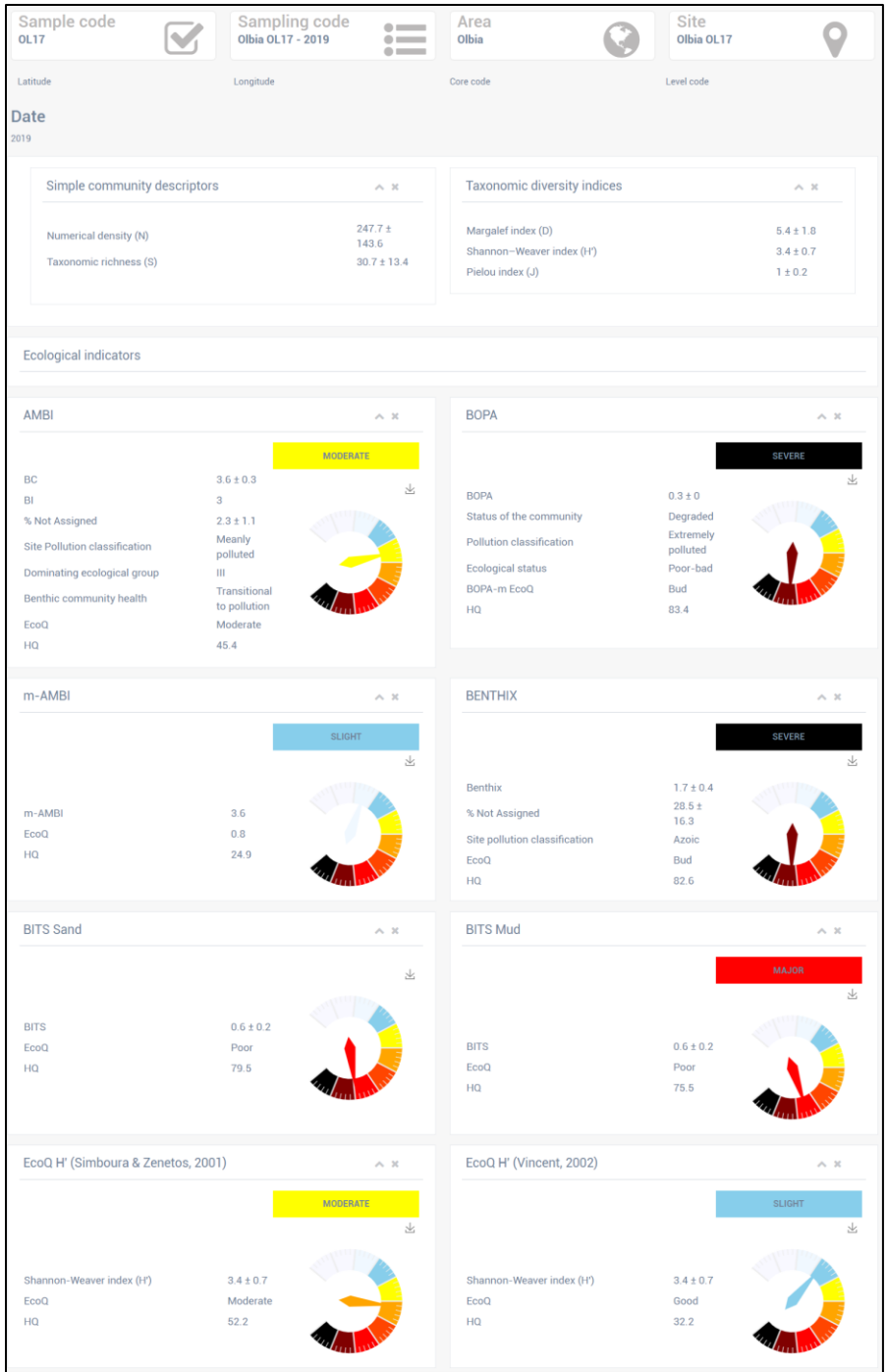


Elaboration and data output

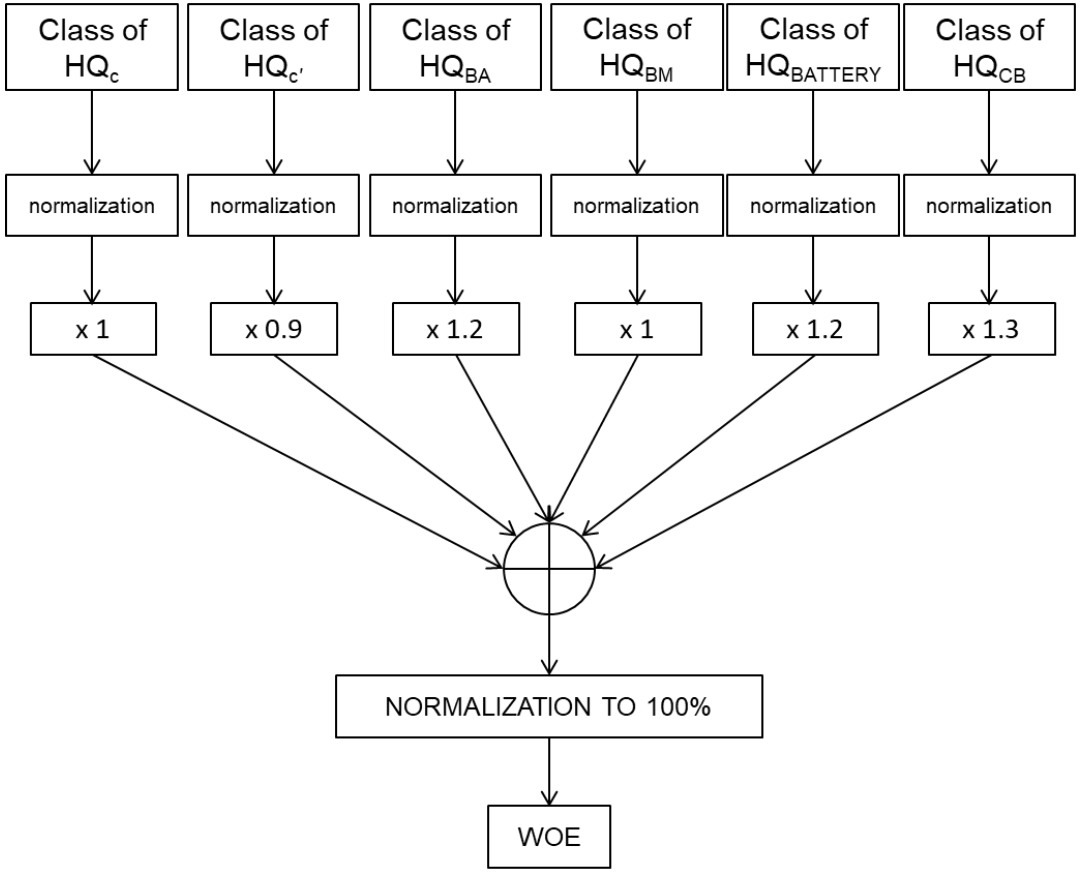
LOE 6 Benthic communities

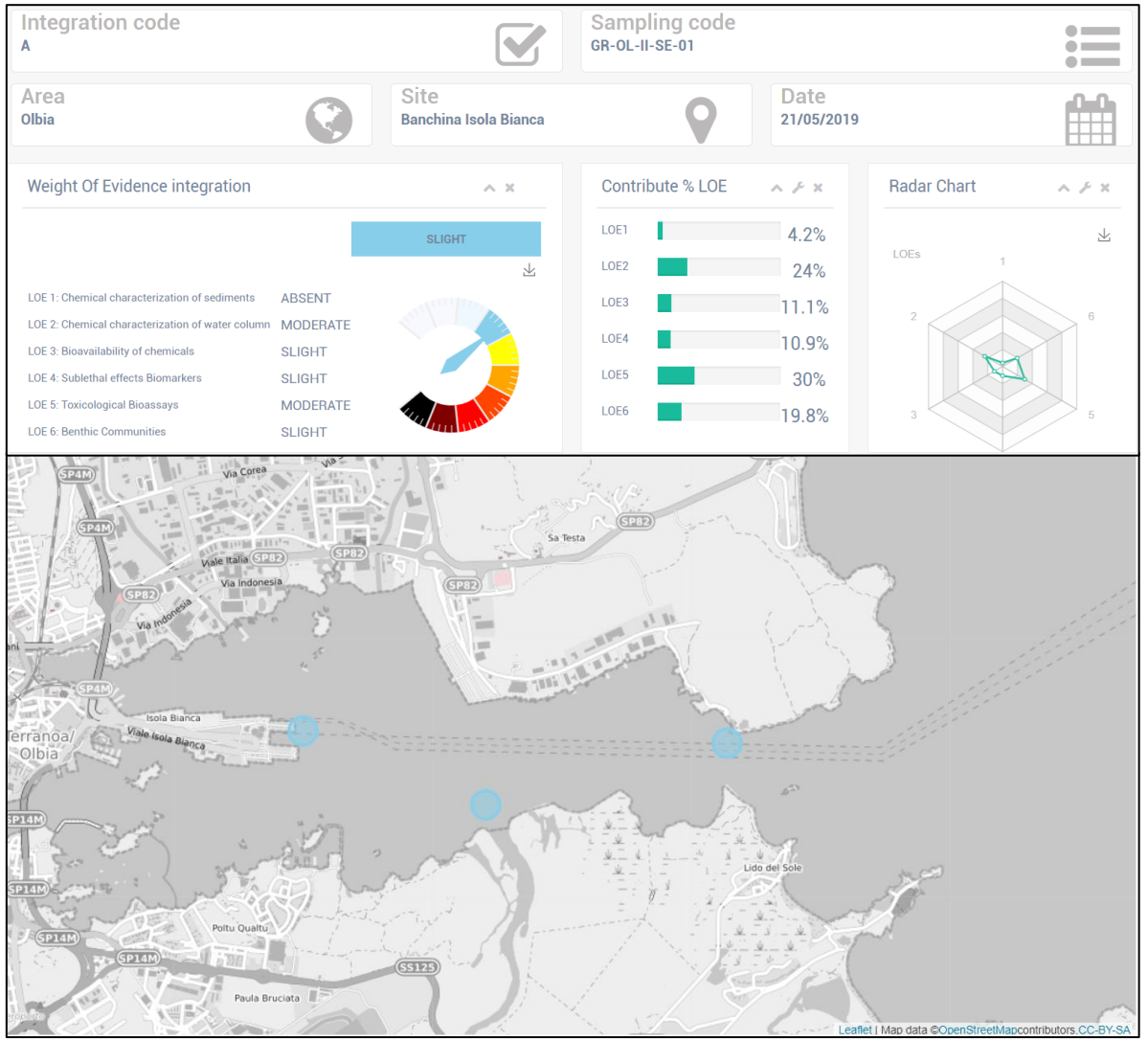
ID	Latitude	Longitude	Area_code	Site_code	Sampling_date	Sampling_code	Core_code	Core_level	Sample_code	Note	Immagine	Phylum	Class	Genus	Species	Family	abb
1			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Anellida	Polichaeta		Ampharete acutifrons	Ampharetidae	17,2
2			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Anellida	Polichaeta		Aricidea albatrossae	Paraonidae	17,2
3			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Anellida	Polichaeta		Cirratulus sp.	Cirratulidae	17,2
4			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Anellida	Polichaeta		Glycera sp.	Glyceridae	17,2
5			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Anellida	Polichaeta		Hesionidae	Hesionidae	17,2
6			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Anellida	Polichaeta		Levinsenia sp.	Paraonidae	120,7
7			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Anellida	Polichaeta		Marphysa bellii	Eunicidae	17,2
8			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Anellida	Polichaeta		Notomastus latericeus	Capitellidae	17,2
9			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Anellida	Polichaeta		Orbinia sp.	Orbiniidae	51,7
10			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Anellida	Polichaeta		Paralacydonia paradoxa	Paralacydoniidae	17,2
11			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Antropoda	Crustacea	Ostracoda	Ostracoda		17,2
12			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Antropoda	Crustacea	Tainadacea	Leptochelia savignyi	Leptochelliidae	17,2
13			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Echinodermata	Holoturidea		Myriotrochus sp.	Myriotrochidae	17,2
14			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Mollusca	Bivalvia		Parvicardium minimum	Cardiidae	17,2
15			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Mollusca			Dosinia lupinus	Veneridae	17,2
16			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Mollusca			Loripes lacteus	Lucinidae	34,5
17			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Mollusca			Mysella bidentata	Montacutidae	17,2
18			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Mollusca			Kellia suborbicularis	Kelliidae	17,2
19			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Nematoda			Nematoda		137,9
20			Adriatic	BARBARA C - BONACCIA	05/08/2010	piatt-eni-08	1	1	AM537_01			Prialupida			Priapulus sp.	Priapulidae	34,5





Integration of various LOEs into WOE and class of Risk





Conclusions

- ***Importance of multidisciplinary WOE approach for characterizing environmental quality and risk assessment***

- ***WOE models represent a fundamental tool for summarizing and interpreting large datasets of heterogeneous data, singularly or in an integrative approach***

- ***They do not use "pass-to-fail" approach, enhancing the capability to discriminate different environmental conditions***

- ***The developed model is versatile, easy to update or adapt to local or national specificities***

- ***Scientifically sound but user-friendly format, to support a more comprehensive process of risk assessment and "site-oriented" management decisions***

Thanks for the attention

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