

Sediment quality classification based on Weight of Evidence approach in the recent Italian regulation



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Environment Ministry Decree n. 173/2016

The Decree of Italian Ministry of Environment n. 173/2016 entered into force on 21 September 2016:

- updates technical procedures on how to apply for a dumping permit for dredging sediments originating from marine and brackish waters or from reclaimed coastal lands;
- the technical Annex establishes criteria and methodological procedures for dredging sediment characterization, their classification and identification of appropriate management options and monitoring.

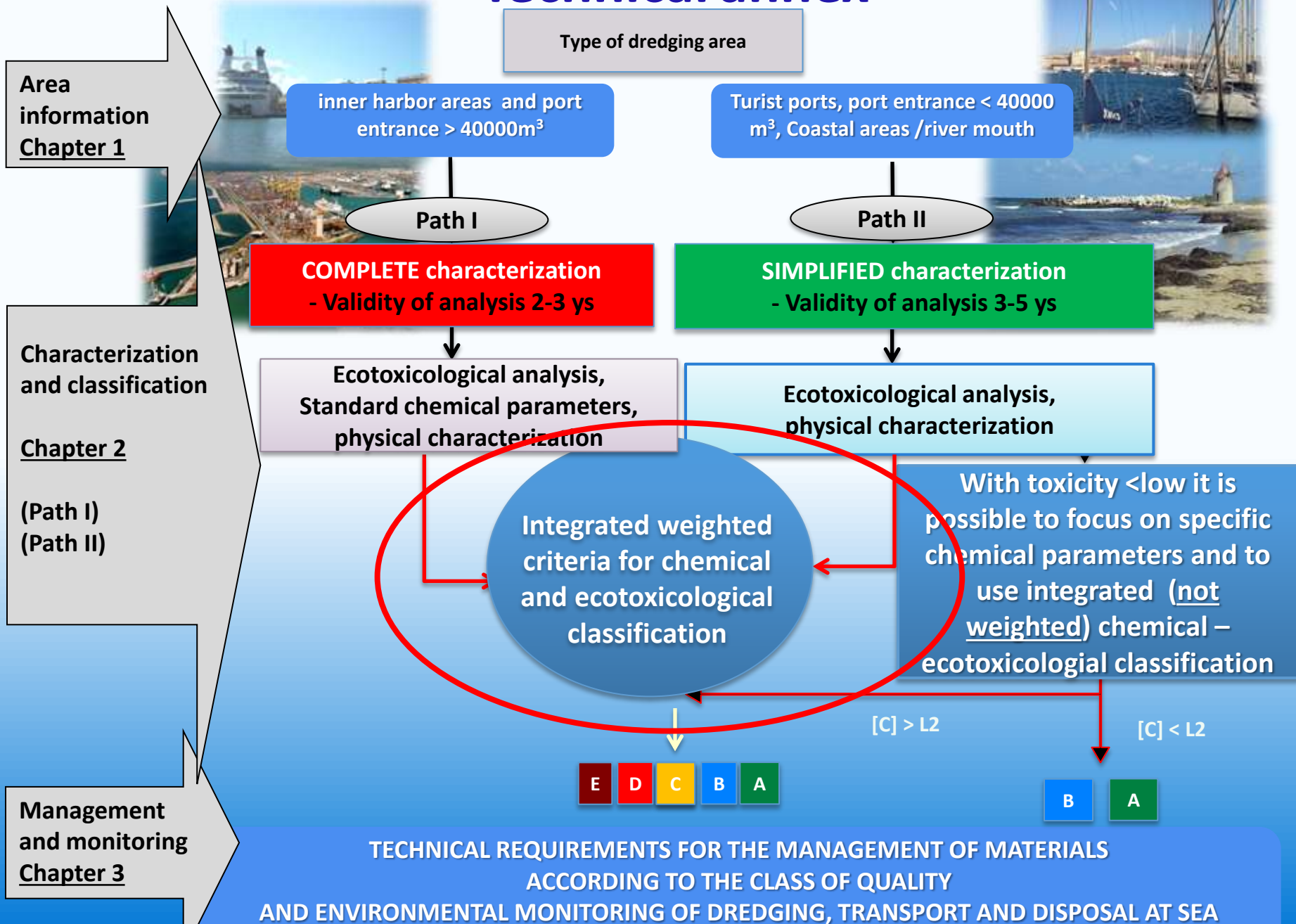


Main novelties

- **Detailed description (present and previous information) of the characteristic of the dredging area;**
- **Sampling strategy according to different areas:** more detailed where the risk of contamination is higher (the docks of a great industrial port) and way simpler where contamination is presumably lower (i.e. recreational beach);
- **Weight of Evidence (WOE) approach for hazard assessment;**
- **Priority role of ecotoxicology (characterization and monitoring)**
- **5 sediment quality classes and corresponding environmental management options.**

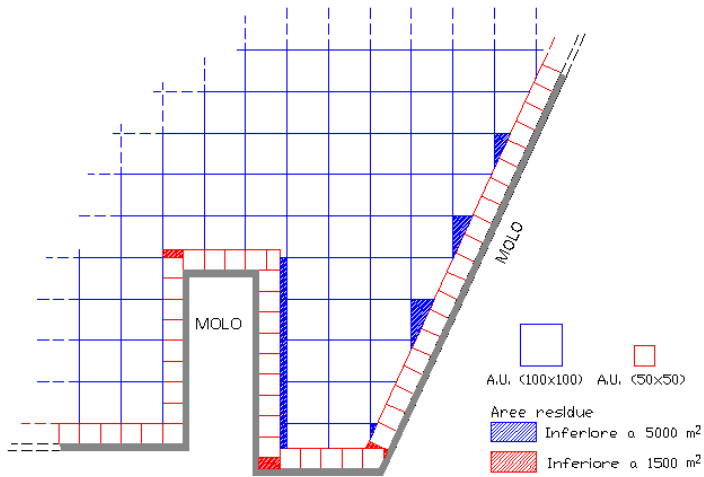


Technical annex

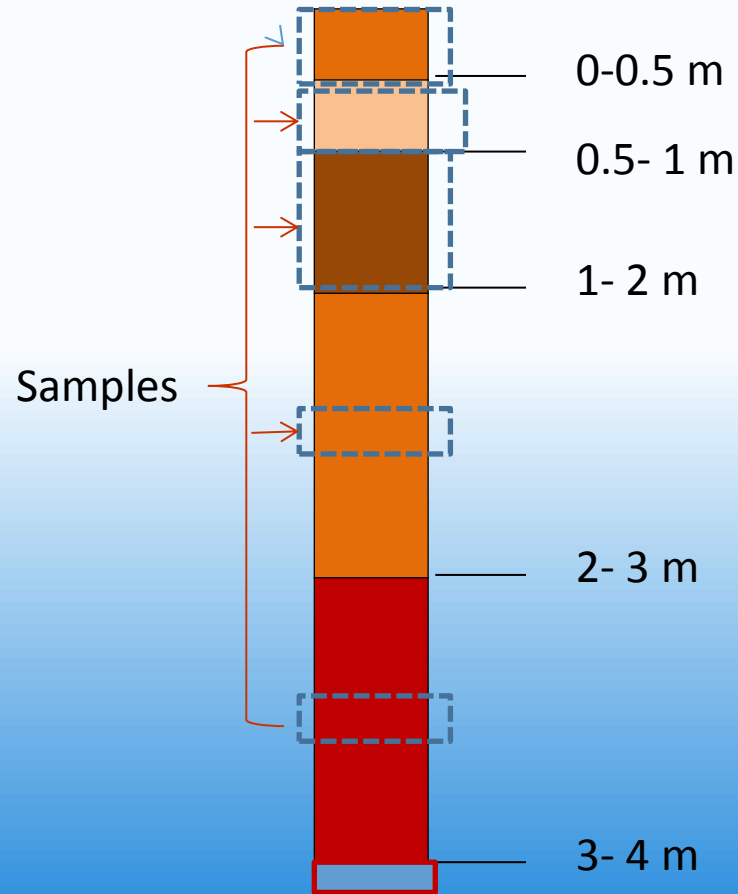


Sampling Strategy

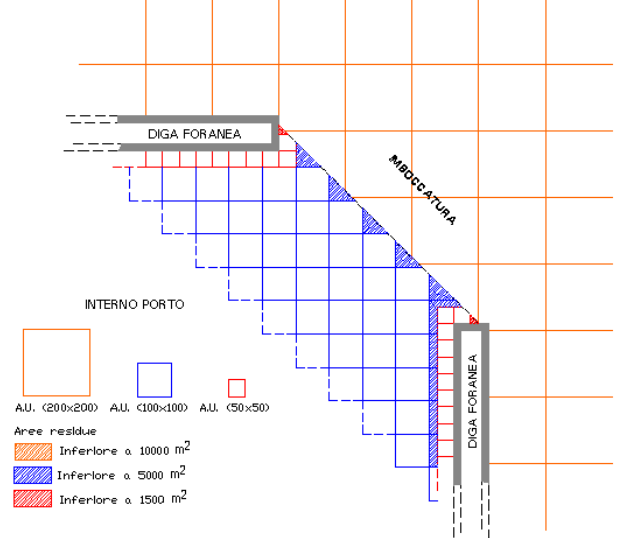
Inner harbour



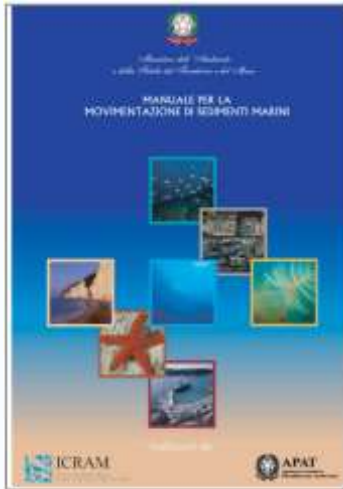
Core sampling: ex.4.15 m to be dredged



Port entrance



From pass-fail/worst result approach to integrated weight of evidence (WOE) criteria

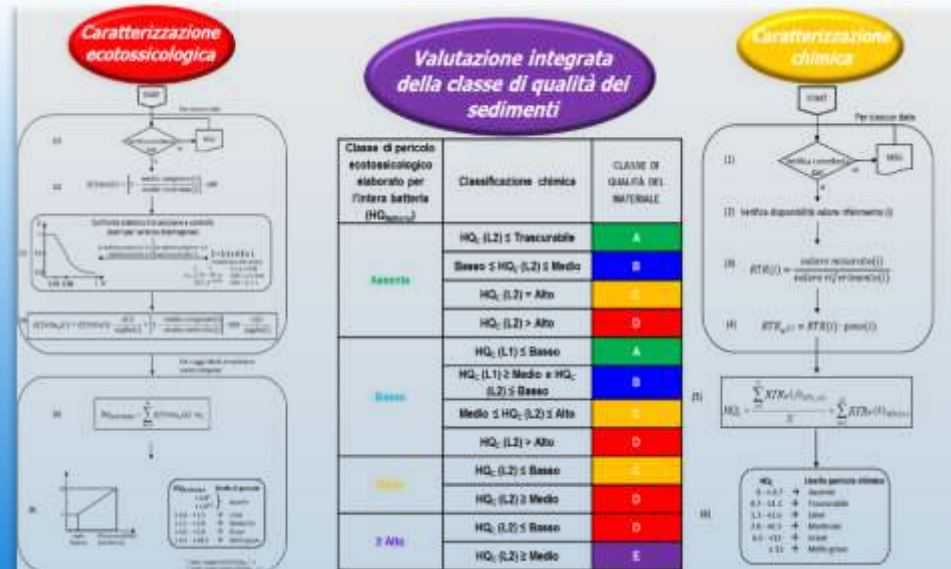


Chemical classification was determined by at least one parameter exceeding the threshold level

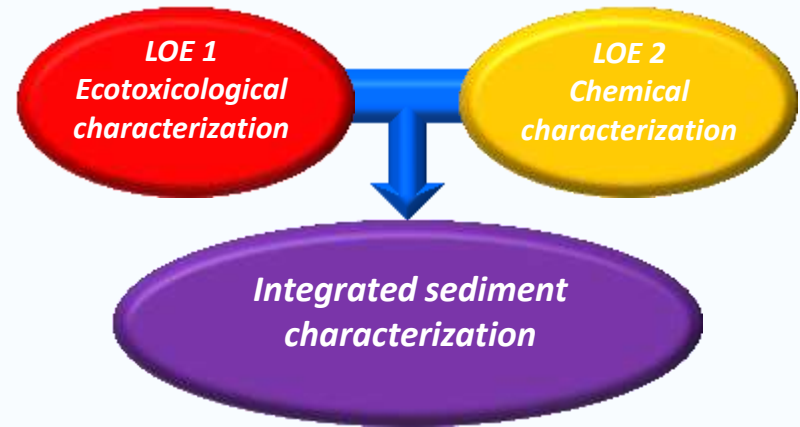
Ecotoxicological classification was determined by the worst bioassay result of the whole battery.



Chemistry	Ecotoxicology		Quality class
	Column	Tox elutriate	
≤ LCB	A	n.c.	A1
	A	n.c.	A2
	B	n.c.	B1
	C	absent	B2
	C	≥ Column C	B2
	D	absent	C1
LCB < C < LCL	D	= Column D	C1
	A	n.c.	A2
	B	absent	B1
	B	= Column B	B2
≥ LCL	C	n.c.	B2
	C	absent	C1
	C	= Column C	C1
	D	n.c.	C2



Integrated Characterization and weighted approach for sediment quality assessment



Ecotoxicological hazard	Chemical hazard	Quality classes
Absent	$HQ_C (L2) \leq \text{Negligible}$	A
	$\text{Slight} \leq HQ_C (L2) \leq \text{Moderate}$	B
	$HQ_C (L2) = \text{High}$	C
	$HQ_C (L2) > \text{High}$	D
Slight	$HQ_C (L1) \leq \text{Slight}$	A
	$HQ_C (L1) \geq \text{Moderate}$ and $HQ_C (L2) \leq \text{Slight}$	B
	$\text{Moderate} \leq HQ_C (L2) \leq \text{High}$	C
	$HQ_C (L2) > \text{High}$	D
Moderate	$HQ_C (L2) \leq \text{Slight}$	C
	$HQ_C (L2) \geq \text{Moderate}$	D
$\geq \text{High}$	$HQ_C (L2) \leq \text{Slight}$	D
	$HQ_C (L2) \geq \text{Moderate}$	E

Criteria for choosing the bioassay battery

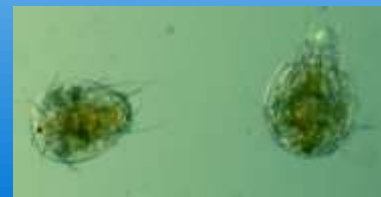
The bioassay battery should include at least three bioassays with three different species, as follows:

1st type: a bioassay on the solid phase;

2nd type: a bioassay on the liquid phase (pore water or elutriate);

3rd type: a bioassay with chronic/sub lethal/long term effects, with proved high sensitivity

	Bacteria		Algae	Crustaceans					Mollusks		Echinoderms		
Specie	<i>Vibrio fischeri</i>		<i>Dunaliella tertiolecta</i> <i>Pheodactylum tricornutum</i> <i>Skeletonema costatum</i>	<i>Amphibalanus amphitrite</i>	<i>Corophium</i> spp	<i>Acartia tonsa</i>		<i>Tigriopus fulvus</i>	<i>Crassostrea gigas</i>	<i>Mytilus gloprovincialis</i>	<i>Paracentrotus lividus</i>		
Matrix	Liquid phase	Solid phase	Liquid phase	Liquid phase	Whole sediment	Liquid phase	Whole sediment	Liquid phase	Liquid phase	Liquid phase	Liquid phase		
Endpoint	Bioluminescence		Algal growth	Mortality	Mortality	Mort (48 h)	Mor (7 gg)	Larval development	Mortality	Larval development	Larval development	Fertilization	Larval development
1 st type		XA			XA			XC					
2 nd type	XA		XC	XA		XA			XA			XA	
3 rd type							XC			XC	XC		XC



XA: ACUTE TEST

XC: CHRONIC TEST

Chemical threshold levels

	L1	L2
Trace elements	[mg kg⁻¹] dry weight	
Arsenic	12	20
Cadmium	0.3	0.8
Chromium	50	150
Chromium VI	2	2
Copper	40	52
Mercury	0.3	0.8
Nickel	30	75
Lead	30	70
Zinc	100	150
Organic contaminants	[µg kg⁻¹] dry weight	
Organotin compounds	5 (TBT)	72(ΣMBT, DBT, TBT)
Σ PCB*	8	60
Σ 2,4'- 4,4' DDD	0.8	7.8
Σ 2,4'- 4,4' DDE	1.8	3.7
Σ 2,4'- 4,4' DDT	1.0	4.8
Chlordane	2.3	4.8
Aldrin	0.2	10
Dieldrin	0.7	4.3
Endrin	2.7	10
a-HCH	0.2	10
b-HCH	0.2	10
γ-HCH (Lindane)	0.2	1.0
Heptachlor epoxide	0.6	2.7
HCB	0.4	50
Petroleum Hydrocarbon C>12	Not available	50000
ΣPAHs16	900	4000
Anthracene	24	245
Benzo[a]anthracene	75	500
Benzo[a]pyrene	30	100
Benzo[b]fluoranthene	40	500
Benzo[k]fluoranthene	20	500
Benzo[g,h,i]perylene	55	100
Crysene	108	846
Indenopyrene	70	100
Phenantrene	87	544
Fluorene	21	144
Fluoranthene	110	1494
Naphtalene	35	391
Pyrene	153	1398
Σ T.E. PCDD,PCDF and Dioxin Like PCBs	2 x 10 ⁻³	1 x 10 ⁻²

* sum of CB: 28, 52, 77, 81, 101, 118, 126, 128, 138, 153, 156, 169, 180.

Integrated weighted criteria: Chemistry LOE







Evaluation of chemical hazard (HQ_C) based on the number of parameters exceeding thresholds L1 and L2, the magnitude of such exceedances and type of contaminant (Priority or Priority Hazardous substances, according to Annex II of Directive 2008/105/EC).

- Ratio to (L1 and L2) reference (RTR);
- Adjustment according with contaminant type;
- Calculation of mean of RTRs < 1 ;
- Calculation of sum of RTRs > 1 ;
- Calculation of Hazard Quotient (HQ);
- Determination of corresponding class of hazard.






$$HQ_C = \frac{\sum_{j=1}^N RTR_W(j)_{RTR(j) \leq 1}}{N} + \sum_{k=1}^M RTR_W(k)_{RTR(k) > 1}$$


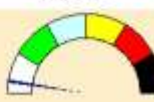
CLASS OF HAZARD

HQ values =

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	

Caratterizzazione chimica dei sedimenti

Latitudine	44° 2.033'N	Dettagli report	
Longitudine	10° 2.706'E		
Area	Porto di Marina di Carrara	<input type="button" value="N"/> <input type="button" value="←"/> <input type="button" value="→"/> <input type="button" value="E"/>	
Sito			<input type="button" value="Chiudi"/>
Data	27/02/2015	<input type="button" value="X"/> Elimina elaborazione	
Cod. Campionamento	MC1-A	Lista report	
Cod. Carota	MC1		
Livello	A (0-50)		
Cod. Campione	MC1/0-50		
Note	15LA08843		

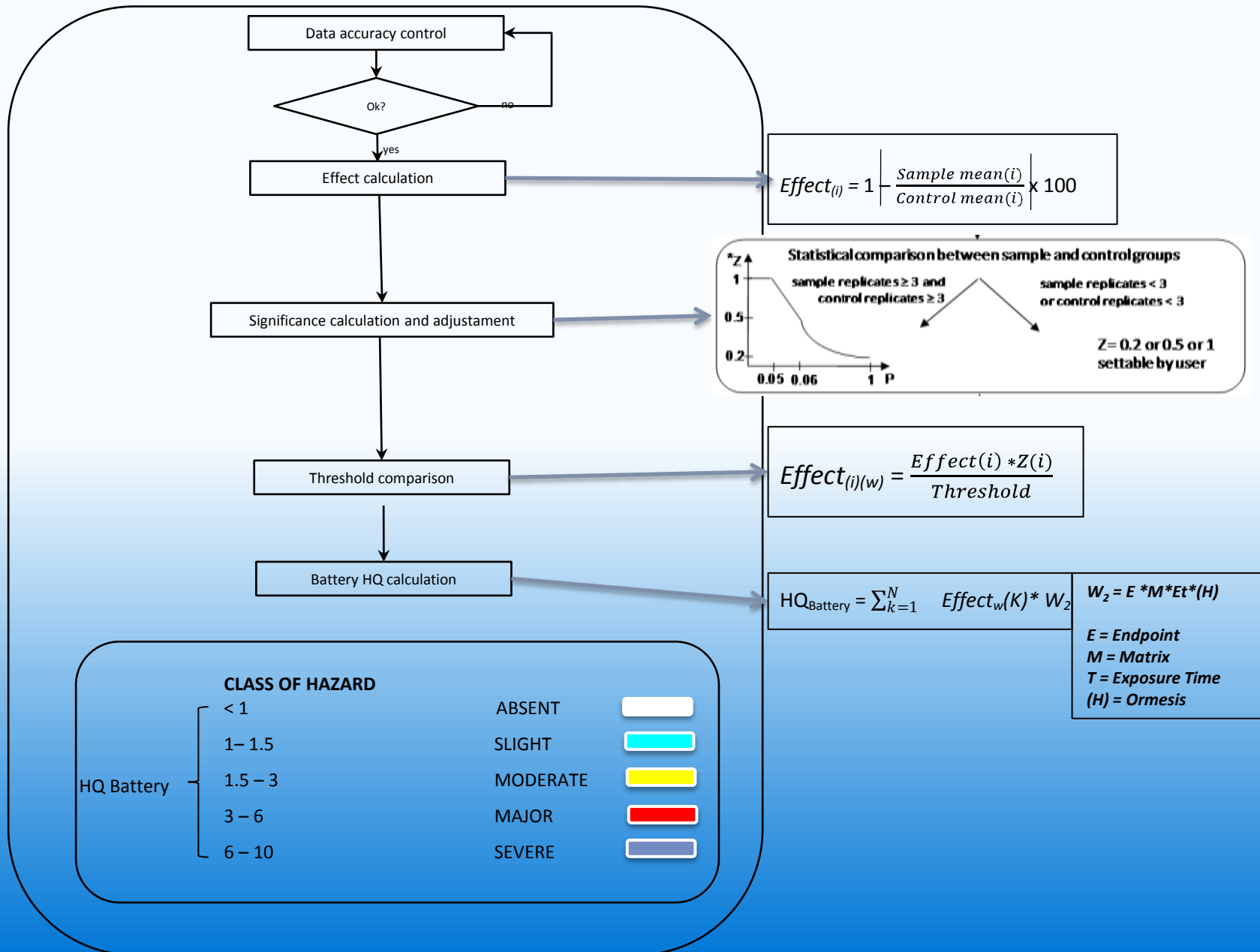
	L1	L2
Indice HQc	6,226	0,172
Max % contr a HQc	34,6% (Somma PCB)	0% (Somma PCB)
N° param. non conformi	4	0
N° param. con riferimento	26	22
N° param. analizzati	42	42
Classe di gravità del pericolo	MEDIO	ASSENTE
		

Integrated weighted criteria: Bioassay LOE

The results of ecotoxicological analyses are assessed as a whole at the level of "battery" (not of single bioassay), weighting the biological relevance of the measured effects (end-point), the statistical significance of measured results, the assay conditions in terms of tested matrix and duration of exposure.

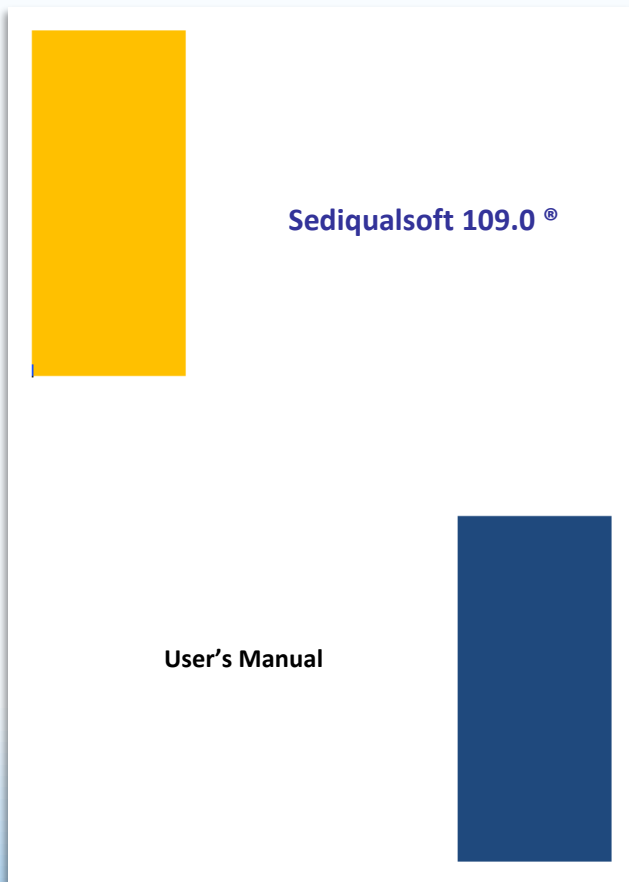
ENDPOINT	(E)	MATRIX	(M)
Fertilization	1.5	Whole sediment	1
Development	1.9	Interstitial water	0.8
Algal growth	2.1	Elutriate	0.7
Bioluminescence	2.4	Wet sediment	0.6
Mortality	3		
EXPOSURE TIME	(T)	HORMESIS	(E_w)
acute	1	$E \leq 40\%$	0
		$40 < E \leq 100\%$	1.25
chronic	0.7	$E > 100\%$	1.5

Integrated weighted criteria: Bioassay LOE



Software-assisted tool

WOE integration



Valutazione integrata della classe di qualità dei sedimenti

Caratterizzazione ecotossicologica	Caratterizzazione chimica
Inserimento e elaborazione dati	Inserimento dati e elaborazione dati
Risultati	Classificazione
Dettaglio risultati	Risultati
	Dettaglio risultati
Classificazione di qualità dei materiali di escavo	Livelli chimici di riferimento
Classificazione	Inserimento e modifica riferimenti locali
Risultati integrazione manuale	
Risultati integrazione automatica	

Crediti Chiudi applicazione

Ideato e realizzato da:

	Università Politecnica delle Marche Dipartimento di Scienze della Vita e dell'Ambiente - Ancona Prof. Francesco Regoli Dott. Giuseppe d'Errico
	Istituto Superiore per la Protezione e la Ricerca Ambientale Dott. Fulvio Onorati Dott. David Pellegrini

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- Environmental agencies
- Governing bodies
- University and Research Institutions
- Private labs & companies

Integration of chemical – ecotoxicological data

Specie:	Phaeodactylum_tricorutum	Media controllo:	467106,7
Durata esposizione:	Chemic	Dev. di controllo:	20818,48
Matrice:	Eutriata	N. repliche controllo:	3
Fittopente:	Growth	Media campione:	519851,3
Nota:		Dev. di campione:	13020,33
		N. repliche campione:	3

Caratterizzazione ecotossicologica dei sedimenti

ID: 1

Specie: **Paracentrotus lividus**

Effetto: **1** %

Effetto peso: 0

Effetto * z: 0 %

HQ (specifico): 0

Soglia HQ (specifico): 0,33 (10%)

Max HQ (specifico): 6,31 (100%)

RISULTATI BATTERIA DEI SAGGI

N. SAGGI: 1

HQ batteria: 0,18

Soglia HQ Batteria: 2,71

Max HQ Batteria: 16,09

% Tossicità elutriata: 100

Classe di gravità del pericolo ecotossicologico: **ASSENTE**

Caratterizzazione ecotossicologica dei sedimenti

Area	Sito	Cod. Campione	Campionamento	Specie	HQ (somma HQ)	HQ Batteria	Classe di gravità del pericolo ecotossicologico
Triapani	Porto di Triapani	TP1A	Triapani_2014	Paracentrotus lividus	0	0,07	ASSENTE
				Phaeodactylum_tricorutum	0,18		
				Vibrio_fischeri	0		
Triapani	Porto di Triapani	TP2B	Triapani_2014	Paracentrotus lividus	2,26	0,84	ASSENTE
				Phaeodactylum_tricorutum	0		
				Vibrio_fischeri	0		
Triapani	Porto di Triapani	TP1C	Triapani_2014	Paracentrotus lividus	0	0	ASSENTE
				Phaeodactylum_tricorutum	0		
				Vibrio_fischeri	0		
Triapani	Porto di Triapani	TP1D	Triapani_2014	Paracentrotus lividus	0	0,05	ASSENTE
				Phaeodactylum_tricorutum	0,04		
				Vibrio_fischeri	0		

Caratterizzazione chimica dei sedimenti

Cod. Campione	L1	L2
MC1/0-50	MEDIO	ASSENTE
MC1/100-150	MEDIO	ASSENTE
MC1/100-200	MEDIO	ASSENTE
MC1/150-200	MEDIO	ASSENTE
MC10/0-50	MEDIO	ASSENTE
MC10/100-150	MEDIO	ASSENTE
MC10/100-200	MEDIO	ASSENTE
MC10/150-200	MEDIO	ASSENTE
MC11/0-50	ALTO	ASSENTE
MC11/100-150	MEDIO	ASSENTE
MC11/100-200	MEDIO	ASSENTE
MC11/150-200	MEDIO	ASSENTE
MC12/0-50	ALTO	ASSENTE
MC12/100-150	MEDIO	ASSENTE

Caratterizzazione chimica dei sedimenti

Nota: 15LA0887

Indice HQ1: 2,519

Max % contr a HQ: 34,6% (IN)

N° param. non conformi: 2

N° param. con riferimento: 26

N° param. analizzati: 42

Classe di gravità del pericolo: **BASSO**

Caratterizzazione chimica dei sedimenti

Latitudine: 44° 2.033'N

Longitudine: 10° 2.706'E

Area: Porto di Marina di Carrara

Sito:

Data: 27/02/2015

Cod. Campionamento: MC1-A

Cod. Carota: MC1

Livello: A (0-50)

Cod. Campione: MC1/0-50

Nota: 15LA08843

Indice HQc: 6,226

Max % contr a HQc: 34,6% (Somma PCB)

N° param. non conformi: 4

N° param. con riferimento: 26

N° param. analizzati: 42

Classe di gravità del pericolo: **MEDIO**

WOE integration: sediment quality assessment

Valutazione integrata della classe di qualità dei sedimenti

Caratterizzazione ecotossicologica

Inserimento e elaborazione dati

Risultati

Dettaglio risultati

Classificazione di qualità dei materiali di escavo

Classificazione

Risultati integrazione manuale

Risultati integrazione automatica

Caratterizzazione chimica

Inserimento dati e elaborazione dati

Classificazione

Risultati

Dettaglio risultati

Livelli chimici di riferimento

Inserimento e modifica riferimenti locali

Integrazione manuale

Integrazione automatica

Chiudi

Estratto_LOE1

ID	Area_code	Site_code	Sampling_code	Sample_code	Clicca se da integrare
Trapani	Porto di Trapani	Trapani_2014	TP7A		<input type="checkbox"/>
Trapani	Porto di Trapani	Trapani_2014	TP7B		<input type="checkbox"/>
Trapani	Porto di Trapani	Trapani_2014	TP7C		<input type="checkbox"/>
Trapani	Porto di Trapani	Trapani_2014	TP7D		<input type="checkbox"/>
Trapani	Porto di Trapani	Trapani_2014	TP7E		<input type="checkbox"/>

Apri Chimica

Estratto_LOE2

ID	Area_code	Site_code	Sampling_code	Sample_code	Clicca se da integrare
38	Trapani	Porto di Trapani	Trapani_2014	TP1A	<input type="checkbox"/>
	Trapani	Porto di Trapani	Trapani_2014	TP1B1	<input type="checkbox"/>
	Trapani	Porto di Trapani	Trapani_2014	TP1C	<input type="checkbox"/>
	Trapani	Porto di Trapani	Trapani_2014	TP1D	<input type="checkbox"/>
	Trapani	Porto di Trapani	Trapani_2014	TP1E	<input type="checkbox"/>

Apri Saggi

Integrazione manuale

Classificazione della Classe di Qualità dei sedimenti

Riferimento: Nazionale

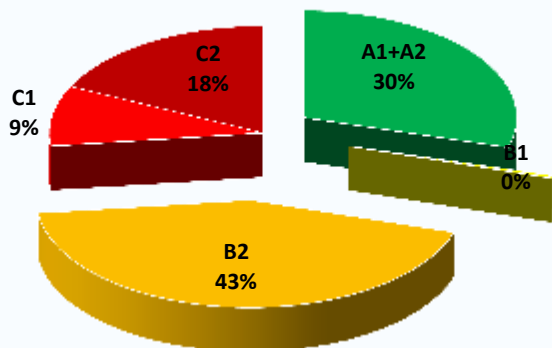
Cod. Campione	Sito	Classificazione chimica	Classe di pericolo ecotossicologico	Classe di qualità del materiale
TP1A	Porto di Trapani	HQc(LCB) <= Basso	ASSENTE	A
TP1B1	Porto di Trapani	HQc(LCL) => Medio	BASSO	C
TP1D	Porto di Trapani	HQc(LCB) >= Medio e HQc(LCL) <= Basso	ASSENTE	A
TP1E	Porto di Trapani	HQc(LCB) >= Medio e HQc(LCL) <= Basso	ASSENTE	A
TP2A	Porto di Trapani	HQc(LCL) => Medio	ASSENTE	C
TP2B	Porto di Trapani	HQc(LCL) => Medio	ASSENTE	C
TP2C	Porto di Trapani	HQc(LCL) => Medio	ASSENTE	C
TP2D	Porto di Trapani	HQc(LCB) <= Basso	ASSENTE	A
TP2E	Porto di Trapani	HQc(LCB) >= Medio e HQc(LCL) <= Basso	ASSENTE	A
TP3A	Porto di Trapani	HQc(LCB) >= Medio e HQc(LCL) <= Basso	ASSENTE	A
TP3B	Porto di Trapani	HQc(LCB) >= Medio e HQc(LCL) <= Basso	ASSENTE	A
TP3C	Porto di Trapani	HQc(LCL) <= Basso	ALTO	D
TP3D	Porto di Trapani	HQc(LCL) <= Basso	ALTO	D
TP3E	Porto di Trapani	HQc(LCL) <= Basso	ALTO	D
TP4A	Porto di Trapani	HQc(LCL) <= Basso	ALTO	D
TP4B	Porto di Trapani	HQc(LCL) >= Medio	ALTO	C

5 sediment Quality Classes

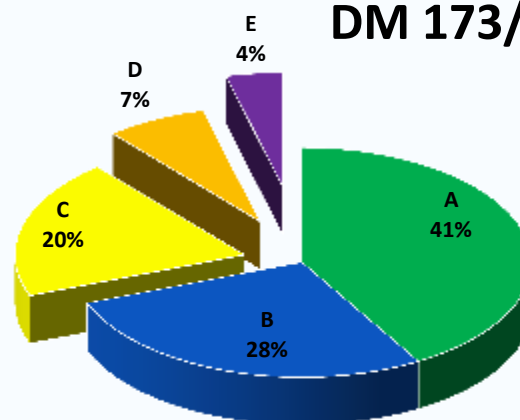
Class	Management Options
A	<p>Sands (fines < 10%) to be used or re-located in the following hierarchy:</p> <ul style="list-style-type: none"> • Beach nourishment; • Reconstruction of natural structures in marine coastal environments including disposal for the restoration of shorelines; • Filling of wharfs and embankments in port areas; • Dumping at sea (more than 3 Nautical Miles); • Disposal in confined facilities.
B	<p>Material to be used or re-located in the following hierarchy:</p> <ul style="list-style-type: none"> • Dumping at sea (more than 3 Nautical Miles) with environmental monitoring; • Disposal in confined facilities, or capping, with environmental monitoring.
C	<ul style="list-style-type: none"> • Disposal in confined facilities able to retain all the grain size fraction of sediment; • Capping, with environmental monitoring.
D	<ul style="list-style-type: none"> • Disposal in completely sealed confined facilities, with environmental monitoring.
E	<ul style="list-style-type: none"> • Material subject to special environmental safety procedures, whose removal and handling must be assessed with ERA procedure.

Comparison of the two classification approaches: 549 samples coming from Italian harbour and coastal areas

Manual ICRAM-APAT 2007

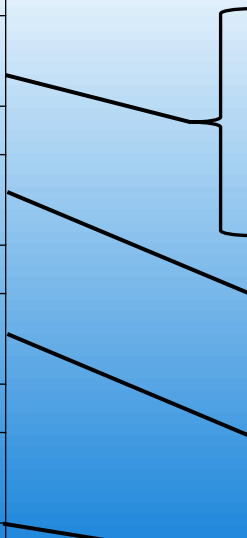


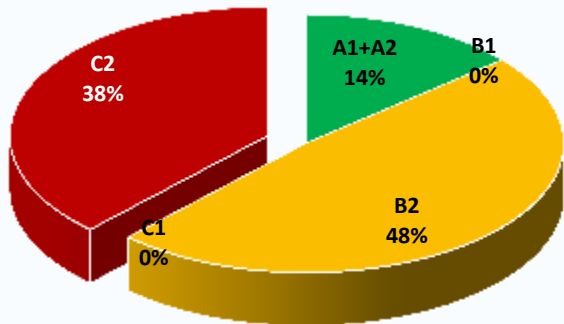
DM 173/2016



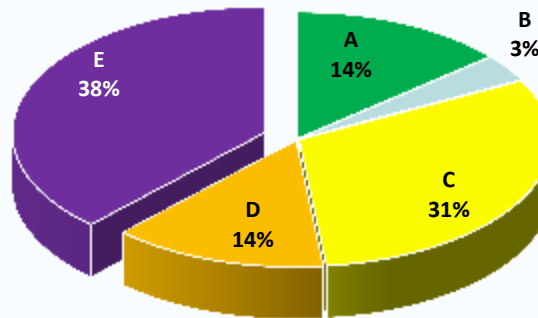
	Manuale ICRAM-APAT 2007
A1+A2	162
B1	2
B2	237
C1	50
C2	98

	DM 173/2016
A	228
B	152
C	108
D	39
E	22

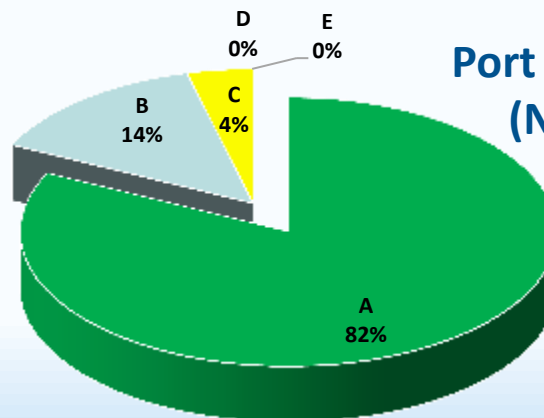
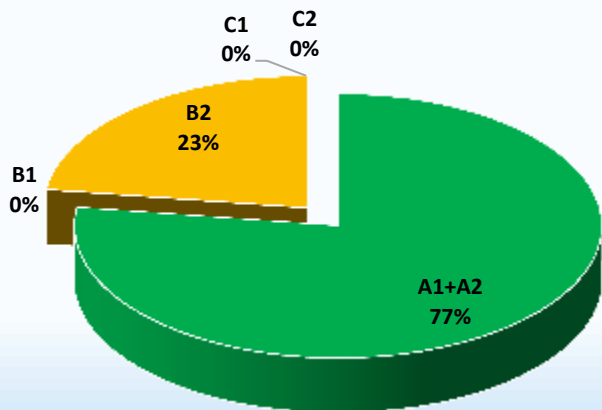




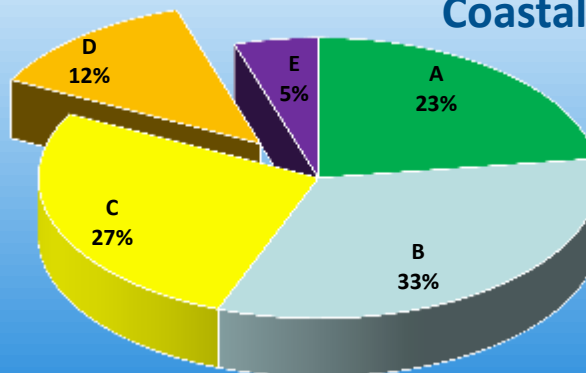
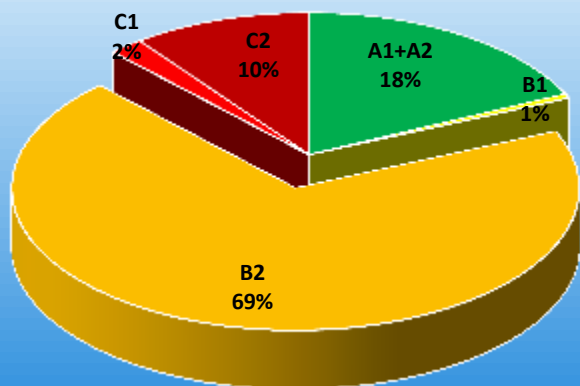
**Port of Cagliari
(Sardinia)**



**Port of Marina di Carrara
(Northern Tuscany)**



**Coastal area of Piombino
(Tuscany)**



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Thanks for your attention!