



Recent Evolution of Sediment Management for Marine Dredging in Italy: Comparison of National Laws, inside the International Frameworks

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Abstract

Marine dredging activities are essential for port operation, navigation safety, coastal resilience and infrastructure development. However, dredging generates significant volumes of sediments requiring appropriate assessment and management strategies to prevent adverse effects on marine ecosystems. During the last decades, sediment management has progressively evolved from disposal-oriented approaches towards integrated frameworks based on environmental risk assessment, precautionary principles and sustainable resource management. The London Convention and London Protocol, together with UNEP-MAP Decision IG.23/12 (*Updated Guidelines on Management of Dredged Materials*), established internationally recognised principles requiring environmental assessment, consideration of alternatives and minimisation of impacts associated with marine disposal. In Italy, DM 173/2016 represented a major regulatory innovation by introducing a harmonised methodology based on the integration of physical, chemical and ecotoxicological information. The updated Technical Annex adopted by the Ministry of Environment and Energy Security (MASE) in 2025 introduces a further evolution towards sustainable sediment management, incorporating site-specific assessment, integrated evaluation approaches and opportunities for beneficial use within circular economy and blue economy strategies. This paper critically analyses the transition between these two regulatory paradigms. Attention is given to the role of ecotoxicology, the scientific basis of sediment classification, the potential implications of methodological changes introduced by the 2025 Annex and the importance of environmental monitoring during dredging operations. The analysis highlights that sustainable sediment management requires a balance between resource valorisation and marine ecosystem protection. The future effectiveness of the Italian framework will depend on maintaining robust ecological risk assessment, adaptive monitoring and transparent decision-making processes.

Keywords: Dredged Sediments; Ecotoxicology; London Protocol; UNEP-MAP Decision IG.23/12; Blue Economy; Environmental Monitoring

Introduction

Marine dredging is a fundamental activity for maintaining navigation channels, ensuring port accessibility,

supporting coastal adaptation strategies and developing maritime infrastructures. Nevertheless, dredging operations may generate environmental pressures associated with sediment disturbance, increased turbidity, resuspension

of contaminated particles and potential mobilisation of pollutants. The management of dredged sediments represents therefore a complex environmental challenge, requiring the integration of scientific knowledge, regulatory principles and operational practices.

Over time, international approaches have progressively moved from a simple disposal-control perspective towards integrated sediment management systems, where dredged material is evaluated according to environmental risk, possible alternatives and potential beneficial uses. The management of dredged sediments in Italy has undergone significant regulatory changes since the Ministerial Decree of 24 January 1996 [1]. This decree established the first systematic technical framework for the characterization and possible disposal of dredged materials at sea, based primarily on their physical and chemical properties and contaminant content. The subsequent Legislative Decree 152/2006 incorporated the management of dredged sediments into the broader Italian environmental regulatory framework. A major development was introduced by Ministerial Decree No. 173 of 15 July 2016, which established specific technical criteria for the characterization, classification, and management of marine sediments [2]. The 2016 framework integrated chemical analyses with strong ecotoxicological assessments and considered the environmental characteristics of the receiving area. Depending on sediment quality, different management options may be considered, including beneficial use, beach nourishment, confined disposal, or marine disposal. The technical framework was further updated by the Italian Ministry of Environment and Energy Security in December 2025, with the revised provisions becoming applicable from 14 February 2026. Overall, the regulatory evolution reflects a shift from contaminant-based assessment towards an integrated, risk-based approach to sustainable sediment management.

The objective of this paper is to analyse the evolution of the Italian regulatory framework, comparing the original Technical Annex to Ministerial Decree (DM) 173/2016 with the updated MASE (Ministry of Environment and Energetical Safety) Technical Annex of 2025, within the broader context of international requirements established by the London Protocol and UNEP-MAP Decision IG.23/12 [3-5].

The paper also discusses the fundamental, over time, scientific contribution of ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale, former ICRAM) in developing the technical basis for sediment management in Italy, with particular emphasis on ecotoxicology, physical modelling and environmental monitoring [6].

International Regulatory Framework

London Convention and London Protocol principles

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention, 1972) represented one of the first international instruments addressing marine pollution caused by disposal activities.

The 1996 London Protocol introduced a more precautionary approach, establishing that marine disposal should only be authorised after appropriate assessment of environmental risks and consideration of alternative management options [7].

The Waste Assessment Framework developed under the London Protocol provides a structured methodology for evaluating dredged material based on:

- physical characteristics;
- chemical contamination;
- biological effects;
- potential exposure pathways;
- characteristics of the receiving environment.

The fundamental principle is that disposal at sea should not represent the default option but should be selected only when demonstrated to be environmentally acceptable [8].

UNEP-MAP Decision IG.23/12

Within the Mediterranean region, UNEP-MAP Decision IG.23/12 (2017) [9], "Annex Updated Guidelines on Management of Dredged Materials", strengthened the harmonisation of dredged sediment management approaches by promoting:

- integrated assessment procedures;
- environmental protection measures;
- reduction of marine pollution risks;
- consideration of beneficial use options.

The Mediterranean context is particularly relevant because coastal areas often combine intense maritime activities, urban pressures, historical contamination and limited sediment availability. Consequently, sustainable sediment management requires approaches capable of simultaneously addressing environmental protection and coastal resource management.

Evolution of the Italian Scientific And Regulatory Framework

The Italian approach to dredged sediment management has developed through a progressive scientific pathway involving, primarily, Ministry of Environment and ICRAM

- APAT and ISPRA (Superior Institute for Environmental Protection and Research).

The Ministerial Decree of 24 January 1996

The Italian Ministerial Decree of 24 January 1996 established technical criteria for the management of materials derived from the dredging of marine and brackish-water sediments. The Decree consists of two articles and three technical annexes. Article 1 defines the scope of application and establishes the conditions under which dredged materials may be disposed of at sea. Article 2 sets out the authorization framework and refers to the technical procedures specified in the annexes. The annexes provide the operational criteria for sediment characterization and assessment prior to disposal. These include requirements concerning sampling and analytical investigations, the physical and chemical characterization of dredged materials, and the evaluation of contaminant concentrations. The Decree also establishes criteria for assessing the suitability of dredged materials for marine disposal and identifies materials for which disposal at sea is not permitted. Overall, the structure of the Decree is based on a preliminary characterization of dredged sediments followed by an environmental assessment and an authorization procedure.

The 1996 Italian Ministerial Decree, for the first time, established a technical framework for the characterization and management of dredged marine and brackish sediments prior to their disposal or other forms of relocation. The assessment was not limited exclusively to physical and chemical properties, but could also include microbiological and ecotoxicological characterization, depending on the type and purpose of the intervention. The technical annexes specified requirements for sampling, analytical investigations, sediment characterization, and the assessment of the environmental compatibility of the proposed sediment management option. However, the decree did not provide the integrated sediment classification and ecotoxicological assessment framework subsequently introduced by Ministerial Decree No. 173/2016. Thus, the 1996 framework can be regarded as an early, multidisciplinary approach to sediment characterization, with chemical and physical properties forming a major component of the assessment.

Early Technical and Scientific Foundations: ICRAM and APAT-ICRAM Contributions

The document *Aspetti tecnico-scientifici per la salvaguardia ambientale nelle attività di movimentazione dei fondali marini: Dragaggi Portuali* [10] ICRAM represented one of the first Italian scientific references addressing environmental aspects of port dredging.

- The document highlighted the importance of:

- minimising sediment dispersion;
- controlling turbidity generation;
- preventing contaminant mobilisation;
- implementing environmental surveillance during dredging operations.

These principles were further developed in the *Manuale per la movimentazione di sedimenti marini* (APAT-ICRAM, 2007), which provided a comprehensive framework for sediment characterisation, dredging management and environmental assessment.

Development of Integrated Assessment Approaches

The subsequent development of ISPRA technical guidance progressively introduced additional scientific components. The ISPRA Manual 169/2017 on mathematical modelling of sediment mobilisation processes highlighted the importance of predicting physical effects associated with dredging activities, including sediment resuspension, transport and deposition [11].

This contribution demonstrated that sustainable dredging management requires integration between:

- sediment characterisation;
- numerical modelling;
- field monitoring;
- adaptive operational management.

DM 173/2016: an Integrated Environmental Assessment Approach

The adoption of DM 173/2016 represented a major step forward in the Italian regulation of dredged sediment management. The Technical Annex introduced a nationally harmonised methodology based on the integration of different lines of evidence, including physical, chemical and biological information.

The main objective was to determine the environmental compatibility of dredged sediments through a scientifically based assessment procedure.

A key innovation of DM 173/2016 was the recognition that sediment quality cannot be evaluated exclusively through chemical concentrations. Marine sediments are complex environmental matrices where contaminant bioavailability, sediment characteristics and interactions among pollutants influence ecological effects.

The inclusion of ecotoxicological tests represented an important advancement because biological responses provide information on the actual effects of contaminants

on marine organisms. The contribution of ISPRA as main counsellor on this field for the Ministry of Environment has been fundamental.

Pellegrini, Onorati and Mugnai [12] highlighted the importance of ecotoxicology as a complementary tool to chemical analyses, supporting a more realistic evaluation of ecological risk.

The methodological aspects of biological testing were further developed by ISPRA through the protocol for preparation of elutriate samples and application of biological tests required by the DM 173/2016 Annex [13]. This contribution provided a standardised scientific basis for the implementation of ecotoxicological assessment procedures.

The main strengths of DM 173/2016 can therefore be summarised as:

- integration of chemical and biological evidence;
- precautionary approach;
- recognition of contaminant bioavailability and biological effects;
- improved scientific support for authorisation decisions.

However, practical implementation also highlighted some limitations. The framework was mainly oriented towards sediment classification and environmental acceptability, while broader aspects related to sediment reuse, site-specific management strategies and circular economy principles had a more limited role. Anyway this framework guaranteed the higher overall standard of the level of protection of marine ecosystems and human health, as the prevention principle ever suggests. Furthermore, this system was fully in compliance with international laws (already noted London Protocol and Dumping Protocol of Barcelona Convention – UNEP-MAP, 2017, UNEP/MAP Decision IG.23/12, Water Framework Directive 2000/60/EC, Marine Strategy Framework Directive 2008/56/EC, Waste Framework Directive 2008/98/EC, Environmental Impact Assessment 2011/92/EU, as amended by 2014/52/EU Directive) and common, standard procedures.

The MASE 2025 Technical Annex: Towards Sustainable Sediment Management

The updated Technical Annex adopted by MASE in December 2025 represents an evolution from a sediment quality assessment framework towards a broader sustainable sediment management approach. The new regulatory philosophy aims to combine environmental protection

with the identification of sustainable management options, including beneficial use of suitable sediments.

The main innovations introduced by the updated framework include:

- greater emphasis on site-specific evaluation;
- conceptual site modelling;
- Weight-of-Evidence approaches;
- integration of environmental assessment with management scenarios;
- promotion of sediment reuse within circular economy and blue economy strategies.

This evolution reflects international trends where dredged sediments are increasingly considered potential resources rather than materials requiring disposal, provided that environmental compatibility is demonstrated.

The approach is particularly relevant in coastal environments where sediments may support:

- beach nourishment;
- coastal restoration;
- habitat improvement;
- climate adaptation measures;
- sustainable coastal engineering.

However, the transition towards resource-oriented management requires careful evaluation of the balance between simplification, sustainability objectives and environmental safeguards.

Onorati and Pellegrini [14], in their technical analysis of the new Annex, highlighted the importance of critically evaluating the methodological changes introduced by the updated framework. Focusing the attention, for example, on the reduction of total number and representativeness of samples, (including aggregation new strategies) – that sometimes could go in contrast with the prevision of “Dumping Protocol” of Barcelona convention - on the elimination and scaling down of ecotoxicological analyses, which could create the idea of what ‘seeming’ improvement in sediment quality, not fully and always matched by an adequate level study of materials.

According to the authors, modifications affecting sampling strategies, integrated assessment procedures and the interpretation of ecotoxicological information require careful implementation to ensure that the level of environmental protection achieved by DM 173/2016 will be maintained.

Comparative Analysis

Aspect	DM 173/2016 Technical Annex	MASE 2025 Technical Annex
Regulatory philosophy	Environmental compatibility assessment	Sustainable sediment management
Main objective	Determine sediment acceptability for management options	Identify sustainable management solutions while ensuring compatibility
Assessment basis	Physical, chemical and ecotoxicological characterisation	Integrated risk-based assessment
Role of ecotoxicology	Strong decision-support element	Maintained within Weight-of-Evidence framework
Site-specific approach	Present but limited	Increased relevance
Conceptual modelling	Not central	Explicitly introduced
Sediment reuse	Possible	Strategic objective
Circular economy	Considered	Strong integration
Main advantage	High precautionary level of environmental and human health protection	Greater flexibility and sustainability orientation
Main challenge	May restrict some reuse opportunities	Need to ensure that simplification does not reduce environmental and health safeguards

Table 1: DM 173/2016 versus MASE 2025 Technical Annex

Ecotoxicology in the Transition from DM 173/2016 to MASE 2025

Ecotoxicology represents one of the key elements connecting the previous and updated regulatory approaches.

The scientific rationale behind biological testing is that chemical contamination alone does not always provide a complete indication of ecological risk. Sediments may contain complex mixtures of contaminants whose effects depend on environmental conditions, bioavailability and interactions among substances.

The application of biological tests under DM 173/2016 was supported by ISPRA methodological developments, including the standardisation of elutriate preparation procedures and biological response evaluation [13]. The importance of maintaining a scientifically robust ecotoxicological framework is particularly relevant in light of recent discussions regarding the updated regulatory approach.

Onorati and d' Errico analysed the potential implications of changes in the weighting assigned to the "third" species - embryonic-larval development - of ecotoxicological batteries, within the weighted integration of biological tests; in fact, the new Technical Annex reduces its weighting from 1.9 to 1.2, thereby decreasing the influence of one of the most sensitive tests. So, in a simulation involving 443 sediment

samples, this change resulted in an average 28% reduction in the ecotoxicological HQ and an improvement in the classification of approximately 26% of the samples (moving, even, from BAD to FAIR, eg: Class D vs. Class B). Therefore, the same sediment and the same biological response may be classified as less hazardous because the integration algorithm has changed, rather than because the sediment itself has actually improved.

Furthermore, the new test battery restricts the choice of test organisms: the 2025 MASE Technical Annex removes crustaceans (entire taxonomic group (!)) from the list of test organisms included in the third type of ecotoxicological batteries (including, for example, *Acartia tonsa*, *Amphibalanus amphitrite*, *Corophium* spp. and *Tigriopus fulvus*, previously all admitted). Modifications in the integration algorithm may influence the final interpretation of sediment quality and should therefore be supported by strong scientific validation.

So, we can consider that any future implementation of the MASE 2025 Annex should ensure that ecotoxicological evidence remains a fundamental component of environmental decision-making and will be not reduced to a secondary parameter. Even in the pre and post dredging monitoring system, maintaining an equivalent level of - overall - environmental protection, having regard to all species of marine organisms, on which dredging operations could collide on.

Sediment Valorisation, Circular Economy and Blue Economy Perspectives

The promotion of sediment beneficial use is one of the most significant changes associated with the updated regulatory framework. The valorisation of suitable sediments may provide environmental and socio-economic benefits by reducing disposal needs and supporting coastal management strategies.

The application of these principles has already been investigated in Italian coastal environments. Onorati, Pellegrini and Macchia [9] presented a case study concerning the valorisation of coastal sediments in Tuscany, demonstrating the potential integration between ecotoxicological evaluation and sustainable sediment reuse.

However, sediment reuse must always remain conditional on environmental compatibility. Circular economy objectives should not replace ecological risk assessment but should be implemented after environmental safety has been demonstrated.

The fundamental regulatory sequence should therefore remain:

- Assessment of environmental acceptability;
- Identification of the most sustainable management option.

This principle could be consistent with the precautionary approach established by the London Protocol and UNEP-MAP guidelines.

Environmental Monitoring During Dredging: Towards Adaptive Management

One of the key elements for the successful implementation of the MASE 2025 Technical Annex will be the strengthening of environmental monitoring during dredging operations. Sediment characterisation performed before dredging provides essential information regarding sediment quality, but it represents a static evaluation of a dynamic process. During dredging activities, physical disturbance of sediments may cause changes in suspended solids concentrations, turbidity, contaminant mobilisation and potential effects on marine organisms. For this reason, monitoring should not be considered only as a post-authorisation compliance requirement, but as an active component of adaptive environmental management.

A comprehensive monitoring strategy should be designed according to site-specific characteristics and potential environmental risks and may include:

- turbidity and suspended solids measurements;

- water column quality parameters;
- assessment of contaminant mobilisation where relevant;
- biological indicators in sensitive environments;
- verification of mitigation measures effectiveness.

The scientific basis for this approach has been progressively developed in Italy through ICRAM and ISPRA contributions. The ICRAM [10] document on environmental safeguards during port dredging already identified the need to control sediment dispersion and minimise environmental impacts during dredging activities.

Similarly, the APAT-ICRAM Manual for Marine Sediment Handling [15] emphasised the importance of integrated sediment management and monitoring procedures. The ISPRA Manual on mathematical modelling of sediment mobilisation processes further introduced predictive approaches for evaluating physical effects associated with dredging operations [11]. Numerical modelling allows the assessment of sediment resuspension, transport pathways and deposition patterns, supporting the design of monitoring plans and mitigation measures.

Therefore, modern sediment management should integrate:

- predictive modelling;
- field monitoring;
- chemical assessment;
- ecotoxicological evaluation.

This integrated approach is particularly important under the MASE 2025 framework, where increased management flexibility requires stronger environmental verification mechanisms.

Implications for Dredging Projects and Permitting Procedures

The evolution from DM 173/2016 to the MASE 2025 Technical Annex will have significant implications for dredging project planning and authorisation procedures. Future projects will increasingly require:

- early integration of sediment management strategies;
- improved knowledge of historical contamination sources;
- evaluation of alternative management options;
- application of site-specific assessment approaches;
- development of appropriate monitoring programmes.

For Port Authorities and dredging operators, sediment management should no longer be considered a secondary environmental issue but a strategic component of project design.

The increased flexibility offered by the new framework may facilitate sustainable solutions and beneficial use applications. However, risk-based approaches require strong technical capacity and consistent interpretation amongst:

- competent authorities;
- ISPRA and regional environmental agencies (ARPA);
- research institutions;
- laboratories;
- project developers.

A scientifically robust implementation of the MASE 2025 Annex will therefore depend on:

- harmonised methodologies;
- transparent decision criteria;
- reliable environmental databases;
- continued scientific validation.

Conclusion

Marine dredged sediment management has progressively evolved from a disposal-oriented approach towards a more integrated system combining environmental protection and sustainable resource management.

At international level, the London Convention, London Protocol and UNEP-MAP Decision IG.23/12 established the principles of precaution, environmental assessment and consideration of alternatives to marine disposal.

In Italy, this evolution has been supported by a long scientific pathway:

- DM 13th January 1996, which established rules for the authorization of disposal at sea of dredging materials following a strict number of physical, chemical and microbiological analysis;
- ICRAM [10], which established early principles for environmentally responsible dredging;
- APAT-ICRAM [15], which provided a comprehensive framework for sediment handling;
- ISPRA developments on physical modelling and monitoring;
- DM 173/2016, introducing integrated chemical, physical and ecotoxicological assessment;
- ISPRA ecotoxicological protocols and scientific contributions;
- MASE Technical Annex 2025, introducing a broader sustainable sediment management perspective.

The updated MASE framework represents an important opportunity to promote beneficial use of suitable sediments and integrate dredging activities within circular economy and blue economy strategies. However, sustainability objectives must remain supported by rigorous environmental assessment. The transition towards more flexible sediment management should not reduce the importance of ecotoxicology, scientific evidence and operational monitoring. MASE new framework would, possibly, require some corrective measures from a technical-scientific standpoint with a cautious approach, based on scientific method, a solid knowledge base, and a realistic integration of characterization and, classification of sediments; their management, and environmental monitoring, in order to achieve the needed administrative simplification, without impairing the level of protection of marine ecosystems and human health.

The main challenge for the future will therefore be maintaining a balance between:

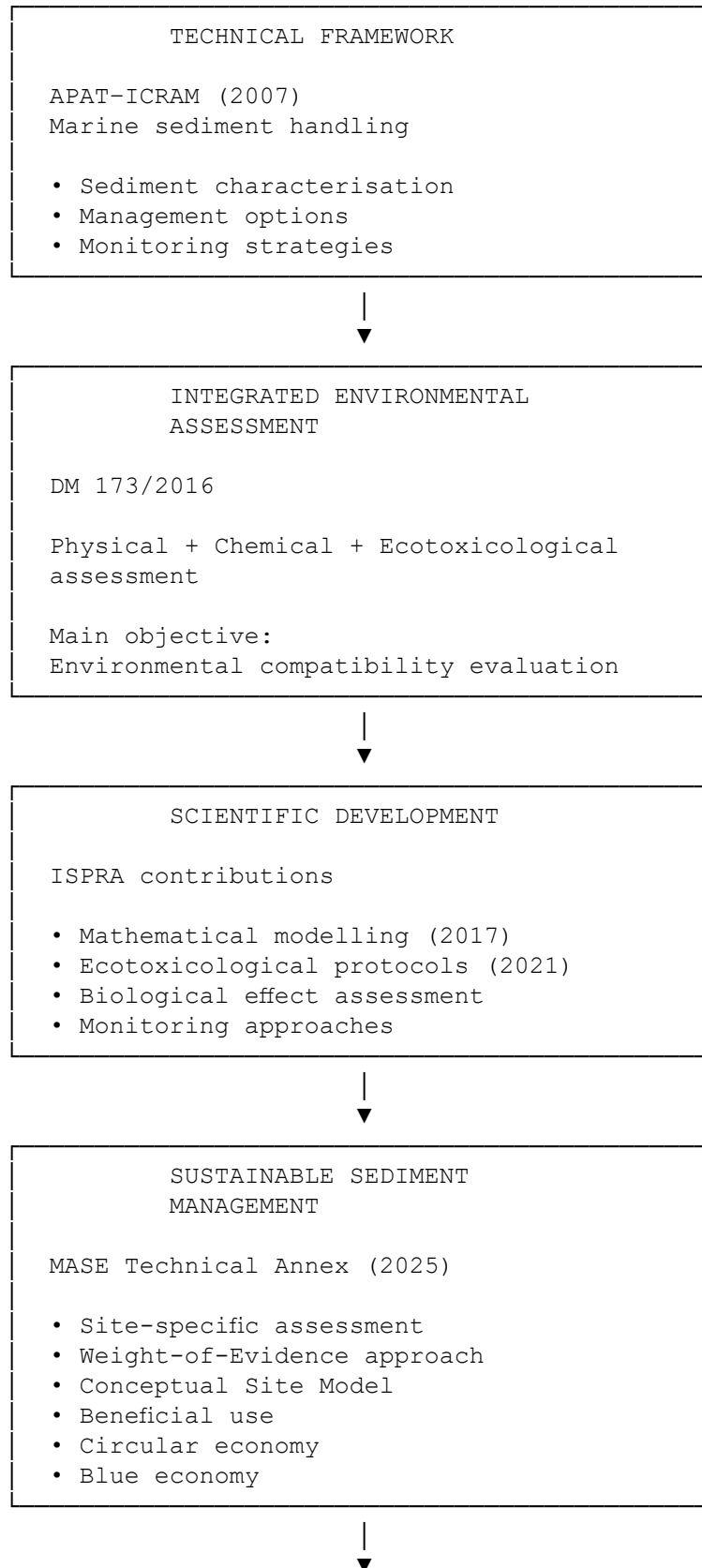
- protection of marine ecosystems;
- protection of human health;
- sustainable reuse of suitable sediments;
- efficiency of administrative procedures;
- scientific robustness of decision-making.

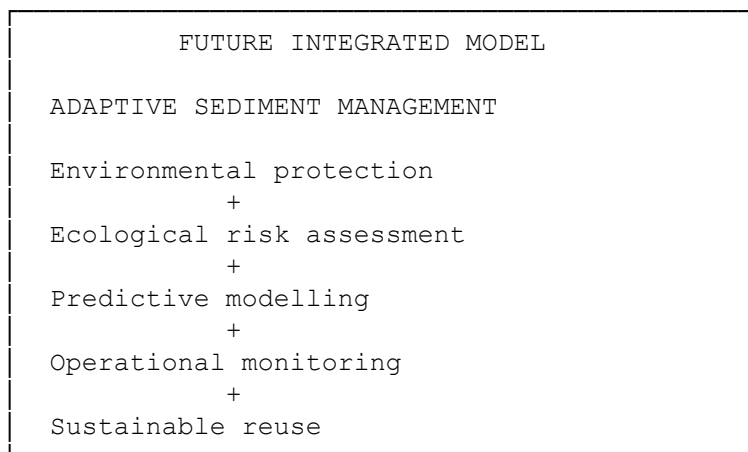
The effectiveness of the MASE 2025 framework will ultimately depend on the capacity to integrate environmental risk assessment, predictive modelling, ecotoxicological evaluation and adaptive monitoring into a coherent, and scientifically robust management system.

Conceptual Framework of Regulatory and Scientific Evolution

Figure 1 Evolution of marine dredged sediment management in Italy. The regulatory and scientific pathway shows the transition from an approach primarily focused on impact prevention and sediment quality assessment towards an integrated sustainable management framework. The current paradigm combines environmental protection, ecotoxicological evaluation, predictive modelling, operational monitoring and beneficial use strategies, partially consistently with the principles established by the London Protocol and UNEP-MAP Decision IG.23/12.

Conceptual framework of regulatory and scientific evolution





Continuous scientific principle: ENVIRONMENTAL SAFEGUARDING → RISK ASSESSMENT → MONITORING → SUSTAINABLE USE

Figure 1: Evolution of marine dredged sediment management in Italy. The regulatory and scientific pathway shows the transition from an approach primarily focused on impact prevention and sediment quality assessment towards an integrated sustainable management framework. The current paradigm combines environmental protection, ecotoxicological evaluation, predictive modelling, operational monitoring and beneficial use strategies, partially consistently with the principles established by the London Protocol and Barcelona Convention - UNEP-MAP Decision IG. 23/12.

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