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Identification of modalities for marine sediments sustainable management – An operational program unit: the SEDI.MAR.D. 83 project

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Abstract:
Dredged operations are necessary to maintain and develop the economical activities of harbours and to restore the natural aquatic areas. These dredging operations are conducted under the authority of the port managers. The systematic habit of dumping dredged sediments at sea presents an important risk of dispersion of ecotoxic substances by spreading on the seabed. This explains the more and more restrictive national, European or international recommendations. French regulations in the field of port and harbour sediments management are only adapted to dumping at sea. There are no specific regulations for the deposition of marine sediments on land. Many Mediterranean ports have to deal with highly contaminated sediments the dumping of which is forbidden. So, the port authorities are confronted (*i*) with finding appropriate technical solutions to treat on land and to eliminate these sediments, and (*ii*) to propose practical recommendations and regulations for a land management of these types of sediments. In this context, the "SEDI.MAR.D. 83" project initiated under the authority of the Conseil Général du Var was planned to clarify the following points: *(i)* characterization of the sediments as waste material, *(ii)* dangerousness of these sediments, *(iii)* beneficial uses of such dredged sediments and inherent testing.

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1. Introduction

Sedimentation in estuarine ports and harbours, in maritime canals and rivers poses problems to shipping and boating activities and changes also the water masses equilibrium in terms of chemical and physical properties. So as to maintain and to ensure the economical and tourist activities, including the remediation of watery natural lands, dredging works must be programmed and carried out.

Many more and more restrictive recommendations exist in different countries for disposals at sea. In France, the dumping at sea obeys to specific regulations which are only adapted for harbour dredging. It is forbidden to dispose of contaminated sediments in the sea due to the high dispersion risk of contaminant substances during and after their spreading. A lack of regulations is evident for the land management of dredged sediments.

Tacking into account the level of contamination in the marine sediments, some Mediterranean port managers have an obligation to find alternative solutions to the dumping at sea. Thus, they are faced with *(i) a* lack of recommendations for a land management of marine sediments and *(ii)* a lack of elaborated technical solutions for beneficial uses of this type of sediments. These beneficial uses are also difficult to identify, and if any, they must be accepted by the national community. It is why a cooperation as large as possible between port authorities, managers, users, the French government or its representatives, has been looked for and constituted, to bring efficient solutions for a sustainable land management for marine sediments acceptable to all., The scientific community might also be associated and the work made by different experts (BENOIT-BONNEMASON *et al.*, 2009; LEVACHER *et al.*, 2009; SANNIER *et al.*, 2009; SEBY *et al.*, 2009) was proved important and very useful to answer to the specific questions relative to the technical, environmental and sanitary safety for any proposed sustainable land management solutions or beneficial uses. Thus, a research and work program could be planned through a project. The Conseil Général du Var has initiated it and proposed a cooperative, arranged and multi-domain programme within the framework of a contract "Contrat d'Objectif Départemental". This programme was named SEDI.MAR.D. 83 in which the main results concern the data relative to the possible beneficial uses or modalities of contaminated marine sediments treated on land with the respect of a sustainable development. Technical and environmental recommendations could be drafted.

2. Problems

The process of sedimentation and the quality of the sediments depend on the geological context, climate, fauna, nature of the basins, slopes, the effects of man on the medium.

The deposits, also called sludge, silts, alluvia, … contain several types of elements. Sediments have played a great part in the development of civilizations (sands, pebbles, boulders …),. Others support the development of vegetation which, according to the

cases, can constitute an advantage or not. Finally, others have a more or less important toxicity according to the living species concerned in the original areas (ports and canals) but also in the receiving ecosystems (ground and sea) when the sedimentary deposits are transferred there, following dredging operations.

Any search for a solution to the displacements of these sediments requires a preliminary reflection on:

- The choice of areas for land disposals of sediments, mainly when they are contaminated, the impact which can be irreversible on the marine or land ecosystems. Practices of spreading, of damping, of storage, are considered to be unacceptable by public opinion. Spreading on land of marine sediments is always dangerous because of sea salt and pollutants.
- Technical, environmental and sanitary considerations, in particular preliminary treatment operations and beneficial uses.
- Main aspects of education (information and formation) of the concerned actors.
- Legal aspects, in particular, the European, national, local legislations in force.
- The economic aspects, whose knowledge is necessary without being determining.
- Aspects of public health posed by these deposits.
- Short, average and long term impacts of the various operations constituting a solution.
- The measures of precaution to be taken, knowing that they will be for the time being financially more bearable than those which will have to be taken in the future regarding the European Stern report.

A sustainable development strategy is therefore considered by the intergovernmental organizations as a national obligation for all the countries, which will make it possible to define and implement the best possible solution for any social problems, whatever its nature.

The fundamental objective of this strategy is the protection of the sea, health and biodiversity, it concerns all the human populations in the coastal zones and will benefit to the tourism activities of the Mediterranean zone.

3. Interests for all the aspects of sustainable development

Considering the environment interest, the protection of the fragile littoral territory subjected to very strong anthropogenic activities, the restoration of the aquatic areas by elimination of the pollution in the Mediterranean coastline, the limitation of the extractions in quarries by substitution of recycled materials, but also according to the specificities of each territory, the increase in waterways transport, the limitation of the CO_2 emissions, the prevention of floods, are as many subjects which depend directly or not on the sustainable management of coastal sediments.

On the economic point of view, the reinforcement of the competitiveness of the French harbours and canals by optimization of the costs of dredging, the profitability of the processes of treatment and recycling of sediments, the development of direct and

resulting employments such as tourism jobs, the supply of alternative materials for use in public works, are dependent on the options chosen for the ultimate recycling of harbour sediments. Problems are posed, in an even more complex way for the marinas which represent a mosaic of authorities and managers for which individual action does not allow a mobilization of the means necessary for the identification of a management solution.
With regard to the community, *(i)* a contribution of alternative solutions making it possible to face the restrictions of the dumping at sea, with the resulting impacts of the land disposals, *(ii)* a relevant help to the protection of the environment within the framework of the regulations, *(iii)* a development of amenities in the river and maritime fields, are the objectives to be privileged.

4. Regulations: a deadlock situation to be changed:

The change and improvement of the regulation is related to the evolutions of the community demand which implies a better knowledge of the effects on the environment and a consideration of the possible hazards, including on the long term. Recent evolutions of the code of the Environment should be noted, in particular, the installation of threshold values of environmental sedimentary qualities in the decree of June 14, 2000 (METL & MATE, 2000) as well as the notion of "waste-sediment" in the decree n° 2002-540 of April 18, 2002 (MATE, 2002) relating to the classification of waste. These texts had an important impact on the dredging activity of and the management of the sediments.
Actual regulations are perfectly adapted to agree with the maritime management of these products. They cannot directly be applied to land management of contaminated sediments. The result is a deadlock situation for the projected operations. An updated legal framing must be developed.
For the French state, these problems were debated by two work groups during the "Grenelle de l'Environnement" and by a question at the National Assembly in May 13, 2008. Moreover, the actual implementation of information and protection policies such as "*Ports Propres*", "*Contrat de Baie*", implies that the human activities will fit and reduce the volume of contaminated sediments. The effects of these important prevention programs will certainly be positive. Unfortunately, their effects will only be perceptible in several years and to be judicious and effective, these policies must imperatively be accompanied by curative actions especially on the existing stocks of contaminated sediments.
Thus, the identification of solutions for regulations making it possible to manage historical storages on the French territory (several tens of millions of tons of highly polluted sediments) remains a present-day problem and constitutes an urgency for the management and the development of the maritime and fluvial areas.

5. The SEDI.MAR.D. 83 program

5.1 Important objectives

In order to bring the first operational answers to generalized problems recently highlighted at the "Grenelle de l'Environnement", the SEDI.MAR.D. 83 project gathered, in an approach of partnership project, ten managers of French and Italian port authorities confronted with the problems. From the beginning, the program took place under the auspice of the Ministry for Energy, of Ecology for Sustainable Development and Territory Planning (MEEDDAT) to be in phase with the data to produce.

The main aims of operation SEDI.MAR.D. 83 consist in setting up strong foundations of knowledge likely to allow, in the short run, proposals of tools for the managers of maritime areas: a methodological guide and a database of reference.

The program thus aims to:

- elaborate and consolidate locally economic processes for the treatment and management of the sediments.
- inform and enrich the work and investigations of the MEEDDAT for an accompaniment in the field of legal regulation, namely on *(i)* the aspects related to the statute of these sediments during the various steps of their treatment and valorisation, *(ii)* the technical assets and experience feedbacks on the current and potential ways of treatment and valorisation of the concerned sediments.

5.2 A grouped operational approach of harbour managers

On the basis that for economic and/or environmental reasons, these sediments, in their globosity cannot be simply put into specific authorized storage centres (CSD3). An approach of multi-beneficial uses for land management of these products is necessary. For this reason, the last ministerial circular of 2008 recalls clearly that these products cannot reach CSD of class 3.

An important technical objective in the SEDI.MAR.D. 83. operation is to be able to define the various possible management modalities and thus, it appears essential to define and associate the ways of valorisation and storage solutions according to the qualitative and quantitative nature of the various fractions constitutive of the sediment.

Started in 2004, on the initiative of the "Conseil Général du Var", the project could be based on a great number of preliminary works. In this direction, the initial works and methodological approach of the national work group "GEODE", which made it possible to provide a framework for the maritime management of the sediments, are exemplary.

Since 1990, a national database related to the environmental quality of the sediments was installed. Completed by many departmental or regional data, it provided a qualitative photograph of the current situation. However, the information relative to the quantitative aspects and the potential for valorisation are approached with difficulty. Similar approaches had also been developed in European countries. Thus, in the

European community, it is advisable to cite the important work of *SEDNET*, which implied more than ten Member States, on sets of themes and bibliographical exchanges.
However, the majority of these programs was of primarily bibliographical nature or corresponded to very academic research works and required to be confronted with an approach more directed towards practical works implying the demands of the harbour managers.
Thus, to bring the first answers to these technical problems for beneficial uses, it was necessary to give a dynamics of project around a true operational program based on real harbour situations of sites in difficulty and targeting the data to be produced.
The program SEDI.MAR.D. 83, under the control of the "Département du Var", has gathered the actions of the following managers: the Navy, the Chamber of Commerce and Industries of the "Département du Var", the "Conseil Général des Alpes Maritimes", the Urban community Marseille Provence Métropole, the "Conseil Général du Finistère", the Italian area of Emilia Romagna as well as the towns of Lavandou, Sanary-sur-Mer and Bandol.
It was built around 14 coordinated missions for an approximately 2 M€ total amount (self-financed up to 70%) with, in particular, the support of the Agency of Water "Rhône Méditerranée Corse", the Ademe agency and the "Région Provence Alpes Côte d'Azur". A project team of 3 persons was mobilized in 2006 for the control of SEDI.MAR.D. 83 within the framework of the "Contrat d'Objectif Départemental".
The interest of the partnership approach between various harbour managers confronted with the same problems rests on *(i)* a pooling of the means and thus an optimization of the related public expenditure, (*ii*) the qualitative range of the sediments which could be characterized and treated.
One of the main parameters of the considered "waste as sediment" is indeed the variability of the deposited sediments. In this way, testing the robustness of the possible treatments on a variety of sediments constitutes a priority.
The main mission was the subject of a European invitation to tender. It consisted in carrying out an *in situ* industrial pilot unit of treatment on an area of 10000 m^2 in the port of Toulon.
The industrial contractor specialized in the treatment of the sediments was Extract-Ecoterres Company. The contractor implemented during 18 months the whole of the combinations of treatment on 200 m^3 volumes unit of sediment dredged from the various harbour sites of the partners of the project.
The environmental quality of the sediments of the 10 sites was very bad, namely higher than the N1 and N2 reference thresholds values, the dumping at sea was forbidden and a land management solution had to be considered.

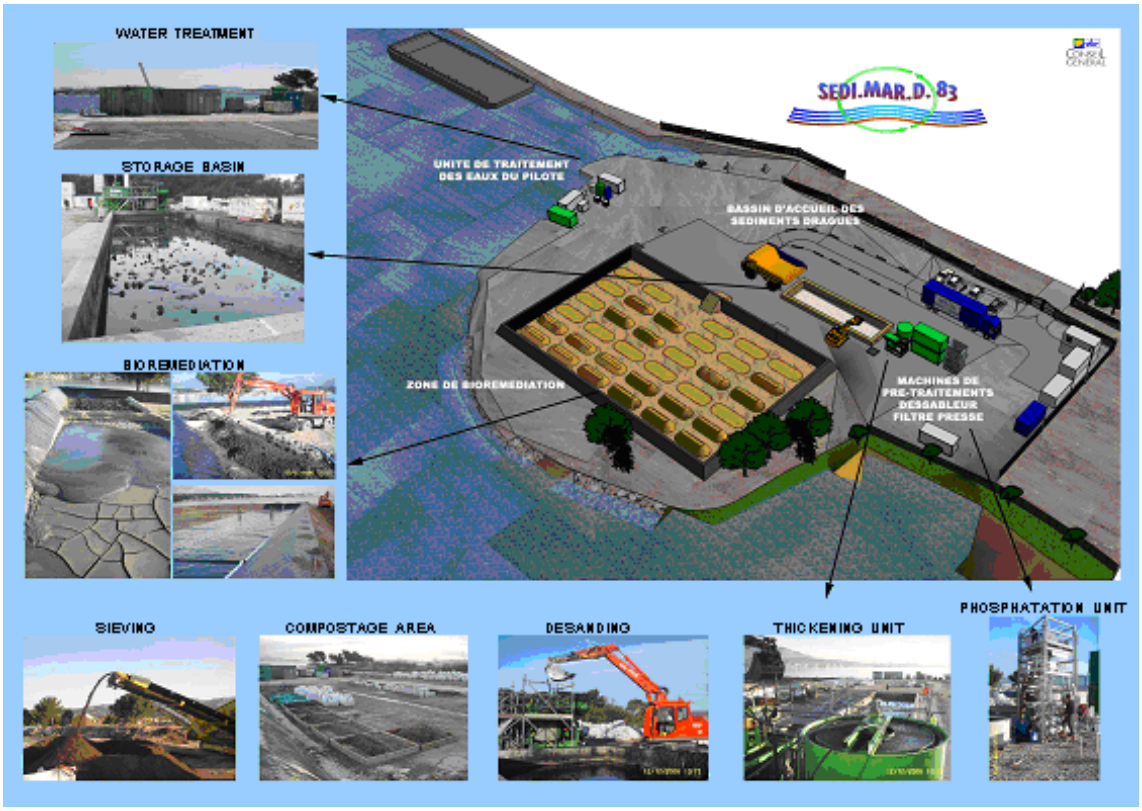

Figure 1. A 3D view of the in situ SEDI.MAR.D. 83 pilot site and pictures of the operations.

5.3 A partnership project associating operational managers and scientists in the field

The harbour managers are confronted with immediate difficulties of operation and development but cannot, alone, bring all the technical, environmental and sanitary answers essential to the evaluation of the impacts required during the legal instructions preliminary to the implementation of the operations. The academic scientific approach is also important for the improvement of knowledge, in the long term, on the problems studied.

Due to the innovating character of the Project and the need for answers to new problems, it was decided to set up an independent Group of Expert Scientists (GES) to accompany the various missions. The GES was a group of scientists specialized in the various disciplines of the field. Thus, experts came from the Ifremer of Sète site, the UT2A laboratory located in Pau University, the M2C research unit from the University of Caen, the CEMAGREF of Lyon, the BRGM agency of Nantes and the environmental laboratory of the École des Mines of Douai.

A large quantitative and qualitative diagnosis of the 54 ports of the department of Var (referenced under the number 83), based on the recommendations of "GEODE", was performed in 2002. The operational and the associated scientific program were interested to different degrees with all the technical and environmental axes of land

management of the sediments. Specific and targeted studies were also required by the GES group.

5.3.1 Part 1: Characterizations of the sediments (main topics of SEDI.MAR.D. 83 project)

Characterizations have been carried out beyond the recommendations of "GEODE", with an approach adapted to land management and within the framework of the definition of the potentialities of valorisation.

In particular, it was important to define a protocol of evaluation of the dangerousness or non dangerousness of the sediments impossible to dump at sea, to classify or not the sediment as waste, to gather fundamental data influencing directly the possible beneficial uses. In the same way, the radio-ecological aspect was developed.

5.3.2. Part 2: Operations of treatments of 10 different sites (main topics of SEDI.MAR.D. 83 project)

Practical work operations were performed on the *in situ* pilot unit, on a 10000 m^2 platform in the port of Toulon where the robustness of more than 60 combinations of treatments was tested.

In the same time, laboratory tests allowed to define the best formulations to implement on the pilot site, and industrial tests were also run on sites in activity. Moreover, washing tests were carried out in a quarry of Jean Lefebvre Company, located in Sisteron. Tests were made in the Lafarge Cements factory in Marseilles where 30000 tons of cement were manufactured with injection of sediment in valorisation matter.

5.3.3. Part 3: Analyses of the possibilities of beneficial uses

This part was developed to make it possible to identify the various possible beneficial uses for the sediments, uses which it would be advisable to make safe in order to generalize their application.

A tool for multi criterion analysis was developed in order to give to the managers the possibilities to decide by analyzing the limits and performances of the different modalities of land management with realization of a legal study for the analysis of the various administrative modes of assembly of the tools.

The definition of the various management modalities can be established only at local decisional level. This part of the study is reproducible but was applied only for the scenarios of the department of Var within the framework of SEDI.MAR.D. 83 operation.

5.3.4. Axe 4 : Advanced studies

During the operation, difficult scientific questions about the behaviour of the sediments and the pollutants during the treatment processes appeared. To elucidate some of them,

specific studies were undertaken. Thus, Battox ecotoxicity tests of impact on the marine environment were carried out jointly with Icram laboratory located in Livourne, a modelling of the speciation of the heavy metals behaviour during the steps of active lagooning was run by the UT2A laboratory from University of Pau. A study of geotechnical characterization was carried out by the M2C laboratory of the University of Caen and a statistical analysis of correlation for the 37000 produced data was also made.

5.4 Main and important results

The data were produced during the phases of characterization and for all steps of the various combinations of treatment. They were gathered using two tools: (*i*), a database and numerical metadata with more than 2700 technical notes giving approximately 37000 produced data and (*ii*), a unit of samples taken during the treatments called "sédimentothèque" with more than 520 stored products. The unit of samples or the "sédimentothèque" was conceived using strict procedures, intended for obtaining the complementary data which could prove to be useful and opened to external requests.

Today and with the results from this pilot project, practical and powerful proposals of management of the various fractions constitutive of the sediments could be identified according to technical qualities and to the levels of contamination.

The result is a large range of possibilities of management which will have to be adapted in function of the quality of the sediments and which confirms the beneficial uses for different applications:

- Construction of a covered mono-specific deposit, recommended for very small volumes of very contaminated sediments.
- Sorting and construction of a non-covered mono-specific deposit.
- Sorting, treatment and valorisation in quarry filling.
- Sorting, treatment and valorisation in public works (terrestrial, fluvial or maritime).
- Dumping at sea for the non contaminated sediments.

5.4.1. References from a scientific point of view

A list can be drawn as follows:

- A significant improvement in the knowledge of the different fractions constitutive of the sedimentary matrix in the case of a land management.
- The carrying out of an operational protocol for the definition of the dangerousness of the sediments when they must be land managed, which was proposed to the Ministry for Energy, of the Ecology of Sustainable Development and Territory Planning (MEEDDAT). In the current state of knowledge, the protocol SEDI.MAR.D. 83 appears to be adapted to the needs of the managers because it proved to be discriminating in highlighting sediment as "dangerous waste" for the two most contaminated of the ten tested sites. The precise definition of the limit of

dangerousness requires the carrying out of additional tests with highly contaminated sediments.
- The gradation of the various processes of treatment tested.
- The original scientific data developed around the most promising processes like the phases of active lagooning

5.4.2. References from an operational point of view

References are listed below:
- A significant experience feedback on operation and environmental risks related to the installation of a treatments unit. Within this framework, it is important to note the perfect control and quality of management of all the rejected water of the site, and the complete absence of air pollution.
- The identification of the difficulties of the works site with the very important level of macro-waste, vegetable fibres or heavy pollution.

Beyond the technical results obtained, this project also highlighted the interest of a partnership work between managers confronted with the same problems and actors of the research which led to supply a comprehensive management tool: the multi criterion analysis of scenarios. The support of populations and environment defence associations to an approach felt like a strong contribution to the protection of the aquatic and coastal environment must also be noted.

6. Conclusions and prospects

Supervised by the Ministry of Energy, Ecology, Sustainable Development and Territory Planning (MEEDDAT), the SEDI.MAR.D. 83 program was proposed in different national and international presentations. It gave place to many debates in various communities, institutional, administrative, scientific and political (French National Assembly). The results, of which a part is published in the online journal "Revue Paralia" (BENOIT-BONNEMASON *et al.,* 2009 ; LEVACHER *et al.,* 2009 ; SANNIER *et al.,* 2009 ; SEBY *et al.,* 2009), are in many cases, new and encouraging concerning the possibilities of land management of contaminated sediments. The operation made it possible to obtain technical and environmental information, useful (*i*) to solve the problems of management and (*ii*) to propose protocols suitable to complete the regulations. Partnership work between the harbour managers and the researchers proved to be a determining factor. And, the solutions for a sustainable management of the contaminated sediments, in conformity with social demands and the legal regulations, are now apprehended by all the contractors or masters of works. They are based on a multi-beneficial approach and adapted to the qualitative and quantitative characteristics of territorial potentialities.

From an operational point of view, it is now interesting to focus on the intended purpose

of beneficial uses of treated materials. The technical and environmental security of these beneficial uses was simply approached in the SEDI.MAR.D. 83 program. Thus, it appears as a priority before considering a generalized implementation. In the same way, the supply of common reference frames, constituting an operational tool for all contractors or masters of works, remains an objective for the future. The multi-partners approach developed by the SEDI.MAR.D. 83 project which allowed to achieve objectives considered to be very ambitious at the beginning could be made profitable to initiate and undertake fundamental programs. Moreover, some programs are drafted or in progress and focused on the improvement of knowledge on beneficial uses. They are *(i)* research projects, developed in laboratory such as SEDIGEST, or *(ii)* partnership operational projects, associating the managers, scientists and industrial actors such as SEDIMATERIAUX.

Beyond the technical and regulatory considerations, the installation of an economic device making it possible to financially accompany the ports in the implementation of the solutions of treatment identified in the SEDI.MAR.D. 83 program remains one of the most important obstacles. The reflection on the financial accompaniment of the installation of new industrial beneficial uses of treatment of the "waste-sediment" can be carried out only under the impulse and the control of the French institutions. The concept of "pollutant-payer" is unfortunately difficult to apply in the majority of the cases, the pollution to be actually managed being the result of several decades of human behaviours.

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