"Eco information" and the "ECOPORTS": project's Case Studies.

Dredging activities in the Port of Marseille

Mr. Marco Faticanti

APAT

Agency for Environmental Protection and Technical Services

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1) General presentation of the site

The Port is located in the south of France, exactly in the Gulf of Fos. This plain is composed by alluvial deposits brought by the Durance and the Rhône rivers. This area is under maritime influence. The soil is composed about fine and silt sands with silting up and warping trends.

The vegetation is sparse but the fauna and flora of this area are considered like originals.

This area is highly industrialised. Port areas are divided up into specialised terminals according to what goods are being handled, such as:

Oil products : 64 million tonnes,

Solid bulk : 13 million tonnes,

Natural gas : 2.7 million tonnes,

Petroleum gas : 1.6 million tonnes,

Chemicals : 2.8 million tonnes,

General cargo : 11 million tonnes,

Passengers : 1.2 million passengers per year

The industrialised zone covers 10,000 Ha.
The global trade figures of 90 million tonnes per year. There is a shipping to every part of the world.
There is not occupational fishing in the port area.
The marine culture is very controlled : the shellfishes must stay in purification basins before consumption.
There are two beaches in the Gulf of Fos having good quality waters.
There are a sailing port and a camping site too.

2) Description of the activities of dredging

Dredging is an essential activity for Ports and offers a solution to the problems of silting up of channels and to the trends of increasing ship sizes.

Dredging scarps the bottom of canals or access passages of ports, to have a constant depth and to facilitate the way for the ships. Over the past ten years, the Port's authority of Marseille (PMA) has dredged more than 150,000,000 m^3 of every conceivable kind of land.

The dredging operations are guided by :
the laws,
the need for the exploitation,
the availability of the machines and the opportunity to do the work.

The PMA makes a sounding every five years, or when a port manager requests it, because his ship has touched the bottom. The sounding evaluates the depth and determines the required dredging.

Dredging is divided in three steps that are,
the excavation (first step), the transport (second step) and the disposal of dredged material (third step).

the excavation (first step)
There are two principal types of excavation: hydraulic dredging and mechanical dredging. The PMA use the excavation by mechanical dredging to remove material with a grab. This technique is optimal to take out coarse non-cement sediment.
Buchet dredger is used for cohesive sediments, coarse sediments and broken rocks, excavated material is discharged in a barge.
Dipper dredger is used for cohesive clays and broken (or weak) rocks, excavated material is discharged on a inclined ramp to a barge.

The material is removed by a dredge or grab and transported in the deposit site by barges. The advantages of this technique are:

- the possibility to work at great depth,
- a high precision in sediment removal,
- low cost and short time
- low environmental impact,
- limited to a local scale.

Different companies having a valve dredge with a capacity from 50 m^3 to 400 m^3 do the dredging activity. The valve dredge must be controlled by the Security of Vessels Centre.

According to the order dated July 17th, 1996 they must have a positioning machine like GPS system.

The choice of a company depends on the dredging cost

The dredging material can be classified by the particle sizes

- Gravel : Diameter > 2 mm
- Sand : 2 mm > Diameter > 0.036 mm
- Silt : 0.036 mm > Diameter > 0.004 mm
- Clay : Diameter < 0.004 mm

The entrance passage is dominated by natural sandy sediment. The harbour areas have the same characteristic of sediment with an increasing percent of silt and clay into the direction of the bottom basins.

The total volume dredged for a period of 15 years is 150,000 m^3. Usually, the dredging is done every five years.

The dredging volumes are low compared to other ports because the PMA is in the Mediterranean sea and there are only weak tides, and low quantities of sediments discharged.

Transport of dredged material (second step)

The materials dredged from the different sites are transported in the deposit sites by barge

Disposal of dredged material (third step)

The disposal of dredged material receives increasing attention, especially for sites where the material is contaminated. The requirements to reduce contaminant inputs to the sea are controlled by international conventions. Near-shore (marine disposal) or off-shore deposition has different impacts.

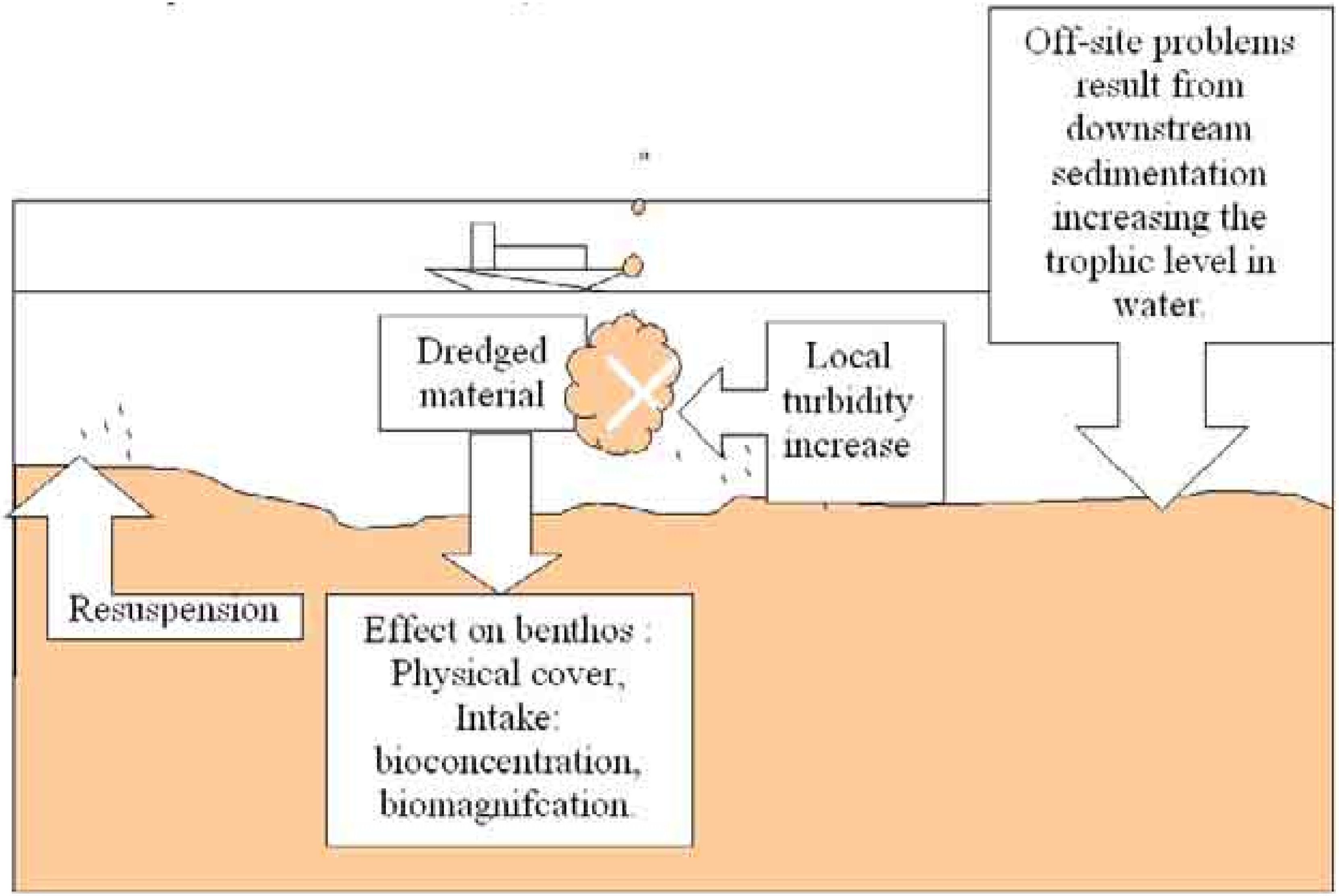
Non polluted dredged material is deposited in a special marine area near the coastline. Only the clay and sandy materials are authorized to be deposited. Other materials are totally forbidden. The depth average of the disposal site is 30 meters. The total capacity is 35,000 m^3.

Near-shore deposition occurs in confined areas named Confined Disposal Facilities, out of the area there is no impact.

The dredging sandy materials, are noble materials, lowly contaminated and can be deposited on the ground to be used in public works, embankment, civil engineering, creation of platform, loading of the beaches, cement works, sea walls, agriculture, creation of artificial reef.

Heavy contaminated sediment cannot be deposit in the sea. They will be either treated, or stored in a special dump that is located at 60 Km from the western PMA in Bellegarde.

Different problems can occur with off-shore deposition:
eutrophication caused by released nutrients;
increase in biological and chemical oxygen demand due to decomposing organic matter;
heavy metals and chlorinated organic compounds release.


Off-site problems result from downstream sedimentation increasing the trophic level in water.
Dredged material
Local turbidity increase
Resuspension
Effect on benthos : Physical cover, Intake: bioconcentration, biomagnifcation.

3) Pollution Sources (related substances and by-products)

The Dredging activities can be source of pollution if the dredged material is polluted. In fact sediment are contaminated by pollutants coming from the industrial discharged: waters, ships, soils washed by the rains, polluted rivers, ports activities as ore dry bulk or noxious liquid....

The pollutants founds in the sediments can be: nutrients (consummation of oxygen), pathogen elements (bacteria, virus), metals (aluminium, iron, manganese) heavy metals (arsenic, cadmium, chromium, mercury, zinc, lead, copper), total hydrocarbon and chemical toxic products (organochloride affecting the genetic code, as polychlorobiphenyl).

During the dredge most of the silt particles are swept in suspension, transporting the contaminants in an adsorbed form. The finest sediments (clay) can bind nutrients (nitrogen, carbon, phosphorus) or pollutants (heavy metals, organic pollutants) adsorbed and absorbed into their structure.

Dredging activities have a variety of negative effects on marine flora and fauna from habitat disturbance of benthic communities in the dredged area, to physical smothering or chemical contamination of those on the disposal site.

Between the different pollutants present in the sediments, the metals are the most dangerous species related to their ability and mobility. The most toxic metals for the living organisms are:

Mercury solubility increases in the water. Bacteria methylate the free form of mercury (which is the process the most toxic). The methyl forms of mercury are stocked into living organisms.

Lead becomes mobile if the pH decreases or the area gets oxygen. It will also have methylation process like mercury.

Cadmium also becomes mobile in oxidising forms and will be very toxic.

The most polluted part of the sediment is usually the finest (less than 60μm), vector of heavy metals and organic pollutants. The metals are fixed through water-sediment ions exchanges.

The physical-chemical conditions of the environment play an important role in the dissolved materials which are mostly ionic shapes. Some of them can precipitate with insoluble complex of other elements by Oxidation-Reduction reactions.

Heavy metals have different reactions in the environment which undergoes chemical transformations.

COMPLEX FORM	RESULT
Carbon monoxide, carbon dioxide	Heavy metals are released when the salts are dissolving
Adsorbed on iron oxide or manganese oxide	The complexes become unstable and release metals
Bond with organic matter	Great stability of the complex
Sulphide	Instability, oxidation in sulphates and release of metals

4) Consequences

Effects on the sea environment:

Dredging installations can induce some modifications of the Oxidation-Reduction conditions in the water-sediment interface when the sediments are stirred up. Heavy metals are released.

Dredged materials

The pollution can come from a nutrients superabundance which, on its turn, can give rise to enrichment of the ecosystem (eutrophication), or form a mix of toxic potentially carcinogenic, mutagenic (cause damage to genes) or teratogenic (cause abnormalities in developing embryos) compounds.

Hg → Hg → Hg → Hg → Hg

The possibility of long term effects are due to bio-transformation, bio-concentration and bio-magnification phenomena, especially for mercury.

Some bacteria transform the pollutants like arsenic. They create toxic gas products accumulating in organisms.

Dredging can also seriously damage the shallow-water habitats. Clay and silt suspension decreases the penetration of light into the water, can cause a decrease in the primary productivity in the water column; this in turn reduces the amount of oxygen in the water and the supply of phytoplankton at primary trophic level.

The burial and the massive injection of nutrients is a disruptive factor for the benthic communities: hence the original ecosystem is destabilised.

Risks of chemical contamination on the deposit site are very low, but the sedimentology and geochemistry (pollutant concentrations) of the dredged material must be similar to the receiving area. The contamination of the water body is possible, but if the deposit site is enough far from the coast, it will not pollute the coastal water.

Effects on the human activities:

Dredging installations can have impact as disturbance
of navigation and sailing activities,
of occupational fishing,
of tourism activities because of noise, view and smell
and as suspension of bathing activity and water sports

Dredged materials can have impact in terms of
Turbidity induce avoidance of dredging area by fishes.
Disturbance of waters quality in turbid cloud area.
Disturbance on tourism activities because of noise, view and smell.
Leisure fishing is forbidden in turbid cloud area.

5) Actions taken

The PMA has to inform the Water Police, three months before the beginning of the dredging activity.

The PMA must specify the volume dumped, and the area that will be dredged.

This information given to the Water Police permits to control the quality of the dredged material. In fact the dredged material can be immersed only if it correspond to non polluted referenced values.

The dumping area is represented in four zones chosen by the Water Police. The physical monitoring of material at the deposit site is essential. A complete monitoring programme goes from the collect of data before and after the deposit of the dredged material, to the observation of the physical modification of the site during the deposit.

The sediments of the PMA are low-grade in metals and so it is very important to have strict analysis protocols, knowing the margin of error. Also particular care with the sampling has to be taken to avoid sediment contamination.

VOLUME DREDGED (m^3)	NUMBER OF SAMPLES
V < 25,000	1
25,000 < **V** < 100,000	2
100,000 < **V** < 250,000	3
250,000 < **V** < 1,000,000	1 sample / 100,000 cu.m
V > 1,000,000	10 samples + 1/1,000,000 cu.m

The dredging operator records all the parameters necessary to make a good operation: date, hour, minute, origin, nature of the materials, volume, co-ordinated, and bathymetry of the dredged site.
A copy of this register is addressed each week during the dredging work, to the Water Police. Then at the end of the dredging campaign, the dredging company addresses an assessment to the Water Police.

6) Monitoring

Different analysis cycles are performed:

The RNO (National Observation Network), is a network managed by IFREMER (French Institute of Research in the Sea) for the Environment Ministry. The RNO existing for more than 20 years measures the quality of:
The water column on three stations once per trimester.
The sediments every time the dredging operation is done.
The living matter on three stations once per trimester.

The REPHY (Phytoplanktonic Network) and REMI (Microbiologic Network) measure the phytoplanktonic and microbiological quality of the water.
The measurements are done by IFREMER which measure both the quality of the water column on two stations REPHY every 15 days in winter and every week in summer, and the living matter on two stations REPHY and five stations REMI once every month or more frequently in case of pollution.

The RSP (Posidonie Watching Network) measure the global quality of the area using the vitality of the vegetal plantation as a biologic indicator. The observations are done once a year by GIS-Posidonie, a research organisation.

The Water Police controls the PMA actions and monitors the direct discharge of the industrial waters and their impacts on the quality of the port area: 8 stations are analysed in the area of port of Marseille.

The DDASS (Departmental Direction of Social and Sanitary Actions) monitors the microbiological quality of the water in the bathing area.
12 measurements are done per year in summer time in the water column on 7 stations along 5 towns in the Gulf of Fos.

REPOM (National network to the survey of the maritime ports) monitors the water quality and the sediments quality of the port areas. This monitoring will permit to :

- Have a global view of the pollution created by ports.
- Actualise data on the quality of the sediments.
- Create adequate standards relating to the disposal of the dredging wastes.
- Evaluate the port quality.
- Incite the port managers to research good solutions to eliminate the pollution at the source.

The REPOM will study the water and the sediment quality on the PMA. The water quality analyse will be done on more than two stations four times a year (one analyse every three months). The parameters analysed will be bacteriological and physical-chemical (temperature, salinity, percent of dissolve oxygen, suspended matter, ammonium, transparency...). The contaminants analysed in the sediment will be done at each dredging operation.

Some more test…
The test of embryo-toxicity on the bivalves (oyster larvae, mussels…) gives a good indication of the quality of the area. Routine ecotoxicological monitoring requires simple, rapid and inexpensive methods. Determining the percentage of abnormalities in D-larvae after 18 hours assesses water quality. If the percent of D-larvae abnormalities is above 50%, the toxicity of the sample is very high.

The water law (1992) and the coastal law (1986) remind users of the importance to monitor the coast in a uniform way.

About the monitoring costs

- A ship CALEMBO II (800 EURO/day).
- The equipment for the bathymetric measurements. It includes the CALEMBO II ship, and the crew, the data gathering equipment, the positioning equipment and two hydrographers (2.000 EURO/day).
- The engineer staff (530 EURO/day).
- The ground treatment equipment: the computer equipment, the elaboration material, the processing of the plans by one hydrographer (620 EURO/day).

So the bathymetric survey costs approximately 590 EURO/hectare.

Cost of the analyses

The cost to analyse one sample of the dredged sediment is about 540 EURO (heavy metals, polychlorobiphenyls, hydrocarbons).

7) Indicators: Assessment of monitoring results

The prevention of the contamination risk needs knowledge about the sediment:

- physical-chemical conditions as oxidation-reduction conditions of the area that will receive the dredged sediments,
- the way of the metals are associated to the sediment.

So it is important to have a normalisation technique to analyse it.

Two referenced levels for different metals have been proposed. These referenced values allow to know, in an objective point of view, the quality of the dredged material and then to decide if the material can be deposited in the sea.

Reference values have been calculated for each metal (the unity is: mg/kg of dry weight) :

	BACKGROUD NOISE	LEVEL 1	LEVEL 2
Mercury	0.2	0.4	0.8
Cadmium	0.5	1.2	2.4
Arsenic	4.4	25.0	50.0
Lead	47.0	100.0	200.0
Chrome	45.0	90.0	180.0
Copper	35.0	45.0	90.0
Zinc	115.0	276.0	552.0
Nickel	20.0	37.0	74.0

Referenced levels for different metals expresses as mg/kg of dry weight

For all the compounds, under the level 1: the dredged material can be dumped without any complementary study.

Between the levels 1 and 2: a further study should be necessary to precise to risk for the marine environment.

The classification prohibits sea disposal of dredged material, if selected contaminants have a concentration above the level 2.

For PCB compounds there is no background noise because they are from anthropological origin. It is toxic for phytoplankton and larval development at weak concentration (1μg/l). The PCB are accumulated in lipid tissue. By analogy with metals, the level 1 is 0.5 mg/Kg of dry weight.

8) Lessons learnt from the case study

The dredging is a necessary activity bringing modification of the physical, chemical and biological environment. So it is important to evaluate the impacts between the different dredging methods.

One important point is to try to reduce the suspended solids by using good dredging equipment and adequate dumping sites.

A good way to reduce the cost of the dredging activity is to find the pollutant at is source, and see if there are not any methods to stop the pollution of the sediments.

It is important to characterize the dredged material (granulometry,% of clay,% of organic matter…). The adsorption and absorption processes of sediments depend on it.

The knowledge of the disposal area characterisation is essential too (the dredged sediments must be similar with the sediments of the disposal area).. It consists of the geography, the physical characteristics, the biologic characteristics, the human activities and the users, and the protected areas existing there.

The non-polluted dredged sediments can be valorised by different ways. If they are concentrated in organic material they can be lead on plants and serve as a fertiliser, or use for the building of route embankments. The sandy material can be spread on beaches.