

Maurizio Gentilomo

# Mechanical Treatment of Dredged Material. The Malcontenta Plant in the Lagoon of Venice

## Abstract

A number of situations in the lagoon of Venice (Italy) require dredging to be carried out in the channels of the lagoon and harbour. But dredging leads to the problem of disposal. A pilot intervention to tackle this problem is one of the measures included in the General Plan of Interventions (1991), drawn up by the Venice Water Authority and its Concessionaire (Consorzio Venezia Nuova, Venice), which are the responsible authorities for improving the lagoon environment.

This intervention consists of dredging a basin located in the Northern Industrial Channel of Marghera Harbour, in which sediment, potentially harmful to the environment, has accumulated over time. This sediment is then subject to mechanical treatment to separate the contaminated and uncontaminated particles. The treatment is carried out at a plant in Malcontenta where dredged material is thickened (dehydrated). This purpose-built plant will remain at the disposal of any public body operating in the lagoon, carrying out further interventions, including dredging.

At the same time, the function of the basin with regard to harbour activity is being restored by deepening the channel. These interventions are aimed at counteracting the present trend towards erosion in the lagoon.

## Introduction

It is widely known that there are a number of situations in the lagoon of Venice (Italy) that require dredging to be carried out in the channels of the lagoon and harbour. These operations can be set within the context of interventions for the protection of the lagoon, with different and complementary goals:

- to favour the exchange of water volumes;
- to reduce pollution in the channels and harbour

- basins; and
- to restore the depths required for navigation.

Dredging leads to the problem of the disposal of any sediment recovered. For reasons related to the protection of the environment, specific regulations prohibit disposal of sediment at sea, which, until recently, took place. The problem of disposal was tackled by the Venice Water Authority, which is responsible for the waters of the lagoon, and by its concessionaire Consorzio Venezia Nuova, by looking into possible destinations for dredged sediment, depending upon its characteristics (Figure 1).

When appropriate, this material is used *profitably* within the lagoon, i.e. to construct lagoon elements similar to those typical of the lagoon itself (salt marshes, mud flats) or to restore the original configuration of islands within the lagoon, in accordance with the objectives and methods defined in the programme for the morphological recovery of the lagoon itself. These interventions are aimed at counteracting the present trend towards erosion in the lagoon.

## INTERNATIONAL CONVENTIONS

There are a number of international conventions ratified by many countries, including Italy, aimed at preventing the use of the sea as a disposal area for dredged material, harmful or otherwise. At the same time, these conventions particularly encourage the useful re-employment of sediment, recommending that dredging be limited to the quantities that are strictly necessary. The first Convention, the London Convention (LC-72), initially called the London Dumping Convention, 1972, and the Oslo and Paris Convention (OSPAR), 1992 revision, are based on the following principles of "precaution" (defined in the Rio Declaration on Environment and Development, 1992):

- “those responsible for polluting must pay” and
- “sustainable use”.

Many “regional” Agreements were later added, including the Directive of the European Community, which follow these guidelines.

In 1996 a new Protocol was drawn up, as an Annex to the LC-72, reversing the approach to the problem: Instead of banning the disposal of material at sea, this Protocol included a list of substances that may be disposed of at sea, including, at the top of the list, dredged material when “damage to the environment is minimal”.

If, however, sediment is contaminated the situation becomes more complicated. In that case, there is a complex question to be resolved: how and where to place the dredged material *permanently*. This question implies solutions that are expensive and difficult to carry out from an operational point of view. In fact this sediment, after undergoing appropriate treatment, must be transported to special deposits on land (disposal sites). It is important to point out that the “treatment” of contaminated sediment could introduce a multiplication factor (as high as 100) to dredging costs.

## MECHANICAL TREATMENT

### How the characteristics of sediment are changed

“Mechanical treatment” is a typical method for treating sediment by separating any contaminated portion which in effect constitutes “waste”, or by conditioning the material as a whole.

In the first case, the treatment acts upon the granular sizes of the material, since polluting agents are linked to the finer fragments, whereas sand fragments are substantially “clean”. Possible treatment consists of:

- the use of hydro-cyclones to separate the sand by centrifuge (this procedure is particularly advantageous if there is a high percentage of sand, which can then be re-employed ; furthermore, the separation of the sand reduces the volume of material sent on to the next phase of treatment);
- flotation, which consists of insufflating air into the sediment-water mixture: the insufflated air-bubbles bind with the micro-bubbles present amongst the fine fragments of sediment, which float to the surface and can then be skimmed and separated from the larger fragments.

In the second case, the water content of the sediment is reduced. Obviously the contaminating substances, if any, are not treated. This is achieved by various means, the more common of which “squeeze” the sediment in filter presses.

Maurizio Gentilomo is a Civil Engineer. Starting in 1969 he worked on behalf of Impregilo (Milan, Italy) and its associates as a site engineer and project manager. In 1987 he was appointed Deputy General Manager. From 1992-98, he was Deputy General Manager at Consorzio Venezia Nuova (CVN), the authority which generally safeguards the Venice lagoon against flooding. He is presently owner of Technologos (Monza, Italy), a consulting company providing technical advice to CVN.



Maurizio Gentilomo

### Which kinds of sediment are critical

As mentioned earlier, although sediment is silt (silt is understood to be sediment in which the maximum diameter of the smaller granules is 60 thousandths of a micron), it contains a fraction of sand which never proves to be contaminated after separation from newly dredged sediment. This is usually described as sediment as it is. It is the silt fraction (which is often the predominant fraction) that may be contaminated.



Figure 1. The area near Venice, the Northern Industrial Channel of Marghera Harbour, where dredging took place, and where the sediment treatment plant is located.



Figure 2. Aerial view of the site of the pilot dredging works in the Northern Industrial Channel of Marghera Harbour.

Furthermore, when sediment is settled on the seabed, and even more, after dredging, it may present a very high water content, and for this reason can only be handled taking special precautions:

- the use of hermetically sealed mechanical buckets (known as “ecological buckets”) or of special suction heads;
- hydraulic transfer (the transfer of granular material mixed with water) through pipes under pressure or transfer by barges; and
- deposit within watertight basins.

All this implies the use of machinery and equipment fitted with devices (operational: hardware, software; servomechanisms) aimed at preventing the leakage of finer sediment particles and the dispersion of any contaminating substances during operations, as well as reducing the turbidity of the water in which such operations are carried out. To this end, purpose-built “screens or membranes” (mobile floating separating element) are positioned around the excavating equipment – floating machinery or equipment for the excavation of soil from the bed of a body of water – when in use.

Continual and systematic monitoring, during and after dredging, are essential phases of the operations, using motorboats, for instance, equipped with the same computerised systems used to position dredges. All data is memorised automatically so that it can be elaborated and used reliably.

#### THE INTERVENTION IN THE NORTHERN INDUSTRIAL CHANNEL OF MARGHERA HARBOUR

##### **Aim of the intervention and methods of execution**

Since this report concerns the *mechanical treatment* of

dredged material, it examines, in particular, a first pilot dredging operation in the lagoon of Venice (Figure 2), which involved this kind of sediment treatment (1997). The treatment is carried out at a plant where dredged material is thickened (dehydrated). This purpose-built plant will remain at the disposal of any public body operating in the lagoon, carrying out further interventions, including dredging.

Note that in the past maintenance work at Marghera Harbour has been insufficient and therefore approximately 5 million cubic metres of sediment have accumulated over time. At present, it has been calculated that 300,000 cubic metres per year need to be dredged for ordinary maintenance; a consistent part of the sediment will require treatment.

This pilot intervention is one of the measures included in the General Plan of Interventions (1991), drawn up by the Venice Water Authority and its Concessionaire (Consorzio Venezia Nuova, Venice), aimed at improving the lagoon environment. This intervention consists of dredging a basin located in the Northern Industrial Channel of Marghera Harbour (Figure 3), in which sediment, potentially harmful to the environment, has accumulated over time. At the same time, the function of the basin with regard to harbour activity is restored by deepening the channel. From an operational view-point, the works will bring the channel bed to a depth of –8 m after the removal of a layer of sediment approximately 2 m thick (around 90,000 m<sup>3</sup>, measured at the site).

It was mentioned earlier that the dredging operations in the Northern Industrial Channel have the characteristics of a pilot intervention. In fact, this work is intended not only to carry out an intervention aimed at improving the quality of the lagoon system, but also:

- to ascertain which setbacks (if any) might occur during the process (excavation, transport, treatment, transfer of sediment to the final destination); and
- to draw up safety criteria for dredging operations in the other areas of the lagoon, including the harbour channels (in other words, compatible with the pertinent national and local regulations and with the particular requirements of the lagoon environment).

Since the safety of the environment during sediment dredging operations cannot be limited only to the phase of mechanical treatment, but must regard the entire cycle of operations, special precautions must be taken during the excavation of sediment (using efficient and ecological techniques to remove the material) and its subsequent transfer (for example, mud – that is, sediment – must be discharged into the barges with no spray; an abundant margin must be left between the open surface of the mud load and the upper rim of the barge tanks), deposit, treatment and delivery to the disposal site.



Note that the efficiency of dredging operations is extremely important: as well as the need to avoid placing fine sediment particles in suspension, the works must be carried out with the greatest precision in order to limit over-dredging and thus also contain the cost of excavation and all subsequent phases of the process.

Economy is as important as the quality of the operation, since the cost of environmental dredging is very high and the feasibility, or otherwise, of interventions is linked to the often limited availability of financial resources.

The general and specific technical regulations for dredging require, amongst other things, that:

- turbidity caused by the operations must not exceed 150% (the limit is set at a figure corresponding to 20 mg per litre), at a distance of 100 m from the excavation, with respect to the situation prior to dredging;
- there must be no leakage of sediment whilst it is carried up the water column and during subsequent phases (from when the barges are loaded until the silt is transferred to the treatment plant);
- *silt enrichment* with water (effectively, *parasite water*) during excavation must not exceed a volume of 20% with respect to the condition before dredging;
- excavation tolerances must not exceed “strict” limits (10 and 25 cm respectively for the floor and the slopes).

## SEDIMENT TREATMENT. THE MALCONTENTA PLANT

### Location of the plant

The plant is located at Malcontenta, in the Fusina area, on land owned by the “Azienda Multiservizi Ambientale di Venezia” (AMAV), a Venice public sector sanitation company. It is very close to the area of intervention and easily accessible by land or from the lagoon (Figure 4).

### Characteristics of the material to be treated

The characterisation of dredged sediment is an essential phase of the activities (see Figure 5). In the case of the Northern Industrial Channel, current regulations were respected, particularly the Protocol dated April 1993, which indicates the “Criteria for safety of the environment during excavation, transport and re-employment of mud extracted from the channels and canals of Venice”. Other regulations were also considered, for instance, the Decree 915/1982 and the Rules of 22.7.1984 enforcing the above-mentioned Decree.

The physical characteristics and grading of silt from the pilot intervention are as follows:

- material on site, before dredging: 1.4 t/m<sup>3</sup>;
- “dry” weight percentage: 43%;
- “dry” density: 2.7 t/m<sup>3</sup>;



Figure 3. The main navigation channel of Marghera Harbour.

Figure 4. The Malcontenta plant financed and constructed by “Azienda Lavori Lagunari Escavo Smaltimenti” (ALLES SRL), Venice, Italy.



- clay content: 24%;
- silt content: 57%;
- sand content: 18%.

Note that dredged material found to be unsuitable for re-employment and classified as *special waste* can be transferred to second category type B waste disposal sites on land. Material classified as *toxic-dangerous waste* may be transferred to a type B disposal site, specifically designed for this kind of waste.

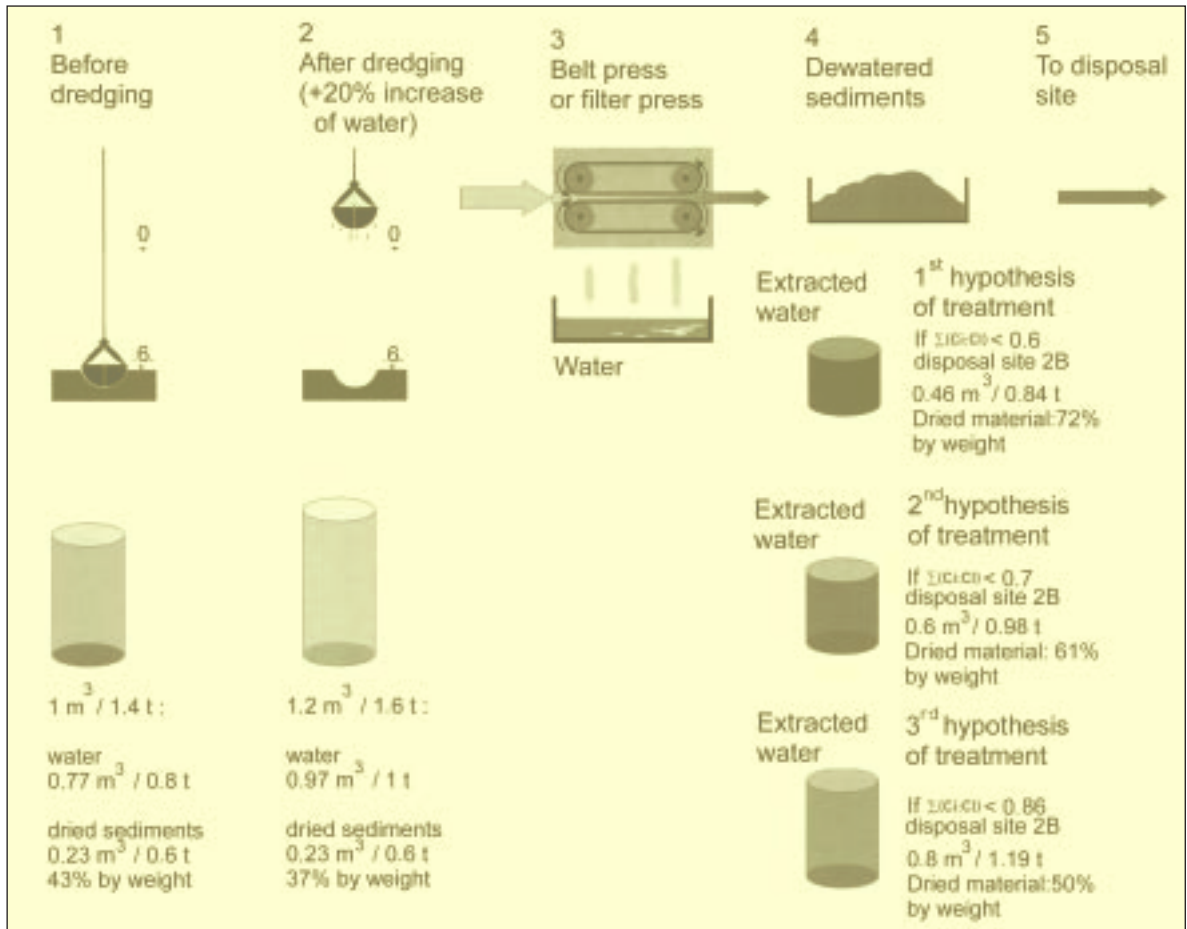


Figure 5. Characteristics of material to be dredged. Silt-thickening process and three hypotheses for thickening material.

### Treatment cycle and safety procedures

Special safety procedures are required not only for dredging operations, but also for the treatment cycle:

- the transfer of dredged material from the barges to the storage basins (which must be watertight, especially in regard to the water tables and soil in the area concerned) and, subsequently, to the plant itself, must be carried out through pressurized pipes, with no possibility of leakage into the surrounding environment;
- the basins, which are constructed of dry, compacted rock material, are all built in relief to ensure the greatest distance from the level of the water tables, and to facilitate any work for the restoration of the area in future (if necessary or appropriate). The basins are fitted with a continuous impermeable layer; the floor is lined with reinforced concrete panels which can withstand the scraping caused by mechanical buckets;
- the foundation soil of the basins must be such as to exclude the possibility of differential subsidence which would jeopardise the efficiency of the impermeable layer. This is achieved by pre-loading the soil;
- the storage basins are independent from one another so that different kinds of sediment may be deposited in relation to each one's final destination. The total

surface area of the group of basins is 6,000 m<sup>2</sup>; each basin measures 50 by 12 (600) m<sup>2</sup>; the height measured from the floor to the upper rim of the basin is 3.50 m. The capacity of the basins is 9,000 m<sup>3</sup> (sufficient to hold material resulting from 12 days of dredging);

- furthermore, each basin is equipped with pumps for delivery to the treatment plant tanks;
- finally, plant areas are paved and fitted with drainage systems for rain-water and water used to hose down lorries and other land-based machinery and equipment.

An outline of the process, from dredging to treatment and then to the final destination, is illustrated in Figure 6.

### Pre-treatment separation of larger elements in the silt

The larger elements and material (measuring more than 20 mm) are separated before the silt is poured into the storage basins. The silt is "sieved" yet again (for elements up to 9 mm) before being transferred from the basins to the plant loading tank (smaller in size). There is no attempt to separate the sand by means of "hydro-cyclones" (given the silt's low sand content).

In the case of the Northern Industrial Channel, it was

also necessary to clear the basin of numerous very large objects such as chains, anchors, steel cables and various wrecks.

**Lime additive in the basins**

This operation is required to prevent anaerobic fermentation in the silt, with the release of unpleasant smells: the lime ensures avoiding this.

**Silt-thickening process**

The machinery used to thicken the silt (in other words, to reduce the water content) consists of flat or strip filter press batteries, working in parallel. The flat filter presses comprise a series of sheets of synthetic filter material, mounted on vertical steel frames. The frames are moved longitudinally by mechanisms operated by oil-pressure.

Material is supplied to the press by a feeder: the sheets are compressed by oil-pressure, and the desired part of water is separated from the silt. Basins are located beneath the presses to collect water running from the sheets and water used to wash the filters.

The thickened material is transferred to the deposit area by cochlea and conveyor belts.

The strip-presses are made up of two conveyor belts, placed one above the other, each one fitted with

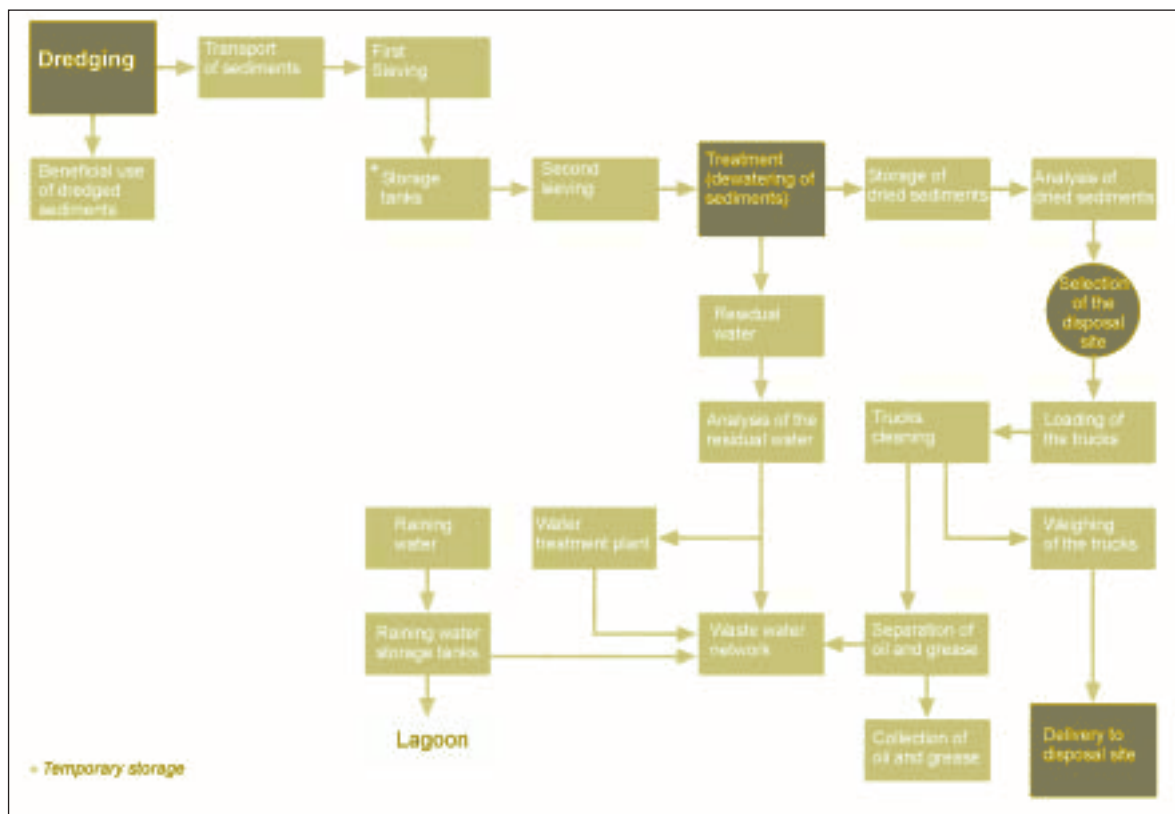
sheets of synthetic filter material. The conveyor belts rotate in opposite directions with a slight convergence. Silt to be treated is delivered to the higher belt by a feeder, and is then transported by the conveyor belt which forces and compresses it through the convergent space (between the sheets of the upper and lower belt). When the belts separate, at the end of the belts' course, the sheets draw apart and the thickened silt is unloaded in a continuous stream. The thickened material is then transferred to the deposit area.

After unloading, the sheets pass through a washing device. In this case as well, water from the thickening process and the water used to wash the sheets is collected in a basin provided for this purpose.

Note that the output with flat filter presses is discontinuous and therefore the continuous production provided by strip-presses generally ensures higher output. However, the dewatering capacity of flat filter-presses is greater. The output of the press depends on:

- the characteristics of the silt and the amount of water it holds;
- the pressure applied by the plates (in the case of flat sheet presses);
- the pressure applied between the sheets of the conveyor belts and on the tension and speed of the belts (in the case of strip-presses);
- the nature and quantity of the additives used; and

Figure 6. Treatment of sediments: An outline of the process, from dredging to treatment to final destination.



- the efficiency of flocculation (the process by which the solid material held in water is aggregated by the action of chemical and biological agents. The granules formed by this process may then be separated from the water).

One automatic strip-press and two automatic flat sheet-press have been installed at the Malcontenta plant. The treatment capacity is 500 m<sup>3</sup> per day of dredged material *as it is* (which corresponds to 600 m<sup>3</sup> delivered by the barges, considering a “parasite” water “enrichment” of 20%) for an output of 300 m<sup>3</sup> of dewatered material, working 24 hours a day, five days a week.

The plant’s capacity is therefore equal to the daily output of the dredger. Four 150 m<sup>3</sup> barges per day ensure the supply of silt, and each barge is expected to take one hour to unload.

After mechanical treatment, the silt must present a “dry” weight of no less than 50% that of the material prior to excavation. Poli-electrolytic additives (in quantities of less than 1%) acting as flocculants are added to the silt, by a suitable meter-feeder, before it enters the presses.

The plant includes, amongst other items:

- pumps and systems for transporting the dewatered silt to the deposit;
- air compressors (for maintenance of the presses); and
- a general control panel.

After passing through the presses, the material is collected in tanks and deposited in a protected area of the plant large enough to store the results of 2 or 3 days of production. This limits any discontinuity in the discharge of material to external disposal areas (there is a pause over the weekend) and allows the quality of the material to be ascertained with a view to its final destination. In relation to these requirements, the deposit has a capacity of 1,500 m<sup>3</sup>.

The controls and analyses are carried out on the dewatered material with a frequency established beforehand (every 500 tonnes of thickened material, after a day of “maturation”) according to IRSA-CNR regulations (*Istituto di Ricerca Sulle Acque-Consiglio Nazionale delle Ricerche* – Institute for Research on Water-National Research Council).

Every day, five days a week, 700 tonnes of material are transferred to the deposit. Lorries used to transport the material are weighed and hosed down before leaving the plant. Water running from the presses is channelled to a storage tank from which it is then discharged into the sewage system, if possible, or channelled to a purpose-built purification plant. This plant is still a part of

the silt treatment cycle even if it is located at a distance from the treatment plant, and in this case the water is still discharged into the sewage system after purification.

It is interesting to point out that although it might appear advantageous to dehydrate the material as much as possible, this is not the case. A high level of dehydration could intensify the concentration of any contaminating substances, and as a result the treated material could fall into one of the more dangerous categories (the most harmful of which can be considered as toxic and dangerous waste): the cost of transferring dangerous toxic waste to disposal sites would be much higher and would not be compensated by the reduced weight of the material. On the other hand, if the sediment was toxic and dangerous prior to dredging, it would be advantageous to intensify dehydration as much as possible.

Figure 5 illustrates three hypotheses for thickening material with respect to the *as it is* condition, as well as the relative indices of admissibility to type B category waste sites. As mentioned previously, the material from the North Industrial Channel is to be concentrated by an average of 60%. With this solution the thickened output is 300 m<sup>3</sup> per day, corresponding to around 500 tonnes; 300 m<sup>3</sup> of water are sent for purification and channelled into the sewage system.

#### **Auxiliary systems and networks at the plant**

Besides the items mentioned above, the service buildings also represent an essential component of the plant; the sheds and covered areas; the remote systems that govern the process; equipment for analyses and control; the maintenance workshop; the electrical systems; the water networks, including those for drinking water, industrial and waste waters; compressed air delivery systems; the equipment for weighing lorries; illumination; fencing; gateway, and such.

#### **Operation of the plant**

Activities for the plant’s operation, beginning with monitoring, must respect the principles and regulation requirements aimed at protecting the health of workers under the guidance of the site manager and the safety officer.

It should be pointed out once again that during treatment of the silt and the transfer of thickened silt from the plant, there must be no leakage of silt or water to the surrounding environment.

#### **Transfer of treated silt to disposal sites**

After treatment, the silt is sent to land disposal sites of the appropriate category. Note that, considering all possible solutions and not those limited to cases in the lagoon of Venice, the envisaged destinations are the following:



*Second category type B disposal sites for special waste:* these may receive thickened silt containing organic synthesis substances (the concentration of each of these substances must not exceed the limit by 1/100th). Each metal in the material *as it is* must not be present in a concentration higher than the upper limit and the sum ratios ( $\sum C_i:Cl$ , where  $C_i$  = actual concentration and  $Cl$  = upper limit of concentration) must be lower than 1. After transfer tests, in accordance with the IRSA-CNR regulations, the presence of heavy metals must be 10 times lower than the values given in the table (Italian Rules, Act 319/1976); the sum ratios must be lower than 30.

*Second category type B disposal sites for toxic and dangerous waste:* these may receive thickened silt containing organic synthesis substances within the limits set out in the previous case; metals in the material *as it is* in concentrations above the upper limit, even with sum ratios greater than 1; the limits of the previous case apply for eluates (interstitial waters that might be released together with concentrations of contaminated substances).

*Second category type C disposal sites:* these may receive concentrated silt containing organic synthesis substances within the limits described in the previous cases; metals in the material *as it is* and eluates without limits.

Tipper lorries with watertight bodies, covered with suitable tarpaulins, must be used to transport silt from the plant to the disposal site.

## Conclusions

The Malcontenta plant demonstrates that the problems posed by the need to improve the quality of the environment in the lagoon of Venice have been tackled decisively. Steps have been taken in the right direction by the Venice Water Authority and the Concessionaire Consorzio Venezia Nuova, in full agreement with other administrations which include the Veneto Regional Authority, the Ministry of Public Works-Maritime Works, the Ministry of the Environment, the local Authorities of Venice and Chioggia, the Venice Provincial Authority, the Port Authority and the local Health Authority.

From an operational viewpoint, the business initiative undertaken by AMAV of Venice, Società "Impregilo" (Milano) and "Mantovani" (Padova) was decisive: these companies created "Azienda Lavori Lagunari Escavo Smaltimenti" (ALLES SRL), Venice, which assumed the task of financing and constructing the Malcontenta plant.

Their path followed the experience of existing plants,

particularly in Europe, albeit on a smaller scale for the time being, with which the treatment of sediment, at a reasonable cost, represents a crucial stage in an overall process that goes much further than the mere dehydration of silt.

In fact, it has become clear that in addition to the objectives of maintaining harbour activities and fulfilling environmental goals, the preferable objective – if and insofar as is compatible with the quality of the sediment – is the useful employment of dredged sediment for the reconstruction of the lagoon morphology, whilst keeping the cost to a minimum by reducing (by dehydration) the volumes of material to be transported to special disposal sites on land.

## References

### **Burt, TN and Fletcher, CA.**

"Dredged Material Disposal in the Sea". University of Gdansk, Poland. September 1996. Republished in *Terra et Aqua*, nr 66, March 1997.

*Italian Rules and Legislation.* Decree 915/1982; Deliberation of 22.7.1984 (Implementation Committee of Decree 915/1982); Decree 22/1997; Acts 319/1976 and 360/1991; Protocol 18.4.1993 (concerning the safety of the environment, transport and employment of mud dredged from the canals and channels of Venice).

*London Convention (LC 1972) and Protocol to the London Convention (Dredged Material Assessment Framework).* 1996.

*Oslo and Paris Convention (OSPAR).* 1992. (A fusion of the *Oslo Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircrafts*, 1972 and *Paris Convention for the Prevention of Marine Pollution from Land-based Sources*, 1974).

### **PIANC-International Navigation Association.**

"Manutenzione e trattamento dei materiali di dragaggio contaminati". *Volume 1, Suppl. al Bollettino n. 93.* Brussels, Belgium.1997.