ABSTRACT

Changes in the legislation about dredged sediments in France resulted in a need for new technologies. The Port Authority of Dunkirk (Grand Port Maritime de Dunkerque, GPMD) was the first to answer this demand by building a treatment facility for contaminated sediments. The project includes not only the installation of the basins but also the dewatering of the dredged sediments in the harbour of Dunkirk. The treatment facility was built on a surface of 6 hectares inside the port area. By means of natural dewatering, sediments are dehydrated and ready to be valorised. With this facility, the GPMD is a pioneer in France and a good example for future facilities. An earlier version of this paper was presented at CEDA Dredging Days in October 2008. This paper is an updated account, reflecting works occurring in the course of 2009.

INTRODUCTION

The ecological aspects in port planning and the sustainable development of areas around the port are of major concern to all people involved in planning, development and construction.

One of the main objectives of the project “Dredging and Treatment of Contaminated Dredged Material” is the development of a recycling centre for the dredged contaminated sediments of the port of Dunkirk. The project is managed by the Grand Port Maritime de Dunkerque (GPMD) and is located in the port of Dunkirk, next to large industrial companies like Polimeri Europe and Lafarge (Figure 1).

The project in Dunkirk is one of the first in France to cope with the historical contamination of the sediments in the harbour. It is a leading project that will encourage a wider action programme in the other harbours in France.

LOCATION AND HISTORICAL BACKGROUND OF THE CONTAMINATION

Dunkirk, France is located 300 km north of Paris near the border with Belgium and covers a stretch of approximately 16 km along the North Sea. The port of Dunkirk is the third largest harbour in France (Figure 2). The East Port has a large tidal range and a navigable depth of 14.20 m to facilitate the passage of
large cargos of 115,000 tonnes. The port also shelters a marina and a fishing port. The West Port has a navigable depth of 20.50 m and can accommodate larger vessels up to 300,000 tonnes.

Dunkirk has a population of 340,000 and is the industrial centre for an area with more than 250 industries. The port specialises in several industrial activities such as petroleum and gas, metallurgy, grains, granular materials and other heavy industries. Since 1999 the GPMD has executed several survey campaigns to characterise the sediments in the harbour, which has resulted in large registers with physico-chemical and biological data.

Because French law has changed, sea placement is subject to strict regulation. Several physico-chemical parameters have been considered in order to fix the maximum allowed values. In the future, the historically contaminated sediments will be dredged in the harbour and these will require treatment.

The GPMD is the first maritime harbour in France to establish a management plan considering the contamination of the sediments and their future valorisation.

ENVIRONMENTAL AND FEASIBILITY STUDIES
The results of the new legislation means that the GPMD is now obligated to treat the contaminated sediments on shore. In order to resolve this issue, the GPMD has conducted several studies over the past few years. The environmental impact of a sediment treatment facility has been evaluated through an Environmental Impact Study (EIS).

Figure 2. Map of the port of Dunkirk.

Figure 3. The site where the Environmental Impact Study was done.
Before the execution of the project could start an EIS was done to characterise the initial conditions of the site and the surrounding sites:
- The site was examined first for practical cautions and secondly for the reuse of the sand as a constructional element for the dike construction (Figure 3).
- The groundwater was examined for pH, salinity, heavy metals and so on before the works started and will be analysed again at the end of the project.
- The Canal des Dunes is the channel in which all water coming from the dehydration of the dredged materials will be discharged (Figure 4). The water was tested on heavy metals but also an eco-toxic test, PCB, TBT and a microbiological test were done in a registered laboratory.

After this characterisation, the execution of the project could start. A similar study will be done at the end of the works in order to evaluate the influence on the environment and the project premises.

**FINANCING AND TENDERING OF THE PROJECT**

The project is financed by GPMD, who also launched the tender for the works. During the tender stage the Joint Venture Envisan Sodraco investigated several options, such as: Mechanical dewatering, immobilisation and natural lagunation.

Several tests were executed by their R&D department on samples taken in the port of Dunkirk; and the Port Authorities selected the proposed alternative solution. At first the sedimentation of the sediments was compared between sediments with an initial dry matter content of 30(w)%, 20(w)% and 12(w)%. Three transparent plastic columns were filled with sediments corresponding to the above-mentioned dry matter contents (Figure 5). During time the sediments height, the upper volume and the drained volume of water were measured. Out of these measurements the dry matter (DM) content of the settled sediments could be calculated.
Because the time for lagooning is dependent on the sediments load, a similar test was performed on a larger column of 2 m height (Figure 6). This large scale test was conducted with sediments diluted to an initial dry matter content of 30% which would be most likely the initial dry matter content of the dredged sediments at full scale. For this larger scale test a dry matter content of 50% was only reached after 21 days of sedimentation. On August 10, 2007, the contract for the installation of the facility, the dredging and dehydration of the contaminated silty sediments in the Port of Dunkirk was awarded to the joint venture Envisan Sodraco.

**EXECUTION**

The project consists of three main stages during the first year and two stages during the following two years. During the first year the following three stages have been executed:
1. Installation of the dehydration basins (Figure 7)
2. Dredging and pumping of the contaminated sediments (Figure 8)
3. Dehydration in the lagoons (Figure 9)

The first stage was the installation of the basins, including all site facilities, such as fences, site offices, access roads and such. Because of the limited area, detailed engineering was done related to the construction and layout of the four basins. The original idea was to use pumps to transfer the water from the lagoons into the next destination. As a result of the optimisation of the layout and the reliability of the system, natural gravitation has been selected.
The excavation of the four basins (Figure 10) started in January 2008. After excavation and construction of the bunds a HDPE geomembrane (Figure 11) was installed. In the meantime the installation of a drainage layer (Figures 12 and 13) also took place and a network of drainage tubes (Figure 14) were installed in de dehydration basins.

Also the connection between the lagoon basins and the water storage basin had to be installed (Figure 15).
Once the first stage was done, in April 2008, the first dredging campaign started and a trailing suction hopper dredger (TSHD) (Figure 16) was used for dredging the first load of 22000 TDM.

The sediments were dredged in “Bassin d’évolution de Watier” and were pumped ashore and distributed in the different lagoons. During the whole dredging campaign samples were taken and analysed for further optimisation of the dehydration process.

During dredging operations and filling the lagoons with sediments, samples were taken at the discharge point at each lagoon. The dredged sediments had an average dry matter content of 33% and a sand content (> 63µm) of 45%.

Owing to the low dry matter content of the dredged sediments, a segregation of the sand content could be expected. As soon as the lagoons were accessible samples were taken at five different locations in the three lagoons (Figure 17). At each location the total sediments height was split up in different depths (steps of 25 cm) which were sampled separately.

The results of the dry matter and sand content of the sediments samples indicate that nearby the discharge point the dry matter content and the sand content of the sediments is much higher compared to the opposite side of the lagoon. While filling the lagoon, larger particles will settle faster and closer to the discharged point compared to the fine silt and clay particles. Once the lagoon is filled, larger sand particles will settle more rapidly resulting in a higher sand content of the deeper sediments layer which will result in so-called graded bed.
The dehydration of the lagoons was done in the following sequence:
1. Decantation: overflow of the superficial water into the water storage basin (Figure 18)
2. Natural dehydration (Figure 19)
3. Mechanical dehydration: preparation of the windrows (Figure 20)

The dehydration of the lagoons started with the decantation, an overflow of the superficial water into the water storage basin. This process was closely monitored: quantities, turbidity and other parameters.

At the end of the dehydration process, the materials will be removed from the basins and will be valorised into new projects. These can include: berm landscaping, aggregate in concrete, road construction and embankments.

The advantages for the Port Authority are clear. This treatment center gives the GPMD the opportunity to valorise their contaminated sediments with a certain continuity. The project offers three lagooning basins which can be reused after the first dredging and dehydration period. A private contractor executes the project for a period of time.

**ACTUAL SITUATION AT END OF REMEDIATION WORKS**
As of August 2009, the treatment centre is fully operational and the dehydration process is ongoing. The first phase of the project was finished by the end of 2008. The sediments issued from this phase will be integrated in an environmental project, more specifically as construction material for berm landscaping. The second phase of the project will start in October 2009 after the valorisation of the sediments in the port of Dunkirk.

**CONCLUSIONS**
The Port Authority of Dunkirk has been studying the sediments at the port for several years. The remaining historically contaminated sediments are still in the port of Dunkirk and have to be treated and valorised during the following years. The project includes three lagoons which can be reused. In fact, once the sediments are dried, the sediments will be removed from the basins and valorised into other projects. This means that the basins will be able to be used for the next 10 years. An environmental project such as Dunkirk is a challenge for all people involved: planners, engineers, environmentalist, contractors, consultants, authorities and many more. This is a first important step for France in the valorisation of their sediments.

**REFERENCES**