AN INNOVATIVE AND SUSTAINABLE SOLUTION FOR SEDIMENT DISPOSAL PROBLEMS

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ABSTRACT

Vast amounts of sediments must be dredged from ports, harbours, and waterways around the world to maintain and improve navigation systems for commercial, defence, and recreational purposes. Globally, several hundred million cubic metres of sediments must be disposed of. Traditional dredging methods discharge sediments into confined disposal facilities (CDF) or oceans, rivers, lakes, wetlands and estuaries. In several countries, dredged material containment facilities currently in use are nearing or are already full to capacity with dredged material. Identifying new containment sites is difficult due to conflicting land uses, potential environmental impacts, and high value of near-water real estate. To counter these difficulties, MWH proposes an innovative approach.

Dewatering the sediment's material, yields an end product with good soil mechanical characteristics. High dry matter content can be obtained, which results in a high reduction in volume. A volume of sediment of 1.000.000 m³ at 30 % dry matter (DM) can be reduced to a volume of sediment of 385.000 m³ at 60 % DM. In an environment with increasing demand for land, this gives an important advantage.

Additionally, the good soil mechanical characteristics make it possible to actually stockpile the dewatered material, and the permeability of the compacted dewatered material can also reach a value of 1.10^{-9} m/s. This offers a huge benefit towards the reduction of risks of stockpiled material towards the environment. Also, a significant decrease in the amount of leachate can be observed.

The dewatering process offers a feasible and sustainable solution and results in a material that shows new possibilities for future applications and reuse of the dewatered sediments. Possible re-use examples are landscape dikes, isolation layers for disposal sites or remediation activities, road construction, sintering and clay-substitution in other industries.

In this paper numerous advantages of dewatered sediments on a social, economic and ecological scale will be demonstrated.

Keywords: Mechanical dewatering, separation of contaminated particles, improvement of dry matter content, decrease of environmental impacts, beneficial re-use.

INTRODUCTION

Enormous amounts of sediments must be dredged from ports, harbours, and waterways around the world to maintain and improve navigation systems for commercial, defence, and recreational purposes. Globally, several hundred million cubic metres of sediments must be managed. Dredging maintenance activities are very often linked with high costs. A good understanding of sediment patterns, tidal energy, river and estuary dynamics etc. is required to estimate sediment volumes.

Natural resonance may explain a variety of observations in some estuaries i.e. the Elbe in Germany (Eichweber 2004). Increasing width of river mouth, growing tidal amplitudes and the development of partial tides are the results of an interaction that might well change regimes and impose increasing maintenance dredging activities. Maintenance dredging in the Elbe estuary increased rapidly after the deepening of the navigational channel in the fifties, sixties and seventies, beginning with 3 to 4 million m³/year and rising up to more than 15 million m³/year.

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Dredged material is often contaminated. Contaminated sediments are often defined as sediments containing chemical concentrations that pose a known or suspected threat to the environment and human health and are in many countries around the world "a national problem". Improved control and treatment of discharges of wastes into water bodies has resulted worldwide in remarkable improvements in water quality nationwide. However, sediments are sinks for many contaminants, and historical releases of contaminants into rivers, lakes, and coastal waters remains as significant problem. In 1977, the U.S. Environmental Protection Agency (USEPA) completed the first comprehensive inventory of sediment contamination nationwide. The results of the inventory indicated sediment contamination present in over 70% of U.S. watersheds, with the total estimated volume of surficial contaminated sediment over 1 billion cubic meters (Palermo 2001). Although the percentage of U.S. waters and associated volumes of sediment with contamination at levels posing a significant environmental risk is much lower, the extent of the problem in the U.S. is massive in both its logistical scope and the overall project costs of remediation.

Europe

The United Kingdom has many ports on its coastline and estuaries. A few may be described as natural and require little maintenance, but in most cases the coastline, estuaries and rivers have been modified. Most ports or channels in the UK created by capital dredging require ongoing maintenance dredging. The majority of the UK's maintenance dredged material, most of it mud, is placed at sea disposal sites. The total for 2000 was about 16.5 million tonnes dry matter (Burt et al. 2004).

Mersey Port is an example where the Port Authorities are struggling with maintenance dredging activities. Mersey Port comprises the Ports of Liverpool and Manchester including the Manchester Ship Canal. The Mersey estuary has a high sediment content, which has consequential effects on the impounded docks at Liverpool and Birkenhead as the entrance is through a lock to the Ship Canal and QEII Dock at Eastham. In addition, river borne silt is discharged into the Ship Canal from the non-tidal rivers Irwell, Mersey and Weaver. Mersey Port wishes to reduce the costs associated with sediment management, treatment and disposal.

The Netherlands and Germany have large river systems such as the Danube, Rhine, Scheldt, Meuse, Elbe, Weser and Ems, which have important hydrological and shipping functions and where dredging is essential for maintenance. Both also have large (sea) ports such as Hamburg, Bremen/Bremerhaven, Rotterdam and Delfzijl, which receive large amounts of sediments both from the sea by tidal processes and from upstream areas by rivers.

The corresponding national volumes of dredged material amount to about 50 million m^3/year for Germany and about 35 million m^3/year for the Netherlands (Köthe et al. 2004).

An annual sediment quantity of 1.7 million tonnes dry matter arrives in the different ports and rivers of Belgium. Additionally, there is about 25 million tonnes dry matter that needs to be dredged as a historic heritage.

The United States of America

In order to maintain the nation's navigation system, several hundred million cubic meters of sediments are dredged from U.S. waterways, ports, and harbours each year. The U.S. Army Corps of Engineers dredges and disposes of some 190 million m^3 of dredged material annually from congressionally authorised navigation improvement and maintenance projects (Vogt et al. 2004). In addition, permit applicants (e.g. port authorities, terminal owners, industries, and private individuals) dredge about 75 million m^3 annually form ports, berths, and marinas.

All quantities mentioned in this section are annually created volumes which imply that on-going maintenance works are required yearly to guarantee navigation systems. This indicates that the flows are repetitive.

TRADITIONAL DISPOSAL FACILITIES

Dredged material contains a large portion of water and only a small fraction of dry matter (DM), typically around 15 to 20 %. Prior to land disposal, the dry matter content has to be increased by removing water. The conventional technique for this is lagooning: the dredged material is filled into specially designed drying fields, also called lagoons, enabling the evacuation of water by both evaporation and drainage.

After a few months, the dredged material can be lined up in rows. Using this technique the dry matter content can be increased to 30 - 40 %. A system of pipes, which are built into the drainage layer of the drying field, collects the drainage water and transports it to a water treatment plant.

The time needed for the total dewatering process strongly depends on the quality of the dredged material (density, sand fraction, etc.) and of course, the climate. Typically, in countries with a moderate climate, the dewatering process takes up to a year to complete. After the process has been completed the dewatered material is removed by excavators and disposed of in a CDF. Typically, the dry matter content which can be reached by lagooning is 45 - 50 % DM. This dry matter content is not sufficient for compaction of the material, hence stockpiling is also impossible. This means that fill material, i.e. sand, has to be used in the CDF to guarantee the global stability of the waste body.

Figure 1. Lagoon fields in Bremen.

The dewatering process can be accelerated by first pumping the dredged material into a pond where it's particles sink; through this process, the dredged material thickens to about 25% DM.

After drying, the sand is recovered; it is in most cases located near the outlet of the discharge pipeline due to differential settling between coarse and fine particles. After emptying the lagoon fields, the top layer of the drainage layer has to be replaced because in the upper layers fine particles could have penetrated into the sand during the dewatering process. The removed sand will also be disposed of in the CDF.

DEWATERING TECHNIQUES

Mechanical dewatering results in an increase of the dry matter content from ± 30 % to ± 60 %. This means that volumes are significantly reduced and the life time of the CDF is also increased as more dry matter per cubic meter dredged material can be disposed of. Besides the increase in dry matter content, the environmental risks are also significantly reduced because dry material rather than wet material is deposited. Limited leaching arising from the low permeability of the dewatered tailings significantly reduces the risks of groundwater and soil contamination. As the dry matter content increases, the amount of leachate decreases. Because of the low permeability, the risk of leakage through the bottom liner is negligible.

Background

Several techniques are already applied for dewatering of various types of sludge, e.g. sludge produced in a municipal wastewater treatment plant. It involves the removal of water through the application of mechanical forces. This occurs either by using increased differences in gravitational forces in a decanter centrifuge, or under pressure in a sieve belt press or a filter press. In all cases the sludge stream is conditioned by adding chemicals that enhance the separation of the water, and hence enable increased dry matter content. Typically poly-electrolytes, iron-chloride and lime are use as conditioners. They can be used separately or in combination, depending on the sludge dewaterability and the requested dry matter content of the dewatered sludge.

Centrifuges

This type of equipment is driven by centrifugal forces. Depending on their density, sediment particles move towards the outside of the drum with different speeds. Centrifuges offer the advantage of being a continuous process, which at least theoretically should render the operation of the centrifuges easier. An important disadvantage is that rapidly rotating equipment is sensitive to abrasive materials and less suitable for ‘heavy duty’ applications. To decrease abrasion (and the corresponding high operating costs) special materials are used and high requirements are set towards sand removal prior to centrifuging.

Additionally, it is common knowledge that under similar operating circumstances centrifuges tend to deliver a lower dry matter content compared to other dewatering devices such as belt presses and filter presses.

In addition, a significantly higher use of poly-electrolyte is often required and the geotechnical characteristics of the dewatered material tend to be unfavourable.

Belt Presses

By belt presses the dewatering is obtained by squeezing the sediments between two moving filter cloths, which are pressed together by a rolling system. The water runs through the filter cloths and the dewatered material is scraped from the cloths at the end.

Figure 2. Sieve belt press.

Sieve belt presses are more robust machines that work continuously, which offers an advantage with regard to their operation. They have the disadvantage of continuously consuming washing water, which is an extra load for the wastewater treatment plant. Conditioning with lime is not advised due to the effects of abrasion and the corresponding abrasion of moving parts. Those machine parts are sensitive to abrasion, which results in high operating costs and energy consumption.

Sieve belt presses have a large number of moving parts. This results in high maintenance costs. The removal of the pressure rolls during maintenance requires a lot of space close to the equipment, which explains the large surface area for the same capacity compared to for instance filter presses.

Sieve belt presses create continuous noise nuisances compared to filter presses, where the noise nuisance is limited to the discharge periods.

Filter Presses and Chamber Filter Presses

Sediments are squeezed into a chamber, formed by parallel filter cloths attached to filter plates. Each chamber has a certain volume that is determined by the surface area of the filter cloths and the distance between the plates. The sediments are squeezed under high pressure into the chamber and the water is pressed through the filter cloths. As the chamber is filled, the pressure required to press the water through the filter cloths increases.

Membrane filter presses are an important alternative to the classic chamber filter presses. The membrane filter presses work according to the same principle as the chamber filter presses, but the filter cake can be compacted after the normal filter cycle by filling the membrane under pressure, which induces an additional dewatering effect.

Applying this technique results in an end product with good soil mechanical characteristics. This improvement of the dredged sediments makes stockpiling possible. The bearing capacity of the dredged material improves and tests show that compaction of the material is possible. Additionally, the pressing process is static, which takes place without any parts of the equipment moving. Therefore, maintenance is much simpler compared to sieve belt presses and centrifuges. The filter presses are also less sensitive to abrasion, which implies lower operating costs. The advantages of the membrane filter press compared to the chamber filter press are the following:

- The possibility to obtain higher DM contents (60% DM is possible without using any conditioners);
- Shorter filter cycle;
- Less probability of poor pressing results.

The filter press has the disadvantage that it operates in a batch process and that the system is closed. If the sediments are badly conditioned, you only discover the poor pressing results by opening the chambers, and then there is no possibility of resolving the problem.

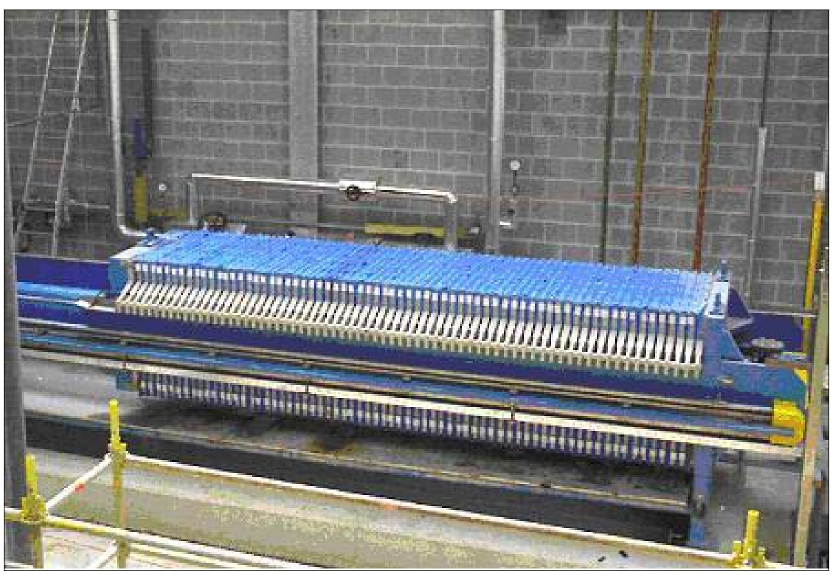

Figure 3. Chamber filter press.

LAGOONING VERSUS DEWATERING WITH CHAMBER FILTER PRESSES

Time

Lagooning consists of 4 phases: filling of the dewatering fields, dewatering of the crude sediments, emptying of the fields and repair of the drainage layer. As stated earlier, the time needed for the total dewatering process strongly depends on the texture of the dredged material and of course, the climate. Typically, in countries with a moderate climate, the dewatering process for lagooning takes up to a year to complete. It can be accelerated by first pumping the dredged material into a pond where it sinks and by this process thickens to about 25%.

On the other hand, the process of mechanical dewatering of the dredged sediments is not sensitive to weather conditions and therefore much faster.

Space (i.e. Social and Economical)

Lagooning requires a large surface area. As land is becoming a very precious resource, its destination is subject to intensive debate, and hence further expansion of lagoon fields is expected to meet with strong public opposition.

With land prices rising (as is happening in Belgium and the Netherlands), this creates a further problem from an economic point of view.

Other public acceptance criteria are noise, dust, odour and visual nuisances. Noise and visual nuisances of lagooning activities remain limited, but odour and dust may cause problems as the dredged material is exposed to open air over a long period of time. Tilling it to increase dewatering intensifies contact with air. In the case of mechanical dewatering, odour and dust problems are less probable. The installation for mechanical dewatering also has a lower visual impact.

Environmental Risks

Lagooning brings about some environmental risks as it implies the construction of a protection layer at the bottom of the drainage layer. Given the large surface area of the drying fields and the field activities (e.g. the use of cranes to remove dewatered material or to repair the drainage layer) the possibility of penetration or damage of this environmental protection layer is not negligible, resulting in a risk of dispersion of contaminants. Emissions may also occur. Furthermore, the breeding season of bird colonies is an important ecological factor that has to be taken into account during the operation of lagooning fields. These ecological risks are basically absent with an installation for mechanical dewatering.

Mechanical dewatering results in an increase of the dry matter content from ± 30 % to ± 60 % (Duerinckx et al. 2001). This means that the volumes are significantly reduced, and as a result, the life time of a CDF (existing or future design) is much longer than hydraulic filling (DM ± 30%) or lagooning (DM 45-50%). Besides the increase in dry matter content, the environmental risks are also significantly reduced because dry material instead of wet material is deposited in the CDF. Limited leaching arising from the low permeability of the dewatered sediments significantly reduces the risks of groundwater and soil contamination. As the dry matter content increases, the amount of leachate decreases. Because of the low permeability, the risk of seepage through the bottom liner is negligible.

When applying hydraulic storage, water pressures in the external dikes are most likely to occur (i.e., damage of liner on the inside of the external dikes) as the deposited material is wet. Flooding of disposed material will have an enormous impact on a large area around the CDF with serious contamination of the soil and groundwater as a consequence. However, if mechanical dewatered sediments are disposed of, the risk of stability failures in the external dikes decreases. This is due to the absence of large excess water pressures in the vicinity of the external dikes that are associated with the stockpiling of dewatered sediments (Foged et al. 2006). Flooding attributable to dike failure is negligible, as the risk of seepage caused by water pressures in the dikes is almost non-existent. This significantly increases the safety of the external dikes and the waste body in the CDF. This difference between dry and wet disposal also improves safety, lowers the risks to the surrounding environmental and human health.

The improved soil mechanical characteristics of the dewatered sediments make stockpiling possible (Duerinckx et al. 2001). The bearing capacity of the sediments improves, and compaction is possible. This behaviour together with the low permeability proves that the stockpiled material will create one impermeable body (Foged et al 2006).

Immobilisation of Pollutants in Sediments

Pilot tests show that the most contaminated part of mechanically dewatered dredged sediments is the filtrate. Several samples of crude sediments were taken. The sand fraction was separated by using a hydrocyclone, and the fraction containing the fine particles were dewatered through a chamber filter press. For dredged material where the sand fraction consists of 10 %, 1.78 % of the contaminants present are in the sand fraction, 27.84 % of the contaminants in the sediments (fine particles) and 70.37% of the contaminants in the filtrate. By mechanical dewatering more than 2/3 of the pollutants will be removed from the sediment via the filtrate and approximately 30% will remain in the dewatered material also called the filter cakes. The degree of contamination in the sand fraction is very low and almost negligible (less than 2%). The pollutants which stay in the filter cakes will be captured in the fine particles. As the permeability of the filter cakes is rather low ($k < 10^{-9}$ m/s), the risk of leaching is very low as well and thus the risk of soil and groundwater contamination in case of seepage too (Duerinckx et al. 2001). The different contaminated loads are pictured in Figure 4.

Through lagooning, the separation between sand and fine particles takes place by segregation at the spigots and is not as well defined as by mechanical dewatering. This means than the separated sand fractions would be lower than through mechanical dewatering. Through mechanical dewatering, the coarse fraction is divided mechanically by means of a hydrocyclone turned at the desired grain size, i.e. 63µm. The DM content of the dewatered sediments is lower through lagooning than through mechanical dewatering, which means that the percentage of pollutants will be higher than through mechanical dewatering.

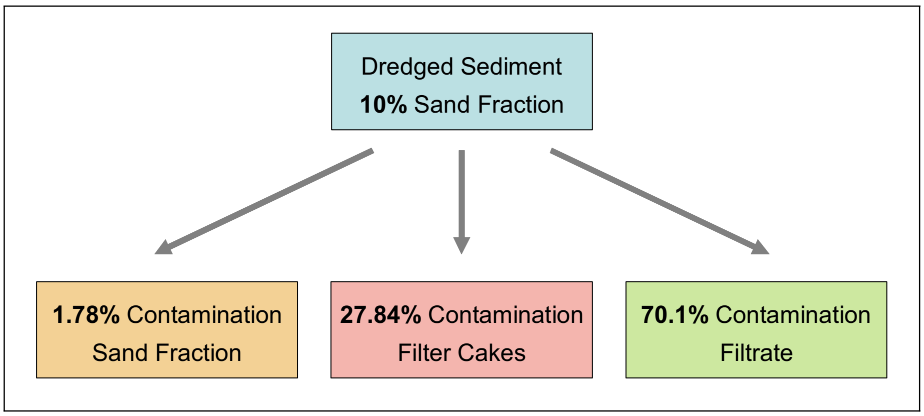

Figure 4. Contamination in percentage of different fractions.

Technological

Lagooning is a largely uncontrolled process. To start with, it is susceptible to weather conditions, as wet periods have a detrimental effect on the total dewatering time. In addition, it is not possible to influence the quality of the end product, as in soil mechanical properties and process ability. These are important issues in view of the final disposal as well as the beneficial use of the dewatered material. In fact, the quality of the end product of lagooning is rather poor, which limits the range of applications. Another disadvantage of lagooning is the discontinuous mode of operation of the often large lagoon fields.

Mechanical dewatering on the other hand is insensitive to weather conditions during the entire process. Furthermore, mechanical dewatering using chamber filter presses is a very well known technique used for many decades in different industries. Moreover, thanks to the polyvalence of the dewatering process (through the use of additives) the properties of the end product can be controlled which offers more opportunities for reuse. The present chamber filter presses are fully automatic and are able to treat dredged material that is difficult to dewater. Even sediments containing a high content of mineral oil can be treated. Presses can even be equipped with heating systems (steam) and rinse or washing systems for the filter cloths during the dewatering cycle. These options give possibilities to decontaminate problematic or heavily contaminated dredged sediments.

Due to the possible use of a large range of conditioners (poly-electrolyte, lime, gypsum, fillers …) it is possible to change the specific physical characteristics of the dewatered sediments. The dosing of the additives can influence the quality of the desired end product or basic material for reuse.

Mechanical dewatering of dredged sediments has the following characteristics that are significantly better than the characteristics of sediments dewatered via lagooning:

- Very high content of dry matter can be reached;
- Maintenance and energy consumption is limited due to the robustness and limited amount of moving parts;
- Automatic transport systems can be installed;
- Capacity of the installation can be easily enlarged;
- Prior sand separation or decontamination of the dredged sediments is easily added;
- Easier categorising of the dewatered sediments.

Costs

MWH has prepared a comparison regarding the costs related to lagooning and mechanical dewatering of dredged material (Duerinckx et al. 2001). Both investment (depreciation over a period of 15 years) and operating costs are presented and include the following topics:

- Required buildings and infrastructure (including access roads, parking lots, water treatment plant...);
- Equipment;
- Transportation to storage depot;
- Automation, electricity and instrumentation;
- Personnel;
- Maintenance of installations;
- Maintenance of buildings;
- Energy consumption;
- Use of additives;
- General costs;
- Land concessions;
- Treatment of the filtrate water.

For lagooning, different scenarios were investigated: variation of the duration of the total dewatering process (due to manipulation of the sediment) and different lay-outs of the lagoon fields themselves. For the mechanical dewatering the options with or without sand separation were taken into account. Assessing these options, the costs were estimated to be as follows:

Table 1. Comparison price/tonnes DM lagooning and mechanical dewatering.

Technique	Investment Costs	Operational Costs	Price Euro/tonnes DM
Lagooning (90 ha):	Low	High	32.50-49
Mechanical dewatering (20 ha):	High	Low	28-31.50

In the cost estimates shown above, no land concession costs are included. The main difference in the prices are the high operational costs by lagooning (surface area is 90 ha). The difference in price between the two dewatering techniques also strongly depends on land concession and land availability in the area where disposal will take place. In Belgium and the Netherlands the land concession prices are extremely high and that makes the unit price per tonnes dry matter by lagooning would be even more expensive than by mechanical dewatering in case those costs are included.

CASE STUDY 'AMORAS PROJECT IN THE PORT OF ANTWERP' – DEWATERING OF SEDIMENTS WITH CHAMBER FILTER PRESSES

Scope

In the Port of Antwerp, Belgium, an amount of approximately 600,000 tonnes dry matter of harbour sediments must be dredged annually. Today, the sediments are disposed of on several confined disposal facilities on land or in underwater disposal cells. Because the present disposal capacity is insufficient and no expansion is possible due to the lack of space, the Port of Antwerp has decided to construct an installation for mechanical dewatering of its sediments, using the dewatering technique with membrane filter presses. Currently, the detailed design of this installation has already been prepared by MWH.

Process

The design criterion of the installation is 600,000 tonnes dry matter per year. The different treatment facilities are divided into several areas:

- An acceptance area where sediments are received. This area is located near a dock in the Port of Antwerp and comprises an underwater acceptance cell, a sand separation unit and the required piping to transport the sediments to the dewatering installation.
- The treatment installation which is located at a distance of about 3.6 km from the acceptance area.
- A confined disposal facility where the dewatered material will be disposed of.

The treatment process can be described as follows:

The sediments arrive directly or via the underwater acceptance cell at the sand separation unit. In this installation, the coarse material and the sand is removed from the sediments. The de-sanded sediments are then pumped by a booster station to the treatment installation, over a distance of about 3.6 km.

The pumped sediments are then discharged into buffering ponds, where thickening of the sediments is allowed to obtain an optimal dry matter content to proceed with the rest of the process.

After thickening, the sediments are pumped to the installation for mechanical dewatering; where the sediments are dewatered using membrane chamber filter presses after optimal conditioning of the sediments have taken place. At the moment, an expected set of 16 filter presses with a volume of 16 m³ each is required for the process.

The produced filter cakes are removed and disposed of at a CDF. This site has a surface area of about 30 hectares and an expected life-time of about 17 years.

The filtrate, produced during the dewatering of the sediments, is collected and pumped via a buffering pond to the wastewater treatment plant. The filtrate is collected together with other wastewater and treated to reach the required discharge standards.

The supernatant of the thickening buffering ponds, which have not undergone any treatment process, will be discharged after gravitational sedimentation, following the described standards.

Quality Control of Dredged Sediments

It is estimated that 20% of dredged material will be contaminated and will have to be disposed of as waste for class II landfills. 80 % of the material is defined as non-polluted sediments and has to be disposed of as waste for class III landfills. The non-polluted sediments are classified as inert material and comply will the Belgian legislation for inert material.

A detailed scheme has been defined for acceptance of the dredged sediments in order to be able to carry out quality control of the received material during the operations activities. The acceptance pathways and the final CDF or end user are pictured in Figure 5. The non-polluted sand fraction can be used internally on the site for maintenance purposes or externally for other purposes. The standards for maintenance purposes internally or re-use externally are not the same, as the standards for external re-use are much more stringed. This also counts for the filter cakes comprised of sediments classified as inert material.

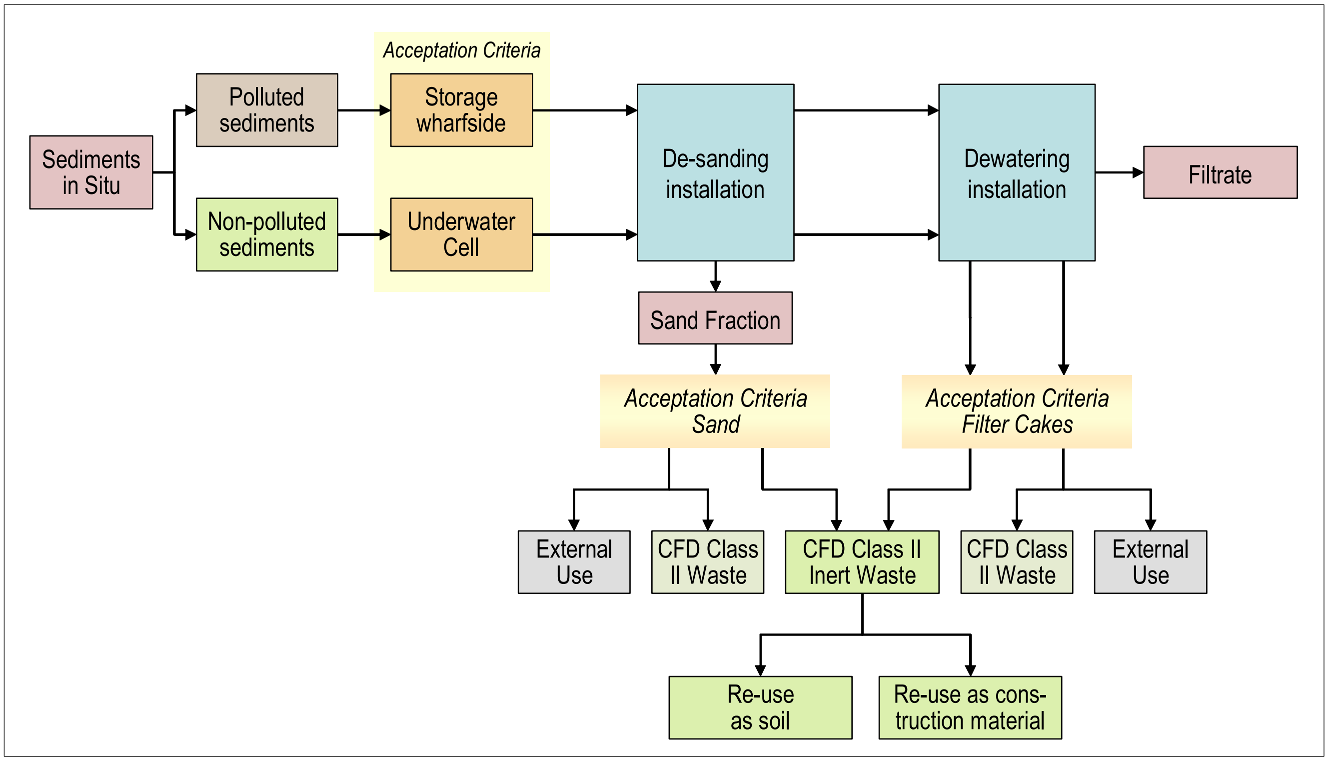

Figure 5. Flow acceptation of dredged sediments.

The CDF is divided into two sections; one for polluted sediments and one for non-polluted sediments. This can both be sand and filter cakes; however, the filter cakes will make up the large quantities. The operational disposal plan comprises the disposal activities for both types of filter cakes for the entire operation period (15 years). The two different types of filter cakes are disposed of in such a way that the filter cakes classified as inert material can always very easily be removed from the CDF in case it would be beneficial to apply this material to re-use applications.

Output Characteristics of Filter Cakes

A pilot test was performed prior to the design of the installation, using chamber filter presses to dewater sediments from the Port of Antwerp. The pilot test presented the results for the sediments in Table 2:

Table 2. Characteristics of sediments.

Characteristics of Sediments	**Results (averages)**
Specific density of sediments	2.64 tonnnes/m³
Dry matter content of sediments	15-20 %
Density of crude sediments	1.10 – 1.15 tonnnes/m³
Sand fraction of sediments	± 5 %

The soil mechanical properties as they were defined after the pilot tests are given in Table 3.

Table 3. Soil mechanical characteristics.

Soil Mechanical Characteristics	Results (averages)
Average dry matter content	62%
Permeability (after compaction, tested in flexible wall cell)	1.10^{-9} m/s
Cohesion c	20 kPa
Internal friction angle φ	25°
Undrained strength c_u (after compaction in situ)	202 kPa

Figure 6. Dewatered sediments after dewatering with chamber filter press.

Use of land

For a port like Antwerp, which annually dredges some 600,000 tonnes of dry matter to maintain its waterways, it is estimated that lagooning activities would occupy 120 hectares (60 hectares if accelerated lagooning was used). This poses quite a problem in densely populated and industrialised areas, where land is needed for new industrial activities and expansion of residential areas etc. For mechanical dewatering, only 20 ha would be required for the Port of Antwerp.

Present Status of the Project

The tendering for the Construct and Operate contract of the mechanical dewatering plant is expected in the first half of 2007. The operation will be for 15 years.

RE-USE

Possible re-use of dewatered dredged material largely depends on the properties of the clay mineral content of the dredged material. The filter cakes obtained in the pilot study showed good soil mechanical properties and processability (see above). Hence, various applications are possible, as will be explained below.

Expanded Clay Grains

Large amounts of mechanical dewatered dredged material can be used as a filler or as a substitute for natural clay in the production of sintered clay grains, an unshaped building material. This form of recycling has the advantage that the product is consumed quite evenly over the whole year.

With regard to this application, attention has to be paid to the following aspects:

- The dry solids content of the filter cakes;
- The leaching behaviour of the end product;
- Influence on emissions during production;
- Possible disturbances of the production process due to increased concentrations of by-products;
- Influence on the quality of the end product (i.e. density).

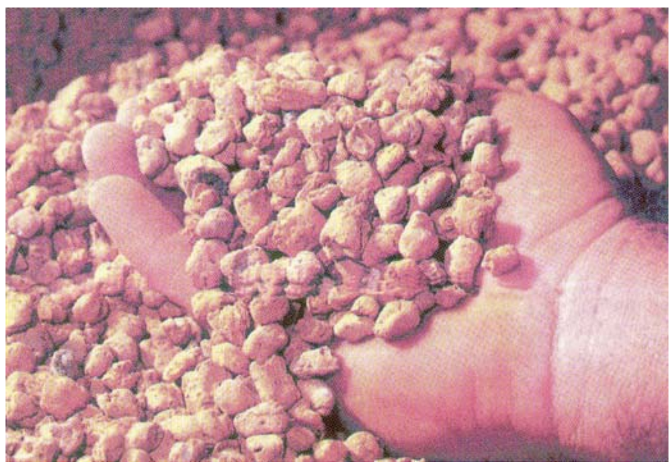

Figure 7. Expanded clay grains from mechanically dewatered sediments.

Landscape Dike

Possible application of dewatered dredged material in landscape dikes largely depends on the properties of the clay minerals contained in the dredged material, because they strongly influence the mechanical properties and processability. The dredged material used in the pilot test showed excellent processability during the construction of a test hill. Due to the increase of the DM content compaction of the dewatered material is possible and a stable material can be created where the stability under optimal conditions can be guaranteed.

Figure 8. Test mound with dewatered sediments.

Furthermore, water management is one of the most important properties influencing the vegetation as well as nutrient exchange. A test zone has been laid out to investigate the growth process of plants. In addition, spontaneous growth of vegetation is also being monitored (followed up by the University of Ghent).

Isolation Layer for Disposal Sites or Remediation Activities

Thanks to the favourable soil mechanical properties (strength characteristics, permeability, etc) and processability, the dewatered dredged material can be applied as a protection and isolation layer for disposal sites or remediation activities (Laboyrie et al. 2004).

Many opportunities exist for redeveloping properties by beneficially using dredged material. Capping brownfield sites with amended dredged material is an excellent way to recycle and reclaim damaged sites. There are a multitude of waterfront sites i.e. in the New York-New Jersey region that can be successfully remediated, using either amended contaminated-dredged material or clay from harbour dredging maintenance projects (Morgan et al. 2001).

Road Construction

Additional additives (e.g. by increasing the lime content) makes the dewatered dredged material suitable for road construction and, especially, of industrial parking lots.

Sintering

Sintering is a thermal immobilisation technique that, just like melting, offers a solution for processing of dredged material which contains a mixture of pollutants. The dredged material should not contain too much sand; hence, usually only the finer fractions that remain after sand removal are used in this application.

Typical for sintering is that the material is shaped prior to heating. Sintering of dredged material yields ceramic products like bricks, tiles, and artificial gravel (e.g. to be used as an additive in concrete).

Energy consumption is the most important negative environmental effect of thermal processes such as sintering. Even though part of this energy can be recovered, energy consumption remains higher than with other, simpler processing techniques. Also, more extensive precautions have to be taken in order to limit emissions to the atmosphere as some pollutants may volatilise during the sintering process.

HANSEATEN-STEIN® Bricks

A good example is the HANSEATEN-STEIN® brick producing factory located in the North of Germany that uses contaminated sediments dredged in the Port of Hamburg as the main raw material (Ulbricht 2001). The factory is running at an industrial scale, producing up to 5 million bricks per year utilising up to 35.000 t of drained port sediments. It has been proven that it is technically possible, ecologically reasonable and economically attractive to utilise contaminated port sediments as the main ingredient for a facing brick. The know-how accomplished serves as a base for a planned large scale industrial plant in Hamburg, Germany utilising 300.000 tonnes of drained port sediments annually.

One of the objectives was to define the 'technical possibilities' which meant finding the right mixture of raw materials and the right production methods in order to produce a facing brick that complies with the German Norm DIN 105 (Deutsches Institut für Normung e. V., 1989) and thus can be sold in the German construction market in competition with traditional bricks.

Making bricks from contaminated harbour sediments is especially valuable for rather highly contaminated sediments since it operates with temperatures above 1000°C/1832°F. At the same time the finished product is a ready to sell construction material, equal to traditional bricks. There are two economical aspects to be considered. First, the port city/authority makes use of a technology, which allows for very low cost as well as high decontamination levels. Second a construction material is produced, which enables the city to use the recycled product in its truest definition

Cement-Lock^{SM} Technology

A good example of sintering is the Cement-Lock^{SM} Technology developed in the United States of America (Mensinger et al. 2001). The Cement-Lock^{SM} Technology thermo-chemically transforms contaminated sediments into construction-grade cement which has properties similar to those of Portland cement. During the thermo-chemical transformation, the mixture of sediment and proprietary modifiers is imparted with latent cementitious properties that allow it to be converted into construction-grade cement. Besides, all organic contaminants are destroyed and converted to innocuous carbon dioxide and water. Heavy metals are locked within the molten matrix to completely immobilise them.

The Cement-Lock Technology has been thoroughly evaluated in bench scale studies and pilot-scale studies with contaminated sediment form estuaries and rivers in the states of New York and Michigan; Because of the favourable environmental attributes, a large scale plant (22,900 m^3/y contaminated sediments) is being built (2001).

In the Cement-Lock Technology the sediments are brought together in a reactive melter with suitable modifiers in proportions for producing an environmentally friendly material called Ecomelt® with latent cementitious properties. These properties are utilised to convert the Ecomelt into construction-grade cement, which has compressive strength properties exceeding those required for ordinary Portland cement. The quantity of modifiers added, which depends upon the sediments composition, is typically less than about 20 weight percent of the sediment.

The melter for carrying out this process is operated at temperatures up to about 1399°C (2550°F), sufficient to melt the sediment-modifiers mixture. In the presence of excess air/oxygen at these temperatures, organic components or compounds originally present in the sediments are completely utilised to their fuel value and converted in innocuous carbon dioxide and water. Inorganic components of the waste material are transformed into the cement matrix (predominately calcium-alumino silicates), which are subsequently pulverised and mixed with an additive to yield construction-grade cement. The sensible heat contained in the flue gas is reconverted to produce steam that can then be used for power generation.

The Cement-Lock product has been tested and shown to be comparable in performance to commercial Portland cement. In addition to general commercial use, other markets that are related to environmental and dredged sediment management include:

- General construction for sediment processing stakeholders;
- Grouting of underground storage tanks;
- Soil conditioning at landfills;
- Sediment stabilisation processes;
- Construction retention walls in mines where sediments are used for backfilling.

CONCLUSION

It turns out that mechanical dewatering using chamber filter presses is not only an economically viable alternative to lagooning, it also enables proper control of the dewatering process and it yields an end product of superior quality. It also creates new applications for re-use. In addition, a mechanical dewatering plant for dredged material has a smaller environmental impact as well as a much smaller footprint than other treatment approaches as i.e. lagooning. The environmental risks of disposal of the dewatered sediments are also significantly improved and soil and groundwater contamination is almost negligible. The improved soil mechanical characteristics of the dewatered sediments make stockpiling possible. The bearing capacity of the sediments improves, and compaction is possible. This behaviour together with the low permeability proves that the stockpiled material will create one impermeable body.

Mechanical dewatering is a well know technique which has been used to dewater organic sludge originating from wastewater treatment plants. Filter presses (chamber or membrane) are often used to achieve suitable dry matter content for additional transportation, disposal and/or reuse. Mechanical dewatering is a very sustainable solution as an alternative treatment approach for dredged sediments.

The Port of Antwerp, Belgium, agrees with this conclusion and has decided to start the construction of a mechanical dewatering plant. The construction works have been scheduled to start in 2007.

Many opportunities exist for beneficial re-use of dredged material such as expanded clay grains, landscape dikes, isolation layers and protection layers at landfills, brownfields and remediation sites, road construction and sintering. Much research has been carried out indicating that re-use of dredged material is beneficial, also showing that the fine particles in the dredged materials can very often replace clay.

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