# Environmental issues of dredged materials used in the DredgDikes Project in context with national legal aspects

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## Abstract:

The demand of different kinds of earthy construction materials increases steadily. Often natural resources have to be transported over great distances to the construction site. These measures often produce a considerable intervention in nature. It is quite obvious that the resource-conserving use of dredged materials as soil and construction material is an alternative. Since there are considerable amounts of dredged materials available along the Baltic Sea coast and dike construction materials such as limey marl or marsh clay are generally in short supply, the idea of using dredged materials in dike constructions is a logical decision. Therefore, the project DredgDikes has been initiated by the University of Rostock, chair of Geotechnics and Coastal Engineering and Gdansk University of Technology, department of Geotechnics, Geology and Maritime Engineering. The main goal of this project is to investigate possibilities to use different kinds of dredged materials in dike construction. According to its utilizability not only the soil mechanical and chemical characteristics of the material are of particular importance but also the legal basics. At European, federal and state level, there is consensus that the onshore accommodation, storing, preparation and beneficial use is subject to waste regulations, as dredged material is classified as waste. According to the German Recycling Management Act (KrWG, 2012) and other public laws, a possible reuse has to be proper and harmless (i.e. no deterioration of the public interest, particularly no accumulation of contaminants in the recycling process, §7 KrWG). The use of dredged materials in dike construction is only possible in specific individual cases (compare EAK, 2002/2007). Due to their classification as waste materials and the associated difficulties for the planning process, there are only very few projects where these kinds of dredged materials have been installed as dike cover material yet (e.g. Bremischer Deichverband, 2013). However, the application of dredged material was carried out as restoration layer at disposal facilities under comparable conditions. The evaluation in these situations may give also conclusions for future dike projects. The Steinbeis Innovation Centre for Applied Landscape Planning in Rostock is responsible for the chemical and environmental analyses in the DredgDikes project. The focus of the present paper is set on the results achieved in Rostock, where a full-scale experimental dike has been built to investigate the different fine-grained materials, ripened on the drying fields of the Hanseatic City of Rostock's containment facilities. The results of the chemical investigation of the dredged material used and the sampled leachate as well as the estimated environmental impacts so far are present here in the context of the legal aspects and realised projects with dredged materials in Greater Rostock.

**Keywords:** dredged material, chemical characteristic, environmental impact, national legal aspects

## 1. Introduction

The need to fit sea dikes as well as river dikes to the new requirements of flood protection increases the demand of applicable material for sealing. So far in Mecklenburg-Pomerania one resorts to marl from this region but the supply of this natural resource is limited and the interference in nature are partly immense. Marl has to be mined open-cast at great areas. For instance the sealing layer from the first section of the sea dike „Ostzingst“ in Mecklenburg-Pomerania 75,000 m³ were needed at a length of 2.8 km. The marl was from terrestrial excavations and was transported over greater distances from the island Rügen (StALU Stralsund, 2009). Since there are considerable amounts of dredged materials available along the Baltic Sea coast and dike construction materials such as limey marl or marsh clay are generally in short supply, it is obvious that the resource-conserving use of dredged material could be an alternative to the procedure to date. But the materials differ largely in their geotechnical and chemical characteristics and they may even be quite inhomogeneous, depending on the drying and processing methods. Therefore, the project DredgDikes has been initiated by the University of Rostock, chair of Geotechnics and Coastal Engineering and Gdansk University of Technology, department of Geotechnics, Geology and Maritime Engineering. The main goal of the project DredgDikes is to investigate possibilities to use different kinds of dredged materials in dike construction. According to its utilizability not only the soil mechanical and chemical characteristics of

the material are of particular importance but also the legal basis for the viability instead of marl.
The Steinbeis Innovation Centre for Applied Landscape Planning in Rostock is responsible for the chemical and environmental analyses in the DredgDikes project. The focus of the present paper is set on the results achieved in Rostock, where a full-scale experimental dike has been built to investigate the different fine-grained materials, ripened on the drying fields of the Hanseatic City of Rostock's containment facilities. Geosynthetic reinforcement and rolled erosion control products (RECP) have been installed in some of the different cross-sections to improve the material behaviour. The test construction (Fig 1) consists of two parallel dikes, one for seepage (East) and one for overflowing experiments (West), both of which can be filled with water to perform the experiments. There are different cross-sections, with varying slopes, with and without sand core, different geosynthetic solutions (for reinforcement and erosion control) and different dredged materials (M1 – M3).

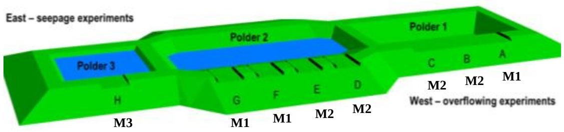



**Fig 1.** Rostock´s test dike with different cross sections and applied materials

An important aspect of coastal protection structures made of earthy materials regarding stability at flood events is the vegetation cover. It gives protection against breach and denudation as well as in part protection against moisture penetration. All materials, ripened on the drying fields of the Hanseatic City of Rostock's containment facilities, have been investigated in an extensive laboratory programme before installation and a monitoring programme has been planned in which the specific chemical parameters will be re-tested several times. The soil chemical investigations of the materials used during the construction period of the test dike mark the status quo and will be the reference level for all further investigation. Thus the discharge and dislocation of substances through leaching and erosion can be determined. These comparisons will permit to deduce the effective risk potential of dredged material. Also the turf development has been monitored from the day of seeding on and some additional experiments have been performed to compare the results on the dike surface. The vegetation and environmental analyses - not yet completed - should document the development of the dike seeding and its success. The conclusions of these analyses should be incorporated into the handbook, which still needs to be compiled.

In Germany the choice and application of the existing regulations depends on whether the dredged material stays in the water body or a disposal or reuse is carried out onshore. According to this decision different legal remedies take effect depending on the way of disposal or reuse and the responsibilities. The complexity of the legal situation and the special requirements could cause considerable needs and costs in project issues. If objective decisions should be made there have to be an understanding for the characteristics of sediments and the system they came from inasmuch dredged material applications are single decisions according to broad environmental assessments so far. One aspect by searching for an environmental sustainable and economical adequate solution should be to focus on the essential efforts (Köthe, 2002; Netzband, 2004).

Due to their classification as waste materials and the associated difficulties for the planning process, there are only very few projects where these kinds of dredged materials have been installed as dike cover material (e.g. Bremischer Deichverband, 2013). In Mecklenburg-Pomerania the application of dredged material was carried out as restoration layer at disposal facilities under comparable conditions. The handling in these situations may give also conclusions for future dike projects. The results of the chemical investigation of the dredged material used and the sampled leachate as well as the estimated environmental impacts from the DredgDikes project so far are present here in the context of the legal aspects and realised projects with dredged materials in Greater Rostock. The intended use of dredged material as substitute in dike constructions provokes different problems which have to be legally cleared, too.

## 2. Project DredgDikes: chemical characterization of the used material (DM) in the test dike

### 2.1 Materials

Given that the river Warnow has a rural drainage basin and a good wastewater treatment in the Greater Rostock; the contaminant content is relatively low in the investigated DM. Through the process of classification on the municipality's containment facilities, where the sediments were sorted after the longitudinal flow, the fine grained materials possess generally slightly higher contents of contaminants and organic matter than the less cohesive materials. However, the compliance with reuse specific guidance and limit values enabled various applications, e.g. in disposal restorations.

The fine grained dredged materials used in the project (M1, M2, M3) are different sediments from dredging works and processed The materials were built up to heaps for further maturing after an initial dewatering. Samples for the chemical characterisation were taken while emptying the containment polders (2006-2010) for a basis investigation. Before using the material for the test dike construction an investigation on soil mechanics was done. At the same time the sampling of single samples for TOC and grain-size distribution after removal of humus and carbonate was conducted to contain relatively homogeneous areas.

Further analysis was performed during the construction and after completion of the test dike. The samples were analyzed in a specialized laboratory. Up to the time of application the material achieved a friable structure and good manageability.

To offer dredged materials for reuse a detailed knowledge of the composition in the different storage heaps as well as their chemical characteristics are necessary. Based on the first investigations, different classes of comparably homogenous substrates were defined for different applications in the test dike (e.g. cover layer, sand core, homogenous cross-sections).

The materials investigated (M1, M2, M3) are fine-grained materials with high organic and lime contents. The materials M1, M2 and M3 were partly applied with geosynhetic solutions in different parts of the test dike (cross sections A to H, see Fig 1).

Previous to the dike construction a compaction testing field (M1 and M2 with a three-dimensional reinforcement mat in different depths) was built. This testing field is designed for further analyses which cannot be conducted non-destructively. Detailed Information to the construction of the compaction testing field and the test dike itself offer Cantré and Saathoff (2013). In polder 1 (cross sections B and C) as well as in polder 2 (section D to G) fittings for leachate with tipping counters for discharge measurement were installed. Samples of leachate were taken from each of these cross sections.

**2.2 Methodology**

The samples of the basis investigation were analysed to determine general geochemical parameters like pH, salt concentration, organic substance, lime content, as well as nutrients, heavy metals and organic contaminants.

The eluates of the materials were investigated to characterize the possible discharge behaviour or mobility of substances. Previous to the application in the test dike construction investigations on soil mechanics, TOC and granulation after humus and carbonate removal were performed in a specialised laboratory.

Another broad investigation of soil samples from the test dike will be performed in 2014 before the project finalises. Comparing the values at the time of construction with those after two years of precipitation, seepage, and overflowing will yield more knowledge about the materials' long-term behaviour. A long-term monitoring plan will be implemented.

Because no differences were expected the results from the basis investigation were used for the actual evaluation of hazardous substances. Accumulating leachate from the dike cross-sections was collected and analysed to determine the actual impact potential of the dredged materials used. In Winter 2012/2013 first leachate water was emitted through the drainage mats due to missing water absorption from the vegetation. The conductivity was measured once to twice a month. Once in a quarter a mixed sample was sent to a laboratory to determine the concentration of salt ions (chloride, sulfate, sodium). At the beginning of the discharge measures (January/February/March 2013) heavy metals, phosphorus, and nitrogen and at the end of the growing period (October/November 2013) only phosphorus and nitrogen were determined in the mixed samples.

At the compaction testing field the vertical leaching of salt ions (chloride, sulfate and sodium) was determined in the compacted soil (M1 and M2) in 2013. Therefore soil samples were taken with a drilling stick (Pürkhauer) at the soil horizon (1m) and from the single layers (0 to 25, 25 to 50, 50 to 75 and 75 to 100 cm below ground level) and were given to a laboratory.

The chemical characterization were realized in compliance with the detailed requirements for sampling, analytics and quality management of dredged material from the Annex 1 German federal soil protection and contaminated site ordinance (BBodSchV, 1999). In view of the specifics of dredged material (origin, composition) additional determinations for sampling and application of analytical instructions were made. Due to the heterogeneity of the dredged material conditioned by the technological processes exclusively mixed samples per area were produced. For the investigation of grain-size being a main parameter in dredged materials the E DIN ISO 11 277: 06.94 (sample preparation through distribution of humus and carbonate) was conducted due to the high content of lime and organic matter for a real determination of sand, silt and clay in mineral fine grained soil.

**2.3 Results**

The results of the solid analysis are listed in **table 1**. No precautionary values of the BBodSchV were exceeded. The eluates of the materials were investigated as well to characterize the possible discharge behavior or the mobility of substances. As expected from the high sorption capacity and the neutral or slightly alkaline pH values, the mobility of heavy metals and organic contaminants in the materials are limited (Schachtschabel et al., 1989). The concentrations in the eluate are therefore usually in the range of the detection limit.

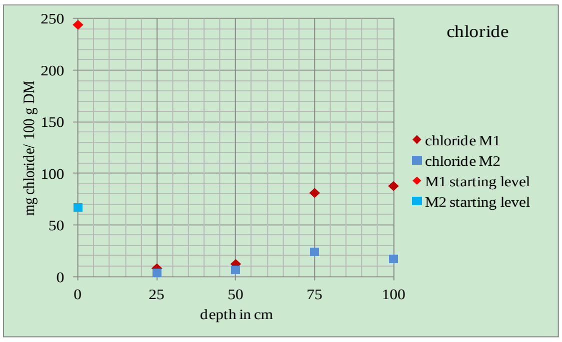
Due to natural conditions - substrates from brackish water- high levels of salinity have been detected. Especially chloride is a very easily soluble and therefore leachable salt ion. Also, sulphate will deliver constantly from sulphur.

**Table 1.** Characterization of dredged materials M1 /2 /3 in comparison to the mean values of the municipality's containment facilities Rostock (IAA ∅) and the precautionary values of the BBodSchV (1999) and assignment values of the LAGA M20

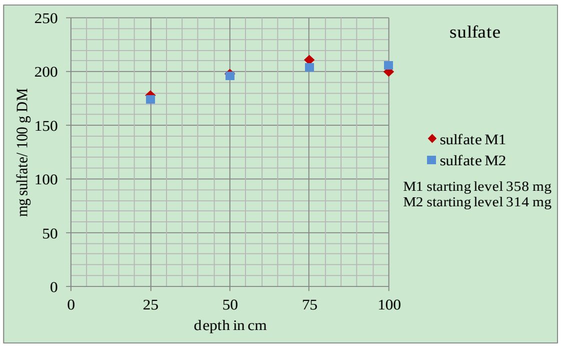
| | unit | M1 | M2 | M3 | IAA ∅ | BBodSchV VSW loam | LAGA M20 *Z0 loam |
|---|---|---|---|---|---|---|---|
| pH value | [-log] | 7.4 - 7.7 | 7.5 - 7.8 | 6.9 - 7.3 | 7.3 | | |
| Calcium carbonate | % | 6.2 - 10.0 | 6.0 - 7.4 | 5.3 - 8.7 | 8.0 | | |
| TOC | | 5.0 - 6.2 | 4.7 - 6.0 | 2.2 - 3.2 | 6.5 | | 0.5 |
| Salt concentration | | 1.8 - 2.2 | 1.5 - 1.7 | 1.2 - 1.8 | 1.9 | | |
| Magnesium | mg/100g silt | 101 - 115 | 116 - 122 | 61 - 69 | 128 | | |
| Potassium | | 26 - 41 | 30 - 33 | 11 - 23 | 31.4 | | |
| Phosphorus | | 0.8 - 1.1 | 1.4 - 2.1 | 1.4 - 2.2 | 2.0 | | |
| Nmin | | 1.4 - 3.2 | 1.6 - 3.5 | 0.5 - 1 | 2.5 | | |
| Cation exchange cap. | mval/100g silt | 27 - 32 | 25 - 26 | 16 - 23 | 26.1 | | |
| Lead | mg/100g silt | 36 | 19 | 23 | 21.2 | 70 | 70 |
| Cadmium | | 0.9 | 0.4 | 0.6 | 0.4 | 1 | 1 |
| Chromium | | 20 | 16 | 13 | 35.2 | 60 | 60 |
| Copper | | 36 | 23 | 22 | 22.4 | 40 | 40 |
| Nickel | | 14.1 | 13 | 9.5 | 14.5 | 50 | 50 |
| Mercury | | 0.57 | 0.28 | 0.37 | 0.3 | 0.5 | 0.5 |
| Zinc | | 179 | 130 | 112 | 101 | 150 | 150 |
| Arsenic | | 9.1 | 9.8 | 5.9 | 9.6 | | 15 |
| Hydrocarbon | | 379 | 115 | 206 | 225 | | 100 |
| PAH | | 1.5 | 0.89 | 1.4 | 0.9 | 3.0 | 3.0 |
| PCB | | 0.028 | 0.015 | 0.01 | 0.033 | 0.05 | 0.05 |

*Z0 – nonrestrictive installation in soil-like applications

The results of the investigation at the compaction testing field show a significant vertical leaching of salt ions in deeper layers during a period of one and a half year after construction. The distribution of the different salt ions is quite similar depending on the depth. As seen in the graphics (**Fig 2a, b**) there is a significant decline of chloride, sulfate and sodium concentrations in the topsoil. The highest concentration increase is in the layer 50 to 75 cm. In the layer 75 to 100 cm the concentration is lower; the maximum amount has not reached that depth yet. The chloride concentration is in the two top layers clearly beneath the base level. Chloride is a very soluble and fast washable salt ion. The content in both materials is almost completely washed away in materials M1 and M2 with natural precipitation. That the contents differ in the deeper layers result from the usually higher initial situation in M1.




a)




b)

**Fig 2.** Content of salt ions a) chloride b) sulfate in the different layers of the compaction testing field (M1 and M2)

The leaching began with increasing precipitation in the first half of January 2013 with cross section D, following E. The installed tipping counters measured the discharge after complete instrumentation. To show the differences in the leaching behaviour a period from mid March to the first filling within the seepage tests (Nitschke et al., 2014) was chosen for cumulating (**Fig 3**). With the beginning tests the measured leachate amount depends on which polder was filled.

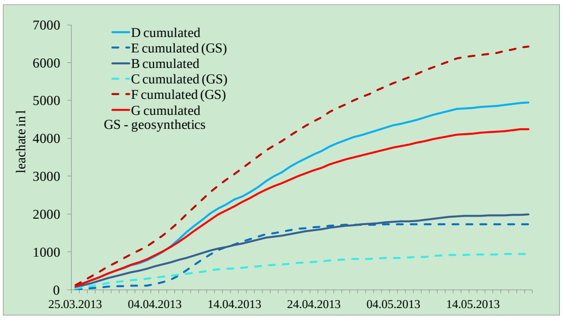



**Fig 3.** Cumulated leachate in different sections (M1- red, M2 - blue) period from end of March to the first filling

The broken lines show the sections with erosion control and reinforcement solutions, the colors show different materials (red - M1, blue - M2). One can see that section C and E with geosynthetic solutions and cross section B (material M2) had a decreased leachate. Cross section F (M1) with geosynthtic solutions had the highest amount. The general assumption that sections with geosynthetic solutions decreases the rate of flow from the cover layer through a prevention of cracks could not affirmed within this period. Also that one material is far better than the other material could not proven (see section D

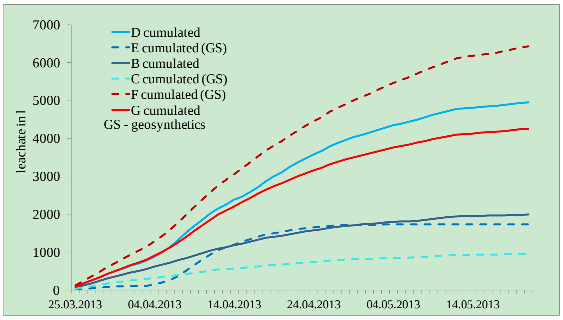



**Fig 3**). The analyzed samples of the leachate are compared with the values of BBodSchV (1999) and the disposal ordinance (DepV, 2009) for orientation (**Table 2**). The requirements of the disposal ordinance for the restoration layer will enable an evaluation of the environmental impact from hazardous substances because of similar chemical requirements of this top layer. The limit values given in the regulations were only exceeded for conductivity; chloride and sulphate (compare DepV, 2009).

Due to the natural origin conditions of the dredged material (brackish sediments) in the leachate from the test dike high salt contents could detect. The conductivity of the leachate increased with the filling of the polders, also depending on the brackish water used for filling (**Fig 4**).

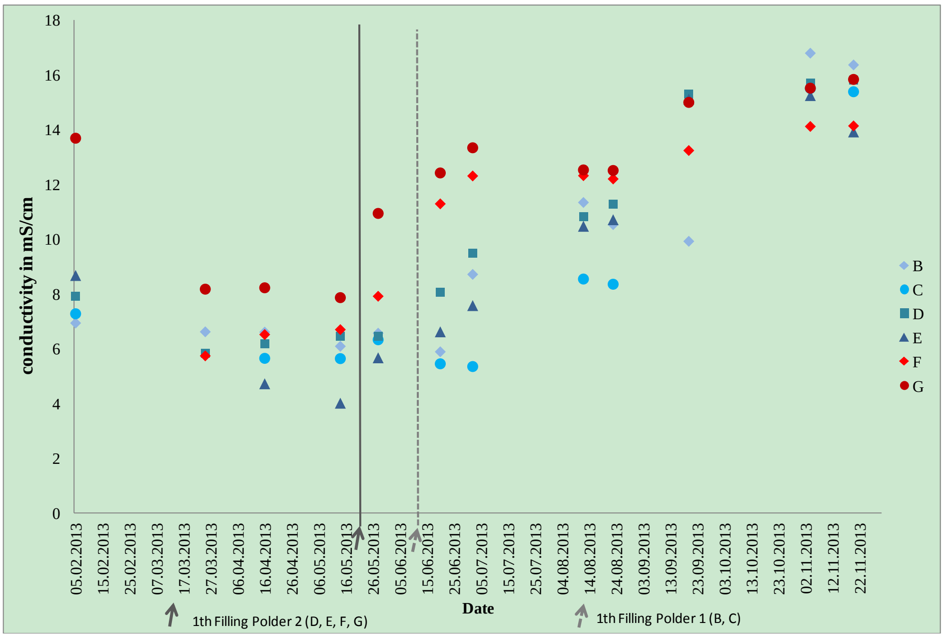
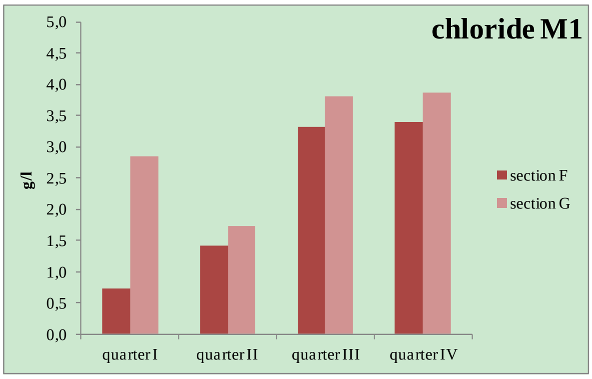



**Fig 4.** Conductivity in leachate from different cross sections (material M1 – red marks, material M2 – blue marks)

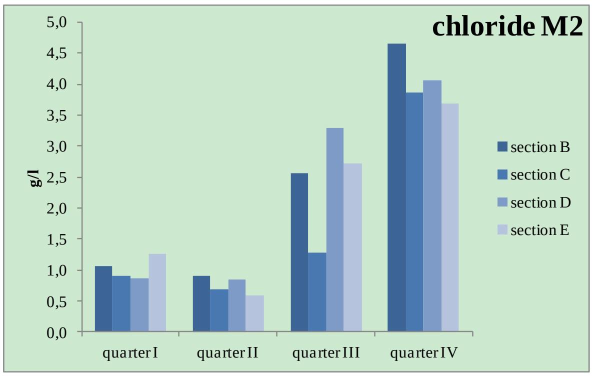
The filling water (brackish water) from the ditches near the construction site had a conductivity of over 18 mS/cm. Chloride, sulfate and sodium were detected in high concentrations before and after the filling and overtopping experiments. Till September the polder were filled and emptied at different times. The graphics (**Fig 5**,

**Fig 6**) show the contents in the sampled leachate in the 4 quarters of 2013. At the beginning of the discharge only through precipitation (January to March, quarter I) high contents of chloride, sulfate and sodium were already detected in material M1 and M2 at which material M2 has the higher initial values in solid. Mostly the contents decreased in the period April to June (quarter II). The percolation through rainfall eased and the vegetation cover dehumidified the topsoil. In the end of May and the beginning of June the filling experiments started and in the following period from July to September (quarter III) a further increase was determined. This fact was expected because of the brackish water used for filling and the almost complete moisture penetration of the materials. Cross section G (material M1 without geosynthetic solutions **Fig 5a,**

**Fig 6a**) shows a peculiarity with the high contents in quarter I. Already at the beginning of the investigations the concentrations of chloride and sodium were at a very high level. Maybe this result comes from the higher initial contents in material M1 and the increased cracking in this cross section at the beginning. The content of sulfate (**Fig 6**) was at the highest stage in almost all sections in the first period and did not differ so much in the periods during the filling. Presumably the filling water with its variable composition ($Cl^-$ 6.5 g/l; $SO_4^{2-}$ 1.5 g/l) is responsible for the difference in the salt ion contents.

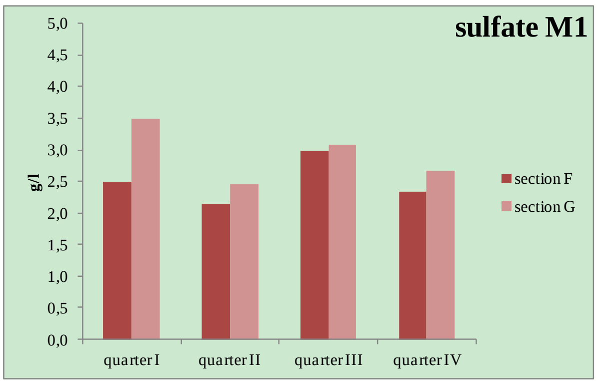



a)




b)

**Fig 5.** Content of chloride in leachte a) material M1 b) material M2

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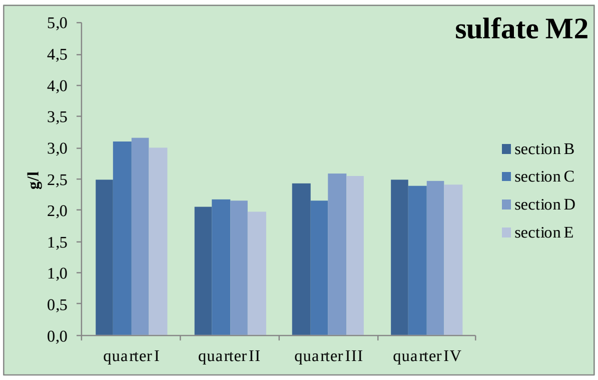


b)

**Fig 6.** Content of sulfate in leachte a) material M1 b) material M2

The exemplary calculation (**Table 2Fig 1**) of the discharge of salt through the leaching water only from precipitation (January to May) shows the high content of salt in the dredged material and illustrates the long-term impact for the environment through brackish sediments.

**Table 2.** Discharge of salt ions from leachate through precipitation (exemplary material M1 mid January to mid May, assuming that density 1 g/cm³; layer thickness 1m)

| | unit | $Cl^-$ | $SO_4^{2-}$ | $Na^+$ |
|---|---|---|---|---|
| Content in dredged material in average | mg/100 g | 244 | 358 | 241 |
| | kg/ha | 24400 | 35800 | 24100 |
| Discharge with leachate | kg/ha | 1270 | 2000 | 890 |
| *Percentage of feed charge* | *%* | *5,2* | *5,6* | *3,7* |

No high concentrations of heavy metals were detected and no limit value of the LAGA M20 (Z0) was exceeded in the leachate (

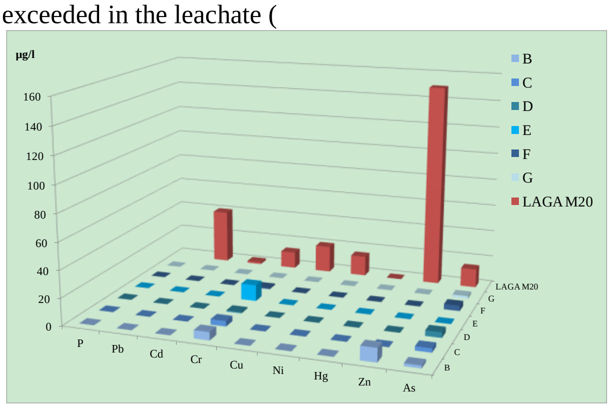


**Fig 7**). Phosphorus and nitrogen were analyzed as well; also there are no conspicuous concentrations. For example the content of nitrogen was significant below the limit value (50 mg/l) for endangered groundwater volumes of the groundwater ordinance (GrwV, 2010).

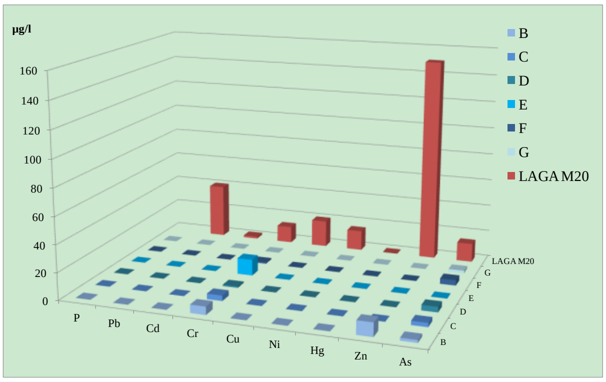


**Fig 7.** Heavy metal and phosphorus contents in leachate

## 3. Legal aspects

### 3.1 European regulation framework and implementation in national law

Since the 70s the European Community follows an active environmental policy e.g. in the field of water protection, air pollution control and waste management. The environmental policy of the EU makes a contribution to preservation and protection of the environment as well as the improvement of their quality and the careful and efficient use of natural resources (Art. 191 AEUV).

Under European law different framework directives rule the handling with subjects of protection e.g. the marine environment or water. Their task is to harmonize the legal frame for the policy within the EU and they are addressed to the national authorities. Purpose is also to heavily align the policy to a sustainable and ecological use of resources.

The disposal of DM in water bodies is widely regulated through international conventions where the contracting parties covenant to implement national conform regulatory. At the first place there are the international and European conventions for the protection of the sea (London, HELCOM, OSPAR) for the handling with sediments and DM. Within the conventions DM guidelines (LC 2000; OSPAR 2009; HELCOM 2007) regulate the environmental sustainable disposal/ relocation in the water bodies. The European environmental policy influenced strongly the German law. Member states can decide how legal acts will be implemented in domestic law. In Germany formal laws or ordinances are necessary by implementation of practical obligations. Directives set a deadline for the implementation in the law system. Many of the EC directives, e.g. the Water Framework Directive (2000/60/EC) and the Waste Framework Directive(2008/98/EC)., are implemented in German law already.

### 3.2 Legal aspects for the reuse of DM in dike constructions

In Germany the common basis forms the recycling management act (KrWG, 2012). By these act the specifications of the EU Waste Framework Directive were implement in German law. At both federal and state level, there is consensus that the onshore accommodation, storing, treatment and beneficial use is subject to waste regulations, as DM (onshore) is classified as waste.

A possible reuse of this waste -if it technically feasible and economically reasonable- has to be proper and harmless (i.e. no deterioration of the public interest, in particular, no accumulation of pollutants in the recycling process, § 7 Recycling Management act (KrWG, 2012)).

The application of DM in technical constructions (dike constructions) can realized according to LAGA M20 part II beneath the rooting zone. DM is explicitly named as mineral waste for reuse but is subject to the restriction that it is gravelly DM with less than 10% fine grain. An nonrestrictive reuse of gravelly DM can only take place in assignment class Z0 and limits the TOC content at 0,5% (TR LAGA, 2004).

Matured DM contains a great amount of organic matter, generally between 4 und 10 percent TOC (4-18 % humus). These stable organic-mineral complexes creates a high stability of aggregates, favorable terms of sorption and a high capability for storage water as well as a good soil fertility. Concerns of degradability of the organic matter could clear with determination of the breathability. Follow-up examinations show that the organic matter is very stable. The degradation rate in the determination of breathability (AT4 – investigation) of matured DM (< 0.5-0.6 mg O2/g TM) underlie significant the limit value claimed of the DepV (5 mg O2/ g TM) (Morscheck & Henneberg, 2012).

Germany adopted suitable regulations by implementation of the soil conservation and contaminated site act (BBodSchG, 1998) and ordinance (BBodSchV, 1999). In these act and ordinance as well as in the discretional implementation help to §12 (2002) DM is named and an application on and in top soils is possible if the conditions comply with the precautionary values (table 2, annex 2 BBodSchV).

The soil ordinance is to apply if DM should bring in a rooting layer respectively a new rooting layer should produce from DM, e.g. by greening of technical structures (LABO, 2002).

Dike construction measures have to be carried out on the basis of the water law because they are considered hydraulic measures according to § 67 WHG. Therefore the application of DM in dike construction has to comply with the requirements of the water law. A sustainable change in the water bodies' condition has to be avoided. § 68 WHG rules the planning permission. However, limit values for construction materials are not listed in these paragraphs. „An explicit regulation tailored for the application of DM in dike construction in the soil conservation or waste management law does not exist yet or rather there are no guidance or limit

values referring to this for the application of DM“ (EAK, 2002/2007).
Authoritative legal basis for the coast protection in Mecklenburg-Pomerania forms the water act of the federal state (LWaG). The act dictates the responsibilities, allowed usabilities and licensing requirements. The coast protection comprises all construction measures for the protection of human usability at the coastline in MV. The lower Federal Agency for Agriculture and Environment (StALU) is responsible for the coast protection and the federal dike system.

Which official approval is required for a reuse measure depends on the kind of reuse, e.g. approval according to construction law. The reuse of DM under the waste law (ECC/170506) does not need a special waste law approval procedure. For the process of application, the waste legislation requires an obligation to provide proof and to keep records.

In the following general view the ambits and regulations are specified for an application of DM in technical structures (**Fig 8**).

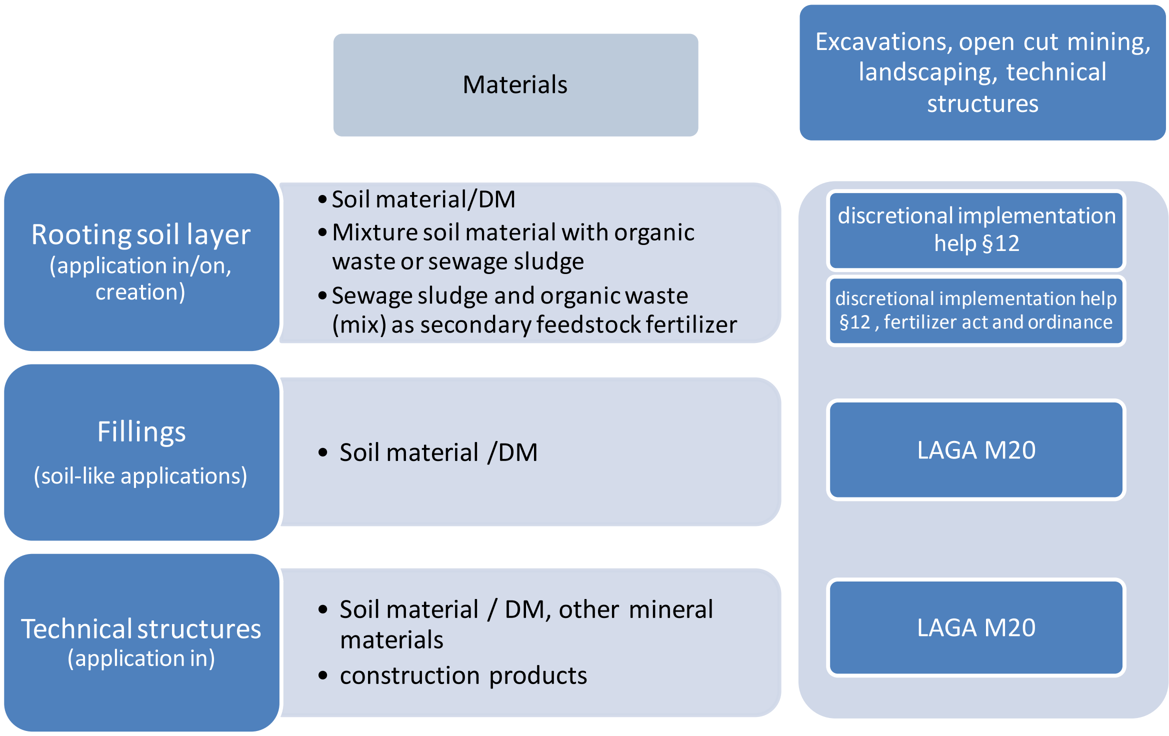


**Fig 8.** Shortened schema of ambits and regulations from the discretional implementation help §12, annex 3 (LABO, 2002)

Previous materials for sealing in dike constructions, e.g. marl or marsh clay, are evaluated according to LAGA M20 or used because they were used for hundreds of years in a proved method. The idea to officially applicate treated DM in dike construction is relatively new and there are many unanswered questions. The individual characteristics of the DMs are partly completely different to other used materials. The humus content of DM in the project DredgDikes differs from 4 – 8% and the classified material is very fine grained.

The application of sandy DM with almost no humus in a construction (underneath the rooting layer) has to comply with the waste regulations (e.g. harmless reuse). The supreme waste authority in MV recommends as discretional implementation help the LAGA M20. If evidence is provided that the common good is not in danger the divergence of assignment criteria could be allowed in individual cases (oral note StALU, 14.01.2011). The investigated DM cannot evaluate with the LAGA M20 because of the grain size with high parts of fines and the high humus content.

For the greening/rooting layer the application of DM according to the BBodSchV is possible if it complies with the precautionary values. The discretional implementation help to §12 BBodSchV restricted the layer thickness to 30 – 15 cm due to the humus content (4- 8%) in the material.

Examples of successful reuse measures with DM were carried out in the federal state of Bremen. The water resources agency (Bremischer Deichverband, 2014) has raised the height of different dike sections applying DM as sealing layer. In Bremerhaven a dike with a DM core instead of sand was built in 2005. The evaluation of the used DM was conducted after the criteria of EAK 2002/2007 for DM and an evaluation procedure of Weißmann (2003) for marsh clay in an expert´s opinion. Through a federal specific regulation the DM of Bremen with generally higher parts of fines and organic matter is implementing in the ambit of the

LAGA M20 (Arnold & Krause, 2008). This year further reuse of DM in dike construction measures is envisaged in Bremen. In Hamburg the department for water management gave recommendations in the 1980s for the application and compaction of marsh clay. The marsh clay is handled as a natural resource which will excavate for the specific measure and not as waste for reuse. The values of the glowing loss should be between 10-15%. These values correspond with the recommendation of the EAK 2002/2007.

### 3.3 Previous measures with application of DM

The beneficial use of waste materials like DM can also realized through the landfill ordinance (DepV, 2009) as restoration material in the restoration layer and the water storage layer. Previous measures (14 disposals in MV) with application of DM could be realized. The conditions complied mostly with the DepV. The application of DM in the coverage of disposals was carried out on basis of an individual case decision of the responsible authority for waste. Appropriate exceptions were needed in case of the DM with contents high in salt due to the origin of DM (brackish water) and organic matter because of the significant exceedance of the guidance values (DepV). The heavy metals values of the DM (Rostock) were significant below the limit values of DepV for restoration layers. Also the organic contaminants were inconspicuous.

Following past experiences the DM is suitable for creation of the cubature as well as the construction of a restoration layer respectively a water supply layer. In Mecklenburg-Pomerania there is a significant need for soil materials for the closure of disposal facilities respectively the covering of hazardous waste contaminated sites.

The application of treated brackish DM should only take into account if the measure could comply with the following aspects.

- Only if heavy impacts of protective goods could reject
- Recipient will reach fast and directly brackish water bodies
- Recipient will reach directly great water bodies (dissemination)
- Recipient possesses already higher accepted salt contents

The application should generally forbid in water reserves.

The TOC content in treated DM between 4 and 10 % are closed in stable organic mineral complexes. A proof of this theory is the investigation for the degradation rate of the organic matter on the $AT_4$–analyses. These statements will also be proven through investigation of DM from Bremen and Hamburg.

| | |
|---|---|
| - DM of investigated restoration layers | 0.7 – 2.0 mg $O_2$/g dry matter |
| - DM Rostock (not completely matured 2005) | < 0.5 – 2.7 mg $O_2$/g dry matter |
| - DM Rostock (matured material 2011) | < 0.5 – 0.6 mg $O_2$/g dry matter |
| - DM Hamburg | 0.1 – 0.4 mg $O_2$/g dry matter |
| - DM Bremen | 0.3 – 0.8 mg $O_2$/g dry matter |

The high stability of the organic matter as well as the organic-mineral complexes leads trough the excellent erosion stability and quality of aggregate structure and stability. Also the good water storage and the nutrient storage capability is the basis of the high soil fertility of the material.

In several pilot tests the DM was applicated in agriculture too.

## 4. Discussion

The determined values of heavy metals in leachate do not constitute a potential risk of the different protective subjects' soil, plants or animals. They are below the limit values of different regulations as also are the values in the solid. Heavy metals and organic contaminants are chemically stable and heavily available. Reversing conditions (reduction – oxidation) could invert this status and the contained heavy metals could be available, e.g. within the first weeks of drying freshly dredged materials. Then the leachability decreases subsequently (Stephens et al., 2001).

A discharge of heavy metals or the nutrients nitrogen and phosphorus could not be detected in the leachate. In contrast to heavy metals there is an oversupply of nutrients and salt. According to agricultural aspects the nutrients magnesium, potassium and calcium are at a high level of supply for plants (Düngung, 2004). If the vegetation can't absorb these nutrients they will be subject to leaching processes.

The salt ions behave likewise. First of all chloride is a very soluble salt ion and therefore easily washed out in short term. In the leachate very high values of chloride, sulfate and sodium were determined. There is evidence to suggest that also the nutrients magnesium, potassium and calcium could be determined in high concentrations. Over 10 years corresponding results provided the lysimeter experiments with dredged material for soil improvement (Henneberg and Neumann, 2011). The exemplary calculation of the discharge of chloride, sulfate and sodium showed that in 4 month 3 to 5 % of the initial content is washed out. Experiences from the lysimeter experiments (dredged material mixed with topsoil) showed analogical results. After 10 years all of the original chloride and about 60 % of the original sodium amount were gone, though sulfate will be washed out constantly for another ten years at least. On the contrary in this experiment it was also proved that phosphorus and nitrogen will not discharge in great amounts from dredged material (compared with topsoil variations).

All in all it therefore becomes clear that the common inorganic contaminants contained in the dredged material don't violate the requirements of the mentioned ordinances, but it is the discharge of salt ions that could be problematic for the environment (Henneberg and Neumann, 2011; Gebert et al., 2010).

These previous scientific findings indicate that the discharge of salt has to be monitored when dredged material is used. Normally the fine grained dredged material with high content of organic matter can store a large part of the natural precipitation which is useful for the plants (Henneberg and Neumann, 2011; Morscheck and Henneberg, 2012). If the dredged material is saturated with water (e.g. because of increasing precipitation, loss of impermeability) and there is no removal by the vegetation, the excess water is discharged and with it also salt and nutrients. Despite of the salt and nutrients dislocation with the leachate a potential risk exists by the dislocation from the dike surface due to damages on the vegetation that allows erosion to transport soil particles.

For dike constructions with comparable dredged material the knowledge of the setting, e.g. construction site or subjects of protection is important. An endangerment of soil and groundwater should be avoided. Consequently dikes with dredged material from brackish sediments should only be built near the coastline and it should be ensured that the leachate is canalized almost directly into the Baltic Sea.

Due to the classification as waste and the associated problems within the planning process and because of the undetermined legal situation there are only few projects in which DM was used as substitute material in dike construction. These measures were carried out according to the recommendations of the EAK 2002/2007. In MV many experiences for realization and completion were derived from the application in gardening and landscaping to produce or improve the rooting layer or the restoration layer of landfills.

In the case of an application of DM from the Baltic Sea coast of MV in dike construction, heavy metals or organic contaminants play a less important role than the contained salts and the high amount of organic matter. The concentrations of heavy metals and organic contaminants are mostly below the substrate specific precautionary values of BBodSchV respectively the limit values of LAGA M20.

Even if the reuse of DM doesn't directly underlie a waste legislation approval, the application of the material within the dike / technical structure has to be approved by the responsible authority and therefore the burden of proof of a proper and harmless reuse has to be assured.

The authorities evaluate the required layer thickness of a technical structure as critical. If DM shall be used to produce a rooting layer on technical structures it has to comply with the requirements of §12 BBodschV. In the corresponding implementation help the maximum thickness of layers depending on the humus content are listed. Only a 15 – 30 cm top soil could be applied with a TOC content of 4 to 8%. On the other hand the thickness of a rooting layer corresponds with the rooting depth that the typical vegetation could achieve at this site. The standard thickness of a rooting layer under grassland (grass seeding at dikes) could be 50 to 100 cm (discretional implementation help §12 p.12 ff.).

The authorities' concern also is the possible negative impact on the common good through nitrogen leaching and an endangering of the ground water. It seems to be important in this topic that there is evidence that only a small part of the total nitrogen is available and there is no increasing discharge compared to top soils. Partly this aspect has been proven in lysimeter experiments for 10 years where DM was applied for agricultural use (Henneberg & Neumann, 2011). These results and results of a follow-up of recultivated disposal sites provide positive information about the stability of the organic matter in DM (Henneberg & Morscheck, 2012).

The possibility of the construction of a homogeneous layer with the function of sealing and greening according to the BBodSchV is not seen from the responsible authorities at this point. Within the recommendations of LAGA M20 DM is subject to the restriction that it is gravelly DM with less than 10% fine grain and limits the TOC content at 0.5 to 1.5% depending on application conditions. A general broadening of the LAGA M20 for fine grained DM in technical structures would make sense.

Since there is no specific DM regulation for direct use or reuse yet, solutions which are well-founded and decided on an individual basis be in the foreground in the future. A general guideline for the reuse of DM is not practical because of varying conditions of reuse options and material composition. Therefore, a detailed monitoring of the application conditions is indicated for every project (compare EAK, 2002/2007). The application of DM should therefore always be an individual case decision. Though for a simplest, efficient and legally secure approval of DM reuse the development of a basic flowchart for the process approval (compare e.g. flowchart annex 1 of the discretional implementation help of §12 BBodSchV) would make much sense. In this way the requirement of the EU to reuse 70 % of the construction wastes (including DM) can be fulfilled until 2020.

## 5. Conclusions

1. Heavy metals, phosphorus and nitrogen are not detected in high concentration in the investigated DM. The concentration of salt ions is very high in the leachate. The placing of dike constructions with dredged material has to conduct under defined specifications to avoid environmental impacts on ground water and soil by possible discharge of salt.
2. The evaluation of fine-grained DM for the application in dike constructions as rooting layers is possible after the BBodSchV, 1999. The layer thickness is restricted depending on the humus content of the DM.

3. Gravelly DM could be used in technical structures like dike constructions according to LAGA M20. The fines and the high humus content of the investigated DM avoids the application as sealing material or homogeneous layer in technical structures according to LAGA M20.
4. Traditionelly used marsh clay with higher parts of fines and organic matter is not subject to LAGA M20. In other federal states dike construction measures with DM were carried out according to the recommendations of the EAK 2002/2007.
5. The application of DM in dike constructions is always an individual case decision of the responsible authority because of the changing frame conditions and changing material compositions. A detailed monitoring/control of the conditions is urgently indicated in every case (EAK, 2002/2007).
6. For a simplest, efficient and legally clear approval the development of a basic flowchart for the process approval to apply DM would make sense.

**Nomenclature**

BBodSchV – soil conservation and contaminated site ordinance
DM – dredged material
EAK – recommendations for the construction of coastal constructions
LAGA M20 – interstate working group for wastes, requirements on the reuse of mineral wastes, part II
MV – Mecklenburg-Pomerania
StALU – State Agency for Agriculture and Environment
TOC – Total Organic Carbon

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