Energy Use and Climate Impact from Management of Sediments in the Baltic Sea

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Summary

This report is one of several case studies performed within SMOCS WP3. The overall aim of the case studies is to serve as examples of how the SMOCS guideline can be used in practice by exemplifying with realistic cases. The main objectives of the study are to illustrate which activities in different sediment handling methods that mainly contributes to energy use and climate impact, and also to describe the significance in a national context of energy use, climate impact and flow of TBT in the Swedish sediment management.

The management alternatives studied is material recovery by stabilization/solidification (s/s) and by METHA – treatment. Further alternatives studied are disposal at sea, river and in landfill.

The method is based on the Life Cycle Inventory (LCI) method. The method also includes normalization where the LCI results are compared with national data on the area of subject. Flows of TBT have been estimated by using data from field samples of sediments.

The study shows that climate impact and energy use from each handling alternatives are connected to certain categories of activities. For example, in the Swedish case on S/s alternative, main energy use and climate impact is due to the production of input material, mainly the binders cement and merit. The same is for the S/s and landfill alternative, but also, transportation of dredged material and construction material to landfill contributes to a large share of the impact. For the dewatering and landfill alternative main part of energy use and climate impact is related to transports of dredged material and of construction material to landfill site. Energy use and climate impact in the METHA treatment alternative is mainly due to the transportation of material. For the cases on sea and river disposal alternatives, energy use and climate impact are caused by dredging (construction work) and transportation of dredged material. When longer distances of transportation of dredged material are needed the energy use and climate impact from dredging activities are relatively small.

Normalization shows that climate impact from sediment management in Sweden corresponds to about 10 % of climate impact from plastic waste which is the waste stream with highest climate impact in Sweden. TBT flows from sediment management were estimated to about 10 % of TBT flows in waste and recycling management sector.

The normalization indicates that climate impact and TBT flow from sediment management has a certain significance at a national level.

Dictionary

CO_2 – Carbon Dioxide

LCA – Life Cycle Analysis

METHA - Mechanical Separation of Harbour Sediments

MJ – Mega Joule

Mton – Mega ton

S/s – Stabilization and solidification

TBT – Tributyltin

TWh – Terawatt hours

1. Introduction

1.1 Background

There are big volumes of contaminated sediments in the Baltic Sea that have to be dredged. Dredging is sometimes done for environmental reasons but mostly to maintain the sea lanes for maritime traffic. Contaminated dredged material can be handled in several ways; deposited on land, encapsulated on the sea floor, or reused as building material. Within the EU project SMOCS (Sustainable Management of Contaminated Sediments) several countries around the Baltic Sea cooperates to improve the management of contaminated sediments and make it easier for ports to make sustainable decisions in the long run.

1.2 Problem definition

Several studies have been conducted in SMOCS to support decision making for an individual port. Some of them have been case studies where different handling options for sediment management have been evaluated from an environmental perspective. From these studies, it can be concluded that there are usually many environmental benefits when contaminated sediments are reused as construction material instead of disposing it in a landfill. However, in a situation where the decisions on management method already have been taken, there is little knowledge on where the efforts for improvements of the environmental performance should be made.

This case study is also about the significance of the environmental issues at a national level. There is little knowledge on if the environmental impact from sediment management is of such magnitude that it should be prioritized at a national level.

SMOCS have set a framework for which aspects that should be considered in sustainable management of contaminated sediments. The environmental criteria is

1. contamination on surrounding areas and organisms,
2. consumption of finite and/or limited resources,
3. impacts on biodiversity,
4. emissions to air and water.

This criteria and associated environmental impacts are relevant at a project level however the importance at a national level is unknown.

The aim of this case study is to determine:

1. which activities that should be in focus when reducing energy use and climate impact at a project level.
2. which issues should be prioritized at a national level, taking into account climate impact, energy use and flow TBT in the management of sediments.

1.3 Objectives

In this study climate impact, energy use and flow of TBT have been estimated.

The goal was to:

1. describe where efforts for reducing climate impact and energy
2. describe the potential environmental impact in terms of energy use, CO2 emissions and flows of TBT, for a likely future scenario, taking into account the total amount of dredged material generated in Sweden,
3. relate environmental impacts from the management of dredged material to the environmental impacts caused by other, comparable, activities in Sweden.

1.4 Methods

The method was based on the Life Cycle Inventory (LCI) method which is based on the Life Cycle Analysis method. The general difference is that LCA includes assessing the total environmental impact by assigning the indicator (material and energy flows) specific impact categories. The LCI method does not include the LCA assessment phase. Instead the indicators are presented as flows of material and energy.

The method also includes normalization where the LCI results have been compared with national data on the area of subject. Normalization has been made in two steps. First LCI results were expanded by using national data on annual dredging activities. This provides a quantified estimate on the energy and material flows caused by sediment management in a national context. The expanded LCI was then compared with appropriate national data.

TBT flows are estimated by using data from analysis of sediments. Since TBT content can vary significantly between locations, values from several locations have been used. TBT flows have been normalized by comparing with national data of other TBT flows in society.

1.4.1 System Boundaries

The system boundaries for the analysis are illustrated in Figure 1.1. The system covered all significant activities in the technical sediment management, from the actual dredging process to the final use of the dredged material. Impact categories studied were energy, climate impact and TBT flows. Results have been compared to corresponding impact categories in a comparable community/sector.

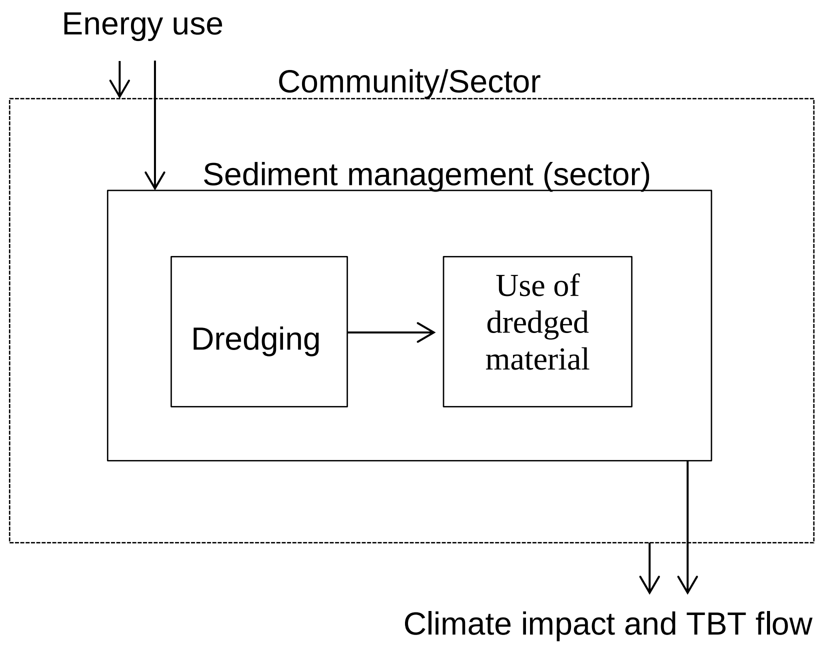

Figure 1.1: The system boarder of the analysis illustrating the input of energy and the output of CO2 emissions and flows of TBT in the sediment management and in the overall sector/community.

Units that were used in this study are:

- for energy: MJ and TWh,
- for climate: kg and Mton Co2 equivalents,
- for toxins: Kg TBT

1.4.2 Data inventory

The LCI calculations have been based on data from previous LCA studies on sediment management in SMOCS. In these studies the environmental performance in different sediment management options have been evaluated in cases studies for different ports, the port of Oxelösund and Gävle (Sweden) and the port of Hamburg (Germany). The specific cases and handling methods are presented in Table 1.1.

Table 1.1. Case studies and their scopes conducted in SMOCS

<table>
<tr><td>Study</td><td>Case (Port)</td><td>Handling Method/ Scope</td></tr>
<tr><td>Simon, 2008</td><td>Oxelösund, Sweden</td><td rowspan="2">-Stabilization/Solidification and utilization of material in Harbour construction
-Disposal on land or at sea (non-contaminated sediments)</td></tr>
<tr><td>Brandt, 2011</td><td>Gävle, Sweden</td></tr>
<tr><td>Lakso, 2011</td><td>Hamburg, Germany</td><td>-Metha-treatment, utilization of material in road, as cover material at landfill or in bricks
-Dewatering and disposal in landfill
-Disposal at sea or in river</td></tr>
</table>

The studies in Table 1.1 aimed to clarify the potential for reduced environmental impact when utilizing the sediments as construction materials. In order to account for the alternative (virgin) material that the sediments could substitute, the system boundaries were expanded and covered both sediment management, production of building materials and the constructions for which the sediments could be utilised. In those alternatives where the sediments were not used as construction material, a conventional construction material was assumed to be used. As the studies aimed to quantify the differences in environmental impact between the management methods, activities that were identical in the management alternatives were excluded. For example, in the case of port of Oxelösund, all dredged material has to be reloaded from a barge to the dock or to a pontoon. Since the activity is identical in all cases it was excluded from the analysis.

In this study, the objectives involved quantifying material and energy flows from only sediment management methods in a national perspective i.e. the beneficial use of sediment as construction material in terms of energy and climate impact reduction, was left out. This means that handling options were dredged material is not reused as building material, was not charged with the production of identical services with conventional material. The study also included activities identical for all scenarios that have been excluded in the previous studies since the scope comprised the total impacts of sediment management and not the relative impact between handling options. Even though the system boundaries are different, much of the data from the studies in Table 1.1 could be used in this study.

The calculations was mainly based on data from - and assumptions made in - the cases in Port of Oxelösund (Simon, 2008) and Port of Hamburg (Lakso, 2011) since it covers most of the sediment management methods practiced in the Baltic Sea Region. The case study of port of Oxelösund has been supplemented with data on the dredging phase from Robert Brandt's (Brandt 2011) case study on port of Gävle.

Data for normalisation was collected from the report ” Stabilisering & solidifiering av förore-nade sediment och muddermassor – PM – potentiella projekt för hamnar 2009. In this inventory of ports from 2008, harbours in Sweden were asked about the volume of dredged sediments between 2009 and 2020. The amount of sediment that may be necessary to dredge in Swedish territorial waters within a ten year period was compiled through both literature review and previous port inventory. General estimates of the degree of contamination of these have been made. The report gives a rough estimate on the future need for dredging in Swedish ports during the period 2009 – 2020. Results have been compared with estimated data on energy and material flows in the Swedish construction sector (Toller, et.al, 2011) and in the sector for waste management (IVL, 2010).

Estimation of TBT contents in Swedish sediments have been based on previous field samples in Swedish ports. In SMOCS, data on field samples from sediments in port of Gävle, port of Falkenberg and port of Oxelösund have been compiled. From this data a median value for TBT content have been calculated. Calculations on TBT flows regarding to annual dredging have been based on the median value for TBT content in sediments and data on annual dredging need. Normalization has been made by comparing TBT flows from sediment management with TBT flows from other activities in the society.

2. Results

In this chapter energy use, CO2 emissions and TBT flows from management of sediments are discussed.

The potential environmental impact is described in terms of energy use, CO2 emissions and flows of TBT for a likely future scenario taking into account the total amount of dredged material generated in Sweden within the coming decade.

Environmental impacts from the management of dredged material are compared with environmental impacts caused by other activities in the community.

2.1 Energy use and climate impact

In Figure 2.1 the energy use for different sediment management alternatives is presented. The figure describes the relation between energy uses of each management alternative, divided in three categories: production of material, transport of material and construction of maintenance. In figure 2.2, the same presentation is made, but for climate impact.

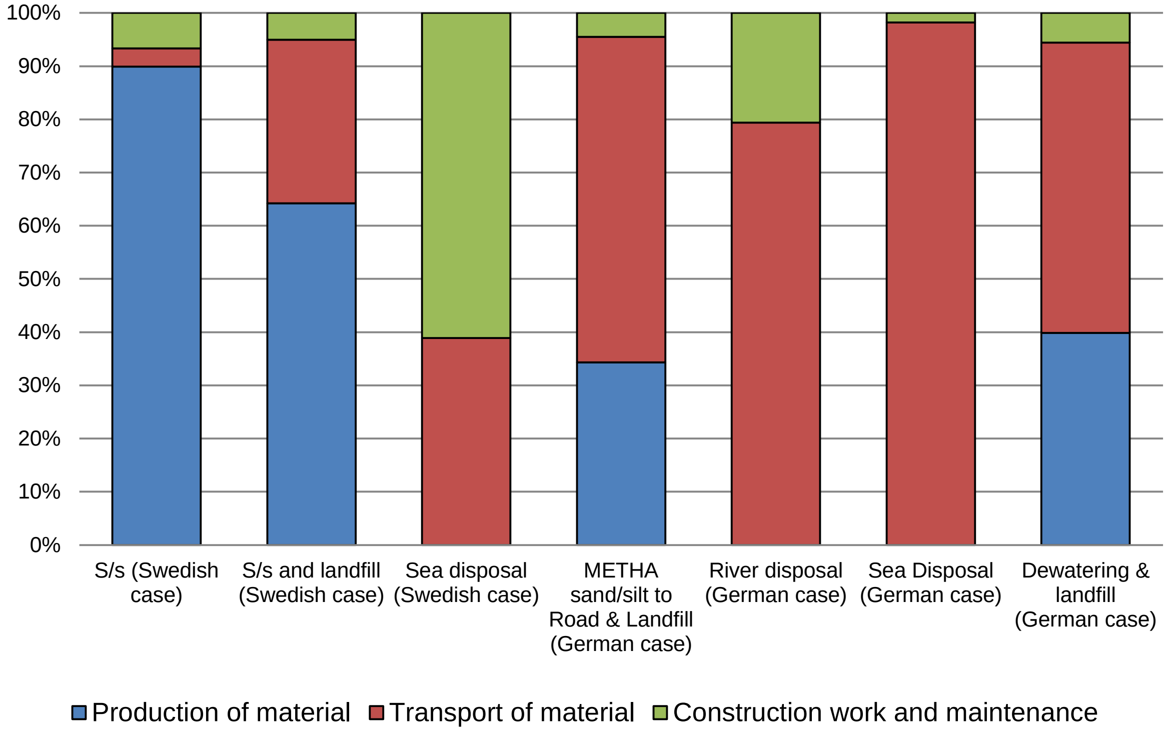

Figure 2.1: Energy use for management of sediments

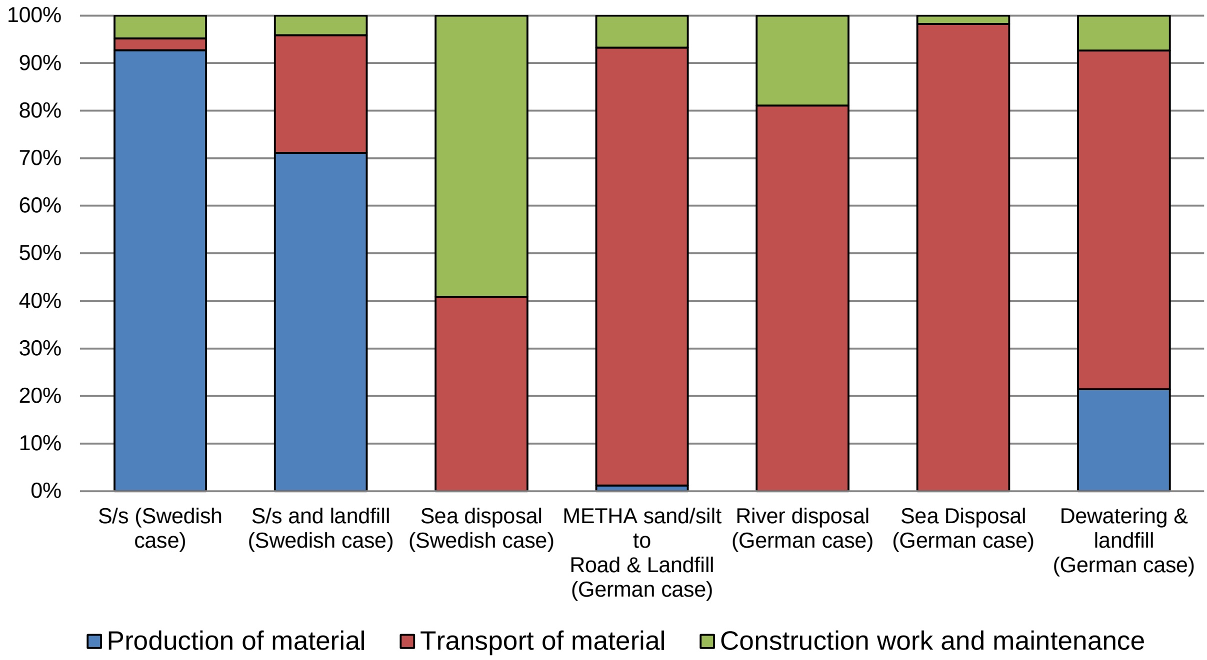

Figure 2.2: Energy use and climate impact for management of sediments

From the figure 2.1 and 2.2 it was possible to identify activities with high significance in the context of energy and climate.

In the Swedish case on S/s alternative, main energy use and climate impact was due to the production of input material, mainly the binders cement and merit. The same was for the S/s and landfill alternative, but also, transportation of dredged material and construction material to landfill contributed to a large share of the impact. The climate impact from stabilization/solidification alternatives was highly influenced by the amount of binder needed per m^3 sediment.

For the Swedish case on the sea disposal alternative, energy use and climate impact were caused by dredging (construction work) and transportation of dredged material. The largest share of the impact was correlated to the transportation.

Energy use and climate impact in the METHA treatment alternative in the German case was mainly due to the transportation of material. The energy use for production of material was caused by The METHA –treatment which is electrified.

In the German case on river and sea disposal, most energy use and climate impact was because of the transportation of dredged material. Energy use and climate impact from construction work was due to dredging, and is only of relative significance in the river disposal alternative where transport distances was shorter than for the sea disposal alternative.

For the Dewatering and landfill alternative, dredged material is stacked up and dewatered passively. Main part of energy use and climate impact was related to transports of dredged material and of construction material to landfill site.

2.2 Estimated volumes of dredged material

Based on previous port inventory an assessment of likely development for future dredging in Sweden is shown in Figure 2.3.

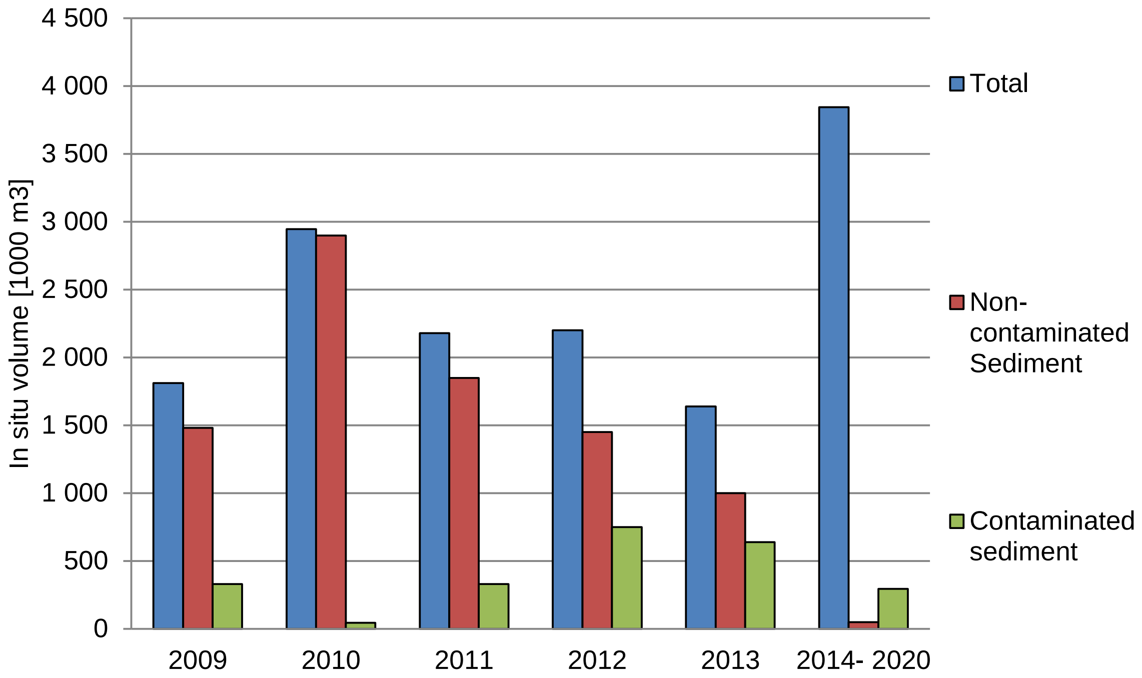

Figure 2.3: Planned annual dredging volumes in Sweden between year of 2009 and 2020.

As seen in Figure 2.1, the annual volumes of dredged material were estimated to decrease from the year of 2010 to 2020. However, the portion which is contaminated was expected to increase between the year of 2010 and 2013. As shown in Figure 2.3, the estimated total of dredged material for 2014-2020 was much higher than the total of clean and contaminated sediment during the same period. This is caused by the uncertainty and lack of knowledge of the sediment that was needed to dredge, i.e. main part of the sediments during the period has not been classified. Between the year of 2014 and 2020 the portion contaminated was estimated to be 8 % of the total dredged sediment volume, see table 2.1.

Table 2.1. Portion of contaminated sediment of the planned annual dredging volumes in Sweden.

Year	Share [%]
2009	18
2010	2
2011	15
2012	34
2013	39
2014-2020	8
2009-2020	**16**

2.3 TBT content in sediments

There was a lack of information on the quantities of TBT in sediments in Swedish ports. However, TBT content in sediments have been estimated by using data from field samples in some Swedish ports. Data on TBT content is presented in Table 2.2.

Table 2.2. TBT content in sediments from the Ports of Gävle, Falkenberg and Oxelösund.

Location of field sample	TBT content [mg/kg dry sediment]
Port of Gävle	0.27
Port of Falkenberg	0.17
Port of Oxelösund (Median: Max)	0.3: 7.3

From data in Table 1.2, a median value of 0, 3 mg/ kg dry sediment for TBT content in sediments was estimated. However, a maximum content of 7.3 mg/kg dry sediment was measured in sample from location in port of Oxelösund. The data on TBT content is therefore very uncertain.

2.4 Potential impact from a scenario - at a national level

Estimating the potential environmental impact from sediment management in Sweden could be done by starting from a likely scenario where realistic handling methods are practiced. For Sweden, a likely scenario was decided, where clean sediments was dumped and contaminated sediments was s/s treated. Considering the magnitude of energy use and climate impact for presented handling alternatives, s/s method was in the same magnitude. Annual energy use, Figure 4, and annual climate influence, Figure 5, were calculated based on the estimated amount of dredged sediments in Sweden.

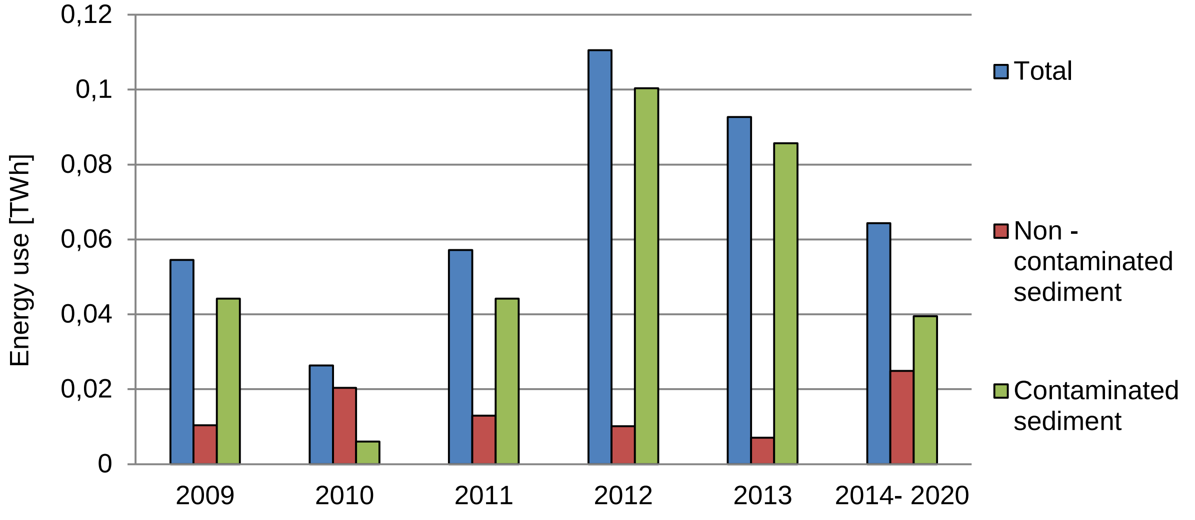

Figure 2.4: Annual energy use based on a scenario where non-contaminated sediments was disposed at sea and contaminated sediments was s/s treated.

Although most of the sediment volumes are clean, both energy use and CO2 emissions was several times higher for contaminated sediments. The planned volume to be dredged between 2014 and 2020 was estimated to only 8 % of the total sediment volume. However energy use and CO2 emissions was 1. 4 - 1. 5 times higher for contaminated sediments than clean sediments.

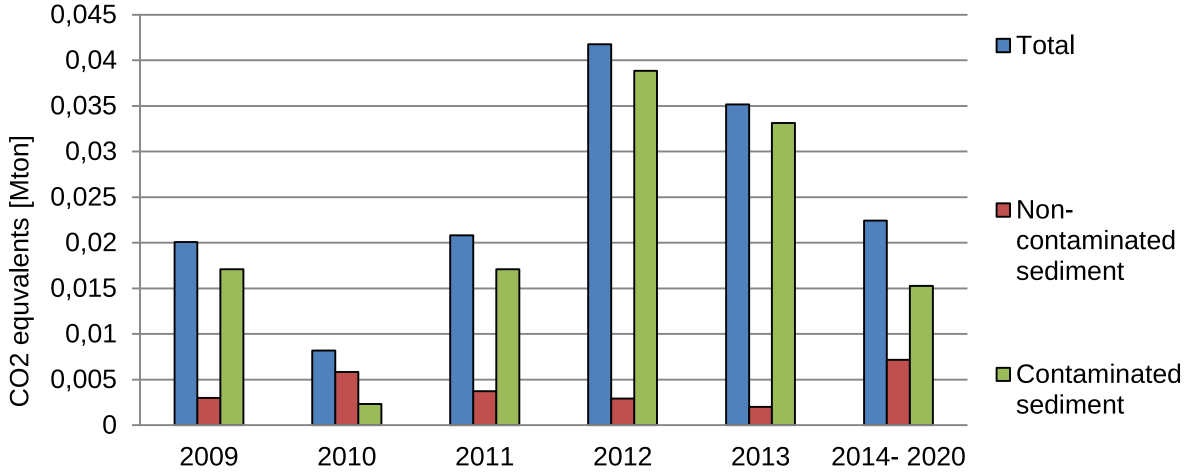

Figure 2.5: Annual CO2 emissions based on a scenario where non-contaminated sediments was disposed at sea and contaminated sediments was s/s treated.

Annually removed TBT due to dredging of contaminated sediments was calculated based on a median values for TBT content in Swedish sediments together with previous presented estimation on the dredging need of both clean and contaminated sediments in Swedish ports. Removing the TBT was defined as relocation of TBT whether it was relocated to a water deposit, land deposit or in a construction.

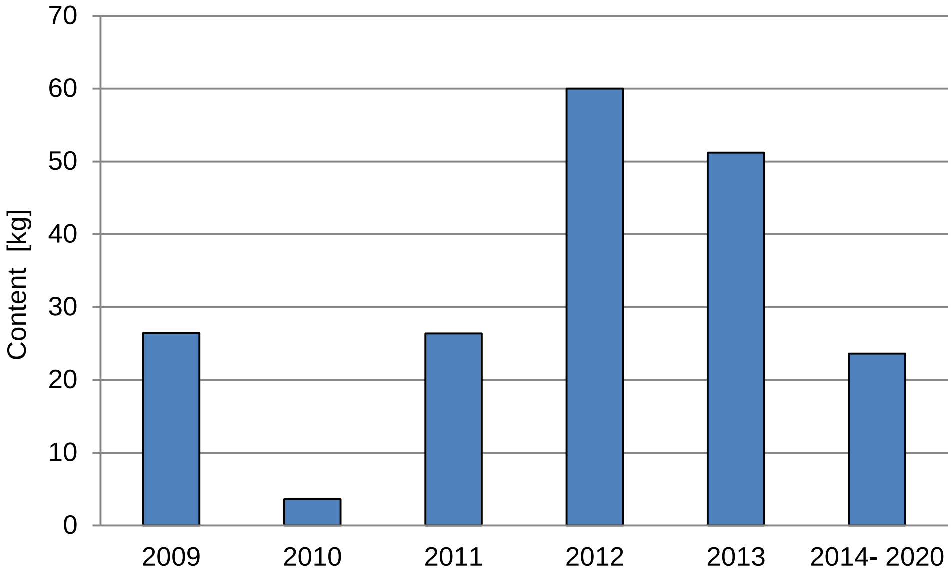

Figure 2.6: Estimated, annually relocated, amount of TBT based on planned dredging in Sweden. Most of the TBT was estimated to be relocated during 2012 and 2013.

It is of importance to stress that the results was very uncertain since calculations was based on only a few measurements and since TBT content can vary heavily between locations and sediments, also the volumes of contaminated sediments are uncertain. In order to make a better estimate of the total amount of TBT, more samples would be needed and areas with TBT hot spots would have to be found in each harbour cases.

2.5 Normalization of the potential impact from the scenario

The normalization of the potential impact from the scenario was made by comparison with corresponding impacts from appropriate selected sectors or regions in Sweden in order to determine the level of relevance of the issue. Normalization of the results can be made by taking into account the total energy use and CO2 emissions in Sweden. In 2009 total annual final energy use in Swedish sectors was 376 TWh while the total annual greenhouse gas emissions in 2010 was 66.2 Mton (Energimyndigheten, 2012) (Naturvårdsverket, 2010). Energy use in the scenario was about 0.002 % of total annual energy use in Sweden while greenhouse gas emissions corresponded to about 0,005 %.

For TBT flows there was no statistics available, but estimations have been made. In Sweden, the annual emissions of TBT to the environment have been estimated to 320 kg where about 10 kg is from waste and recycling sector (COHIBA, 2012). Annual TBT flow in the scenario was about 0.3 % of the total TBT flow in Sweden and about 10 % of the TBT flow in waste and recycling sector. With such argumentation, TBT flows from the management of sediments should be an important issue in a national context.

The results on energy use and climate impact for the scenario was further normalised by comparing with corresponding impact of a sector where handling of sediments is included. The knowledge about energy use and climate impact in Swedish sectors is generally poor. Energy use and climate impact from the Swedish construction sector (in which the management of sediments belong to) have been estimated by Toller et.al. (2009). In the study, the environmental impact from construction work in facilities taking into account a life cycle perspective, was studied. Construction work in facilities is defined as work with facilities during construction, rebuilt, repair, maintenance and demolition. It also includes work on ground, underground and under water, piping, installation and line construction (Arbetsmiljöverket, 2009). Hence, dredging activities is a part of this sector. The comparison is presented in Figure 2.7 and 2.8 and was based on annual dredging activities in Sweden during 2009 and 2013. Managing the Swedish contaminated sediments was estimated to demand about five times more energy than the managing of non-contaminated sediments. Similar pattern could be seen for CO2 emissions.

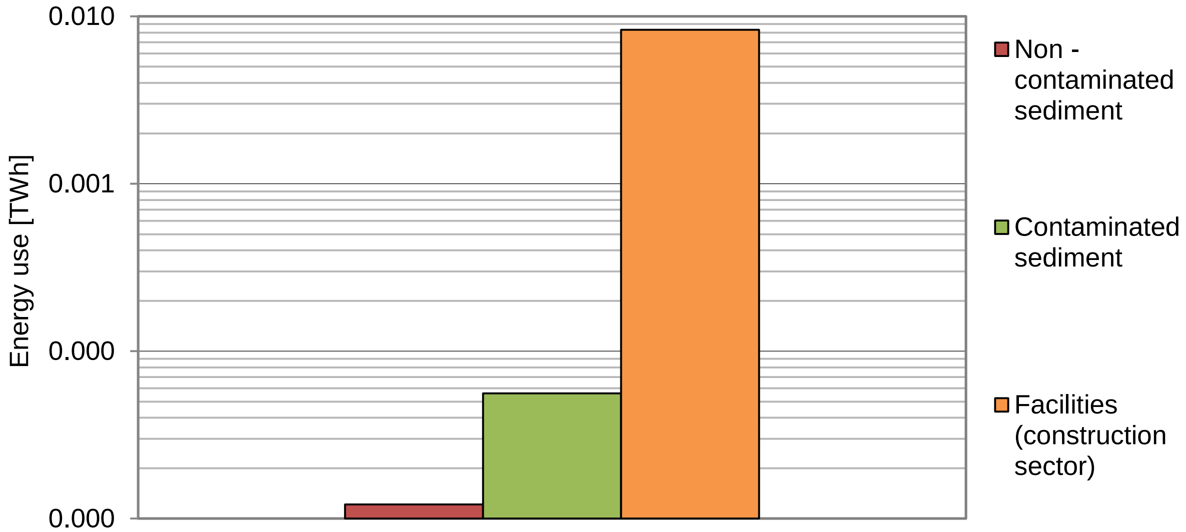

Figure 2.7: Annual energy use for management of sediments in Sweden and for the facilities work in the Swedish construction sector.

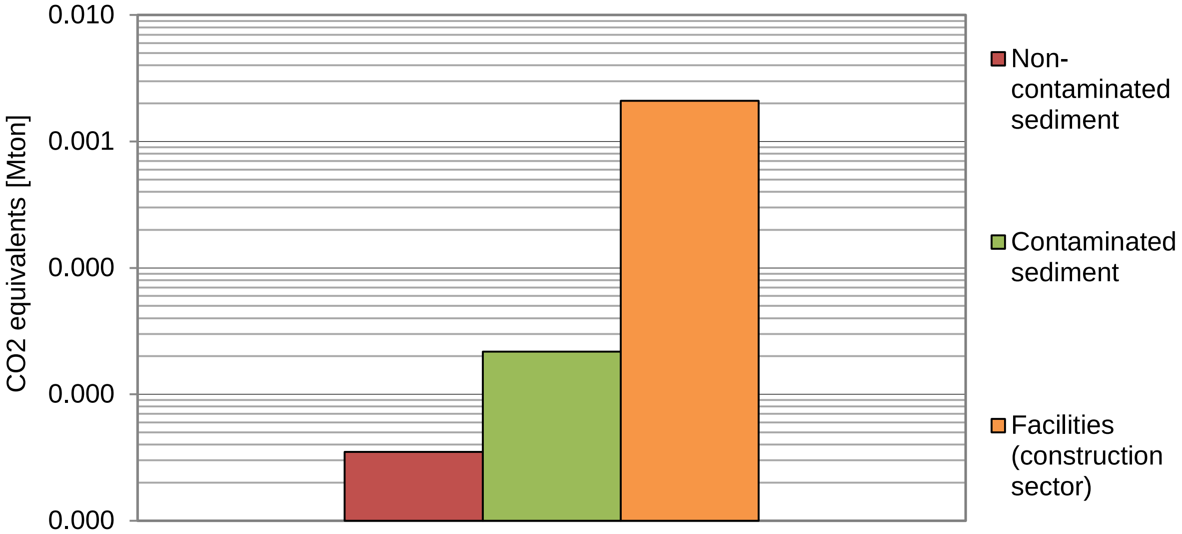

Figure 2.8: Annual CO2 emissions for management of dredged material in Sweden and for facilities work in the Swedish construction sector.

The annual energy use and climate impact between 2009 and 2013 caused by managing of sediments was less than 1 % of the energy use and about 1 % of the climate impact in the Swedish sector for construction works in facilities. The management of sediment did not seem to have significance in the context of the construction sector.

In Figure 2.9 a comparison of climate impact was made with the management of plastic waste which has been estimated by IVL (2010) to be the waste stream in Sweden with the highest climate impact.

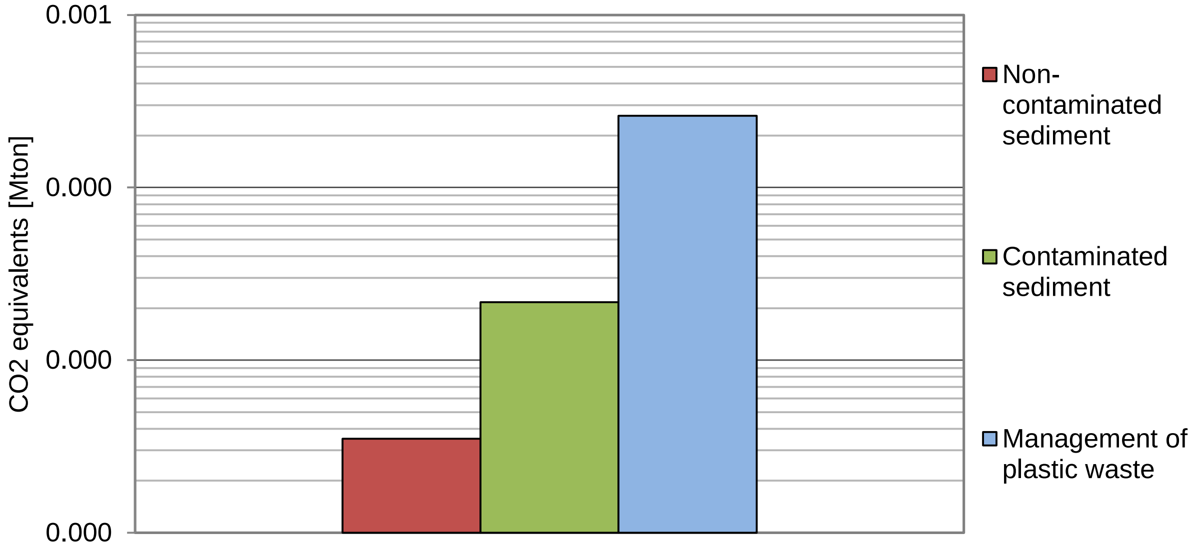

Figure 2.9: Annual CO2 emissions for management of dredged material in Sweden and for management of plastic waste

The climate impact from management of sediments corresponded to 10 % of the impact from management of plastic waste.

3. Conclusions

The overall aim of this study was to

1. describe how climate impact and energy use vary due to different handling methods,
2. describe the potential environmental impact in terms of energy use, CO2 emissions and flows of TBT, for a likely future scenario, taking into account the total amount of dredged material generated in Sweden,
3. relate environmental impacts from the management of dredged material to the environmental impacts caused by other, comparable, activities in Sweden.

The results showed that in Sweden about 1.4 Million m3 of dredged material is managed annually. Even though the total amount of dredged material seemed to decrease in the future, the share of sediment that is contaminated will increase. From an average of the total dredged sediment volume, the volumes of clean sediments was larger than the volumes of contaminated sediments, however from the energy use and climate impact point of contaminated sediments was more important.

The study shows that climate impact and energy use from each handling alternatives are connected to certain categories of activities. In the Swedish case on S/s alternative, main energy use and climate impact was due to the production of input material, mainly the binders cement and merit. The same was for the S/s and landfill alternative, but also, transportation of dredged material and construction material to landfill contributed to a large share of the impact. For the dewatering and landfill alternative main part of energy use and climate impact was related to transports of dredged material and of construction material to landfill site.

Energy use and climate impact in the METHA treatment alternative was mainly due to the transportation of material.

For the cases on sea and river disposal alternatives, energy use and climate impact was caused by dredging (construction work) and transportation of dredged material. When longer distances of transportation of dredged material are needed the energy use and climate impact from dredging activities are relatively small. Energy use and climate impact from dredging is only of relative significance in the river disposal alternative where transport distances are relatively short.

This study only considered the issue of energy and climate at the project level. However there are many other environmental issues that must be considered when choosing efforts for environmental impact reduction.

When assessing the environmental impact at a national level a future scenario for Swedish sediment management have been used. Investigation was made on how important issues related to energy, climate and TBT, are on a national level. The results have been normalized in different ways to give a broader picture of the issues that are important.

From the normalization it can be concluded that management of sediments seems to have significance at a national level since it is has significance in the context of waste management. Energy use and climate impact from the management of sediments was corresponding to less than 1 % of the energy use and about 1 % of the climate impact from the construction work for facilities sector. However, it corresponded to 10 % of the climate impact from management of plastic waste which is the waste flow in Sweden with the largest climate impact. TBT flows from sediment management were estimated to about 10 % of the TBT flow in the waste management sector. However, the estimations on TBT are very uncertain.

Since this study was based on a scenario on sediment management in Sweden it is not known if the significance of the issue at a national level would be the same in other countries in the Baltic Sea region. This study takes into account only a few of the issues that have significant when considering sediment management. Regarding flow of contaminants, this study has only scratched the surface of the issue by using TBT flow as an indicator. Also, other aspects such as abiotic resources and land use could be relevant. Especially in high densely populated countries with less available space such as for landfills and rock quarries.

Most data in this report was based on previous studies in SMOCS where input data and calculations can be found.

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