CEDA Position Paper

ASSESSING THE BENEFITS OF USING CONTAMINATED SEDIMENTS

Central Dredging Association

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ASSESSING THE BENEFITS OF USING CONTAMINATED SEDIMENTS

Position Paper Thesis

Using a wide range of case studies, this paper demonstrates that contaminated sediments can be used beneficially. The driving principles are:

(1) Sediments should be viewed as a resource
(2) Potential risks can be managed or avoided
(3) There is a positive socioeconomic value

The key objective of this paper is to demonstrate that it is technically suitable to use contaminated sediment for a range of beneficial end-use applications. Additionally, no dredging project should be avoided on the basis that "no action" is preferable to a risk management approach when all benefits are considered.

Introduction

This paper has been prepared by the Central Dredging Association (CEDA) Working Group on the Beneficial Use of Sediments (WGBU). The WGBU was initiated by the CEDA Environmental Commission in 2017.

The beneficial use of contaminated sediments is generally no different to the use of uncontaminated sediments. Both types of sediment can be beneficially applied, yet there are restrictions imposed on contaminated sediments regarding the potential environmental impacts from contaminant exposure; as such, this sediment must be managed appropriately. Approaches to managing the risks associated with this sediment includes treatment, which has led to the development of innovative construction techniques over the last two decades.

This paper provides several case studies regarding the beneficial use of contaminated sediments, an overview of effective treatment techniques and examples of relevant risk evaluation and decision-making frameworks. Within this context, this paper demonstrates that the beneficial use of sediment with varying degrees of contaminations is feasible when decision makers focus on value-added solutions and risk management, as opposed to "no action" and risk avoidance approaches.

While this paper does not include a detailed comparison of country-specific legislation (e.g., sediment quality standards or disposal regulations), the case studies and situations described herein illustrate the importance of flexible regulations that facilitate beneficial use of (contaminated) sediments, considering the specific origin, properties and application opportunities.

Perception of Risk

The definitions of 'contaminated' and 'uncontaminated' sediment are generally based on regional screening levels or sediment quality standards, compared to the sediment concentration. These standards are only an indication for the potential (eco) toxicological risks and are not directly linked to the actual, location-specific impact that contaminated sediments have on the environment. There is also a large geographical variation in the natural occurrence of contaminants in sediment. This variation is often discounted when using local standards, yet it illustrates that the definition and interpretation of 'contaminated' is subjective.

This paper does not present a case for disregarding the presence of contaminants in the sediment. Instead, it illustrates the importance of revisiting the original purpose of why sediment standards were derived, which is to prevent the degradation of the ecosystem by exposure to contaminants. As the beneficial use of contaminated sediments avoids this exposure and eliminates the risk, it can be as beneficial as the use of 'clean' sediments. As such, the perception and regulatory barriers regarding contaminated sediments need to be re-assessed.

By focusing on the perception of risk in a broader context, we intend to avoid discussing the different directives and legal definitions of contamination or waste and the different sediment quality standards, which are typically country specific. The purpose of this paper is to illustrate what can technically be done to mitigate environmental risks when beneficially using contaminated sediments, as opposed to "doing nothing" on a watershed system scale, which leads to environmental management paralysis.

This paper provides an overview of the different sediment treatment techniques that can be used to mitigate the environmental risks. The selection of a treatment technique is often guided by both the legal/regulatory system and the applicability of the treatment process and characteristics of the project location itself. In countries with a well-defined soil/sediment assessment system, each contaminant that has impacted water or the sediments is traceable to their legal owners (e.g., United States [US] Superfund sites); the policy is implemented to reduce the contaminant levels through source control. These remedial actions may include dredging and treatment, capping, natural attenuation or a hybrid of these approaches that encompasses adaptive management. Under the US Superfund, clean-ups are financially governed by the "Polluter Pays Principle", who will then support 100% of the clean-up. When ownership is less clear and/or if funds are lacking, this situation often leads to the "do nothing" scenarios. Some countries choose to implement a "stand still principle" with regard to the emission of contaminants to surface and groundwaters. In that scenario, the focus shifts from total concentration standards (like in the EU Waste Directive) to a (bio) available fraction approach (as in the Dutch Soil Directive).

Tools for Decision-making

Sediment use, including the use of contaminated sediments, can and should be evaluated in a broader multi-criteria evaluation of long-term cost and benefits of sediment use, rather than a short-term economic analysis. There are several tools that can be used to incorporate the different aspects of sediment use.

One such tool is the Life-Cycle Assessment (LCA), also called the "cradle-to-grave" analysis. While this assessment normally targets production as well as the use and disposal cycle of a product, the method can be adapted to both avoid use and reuse primary and/or unrenewable resources. The LCA approach can also score and rank different sediment solutions (disposal, treatment, beneficial use) against multiple criteria. One particularly popular criterium is the carbon footprint; however, environmental impacts are also evaluated and as such, an adapted Social Life Cycle Assessment (UNEP, 2013) can be used to look at social cost/benefits. Sustainable practices are also encouraged in LCA evaluations.

Another method to balance the cost/benefits of sediment use is to look at the "services" that the sediment provides. More information on types of criteria regarding the definition of services provided by the sediment, including setting up an assessment framework, can be found at the Millennium Ecosystem Assessment website[1].

An example of a project evaluation within a broader context is illustrated in Figure 1.

1 Millennium Ecosystem Assessment, 2005, http://www.millenniumassessment.org

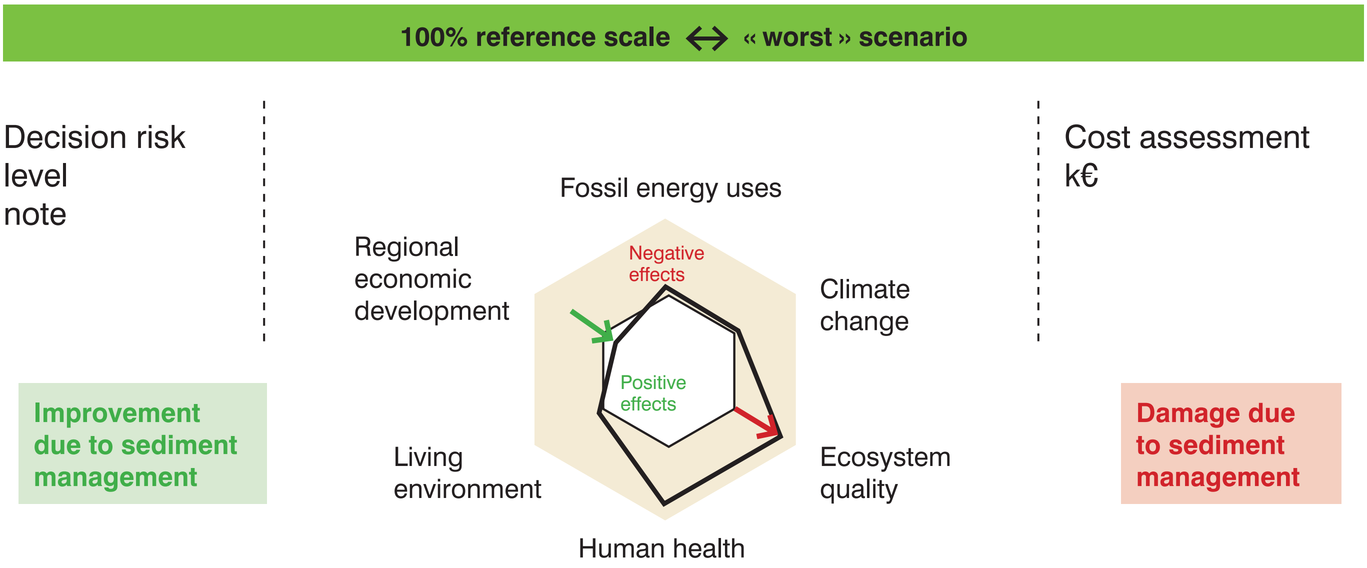

Figure 1 Example of a relative ranking method for the management and material recovery of waterway sediments (Lemiere, 2010), https://hal-brgm.archives-ouvertes.fr/hal-00691510

From "No Action" to Beneficial Use

Sediments from urban and port environments may be contaminated by point or non-point sources. They are also subject to complex sediment transport regimes, which may disperse contamination away from the original source. These sediments pose unique challenges for dredging and remediation/restoration programs. Sediment contamination is usually associated with fine-grain size fractions, which have fewer beneficial opportunities for coastal restoration and construction applications when compared to sand. Conversely, fine-grained sediments provide suitable raw material for several treatment options (reducing/binding or destroying the contaminant load) with high value and beneficial applications. Global regulatory programs often deem these contaminated sediments as waste, but in the 21st century they should be viewed as a global resource.

There is a negative public perception of using contaminated sediments. However, the "no action" alternative or delay of dredging results in economic, environmental (remedial) and societal losses. The "no action" response eventually can lead to a variety of adverse effects on navigation, water storage capacity and ecological services, as sediments accumulate in waterways. In the near future, these effects are likely to be enhanced by climate change. Therefore "no-action" dredging alternatives have the potential to shift of costs from an individual project to a societal problem, which may ultimately require additional flood protection measures or alternative infrastructure. The costs not only shift between projects but also in time, thus contributing to conditions that can make dredging not only unavoidable, but likely even more expensive. The "no action" response can lead to regulatory and decision-making paralysis; it also reduces the incentive for continuing innovative technology development to create a better outcome for the beneficial use of contaminated sediments.

Conversely, the applications of amended and/or treated contaminated dredged materials provide multiple options for beneficial use. From a sustainability perspective, dredged material may, for example, replace non-renewable resources (from quarries) in the creation of manufactured soils. With the stabilisation of dredged materials with cements, blast furnace slags, lime and fly ash, it is possible to provide structural and non-structural fill material for Brownfield economic and community development projects. Physical treatment processes such as sediment washing result in manufactured soil production and high temperature applications using rotary kilns to produce light weight aggregates or construction grade cement; both have been used to repurpose contaminated sediments. The use of amended/treated dredged materials as a raw material replaces primary soil material, which is a limited and increasingly expensive resource.

The beneficial use of contaminated sediments also minimizes the disposal of contaminated dredged material in upland landfills, thus increasing the landfill service life.

There has been significant programmatic progress regarding the efficient use of contaminated sediments as a resource. Programs focused on the beneficial use of sediments focus on upland ex-situ materials science (structural) and include EU projects[2] and the US Environmental Protection Programs[3] (EPA, 2011). These programs have been at the forefront of changing the perception of contaminated sediments from a waste to a sustainable resource. There is increasing global acceptance of applying innovative sediment treatment processes as part of the Regional Sediment Manufacturing Facility (RSMF) programs (Stern, 2017) that use back-end integration to incorporate beneficial uses of contaminated sediments in upland Brownfield and Greenfield development. This RSMF approach can drive policy and legislative changes that will encourage economic development and revitalize the impacted urban landscapes. These strategies should reduce processing costs (and encourage manufacturing) through a Life Cycle Approach that combines treatment with end user applications.

Many countries are working cooperatively on market drivers for the beneficial use of contaminated sediments in soils, biosolids and structural amendment-fill areas. This collaboration creates economic incentives and good technical knowledge for development of future business, i.e. entrepreneurial incubators. Ultimately, large-scale operations focused on the beneficial use of contaminated sediments could be integrated with other alternative approaches for using contaminated sediments.

Case Study Examples

The beneficial use of contaminated sediments can be categorised into five different applications, known as the Five Rs (see the CEDA Information Paper (CEDA, 2019)).

1. **Raw Material**: substitution for virgin manufactured soil or building materials, such as tiles or aggregates.
2. **Remediation**: clean up of contaminated sites or closure of landfills or mines.
3. **Reclamation**: creating new or expanding existing land, primarily for human/ commercial development activities.
4. **Restoration**: creation of habitat to support aquatic organisms and wetlands to improve the natural value of the environment.
5. **Resiliency**: shoreline nourishment and (dike) reinforcement for defence against floods and extreme climatic events.

These Five Rs are ordered in increasing use of nature and decreasing human intervention. The case studies which illustrate the beneficial use of contaminated sediments cover all of these areas, but mostly concentrate on the solutions that are influenced more greatly by human activity and high socioeconomic value. This bias is because handling contaminants always increases project costs, thus requiring a solution with a combined benefit of cost avoidance and additional economic and social benefits.

Table 1 categorises all case studies for the Information Paper and Position Paper in relation to the Five Rs and their areas of application. Case studies for contaminated sediments are highlighted with an underline, and treatment with an italic font. For further clarity, Table 2 provides a list of the case studies by title and cross-referenced against their classification.

All case studies are described in standard two-page summaries and are available on the CEDA website at: https://dredging.org/resources/ceda-publications-online/beneficial-use-of-sediments-case-studies

2 European examples include: SEDI.PORT.SIL (LIFE+ Environment Policy and Governance, 2010-2013), CEAMas (North-West European Interreg IVB, 2012-2013), SETARMS (North-West European Interreg IVB, 2007-2013), SEDILAB (supported by CD2E, France), SMOCS (Huxley College of the Environment, 2012), CIRIA (Construction Industry Research and Information Association), EcoSed (Industrial Research Chair in Sediment, Mines Douai, France), GeDSET (Interreg France-Wallonie-Vlaanderen, 2008-2013) and the Sedimateriaux Approach (supported by CD2E, France).

3 New Jersey Department of Transportation/New York and New Jersey Harbor Sediment Decontamination Program in the United States (part of US Superfund Innovative Technology Evaluation Program, 2005-2009).

Table 1. Case studies classified after Function (Rows) and Technique (Columns). Rows 1 through 5 refer to Function and columns A through D refer to Technique. Case study nomenclature includes a reference to the Function, Technique, the year at project start, and the country location of the project. Underlining indicates contamination present; Orange *italics* indicates treatment (see Position Paper for details on treatment techniques).

Technique → / ↓ Function	A. On Land Natural or enhanced treatment	B. In Water Reallocation at final location	C. In Water Reallocation at strategic location	D. In Water Enhanced Trapping
1. Raw Material	R1A_1985_DE *R1A_1993_DE* *R1A_1996_DE* R1A_2006_DE R1A_2006_NL *R1A_2012_FR* *R1A_2015_US* *R1A_2017_IT* *R1A_2018_US*			
2. Remediation	*R2A_1988_DE* *R2A_1995_NL* *R2A_2015_DE*			
3. Reclamation	R3A_2016_US R3A_2018_NL	*R3B_2006_NZ* *R3B_2010_NO* *R3B_2018_SE*		
4. Restoration	R4A_2010_NL	R4B_2002_US R4B_2005_US R4B_2008_US R4B_2016_NL R4B_2016_UK(a) R4B_2016_UK(b)	R4C_1999_NL R4C_2002_US R4C_2007_US R4C_2016_NL	
5. Resiliency	*R5A_2004_DE* *R5A_2005_BE* *R5A_2013_FR* R5A_2018_NL *R5A_2019_BE*	R5B_1990_UK R5B_2006_NL R5B_2010_US	R5C_2008_US	R5D_2015_ID

The case studies were made available by the WGBU members and their industrial contacts.

As the overview given in the papers is not exhaustive, the authors openly invite the professional community to share their experiences with the CEDA community. A platform and email contact are available on the CEDA website to facilitate submission of additional and future case studies, and mutual knowledge exchange, regarding the beneficial use of sediments world-wide.

The treatment techniques used for the contaminated sediment case studies are briefly described in the next section of this paper.

The contaminated sediment case studies show that higher cost solutions typically involve on-land construction applications in urban environments. These applications are spatially constrained by distance to the source material site. Transport costs hamper long distance applications, often rendering the solution site-specific. We note that there are still no large-scale solutions for contaminated sediments on a fully integrated watershed or on a regional scale. Pollution prevention, regional assessments and public education continue to be important to identify and drive solutions on a large watershed scale.

Treatment Techniques with Beneficial Applications

The choice of the treatment technique is site-specific. It depends on the site configuration, nature of the contaminants (chemical vs. physical), treatment goals and local governance. Here we focus mainly on techniques. The methods outlined below illustrate the main principles of the more commonly used methods for treating contaminated sediments. The differentiator is that some of these treatment options can produce a beneficial use that is in line with the Five Rs.

Table 2. List of case studies by title and classification code.

Classification Code	Case Study Title
R1A_1985_DE	Production of raw material through dewatering fields, Hamburg – DE
R1A_1993_DE	Production of raw material through a dewatering plant, Hamburg – DE
R1A_1996_DE	Use in ceramic industry through industrial treatment, Hamburg – DE
R1A_2006_DE	Use as agricultural soil after dewatering, Ihrhove – DE
R1A_2006_NL	Reclamation of clean sand through sand separation, Rotterdam – NL
R1A_2012_FR	Use in road construction after immobilisation and stabilisation, Dunkirk – FR
R1A_2015_US	Use in civil and environmental applications after stabilisation via Pneumatic Flow Tube Mixing, New Jersey – US
R1A_2017_IT	Use in civil and environmental applications after multiple phase cleaning and sorting process, Palermo – IT
R1A_2018_US	Production of grade cement after thermo-chemical high temperature treatment and immobilisation, New Jersey – US
R2A_1988_DE	Use as sealing material after dewatering, Hamburg – DE
R2A_1995_NL	Use as landfarming through bioremediation, Oostwaardhoeve – NL
R2A_2015_DE	Use as substitute for sand to backfill former harbour-basins, Hamburg – DE
R3A_2016_US	Raise elevation of near-shore agricultural fields after natural dewatering, Ohio – US
R3A_2018_NL	Raise elevation of low-lying peatlands and production of high value soil through blending with local organic waste, Krimpenerwaard – NL
R3B_2006_NZ	Use in expansion of port terminal after blending with cement, Auckland – NZ
R3B_2010_NO	Use in expansion of port terminal after blending with cement and stabilisation contaminated sediments, Oslo – NO
R3B_2018_SE	Use in civil applications after testing with various binders, Gothenburg – SE
R4A_2010_NL	Raise elevation of low-lying peatlands after natural dewatering in confined facilities, Jisperveld – NL
R4B_2002_US	Creation of natural habitat and morphological stabilisation through strategic deposition, New Jersey – US
R4B_2005_US	Counter subsidence and creation of natural habitat through strategic deposition, California – US
R4B_2008_US	Habitat restoration through creation of islands, Wisconsin – US
R4B_2016_NL	Habitat restoration through creation of islands, Lelystad – NL
R4B_2016_UK(a)	Habitat and wetland restoration through strategic deposition, Brightlingsea – UK
R4B_2016_UK(b)	Habitat and wetland restoration in three locations through strategic deposition, Hampshire – UK
R4C_1999_NL	Feeding the natural system through natural dispersive processes, Waddensea – NL
R4C_2002_US	Creating islands through natural dispersive processes, Louisiana – US
R4C_2007_US	Beach replenishment and lagoon restoration through natural dispersive processes, California – US
R4C_2016_NL	Wetland enhancement through of natural dispersive processes, Harlingen – NL
R5A_2004_DE	Use in dyke construction reinforcement to enhance flood resilience after industrial dewatering, Hamburg – DE
R5A_2005_BE	Use in dyke construction reinforcement to enhance flood resilience after dewatering and treatment, Dendermonde – BE
R5A_2013_FR	Use in breakwater components to enhance flood resilience after dewatering and treatment, Dunkirk – FR
R5A_2018_NL	Use in dyke construction reinforcement to enhance flood resilience after natural ripening, Delfzijl – NL
R5A_2019_BE	Use in dyke construction reinforcement to enhance flood resilience after dewatering and treatment, Waasmunster – BE
R5B_1990_UK	Coastal defence and habitat restoration through strategic disposal, Essex - UK
R5B_2006_NL	Making room from rivers through various beneficial uses, various location in NL
R5B_2010_US	Use for coast defence and nature restoration through strategic placement, Mississippi – US
R5C_2008_US	Use for coast defence and nature restoration through strategic placement and use of natural processes, California – US
R5D_2015_ID	Use for coast defence and local economy enhancement through natural trapping, Demak – ID

CHEMICAL IMMOBILISATION

Chemical immobilisation uses binders to physically strengthen the sediment for structural or non-structural engineering use (such as infill for land reclamation) while also reducing the mobility and solubility of the contaminant. This process achieves both the beneficial use of contaminated sediments and contaminant immobilisation.

Suitable materials include hydraulic cements, GGBS (ground granulated blast furnace slag), fly-ash, lime, bentonite, calcium aluminate, super-sulphated cement, magnesium and iron oxides and activated carbon. Chemical immobilisation is frequently used not only because of the relatively low cost and high availability of these materials, but also because of its demonstrated ability to immobilise heavy metals, TBT (tri-butyl tin) and inorganic compounds. These binders can be mixed with the sediments both in-situ and ex-situ; mixing ex-situ has the advantage of producing a more homogenous mix.

See the case studies *"R1A_2012_FR: Use in road construction after immobilisation and stabilisation, Dunkirk", "R1A_2015_US: Use in civil and environmental applications after stabilisation via Pneumatic Flow Tube Mixing, New Jersey", "R3B_2010_NO: Use in expansion of port terminal after blending with cement and stabilisation contaminated sediments, Oslo"* and *"R3B_2018_SE: Use in civil applications after testing with various binders, Gothenburg"*

BIOREMEDIATION

Bioremediation is the addition of microbial agents to the sediments (either in situ or after dredging) to break down contaminants to non-toxic by-products. It is relatively inexpensive to carry out and is particularly suitable for the treatment of organic contaminants and many heavy metals. Bioremediation requires very specific environmental and physical conditions to be most effective for contaminated sediments.

See the case study *"R2A_1995_NL: Use as landfarming through bioremediation, Oostwaardhoeve"*

PHYTOREMEDIATION

Phytoremediation is the use of plants such as hemp, pigweed and mustard to bioaccumulate and degrade heavy metals and organic pollutants. It is a relatively low-cost solution and has the added value of potential recovery of valuable metals from the plants. It is suited to shallow contamination events, such as spills and discharges. This method requires a commitment to long-term monitoring to ensure that the plants continue to thrive. Like bioremediation, phytoremediation returns the sediment to a natural and environmentally stable state.

See the case study *"R2A_1995_NL: Use as landfarming through bioremediation, Oostwaardhoeve"*

THERMAL DESORPTION

Thermal desorption is a specialized ex-situ process in which the sediment is heated indirectly in a rotary kiln to volatilize the contaminants. The off-gas is then treated separately and either discharged, collected or thermally destroyed.

For more information see (EPA, 1994)

SEDIMENT WASHING AND SAND SEPARATION

Ex-situ sediment washing separates the coarse, non-contaminated fraction from silts and clays, which have the greatest contaminant absorption capacities. This separation produces sands and gravels that can be beneficially re-used. The finer fractions can also be further treated by organic destruction using strong oxidants, liquid-solid separation and subsequent back-end dewatering to produce a sediment filter cake end-product, which can also be beneficially used. The creation of a beneficial use product, such as a blended manufactured soil that meets residential or non-residential standards, has been demonstrated in the Palermo (Italy) case study.

See the case study *"R1A_2017_IT: Use in civil and environmental applications after multiple phase cleaning and sorting process, Palermo"*

EX-SITU HIGH TEMPERATURE PROCESSING

High temperature rotary kilns or plasma systems operating at 1400 ^{o}C can be used for commercial-scale treatment and beneficial use of sediments. When heated at high temperatures sufficient to melt sediments, the addition of modifiers/minerals creates a pozzolan. The organics are dissociated or destroyed and the metals are immobilised in a glassy slag and pulverised to produce a construction grade/stabilised cement. Rotary kilns are also used to produce light weight aggregates from pelletised sediments. Both construction grade cement and light weigh aggregates comprise the beneficial outputs of this process, replacing the use of virgin natural resources.

See the case study *"R1A_2018_US: Production of grade cement after thermo-chemical high temperature treatment and immobilization, New Jersey"*

CONFINED DISPOSAL FACILITY (CDF)

Strictly speaking, a CDF is not considered a sediment treatment option; however, it can be classified as beneficial when used for land reclamation or a continuous source to substitute a raw material.

A CDF is often used to create a long-term viable storage solution for contaminated sediments, provided that there is adequate space and engineering/ ecological feasibility to show that the CDF option can be supported with long-term management and monitoring protocols (also see the chapter "Examples of Beneficial Use Techniques"). Alternatively, CDFs can be integrated with sediment treatment as part of a "renewable" CDF strategy. For example, consider a situation when a CDF is filled to capacity and the re-siting of a new CDF is not feasible. Through "mining" the CDF with subsequent sediment treatment options, such as sediment stabilisation, the CDF could then be "renewed" to create a potentially infinite capacity when the sediments are mined, treated, and beneficially used.

Creating a CDF can often be combined with the local mining of clay, sand or gravel. CDF's create the needed upland land reclamation for construction activities that become economic drivers (mostly in ports). CDF's can be part of an overall sediment strategy solution through combining economic benefit with a safe long-term storage solution for contaminants. As such, CDF's contribute to the overall ecological value of the project by creating high value habitats like wetlands and shallow lakes.

See the case study *"R5B_2006_NL: Making room for rivers through various beneficial uses, various location in NL"*

ASSOCIATED ACTIVITIES

Dewatering

Dewatering is used to prepare the sediment for treatment, enabling more effective mixing of the immobilising agent, if applicable. Dewatering can be carried out by lagooning and draining in settling ponds or barges, mechanical dewatering, geotubes, electro-dewatering and as a pre-cursor to thermo-chemical treatment. Dewatering can also be used to reduce sediment volume or as part of a storage solution (landfill).

See the case studies *"R1A_1985_DE: Production of raw material through dewatering fields, Hamburg", "R1A_1993_DE: Production of raw material through a dewatering plant, Hamburg", "R1A_2006_NL: Reclamation of clean sand through sand separation, Rotterdam", and "R2A_1988_DE: Use as sealing material after dewatering, Hamburg"*

Secondary Mining

Secondary mining is the removal of the contaminant for further use. This can be carried out as part of the immobilisation technique, as in the case of phytoremediation (burning the plants to extract metal compounds - "phytomining") or liquefied gas solvent extraction (when solvents are vaporized to isolate organic materials for recycling). The benefit of this process is that the treated sediment can then be reused elsewhere.

See the case study *"R1A_1993_DE: Production of raw material through a dewatering plant, Hamburg"*

FIELD TRIALS

Field trials are an important way to demonstrate the full-scale performance of a treatment process, including immobilisation techniques. The information derived from both the engineering and process effectiveness, coupled with a beneficial use application, is particularly valuable to support public education about the process, especially when using high temperature and physical separation technologies. Field trials are also particularly relevant to chemical immobilisation where binders are mixed into the dredged sediments. A field trial is carried out to confirm the efficacy of binders that have been selected from laboratory-scale bench testing; the binders are then used for full-scale verification testing (e.g., in-situ strength and permeability testing, leaching tests).

Abbreviations Used*

CDF – Confined Disposal Facility
CEDA – Central Dredging Association
LCA – Life Cycle Assessment
RSMF – Regional Sediment Manufacturing Facility
WGBU – CEDA Working Group on the Beneficial Use of Sediments

*The list does not include project name acronyms

Conclusions

In this paper we show how sediments are a resource, even when contaminated. Sediment management and therefore use of sediments is necessary, as "no action" simply transfers, often increasing, risk and cost to future generations.

The tools to assess the impact of using contaminated sediments versus "no action" are well established and are applicable to a wide range of conditions/project scenarios. In addition to assessing the environmental risks associated with contaminants, these tools evaluate and rank the sediment use solutions based on conventional metrics (e.g., economics, LCA) and their overall contribution to sustainability.

The case studies illustrate that most of the current applications that include contaminated sediments fall within the ***raw material*** and ***remediation*** categories. These categories are relatively capital intensive and therefore may be predominantly small scale and ad-hoc (point source) solutions. To avoid the long-term financial and ecological losses of "no action" scenarios, and to use contaminated sediment as a solution for climate change and circular economy challenges, we need a more integrated view on sediment management and a shift to more field- and full-scale applications in restoration and resiliency categories.

There are several available well-demonstrated treatment techniques that can reduce the risk of contaminant exposure. If an application is chosen and the sediment is characterised, field trials will help to validate the effectiveness of the treatment options. These field tests can also help to assess any additional benefits (like secondary mining).

The main conclusion is that the presence of contaminants is only one factor in the evaluation of how sediments can be beneficially used. It is evident that sediments must be used beneficially, as "no action" often leads to unacceptable risks and/or decision-making paralysis. There are many scenarios in which the use of contaminated sediments is beneficial; these scenarios are both economical, ecological and in view of the Sustainable Development Goals (see the case studies). Legislation should therefore follow the approaches used in the case studies as much as possible to implement the beneficial use of contaminated sediments.

Finally, as a call for ongoing collaboration, the authors invite the readers, and the professional community, to share their experience, knowledge and further case studies, by sending them to ceda@dredging.org. As identified in Murray (2008) communication on this subject is vital in order to see more and larger projects achieved. Therefore, CEDA will provide a platform for ongoing knowledge and experience exchange on the subject of beneficial sediment use.

References

CEDA (2019). *Sustainable Management of the Beneficial Use of Sediments. Information paper*. [Online] Available at: http://www.dredging.org/media/ceda/org/documents/resources/cedaonline/2019-05-BUS-ip.pdf [Accessed: May 2019].

EPA (1994). *Common Cleanup Methods at Superfund Sites,* EPA 540/R-94/043

EPA (2011). *The Superfund Innovative Technology Evaluation Program summary and closure report,* EPA 540/R-11/001

Lemiere, Bruno, P. Michel, N.E. Abriak, L. Haouche, A. Laboudigue, C. Alary, R. Badreddine, B. Hazebrouck and J. Meerseman (2010). *The GeDSeT project: constitution of a decision support tool (DST) for the management and material recovery of waterways sediments in Belgium and Northern France,* Déchets, Sciences et Techniques, 2010, 57, 10 p. <hal-00691510>

Murray, L. (2008). *Dredged material as a resource.* Terra et Aqua, September, Number 112, pp. 3-10. https://www.iadc-dredging.com/ul/cms/terraetaqua/document/2/4/0/240/240/1/article-dredged-material-as-a-resource-terra-et-aqua-112-1.pdf [Accessed: May 2019]

Stern, Eric, A. Maher, R. Miskewitz, M. Kitazume, D. Yang and A.N. Kovalik (2017). *Alternatives to Aquatic Placement Applying Regional Sediment Manufacturing to Innovative Stabilisation for Brownfields Beneficial Use,* SedNet 10th International Conference, Genoa, Italy, Disposal of Sediments at Sea Session

UNEP (2013). UNEP-SETAC, *The Methodological Sheets for Subcategories in Social Life Cycle Assessment* (S-LCA), DTI/1752/PA, https://www.lifecycleinitiative.org/wp-content/uploads/2013/11/S-LCA_methodological_sheets_11.11.13.pdf [Accessed: May 2019].

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