Revising sediment quality guidelines to reflect current scientific understanding of chemical interactions in sediment with ecosystems

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1. Sediment quality guidance and sediment quality assessment

Introduction: In the nearly 20 years since the Wenning et al. (2005) comprehensive review of the state of the science for sediment quality guidelines (SQGs) and related tools and their use [1], the methods used to derive numerical chemical concentrations intended to be either protective of aquatic life or predictive of adverse effects, have changed little. A recent review indicated 19 variations of the fundamental derivation methods used to set numeric SQGs [2]. Empirical, mechanistic and sediment quality index (SQI) methods are well-established and widely used. The narrative intent should drive their selection and use – are they being used proactively or retroactively to assess or prevent risk, and to manage or monitor? Determining how chemical and other data are used to inform regulatory and management decisions is essential in evaluating their derivation and meaning.

There remains a need to define acute and chronic sediment toxicity clearly. Predicted no-effect concentrations (PNECs) for some chemicals can vary by up to four orders of magnitude, partly due to a lack of agreement on what constitutes acute versus chronic toxicity [3]. Furthermore, current methods of deriving PNECs or threshold-effect levels (TELs) continue to rely on laboratory bioassays using organisms and conditions that may not be ecologically and environmentally relevant. Most SQG values regulatory agencies use ignore the influence of chemical mixtures, exposure routes, and ligands in the sediment that may limit bioavailability [4,5], and the list of chemicals being measured and monitored may not fully represent those driving effects.

Need to Review Current State of Practice Involving SQGs and Sediment Assessment: The consensus recommendation from 2005 is unchanged; current SQGs are useful for screening purposes and should not be applied as definitive determinations of sediment risk or cleanup goals [1,6]. Still, a strong desire remains to use SQGs for sediment monitoring, management, and regulatory purposes. Without site-specific biological, chemical, and environmental considerations, a chemical-specific threshold may not protect resident aquatic life and the ecosystem from significant harm or ecological impact. Hence, SQGs and other environmental quality benchmarks, both empirical and theoretical, are confounded by scientific and management uncertainties and have "good", "bad", and "ugly" components [7].

Ecologically Relevant Approaches are Needed: Because aquatic ecosystems and management goals differ widely, more than one sediment assessment tool is needed to evaluate sediment and biotic interactions and to derive ecologically meaningful assessment approaches. Though the weight of evidence (WOE) approach is widely endorsed, many commonly used lines of evidence are weak and poorly supported by current science. New approaches and tools are needed that account for factors such as biodiversity, climate change, chemical mixture interactions, and different sediment management purposes. Examples include the ecosystem-based [8] and BioCriteria approaches [9], the consideration of non-chemical stressors [10], assessments of sensitive species representative of different ecological niches, exposure pathway and life cycle analyses, habitat condition assessments, high throughput omic-based toxicity screening, *in situ* toxicity tests, and the adverse outcome pathway (AOP) approach [11].

This presentation discusses preparing a new edition of the 2005 SQG book [1]. Following a brief review of improvements to SQG derivation methods and regulatory guidance in different countries, we focus on engagement with experts to identify the tools needed to bridge the gap in the current state of the science regarding environmental contaminants (and other stressors) in sediments, biological effects, and ecosystem "health". We examine the role SQGs can and should have in determining sediment and ecosystem quality and sediment management. International knowledge exchange is needed to promote best practices; collaboration is invited.

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The importance of reviewing the Portuguese legislation for the assessment and management of dredged materials: The case of butyltin compounds

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Conference theme number(s): …..

Introduction: The maintenance of harbors, ports, marinas, and navigation channels in conditions that allows the development of economic activities implies regular dredging operations. These operations generate significant amounts of contaminated dredged materials and due to that it is required the assessment of the levels of contaminants in the dredged materials to prevent and reduce the release of these hazardous substances in the marine environment.
Like in other countries, Portugal implemented, in 2007, its own legislation to deal with the assessment of contaminants. According to Portuguese environmental legislation, the management of dredged materials is based on a 5-category scheme with increasing trace metal (As, Cd, Cu, Cr, Hg, Ni, Pb, and Zn) and persistent organic pollutant (PAHs, PCBs, and HCH) concentration ranges, from Class 1 (clean dredged material) to Class 5 (heavily contaminated dredged material). In this regulation, butyltin compounds (TBT, DBT, and MBT) are not considered due to the absence of screening levels, which means that in practice they are not frequently monitored.
Based on a set of butyltin compounds data in marine sediment collected in the CSS project, this study intends to demonstrate the importance of modifying the Portuguese Legislation to include these organic compounds and other booster biocides (e.g., irgarol).

Methods: A set of thirty-eight surface samples were collected in two oceanographic campaigns carried out in 2019 and 2021 in the SW Portuguese Margin (western Iberian Margin, NE Atlantic). Butyltin compounds were measured in the sediment fraction lower than 2mm, by solid-phase microextraction (SPME)-GC-MS, using NaBEt4 as a derivatizing agent, based on a previously optimized methodology [1]. Additionally, the fine-fraction and organic carbon contents were also determined.

Results: Results indicate in general the presence of TBT in sediments in the vicinity of coastal disposal sites for dredged material, giving proof of the dispersion of contaminated materials after being dumped.

Discussion: Therefore, a review of the Portuguese Legislation for the assessment and management of the dredged materials, considering the inclusion of butyltin compounds (and other booster biocides) will be the adequate precautionary approach. Furthermore, it should be established the respective definition of screening levels of contamination based on a weight-of-evidence approach to decision-making on the disposal of dredged material to sea, where are considered the sediment chemistry historical (when available), and new data to be acquired, bioassays, knowledge of both dredging and disposal sites, physical characteristics of the dredged materials and other relevant dat. The major benefit of implementing a revision of the legislation is to reduce the contaminants disposal in the marine environment. This will represent a restrictive action to protect the Portuguese marine shelf environment from the effects of TBT (and other contaminants), particularly in the vicinities of dredged material coastal disposal sites.

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Spatial variability of organic matter quality and metal reactivity in the port of Rotterdam sediments

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Introduction: Each year, 10-15 million m^3 of sediment are dredged from the waterways in the port of Rotterdam, one of the world's largest harbors [1]. The fine-grained and often organic-rich sediment is either relocated at sea or, when contaminated, disposed in a confined facility. In light of the poorly understood environmental impact – in particular, greenhouse gas and metal emissions - of dredged material and considering the growing interest in sediment reuse for 'building with nature', it is of great interest to understand the chemical composition and biogeochemical behavior of dredged harbor sediment, particularly the organic matter (OM) quality and metal mobility.

Methods: Bulk sediments throughout the harbor were collected during a sampling campaign in 2021. Total elemental composition of porewater and solid phase (after total digestion) were analyzed with ICP-MS. We employed C/N with isotope analysis and flash pyrolysis GC-MS to characterize the bulk OM and the isolated macromolecular organic matter (MOM). To further understand the metal speciation and mobility, different metal extractions were performed with extraction strengths from ion exchange in salt solutions to dissolution of stable minerals in concentrated oxidizing acids. Additionally, heavy metal release under different pH was quantified for two contrasting sites through pH-static leaching experiments and geochemical modelling.

Results: OM content was high at all sites except several sandy sediments mainly located in the river channel. A general west-to-east gradient of marine influence was presented throughout the harbor, which coincided with the changes of carbon and nitrogen content and their isotope abundance. The MOM was of a mixture of terrestrial, marine, and potential anthropogenic origins, and particularly the abundance of terrestrial biomolecules (guaiacol, phenol and syringols) decreased as deposition setting became marine influence dominated. Trace metals (Cd, Ni, Cu, Zn) were enriched in finer and less marine influenced sediments, while grain size and the extent of marine influence were poorly correlated with the highly reactive metal fractions. Additionally, the highly reactive fraction among trace elements were different, with Zn and Cd (>85%) significantly larger than Ni (33%) and Cu (55%). Such mobility variance among elements was also reflected in the pH-static leaching experiment and modelling results, where mobility was lower at neutral condition while higher at acid or alkaline conditions.

Discussion: Our results suggest depositional environment plays an important role in sedimental geochemistry. Grain size significantly affects Al/Fe content, TOC preservation, and S sequestration [2]. Salinity at the depositional environment affects metal behaviors, in particular Fe, through sulfur cycling [3]. The variance of OM quality between marine and river sediments might influence the early diagenesis and greenhouse gas generation. The strongly reducing nature and high content of (reactive) organic matter suggest these sediments likely respond strongly to oxidation during dredging and disposal. The implications of our findings within the context of sediment reuse and present future plans therefore offer theoretical explanations for estimating greenhouse gases and metals release under different disposal scenarios.

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Assessing sediment toxicity in reservoirs before flushing: developing a protocol for freshwater in Italy

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Conference theme number: 1

Introduction: Desiltation is often necessary in reservoirs to maintain the storage capacity and in Northern Italy it is frequently achieved by sediment flushing.

Fig. 1: Sediment flushing

These operations may determine a release of contaminants (e.g., trace elements, PAHs) from resuspended sediments, determining potential toxicity to aquatic organisms living in the downstream river [1]. Based on case studies in Lombardy Region, characterized by different degrees of silting and anthropogenic pressures, a protocol for chemical and ecotoxicological characterization of sediments in reservoirs (PrATo) was developed for a proper management of flushing operations [2]. This approach has been adopted in Lombardy in the Technical Guidance for the Reservoir Management Plans [3]. However, there is still much to do to improve its applicability in different regions and to select proper criteria for environmental risk assessment. The main constraints and potential solutions are here addressed.

Methods: PrATo includes standard protocols for sampling, chemical and ecotoxicological characterization of sediments in reservoirs and in the downstream river. It is based on an approach similar to TRIAD, taking into account: 1) chemical analysis of (micro)pollutants in sediments and elutriates; bioaccumulation in native macroinvertebrates can be also analyzed; 2) sediment toxicity analysis using test batteries; 3) results can be combined with the ecological assessment of aquatic communities in the downstream river. The protocol is applied *before* flushing, as basis for planning proper operations for minimizing the risk of detrimental effects in the river. For example, a safe sediment:water dilution factor to be applied during flushing can be calculated, preventing the exceedance of toxicity thresholds. The same characterization is performed on sediments collected in the downstream river *after* flushing to assess potential alterations.

Results and discussion: Some focal points of the protocol still need to be defined. The main constraints and potential solutions are:

- background concentrations of contaminants and toxicity are generally unknown: quality guidelines can be selected from existing national legislation or from literature, but the analysis of a "reference" site located upstream from each reservoir is also necessary as a site-specific criterion.
- the number of sampling points, surveys and analyses for each case study is limited because of cost/beneficial constraints, therefore a strict statistical approach can't be generally adopted for evaluations. Rather, proper screening and risk thresholds need to be defined.
- in a first version, only one sediment-contact test was performed (with the ostracods *H. incongruens*), but some false positives or negatives limited its effectiveness. Test batteries have been adopted for a more robust evaluation [4].
- the different lines of evidence need to be properly combined to obtain a final judgment. A translation into operational guidelines for reservoir managers is needed.

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Sediment quality assessment at small streams affected by different types of anthropogenic pressures

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Conference theme number(s): 1

Introduction: Under the Water Framework Directive, a tiered approach is recommended for sediment quality assessment [1]. A first tier consists of chemical analyses and the evaluation against sediment quality standards (EQS). EQS are recommended as a screening tool, triggering additional investigations to refine potential risks or verify the possibility of observing poor ecological quality at the sites. The use of bioassays for sediment quality assessment have been already tested within different national and EU projects [2,3]. A pilot project was carried out to test a battery of bioassays at small streams affected by different levels and types of contamination.

Methods: Thirteen sites were studied; five sites influenced by agricultural activities, four sites subject to mixed sources of pollution (agricultural and urban), and four sites with less anthropogenic influence. The tested battery included three standardized bioassays: the crustacean ostracod *Heterocypris incongruens*, the nematode *Caenorhabditis elegans*, and the insect *Chironomus riparius*. The sediment samples were analyzed for traditional sediment properties, metals and major elements, and organic contaminants (PAHs, PCBs and pesticides among others). The ecotoxicological quality of sediments was assessed by means of existing toxicity thresholds. Measured concentrations were compared with EQS derived according to the WFD Technical Guidance [1].

Results and discussion: Sediments from less impacted sites were less toxic than those from agricultural or mixed watersheds and chemical analyses also showed less chemical contamination. However, three out of four sites cause medium sublethal effects in ostracods together with slight exceedances of the EQS for some metals, PCBs and pesticides. Three out of five sites from agricultural watersheds showed unsatisfactory ecotoxicological quality with severe effects in the ostracod and medium effects in the chironomid tests. At these sites, several pesticides exceeded the EQS, sometimes by more than a factor 10. Traditional sediment contaminants (metals, PAHs and PCBs) only showed slight exceedances of the EQS at few agricultural sites. Sites affected by mixed pollution sources showed the highest risk according to chemical analyses for all substance types. Medium or severe effects in the ostracod and chironomid tests were also shown, with two sites of medium ecotoxicological quality and two of unsatisfactory ecotoxicological quality. Despite of statistically significant effects in the nematode test compared to the controls at several sites, none of the sites exceeded existing toxicity thresholds.

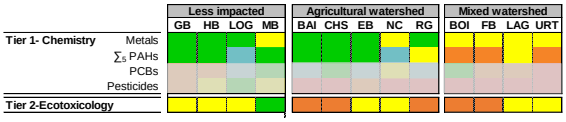

Fig. 1: Summary of risk assessment based on chemical analyses and bioassays. Colours are shaded when EQS are preliminary. Colour code attributed for a given substance type is the worst class among the individual substances except for PAHs (cumulated risk).

Conclusions: The ostracod test was the most sensitive among the bioassays, indicating good potential as screening tool. The high number of exceedances of the toxicity threshold for the endpoint growth should be considered with caution because the sensitivity of this species to specific contaminants remains unexplored. Moreover, sediment properties could be confounding factors in the interpretation of the results. The chironomid test showed complementary results to the ostracod test, supporting the use of both bioassays within a test battery. The toxicity thresholds should be further validated at less impacted sites to minimize the number of false positives in the ostracod test and false negatives in the nematode test.

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REE Contaminated Sediment Causes Avoidance Behaviour of *D. magna* and *C. elegans*

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Introduction: Rare Earth Elements (REE) are currently discussed as emerging contaminants, because their increasing use in green technologies leads to elevated environmental concentrations while up to now, little is known about their ecotoxicity. While conventional ecotoxicity tests are currently ongoing, establishing acute and chronic effects, in this paper, we focus on the possibility of an indirect effect of REE with potentially high environmental relevance: Active avoidance. If organisms actively avoid REE-contaminated sediments, changes in their behaviour may have effects on their energy metabolism and survival rate, e.g. by rendering them more susceptible to predators. The objective of our study was to determine if sediment contaminated with lanthanum (La) and gadolinium (Gd), leads to avoidance behaviour by pelagic and benthic species. We hypothesize that, while both pelagic and benthic organisms will try to avoid contaminated sediment, benthic species will be more likely to show avoidance behaviour because we assume that the major exposure route is via sediment-contact.

Methods: We used one pelagic species, *Daphnia magna*, and one benthic species, the nematode *Caenorhabditis elegans*, to measure REE contaminated sediment avoidance behaviour. Dried sediment was spiked with La and Gd at nominal concentrations of 10, 50, 75, and 100 mg kg^{-1}. M4 media was used to moisturize the sediment, making it mouldable. The set up for *D. magna* was as such: An area of sediment (Ø 35 mm) was confined to the centre of a petri dish (Ø 88 mm), and carefully covered with 30 mL of media. Each petri dish contained five adult daphnia. Daphnia had to be found outside or on the edge sediment to be counted as avoidance behaviour. *C. elegans* avoidance was measured by filling up a cut-out circle (Ø 25 mm) on an agar petri dish with contaminated sediment and adding a suspension of nematodes (± 93). Avoidance was determined with binoculars by counting the number of nematodes in the agar. Measurements were done at 0h, 1h, 2h, and 3h for daphnia and additional measurements up to 6h for the nematodes after exposure. All tests where repeated at least 5 times.

Results: For both species, exposure time was not a significant factor. *D. magna* showed an immediate avoidance behaviour that was significantly different between the control and REE at nominal concentrations of 100 and 75 mg kg^{-1}. Although both element set-ups, La and Gd, where not found to be significant at the lower concentrations, a clear trend is visible as numbers are below the control (Fig. 1). For *C. elegans*, the (preliminary) results indicated no avoidance behaviour observed within 6 hours of exposure, with the current set-up.

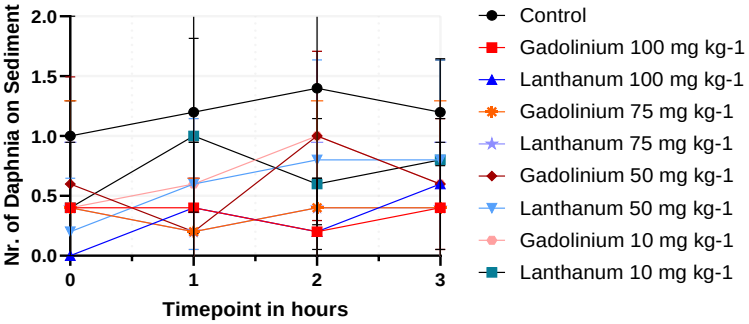

Fig. 1: *Number of D. magna on contaminated sediment at different concentrations of La and Gd.*

Discussion: The results from studies of *D. magna* indicate that avoidance is related to REE concentration. Previous work has shown that REE can cause mortality for both *D. magna* and *C. elegans* [1]. Avoidance has been found to be a more sensitive endpoint than mortality [2], and these experiments indicate perceived stress of the organisms resulting in behavioural changes. Planned studies looking into the interaction of 5 species, exposed to contaminated sediments in microcosms, will now not only look at endpoints such as immobility, but also on avoidance behaviour. The results of more detailed studies for all species will be presented.

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Targeting mercury bioremediation of marine sediments by using *omics* and culture-driven approaches

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Conference theme number(s): 7, 8

Introduction:
Marine sediments impacted by urban and industrial pollutants are major reservoirs of toxic mercury species, like inorganic mercury (Hg^{2+}) and monomethylmercury (CH_3Hg^+). Some microorganisms inhabiting marine sediments play a key role in the transformation of these mercury species. Mercury reduction and demethylation driven by the mercury reductase (MerA) and the organomercurial lyase (MerB) enzymes are mechanisms of resistance to this metal and hold great potential for bioremediation applications. In the context of the European project MER-CLUB we have performed a large-scale screening of marine sediment samples to identify and isolate environmental bacteria or microbial consortia able to carry out these key processes. The aim of this project is to advance our understanding of mercury biogeochemistry in marine sediments and design novel bioremediation solutions for this complex environmental matrix.

Methods:
Sediments from three different basins (Atlantic, Mediterranean and Baltic Sea) impacted by mercury releases were collected and used in parallel for environmental DNA analysis and the isolation of bacteria and microbial consortia. Marine bacteria were grown on selective media and a soil-substrate membrane system (SSMS; [1]) to try to increase the genetic diversity of the isolates. Consortia were obtained by cell sorting or the dilution-to-extinction approach. The taxonomic identification of isolated strains and consortia was performed via 16S rRNA gene amplification and metagenomic analysis, respectively. A screening of *merA* and *merB* genes was subsequently performed to identify potential mercury detoxifiers among the isolates and consortia. DNA was extracted in more than 30 sediment samples and used for metabarcoding and metagenomic analysis to retrieve the taxonomic composition of microbial communities and specifically, those taxa containing *merA* and *merB* genes in the sediments.

Results: Environmental DNA analysis of mercury polluted sediments revealed that bacteria were dominated by sulfide-oxidizing bacteria, sulfate-reducing bacteria and heterotrophic bacteria commonly found in marine environments. From a set of samples, a culture collection was obtained containing more than 1000 isolates and 400 consortia. The composition of the isolated bacteria was dominated by Proteobacteria and also included other clades such as Bacteroidetes, Firmicutes, and Actinobacteria. The screening of *mer* genes in both the culture collection and the metagenomic dataset resulted in contrasting results, with Proteobacteria and Desulfobacterales dominating the bacteria harbouring *merA* genes in the cultures and *in situ*, respectively.

Discussion: Our results unveil a new role of Desulfobacterota in mercury transformations in marine sediment. In addition to the participation of some members of this group in mercury methylation [2], our results highlight the crucial role of this taxa in its detoxification via mercury reduction. Due to their anoxic lifestyle and metabolic requirements, we were not able to retrieve Desulfobacterota by our culturing approach. However, we have obtained a large diversity of bacterial isolates with *merA* genes, able to detoxify mercury and adapted to the sediment environment, which can be potentially used for bioremediation purposes.

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Soil erosion and associated pollution and siltation compromise the food, water energy and security nexus. A river basin study case in central Chile.

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Introduction: Every year, more 24 billion tons of fertile soils are lost due to erosion, with very serious impacts on climate, water sources, biodiversity, agriculture, forestry, urban water supply, energy supply, and a wide range of productive activities [1]. The economic, social, and environmental costs of this destruction is countless. In Chile there are 60 dams, which are widely distributed throughout the national territory. This indeed, has the potential to affect the power generation capacity, as the dams are losing water storage capacity as sediments are being accumulated affecting the water energy and security as well food production due to erosion nexus.

Methods: To tackle this problem, specifically in the 6th Region of Chile (Central Chile) where the erosion problem is a major issue, social and natural science was set into action. The first, was done through a participatory process where it was possible to evidence the main sources subjected to erosion from the main stakeholders of the catchment. The second approach was performed to provide scientific evidence and to confirm or not the prior hypothesis stated by the stakeholders that mining and agriculture activities were the main sources of sediments to an artificial lake that forms a dam. For the second, was developed a sampling campaign that followed a geology approach with three main geologies identified (Andes, Central Valley and Coastal Range). Around 850 samples were taken from the main rivers and tributaries (sediment sources) and samples of the lake (final mixtures). Chemical tracers were quantified by means of XRF were used as fingerprinting method by using MixSIAR as a mixing model [2]. The idea was to generate a watershed-scale measurement model that is applicable to other study sites both nationally and internationally [3].

Results: Results demonstrated that the larger proportions of sediment were derived from agriculture (53%) and mining (34%) compared to natural erosion sources (glaciers 4%, natural mountain erosion 5% and drylands 4%). Results were cross referenced with evidence from a participatory process that delivered both a strategy formulation via mapping of the multiple dimensions of the problem from stakeholder viewpoints and co-designing and implementation of innovations under the guidance of a multi-actor governance framework. The study demonstrates the challenges and opportunities of applied environmental forensic tools in evaluating spatial and temporal patterns of complex erosion problems at the basin scale.

Discussion: Results were according to the previous concept that the stakeholders were expecting. Mining is an important economic activity and even with the efforts to minimise the impact of it is still present in the catchment. The same is true for agriculture, where hilly areas have been cleared from native vegetation to plant avocado, citrus and olives trees leaving the soil bared for a long time until the planted trees grow to protect the soil from intensive rain.

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French and Norwegian sediment quality guidelines comparison - case study in the NE Adriatic Sea, Croatia

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Conference theme number(s): 1 Sediment Quality Guidance and Sediment Quality Assessment

Introduction: The eastern coast of the Adriatic Sea that belongs to Croatia is 1,777 km of the land line and in total more than 6,000 km including coasts of islands. Aimed at assessing and maintaining GES (Good Environmental Status) as obliged by European regulations, Croatia conducted an initial assessment of the state of the marine environment which defines ecotoxic metals and persistent organic pollutants present in the water column, sediment and in biota (shellfish *Mytilus galloprovicialis*) [1]. The threshold values that separate acceptable from unacceptable status have not been determined for marine sediments.

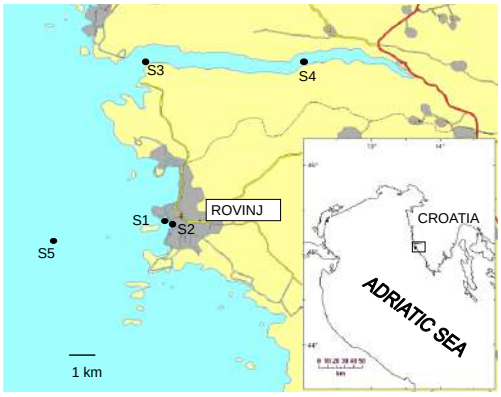

Fig. 1: *Location of the Sampling Sites in NE Adriatic Sea: S1 - Local Harbour, S2 – Shipyard, S3 - Lim Bay Out, S4 - Lim Bay Middle and S5 - Open Sea (3 NM in Front of the Town of Rovinj).*

Methods: The authors assessed the state of marine sediment at five stations of Rovinj NE Adriatic Sea (Fig.1.), differently exposed to anthropogenic influence applying the French regulation for dredged sediments with N1, N2 thresholds [2,3] and Norwegian criteria [4] that distinguish five categories of polluted sediment with regard to the achieved biological effect (*background, good, moderate, bad, very bad*). The samples were collected in August 2011 by Ven Veen grab (6 m – 30 m depth). The surface layers (3 cm - 5 cm) were subsampled and separated for sediment grain size analysis by wet sieving using the set of Retsch 7 sieves (4 mm, 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm and 0.063 mm), chemical analysis of concentrations of the metals (As, Cd, Cu, Ni, Pb, Zn, Hg, Cr), PAH compounds, PCB (Arocolor 1260) and phytotoxicity assay (*Linum usitatissimum* seed germination, biomass production and root inhibition growth). Before the analyses performed the samples were defrosted from (-80°C), dried (70°C) and weight.

Results and Discussion: The comparison of the threshold values of the ecotoxic metals, PAH compounds and PCBs shows that the categories of the Norwegian criteria *bad* and *very bad* are significantly above the French regulation threshold N2. By comparing the results of concentrations of the metals, PAHs and PCBs in marine sediment samples according to the French regulation, the metals Cu, Ni and Cr slightly exceeded N1 values in the harbour, while Hg exceeded N2 value (0.838 mg/kg d.w.). The concentration of total PAHs at the harbour, marina and Lim out stations ranged between N1 and N2 (1.5 – 15 mg/kg d.w.). All stations showed concentrations of PCBs in the sediment samples below the N1. The calculation of a probability of a toxic effect showed that the average toxic effect quotient (QPEC) [2,5] classified the Rovinj harbour and the Rovinj marina stations as potentially toxic for biota.

Conclusion: Although the French regulation has lower thresholds than the Norwegian criteria, therefore stricter for contaminated sediments intended for further use, the later is more suitable for differentiation of less polluted marine sediments.

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A conceptual model for enabling sustainable management of soil-sediment-water ecosystems in support of European policy

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Conference theme number(s): 7. Sediments health

Introduction: The health of soil-sediment-water ecosystems is under pressure from economic activities and a changing climate. This decreases health and hampers the service provision capacity of these ecosystems and thus impacts human well-being.

Protecting and where feasible restoring of ecosystem health has currently become the key European environmental policy objective and for this it is needed to take an entire system approach and engage stakeholders. 'Entire' means that soil, sediment and water are regarded as closely interlinked environmental matrices that need to be managed by taking a 'river (or mountain) to sea' perspective, crossing spatial, discipline, political and cultural boundaries.

Results: This paper presents a conceptual model (Fig. 1) – and its objects formulated in a common language (Table 1) – to support that purpose. Essentially, the conceptual model presents an approach for ecosystem-based management aimed to achieve healthy ecosystems, i.e. soil-sediment-water ecosystems that have the continued capacity to support ecosystem services to the benefit of their users.

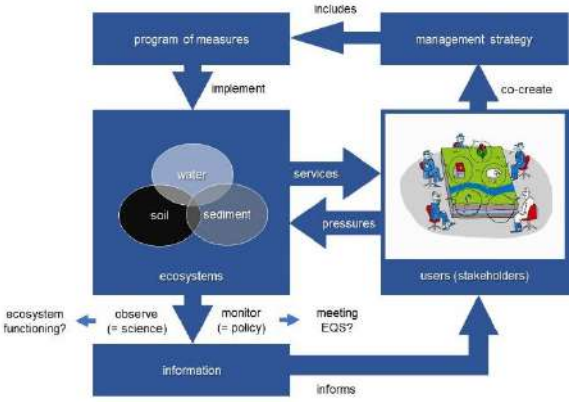

Fig. 1: *Conceptual model*

The model proposes a cyclic (iterative, learning-by-doing) approach and integrates soil-sediment-water, ecosystems, ecosystem services, users (stakeholders), pressures, information, management strategy and program of measures as building blocks.

Table 1: *Common language*

Object	Described in common language	Source
Ecosystem	A dynamic complex of plant, animal, and micro-organism communities and their non-living environment interacting as a functional unit	United Nations, 1992
Ecosystem services	Services provided and the benefits people derive from these services, both at the ecosystem and at the landscape scale, including public goods related to the wider ecosystem functioning and society well-being	Haines-Young and Potschin, 2018
Information	Organized, structured, interpreted, summarized data	Baskarada and Koronios, 2013
Management	The application of measures to achieve healthy ecosystems	This publication
Management Strategy	Sets out how users will work together to achieve healthy ecosystems	This publication
Measure	Action aimed to achieve healthy ecosystems	This publication
Pressures	The use of ecosystem services and the release of substances (emissions), physical and biological agents which impacts ecosystem health	Modified version EEA glossary*
Program of measures (PoM)	Set of actions aimed to achieve healthy ecosystems	This publication
Sediment	Suspended or deposited solids, of mineral as well as organic nature, acting as a main component of a matrix, which has been, or is susceptible to being transported by water	Brils, 2004
Soil	Upper layer of the earth in which plants grow	AGROVOC**
Users (stakeholders)	Those who are affected in their interest or concern by changes in soil-sediment-water management	This publication
Water	A colourless, transparent, odourless liquid that forms the seas, lakes, rivers, and rain and is the basis of the fluids of living organisms	Lexico, Oxford English dictionary

Discussion: To successfully apply the model, it is above all needed to take an entrepreneurial approach, i.e. leave comfort zones, take an adventurous road, learn together to manage together, be adaptive and consider other than only command-and-control solutions. Furthermore, authorities should become facilitative leaders to engage users in co-creation of an ecosystem-based management strategy. Real live and place-based experimenting with multiple stakeholders, such as in the Living Labs and Lighthouses that are proposed in the EU soil mission, may provide an ideal instrument for such application, i.e. where the conceptual model can be used and support the achievement of European environmental policy objectives.

Acknowledgements: Writing of this publication [1] was a.o. facilitated by the Soil Mission Support (SMS) project which has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 101000258

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Improving risk assessment of dredging activities by passive sampling

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Conference theme number(s): 1,3

Introduction: One of the main environmental risks of dredging activities in waterways is the remobilization of contaminants associated with the sediments at the operation site itself [1]. If the sediment is disposed in aquatic environments, sediment-associated chemicals may also result in negative impacts by increased contaminant bioavailability at the disposal sites [2]. A measure of bioavailability are freely dissolved concentrations that can directly be quantified by passive sampling [3]. During the last years, we have applied silicone-based passive samplers for monitoring hydrophobic organic contaminants (HOCs) during dredging activities at operation sites and at a sediment disposal site in German waterways.

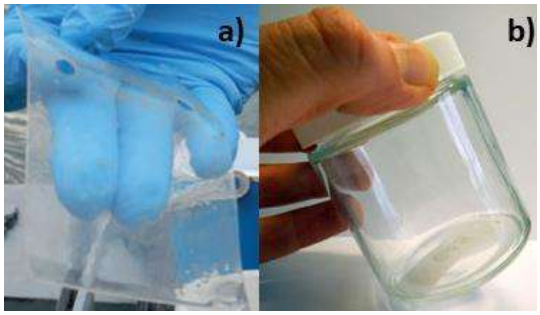

Fig. 1: Silicone-based passive samplers for a) the water phase *in situ* b) for sediment *ex situ*

Methods: Silicone-based passive samplers were applied for quantifying HOCs either in the water phase or in sediments (Fig. 1). For monitoring remobilization of contaminants at the operation site, we used silicone rubber (SR) sheets [4] that were exposed before, during and after the dredging activities directly in the water phase. Fixed by deployment devices to e.g. boys SR sheets were exposed for four weeks in the water.
For assessing bioavailability of contaminants at a disposal site, we used silicone-based equilibrium samplers that are applied *ex situ* [5]. In the laboratory, sediment is incubated in glass jars that are coated with µm thin silicone coatings for several weeks.
After exposure or incubation, both types of samplers were extracted by solvents and HOCs (PCBs, PAHs, DDT and their metabolites) were analyzed in extracts by GC-MS/MS. Silicone-based passive sampling in water yielded freely dissolved concentrations of HOCs that were averaged over the exposure time of the samplers. In contrast, freely dissolved equilibrium concentrations in sediment pore waters were obtained when applying coated glass jars.

Results: With both approaches very low quantification limits up to the low pg L^{-1} range were obtained. At a coastal site, dredging of sediment with low contamination resulted in no or only minor changes in freely dissolved concentrations of HOCs measured by SR sheets in the water phase. In the German North Sea, equilibrium sampling in sediments indicates that freely dissolved concentrations of DDT metabolites were increased by a factor 2 in sediment porewaters in close vicinity to a disposal site. Levels of all analytes were, however, distinctively elevated at sampling sites influenced by the river Elbe.

Discussion: This presentation gives insights in the practical application of passive samplers for monitoring bioavailability of HOCs in water and sediment. Chances to combine passive sampling with biomonitoring are demonstrated. Furthermore, we present the pros and cons of this approach for improving risk assessment of dredging activities and their implementation in sediment management.

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Applying environmental geochemical monitoring of fluvial sediments using unique automated and passive sampling in the Danube Basin

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Conference theme number(s): 9 (7, 1)

Introduction: This study reports on the unique results of the recently concluded Sediment-quality Information, Monitoring and Assessment System to Support Transnational Cooperation for Joint Danube Basin Water Management (SIMONA) project the largest of its kind in Europe, which was carried out in 2018-2022 as a project of the EU DTP aiming at delivering a ready-to-deploy sediment-quality monitoring system for the effective and comparable measurements and assessment of sediment quality in surface waters in the Danube River Basin in accordance with the EU Water Framework Directive (WFD).

Methods: The project has developed, tested, demonstrated an innovative environmental geochemical monitoring platform of fluvial (suspended, river bottom and floodplain) sediments using state-of-the-art automated and passive sampling technology (Fig.1) for the contamination risk assessment according to the EU WFD in the Danube Basin. Time series analysis and signal processing of one year multi-variate and multi-matrices monitoring data could be used to identify the geochemical background, temporal trends, periodicities and contamination events in the studied EU-defined Hazardous Substances (HSs). Since the applied technology, methods and data interpretation is fully consistent with EU legislation risk assessment, results may provide a 'best solution' for the spatial and temporal discrimination of contamination.

Results: The results demonstrate the efficacy of these techniques in identifying potential sources of pollution and assessing their impact on the environment.

Fig. 1: *Automated and passive sampling monitoring stations (photo by Zsófia Kovács)*

Discussion: The use of unique automated sampling techniques allows for accurate and reliable data collection, which can inform future management and protection strategies for the Danube Basin.

Acknowledgements
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Monitoring of microplastics in port sediments. Evaluation of different analytical methods.

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Conference theme number(s): 1. Sediment quality guidance and sediment quailty assessment

Introduction: Pollution of the marine environment by microplastics is an emerging issue in the field of dredging. The development of monitoring of microplastics in the marine environment and in particular in sediments is recommended at national level, via the zero plastic waste at sea roadmap, at European level, via several measures of the Marine Strategy Framework Directive (MSFD), and at the international level via the various recommendations of the regional seas conventions.
The OSPAR convention is working in particular on the development of a microplastics indicator in sediments. In this context, a sampling and analysis protocol should be recommended by this agreement.
Cerema is in charge of the technical management of the national maritime port surveillance network (REPOM). The purpose of this network is to monitor the quality of port sediments by relying on the services responsible for policing coastal waters.
In order to acquire data on the contamination of port sediments by microplastics, specific monitoring was initiated in 2021 at the ports of Brest and Douarnenez. In 2022, 15 additional ports, spread over several seaboards, were monitored.
Different analysis methods were tested in conjunction with Cedre, IFPEN and the Labocea laboratory. The results of this test phase will make it possible to decide whether or not to generalize the monitoring of microplastics to all REPOM points.

Methods: Sampling is carried out by the Water Police services of each department. The sampling plan for REPOM points should not change from year to year in order to maintain some continuity in the data series. The same is true for the analysis of microplastics, the concentrations of which can thus be compared with those of other contaminants, in particular phthalates.
Currently there is no standard for the analysis of microplastics in sediments. As part of the 2021 and 2022 test campaigns, several methods were tested in order to identify the method best suited to REPOM's needs:
- visual analysis
- Fourier Transform Infrared (FTIR)
- pyrolysis via IFPEN's Rock-Eval process
- pyrolysis coupled with gas chromatography and mass spectrometry (Pyr-GC/MS)

Results: The first results received concern the FTIR analyses. There is a marked disparity in the results. The contents vary between 470 MP/kg and nearly 35,000 MP/kg.
An important variability is also observed within the same port depending on the sampled points. The median of the values is 8,300 MP/kg for a standard deviation of more than 10,000 MP/kg. The most frequently identified polymers are polyethylene (23%), polypropylene (20%) and finally the polyethylene-propylene copolymer (12%).
The particles are mainly of size less than 500 µm.
According to the first visual analyses, the microplastics found in the port sediments are mainly composed of fragments of hard plastic (45-80%) and synthetic fibers (15-60%).
Pyrolysis analyzes are in progress. Difficulties were encountered due to the high load of organic matter in the port sediments. Thus, the extraction method must be subject to adaptations.

Discussion: Currently there is no standard for the analysis of microplastics in sediments.
As part of the 2021 and 2022 test campaigns, several analysis methods were tested in order to identify the most suitable method for generalizing this monitoring via the REPOM. Several criteria will thus be evaluated: results obtained, speed of analysis, and cost.

Thanks to the Cedre, IFPEN and LABOCEA teams who made themselves available to adapt their microplastic analysis methods to port sediments.

Assessing Microbial Quality of Polluted Marine and Soil Sediments with Advanced in Situ Monitoring Tools

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Conference theme number(s): 1

Introduction: The assessment of sediment quality usually focuses on pollution and the microbial performance for contaminant degradation. However, in polluted sediments the proof and quantification of microbial purification is a challenging task, particularly within the frame of remediation technologies. Here, we present four *in situ* tools to characterize the microbial quality of marine and soil sediments with a special focus on the attenuation of polyaromatic and aliphatic carbohydrates (PAH, AH): Isotope-labeled *in situ* microcosms (BACTRAPS, MYCOTRAPS), diagnostic ratios of pollutants, phospholipid patterns (PLFA), and metabolite analysis. These methods are applied to develop and control innovative remediation technologies for a coastal sediment (EU-LIFE project SEDREMED) and for several soil types (EU-LIFE project MySoil).

Fig. 1: Variations of *in situ* microcosm cages containing carrier materials for ^{13}C-labeled pollutants.

Methods: BACTRAPS and MYCOTRAPS are *in situ* microcosms newly developed for the trapping of pollutant-degrading bacteria in a marine sediment from Bagnoli (Italy) and of pollutant-degrading fungi in various contaminated soil types, respectively. According to different environments, specific cages (teflon, stainless steel) were designed (Fig. 1) containing carrier materials (active coal, sediment) loaded with a ^{13}C- or ^{2}H-labeled pollutant (phenanthrene, naphthalene, acenaphthene, hexadecane). The TRAPS were exposed in pilot mesocosms or in real sediments for several weeks. Retrieved *in situ* microcosms were analyzed for specific biomolecules (PLFA, amino acids) in order to record the colonizing microbial community. In addition, ^{13}C- and ^{2}H-isotope values of biomolecules were determined showing up semi-quantitative evidence for natural or enhanced attenuation of target pollutants.
Further monitoring tools provided a differentiated characterization and thereby a multi-line of evidence of degradation processes. For instance, GC-MS fingerprinting for specific diagnostic ratios of contaminants delivered the stage of chemical and biological weathering, while determination of certain metabolites indicated actual pathways of PAH degradation. The amount of bacteria as well as the amount of fungi could be estimated by analysis of amino acid and PLFA patterns, respectively.

Results: The applied monitoring tools provided a clear picture of variable microbial degradation activity in marine as well as in soil sediments. Due to different features (target compounds, validity, sensitivity, precision, duration, expenditure, workload) the combination of these methods delivered an effective proof and understanding of microbial processes, which are highly relevant for sediment management.

Discussion: In a nutshell, a suitable toolbox of methods is available to assess the microbial activity in polluted sediments. It can be adapted according to sediment conditions (marine, soil, aquifer) and contamination patterns. Investigations like that will deliver key information on the necessity and also the success of remediation strategies (e.g. dredging vs. monitored natural attenuation vs. *in situ* treatment). Therefore, they are highly recommended for the assessment of sediment quality.

Impact of Rare Earth Elements on the growth and photosynthetic efficiency in *Myriophyllum aquaticum*

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Conference theme number(s): 1

Introduction: Rare earth elements (REE) are naturally present in the environment, constituting a chemical group of 17 elements sharing similar characteristics [1]. Increasing amounts of REE-containing by-products are reaching the environmental systems as never before because of their use in many advanced technological applications [2]. *Myriophyllum* spp. is widely considered a suitable bioassay plant for assessing whole sediment toxicity as well as the toxicity of sediment-bound substances [3]. The objective of the present work is to provide a comprehensive investigation of *Myriophyllum aquaticum* responses upon La, Ce, Nd, and Gd exposure to study the potential toxicity of these elements.

Methods: Non-axenic pre-cultures of *M. aquaticum* were grown in artificial sediment and saturated with Steinberg medium under defined growth conditions in a growth chamber. Various concentrations of 50, 250 and 500 mg kg^{-1} of Ce, Nd, La and Gd were prepared in a modified Steinberg medium and were used for spiking. The observation parameters are the fresh weight change (FWC), measured at the beginning and the end of the 10-day exposure duration and the non-invasive measure of the photosynthetic status over time using IPAM.

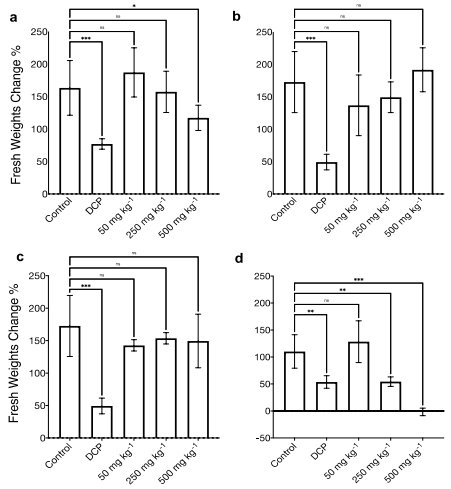

Figure 1. Fresh weight change (a-d) of *M. aquaticum* whorls in control and spiked sediments after a 10-day exposure in %. Sediments were spiked with La (a), Ce (b,) Nd (c), and Gd (d) at three concentrations.

Results: Whorls treated with Ce and Nd did not show a significant FWC at all concentrations. La induced significant FWC at 500 mg kg^{-1}, while at the lowest concentration (50 mg kg^{-1}), the FWC was significantly higher than the control. Gd had the highest effect at 250 and 500 mg kg^{-1}. Ce and Nd for the two highest concentrations showed a decrease in the yield on the first three days of the experiment, but towards the end of the test, it did not differ from the control. La showed a steady stability of the Y(II) of the exposed whorls throughout the experiment. Whorls treated with Gd showed time and concentration-dependent effects. Here, the highest concentration showed a fast response within 1 day, followed by a steady decrease in Y(II) throughout the remaining experiment.

Discussion: The various REEs have a different effect on the non-invasive parameters measured on *M. aquaticum*. The measurement of the effective quantum yield of the PS II was found to be a useful additional effect observation and of high environmental relevance. The difference in sensitivity between the functional and growth observation may give hints about the mode of action of contaminants in sediments to macrophytes and offer scope for an advanced hazard assessment. Due to its emersed growth, *M. aquaticum* is especially suited for investigating naturally polluted sediments. We will further explore the results in the presentation.

Acknowledgment: The authors thank U. Feiler and the Federal Institute of Hydrology (BfG, Koblenz, Germany) for providing us with the culture of *M. aquaticum* and for continuous assistance. This project has received funding from European Union's Horizon 2020 research and innovation program under the Marie Sklodowska - Curie Grant Agreement N°857989.

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Multiple lines of evidence approach to assess the quality of sediments in canals of the Rhône valley in Switzerland

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Conference theme number(s): 1

Introduction: A robust assessment of the toxic risk of contaminants in sediments requires information on their chemical, ecotoxicological and ecological qualities. In this context, we collected fine sediment samples from ten sites in 3 artificial channels (I, BN and STO) impacted by urban, industrial and agricultural activities to assess their quality, using a triad approach.

Methods: The triad we applied included (i) chemical analyses (metals, PCBs, and PAHs), (ii) ecotoxicological assessment using laboratory tests on the nematode *Caenorhabditis elegans* (reproduction and growth) and the ostracod *Heterocypris incongruens* (mortality and growth), and (iii) a study of nematode and oligochaete community composition using the NemaSPEAR[%] and IOBS indices, respectively. To assess the risk based on chemical analyses, we used the method and quality criteria developed and recently published by the Ecotox Centre [1]. For the bioassays, we used previously published toxicity thresholds: 50% of reproduction inhibition and 25% of growth inhibition for the nematode [2] and 20% mortality and 35% of growth inhibition for the ostracod [3]. If none or one of the endpoints exceeded the toxicity thresholds, we classified the sediment as good (green) or moderate (orange), respectively, whereas if all the effects exceeded the toxicity thresholds, the sediment was bad (red). We used hierarchical clustering to compare the different sites in an integrative way.

Results: None of the samples resulted in a significant reduction in ostracod survival, while seven samples induced a significant inhibition of the growth of this organism. In contrast, for all sites, we observed no significant effect on *C. elegans* reproduction and growth. At the community level, the diversity of nematode taxa was rather low in all samples and the NemaSPEAR[%]genus index indicated a moderate to poor biological quality of the sediments at all sites. In addition, at each site, the diversity of oligochaete taxa was very low and the IOBS indicated poor to bad quality. Calculated risk quotients (RQ) for Ni, Zn, and Cu indicated potential toxic effects (RQ > 1) in all samples. We measured lower concentrations of PAHs and PCBs in samples that exhibited toxicity to *H. incongruens* than in samples that did not exhibit toxicity to this species. The PCB concentrations measured however showed a strong risk for benthic organisms in 6 sites.

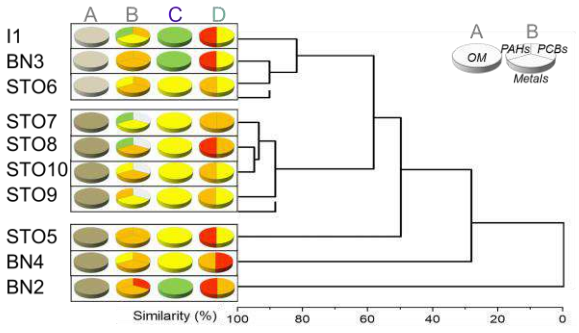

Fig. 1: *Hierarchical clustering of the studied sites (Euclidean distance). (A) OM, (B) worst RQ for metals, sum RQ PAHs and worst RQ for PCBs, (C) biotests, (D) biological indices scores.*

Discussion: Many other pollutants that were not measured in this study, such as pesticides or PFAS for example, or the effects of mixtures of contaminants, could be involved in the observed toxicity. This work represents a first study in Switzerland, mandated by a canton, on the use of a wide range of complementary tools for a thorough assessment of the quality of river sediments. This case study showed the strength of using a triad approach in contaminated sediment assessment. There has been however no decision made yet on the future of those highly contaminated canals in a recreative region.

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Geochronology and historical records of heavy metals in the marine sediments from western part of Black Sea Coastal Area, Varna/Bulgaria

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Conference theme number(s): 1. Sediment quality guidance, sediment quality assessment

Introduction: The influx of nutrients, pesticides, industrial waste from the surrounding countries, oil shipments, and to a great extent introduced debris by the Danube River, brought the Black Sea marine environment to the precipice of almost damage due to Black Sea a semi-enclosed basin. Therefore, there is much interest and research of the Black Sea environment because of its particularities related to the contemporary ocean and seas priorities, in terms of global sustainable development. Marine sediments can be sensitive indicators and serve as natural archives for environmental changes in the aquatic systems and sediment dating provides a chronology of these changes. This study deals with the combined use of ^{137}Cs and ^{210}Pb radiotracers for sediment dating and heavy metal pollution history from western part of Black Sea Coastal Area, Varna, under the frame of IAEA Regional TC Project RER-7009.

Methods: One-day sampling expedition was conducted in Varna Coastal region /Black Sea on 26th September 2018, onboard of R/V *Akademik*. The sampling has been performed using Multi-Corer sampler. The sampling stations were selected based on recent preliminary information about the regional geology, bottom morphology and bathymetric maps as shown in Fig.1.

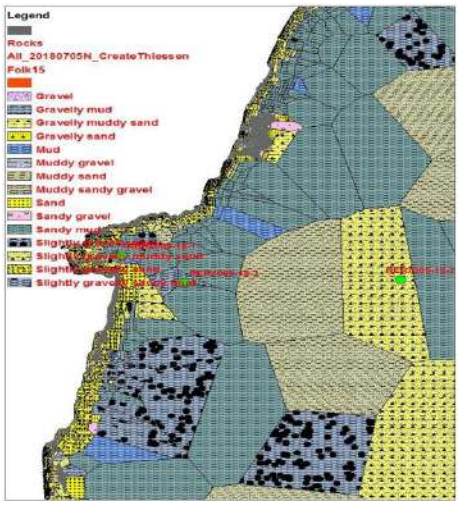

Fig. 1: Sedimentology map of selected RER7009-18 sampling stations.

On the frame of IAEA Regional TC Project RER-7009, the labeling cores as "***Core RER7009-18-02-04*** *(with length 27.0 cm; sliced at resolution of 1cm)* were dated in the Institute of Nuclear Science, Ege University, Turkey. The sediment cores were representative and undisturbed. The retrieved material consisted of olive gray/dark greenish gray (color by Munsell soil colour chart) very fine sandy mud (or silt) with whole and broken shells.
The quantitative determinations of the ^{210}Pb and ^{137}Cs have been carried out by HPGe gamma spectrometry. Heavy metal analyses were performed by Wavelength Dispersive XRF spectrometers.

Results: In the study, CRS and CIC Model were applied to date the sediment cores [1-3]. Furthermore, the validation of the ^{210}Pb-based geochronology by ^{137}Cs as independent time markers gives additional credit to the suitability of the techniques. The greater concentrations are observed in the recent sediments, after the 1970s according to the established chronology. Sediment Quality Guidelines (SQGs) were used for heavy metals. According to ERM criteria, all concentrations are normal while Cr and Ni concentrations exceed the limit values for ERL criteria.

Discussion: The combination of trace metal analysis, ^{210}Pb and ^{137}Cs dating as well as sediment quality data in the studied coastal region provided vital information on the historical accumulation of the metals in the sediments.

Acknowledges: We would like to thanks to IAEA for supporting this study under the frame of Regional TC Project RER-7009 and RER-7015.

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Historical contribution of sediments to a hydropower reservoir: a case study in central Chile.

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Conference theme number(s): 1, 5, 8

Introduction: Soil erosion increases mobilisation of sediment to downstream water bodies affecting water and sediment quality with degradation of natural or artificial reservoirs [1]. Anthropogenic activity in river basins has a profound impact on the quality of reservoir sediments that compromises water supply and ecosystem services e.g. fisheries. In terms of changes in sediment quantity, hydrographic systems such artificial reservoirs (dams) are very susceptible to sediment accumulation and production efficiency of hydropower can be directly affected by soil erosion upstream. This is the case of the study site, an artificial reservoir built in 1968 located in the VI Region of Chile created for energy production, recreational and irrigation purposes. Since its creation, the dam has received inputs of sediment from the upper Raple river basin (13,000 km^2) the Rapel river basin. This study focuses on determining the value of the reservoir sediment column to elucidate historical sediment source contributions in response to human and climate change factors.

Methods: Radioisotopic techniques, multi-elemental analysis, multi-parametric analysis and a Bayesian mixing model were used to determine the nature and the relative contribution of the different sediment sources. Source samples were taken from sediment deposited within channels of tributary rivers in the different sub-basins. A 120 cm sediment core was taken and sectioned every 2 cm in situ. Samples were sieved at < 63 μm and analysed by WD-XRF to quantify major and minor geochemical elemental composition. All source-related statistical analysis of the data was performed with the program R study version 4.0.2 and the MIxSIAR package was used as mixing model. For core dating, Pb-210 geochronolology was used and contrasted with historical records of catchment process.

Results: Four main sources of sediment to the reservoir were considered. Soils affected by agricultural and mining activity as well as rivers resulting from the melting process of glaciers and finally flow fed by mountain snowmelt. The age and accumulation rates of the sediment core were determined. The date ranged from 1968-2019 and the sections were sub-grouped according to the mass accumulation rate (MAR) calculated from the dating with Pb-210. From these, eleven mixing zones within the core were selected. Finally, the mixing model showed as main contributors the two anthropogenic activities, agriculture and mining, that historically represent over 50% of the historical contribution in the sediment.

Discussion: Mining and agriculture activities were demonstrated to be the main historical sources of sediment within the catchment, and non-anthropogenic sources e.g. Andean mountain erosion, provided minimal historical contribution. Results were compared with historical records of flow into the reservoir wherein extreme events were observed to be closely related to patterns in the rate of sediment accumulation. Agricultural activity is widely known to enhance sediment transport [2]. While there has historically been a high commercial demand for agricultural production in the region due to fertile valley floor soils and a favourable climate, recent years have seen an advanced degree of erosion linked to expansion of some productive sectors (e.g. citrus fruits, avocadoes and olives) into steeper terrain converted from natural vegetation cover. In parallel, mining represents a problem of transport of heavy metals, harmful to the environment and to the entire trophic chain that coexists with the ecosystem. Interaction between mine pollutants and high sediment loads presents a critical problem of pollutant storage in the sediment column requiring a holistic system-wide approach for co-design of solutions to reduce pollutant and sediment loads to the reservoir.

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Sediment Status in Europe: Frameworks, Standards and Approaches, Synthesis of Expanded Review

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Conference theme number(s): 1

Introduction and approach: It has been two decades since the European Water Framework Directive, which mandated catchment-wide approaches to managing waterways, and over a decade since the European Sediment Research Network (SedNet) published a series of books addressing the role of sediments in achieving this goal. In 2008, the European Commission published a directive on environmental quality standards in the field of water quality, but declined to specify or require sediment quality guidelines except under special circumstances, although it still required that Member States monitor sediment and biota for priority substances that accumulate in them. Subsequently, a significant body of work has addressed contaminant trends, drivers of toxicity and contaminants of emerging concern in European waters.

Results and discussion: Many national and European approaches have evolved, or are under review. Documents on national approaches to freshwater and marine sediment assessment are being continuously reviewed for a range of European countries and regions. An additional focus has been on evaluating both national approaches to emerging contaminants not currently identified as priority pollutants, and how future attention on these might change sediment assessment frameworks in the near term. Europe remains quite diverse in its approach to sediment standards and assessment. Approaches range from a complete absence of standards and guidelines to highly detailed frameworks; applications can be broad or narrow.

The assumptions behind frameworks and policies are critical to their application; not all countries clearly distinguish between screening and action levels. Where specified, lists of potential contaminants to be monitored range from a handful to dozens, and differ for freshwater and marine systems. This paper will compare approaches to sediment chemical assessment in a much broader range of European countries and regions. Trends and changes, and the relationship between chemical and other assessments, will be discussed.

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Overview of sediment quality and quantity over two decades - Case study of the Great Bačka Canal (Republic of Serbia)

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Conference theme number(s): 7

Introduction: In the 20th century, extensive industrialization took place between Crvenka and Vrbas (R.Serbia). This led to an increased settlement of people in small towns along the canal. The canal is becoming more and more polluted, and in the worst part around Vrbas, the canal is completely filled with sediment. Industry (sugar beet processing, pig farms, edible oil, metal processing) are the worst polluters in addition to untreated sewage from cities. In addition to causing local problems, pollution in the Great Bačka Canal is a problem for the Tisza, and a significant source of pollution for the Danube. The low level of awareness of the local population about the state of the environment had a major impact on canal pollution.

The amount of sediment in the vicinity of Vrbas was about 350,000 m^3. The first data on this amount of sediment was obtained on the basis of the project financed by Norway and carried out by NIVA [1]. Furthermore, the study with the general project of dredging, deposition and remediation of the sediment of the Vrbas channel was carried out in 2015 [2], determined the same amount of sediment, but the methodology was done in more detail and the amount of sediment by sediment class was clearly identified.

The aim of the work is to shed the light at the situation that has been happening in the Veliki Bačka canal for two decades and to look at the possibility of solving the long-standing problem.

Methods: The paper covers three periods of analysis of various parameters (metals, organic components, nutrients). The first period was two decades ago in 2003, when for the first time the problem of the Great Bačka Canal was shown through the project [1]. After that, the monitoring was done continuously, so in 2015, another case study with remediation techniques was conducted. Since the situation has not changed and no dredging and remediation works have been carried out on the canal, a scientific project is being carried out in 2022 [3]. All the samples that were analyzed within the studies presented were done according to standard methods.

Results: Through the town of Vrbas, the canal looks like a smelly, ugly septic tank. The sediment of the Veliki Bačka channel did not show a high load of organic micropollutants. Sporadically, in the examined period of 20 years, in the case of polycyclic aromatic hydrocarbons, class 2 was determined, while the other samples were classified as class 0. In 2012, Serbia adopted a Regulation [4] based on which sediment can be classified. Therefore, the presented metal analysis included only two analyzed periods, 2015 and 2022 (Table 1).

Tab. 1: *Metal concentrations through two series of monitoring*

Year of monitoring

Metal	2015		2022	
	Measured value of in mg/kg	Class according to regulation[1]	Measured value of in mg/kg	Class according to regulation[1]
Arsenic	32.7	1	12.28	0
Cadmium	0.147	0	0.44	0
Chromium	64.4	0	70.36	0
Copper	220	4	131.2	3
Mercury	0.421	1	0.30	0
Lead	30.3	0	31.7	0
Nickel	53.2	3	34.2	2
Zink	286	1	250.2	1

The reduction in metal concentrations can be attributed to measures implemented in the last two decades. Certainly, one of the measures was that the industries did not discharge their untreated wastewater, which was mostly done, and certainly the change in the situation was influenced by the shutdown of two industries whose impact was great.

Discussion: Previous research have dealt with the analysis of sediment quality, which showed a slightly improved condition. What needs to be done is an assessment of the negative environmental impact and the possibility of beneficial use considering large amount.

Acknowledgement: This research was supported by the Science Fund of the Republic of Serbia, #7753609, BEuSED

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Contamination and Risk Assessment of Heavy Metals in surface sediments of the Montenegrin coast

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Conference theme number(s): 1. Sediment quality guidance and sediment quality assessment

Introduction: One of the most challenging environmental concerns is heavy metal pollution in aquatic ecosystems because of their persistence, environmental toxicity as well as bioaccumulation [1, 2]. Heavy metal contamination in sediments is one of the most important quality indicators for the assessment of potential ecological risks in coastal marine ecosystems [3]. Heavy metals in marine sediments have natural and anthropogenic origins: distribution and accumulation are influenced by sediment texture, mineralogical composition, reduction/oxidation state, desorption processes, and physical transport. Montenegro is a popular destination, and tourism development is one of the most important activities related to the pollution of marine areas, and heavy metals have negatively affected their natural environment [3, 4].

Methods: The sediment samples were collected from 10 sites along the Montenegrin coast: Dobrota (L1), Orahovac (L2), Sveta Nedelja (L3), Tivat (L4), Shipyard of Bijela (L5), Herceg Novi (L6), Žanjice (L7), Budva (L8), Port of Bar (L9), and Ada Bojana (L10) (Fig. 1). The sediment samples were taken in the autumn of 2020. Determinations of heavy metals in sediment (Fe, Mn, Zn, Cu, Ni, Pb, Cr, Cd, As and Hg) were measured according to methods Laboratory Procedure Book, IAEA (International Atomic Energy Agency), Marine Environment Laboratory, Monaco 2009 [5]. All measurements are performed on Shimadzu AA 7000.

Fig. 1: Map of the investigated area

Results: The values of Fe, Mn, Zn, Cu, Ni, Cd, As, Pb, Cr and Hg (mg/kg dw) at a different location from the Montenegrin coast decrease in the following order Fe > Mn > Cr > Ni > Zn > Pb > Cu > As > Hg > Cd. The most abundant elements in the sediments from the Montenegrin littoral are Fe and Mn, which is not surprising considering that these two elements are the most abundant metals in the Earth's crust. In general, the results of the research show that higher concentrations of Zn, Cu, Pb, As, and Hg are mainly found in sediments from locations inside the Bay of Kotor, while higher concentrations of Fe, Mn, Cr, Ni, and Cd are mainly found in sediments from locations in the open area, which is in agreement with earlier research [6]. The PLI values in this study were > 1 for all investigated locations during the sampling, except for the Žanjica and Budva locations where the PLI values were < 1. Igeo values indicate that the examined locations are mostly categorized as unpolluted or slightly to moderately polluted with the examined heavy metals. Higher Igeo values were observed for Pb and Hg in Tivat; Pb and Cd in Bar and Cr on Ada Bojana.

Discussion: Comparing the results obtained for 10 selected heavy metals in sediment samples, collected from 10 locations along the Montenegrin coast, it can be concluded that the high concentrations of metals in the sediment may be the result of port activities, municipal and industrial wastewater, tourist and recreational activities in the coastal area, as well as pollution from former industrial activities whose pollution consequences are still visible. Also, differences between the concentrations of certain examined heavy metals in sediments may be the result of geographic, hydro morphological characteristics, sea currents, and waves, the sampling season as well as the precision during sampling.

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Comparing sediment heavy metal concentrations in Italian harbors with the Environmental Quality Standards

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Conference theme number: 1

Introduction: The Environmental Quality Standards (EQSs) are the tools to define the status of surface water bodies, according to the Water Framework Directive. While the EQSs for assessing the chemical status of waters were established at a European level, member states defined those of specific substances in sediments. In Italy, the EQSs for marine coastal and transitional environment sediments were determined based on a chemical-physical and ecotoxicological approach. Up to now, these threshold values have been considered not applicable in areas of high environmental criticality, such as harbors.
This study aimed to verify the applicability of the EQSs of heavy metals for defining the chemical status in Italian harbors and identifying the main pollutants of sediments in these areas.

Methods: A dataset was arranged with the concentrations of the same heavy metals (As, Cd, Cr, Hg, Ni, and Pb) recorded in 34 Italian harbors having a corresponding EQS in the national legislation for a total of 3187 stations and 7036 samples. The harbors have different shapes, sizes, sediment textures, sediment geochemistry, and degree of contamination. Different institutions and authorities acquired data between 2001 and 2013 during several environmental characterizations. The total data distribution of each chemical parameter was studied by applying Johnson's method [1] using the R 3.6.2 software, SuppDists package. The output of these analyses was a control chart for each metal with a normalized curve of concentration data, reporting the Overall Median (OM), the Upper Bound (UB) of the whole distribution, and the median concentrations of each harbor. Moreover, the position of the EQS (defined by the percentile) was highlighted on the curve (Fig. 1).

Results: The positioning of the EQS on Johnson's curve (EQS percentile) with respect to the Overall Median (OM) and the Upper Bound (UB) of data distribution served to recognize the capability of this value to discriminate different chemical statuses (Fig. 1, Tab. 1). The EQSs resulted for all metals coinciding or very close to the OM, in the range between 46 and 62 percentiles (Tab. 1).

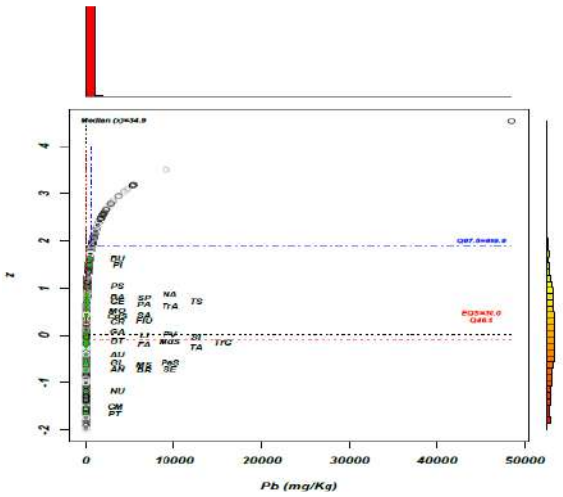

Fig. 1: Johnson's control chart of Pb (Black line: OM; blue line: UB; red line: EQS). The medians of harbors (abbreviated names) are also reported.

The rate UB/EQS, which quantified to what extent concentrations exceeded the EQSs, was very high for Cd, Hg, and Pb (Tab. 1).

Tab. 1: Positioning the EQSs in the whole data distribution.

	As	Cd	Cr	Hg	Ni	Pb
EQS (mg kg^{-1})	12.0	0.3	50.0	0.3	30.0	30.0
EQS percentile	50.0	62.0	54.4	51.0	46.1	46.0
OM (mg kg^{-1})	12.0	0.2	46.5	0.29	32.6	34.9
UB (mg kg^{-1})	54.2	7.4	212.5	6.8	95.3	670.0
UB/EQS	4.5	24.6	4.3	22.7	3.2	22.3

Discussion: The positioning of the EQSs in the comprehensive data distribution pointed to the suitability of the EQSs to be successfully applied on harbor sediments to define the chemical status. It also showed that, in many observations, all metals largely exceeded the EQSs, pointing to the widespread contamination of metals. Among these, Cd, Hg, and Pb were identified as the heavy metals mostly contributing to the contamination of the Italian harbors.

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Different rivers, common problems – Linking chemical and ecological status in polluted sediments of three different European river basins

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Conference theme number(s): Sediment quality assessment (1)

Introduction: Contaminated sediments are still a major obstacle to achieve good chemical and ecological status in aquatic ecosystems, with the consequence that less than half of the EU's water bodies are in good status. Due to contaminant effects on sediment dwelling organisms, sediment-associated contamination contributes to disruption of the whole aquatic ecosystem because of benthic-pelagic food web coupling, which is a natural component of nutrient cycles influencing benthic and pelagic food webs and by that the ecological status. Weight-of-evidence (WoE) approaches, such as the sediment quality triade, using various lines of evidence (LoE) based on chemical, toxicological and ecological information, can help to reliably determine sediment quality and to identify cause-effect relationships and thus allow a more effect-directed decision making in water management. However, there is a lack of specific pollution-sensitive metrics, and many macroinvertebrates in data of the EU water framework directive are not exclusively endobenthic and are to a large extent exposed rather to contamination in the water phase. These shortcomings may lead to misinterpretations of cause-effect relationships and, in the worst case, to inappropriate water management actions. Sediment-based LoEs (sediment quality guidelines; sediment toxicity tests; endobenthic bioindicators) might be more appropriate to reliably determine sediment quality and predict the risk of contaminated sediments for the aquatic ecosystem. The EU Interreg project "Sullied Sediments" aimed to provide the tools for sediment assessment to enable better risk assessment and reduce economic costs.

Methods: contaminated sediments were sampled at three different river basins in Germany (Elbe), UK (Humber) and Belgium (Scheldt) over a period of 21 months (9 sites; 6 sampling campaigns) for analyzing physico-chemical properties, potentially toxic chemicals, ecotoxicity and the endobenthic invertebrate fauna. As LoEs, the toxic potential based on sediment quality guidelines (LoE1), the ecotoxicity based on a toxicity test battery (bacteria, algae, nematodes) (LoE2), and chemical stress-sensitive biotic indices based on endobenthic macro-invertebrates (Biotic Sediment Index; BSI) and meio-invertebrates (NemaSPEAR[%]-index) (LoE3) were applied.

Objective: The aim of this study was to evaluate the sediment quality triad as a tool for a more reliable and, thus, better decision making for water managers. On this poster, we will show and discuss the different combinations of the LoEs, conclude on the sediment quality status at the 9 sites and address potential causes. We will point out additional information that may be needed for assessing the environmental risk from the respective sites.

Environmental characterization addressed to port sediment management: two case studies in the central Tyrrhenian sea (Italy)

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Conference theme number: THEME 1 - platform presentation

Introduction: Sediment dredging is necessary and vital to preserve maritime activities and prevent floods and the management of sediments represents an environmental challenge for many countries worldwide. It is estimated that the amount of sediments annually dredged in Europe is approximately 200 million m^3 [1]. In this context, a proper characterization plays a fundamental role in considering dredged sediments as a resource and, where possible, promoting their reuse in the marine-coastal and port environment.
In Italy, the management options for dredged sediments are defined on the basis of their quality obtained through a multiple line-of-evidence approach, according to the Ministry Decree (M.D.) 173/2016. It is known that the combination of chemical and biological analyses represents an added value for monitoring and management purposes [2].
This study summarizes the results of the environmental characterization carried out before capital and maintenance dredging in two areas, "Darsena Servizi" of the port of Civitavecchia and the canal port of Fiumicino (central Tyrrhenian sea). In particular the marine area outside the port of Civitavecchia is characterized by the presence of protected habitat (Habitats Directive) [3].
The aim of this work is to assess the environmental quality and to suggest the proper management options minimizing the adverse effects on marine ecosystems.

Methods: Sediment samples were collected in both ports according to the strategy defined by M.D. 173/2016: a total of 11 samples in the dock of Civitavecchia port and 16 samples in the canal port of Fiumicino. For each sample granulometric, chemical and ecotoxicological analysis were carried out. Data were elaborated using Sediqualsoft 109.0® software to identify the overall quality classes for management.

Results: In the port of Civitavecchia, results showed a sediment quality classified as A and B, with a limited amount of C class. For class A and B it is possible to manage sediment directly in the marine environment and for C to dispose them into a confined disposal facility (CDF) without isolation, i.e. any exchanges with the marine environment do not generate adverse effects.
As far as the sediments of the Fiumicino port canal are concerned, results showed a worse quality which includes classes D, suitable for disposal in a waterproofed CDF and, to a limited extent and class E for sediments that have to be safely removed from the marine environment.

Discussion: The characterization of the sediments to be dredged confirmed, in both cases, the management options preliminarily identified by the Port Authority. The environmental quality of canal port of Fiumicino is probably influenced by the contamination coming from the mainland and by the activities historically present in the area [4]. The "Darsena Servizi" of Civitavecchia, not affected by direct discharges and far away from main maritime traffic, shows a quite good environmental quality. In both cases, chosen management options were considered in Harbour Master Plan to increase the port efficiency.
Finally, the application of the integrated assessment proposed by M.D. 173/2016 has proved to be a valid support tool for verifying the adequacy of the management options proposed by the competent Authorities in their master plans, favoring a sustainable use of sediments. In line with the principles of the circular economy that consider sediment as a resource it promotes the reuse of dredged sediments with adequate precautions, such as impact mitigation measures and monitoring plans, focusing the attention on protected and sensitives habitats and species.

References: [1] Svenson et al. (2022). *Waste Management* 138, 30-40; [2] Regoli et al. (2019). *Front. Mar. Sci*., 08, *6 art 377: 16 pp*; [3] Marcelli et al. (2021). EGU *General Assembly 2021, online, 19–**30;*** [**4**] Onorati et al. (2013) *J. Soils Sediments* 13:474-487.

Title: Reconstruction of radioactivity levels and sediment quality assessment in a deep basin at Lemnos, North Aegean Sea, Greece

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Abstract

The marine environment has undergone substantial changes in recent decades, due to by-products that cause pollution and end up to the marine environment mainly from the coastal zone and the drainage basins of the marine area. Sea bottom sediments are the final recipient of the largest portion of discharged pollutants. In this work a sediment core is studied from Lemnos basin at North Aegean Sea collected at a depth of 1550 m. The sediment core was sampled with a box corer and it was analysed to determine the rate of sedimentation of the basin, to measure and assess the levels of radioactivity of ^{137}Cs due to the Chernobyl accident, to study the temporal variation of anthropogenic microparticles in the sediment and finally to investigate and assess the influence of the rivers flows discharging into the North Aegean on the concentrations of pollutants. The activity concentrations of the radionuclides were measured in Marine Environmental Laboratory of HCMR by the high resolution gamma spectroscopy method while the sedimentation rate was determined by both the ^{210}Pb and the ^{137}Cs methods. The anthropogenic microparticles were isolated from the sediment and the analysis was performed by a stereoscope. The results exhibited that the increased water supply of the rivers flowing into the North Aegean the last decades as well as the production of dense water masses, was related with the increase of the concentrations of the pollutants.

Sediment management in a circular economy

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Conference theme number(s): 2,3,4,5,6,7,8

Introduction: In 2022 the Dutch Ministry of Infrastructure and Water management developed roadmaps for improvement of the sustainability of the different field of activity's activities of Rijkswaterstaat, the Asset Manager of the main Dutch water systems and roads. The roadmaps for different fields of work describe the route towards a climate neutral and "circular" way of working.

Methods: Starting point is the widely accepted definition of a Circular Economy (CE) of the Ellen MacArthur Foundation. CE is not a goal on itself but a tool for reaching sustainability goals. In particular CE is about the use of scarce raw materials. Relevant stakeholders were involved in developing the roadmap. For (circular) sediment management this are regulators, clients, contractors, knowledge-institutes and consultants. To identify opportunities for improvement of the current practice, we made use of a conceptual model of the actual playing field for sediment management.

Results: Besides a route for changing the engines and energy carriers of the equipment, the roadmap for dredging and beach nourishment also addresses the circularity of the management of dredged sediments. Although still abundant now, sediments are becoming increasingly scarce in the Netherlands. The Dutch coastline and riverbeds are eroding, the soil (in polders) is slowly sinking, whilst the sea level is rising. For improving the circularity of sediment management, we identified three main targets:

1. Protection of stocks of sediments;
2. Reduction of negative environmental impact due to the extraction of sediments;
3. Retention of the value of the sediment during the use of it.

Ad1.
Policies and regulations create a playing field for sediment management and therefore are important instruments. Relevant are (a.o.) policies and regulations for the protection of water and sediment quality and the National decision making process on the need for dredging. The implementation of EU policies for the protection of the environment, such as the Water Framework Directive and the Waste Framework Directive into the Dutch regulatory framework created a playing field in which the practice of sediment management is quite circular already. Approximately 80-90 % of the dredged sediments nowadays is beneficially used. However, sediments are still being polluted and this poses a threat for the future use-ability of the sediment stock. Improvement of policies and regulations by policy-makers therefore is a very important instrument for improving the CE of sediment management. For implementation it is important that regulations are clear and fit for purpose.

Ad 2, 3
The second and third target refer to the design of -, and execution methods used in dredging projects. Expertise of Clients [1] and Contractors has to be used for reaching the second and third target. Building up of knowledge and innovation is necessary for improving policies and regulations but also to improve current practices.

Discussion:
Although sediment management (dredging) is an important tool for water management, the Water Framework Directive does not address sediments explicitly. Only this year a technical document [2] on sediment management was published. The Waste Framework Directive does not take the specific characteristics of (dredged) sediments into account. Rigid interpretation therefore can lead to inadequate management of dredged sediments. Exemptions for sediment management in both EU directives show that there is/was doubt if those Directives were suitable (fit for purpose) for regulating sediment management. How can we make sure that (clear) regulations will facilitate a circular sediment management? Is it necessary to clear things up on the EU level? Should we have a technical document on sediment management under the Waste Framework Directive too?

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[2] CIS, Integrated sediment management Guidelines and good practices in the context of the Water Framework Directive (2022).

A PFAS mass balance– impact on the sediment (re)use policy

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Conference theme number(s): 2. (Circular economy – sediment as a resource)

Introduction: Due to the combination of subsidence, soil erosion and sea level rise, sediment use is essential for the Netherlands. While the sediment quality has improved greatly over the past 25 years, "new" substances of very high concern like PFAS have spoiled the party and legislation has severely limited the use of sediments. In this presentation we want to look at the mass balance of PFOS (one of the PFAS components) (see Figure 1) to evaluate what can be done on a system scale to limit the PFOS load in two Dutch rivers.

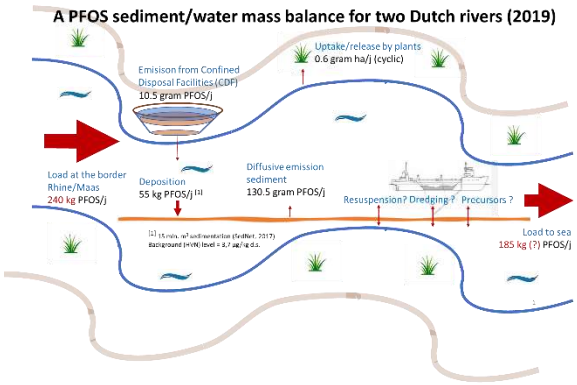

Figure 1 An indicative PFOS mass balance for the Rhine and Maas (2019)

Methods: To set up a PFOS mass balance and evaluate the role of sediment in the mass balance data has been collected on two of the main Dutch rivers, the Rhine and the Maas. Based on the discharge and PFOS concentration in the two rivers the incoming (border) and outgoing (sea) PFOS load has been calculated [2]. When combined with the average sedimentation rate [1] and the PFOS background concentration [3] a global PFOS balance can be made. To evaluate the impact of sediment related processes (erosion, dredging, use for nature development, storage in a CDF) batch and mesocosm experiments (Figure 2) have been carried out.

Figure 2 Mesocosm experiment for PFAS

Results: The results yielded some important insights how sediment, when disturbed (erosion, dredging, application) release PFAS and more specific PFOS (Figure 3).

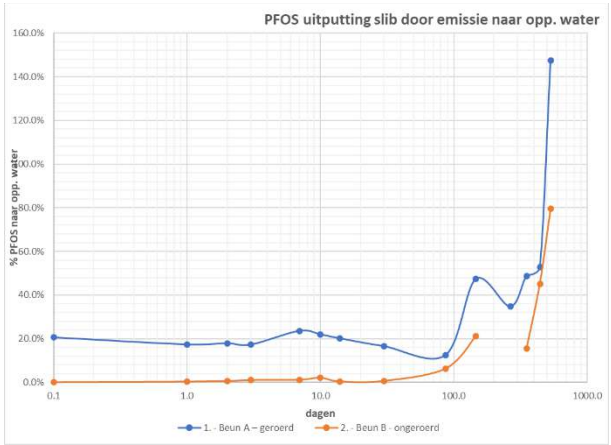

Figure 3 PFOS emission to water as % of sediment conc.

Discussion: What we can learn from the PFOS mass balance and sediment related processes is what we can do to avoid the release of PFOS as much as possible, and where the priorities should be to improve the water quality.

References:

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[2] M.T.O. Jonker, Poly- en perfluoralkylstoffen (PFAS) in de Rijkswateren, concentraties in water en biota tussen 2008 en 2020
[3] Handelingskader voor hergebruik van PFAS-houdende grond en baggerspecie, 2021

Lessons from pilot-scale sediment reuse projects on the Scottish canal network.

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Conference theme number(s): 2

Introduction:
Beneficial reuse of dredged sediment from canals, harbors, and waterways would appear to be a straightforward opportunity to transform a waste product into a valuable resource, in line with developing a circular economy. In practice there are multiple technical, regulatory, and economic barriers to their beneficial reuse. Two pilot studies were undertaken in Scotland in conjunction with scheduled maintenance dredging on the Scottish canal network to investigate the practical difficulties to sediment reuse on a 1,000 – 15,000 m^3 scale.

Pilot sites:
Projects were undertaken on the Forth and Clyde Canal at Bowling, Dumbartonshire and on the Caledonian Canal at Laggan, Highland Region. At Bowling, sediment characteristics favored reuse as a topsoil following bio-conditioning in a cell constructed for this pilot. After only 5 months in this cell, samples met the specifications of BS 3882:2015 and was suitable for landscaping on an adjacent construction site.

Fig. 1: Suction dredging on the Caledonian Canal.

By virtue of its location within in a steep valley and the underlying geology, sediment entering the Caledonian Canal is granularly coarser than that of lowland canals. Consequently, dredged sediment from this canal was better suited to reuse as aggregates and as components for concrete. At Laggan, suction dredging (Fig. 1) was used to remove over 8,500 m^3 of material, which was delivered as a slurry to a series of lagoons. As the slurry washed through the lagoons, sediment particles were separated by gravity resulting in clean sand, with gravel fractions removed by screening.

Sand and gravel fractions were mixed with Portland cement to manufacture two tonne concrete blocks for erosion control. The residual silty deposit in the lower cell met the criteria for topsoil and was used to restore the site to its original grade. Meanwhile, sand in the upper lagoon (Fig 2) contained <10 % of <0.063 mm, so met the requirements for reuse as fine aggregate in asphalt (BS EN 13043:2002).

Fig. 2: Sediment segregation within lagoons.

Conclusions:
The pilot studies demonstrated the viability of reusing dredged sediments for infrastructure projects. However, they highlighted the importance of minimizing transportation and handling of wet sediment to the viability of sediment reuse.

Exploring unconventional approaches to sediments decontamination

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Conference theme number(s): 2

Introduction: Sediments are soil particles found at the sea bottom and comprised of organic matter, iron oxides, carbonates, sulfides, clay, sand, silt and interstitial water. Natural organic matter is derived from humus, decomposed plant and animal residues and other organic matter such as woody or plant material, garbage, dead organisms and other debris. Sediments are heterogeneous and their composition significantly varies from site to site. Accumulation of pollutants during long periods and multiple pollutant sources at the harbors are the reasons that the sediment is a complex mixture of multiple types of pollutants including Persistent Organic Pollutants (POPs), microplastics and heavy metals among others.

The technologies for decontamination of multiply-polluted sediments must be improved to address the whole complex of contaminants. The existing technologies are frequently incompatible for different mixtures of pollutants, for example for microplastics and biochar on the removal of polycyclic aromatic hydrocarbons and phthalate esters.

Methods: A plausible and potentially more efficient alternative to the current decontamination paradigm relies on the application of unconventional ways for triggering chemical reactions. The new approach, to be done within the spanish project "Exploration of unconventional reactional pathways for an integrated and sustainable decontamination of dredged sediments (UNIDEC), intends to employ, in a concerted way, different types of energy including mechanical energy, sonication, electrokinetics, electromagnetic radiation, microwave and UV light. Such reactions usually have different reaction pathways and unusual reaction products, which are unattainable by conventional thermally driven chemical reactions [1].

This approach is ambitious but is grounded on solid experimental evidences obtained in investigation of synergistic enhancement of chemical reactions by non-thermal driving forces. For instance, piezoelectric materials with photocatalytic activity may employ the piezoelectric field directly for separating photo-generated charge carriers during the light/piezo-excitation increases the lifetime of generated charges and the overall catalytic effectiveness [2].

Results: To tackle this problem a multistage research plan, which involves understanding the fundamental mechanisms of non-thermally driven chemical reactions on various components of real sediments, exploration of the possibility to use the non-thermally driven reactions for decontamination purposes and tuning the technological parameters of such reactions, was developed.

At the first stage, we analyzed tribochemical activation of mineral and organic components of sediments using the measurement of rates of electron emission and radical generation. In parallel, an original tribo-mass-spectrometry method was developed to quantify the rate of organic contaminants and plastics decomposition under a combination of mechanical energy and UV light. Model organic contaminants can be used to simulate typical POPs.

At the second stage, real sediment is subjected to various combinations of non-thermal treatment processes including mechanochemically and electrokinetically assisted photocatalysis. The reaction rate is assessed *operando* using coupled mass-spectrometry.

At the third stage, socio-economic impact of the new technology is analyzed and the measures to increase its acceptance by general public and stakeholders are developed.

Summary: The alternative non-thermally driven chemical reactions are very promising to face the problem of sediment contamination and revalorization in the frame of the paradigm of circular economy, though much research is still needed to scale this technology to industrial level.

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Twenty-years forecast of coastline evolution on sandy coastal stretches in mainland Portugal

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Conference theme number(s): 2.

Introduction: An assessment of worldwide sandy coastlines performed using satellite images suggests that about 30% of the world's coastlines are sandy [1]. Among those sandy beaches, about 25% are retreating. This retreat is usually analysed based on the time evolution of a spatial contour (i.e. coastline), that is associated with some tidal level, or based on the dune toe or vegetation line.

Besides the factors that contribute to coastline advance or retreat and from a coastal management point-of-view, coastal managers often need to plan the most appropriate interventions to be performed in the upcoming future (e.g., 20 to 100 years). This planning can be undertaken through a cost-benefit analysis among different intervention scenarios [2]. These scenarios can range from do-nothing to advance the coastline seawards. Moreover, they may consider implementing coastal protection works, such as groynes, seawalls, or soft measures, such as beach or shoreface nourishments [3,4].

In this project COBE, we used a coastline numerical model to forecast the 20yr coastline position among different intervention scenarios. This forecast was performed to five sandy coastal stretches, in the high-energy wave-dominated western coast on mainland Portugal.

Methods: Long-term forecast *O*(decades) of coastal evolution is usually performed using one-line numerical models [5]. In general, they use the sediment conservation equation to predict the future coastline position as a function of the gradients in the wave-induced longshore sediment transport rate. Therefore, they calculate wave propagation and transformation based on linear wave theory and the potential longshore sediment transport is based on semi-empirical equations (e.g., CERC equation).

Here, we used a newly developed coastline model called ShorelineS [6]. This model has the same physical processes as previous coastline models but it can handle complex shorelines due to its vectorised conceptualization.

Results: The project is still in an early stage. In more details, ShorelineS is being applied to the Aveiro coastal stretch that ranges from Costa Nova to Mira (Fig. 1). Along that stretch, several authors obtained a net longshore sediment transport value of $1x10^6$ m^3/yr directed towards South. To attain a similar value in ShorelineS, a time and space constant sediment transport factor (*qscalc*) of about 0.2 is needed to multiply by the potential longshore sediment transport rate obtained with the CERC formula.

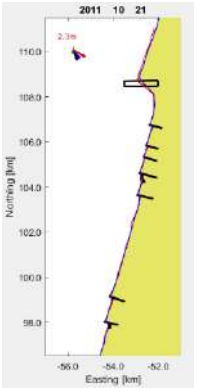

Fig. 1: *Output of ShorelineS numerical model for the coastal stretch between Costa Nova and Vagueira.*

Discussion: The required modification in the sediment transport factor is likely to incorporate uncertainties associated with: (1) the use of linear wave theory during wave propagation and transformation; and (2) the use of semi-empirical longshore sediment transport formulas (e.g., CERC formula). Although *ad-doc*, this modification is proposed by Kamphuis [7] to account for the difference between the potential longshore sediment transport rate, obtained by the formula, and the actual longshore sediment transport rate that occur in the field.

Acknowledgement: This work is a contribute under the project COBE, coordinated by the Portuguese Environment Agency and co-funded by POSEUR (Reference: POSEUR-02-1809-FC-000098).

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[7] Kamphuis (2020). *Introduction to Coastal Engineering and Management*, World Scientific, 544 pp.

A mobile & continuous granulometric classification & dehydration pilot to improve sediment reuse strategies. Case studies & results interpretation

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Conference theme number(s): 2

Introduction:
Dredged sediments are a mix of various granulometry of matters with variable chemical characteristics in each fraction, and water. The water content of fresh dredged sediment is a key limiting factor for reuse where chemical and physical characteristics need to comply with the final application requirements. The water content increases the transportation cost, generates complexity and limitations for sediment manipulation, impacts of road transport and, in addition, needs time and specific sites for dehydration. To address chemical/physical properties variations and water content issues and make reuse applications possible, various techniques exist: Natural, Chemical, Thermal and Mechanical treatments. With the SURICATES Interreg NWE project, IXSANE developed and tested a mobile pilot plant to be used as close as possible to dredging site with fresh dredged materials. Packed in three containers to be installed on land or on barges for ease of operation, the capacity of this equipment is up to 50m^3/hour of fresh dredged sediment and combines mechanical and chemical processes for continuous dehydration and granular classification.

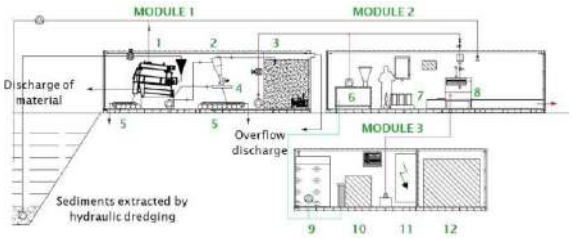

Fig. 1: Granular classification and dehydration pilot.

Methods: Mechanical processes are used to extract residual waste (> 2.5mn), to extract for reuse the sandy fraction (>60µm), and to press the thin sediment fraction after flocculation treatment in a continuous process for dehydration. Newly built in 2020, an evaluation campaign has been engaged in France and Scotland with fluvial or marine sediments and sand quarries washing waters to evaluate the technical performance of this equipment and economic data related to such operation.

The flocculation process is a sensitive part of this continuous process. It has been addressed by specific tests in quarries with wasted fine fraction of extract materials to complete on-site tests with fresh dredged marine or fluvial sediment. Technical parameters and sediment properties have been monitored in addition to economic data related to the use of such equipment from the perspective of the circular economy (direct and indirect cost & benefits evaluation).

Results: Real scale tests demonstrated the efficiency of the sand fraction extraction to increase sediment mineral fraction reuse options with 20% of fine fraction (2-63µm) and 80% of sand (63-25µm). Dehydration of fine fractions reach more than 50% of dry matters in less than 1hour.

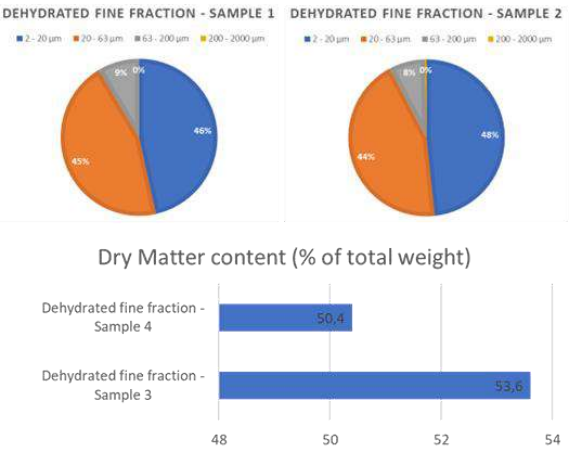

Fig. 2: sand and fine fraction dehydration results.

Discussion: Valuable results are obtained with a pilot scale unit with limited capacity. Obtained results, upscaling challenges and operational issues will be presented and discussed.

Acknowledgments: Interreg NWE Program for its support to SURICATES project; ARMINES IMT Lille-Douai (FR) for sediment analyses and their expertise; Scottish Canals (UK), EPTB Rance Fremur (FR) for onsite sediment processing tests supports; Sablière de la Lande (FR) for onsite tests with sand quarries waste waters.

Reuse of Metal Impacted River Sediments

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Conference theme number: 2 Circular Economy – sediment as a resource

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Introduction: The Coal Authority, Environment Agency and DEFRA are working to address the widespread legacy of contamination from disused metals mines to deliver a cleaner water environment for people and wildlife. One part of the strategy is to construct check weirs within the polluted rivers to capture and subsequently remove metal impacted sediments, thus reducing the contaminant loading in the rivers. The check weirs require regular dredging to ensure they work at optimum efficiency. The dredged sediment was historically disposed to landfill, often as hazardous waste due to the high lead and zinc content. This approach involved transport of the sediment via minor country roads to landfill facilities >100km away. This had a significant carbon impact from lorry emissions and caused severe disruption to local communities to the point where the benefits of improving river water quality were outweighed by the negative impacts. Ramboll challenged the waste classification process to consider the excavated sediment as a resource rather than a waste and developed solutions to reuse the dredged sediment lcoally and is a perfect example of Circular Economy within contaminated land management.

Methods: Ramboll carried out a sampling, testing and assessment programme to characterise the sediment, including the grain size fractions, metal species, and contaminant concentrations. Ramboll carried out enhanced waste classification and human health and environmental risk assessments to explore options to reuse the sediment in a safe and sustainable way. Ramboll used our SURE tool to perform a sustainable remediation assessment. The SURE tool considers and evaluates the environmental, social, and economic dimensions (i.e., the sustainability) of different remedial options, to help communicate key decision-making factors to stakeholders.

Results:

Potential reuse options were identified which included;

- Using the coarse fraction within gabion baskets to improve river bank stability (photo 1)
- Using the gravel fraction for footpaths (photo 2)
- Using the fine fraction to create a *calaminarian* grassland nursery (plant species tolerant of high concentrations of heavy metals) (photo 3)

Fig 1 Gabion Baskets, Footpath & Grassland Nursery

Using the detailed risk assessment, Ramboll were able to demonstrate the materials were suitable for these reuse options. The CL:AIRE Definition of Waste: Industry Code of Practice (DoWCoP)[1], allows the reuse of the dredged sediment as a construction material for development projects. To reuse materials through the DoWCoP approach requires the waste producer to establish lines of evidence to demonstrate:

i) Protection of human health and the environment;
ii) Suitability for use without further treatment;
iii) Certainty of Use; and
iv) Quantity of Material.

Ramboll demonstrated these factors to the EA's satisfaction, thus avoiding tortuous waste regulations. By using the DoWCoP approach, material which was previously being sent to hazardous landfill could be reused safely and sustainably locally to create the enhanced biodiversity grassland feature. This approach was untested and although the principals of the project followed common sense and science, the key element of the project was to adequately demonstrate suitability of use and give the Regulator confidence to consider the excavated sediment as a resource rather than a waste.

Conclusion: This is an excellent example of contaminated land management practices that enhance soil health and local biodiversity, whilst reducing the negative economic, social and environmental impacts associated with the previous approach. This project demonstrates a safe, sustainable and circular use of excavated sediments. The mitigation solutions used were simple, easily implemented and required little technology or specialist equipment. This work aligns with the vison of the EU Soil Strategy for 2030 and also contributes to the UN Sustainable Development Goals:

Fig. 2: UN Sustainable Development Goals

6 and 14 – Improving river water quality by removing lead and zinc contaminants from the rivers

9 – Using detailed modelling and risk assessment to allow the reuse of dredged sediment under DoWCoP

11 – Reuse of sediment avoiding transport, landfilling and the need for virgin materials in construction.

15 – Enhancing the biodiversity in specific areas by preserving and expanding the *calaminarian* grassland.

Acknowledgements: UK Coal Authority, UK Environment Agency and UK Department of Environment, Food and Rural Affairs
References: [1] CL:AIRE et al. (2011) *Definition of Waste: Industry Code of Practice* Version 2 March 2011

Landfilling and soil conditioning of dredged sediments: evaluation throughout a life cycle assessment

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Conference theme number(s): Circular Economy – Sediment as a resource

Introduction: Dredging of sediments is carried out worldwide to increase water levels or restore aquatic ecosystems. Sediments in land require proper management and traditionally were taken to landfills of discharge in open oceans. However, these methods are restricted by environmental and legal reasons. Open ocean discharge can pollute other ecosystems and is forbidden in several countries. Moreover, landfills produce leachate and methane, which can negatively impact the environment. Alternatives to handle dredged materials are required and the use for beneficial purposes is an option that also contributes to stopping the depletion of natural resources sources [1]. Nutrients are essential for life and some like phosphorous are limited on the planet. Therefore, more sustainable sources are required. Dredged sediments commonly contain nutrients that can be recovered for beneficial uses. The use of dredged material as a soil conditioner can provide nutrients to soils and additionally enhance physical properties like water retention [2].

The evaluation of management scenarios for dredged sediments is fundamental to determining the best alternative in environmental, economic, social and technical terms. This study focused on the assessment of soil conditioning and landfilling using a life cycle assessment to evaluate the environmental impacts caused by the scenarios.

Methods: A life cycle assessment (LCA) was conducted to analyse the environmental impacts of (S1) landfilling and (S2) soil conditioning of dredged sediments from Malmfjärden bay, Sweden. The LCA software EASETECH [3] from Denmark Technical University was employed for the modelling. The scenarios contemplated the impacts caused from transportation from the treatment site until final use/disposal. The functional unit was 22 tons of sediments, and the selected evaluation method was ReCiPe V1.11 Hierarchies Europe.

Results: The impacts caused in both scenarios are shown in Table 1 that includes the main categories of global warming, toxicity and eutrophication. The results are provided in personal equivalent (PE).

Tab. 1: Impacts caused in landfilling and soil conditioning of dredged sediments in PE (positive and negative values show negative and positive impacts, respectively)

Scenario	Total*	Global warming	Eutro-phication	Toxicity
Landfilling	0.6	0.03	0.01	0.4
Soil cond.	-6	0.1	0.64	-5

*Includes other categories

Discussion: The scenario with higher negative impacts was landfilling and the most impacted categories were global warming, toxicity and eutrophication. The activity that caused most of the impacts was the operation of the landfill. The facility was modelled containing environmental protection measurements to collect leachate and methane. However, the emission of the collected methane and the treated leachate were responsible for causing the previously mentioned environmental impacts. The scenario had no-extremely high negative impacts, showing the importance of including protection measurements in landfills.

The second scenario had an overall positive score, and the positive impacts were related to the avoidance of producing and using fertilisers. However, the scenario presented negative impacts in the categories of toxicity, global warming and eutrophication. The impacts were caused during the spread of sediments due to the possible metal and nutrient emissions. Moreover, the decomposition of organic matter produced methane, affecting global warming. The overall score of the scenario showed the positive impacts to avoid using fertilisers; however, proper uses shall be considered to avoid polluting soil and aquatic ecosystems.

Funding from the EU LIFE program (LIFE15 ENV/SE000279). The data is published in Ferrans et al. (2022) *Sustainability* **14.**

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Bankbusters: A Nature-based Solution engineered tidal marsh river banks, beneficially re-using soft dredged sediments

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Conference theme number(s): 2 / 6

Introduction: Socio-economic development activities along the tidal river Scheldt ubiquitously require dredging maintenance works in the access channel. Currently, during dredging maintenance the coarser sandy dredged material is mainly reused, while large volumes of fine dredged sediment are disposed without beneficial reuse, due to economic, logistical, legislative and/or environmental constraints.
Further deepening of the access channel induces a steepening towards the borders and their estuarine habitat. Consequently, productive ecosystems are under pressure, leading to severe habitat deterioration, especially in lowly elevated tidal marshes that flood frequently. Increasing erosion can alter these habitats into non-vegetated mudflats, with an unfavorable steep transition to highly elevated marshes. As estuarine tidal marshes provide various ecosystem services like natural flood protection lessening the impacts on embankments, the above anthropogenic and natural pressures in the Scheldt estuary will result in increased flood risk, tidal amplification and strong erosion. Moreover, these bare and steep riverbanks water and riparian plants offer only limited opportunities to rich vegetation growth. Consequently, fish and small aquatic animals have nowhere to hide or "low quality" spawn areas. The result is an impoverished ecosystem.

Fig. 1: R&D Consortium Bankbusters

Methods: The R&D project "Bankbusters" consolidates and acquires knowledge on ecosystem processes, boundary conditions and beneficial re-use of soft dredged material, in order to facilitate tidal marsh habitats restoration in previously eroded environments, enhancing ecosystem services delivery. A public private consortium researches and designs an eco-engineered tidal marsh, beneficially re-using soft dredged sediments.
Innovation is actively pursued in detailed biological process insights, global ecosystem understanding, more sustainable technological solutions and resilient operational features with a strong emphasis on developing synergies and integration to tackle the high risks linked to the highly dynamic and complex environment this project is situated in, i.e., erosive tidal rivers embankments of the Scheldt river, driven to enhance biodiversity. Dedicated living lab prototypes validate and regulate the experimental containment of soft dredged materials, while real-time flux sensors monitor the evolution of the newly placed marsh.

Results: The industrial dredging partners are designing DRECO (Dredged Ecological Compartment) unit, using well-known bundles of braided willow wood connected to mat configurations to hold the dredged finer sediments.
Dedicated living lab prototypes validate and regulate the experimental containment together with the marsh-soil development of the beneficially re-used fine dredged materials. Real-time lab-on-chip flux sensors monitor the groundwater dynamics of the newly placed marsh soils. A pioneering vegetation monitoring completes the observation of the critical, initial marsh land development stage.


Fig. 2: Marsh land development along the Scheldt

Doing so, a framework for the integration of boundary conditions for ecosystem services – taking into account the biological complexity and ecosystem functioning - in engineering design is delivered.

A management of port sediment in a *Working with Nature* context to achieve a zero residues generation

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Conference theme number(s): 2. Circular economy. Sediment as a resource

Introduction: The harbor of Seville is the only inner harbor in Spain. Along 89 km ships navigate from the river mouth in Sanlúcar de Barrameda (Cádiz) to the center of Sevilla, through de Guadalquivir River, one of the most turbid rivers in the world.
The harbor operates a lock that allows to regulate tidal levels both sides of it. The lock connects and levels the river and the dock port.
The Guadalquivir estuary is subdued to a tidal regime, so the tide is noticeable even at the dock, 89 km far away from the river mouth.
The river and its valley support several and different uses: rice and citric crops, aquaculture and fishing, population, tourism, etc.
The discharge regime of the river is highly regulated. The last dam downstream is Alcalá dam (Alcalá del Río) close to the harbor.
In order to ensure a safe navigation, the Port Authority of Seville (PAS hereinafter) must dredge almost every year about 350.000 m^3 of sediment in different sections of the navigation channel. Before 2015 almost all the sediment was disposed of on a marine sump, but from that date the PAS has started several research lines and is giving a new life to most of the dredged sediment, such as, beach regeneration, protection of erosive margins, use in public works and even brick construction. All these initiatives are framed in a Working with Nature context according to PIANC philosophy and the PAS has even been awarded by the regional government.

Methods: the Guadalquivir River is periodically dredged using a suction hopper dredge (TSHD hereinafter). The auxiliary equipment of the operation: suction pump, drive pipe and ship are used to dispose the sediment and distribute it to the purpose it has been conceived. Land machinery gives support to the process.

Results: Among the different uses given to the dredged material there are the remodeling of the terrestrial dumps of the PAS to favor the breeding and reproduction of birds, creating inner islands with the dredged material and maintaining the pumped water level during spring through a water box system. This ractice was awarded the Environmental Award in 2020 from the Regional Government (Junta de Andalucía).

Fig. 1: *Artificial wetland in Harbor land. Source: PAS, 2021.*

The regeneration of Sanlúcar de Barrameda beaches or several erosive margins, such as the one executed last year in Doñana, one of the most important natural areas in Europe, a Biosphere Reserve, UNESCO.

Fig. 2: *Regeneration of an erosive margin in Doñana. Source: DRAVO, S.A., 2022.*

The construction of ceramic material to be used in cities is another investigation line currently under study.

Discussion: In a working with nature context the PAS is managing the dredged sediment each maintenance campaign to give it different and productive uses to improve the resilience of the natural system and produce benefits for all the stakeholders in relation to the river, which is undoubtedly a good practice in line with the circular economy criteria.

Acknowledgements to DRAVO, S.A. and the Port Authority of Seville.

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Agricultural soil recovery using dredged fluvial sediments: Mont-Cenis hydropower plant experiment as a success to be replicated

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Conference theme number(s): 2 Circular Economy – Sediment as a resource

Introduction: Fluvial sediments are natural materials that are issued by the process of erosion.

Hydropower is today the first power renewables in the world, and also in France. The creation of a dam associated with hydropower is necessary for electricity generation. By trapping sediments in the reservoir, dams interrupt the continuity of sediment transport through rivers. Sedimentation thus affects the safety of dams and reduces energy production, storage, discharge capacity and flood protection capabilities. These sediments may also increase loads on it and its gates, damages equipment and creates a wide range of environmental impacts.
EDF is operating in France 433 hydropower plants totalling capacity of 20,000 MW with a CO2 electricity generation of around 50 TWh a year. These power plants were associated to 622 dams, including 150 more than 20 meters. The storage capacity of reservoirs created by these dams is 7.5 billion m³ of water, i.e. 75% of the surface water storage reserves in France.

EDF has to dredge sediments for several reasons: i/ Ensure sediment continuity (i.e. priority sediments stay in water); ii/ Ensure the safety of the operation/maintenance; iii/ Limit the loss of energy generated and/or loss of flexibility; and iv/ Maintain navigation. Sediment continuity is preferred as much as possible in France for EDF, according to our integrated sediment management. However sometimes sediments have to be dredged and remove from the water. These dredging sediments become waste by regulation (cf. Waste Framework Directive 2008/98/EC).

The soil is formed by the alteration of the underlying parent rock (pedogenesis): it is a non-renewable resource. In France the thickness of the soil is around one meter, for an average age of 10,000 years. Water erosion affects around 18% of the French territory. Landslides affect around 7,000 municipalities. 70% of French soils have a moderate to high susceptibility to landslides and runoff. Erosion, and to a lesser extent the mineralization of organic matter, lead to loss of carbon in soils. Soils have several roles and functions (memory of the past, landscape support, filtration and purification, support of vegetation, biodiversity reservoir, etc.).

Mont-Cenis hydropower plant (HPP) is an artificial lake created by a dam. It is located between France and Italy, in Les Alps. It was constructed between 1963 and 1968 (additional works date 1978-2015). The reservoir capacity, at a 2000m altitude, has a storage capacity of 320 hm^3.

Methods: This paper will present a methodology developed by EDF with several stakeholders, using dredged sediments of Mont-Cenis reservoir, to recover an agricultural land. First the context and main issues are presented. Then the method to address them, with the different stakeholders will be described (different preparations of the sediments, different seed species, a 5-year monitoring period, independent science analysis). Finally main results are exposed, highlighting the beneficial use of local sediment for soil restoration in the context of climate change mitigation and adaptation (rooting, flora development, water reserve, …). This experiment allows prospects to replicate this model elsewhere.

Fig. 1: Mont-Cenis dam and reservoir.

References: [1] CIS document. (2022) *Integrated sediment management - Guidelines and good practices in the context of the Water Framework Directive* ; [2] EDF (2022) *Retour d'expérience sur la renaturation pour un usage agricole du site de Mont-Cenis avec ses sédiments*.

Phytoremediation of dredged sediments polluted with mineral oil, naphthalene and PAHs

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Conference theme number(s): 2 and 4

Introduction: Phytoremediation is a sustainable bioremediation technique that uses plants and their associated microorganisms to remove, degrade, extract or immobilize pollutants from soil and (ground)water. In order to ensure an efficient degradation and to avoid evapotranspiration of volatile pollutants to the atmosphere, microorganisms equipped with the appropriate degradation pathways are enriched inside the plants by means of inoculation.
In addition to clean-up polluted soil and groundwater, phytoremediation offers added values in terms of sustainability by lowering the use of materials and energy, CO_2 sequestration, increasing biodiversity, and producing biomass for bioenergy.

In the Interreg project RESANAT (Remediation of Residual Pollution with Nature-based Techniques) the re-development of polluted sites in Flanders and the Netherlands is stimulated by increasing the practical applicability of nature-based techniques, such as phytoremediation.
In one of the pilots, we explored the possibilities of remediating excavated sediment by means of phytopiles and using microorganism-stimulated phytoremediation.

Methods: Dredged sediment was dewatered and beginning of October 2020 stacked in piles of different sizes (3m x5m x0,5m and 4m x8m x1,5m) with or without topsoil and passive aeration via drains.
The piles were seeded with different grass species based on the results from a previously conducted feasibility study. In addition to frequent monitoring of pollutant concentrations, degradation potential was examined using qPCR for EUB and alkB. Furthermore, via GC/MS and determination of diagnostic ratios, degradation through biological processes was investigated. Monitoring ended in July 2022.

Fig. 1:*Phytopiles*

Results: The phytopile that was not equipped with an aeration tube and to which no topcoat was applied continues to have the highest mineral oil content. The smaller phytopiles were also found to exhibit lower final mineral oil concentrations compared to the larger piles. No specifically adapted bacterial strains were picked up with the qPCR assay perhaps due to the heavy load of PCR inhibitors. Interpretation of diagnostic ratios showed evidence of degradation of pyrene and fluoranthene. Over 18 months, for PAHs, there is a reduction from 52% to 90% at a depth of 15 cm and from 62% to 89% at a depth of 80 cm. For mineral oil, there is a reduction from 49% to 70% at a depth of 15 cm and from 43% to 68% at a depth of 80 cm. Furthermore, the results show that performing inoculation with suitable microorganisms results in about 10% more degradation.

Discussion: Both the feasibility study and monitoring show that mineral oil and PAH degrading microorganisms are naturally present in sediments polluted with these compounds and are able to metabolize the pollutants in constructed phytopiles. Smaller size and presence of passive aeration appears to stimulate these processes as well as inoculation with suitable microorganisms.
As a result, the use of phytopiles and microorganism-stimulated phytoremediation may offer particular added value for treating cleared sediment. This may be possible on site in the riparian zone and reduces the ecological footprint of remediation.

Social, Economic and Environmental Analyses for Sediment Reuse Applications

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Introduction: There remain significant challenges associated with dredged sediment management and reuse. The EU Interreg-funded SURICATES project has contributed to addressing this challenge by studying the potential to upscale sediment use. Successful upscaling of sediment use is not only a technical challenge but also a socio-economic one. The project has developed and applied a number of modelling and analysis tools to assess social, economic and environmental aspects of sediment management projects. This paper focuses on the application of these tools to a range of sediment management projects.

Methods: Four tools (GIS, Direct Cost, Economic and Environmental) have been developed to support the decision-making process and have been applied to dredge sediment management projects in the SURICATES Project partner countries of Ireland, Scotland, France and the Netherlands. The sediment management projects chosen represent a range of different applications of the reuse of dredged sediment.

The RAIES (Repulsion – Attraction – Included - Excluded - Sanctuarised) GIS tool developed by the University of Lille provides stakeholders with a GIS solution to support selection of the best location(s) for sediment reuse. The tool uses a spatial decision support system, which determines the best location available based on inputs from a range of different stakeholders. The strength (and weakness) of this model is that the biasing of stakeholders (for or against sediment use) is considered. Economic cost/benefits are also based on stakeholders' opinions.

The USAR Direct Cost Model developed by IMT Douai Nord Europe allows selection of the most suitable sediment management option based on criteria including sediment granulometry, physical and chemical characteristics, project costs, environmental criteria, site location and local and national regulations. USAR uses mathematical laws to simulate treatment applications of sediment to ensure the correct sediment properties for the targeted use. This model is the most accurate for cost comparison but needs detailed information for the source material and the type of application. It does not consider social constraints.

The Economic Model developed by Munster Technological University estimates the direct, indirect and induced impacts of a sediment management project in terms of Gross Domestic Product (GDP) and jobs created and is based on industry specific economic multipliers and coefficients, derived for each of SURICATES partner countries. The economic and employment contributions were downscaled to a regional EU NUTS3 level. This model is the most accurate in calculating secondary costs and benefits. The direct project cost calculation depends on stakeholder input.

The BROADSEAT (Beneficial Reuse Of Any Dredged Sediment Environmental Assessment Tool) Environmental Model developed by the University of Strathclyde is designed to analyse the environmental merits of a beneficial use dredging project. It compares a real or hypothetical Beneficial Reuse Option (BRO) to the Business as Usual (BAU) Case. It provides a qualitative assessment on a binary scale. i.e., 'the better'/'the same'/'worse'. The model can be used for a wide set of variables (social, economic,

environmental), but the ranking is based on a user-defined awarding of points.

Results: The four tools have been applied to analyse the impacts of a range of different sediment management projects and techniques, including at a number of SURICATES pilot sites. The results presented in this paper are based on the following sediment management projects and techniques applied across the SURICATES Partner Countries: sediment bioremediation, Falkirk Pilot Site, Scotland; in-water sediment reallocation, Port of Rotterdam Pilot Site, The Netherlands; breakwater construction and land reclamation, Port of Calais, France and wetland creation and dyke construction, Port of Fenit, Ireland. The dredge sediment volumes involved range from approximately 500 m^3 to 500,000 m^3.

The detailed analyses undertaken allow an overview of the different potential impacts of specific sediment management approaches in a site-specific context and allow, as appropriate, comparison of the 'Business as Usual' case with one or more beneficial use options. It also shows that for different projects and beneficial use techniques that the impacts can vary across social, economic and environmental criteria emphasising the complexity of the analyses undertaken and ultimately the challenges faced by stakeholders in managing dredge sediments in the context of the Circular Economy.

Discussion: This paper applies a new integrated modelling approach allowing assessment of the social, economic and environmental aspects of a range of beneficial use approaches to the management of dredged sediment.

Each individual model has strengths and weaknesses when it comes to the economic, social and environmental assessment of sediment use. The combined application of this suite of integrated tools provides valuable new insights into the analysis of the potential benefits of sediment reuse projects at a local and a regional scale in the context of the circular economy and also provides the stakeholder community and the overall decision-making process with the potential capacity to assess sediment management strategies and projects using multi-criteria analyses.

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Key words:
- Sediment, Beneficial, Reuse, Economic, Environmental, GIS, Decision Making, Stakeholder.

Beneficial use of sediments for our future: compared pathways for taking profit of them as resources for new challenges

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Conference theme number(s): 2

Introduction: Sediments are made available in massive quantities by dredging operations for the needs of the development of sustainable marine and waterways transport. This may end either as a huge flow of waste, or as a blessed resource for highly needed materials for climate adaptation works. Operators need a clear roadmap to beneficial use options, in a Circular Economy perspective. This roadmap has to include EU accepted alternatives for flood and coastal defence based on eco system based approaches. Since sediments are an 'end of pipe' resource this also includes ways to deal with contaminants.

Methods: Several European projects, mainly InterReg, funded RTD development to support beneficial use options for sediments as an alternative to waste disposal (GeDSeT, CEAMaS, USAR, VALSE, SURICATES). All contributed by investigating beneficial use (BU) pathways, benefits, options and potential traps. Real size pilot tests were developed in the later projects to demonstrate the validity of BU pathways. The authors took part in these projects and summarise their most promising findings. The key methods are geography (GIS based, [1]), economics and social modelling [2], engineering compliance, and environmental modelling.

Results: Climate adaptation operations must be on large volumes and at low cost, implying that potential reuse works are based on bulk sediments, with as little processing or storage as possible. These include coastline, harbour and river works, civil works and landscaping and agricultural uses [3]. Regardless of the type of application, the key features for the viability of a BU project lie in distance between source and target, timing of operations, suitability of specifications and public support. The main barriers are in the extra cost of BU vs. disposal, in dissuasive regulations and permitting, in social acceptance and in risks associated with contaminants.

Discussion: Project promoters are increasingly keen to develop beneficial uses and circular applications with sediments as an alternative to disposal. But these alternatives must be able to accommodate large volumes of sediments in a constrained timing, with varying levels of contamination, controlled by dredging and BU project agendas.

High value, small volume pathways are less useful here than large volume bulk applications. BU must entail low costs, as disposal is still a cheap option. To promote BU it helps to quantify the added value in social economic (job creation), in citizen awareness and participation, in greenhouse gas emission reduction and carbon sequestration, in ecosystem robustness and reduction of toxic stress, and on risk reduction due to the adaptation to climate change. The mentioned InterReg projects have developed tools to quantify these aspects and applied these on several pilot sites. The benefit from circular projects has to be sought from indirect benefits for the territory or public works, for which the availability of sediments can be seen as a trigger.
BU projects need therefore to be assessed within larger system boundaries than the original project. They need to involve many stakeholders in the initial design phase of the project, and most often the intervention of administrations and communities.

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Converting fiber sediment to hydrochar - new technology to eliminate landfilling and extract energy when remediating fiberbanks

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Introduction: Wood fiber-contaminated sediments, originating from discharges from pulp and paper industries from the early 20th centuary, have been found in many places in Sweden and Finland and many of them are priority objects for remediation due to their contamination status of chlorinated organic pollutants and metals [1]. At many places this fibrous waste has formed meter thick deposits (so-called *fiberbanks*) in the Baltic Sea, lakes and rivers [1]. Only 10% (40 sites) of potential sites in Sweden have yet been investigated, finding fiberbank sediments corresponding to a total volume of approx. 7 million cubic meters [1]. To prevent the spread of environmental toxic substances [2] and greenhouse gases [3] from the fiberbanks, innovative remediation methods are needed to handle potentially large volumes of contaminated fibrous sediment and at the same time eliminate landfilling.

The aim with this pilot study was to investigate the potential of producing hydrochar from fiberbank sediment, which can safely be incinerated in waste classified boilers, reused or disposed of, depending on the pollution content. Sediment from three different fiberbanks that represent different types of fiber material and pollution profiles were tested to evaluate whether the proposed technology (wet oxidation combined with hydrothermal carbonization, Oxy-power HTC™) is a way forward for treating different types of dredged fiberbank sediment.

Methods: Laboratory tests that simulates all unit operations of the Oxy-Power HTC™ treatment in a full-size facility (i.e. treatment under pressure at about 200 °C for one hour, wet oxidation of the separated water with oxygen for two hours and dewatering form a slurry of solid hydrochar) was performed with each of the three fiber sediments. In each test sediment corresponding to approximately 35 g of dry substrate was treated.

The concentration of chlorinated organic pollutants such as dioxins (PCDDs), furans (PCDFs), polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDTs) and heavy metals were measured in the sediment prior to treatment and afterwards in the obtained hydrochar and wet oxidized process water.

Results: All three fiberbank sediments were successfully converted into hydrochar using this method. The concentration (ng/g dry weight) of ΣPCBs in sediment and hydochar was found to be similar or slightly higher in the hydrochar. For ΣPCDD/Fs an increase in higher chlorinated congeners was observed in the hydrochar compared to the sediment. Whereas for ΣDDTs lower levels were found in the hydrochar compared to the corresponding sediment. Neither PCDD/Fs, PCBs and DDTs were found in measurable levels in the wet oxidized process water. For metals, similar or slightly higher levels were found in the hydrochar compared to sediment. Whereas, for methyl-Hg lower levels were found in the hydrochar. Metals (including methyl-Hg) were also found in the wet oxidized process water.

Discussion: This study shows that the hydrophobic organic contaminants are efficiently retained in the hydrochar and that the reduced contaminant levels of ΣDDTs are likely due to degradation occurring in the HTC treatment. However, this study also shows that the process water needs further clean-up to avoid release of metals when discharged. Overall the results are promising, showing the potential of using the Oxy-power HTC™ process to convert wet contaminated fiberbank sediment to hydrochar without the need for pre-dewatering and eliminating the need for landfilling as the hydrochar can be easily incinerated in a waste classified incinerator.

Acknowledgements: This research project (FIB-GREEN) was funded by Tuffo – A research and innovation program on contaminated sites managed by the Swedish Geotechnical Institute.

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Towards an integrated and circular management of dredged sediments: HAROPA PORT | Rouen as a transforming force in the territory

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Conference theme number(s):
2-Circular economy - sediment as a resource;
8. Zero pollution in the soil-sediment-water nexus.

Introduction: HAROPA PORT | Rouen is strategically positioned within the French port system. Within the limits of its district, this institution ensures that sustainable development issues are integrated into its current operating strategy and future developments, particularly in the context of maintenance dredging activities. In collaboration with Neo-Eco, a territorial framework has been developed to recycle part of the dredged sediments according to the circular economy models. In addition to the deployment of recovery synergies, an experimental research project on bio-dredging, on another site of the port, which is unique in Europe. This pilot should make it possible to reduce pollution in sediments, to optimise their management while controlling upstream risks. The overall approach aims to explore the feasibility of new dredged sediment "recovery loops" and built a case for local authorities and economic actors.

In a more prospective manner, this paper aims to present two complementary methods, on two different types of sediments, but managed together allows an integrated approach where bio-dredging and the creation of recovery channels would go hand in hand. By presenting this unique feedback in Europe, HAROPA PORT | Rouen and Neo-Eco wish to prove that this "territorial approach", based on sorting waste at its source and risk management represents an unprecedented opportunity to take the turn towards sustainable development.

Methods:

Two methods will be presented, highlighting in a third step their complementarity.

1. SEDINNOVE

The SEDINNOVE project concerns the building of new sustainable economic sectors, based on marine sediments valuation from HAROPA PORT | Rouen stocks. The study consisted in characterising the sediments to define their technical and environmental properties, to then underline territorial needs and demand. This modelling of the value chain made it possible to highlight the most relevant applications in line with local economic dynamics. On another hand, by correlating those characterisations to process and local infrastructure analysis, it was possible to validate two different *eco-material applications*: a new concrete and a geo-sourced roadbed. After the formulation phase, the research team could assess the percentage of sand that could be substituted by sediment, while maintaining technical and environmental performances of a standard product (without sediment). To finalise the research, an economic evaluation of the sector was carried out. This comprehensive approach aims to provide technical, environmental, and economic elements to define the interest of setting up a recovery system and its sustainability.

2. Neo-Bio

HAROPA PORT | Rouen has a harbour basin containing polluted sediments. The dredging of these sediments was necessary for the maintenance of the basin and in the context of the replacement of its floating dock. The Neo-Bio project consisted in a bio-dredging process based on micro-organisms capable of reducing the organic pollution present in sediments. This process is using category 1 bacteria integrated into mineral substrates (aggregates of all sizes - µm to mm), allowed not only the decontamination of sediments, but also the reduction of their volume. Its implementation was done directly in the basin by surface spreading, but also underwater with the help of divers to allow the penetration of substrates within the sedimentary matrix. The biotreatment was monitored following a scientific protocol, defined beforehand with local authorities and carried out by an independent organization. This monitoring made it possible to verify the harmlessness of the micro-organisms on the environment and to observe the evolution of the pollution levels throughout the treatment.

Results:

The SEDINNOVE study demonstrated the opportunity of creating a robust economic sector based on sediments valuation, in line with local needs and demands of raw materials. By confirming the environmental safety of the different formulas as well as their long-term performance, it was possible substitute up to 30% and 100% of natural material. The next step is to implement full-scale experimental worksites.

The Neo-Bio study made it possible to cut down on pollution rates *in-situ*, reaching the recovery thresholds that had been set after 3 months of treatment. This bio-dredging was an opportunity for HAROPA PORT | Rouen as the volume of sediment to be dredged was reduced and the final outlet could be re-evaluated. Thanks to this project, HAROPA PORT | Rouen was able to highlight an innovative and economically competitive de-pollution technique, which allowed the valuation of its sediments and meet the project schedule initially set.

Discussion: Controlling its sediments

Thanks to these complementary steps, HAROPA PORT | Rouen has implemented a complete approach to the exploitation of sediments: on site treatment to manage risk and pave the way to circular valuation. Characterization of used materials, understanding of value chains and modelling of sustainable economic balances are the key steps to enable a "*closed loop valuation process*". This feedback allows us to reveal the incentives and obstacles in the establishment of a circular approach. HAROPA PORT | Rouen has positioned itself as a virtuous institution by considering its sediments as resource (and not waste). This radical change in waste management allowed to change its position from a waste producer to a producer of secondary raw materials. From a desire to offer new sustainable solutions, the port institution structured a new sector for resource exploitation in the region.

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Stabilized *in situ* sediment as material used for experimental coastal protection and habitat restoration measures

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Conference theme number(s): 2

Introduction: In connection with the change in the water level manipulation of the reservoir, according to the EIA process, it was decided to take compensation measures to protect the littoral zone and create 43 ha of islands for water birds. The traditional approach of using stone for construction is costly due to long transport distances. Therefore, we designed and tested the possibility of reshaping local sediment into a material suitable for construction and implemented a pilot experimental polygon.

Methods: Within the lake, sediment samples were collected to determine spatial differences, recipe tests were conducted with the most suitable sediment type. Two approaches were tested, alkali activation with slag addition and Portland cement with improvement of grain-size distribution (increase of the coarser grains proportion).
Several types of new material with different properties and material costs were proposed. Finally different types of "products" were made and an experimental island with beach (Fig. 1) was built using low-drought boats.

Fig. 2 The experimental polygon („island with beach“) is soon to be finished.

Results: As the lake is the second in a cascade all the sediments were fine grained (d0.5 range 18-31 µm) with organic matter content 8-10 % (as LoI). The highest economical efficiency was reached by the combination of Portland cement and fine fraction (0-8 mm) of recycled concrete. Three materials with different geomechanical properties were made: the “crisp” one, which was used as the filling of the island and also as material on beach. This material has also been tested for the construction of submerged breakwaters. The “medium” material has been shaped as 10 to 10 cm cubes which would simulate the rough bottom substrate, naturally made of rocks, and the “hard” material was used to make octapode cube like blocks used as the other type of submerged breakwater. To make the field work realistic, the laboratory recipes were simplified. SED/CON/CEM weight ratio was 2/1/1 for “crisp” material; 2/2/1 for “medium” material and 2/2/2 (plus water-glass) for the “hard” material.
The monitoring of the geotechnical stability of the island as well as of the other materials was conducted for the next 12 months after the completion of construction.

Discussion: The geomechanical properties of the “new” materials remained the same after one year or improved a bit as the cement hydration reactions continued. Mainly the “crisp” material became harder and it also increased its volume for appx. 10 %.

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Please submit your abstract before the 15th of January 2023 to the SedNet secretariat: secretariat@sednet.org.

Nature-based geotextile tubes: a new circular and nature-friendly solution for the dewatering of dredged material

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re-use of dredged sediment, circular economy; public-private cooperation

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Conference theme number: 2. Circular Economy – Sediment as a resource E-mail: Jip@Netics.nl

Introduction:
The Dutch water boards have set an ambitious target to become 50% circular by 2030 and 100% circular by 2050.The main resource flow within the water boards consists of locally dredged sediments. The beneficial reuse of these dredged materials fits within the philosophy of a circular economy[1]. Dredged sediments, often seen as waste, therefore offer a natural resource that can be applied in many sustainable infrastructural and ecological applications.

One of these sustainable applications is geotextile dewatering tubes. Woven geotextile is commonly applied in geo-engineering for reinforcing soil and erosion/scour protection[2], but also for dewatering soft sediment. Instead of using sand as filling material, NETICS has been performing intensive studies on the large-scale dewatering and reuse of soft waste sediments in dewatering tubes[3].

Geotextile tubes are often made from synthetic polypropylene, which after exposure to degradation, can release harmful microplastics into the environment[4]. In Europe, this problem is increasingly relevant, since geotextiles are also commonly used in vulnerable and protected natural areas. Therefore, there is urgent need for a nature-based replacement that can degrade biologically.

Methods:
The usage of biodegradable and natural geotextiles is not new. Natural textiles such as jute and coir are abundantly used as for example scour protection[2]. In case of geotextile tubes however, it is commonly believed that the larger tensile forces released during the filling of geotextiles tubes can only be absorbed by synthetic materials.

NETICS collaborated in a consortium with the municipality of Rotterdam, geotextiles suppliers and dredging contractors, to tackle the societal challenge of geotextile plastics. The goal of this consortium was to prove that nature-based textiles are suitable for dewatering tubes in day-to-day dredging works.

For this study the most commonly used woven natural textiles: jute, hemp, flax and ramie/nettle have been investigated. These textiles have been tested on density, O_{95}, sediment dewatering speed and tensile strength. Continuing on these findings, together with the consortium, multiple full-scale jute geotextile tubes have been produced and used for dewatering two types of soft sediments in a full-size practical experiment.

Results and discussion:
This study has yielded insights into the possibilities for applying nature-based geotextiles as a sustainable replacement for synthetic dewatering tubes in a full-scale dewatering plant. In fact, all but one of the chosen natural materials were deemed technically suitable for upscaling into a real-world application. Moreover, the natural materials even offer various co-benefits for this type of application, such as increased evaporation, wet stiffness, being a substrate for vegetation and most importantly its (controlled) biodegradability.

This study found that, large-scale application of biodegradable tubes is limited by the readiness of the local textile markets. Large scale production of nature-based textiles is considered by modernized industries as ancient craftmanship and is only available in emerging economy countries. However, due to the increasing awareness on the damaging effects of synthetic materials produced from non-renewable oil, there is growing demand for bio-based materials.

This presentation will give insight in the potential of natural textiles for beneficial use of dredged materials, and the challenges we face now and, in the future, to integrate these eco-friendly materials in large scale industry practices.

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Please submit your abstract before the 1st of March 2023 to the SedNet secretariat: secretariat@sednet.org.

Sand sourcing from dredge disposal grounds for nature-based solutions

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Conference theme number(s): 2

Introduction:

In view of climate change, nature-based solutions (NBS) gain interest for coastal safety as human benefits (e.g. coastal protection, recreation) are combined with biodiversity conservation. However, NBS require a lot of sand, while the global demand for aggregates has already increased to a point that much more sand is being extracted than is naturally replenished. On top of that, sand reserves in the North Sea are rapidly depleting and the limited high-quality sand is mainly used for beach nourishments and as a basic raw material for construction. (Re)use of natural sand in more efficient and beneficial ways or replacement with viable alternatives have been identified as key strategies for continued supply of sand (Recommendation 8: Promote resource efficiency & circularity; UNEP 2022). Yet the capacity of alternative sand (composition, grain size, origin) to build NBS and to provide ecosystem services (ES) by coastal protection structures, such as dune-for-dike, has not been explored. In the Belgian part of the North Sea, suitable secondary sands are being sought in disposal grounds of dredged material.

Methods:

In March 2023, a geological and geophysical campaign was conducted to investigate sand quality and quantity of two dumping sites off the Belgian coast and more offshore. 11 undisturbed vibrocores up to 2 m in length and 96 mm in diameter were taken. High-resolution multibeam echosounder (MBES Kongsberg EM2040) and parametric echosounder (PES Innomar SES Quattro) data were acquired simultaneously, resulting in an acoustic image of the shallow subsurface, i.e. from the seabed to ± 10 m below the seafloor in dm resolution.

Vibrocores were split and prepared for photographic line scanning of the sediment surface at 50 µm resolution, and for Multi-Sensor Core Logging (MSCL) of downcore geophysical properties at 1 cm interval (i.e. gamma density, magnetic susceptibility and spectrophotometer reflectance). Subsamples were taken from each vibrocore for sediment analyses of organic matter, calcium carbonate and grain size.

Results:

First geological and geophysical results on the quality and quantity of sand in dredge disposal grounds are expected in summer 2023.

Discussion:

Beneficial use of dredged material is of interest to many stakeholders to safeguard volumes of high-quality sand for high-end purposes (e.g. for construction) and to sustain extraction activities on the longer term. Its potential to act as an alternative sand source depends on (1) the nature (properties, heterogeneity) and suitability of the sand compared to the characteristics of primary sand of the extraction sectors; (2) the expected quantities; and combined (3) the feasibility and usefulness of the sand for building NBS. Furthermore, better sediment management of dredged material will facilitate the reuse of this resource.

Acknowledgements:

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Re-use of dredged sediments for sustainable mangrove forests development

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Conference theme number(s): 2.

Introduction: Jan De Nul Group has a long-standing presence in Ecuador, particularly since 2018, when a 25-year concession contract began for performing maintenance dredging for the Access Channel to the ports of Guayaquil. This area is part of the Guayas river delta and is covered by mangrove forests. Mangroves are among the most productive ecosystems and provide a long list of important ecosystem services. For example, they: i) protect coastal communities from flooding, erosion and extreme weather events; ii) have a strong ability to capture and store carbon with their "carbon sequestration rate" being even higher than that of the terrestrial tropical forests [1], iii) are biodiversity ecosystems with high biodiversity rates and limited to tropical regions, iv) perform water purification; and v) contribute to the subsistence of local forest-dependent communities and their livelihoods. However, in the last few decades there has been significant loss of mangrove habitats in the Guayas delta [2], mainly due to land use change driven by intensive shrimp aquaculture activities, agriculture, and urban and rural settlements. At the same time, mangrove loss intensifies coastal safety problems, making the land around the Guayas river delta more exposed to floods and erosion [3].

Based on the above, the new innovation project AquaForest was introduced in January 2023. Within AquaForest, dredged material from the Access Channel of Guayaquil will be reused in a circular and sustainable way for the reclamation of an island for the creation of a mangrove habitat, within the area where modelling results have shown that sediment starts to be deposited naturally. The AquaForest project consortium is coordinated by Jan De Nul Group and is composed of two large international companies (Jan De Nul Group and South Pole), two Flanders-based consultants (Mantis Consulting and Haedes), three universities (ESPOL, University of Antwerp and VUB), and one NGO (Fundación Calisur).

Methods: The AquaForest project concept is based on the development of "green-grey infrastructure". This approach combines conventional engineering techniques for land reclamation with the circular reuse of dredged material to create a mangrove forest through assisted afforestation, in first instance. At the same time, the methodology focuses on establishing the initial conditions (mainly referring to sediment characteristics and hydraulic conditions) that are ideal for the growth of mangrove propagules, the proliferation of new accompanying tree seeds and the colonization process of associated biodiversity (micro and macro fauna). The new mangrove habitat will be developed on a new intertidal flat created in the Guayas river delta, located 15km NE of Posorja.

Results: Even though mangrove restoration is widely applied worldwide, AquaForest is an unprecedented project in the region due to the innovative reuse of dredged sediments for the creation of a new habitat. As such, AquaForest will become a Nature-based-Solutions (NbS) 'Living lab' where important mangrove ecosystem services will be demonstrated i.e. protection against floods, biodiversity gain and socio-economic benefits (the latter, with a special focus on local communities and gender inclusiveness). Importantly, technical and economic feasibility of such NbS will be demonstrated through the 'AquaForest Living Lab'. Moreover, international collaboration between key stakeholders will be the basis of AquaForest, i.e. co-creation between private companies, public institutions (state and local governments, and municipalities), international organisations, local communities and citizens, NGOs, universities and researchers.

Acknowledgements: The pilot AquaForest project is supported financially by: (i) the Flemish Government through the G-STIC Climate Action Programme 2022; (ii) the IUCN (International Union for Conservation of Nature) through the 'Blue Natural Capital Financing Facility' which supports Nature-based-Solutions within coastal and marine environments.

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Beneficial reuse of sediments as secondary raw materials for construction sector

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Conference theme number(s): …..

Introduction: The materials resulting from the erosion of rocks and soils are transported under the effect of climatic actions (wind, tides) or human actions (development works) and are deposited in harbors and waterways. The main problems linked to this accumulation of sediments concern economic activities, the risk of flooding and the impact on the physical and chemical balance of aquatic environments. Therefore, dredging operations are a necessary practice to ensure acceptable navigation thresholds of the waterways. The reuse and recycling of industrial waste and by-products are nowadays major priorities in order to preserve natural resources. Moreover, this is also part of a sustainable development and circular economy approach for the territories. As a consequence of dredging operations, large volumes are produced and need to be managed every year, which represents economic, environmental and technical issues. Therefore, it is essential to find alternative eco-responsible solutions, in particular through the recovery of dredged sediments in viable sectors such as civil engineering where 400 million tons of granular materials are consumed annually in France. In the Suricates European project framework launched in France in 2019, several innovative ways for recycling Rance sediments (France) have been studied: materials for Dike construction, as well as the use sediments in the concrete manufacturing.

Methods: The materials studied were collected in 2019 from Rance sediment storage areas located in Brittany (France). Physicochemical and geotechnical characterization tests were carried out on two separate sediment samples, according to French standards. The both sediments were classified in class A, according to the GTR classification, which represent the fine material.

Following this characterization study, it turned out that the sediments studied were of a very fine nature for the first (SBF) and more sandy for the second (SBS). As a result, fine sediments have been prepared for use in concrete formulations as mineral additions to cement for concrete application and sandy sediments have been prepared for use in dike materials.

Results: for concrete application: There are several technical requirements for raw materials that can be used in concrete application and especially as cementitious addition. Using the chemical composition, the sum of the SiO_2-CaO-Al_2O_3 oxides had to be sufficient to be used as an addition to the cements. According to the characterization tests of mineral additions according to the NF EN 196-1 standard, fine sediments can be used as an addition to cements with a mass replacement rate of 10% [1].

For dike application: From the obtained results and according to the triangle of texture SBS and SBF are classified as silty sand and silty (fine silty) respectively. Referring to the different characteristics, and based on the technical requirements for the materials constituting the dyke (Fig. 1), it can be concluded that:

- SBS sediment can be applied as core material without treatment;
- SBF sediment can be applied as core material after treatment (granular correction).

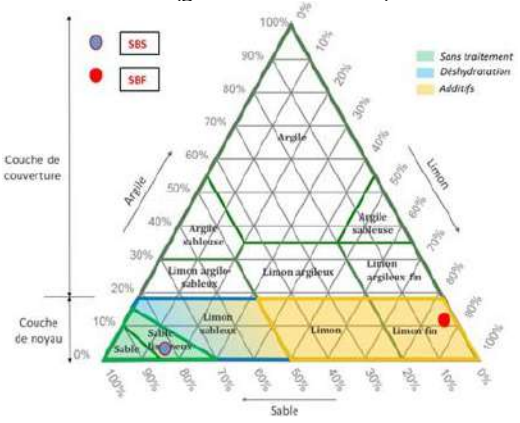

Fig1. *Conditions of use of sediments in dyke materials according to their physical characteristics*

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Desalination of dredged sediments for circular reuse to raise agricultural peatlands

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Conference theme number(s): 2,3

Introduction: Beneficial use of dredged sediments from the Eems-Dollard estuary (Netherlands/Germany) is tested within the Eems-Dollard 2050 program. The sediments are used in pilots, such as the Raising of Agricultural Land Pilot (*Pilot Ophogen Landbouwgronden*, POL). POL uses fine sediment from Eemshaven for agricultural (peat)land elevation, contributing to reduce the CO_2 emissions from of organic matter (OM) oxidation and improving the agricultural productivity and water management. Due to the high salinity, this sediment is not directly suitable for agricultural purposes and is first rinsed with fresh surface water. One of the knowledge questions of the pilot concerns what happens to the chemical composition of the sediment as result of this rinsing process. Therefore, laboratory tests were carried out on the salty sediment, in addition to electric conductivity (EC) measurements in the field (pilot). This paper presents the results of these laboratory tests.

Methods: The rinsing with fresh water was mimicked in the laboratory: the marine dredged sediment was mixed with fresh water at a 1:6 (volume) ratio with a HOBART planet N-50 Mixer. The mixing time was 5 minutes at a constant mixing rate of 285 rpm/minute. The resulting mixture was poured in 18 glass columns where it was allowed to settle and consolidate. The settling of the sediment-water interface was monitored. Supernatant and pore water (filtrated) samples were taken from 3 replicates at each of the following times: t = 1 day, t = 3 days, t = 7 days. To check the effect of a second mixing cycle, the consolidating sediment was remixed again at t=7 days for 9 of the 18 column replicates. The mixing was done with the supernatant water of the column (i.e. not with new fresh water) and with the same mixing procedure. For these columns, samples were also taken from 3 replicates at t = 8, 10 and 14 days. At all sampling times, the total mass of the column and the mass of the different fractions (mass of supernatant and mass sediment bed) was measured, as well as the EC of the supernatant water. For all samples, concentrations of main ions were determined using ion chromatography (Dionex). Additionally, the organic matter content from sediment samples before and after mixing was determined by thermogravimetric analysis (TGA).

Results: The results show that mixing with freshwater does reduce the concentrations of ions, and expectably the reduction of bi- and trivalent ions (Ca^{2+}, SO_4^{2-}) is lower than monovalent ions (Na^+, K^+, Cl^-). Monovalent ions such as sodium and chloride are released immediately when mixing, remaining the concentration stable during the rest of the experiment. However, ions with higher valence such as sulfate are released progressively during a longer period of time (Fig. 1). Mixing with fresh water also reduced the amount of OM. Quantification of OM for salty sediments is not straightforward because salt hinders water release, which means that temperatures higher than 105 °C are needed to remove water completely.

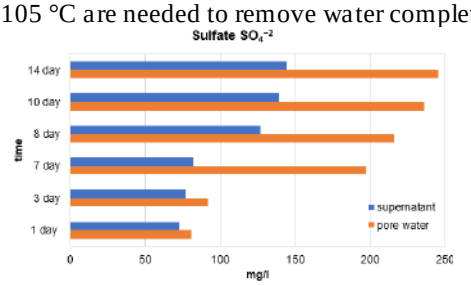

Fig. 1: Evolution of the concentration of sulfate ions (bottom panel) in the supernatant and pore water.

Discussion: More information about the optimal soil parameters is needed: it is important to maintain suitable nutrient levels and OM, but also to reduce the salt to avoid salinization of the groundwater and be suitable for more crops types. The results can be used to obtain a rough estimate of effects on other anions/cations, even if only reduction of conductivity is measured.

Application of GEOWALL® dike revetment elements made from dredged materials

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Conference theme number: 2. Circular Economy – Sediment as a resource

Introduction

With the acceleration of sea level rising, flood protection is becoming increasingly predominant worldwide. In this perspective 300 km of dike is being strengthened in the Netherlands every year[1]. Still a significant number of concrete elements are used, for example in dike revetments. Therefore, to contribute to ambitious global climate goals such as emission or circularity, there is a growing need for applying sustainable concrete replacement in the dike sector.

On the other hand, siltation of waterways is worldwide an environmental and economic problem. Almost 200 million cubic metres of sediment is dredged every year only accounting for the European waterway system. The management of dredged sediment is an increasing issue for harbours and local authorities. At this moment most of the dredged sediment is transported to depots as waste. This is a missed opportunity, since 90% of the sediment in Europe is expected to be clean enough to be reused in high value applications.

GEOWALL® technology

NETICS has developed a novel recycling solution wherein dredged sediments are reused in high quality solid building blocks. This unique innovation, patentedby NETICS, is called GEOWALL®. One example of GEOWALL® blocks are concrete-like elements consisting of compressed locally available dredged sediment. The blocks are made by mixing the sediment with some (natural) stabilising binders such as eco cement, lime, zeolites (according to a designed recipe with the NETICS recipe model) and by pressing it directly into the right shape. This is done with a unique built GEOWALL® Press. This method of mechanical stabilisation prevents high percentages of binders and a long curing period like concrete blocks.

Methods

In close collaboration with the Dutch flood protection program (HWBP) and the Scheldestromen Water board, NETICS performed a full-scale study on the applicability of dike revetments made from dredged materials using the GEOWALL®-technology. The main goals of this study were to prove the feasibility of the product under laboratory conditions, develop practical production equipment and techniques, control the production and apply this material in real.

Results and discussion

Results have shown that dredged material can be added in a significant quantity up to >35% (m/m) in the production of dike revetment elements. The product, compressed with a mechanical pressing device, had similar mechanical properties as regular concrete: Compressive strength 31 MPa, bending strength 6.5 MPa, specific density: 2200 kg/m^3. At the same time, life cycle analysis (LCA) gives an improvement of at least 20% compared to concrete.[2] These results are very promising considering this to be the first pilot with dike revetments from dredged material as local waste stream. Application of GEOWALL® dike revetment elements was done by a pilot section in the Dutch Western Scheldt.

By locally using dredged sediment as waste product environment impacts are kept to a minimum. Low emission rates (compared to concrete elements) decrease the LCC (Life Cycle Costs) and Eco Costs significantly, depending on the sediment composition and recipe. In addition created elements are 100% circular as these can be completely crushed into the original sediment to be re-used again for any other or same GEOWALL® elements.

The material is suitable for application in dike reinforcement projects, since conceptually it complies with technical standards described in the Dutch NEN norms for dike revetments (NEN 7024-1+C1(nl)). Next step is to optimize the mixing ratio and production for this material to reach an even lower environmental impact and reduce the production costs. Also, the shape and size of the material will be optimized to boost hydrological performance and ecological benefits.

In the near future for sustainable projects this material offers enormous benefits in terms of sustainability, circularity and ecology. The latter will be studied from ecologists from NETICS, Deltares, and NIOZ. The ongoing pilot section will give insight in the potential for this material and the development challenges. Currently NETICS and Deltares are writing a specific guideline for GEOWALL® dike revetment elements.

References:

[1] Kok, M., Arevalo, V. C., & Vos, M. (2022). Op weg naar verbeterde keringen: vijf jaar. TU Delft

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Beneficial Reuse Of Any Dredged Sediment Environmental Assessment Tool (BROADSEAT)- An open access tool for circular economy optioneering

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Conference theme number(s): 2

Introduction: BROADSEAT stands for "Beneficial Reuse Of Any Dredged Sediment Environmental Assessment Tool" [1]. It is designed to help you analyze the environmental merits (and any trade-offs) of a proposed or completed beneficial reuse/use dredging project. It uses your professional judgement of a real or hypothetical Beneficial Reuse Option (BRO) compared to the Business As Use (BAU) case, which is what you would do otherwise, or what would normally be common practice.

Methods: It works by scoring your qualitative assessment of whether the BRO is better/the same/worse than the BAU reference case on a binary scale (plus one/zero/minus one), using your answers to a series of questions. These questions attempt to address the range of factors which might be considered. For each question you answer by selecting a decision from the dropdown list. There are 52 questions each relating to a single factor, split between 10 categories (transport comparison, energy comparison, circular economy aspects, waste management aspects, waste regulation aspects, water environment, ecosystem services, biodiversity & conservation, socio-economic impacts, UN Sustainable Development Goals), which are then arranged into 4 groups (Energy, Waste, Environment, Societal).

Results: For each factor a weighting is provided, which is multiplied by the binary score generated by your answer to each question to give a score for the performance on this factor. The cell containing the resulting score is coloured, red (poor) through white (same) to green (good), reflecting the answers visually (Fig. 1). The weightings are designed to give equal emphasis to the four groups, with a maximum score of

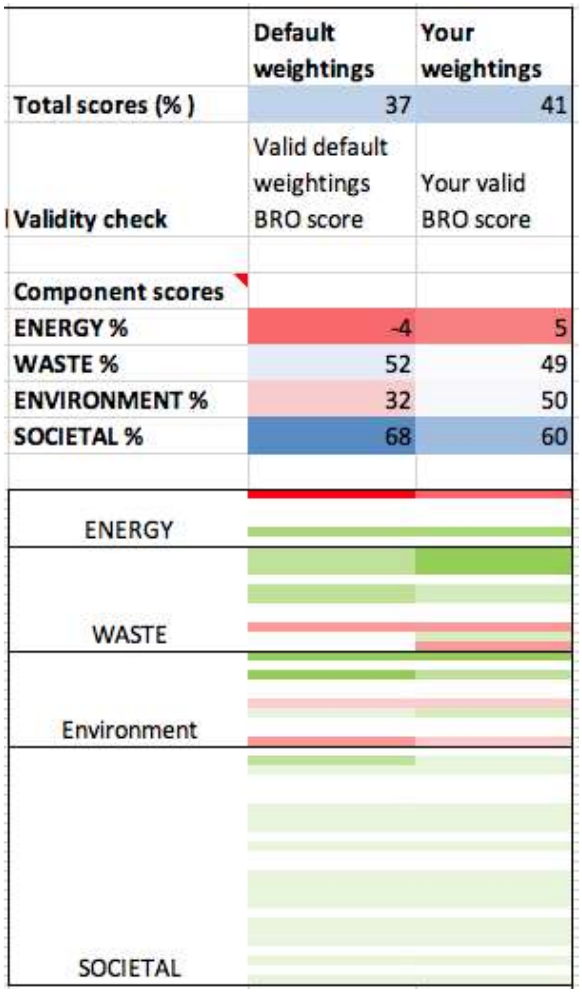

Fig. 1: Output scores from BROADSEAT as applied to the Falkirk dewatering trial [2].

25 for all factors/categories in each group. Thus the maximum (or minimum) possible score overall is 100 (or minus 100). The scores for each factor are shown as a radar plots (Fig. 2). Here each factor ranges

between 100 and minus 100. The cells containing the scores for each group and the overall score are colour-coded, blue (higher) through white (same) to red (lower). The example used here is for the Falkirk trial where clean dredged canal sediment was allowed to dewater naturally before being planted with grass seed. The results illustrating the possible trade-off between energy use and the waste, environmental and societal benefits of the BRO compared to the BAU, in this case natural dewatering and phyto-conditioning of sediment to make topsoil, rather than disposal to landfill.

Discussion: The BROADSEAT tool is designed to compare the merits of your Beneficial Reuse Option to the Business As Usual case in an objective and comprehensive way. It avoids having to have actual numerical values for factors. You decide whether the BRO is better, worse or the same for a particular factor using your professional judgement or stakeholder opinion and preferences. This in turn means that actual data (e.g. tonnes of CO_2, miles, areas, species etc) are not required. This avoids having to make the very difficult numerical conversions between different units or factors, which may not be readily quantifiable, e.g. extra transport distance versus flood risk protection gained, extra cost versus biodiversity gains). It is your answer, there is no right answer, different people will score the same project in different ways, reflecting their own perception or profession.
The English version of the BROADSEAT model is available to download and use via a permanent DOI [1] and a French translation is currently in preparation.

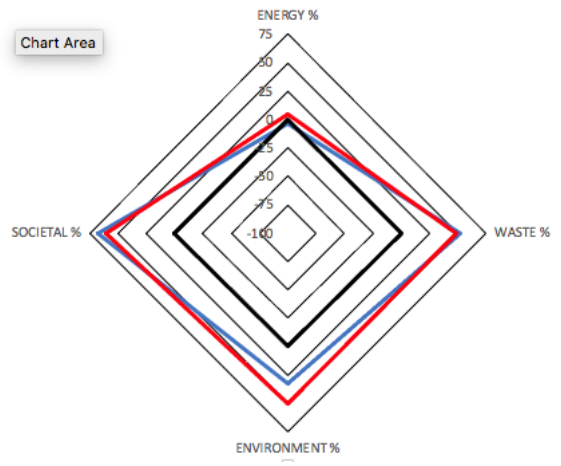

Fig. 2: Output radar plots from BROADSEAT as applied to the Falkirk trial [2], for default blue) and bespoke (user-defined) weightings (red).

Acknowledgements: The BROADSEAT tool forms part of the project deliverables for Work Package T1 Deliverable D2.1 of the SURICATES (Sediment Use as a Resource In Circular And Territorial EconomieS) Interreg Project NWE 462 funded by the European Regional Development Fund [3]-[5]

References: [1] Lord R. A. & Torrance K (2021) DOI: 10.15129/2e620d12-44bc-42fb-9b14-b0e89a8a7457 ;
[2] Harrington et al., (2022) *J Soils Sediments* **22**:2900-2911;
[3] https://www.nweurope.eu/projects/project-search/suricates-sediment-uses-as-resources-in-circular-and-territorial-economies/
[4] https://www.linkedin.com/company/suricates-project/
[5] https://twitter.com/SuricatesNWE

Sediment management in Lake Trakoščan, Croatia - an example of the social and economic aspects of sediment long-term impacts

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Conference theme number(s): 2

Introduction: Trakošćan Lake is an artificial lake located next to the Drašković family castle of the same name. The castle is in the north-western part of Croatia and is one of the most attractive in Croatia, it was first mentioned in written documents back in the 14th century. At the beginning of the 19th century, Count Juraj Drašković restored it into a residential castle, which in its present form represents a preserved ensemble of the romantic park and residential architecture.

Lake Trakošćan was built in the period from 1850 to 1862 as a pond and landscape addition to the castle, and fish was bred in it. The topographic catchment area of the lake is 10,7 km2, it is about 1,5 km long, and its area is about 17 hectares, with an average depth of about 2,5 meters. The lake's total volume was originally 400,000 cubic meters. [1]

Fig. 1: Lake and Trakošćan castle [1]

Methods: In the beginning, the lake was emptied every two to three years, silt was picked up and deposited in the fields to improve soil fertility, and after filling the lake with new water, restocking was carried out. This was the case until the end of World War II, and the silt was no longer removed from the lake. After 61 years, the lake was drained at the end of 2021, and in 2022 work began on sediment excavation to improve the lake's ecological condition due to about 200,000 cubic meters of deposited silt in the lake. The estimated depth of the lake averages around 6 meters after removing the excess sediment.

To preserve plant and animal habitats, a part of the lake that will not be touched is separated. It was estimated that there are as many as 9 tons of fish in the lake. The fish was caught and selected by an authorized fish owner, indigenous species were moved to another water pond, and allochthonous species were disposed of as provided by the appropriate documentation, management plan and conditions of the Ministry of Agriculture, Fisheries Directorate. indicated.

The entire project is under the jurisdiction of Hrvatske vode (Croatian Waters), a public water management company in the Republic of Croatia. The project is worth about 2 million euros, which includes two contracts – a contract for works worth HRK 1,87 million euro based on an estimate of 200,000 cubic meters of sediment and a contract for a professional supervision service worth 15.600 euros. The planned completion of the project was by the end of winter 2022. [1]

Fig. 2: Drained Lake Trakošćan

Results: Geotechnical research and laboratory testing of sediment samples was carried out during 2019 and this results with sediment quantity estimation were published in Geotechnical study [1].

Discussion: Although the work was announced much earlier, there were a series of delays. First, the contractor had to make a temporary barrier (dam) on the final part of the lake, at the mouth of Čemernica stream, to ensure that 20 per cent of the area remained an untouched habitat. Also, the fish needed to be "moved" out of the lake. The downtime was due to waiting for an annex to the Management Plan contract.

References: [1] https://www.jutarnji.hr/vijesti(2021), [2] Geokon Zagreb d.d., (2019) *Geotechnical study on conducted research of the sediment thicknes, sediment composition and water quality in the Lake Trakošćan*.

Exploring the remediation of contaminated sediments

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Conference theme number(s): 5 & 1

Introduction: In line with the European Water Framework Directive, Flemish authorities have addressed major issues with respect to the impact of pollution from urban waste water and industry on surface and groundwater at the level of river basins. Historic contaminated stream sediments and those currently deposited are also known to negatively impact the water quality, and often spread gradually downstream causing damage to vulnerable ecosystems. Although the role of contaminated stream sediments has been acknowledged by authorities, an integrated approach to remediate and manage sediments is lacking. Such an integrated approach by means of a dedicated software tool is the topic of the current paper and has been put to practice in a collaborative project between VITO, the Flemish Institute for Technological Research, and OVAM, the public waste agency of Flanders. The project aims were twofold; 1) to identify potentially critical sites that allow decision makers to prioritize in efforts on further investigation, remediation and management of, and 2) to perform a cost-benefit analysis to inform the Flemish government about the societal costs and benefits of remediation in general and for specific areas as part of an integrated approach for sediment and water management.

Methods: In Flanders, sediment quality data are collected by different local and regional authorities for different purposes. To support the decision making process on further examination, remediation and/or management of sediments, a web-based spatial tool called Sediment explorer (dutch. Waterbodemverkenner) was developed, that collects data from these authorities and from publicly available sources. The tool considers data on the level of contamination (i.e. sediment quality) at measurement locations, spatial data mapping of the potential environmental risks (i.e. variables representing the quality of the aquatic ecosystem and riparian zones) and the potential for sustainable remediation (e.g. variables representing the chance for re-contamination) when contamination occurs. A weighted score is determined based on the relevant technical and environmental variables per stream in Flanders to derive the remediation priority of streams. A cost-benefit analysis is performed to compare costs for research and remediation with benefits for water quality, and reduced remediation costs downstream if complete or partial remediation of the identified contaminated sites is achieved.

Fig. 1: *Waterbodemverkenner tool developed to share data and harmonize assessment of contaminated sediments.*

Results/Discussion: About 40% of measured sites show signs of physico-chemical contamination with significant ecological risks but also often high chances on sustainable remediation if appropriate measures are taken. The cost-benefit analysis indicates that only 60-90% of all costs can be compensated by the benefits of remediation. Best cost-benefit ratios are achieved when focusing on pollution hotspots near protected natural areas or urban settlements. Limited direct benefits of remediation suggest that additional incentives need to evoke remediation. It is therefore a strong plea for targeted prioritization and a location-specific approach. Consider it is an integrated project approach where sediment remediation is not an end in itself, but a necessary precondition to achieve or safeguard other functions. For example, during urban development in cities or river restoration projects within protected nature areas.

Local and regional authorities can consult, analyze and get insight in the prioritization and cost-benefit results through the web-based tool 'Waterbodemverkenner'. It has proven to be a very useful instrument to not only involve different stakeholders in the decision making process but also help streamlining operational activities between different authorities.

Please submit your abstract before the 15th of January 2023 to the SedNet secretariat: secretariat@sednet.org.

The fluvial sediment quality monitoring in the context of the implementation of 2030 Agenda in Portugal: a study in N Portugal

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Conference theme number(s): …..

Introduction: Sediment have a complex and dynamic role in a variety of ecosystem functions and services, in all aspects of the ecosystem's quality and health services, which can be positive, or negative, and that must be addressed in the management of fluvial systems at the hydrographic basin scale. Portugal, when implementing the 2030 Agenda into its national strategies, identified as priorities for SDG action with an environmental dimension: the climate change (SDG 13) and life below water (SDG 14). From all the SDG indicators being monitored at a national scale, a few are directly linked to ecosystem monitoring, management and protection (INE, 2022). The good status/ecological potential and the classification of the chemical status of surface water bodies are addressed in target SDG 6.3.2, but no evaluation is available, too short, or irregular and/or inconclusive. The targeted mean area that is protected in freshwater sites, important to biodiversity, is addressed in SDG 15, but significant challenges remain to achieve this target (Sachs et al., 2022). Anthropogenic wastewater treatment (SDG 12), as well as the proportion of municipal waste prepared for reuse and recycling (SDG 15), are targets that, indirectly, are a means of protection of freshwater ecosystems. For the latest, major challenges remain to progress on the indicator.

In this context, the present study discloses valuable information on the chemical quality of riverbed sediment from two medium-sized mountainous catchments (ca. 300 km2), located in northern Portugal, in relation to land management. Moreover, it highlights the need to include regular sediment monitoring, as an indicator of the fluvial ecosystem's quality assessment, in management plans. The conducted investigation aimed to evaluate the contamination of sediment by and to assess the ecological risk associated.

Methods: Composite samples of riverbed sediment (0-2cm: oxic layer) were collected at the end of the dry season (DS), and at the end of the rainy season (RS). The fraction <63µm was separated by wet sieving and studied for As, Cd, Co, Cr, Cu, Ni, Pb, Zn and V. Total contents were determined after aqua regia digestion. To assess potential mobility and possible origins (natural and or anthropogenic), a sequential chemical extraction approach, modified from Tessier et al. (1979) was used, considering five geochemical fractions. The elements' concentrations were obtained by ICP-OES. The sediment quality guidelines – SQGs - for freshwater ecosystems were considered, and the risk assessment indices were calculated, to assess the environmental risk associated with total and labile contents of metals.

Results and Discussion: The studied catchments are subject to different microclimates and anthropogenic pressures: a) River Vizela catchment, located in the Northwest, has a strong industrial component in the textile sector, the agriculture has a strong component in milk production and a crop system subject to animal manure application; b) the River Vilariça catchment, in the Northeast, has a strong agricultural component focused on the production of vegetables, vine and fruit trees, with increase intensification due to the strengthening of the Irrigation System. The results showed that Cd, Pb, and Cu presented higher potential risk of mobility to the water column and represent a potential threat to the aquatic ecosystems. For Cd in particular, this potential risk is confirmed by its contents concentrated mostly in the soluble phase, as an exchange cation, above PEL values in the dry season, in both catchments. According to the Risk Assessment Code (RAC) data, Cd was the most labile metal in the sediment samples and represents a very high ecologic risk, in a significant part of the samples. Copper, Pb e Zn represent medium risk.

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Towards sustainable sediment management and estuary functioning of the Upper Sea Scheldt based on a state of the art modelling approach

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Conference theme number(s): 3 – 5 – 6

Introduction: The Upper Sea Scheldt (Flanders, Belgium) is the upstream part of the Scheldt estuary. The estuary extends from the North-Sea in the Netherlands to the shipping locks in Ghent, with a total length of 160 km. It is characterized by a high suspended sediment concentration which has a detrimental effect on light penetration (and hence primary production). This is partly the result of intensive dredging and sand extraction. In 2016 a 'Sustainable Management Plan' has been implemented for the Upper Sea Scheldt. In this strategy the dredging activities are directed to the zones where waterway sections need to be managed for navigation purposes. In addition, several pilot projects are realized in which sediment was successfully reused to reshape sections and divert currents to maintain these sections [1]. These actions however are not sufficient to tackle the challenges the system is faced with due to continued dredging practice more downstream in combination with the cumulative effects of other works.

Methods : With the 'Integrated Plan Upper Sea Scheldt' De Vlaamse Waterweg, the responsible waterway manager, aims at improving the ecosystem functioning in combination with habitat improvement and navigation functions. To develop and evaluate the Integrated Plan a state of the art modelling instrument [1] (including a hydrodynamic model, sediment transport model, ecosystem model, higher trophic level model and nautical evaluation) combined with systems theoretical approaches was developed. It was used to learn about the system response to changing boundary conditions and physical interventions. Various measures (i.e depolderings, bend cut-offs, flood control areas with controlled reduced tide, narrowing of the main channel, flood gullies) have been combined into three alternatives (1: minor adjustments to the river, 2: including limited depolderings and bend modifications, 3: larger depolderings and more extreme bend modifications) and evaluated with the modelling instrument.

Results: The integrated analysis of the results of the three research alternatives proved that depolderings are an effective way to mitigate the challenges the estuary is faced with. Besides a reduction of the tidal range, the depolderings also act as a sink for sediment, resulting in a drop in suspended sediment concentrations. This in its turn has a positive effect on the light climate and primary production. Based on a long-term morphological assessment it is expected that the large-scale measures have a long longevity.

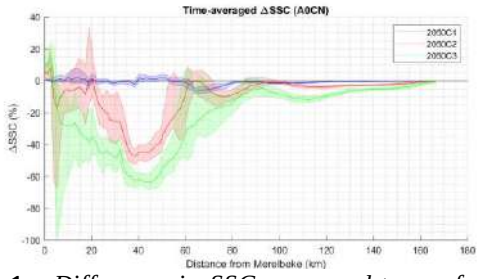

Fig. 1: *Difference in SSC compared to a reference situation (in %) for the three researched alternatives [2]*

Discussion: In the investigated alternatives, a large set of measures are included. In practice, a more gradual realization/implementation of depolderings is more likely and also desired. A gradual construction allows for settling of sediment in order to create a desired mix of habitat types and prevent drowning of certain habitat types. The results from the model instrument also indicate that depolderings are beneficial with respect to flood protection and can compensate for a shortening of the estuary (introduced for navigation). The results from the modelling instrument will be further used to formulate a vision for a sustainable and balanced multifunctional system.

Acknowledgements : We would like to acknowledge the contribution of our partners Flanders Hydraulics, University of Antwerp, Research Institute of Nature and Forest in the development of the modelling instrument and definition of research alternatives.

References: [1] De Beukelaer-Dossche et al. (2022) *Martec Proceedings;* [2] Bi et al. (2021) *FHR Reports, 13_131_18*

A nation-wide survey of polluted sediments in Sweden

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Conference theme number(s): 1 or 5

Introduction: To achieve a healthy water environment in Sweden there is a need of increased activities related to identification, investigation, and remediation of contaminated sediments. As part of a government mandate, initial investigations have been performed in selected sediment areas across the country. The objectives with the survey were to contribute to an improved national overview of contaminated sediments, and to provide a basis for further development of a methodology for prioritization and initial investigation of sites with contaminated sediment. The outcome of the survey is briefly presented here.

Methods: Study areas along the coast, in lakes and waterways were selected based on the water administration's risk assessments, known sources of emissions and local hydrological and geological conditions. The selection was refined in consultation with representatives from the County Administrative Boards. The approx. 70 sites that were selected (Fig. 1), as well as 15 sites for a separate survey of lake Vänern, were investigated using hydroacoustic methods to select suitable localizations for sediment sampling. Surface (0-5 cm) and deeper (15-20 cm) sediment layers were analyzed for metals and organic pollutants (e.g., PAHs and PCBs). Moreover, a wider range of substances such as PFAS, chlorinated pesticides and pharmaceutical substances were selected based on the assessed impact at each area. Degree of contamination was reviewed for substances with national environmental criteria. At selected areas, tests for toxic response (CALUX, Chemical Activated LUciferase gene eXpression) were carried out regarding dioxins, PAHs and estrogen-like substances.

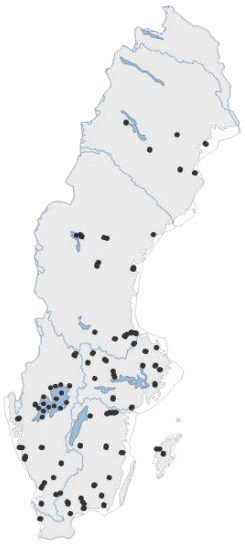

Fig. 1. Investigated areas in Sweden.

Results: Metals and PAH were occurring in elevated levels at sites in the vicinity of urban areas, harbors, and larger industries. PFOS and substances with risk being enriched higher up the food chain, such as PCBs and dioxins, were also frequently detected. The pattern for the different dioxin congeners varied among the areas and may provide information for further studies of sources to pollution. The toxic response measured by means of CALUX generally co-varied with measured levels in the chemical analysis of the respective substance group.

The results of the investigations are presented in field reports [1][2], and yet another field report and summary report will be published later in 2023 (in Swedish with English summary) available at renasediment.se. Analysis data is reported to the open data hosting for sediments at the Geological Survey of Sweden.

Discussion: The surveys have contributed to the national overview of sediment pollution in Sweden, and with increased knowledge about methodology and choice of parameters for further work with prioritization and investigation of sediment. A thorough review of information on potential pollution sources and sediment geology is crucial for prioritizing suitable areas for investigation, especially in watercourses and highly impacted urban areas. Hydroacoustic measurements proved to be essential to understand the conditions at each location and to select appropriate sampling points. The results also show that toxicity tests may be a useful complement to chemical analysis and a tool for the interpretation of total load of substances that have similar effects and impacts on the benthic environment.

Acknowledgements: We are most grateful to all participants in the project and to representatives at the County Administrative Boards and employees at NIRAS Sweden AB for the contribution to site selection and field work respectively.

References: [1] Larsson et al. (2021) *SGU-report 2021:21*. [2] Norrlin et al. (2022) *SGU-report 2022:16.*

Sediment remediation pays off: Socio-economic analysis and cost disproportionality of measures using the example of the Elbe river basin

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Conference theme number(s): 5. Sediment management concepts and sediment policy

Introduction: A shortcoming in the implementation of the Water Framework Directive (WFD) in the international river basin of the Elbe is that a river basin-wide analysis of the most cost-effective pollutant remediation measures to improve sediment status has not yet been carried out, resulting in a lack of measures for reasons of cost disproportionality. This inevitably leads to the problem being merely shifted within the river basin, as can be seen, in the persistently high pollutant loads in the sediments of the Elbe catchment area and their transport to the North Sea. Here, as in many river basins across Europe, deficits in sediment quality are significant obstacles to achieving the goals of the WFD and the Marine Strategy Framework Directive (MSFD). Better sediment quality is therefore an important step towards good ecological and chemical water status or good status of the marine environment [1].

As a result, integrated sediment management concepts were developed some ten years ago [2], which identify coherent measures to achieve supra-regional management objectives. However, to date, not a single effective sediment remediation measure has been implemented through the WFD programme of measures.

In particular, the consideration of economic effects in the selection of cost-effective measures and the determination of the cost disproportionality of measures still cause problems in Europe. Up to now, there has been a lack of application of suitable methods and thus also of experience with their use. In Germany, a river basin-wide coordination of measures and exceptions is particularly complex due to the federal structures.

According to the current legal situation in Germany, the federal states can decide which measures they want to implement in order to comply with the WFD. This leads to a prioritisation of locally effective measures in particular. The costs incurred are directly offset by a corresponding local benefit. On the other hand, remediation measures that would only have a positive effect in downstream water bodies and the sea are classified as "disproportionate costs" by the responsible federal states. The situation is similar in international river basins, where downstream riparians depend on measures being implemented upstream to remediate pressures at source.

Methods: But how would the proportionality test turn out if the local costs were compared with the benefits in the entire river basin, as is actually intended by the EU in the sense of integrated river basin management according to the WFD? Our study clearly shows that remediation is worthwhile, here and now, in order to achieve a good condition of the waters and the marine environment. A toxic-free environment by 2050, as envisaged in the EU Commission's ambitious zero pollution strategy, cannot be achieved in the Elbe river basin without remediation of sediments - probably not in other river basins either. Looking to the future, the investments are even more worthwhile - we will need clean sediments to protect the coasts from sea level rise.

But how do you solve the problem that, according to the current legal situation, the regularly high costs of remediation measures have to be paid by just one party, even though everyone benefits? The answer: share the burden. In a first step, through a solidarity fund in the river basin community, in which a supra-regional, internalised financial compensation is created that also reflects the benefits for the individual federal states. In a second step, a financing concept should be sought that also takes into account the 'polluter pays' principle [3]. Such funds are currently very popular, for example to finance the elimination of trace substances in wastewater treatment [4] or special European funds to cover the costs of pollution from the main pollutants and polluting sectors.

References: [1] CIS (2022) Integrated sediment management; [2] FGG Elbe (2013) Sedimentmanagementkonzept, IKSE (2014) Sedimentmanagementkonzept; [3] European Court

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Policy solutions for management of contaminated sediments in the EU

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Conference theme number(s): 5

Introduction:
LIFE SEDREMED project aims to promote the interinstitutional debate to develop a uniform and clear legislative framework for the identification, classification, and management of contaminated sediments. The Environmental Quality Standards directive and the Italian law fail to provide extensive sediment-specific pollutants concentrations limits.
Unfortunately, as of today the Italian law only foresees detailed guidelines for dredging interventions and thus does not answer the needs of environmental operators when working in an area that has contaminated sediments but does not need dredging (as in Bagnoli).
A specific divulgation event was organized on the 9th of February in Brussels and saw the participation of DG ENV, the Italian Ministry of Environment, the Swedish Geotechnical Institute, Rijkwaterstaat (NL), the Flemish Waste Management Agency (OVAM), the Wallonia Ministry of Environment, the Finnish and Italian Permanent Representations to the EU together with other experts from industry and academia. This event was also the occasion to build on the work realized by SedNet and summarized in the CIS document connected to the implementation of the Water Framework Directive. The main question that was addressed by experts is: **Do we need an EU-wide intervention on sediment management or are national policy and regional cooperation more suitable to address the topic?** The European Commission confirmed that "*Defining EU restoration thresholds at European level concerning environmental assessment, unfortunately, wouldn't take into consideration the other environmental and socio-economic impacts of restoration intervention".*
It also sponsored regional cooperation as an excellent tool for policy coordination at sea-basin level recognizing however that there is a high disparity between the activities of HELCOM (Baltic sea) and OSPAR (North sea) compared with the Barcelona Convention (Mediterranean sea) where, given the presence of several non-EU countries, *"it could be very difficult to set standards higher or more detailed than what is required by EU legislation.*
Sweden, Flanders and the Netherlands confirmed that they share the same kind of approach, through determination of sediment specific EQS and "trigger values" at national level but also by developing site-specific risk analysis that allows to take into consideration also different aspects that cannot be taken into account at EU level such as area destination, specific pollutants and financial expenses.

Methods: The SedNet conference will allow us to organize a second roundtable to deepen the thematic and continue the discussion in order to better integrate the expertise from SedNet and prepare the work for the next LIFE SEDREMED institutional event that will be organized in Rome together with the Italian Government in the first semester of 2024.

Expected Results and Discussion:
More detail on the event will be soon accessible on our website, but in the meantime, we report hereafter our preliminary discussion: We consider as useful an inter-institutional debate to evaluate the definition of sediment-specific EQS at European level to align all Member States on a common benchmark for sediment classification and management. These pan-European EQS could be completed with EU targets for the prevention of sediment contamination that include pollution reduction plans specifically dedicated to sediments. Then at regional level (sea-basin cooperation) and national legislation can provide the possibility of defining more stringent limits and including additional specific substances associated with more detailed management guidelines. At the national level, EQS could be transformed into "intervention thresholds" and the application in parallel of site-specific risk analysis processes to define the details and objectives of intervention projects according to final use of the areas and the socio-economic aspects. This could enable to implement decontamination/management plans using the BATNEEC approach (Best Available Techniques at Not Exceeding Excessive Cost). The objective is to integrate and support SedNet work in the process for policy innovation in the field of sediment management.

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A new methodology for prioritisation and initial investigation of contaminated sediment in Sweden

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Conference theme number(s): 1, 5, 8

Introduction: There are approximately 86,000 potentially contaminated areas on land in Sweden. The number of contaminated sediment areas is still unknown, but there are likely tens of thousands of sediment areas with varying degrees of contamination level. A new methodology has been developed by Swedish authorities with the objectives to identify potential contaminated sediment areas, to prioritise among the potentially most serious areas, and how to initially investigate the areas (Figure 1).

Fig. 1: The different steps in the methodology.

Methods: The starting point for the identification phase is to assign a *sediment class* to all objects in EBH-Stödet (the Swedish national database of contaminated areas), based on the industry's potential to contaminate sediment. To identify the most potentially contaminated areas affected by several industrial activities (sources), the total emission load to the aquatic environment is calculated for each water area in the country (Figure 2). By categorising all the sources for each area, the contaminants that can be expected to be found in the sediment are principally identified. The investigation is divided in two phases. The initial investigation phase is to verify the sources potential load on the water body based on historical data and physical parameters. The second investigation phase consist of a field survey with the aim to verify if the sediment is negatively affected.

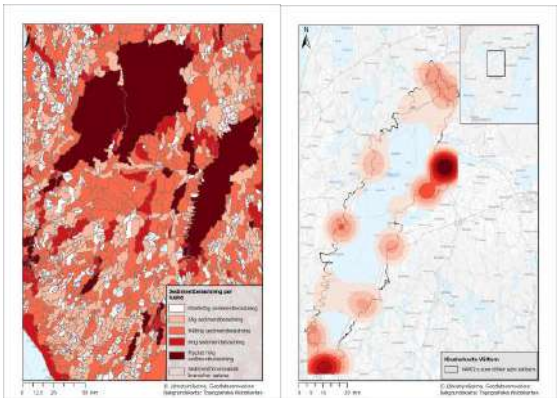

Fig. 2: The left figure shows the total emission load of industrial activities for all water areas. The right figure shows areas in Lake Vättern where the industrial emission load is high.

Results: Maps of the emission load at larger lakes clearly show where areas contaminated sediments can be expected (Figure 2). The emission load maps are very helpful in prioritizing where to focus the sediment contamination identification.

Discussion: The primary aims of the methodology are 1) to facilitate and coordinate the prioritisation and initial investigations of contaminated sediments in Sweden, and 2) to initiate a systematic work to identify and inventory the most serious potential sources (ongoing and/or historical industrial activity) and subsequently the most affected the water catchment areas.

With the methodology we now have a tool that can take us a big step closer to a cleaner and healthier sediment in Sweden.

The development of the methodology is part of a larger government mission to increase knowledge about contaminated sediments.

Rhône Sediment Management Master Plan between Geneva and Mediterranean Sea in order to achieve good ecological status

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Conference theme number(s): 5

Introduction: The study leading to the Rhône Sediment Management Master Plan between Lake Geneva and the Mediterranean Sea, carried out by a DREAL / CNR / EDF / Water Agency partnership, was finalized in October 2022. This is the outcome of a long process of compiling and summarizing technical, scientific and social data in order to guide management and restoration measures for the river and reach 2027-2050 objectives.

Methods: These objectives are organized into 3 categories: biodiversity, safety-security, socio-economics. Biodiversity objectives are especially linked to the achievement of the good ecological status and potential according to WFD. Safety-security objectives deals with the safety of dams and the security of the populations against flood envents. The sustainability of the socio-economic uses, under climate change uncertainties, concern navigation, hydroelectric plants, nuclear power plants, drinking water production, irrigation and leisure activities.

Results: The study valued and completed the works of the Rhône Scientific Observatory of Sediment (OSR4-5 Program). The sedimentary fluxes of the Rhône have been updated, showing a good continuum for silt and sand, whereas bedload continuity is strongly affected by impoundments and run-of-the-river dams. Sediment balances has been established over the last four decades and identify degraded and aggraded reaches.

At the same time, the sedimentary contributions of the tributaries were estimated from existing watershed studies and dredging operations carried out at the confluences; the future trends of these inputs - stability, drying up or return of sediments - have been analysed, in connection with climate change and the role of implementations in these catchment areas.

Feedback from the past actions shows that for 25 years (from 1995 to 2018), nearly 300 sites have been the subject of management interventions by dredging, with a total volume of 850,000 m³/year. Flushing and sluicing dams complete the management measures. In parallel, the Rhône and its hydrosystem has been restored on around 150 sites : increase of biological flows, restoration of around 80 secondary arms, reactivation of alluvial margins, and first sedimentary reinjections since a few years.

Discussion: The means for the master plan, focusing on the previous objectives, are based on key actions, including innovative actions such as coarse sediment nourishment or morphogeneous flows. These actions must lead to better continuities for coarse sediments, that must accelerate the achievement of good ecological status (18 over 26 water bodies by 2027; all of them by 2050). The operational objective is to gradually increase the annual reinjected volume from 40,000 m³ over 1995-2018 to around 200,000 m³/year by 2030-2035, giving priority to by-passed reaches (Vieux Rhône), with high ecological value and needing to be resilient to climate change. The strategic orientations are formulated along major sectors and are accompanied by recommandations, technical toolboxes, factsheets, etc. in order to accelerate and improve the operational implementation. During 2023, this master plan will be discussed by the Rhône basin committee in order to be definitively adopted.

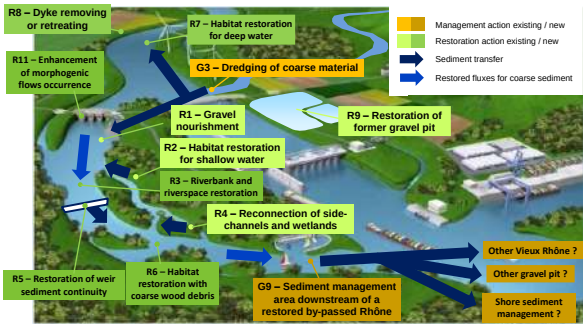

Fig. 1: Summary of sediment management key-actions to achieve better sediment management and good ecological status

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Sustainable port maintenance strategies - trade-offs between dredging cost and port call efficiency

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Conference theme number(s): 5

Introduction: Sedimentation affects water depths in port basins and port water areas. This may result in partial or full access restrictions which impacts a port's performance. Sediment management strategies in ports are typically aimed at maintaining desired accessibility levels against minimal cost. While there is a range of sediment management measures available (i.e. bypassing, sediment traps, current deflection walls, bubble screens, sailing through fluid mud, etc), dredging is still a key component of most sediment management strategies.

Especially in busy and sedimentation-prone ports, dredging can be a significant component of the port's operating cost. From a port manager's perspective these operating costs are not only related to the dredging works, but also to the dredging-related down time. So far an integral approach that quantifies the trade-offs between dredging cost and port call efficiency does not yet exist. Next to costs, port managers are increasingly confronted with the need to include sustainability into their trade-offs.

This paper discusses a method that links dredging efforts and port performance, as a function of sedimentation rates and accessibility. The approach allows to include energy use and emission footprints.

Methods: Discrete event simulation is an increasingly common tool to investigate the performance of dredging strategies [1]. Likewise port accessibility, as a function of currents and tides, is regularly investigated with discrete event based approaches [2]. So far, however, a combination of both approaches that would allow to quantify the overlaps between maintenance dredging and port operations for different strategies, has not yet been published.

In our approach we schematise ports with a graph that represents the port's water transport network. The nodes and edges of the network can contain physical properties such as bed level, water level, currents, sedimentation rates etc. Through accessibility criteria, we can derive (horizontal and vertical) tidal windows and assess how these affect the port's performance (Fig 1 – right). At the same time sedimentation and maintained-bed-level criteria can trigger dredging activities (e.g. trailing suction hopper dredging, water injection dredging, grab dredging, plouging); aimed at collecting the accumulated sediments and return the water depths to the desired levels (Fig 1 – left).

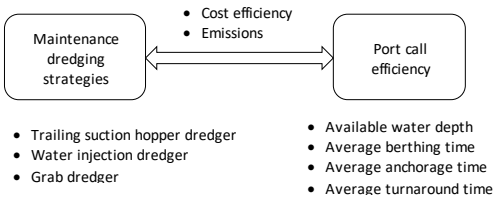

Fig. 1: Trade-off between maintenance dredging strategies and port call efficiency

By simulating the port processes and dredging activities on the same network, we can evaluate which dredging strategy is most cost effective, both in terms of minimal dredging costs and minimal disruption of the port's operations. Through vessel resistance calculations, we estimate the energy that is needed for both the dredging activities and the in-port manoeuvring of the cargo vessels. This allows us to include the sustainability of maintenance strategies, in this paper mainly in terms of energy footprints and emissions, into the above-mentioned tradeoff [3].

Results: The obtained result of this study is a trade-off analysis framework that aids the comparison and selection of the maintenance dredging strategies for a given port, taking cost-efficiency and sustainability criteria into account.

Discussion: The proposed framework enables port operators and marine contractors to design port maintenance strategies that minimize both dredging costs and port disruptions. The method includes sustainability through emission footprint estimates.

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Sediment Management for the Tidal Elbe
- between the poles of science and politics -

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Conference theme number(s): 5, 9

Introduction: As for most tidal seaports, an effective sediment management is of the essence. This is particularly the case for the Port of Hamburg at the upper tidal Elbe, Europe's third largest Port, as it faces strikingly increased sedimentation and dredging necessities after almost a decade of well below average headwater discharges. In addition, options for an efficient discharge of excessive sediments are limited, leading to an increasing level of sediment inventory within the port and the fairway.

Developments: The overall principles for an effective and sustainable sediment management for the tidal Elbe and the Port of Hamburg that could indeed face the current challenges are scientifically founded. For almost two decades now, experts have agreed on three basic objectives: 1) minimizing dredging cycles by sufficient discharge of excessive fine sediments, 2) dissipating tidal energy by river engineering and 3) reducing pollutant levels in the sediment by effective remediation of old industrial sites and targeted removal of contaminated sediment depots.

In practice, however, these undisputed objectives are facing a tremendous number of challenges.

1. Regulatory requirements for new disposal sites have increased substantially and even when all requirements are technically fully met, many politically or perceptively motivated resistances persevere. Latest example is a scientifically proved suitable disposal site near the island of Scharhörn where no societal and political agreement on its actual use could be obtained and even juridical measures were threatened on the highest political level with the effect, that Hamburg refrained from its highly needed (significant reductions of the navigable depths had already been proclaimed) use up to today.
2. Effective river engineering measures are very costly and require large areas to be remodeled. Thus, the political motivation is relatively low (costs) and the local opposition high ("not in my backyard!") resulting in even lower political motivation. So far, only the Hamburg Port Authority has built a new shallow water area, 30 hectares at the Norderelbe at the costs of 80 million Euros. Other potential sites for more "room to the river" are strongly opposed locally, lack financing, and are thus procrastinated.
3. Cleaning up the sediments can only be done effectively at the sources, before significant dilution occurred along the course of the river. Unfortunately, the negative effects of the contamination are most severe for the handling of sediments far downstream, especially for Hamburg, where 30 million Euros annually are spent on land treatment and disposal of contaminated sediments. Substantial offers from Hamburg to help with remediation upstream have so far been mostly rejected by the responsible authorities.

These challenges are also related to a profound level of mistrust in institutions and science as a new comparative study shows [1].

Prospect: As the principal objectives of the sediment management still stand, the Hamburg Port Authority is continuing its course of technical elaboration and societal discourse towards a more sustainable and need-orientated handling of sediments. Exchange and compromise-finding with the other responsible actors along the Elbe will be crucial as will be transparency and public education to improve trust in the responsible authorities and scientific institutions [2]. After all, keeping the Port of Hamburg fully accessible is of overriding importance for the prosperity and the supply, not only of the Hamburg region, but for Germany in total and beyond.

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Integrated beneficial sediment management in practice

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Conference theme number(s): 5 / 3 / 2 / 6 / 6

Introduction: Sediment is a critical natural resource. Human activities interact with the natural sediment cycle, creating areas of sediment abundance, often local and limited in extension (e.g., harbor siltation), and areas of sediment scarcity, often influencing large areas (e.g., coastal erosion). Sediment scarcity is a critical concern in various regions globally, including various densely populated and high-value shorelines of Europe. This criticality is destined to increase with climate change and can benefit from integrated beneficial sediment management practices.

Integrated beneficial sediment management contributes to re-establishing natural sedimentary processes, delivering social and economic benefits, hence contributing to sustainability. In early 2023, PIANC Working Group 214 (WG214) published a guideline report on Sediment Beneficial Use (BU), focused on identifying key catalysts to promote BU and centered on sustainability principles. In parallel, various concrete pilot and commercial projects are ongoing where integrated BU is applied in practice.

This presentation connects the PIANC BU guidelines with practical lessons learned in the field.

Methods: The WG214 PIANC guidance recognizes that BU approaches must be tailored to site-specific conditions and to regional environmental, economic and socio-legislative frameworks. The report builds on the work of previous studies and guidance documents, and highlights important factors that should be considered when assessing BU opportunities. These include: the possibility to connect supply and demand; explore BU costs and opportunities for shared costs among beneficiaries, distributing cost burdens among stakeholders enjoying the broader range of benefits; involvement of multiple stakeholders with different objectives and levels of participation, from partners to affected communities; expand the business model for BU beyond traditional cost-benefit analyses and include ecosystem services (PIANC WG 195; 2021) and life cycle considerations; and to focus on added value to the environment and communities.

Three projects, carried out in the Scheldt estuary (Belgium), will be discussed, reflecting different BU applications: restoring an eroding bank through Nature-based Solutions (R&D project Bankbuster); reclamation and redevelopment of a former contaminated site into a heritage park through clean-up and safe use of sediment (Sanitation project Fort Filips); retreat, developing a natural tidal area managing local sediment (Hedwige Polder).

These projects were made possible by applying the PIANC guidelines in practice, for examples: emphasizing stakeholder and community involvement, public-private partnerships, connection of supply and demand, realizing different complementary objectives to reach added value beyond clean-up, and availability of different financial sources. Projects were made more successful through initial advocacy efforts to gain public acceptance and support of projects. Operational experience and innovative expertise of contractors and consultants were integral to successful realizations of projects.

Results: While BU is not new, BU has not yet achieved its full potential. Numerous projects exist that provide important lessons learned to be applied elsewhere. Especially important, these lessons provide a paradigm for sediment management solutions, complemented by different financial and governance models, which can be combined to develop optimum integrated sediment management plans at local and regional levels.

This experience basis is further available to inform legislation and policies at regional, national and international levels. This is particularly important at this historical time where different organizations (e.g., the European Union or the US Army Corps of Engineers) are working to develop legislation and practices to achieve sustainability objectives.

References:

[1] PIANC (www.pianc.org) is the World Association for Waterborne Transport Infrastructure. Established in 1885, PIANC's mission is to provide expert guidance on design, development, and maintenance of ports, waterways, marinas and coastal areas.

Moving the Needle:
Beneficial Use of Contaminated Sediments in the United States

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Conference theme number(s):5, 4, 2

Introduction: Assessment and management of contaminated sediments in the United States represents a significant cost to the US Department of defense (DoD), ports and private industry impacting the nation's navigation infrastructure and affecting the free flow of commerce. Current estimates for management of contaminated sediments associated with US DOD facilities are in excess of $2B. Private industry expends $100s of millions each year on contaminated sediments and is facing multi-billion dollar clean-up costs to address contaminated sediments at legacy "mega-sites" (e.g., $2-2.5 billion for the Port of Portland in Oregon and $2-3 billion for the Lower Passaic River in New Jersey). Additionally, the USACE's navigation dredging program expends $10s-100s of millions on an annual basis managing the 10-20 million cubic yards of contaminated sediments in Federal navigation channels.

Many sediment management projects are in locations subject to the impacts of sea-level rise, where the need to develop and implement beneficial use (BU) for dredged and contaminated sediments is real and, in some cases, urgent. Currently only 30-40% of the 200+ million cubic yards the USACE dredges on an annual basis is used beneficially. The Chief of Engineers recently instituted a policy goal of 70% BU of dredged materials by 2030. There are significat opportunities to beneficially use relatively clean dredged materials and innovate beneficial uses of more contaminated sediments as well.

It is critical that the US invest in strategic planning, technology development, and creative thinking around implementation approaches to enable more cost effective and sustainable practices for the assessment and management of contaminated sediments. In 2023, US Congress directed the USACE ERDC to develop a public-private partnership focused on research, development and implementation of solutions for the assessment and management of contaminated sediments. Both the public and private sectors are motivated to advance innovation in sediment management to reduce costs, accelerate project schedules, and develop a diverse array of benefits through BU of sediments.

Approach: This presentation will summarize initial efforts in the development of a public private partnership to include findings from a recent white papers developed for Industry and the USACE on the current state of the practice for BU of dredged materials and contaminated sediments. The first of these efforts is a literature review summarizing existing programs, regulatory frameworks, and/or systems that have been developed to encourage BU of contaminated sediment across North America and Europe, identifies benefits and challenges of BU and culminates in a series of key observations/ recommendations regarding the current state of the practice and barriers to be overcome to "move the needle". A second paper summarizes the current state of the science around treatability technologies to promote the chemical and physical stabilization of contaminated sediments for potential BU. Finally, a third and related effort, underway within the USACE will summarize the current state of the science with respect to the BU of dredged materials along with limitations and barriers to help shape future regulation and policy. An overview of each of these papers will presented along with general conclusions and recommendations.

Summary: A Public Private Partnership between the USACE-ERDC and Industry is in development to support research and technology needs for the assessment and management of contaminated sediments and expand potential opportunities for BU. A series of white papers were developed to capture the current state of the science and identify information and policy gaps. Results of these efforts are summarized along with a notional path forward for a research and technology development strategy.

System dynamic plan as a comparison framework and decision model for the competent authority

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Conference theme number(s): 5.
Sediment management concepts and sediment policy

Introduction

In connection with the desire to better repurpose soil use of sediments in the Netherlands from the construction of Water Framework Directive (WFD) projects, the soil flow model was developed in the course of 2022 as a tool for improve the circular economy around soil remediation.

The system dynamic soil flow model is a system dynamics model, wich has been developed to simulate flows of soil throughout the process of extracting from, transportation and dumping or applying soil to various possible and useful destinations. System dynamics is a scientific field where mathematical models are used to study and understand behavior over time of complex systems. The model, which is currently under further development, takes into account various indicators as costs, value, emssions in order to get a more complete set of variables which are meant to improve decision making.

It is customary in the Netherlands to process all kinds of emerging materials in road and hydraulic engineering works.
In some cases, the soil flow model will break with this working method because in sectors other than civil engineering soil can sometimes be given a much better circular social value.

The destinations therefore include other sectors than the usual end use, such as the agricultural sector, tree nurseries and the brick industry and sometimes also the ceramic industry. This maintains or even improves the value of the Soil.

The basis for a well-functioning soil flow model is the knowledge of where materials are offered and where materials are requested. At this point, the national water framework directive team works with a national GIS map that includes the supply of WFD and the demand from the flood protection program, which already coordinates a lot of supply and demand.

The coordination between different parties is important because soil that is not suitable for use in civil engineering can, for example, be used very well in other sectors where other requirements are set for the soil.

The model has now proven itself in the LIFE project Co2 Sand Due to the use of the model by Rijkswaterstaat, the application is broader, making the LIFE project more interesting for the European Union The model is now being further developed in the WFD measure Floodlands Wamel Dreumel Heerewaarden and in innovation project Innova 58 where the first exercises are taking place.

Although the model for Rijkswaterstaat is in the experimental phase, it has great potential for a more sustainable reuse of all released materials.
The proposal is to include the results of using the model as a destination in the realization contracts of the WFD or to ensure that the contractor of WFD is also the contractor of the destination

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Please submit your abstract before the 1st of March 2023 to the SedNet secretariat: secretariat@sednet.org.

Fifty years of shallowing former sand- and gravel pits in the Netherlands: from win-win opportunity to major headache.

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Conference theme number(s): 5

Introduction:
What around 2008 looked like a win-win situation for applying soil and sediment from dredging rivers and later water safety measures grew to be major headache for Dutch governments. Wouter Klein Koerkamp demonstrates in his master thesis that more than 35 years of research experience of making novel lakes shallow (shallowing) was not used in 2008 for policymaking. The licensing requirement abolished in 2008 will return in 2023 aiming at more careful consideration for shallowing [1]. This presentation provides an overview of known (policy-) solutions for today's problems, that can possibly help to improve future policy.

Methods: The study is executed by mapping assumptions and its (in)consistencies under the shallowing policy in the period 1973-2023. The major juridical aspects of beneficial use for shallowing, were not studied before. For this study over 70 policy documents were coded into over 700 individual relevant text segments. As a result, dominant actors, knowledge, interactions and external events could be outlined over a period of 50 years of policy making.

Results:
The final results of the reconstruction are expected in the summer of 2023. The first results show that the main driver for the 2008 policy was the task of storing sediment (dredging rivers for navigable rivers) combined with a spatial problem (lack of possibilities) and the request for water safety. The shallowing of lakes seemed to result in a win-win situation because of the narrative of ecological quality of shallow lakes compared to deep lakes in line with the EU Water Frame Directive. However, the beneficial ecological impact of shallowing of deep lakes became a point for debate in later years [2]. Additionally the still existing 2008 policy for quarry lakes are basis for a favorable business case of the industry of mining aggregates. After mining sand and gravel it grew to be a second revenue model by applying moderately contaminated (foreign) material. Further unwanted effects are diverse, ranging from negative impact on ground water quality to loss of ecosystem services, both as a result of the application of dry soil under water in lakes [3, 4].

Discussion:
Whereas nearly 500 pitlakes emerged from the production of sand and gravel, in recent years 10-20 % of the yearly production of dredging and construction works was applied in about 100 lakes [5]. The 2023 compulsory license is expected to lead to a decrease of new initiatives for shallowing [1]. On the short-term, capacity for application is available in ongoing initiatives. The problem of lack on possibilities for application of material will probably arise again. Meanwhile, other 'new' aspects of the problem became more urgent such as greenhouse gas emissions from transportation of material [6]. For over 35 years policymakers searched for solutions for handling dredged material ultimately leading to the cost-efficient solution of application in lakes. This study makes clear that policymakers cannot avoid lessons learned from the pre-2008 when making integrated policies for dealing with dredged material and shallowing of lakes.

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"Once upon a time … a beach sand grain": a bed-time story and scientific outreach activity for toddlers to increase sediment literacy

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Conference theme number(s): 9

Introduction:
Scientific literacy is the ability to use scientific knowledge to identify questions and draw evidence-based conclusions to understand and make inform decisions about the natural world [1].
NSTA affirms that learning science in early years can foster children's curiosity and enjoyment in exploring the world around them and lay foundation for progression of science learning [2]. Recent works have identified that storytelling is an effective way of communicating geoscience with children (e.g. [3]).
Here, we present an example of a tailored pre-school scientific activity that is aimed to increase literacy about sediments and to show how important they are to us humans and to nature. The activity comprises a bed-time story and the observation of different sand grains, and it has been developed for preschoolers and adaptable for primary school students.

Methods:
The activity was structured so that basic concepts about sediments could be conveyed with adjustments to children with 2 to 8 years old, using as main theme a story about a grain of sand (the main character) and its journey from the mountains, where it was "born", to the bottom of the sea. The story develops over 12 pages, with simple phrases, accompanied with cartoon images (Fig 1). The story revolves around:
1) Erosion – the grain of sand is born larger and with more angular edges, and becomes smaller and rounder with time, distance of travel and effect of water (environment); 2) Source to sink – the grain of sand is born on the mountains, travels through rivers until it reaches the beach and will be later deposit at the bottom of the ocean; 3) Different type of sand – the story also talks about different grain composition.
Complementing the main activity there are (A) information cards that communicate about different environments where sand can be found (e.g., beaches, deserts) and the importance of sand as a resource (e.g., for construction, for leisure); and (B) different types of sand to be observed under a geology hand lens.

Results and Discussion: Until now, the activity was repeated 3 times, reaching ~30 children. It provided good results both with pre-school and primary school students, as they were engaged in the story and enjoyed handling and seeing the magnified grains.

Fig. 1: Bed-time story for creche children (age 2 to 3 years old).

In what concerns the follow up of the information, the toddlers could remember the story and relate it to nature up to 6 months. After that, toddlers forgot the story. This is expected because to effectively build science understanding, young children need opportunities for sustained engagement with materials and conversations that focus on the same set of ideas over weeks, months, and years [2]. Primary schoolers remembered the information and the story longer and more precisely.

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Long-term investigation of the morphological development of groyne fields on the two waterways Elbe and Upper Rhine

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Conference theme number(s): 5

Abstract: To enable navigation on the rivers and for land reclamation purposes, it was necessary to fix the course of the river while causing as few morphological changes as possible. For this purpose, groynes were often built in groups as regulating structures in the past. In free-flowing river sys-tems regulated by groynes, lateral hydrodynamic and morphodynamic processes still continue to interact between the main stream and groyne fields, so that groyne fields are subject to chang-es. Lateral morphological changes can lead to longitudinal changes, e.g., in riverbed elevation and water level, and thus have implications for erosion or accumulation trends of the river course. In order to assess and evaluate these changes in groyne field morphology, the Elbe has been the sub-ject of a measurement campaign for almost a decade. In particular, the aim was to gain new in-sights into how the bed elevations in the groyne field change during the study period as a function of previously known influencing parameters such as discharge conditions, geometry of the groyne field, bedload offer and vegetation. A single beam and an ADCP were used to measure bed elevation, water level, and flow velocity for 2-3 adjacent groyne fields at 8 different locations between Elbe km 188 and km 571 at mean and high discharges. Because sedimentation and remobilization of sediment also depend on wa-ter discharge, measurements were also made in a cross section near the groyne fields. For groyne fields, a procedure has been established on how to define the geometric boundaries for further examinations. For the study area and the study period of about 12 years on the Elbe, no clear sed-imentation or erosion trend could be proven by regular field measurement. This contribution gives an overview of the results of groyne field measurements at the river Elbe and an outlook on a characteristically different river section. In contrast to the sand-dominated Elbe, the Upper Rhine is gravel-dominated and shows further differences, e.g. a different gradient, nurishment, besides its history of antropogenic interventions. In the free-flowing section of the Upper Rhine, a further measurement campaign was started in 2022 on the basis of the knowledge gained on the Elbe regarding measurement concept and method.

Development of a knowledge platform on sediment in Sweden

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Conference theme number(s): 9

Introduction: In 2019, five national authorities in Sweden received a government assignment with the aim to improve knowledge about the management of contaminated sediments. Part of the assignment consisted of creating a knowledge platform to strengthen cooperation between different actors and make information about contaminated sediments available. As the assignment ended in January 2023 a knowledge platform including a website, a network for stakeholders and an expert support function for regulatory authorities have been established.

Methods: The work was carried out jointly by representatives from the collaborating authorities and included:

- structuring and visualizing the knowledge platform and its functions,
- building a website for gathering and making information available, based on requested needs expressed by actors working with sediment issues,
- creating a network for collaboration between stakeholders and authorities, and
- developing and providing expert support to county administrators and municipalities.

Results: A structure has been developed for a long-term sustainable cooperation between authorities where joint long-term goals and roadmaps are established. The work includes both knowledge building and cooperation with external actors.

A new website, www.renasediment.se ("clean sediment"), has been developed and is run jointly between the cooperating authorities (Fig. 1). The idea is that the website should serve as a gateway to useful information for different target groups working with contaminated sediments. The website is in Swedish and was published in January 2022.

A network was developed within the government assignment, inviting all interested parties to participate in a forum on contaminated sediments. Participants can choose to be part of a wider network where they receive regular information on events and news from the authorities. They may also choose to participate more actively by, for example, answering surveys or providing opinions on guidelines etc produced by the authorities. Since the beginning of 2021 more than 200 participants have joined the network. The intention is for the network to continue even after the government assignment has ended.

Finally, an expert support function has been set up to which county administrations and municipalities can turn for advice regarding projects relating to contaminated sediments.

Fig. 1. Frontpage of the website renasediment.se (2023-01-14).

Discussion: The work within the government assignment and the building of a knowledge platform have resulted in an improved collaboration between authorities and among actors that are involved in the management of contaminated sediments or policy making.

The website presents information that will also provide a broader audience a better understanding of the complexity and importance of healthy sediments. Our presumption is that knowledge building in the long term will lead to a more efficient management of contaminated sediments but also a more holistic and interdisciplinary approach. The objective is to continue to run the platform further, jointly by the collaborating authorities.

Fixing Failures or Re-thinking Futures? From Resilient Remedies to Resilient Land- and Water-Scapes

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Conference theme number(s): 4

Introduction and approach: Climate change is an existential threat, but global change is broader – human population growth, land (and water body) use change, resource depletion and waste accumulation, and their resultant habitat, biodiversity and service impacts are multi-dimensional and complex challenges facing mankind**.** As essential habitats, resources, carriers of contaminants and retainers of records, sediments play complex roles in hydrodynamic, ecological and human socio-economic systems, in which sediment quality, quantity, location and transport all control its function. Human management can change these dimensions of sediment status, impacting its roles and behavior; we manage and remediate systems to address changes and their effects.

Remediation and site re-use, including restoration and redevelopment activities, are intrinsically linked, although a disconnect between these two remains. A sustainable conceptual site, system, or basin model for remediation or restoration projects considers traditional CSM elements, as well as resource inputs and outputs, land re-use and restoration goals, stakeholder well-being, and resilience; it should include desirable and undesirable pathways of environmental, economic and social impact of management alternatives, both during and after the project completion.

Resilience and ecosystem service [1] considerations can include potential effects of re-contamination or recovery from point and non-point sources; erosional, depositional or disturbance events from ongoing, changing or extreme natural or anthropogenic processes; and potential impacts from changing socio-economic, political and infrastructure changes. Management alternatives are dictated by site conditions. They are also affected by the use envisioned for a site. Choices may limit site re-use, and how we re-use a site may affect the resilience of the alternative.

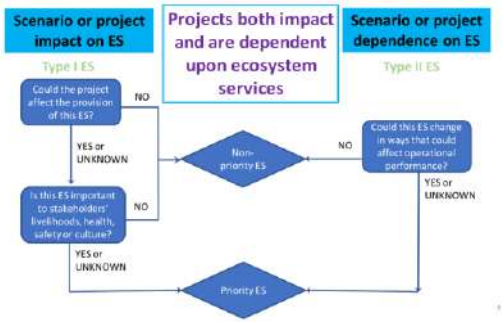

Fig. 1: Projects both impact and are dependent upon ecosystem services. Sustainable projects avoid vulnerabilities, optimise opportunities, seek to avoid impacting regional resilience, and, ideally, also seek to enhance regional resilience.

Results and discussion: While, in general, management technologies for soils and sediments may look more similar to each other than those for groundwater, many of the site characteristics that drive alternative selections may be more similar for sediments and groundwater/NAPL – both have greater accessibility and feasibility challenges than do most soil sites, and both are more strongly affected by source control issues that may drive long-term resilience. A holistic approach brings together remediation and reuse to achieve whole-system sustainability benefits, exploit synergies and minimize the costs and environmental impacts associated with bringing land back into beneficial use. Strategies for expanding the scope of management sustainability assessment, to better effect more resilient futures, will be explored.

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Towards net-zero sediment management of inland waterways – comparing embedded and embodied carbon emissions for dredging and reuse scenarios

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Conference theme number(s): 4

Introduction: Dredged sediments from inland waterways typically contain higher levels of organic matter than marine sediments (averaging 12 % solid organic matter in UK canals). Ongoing degradation releases CO_2 and the potentially more potent greenhouse gas CH_4 while the sediment is still *in situ*. After disturbance and dredging this may continue at differing rates with different proportions of methanogenesis and oxidation, depending on the type of dredging, disposal or reuse options chosen. As a consequence, attempts to manage and reduce the greenhouse gas emissions from dredging and sediment removal or relocation should consider the fate of this embedded carbon in the form of organic matter in addition to the embodied carbon resulting from operational activities and transport fuel use. The aim of this paper is to compare the embedded and embodied carbon for the annual canal dredging activity in England and Wales, together with scenarios for the likely effects of typical dredging and sediment reuse or disposal options.

Methods: The annual operational carbon emissions (embodied carbon) for the Canal & Rivers Trust provided by their national dredging team framework contract are compared with the estimated organic carbon content of the c 100,000 tonnes which are dredged annually (embedded carbon). Using the most common dredging and reuse scenarios, qualitative estimates of the relative emissions during and after dredging operations are suggested.

Results: Fuel use carbon emissions including diesel plant operation, plant mobilization, personnel travel and disposal haulage (for 55% of arisings) are estimated as 1340 tonnes CO_2 equivalent. Assuming 38% dry matter content, 12 % total organic matter on a dry basis and 58% carbon content of the organic matter, the 100,000 tonnes of wet sediment contain 2645 tonnes of organic carbon. If fully oxidized this would equate to 9706 tonnes of CO_2, so roughly 7 x the operational CO2 emissions, far greater than this if the long term storage conditions of the sediment promote methanogenesis. These calculations indicate the importance of considering the fate of embedded carbon within the dredged sediment if estimating the whole life emissions of a dredging project.

Discussion: Dredging options for UK canals include reallocation by ploughing, cutter suction and hydraulic transfer, or most commonly, pontoon-mounted excavation for barge transfer and road haulage. Arguably these represent successive increases in the expected operational emissions. Reallocation, dewatering and disposal result in similar or enhanced rates of emissions from oxidation of embedded carbon, with landfilling likely to enhance methanogenesis. However, nature-based solutions reusing sediment for soil creation and revegetation can be shown to lead to storage and future increases in soil carbon, so could be used to offset the operational emissions of dredging activity. In conclusion, using low carbon or renewable energy will not in itself achieve Net Zero dredging, so sediment managers must consider the fate of embedded carbon after dredging and reuse or disposal.

Fig. 1: Oxidation of organic matter at edges of sediment desiccation polygon, Kleiriperi, Delfzijl.

Climate Change Impacts on the Sediment Structure in the Hamburg Port -Challenges and Opportunities: Use of Fluid Mud for Navigational Aspects-

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Conference theme number(s): 4

Introduction: For future strategies in water depth maintenance in the Port of Hamburg, determining the navigability limit (i.e., the nautical safe depth) is of major importance. For this purpose, a project "Nautical Depth" was set up at the Hamburg Port Authority (HPA), which is dedicated to deal with this issue. The aim is to measure a nautical safe depth under various boundary conditions and to identify limits for a safe passage of high concentrated soil suspensions [1].
Regarding the climate change aspect, the sediment structure in the port changed in the last 10 years driven by low precipitation and discharge rates in the catchment area of the river Elbe. These changing boundaries lead to a change of the bio-geochemical composition of the sediments and the amount of suspend matter concentration within the system. This also increase the sedimentation rates and dredging amounts within the port area [2].

Methods: To identify the processes and changes within the settling of suspended material in Hamburg, several research works were carried out within the MUDNET framework of the TU Delft [3] and further works at the TUHH. One main question in the project "Nautical Depth" is the investigation of boundary conditions until which sediment properties the safe sailing of bulkers, tankers, or ultra large container vessels (ULCV) within a fluid mud condition will be possible.
Therefore, the Institute for Fluid Dynamics and Ship Theory enhances existing CFD-models to represent and calculate the forces of fluid mud on the ship hull, rudder, and propeller properties to give the basics of the adaption of ship handling simulators regarding the maneuverability of vessels within fluid mud.
The CFD-models should be validated with hydraulic model tests within the ship handling water and wave basin of the BAW. For the tests within the hydraulic model, it is necessary that the used fluid mud (or its substitute) is represented by stable and only slow changing sediment properties during the time of investigation.

Results: Different investigations of existing fluid mud material and its substitutes were carried out and the production and availability for the BAW model basin was analyzed during a pre-investigation phase within the project "Nautical Depth" of HPA. E.g., Figure 1 gives an overview of the changing fluidic yield stress (FYS) of fluid mud (FM) from the Köhlfleet Hafen area in Hamburg over the time during the consolidation of the material under conditions within the model test hall.

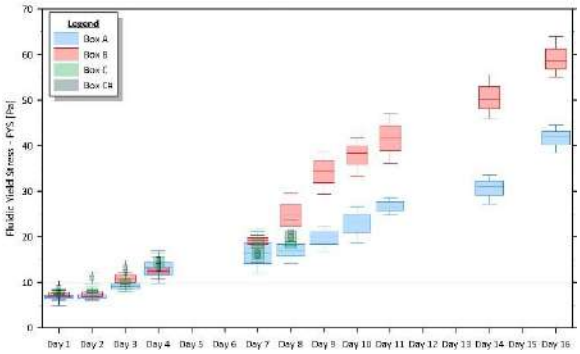

Fig. 1: Change of FYS during the consolidation within different big boxes (Box A: FM - without water overlay and undisturbed; Box B: FM with water overlay undisturbed; Box C and C#: FM without water overlay and disturbed and remixed after 7 days).

Discussion: The presentation will give an overview of the impacts of climate change on the sediment structure in the Port of Hamburg. It will show the challenges and consequences of the changed boundary conditions regarding the sediment management within the Elbe estuary. Furthermore, it will show the started investigations regarding the adaption of the nautical depth and will therefore also show their opportunities.

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The impact on sedimentation in case the Adriatic Sea becomes meromictic due to global climate change

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Conference theme number(s): 4. Climate change and sediment pledge

Introduction: Stratification without mixing of sea layers is known as the meromictic state. This condition currently prevails in the Black Sea. The fact that the Adriatic Sea is prone to meromictic conditions is evident from the periodically increased organic carbon content in Holocene sediments. The Adriatic Sea exhibited many periods of benthic anoxic/hypoxic conditions. The last one occurred only 1650 ±100 years B.P. as determined by ^{14}C AMS dating of sediment cores [1]. The organic-rich sediment layers are associated with periods of warm climate and elevated sea levels. Mangini and Schlosser [2] have shown that the Adriatic Sea is very sensitive to small increases in water temperature (0.7 °C) or small decreases in salinity (0.2) that could cause stratification of Adriatic water masses. The ^{18}O stratigraphy has shown that the anoxic conditions in the Adriatic Deep-Sea Water (AdDW) cannot be attributed solely to increased freshwater input from the Adriatic rivers, nor to increased primary production [2].

The stratification of the water column requires more energy to break the thermohaline and mix the water layers. This could make it increasingly difficult to ventilate the lower layer. If the Adriatic Sea drastically changes its properties and becomes meromictic, the lower layer will become increasingly hypoxic, hindering the decomposition of organic matter and restoring the organic-rich sedimentation.

In the last decade, and especially in the last five years, the increase in temperature and salinity in the Adriatic Sea has accelerated along the entire water column. This could be both a sign of the inflow of warmer and less oxygen-rich deep waters from the Aegean Sea into the Adriatic Sea or a consequence of the ongoing warming and salinization of the entire Mediterranean Sea. Progressive warming of the upper layer combined with an increase in salinity in the lower layer of the Adriatic Sea will result in more stable thermohaline. This event will trigger a chain reaction on the Mediterranean Sea. One of the expected consequences will be destabilization and release of methane hydrates (MH) in the Mediterranean Sea, which will further exacerbate global climate change [3].

Methods: Trends in the Adriatic thermohaline formation will be assessed by evaluating existing data on vertical profiles of temperature, salinity, and oxygen over the last two decades throughout the water column of the Adriatic and Ionian Seas. Existing vertical current meter profiles will be analysed to determine trends in the water flux. Sediment cores will be analysed to identify reduced oxygen content events in Holocene sediments. A hydrodynamic model will be created to estimate the downward flux of water during winter and in events of strong bora winds in the northern Adriatic. MH stability estimates compared to temperature and salinity trends will also be evaluated.

Results and Discussion: Over the past two decades we have observed an abrupt increase in the average temperature and salinity of the AdDW. The temperature increased from 12.6 °C (until the 2000s) to 13.9 °C (currently), while the salinity increased from 38.6 to 38.9. The AdDW is formed by the contribution of dense water from the northern and southern Adriatic, formed due to cooling by the intense bora wind during the winter months. The AdDW, which is denser and more oxygenated than the adjacent Mediterranean water, overflows into the Ionian Sea and then into the Eastern Mediterranean Sea, filling and ventilating the deep layers and promoting the existence of the benthic ecosystem. The modification of the AdDW characteristics in the late 1980s and early 1990s [4], dramatically changed the hydrodynamic situation of the entire Mediterranean basin. If the trend of warming continues and leads to oxygen depletion, most bottom-dwelling marine fish will disappear, with direct economic consequences for fisheries. In addition, MH could become unstable in the surface sediments of the Mediterranean Sea, further contributing to global warming.

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Port Sediments as Carbon Sink and Source

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Conference theme number(s): 1, 6

Introduction: Sediment organic matter (SOM) originates from autochthonous planktonic biomass [1, 2] or allochthonous sources such as eroded topsoils or effluents from wastewater treatment. In tidal systems such as the Port of Hamburg, allochthonous SOM is also imported with the upstream transport of marine sediment [3]. Microbial degradation of SOM is part of the natural carbon cycle and depends on the amount and lability of SOM, the environmental conditions driving microbial activity and the availability of terminal electron acceptors [4]. Depending on the latter, carbon can be released as CO_2, or, in addition, as CH_4, strongly changing the climate impact of SOM degradation. This study investigates the degradability of SOM and quantifies differently and non-degradable SOM pools in the tidal river Elbe.

Methods: Sediment was sampled every two months in 2018-2020 from nine locations along an upstream-downstream gradient through the Port of Hamburg. Standard solids properties, anaerobic and aerobic decay of organic matter and SOM pools based on degradation kinetics were analysed as described in [5].

Results: Total organic carbon (TOC) contents averaged around 4% (Fig. 1, left) and correlated closely with total nitrogen (TN), with 80% of all TOC/TN ratios between 7.4 and 10. The ratio of aerobic to anaerobic C release averaged around 3.5-4.5; however, also very high rations >15 were observed (Fig. 1, right).

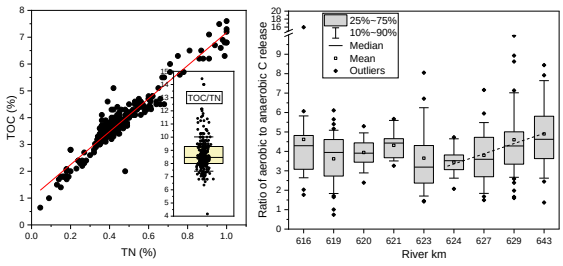

Fig. 1: Ratio of aerobic to anaerobic C release in 21 days per location P1 (left) to P9 (right).

Between km 624 and 643, a systematic increase in the ratio was observed. At all locations, the non-degradable pool 4 was the largest (Fig. 2 bottom right), for both, anaerobic and aerobic conditions, comprising around 67-85% (aerobic) and 78-85% (anaerobic) of TOC. This means that only 15-25% (anaerobic) or up to 33% (aerobic) of SOM is degradable. The fast pool 1 was only found at phytoplankton-fed upstream sites. While the medium degradable pool 1 decreased towards downstream, the slowly degradable pool 3, thought to be associated with mineral-bound SOM, did not show any spatial gradient and is assumed to represent a baseline of hardly accessible SOM (~12-16% of TOC).

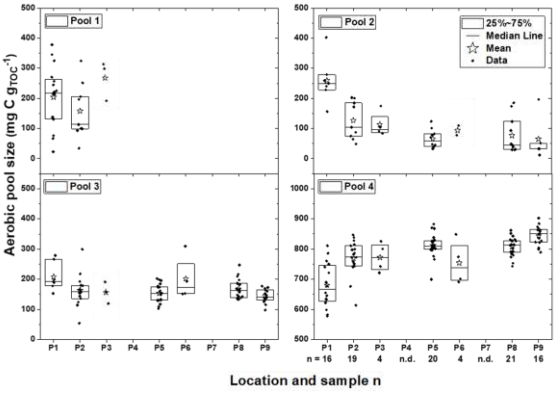

Fig. 2: Aerobically degradable SOM pools per location P1-P9 [5]. Line: med, star: mean, box: 25th, 75th percentile.

Discussion: Fine grained port sediments contain large quantities of recalcitrant, non-degradable SOM and hence present a large storage term for organic carbon. Aerobic decay on average releases by factor 4.5 (short-term) to 2 (long-term) more C than anaerobic decay (max. factors of 25 observed). Bringing anoxically buried sediments in contact with oxic conditions may hence result in increased release of organic carbon. The data of this study provide the basis for C foot-printing and balancing questions, when coupling SOM decay to in situ temperatures.

This study was funded by Hamburg Port Authority and was carried out within the MUDNET academic network. https://www.tudelft.nl/mudnet/.

References: [1] Wolfstein et al. (2000) Estuar Coast Shelf Sci 51: 651-662; [2] Grasset et al. (2018) Limnol Oceanogr 9999: 1-13; [3] Kappenberg & Fanger (2007) GKSS report 2007/20; [4] Arndt et al. (2013) Earth Sci Reviews 123: 53-8; [5] Zander et al. (2022) Limnologica 96: 125997

Residual sand and mud transport in the Scheldt estuary derived from the sediment balance

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Conference theme number(s): 4, 5, 6

Introduction: Sediment transport is important for several estuarine functions. The morphology determines both the tidal propagation in the estuary and the port accessibility [1]. Suspended sediment influences the light penetration in the water column and therefore it is crucial for ecology [2]. The residual sediment transport is crucial for the future evolution of the estuary. To visualise this residual sediment transport on a longer time scale (years), a sediment balance was calculated for the Flemish part of the Scheldt-estuary.

Methods: The sediment balance is calculated starting from the principle of conservation of mass applied to a simplified schematization (boxes) of the system. The boxes were defined as 5 to 10 km-long segments (Figure 1), which were previously defined within the OMES-project. Within a certain box, changes in sediment volume are explained by (1) an up-estuarine flux of sediment, (2) an down-estuarine flux of sediment and (3) external factors creating a flux of sediment (e.g. sand mining and dredging works).

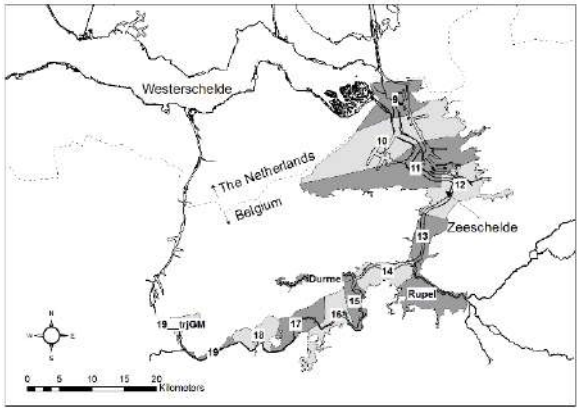

Fig. 1: The Schelde-estuary and the schematisation in *OMES* boxes

The changes in volumes are derived from topo-bathymetries for different moments. The volumes are converted to mass fluxes for sand and mud separately by sand-mud bottom characteristics based on 100's of individual bottom samples, taken over different habitats. Based on Koltermann et al. [3] the porosity was derived depending on the sand-mud-percentage within the specific habitat.

At the most up-estuarine boundaries, the fluvial sediment influx is derived from measurements upstream the estuary and its tributaries.
The anthropogenic fluxes are derived from registrations. Starting from these known parameters the down-estuarine sediment flux is derived, which is also the up-estuarine flux for the neighboring box.

Results: The sand balance for the period 2016-2019 (Figure 2) shows up-estuarine transport of sand over the entire estuary. This can be explained by the importance of higher flow velocities in the sand transport, where the sand transport relates to velocity to the power 3 to 5 (eg. Engelund-Hansen formula). The Schelde-estuary is characterised by higher flood velocities, leading to a flood dominance in sand transport.

Fig. 2: Mean annual residual sand transport 2016-2019 (Million Ton Dry Material)

The mud transport has a different pattern, with a down-estuarine transport over most of the estuary. Only at the most downstream location, mud transport is up-estuarine. For mud transport the classic advection-diffusion equation is valid. The tidal asymmetry (increase of ebb period up-estuary) and the increasing importance of fresh water discharge up-estuary, will result in a more ebb-dominant mud transport.

References: ; [1]Smolders et at. (2015) *Nat. Hazards Earth Syst. Sci.* 15 (7): 1659–1675; [2]Meire et al. (2005) *Hydrobiologia* 540 (1–3): 1–11; [3] Koltermann et al. (1995) *Water Resour. Res.*, 31(12), 3283– 3297.

Impact of climate change scenarios on sediment load assessments

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Conference theme number(s): 6

Introduction: Environmental models play a key role in assessment of sediment loads released from the catchment and transported through the riverine systems under current and future conditions. To discuss the future ones the climate change scenarios are commonly incorporated into the models. Since precipitation have the most significant impact on surface runoff consequently the choice of its projections seems to be crucial for future sediment assessments. To highlight the difference in sediment loads under the different scenarios the digital platform - Macromodel DNS, has been employed to calculate sediment loads released from the Raba River (Poland, Carpathian Mts.) to the impoundment reservoir.

Methods: The sediment loads were followed under the RCP 4.5 and 8.5 predictions in the short (2021-35) and long (2036-50) time horizons. Regarding the importance of spatial resolution of the model, especially in the case of precipitation (RR), two sets of data were investigated (both ensembles initially composed from 14 different GSM-RCM model chains): 1) of a single meteorological station located in a vicinity of the study area (V), and 2) of the whole catchment, i.e. areal mean calculated from gridded data (E). To display the possible range of load variability under different precipitation projections additional two sub-ensembles (selected from E) were examined: dry (RR<25th percentile calculated for a reference period 1981-05, D) and humid (>75th percentile for the same reference period, H).

Results: As the reference point for the all created precipitation change scenarios (V, E, D, and H) the calibrated and verified Raba River model has been used (baseline scenario) [1]. The response of the model has been presented and as monthly sediment loads expressed in tones/month (t/m).

Discussion: The simulations showed pronounced differences between sediment loads predicted under the V and E scenarios, reaching over 1000 t/m in April under the RCP 8.5-long scenario (Fig. 1). When dry and humid conditions have been taken into consideration the range of monthly load differences varied from approx. 1 to 630 t/m (Fig. 2).

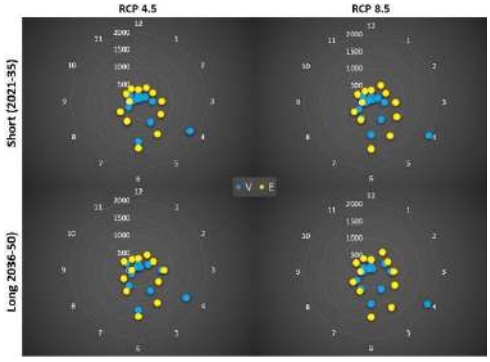

Fig. 1: Monthly sediment loads (t/m) for the V and E scenarios under RCP 4.5 and 8.5

These results show that special attention should be paid when a precipitation model ensemble is selected for the sediment loads calculations as well as its spatial representativeness. Especially, when e.g. the load delivery to the impoundment reservoir is discussed. In this case such extreme load differences could greatly affect not only reservoir management actions but also measures undertaken in the entire catchment [2].

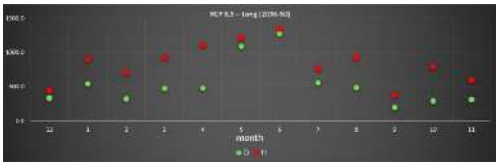

Fig. 2: Monthly sediment loads (t/m) for the D and H scenarios under RCP 8.5- long

However, given current number of possible models to be used to form the ensemble and the differences in their predictions, further research focusing on the best precipitation representativeness in particular models as well as practical aspects of their usage is absolutely necessary.

References: [1] Szalińska et al. (2020) *J Soils Sediments* **20**:2641-2652; [2] Wilk et al. (2022) *J Soils Sediments* **22**:2929-2947.

Mapping and quantifying methane emissions from contaminated fibrous sediment

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Conference theme number(s): 6

Introduction: Contaminated fibers have been discharged from pulp and paper mills for decades in many countries over the world, until stricter regulations came into force – in 1969 in Sweden. These deposits have accumulated and formed large banks (so-called fiberbanks). They have been identified as a risk for the environment in terms of the release of contaminants, such as heavy metals and Persistent Organic Pollutants [1,2]. Presently, there are more than 383 sites which may be polluted with these sediments in Sweden [1]. In addition, significant emissions of greenhouse gases, primarily methane, have been measured from these sediments in the laboratory [3]. Hence, an additional concern is that emissions from fiberbanks could account for a significant part of Sweden's total emissions. This study aims to develop a field technique to characterize the emissions of methane from fiberbanks in natural conditions.

Methods: In this study, a drone equipped with a methane sensor was used to survey several fiberbank sites. The drone also carried an anemometer, a thermometer, and additional sensors to measure air pressure, relative humidity and positioning.

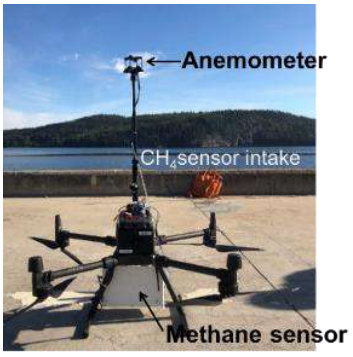

Fig. 1: *The drone system ready to fly*

Depending on the wind speed, different measurements strategies were used with the drone. If the wind speed was low, horizontal mapping (measurements at the same altitude over an area) was performed to detect emission hotspots. If the wind speed was higher than 2 m/s a mass balance method was applied to estimate the emissions from the fiberbank. This was performed by measuring the wind speed and methane concentration in a vertical cross section, as a fence, across the emission plume down wind of the fiberbank.

Results and discussion: Horizontal mapping allowed for the detection of ebullition events from the fiberbanks. These events lead to an increase of methane concentration in the air from background concentrations (around 1.9 ppm) to peak concentrations of between 2 and 2.6 ppm. Across the area of the fiberbanks methane is released more consistently at very active points ("hotspots") and more sporadically at other points. Hence, repeated horizontal mapping is required to adequately characterize the areas with more sporadic emissions.
Measurements along fences (vertically stacked profiles) allowed for the estimation of the extent of the methane plume emitted by the fiberbanks as well as an evaluation of the average flux. In one site, we evaluated this flux to be about 13.1 kg of methane per day.
During fieldwork, some measurements were conducted about 10 hours after an earthquake (magnitude 2.6) occurred. These showed very high concentrations of methane (up to 7.7 ppm) above the water surface. This shows that many methane bubbles were suddenly released, highlighting the fact that fiberbanks are likely to emit large amounts of methane if disturbed (such as following a submarine slide, boat traffic, waves and after certain types of dredging).
Finally, it is important to keep in mind that the methane production will increase with increasing temperatures, leading to higher emissions [3]. Hence, careful remediation actions are likely to be needed in the near future.

Acknowledgements: This study is funded by VINNOVA (project no. 2021-04569).

References: [1] Norrlin & Josefsson (2017) *SGU report*, 7 ; [2] Göransson et al. (2021) *Front Marine Sci* **8**: 729243; [3] Lehoux et al. (2021) *Sci Total Environ*, **781**: 146772.

Contaminated Sediment and Climate Change – Sediment Desiccation, The Unthought About Hazard for Caps and MNR

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Conference theme number(s): 4) Climate Change and Sediment Pledge

Introduction: Climate change poses an increasing threat to remedy effectiveness at contaminated sediment sites, especially those sites located in rivers, coasts, and inland waterways. Contaminated sediment sites are some of the nation's most contaminated sites, often acting as a reservoir for persistent pollutants that pose a risk to human health and the environment. Many of the contemporary remedies were designed and/or constructed decades ago without considering the effects of climate changes. While many events are associated with climate change, this evaluation focuses on how increasing air temperatures and increased drought potential may affect climate resiliency at contaminated sediment sites. Surface temperatures are projected to rise over the 21st century with heat waves predicted to occur more often and last longer. Record-setting hot years are projected to become more common, leading to the possibility of chronic, long-duration droughts. In some regions, the combination of climate change and increased withdrawal of water from aquifers are causing surface water levels to drop, resulting in exposed and desiccated sediment. Our objective was to evaluate the effect of sediment desiccation on existing and future sediment remedies such as subaqueous sediment caps, monitored natural recovery (MNR), and enhanced monitored natural recovery (EMNR).

Methods: We reviewed the well-established body of literature evaluating sediment characteristics and properties, including the effects of sediment desiccation. Then, we evaluated how that could affect contaminated sediment sites in the context of climate change, specifically focusing on increasing air temperatures, drought, and sediment desiccation. We focused on physical and chemical changes to contaminated sediment and the performance of subaqueous sediment caps and MNR/EMNR during drying and rewetting cycles. We also evaluated unanticipated risks, such as shifting exposure pathways from desiccated contaminated sediment from inhalation, dermal contact, and impacts to new receptors.

Results: Damage to remedies at contaminated sediment sites can lead to releases of contamination. Existing and future remedies will need to account for the effects of climate change, including the focus of this evaluation—increased temperatures and increased drought risk. Regions at risk for increased drought may have lowering surface water levels and increased sediment desiccation. As water levels drop, sediment caps can be exposed to the atmosphere, causing desiccation and cracking, ultimately decreasing the cap's ability to cover or sequester contamination. This can result in migration of the previously contained contamination to ground or surface water and/or resuspension of contaminated sediment. Sediment desiccation can also change the biodegradation potential as contaminants shift from anaerobic conditions to aerobic conditions.

Discussion: Lower water levels also could impact the suitability of caps in working river and harbors if additional dredging is required to allow for a deeper navigational channel. The success of MNR/EMNR depends on an assumed sedimentation rate of new uncontaminated material. Decreased water flow due to drought could decrease the deposition rate of new material and impact the success of MNR/EMNR as a remedy. Desiccation can also change exposure pathways, such as exacerbating the exposure and inhalation risk posed by wind-blow contaminated particles. Higher temperatures, increased drought risk, and associated desiccation of sediment are an important consideration of climate resiliency and contaminated sediment sites.

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Sediments, creating a vibrant estuarine habitat to protect the Scheldt hinterland against flooding

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Conference theme number(s): 2 / 6

Introduction: A combination of contractors working on the creation of estuarine ecosystem – strange?
Indeed, as the main deliverable seems to be a return to a fully explored natural tidal flood plain by depoldering two low-lying land sides along the Scheldt estuary. Two polders at the Belgian-Dutch border are being returned and re-integrated in the estuarine environment of the river Scheldt: the Hedwigepolder (295 ha) on the Dutch side and the Prosperpolder (170 ha) on the Flemish side. It has taken some time to realize – due to environmental consent and intensive stakeholder interaction – but we are proud to present the integrated results of our concerted efforts over the last years.

Methods: As part of the Development Sketch 2010, part of the Scheldt treaties that were concluded at the end of 2005 between Flanders (Sigma plan) and the Netherlands (Western Scheldt Nature Package), this "depoldering" project creates a mudflat and salt marsh area as an extra flood buffering space along the river Scheldt - protecting the hinterland from flooding Trenches and creeks will be dug in the flood plain to initiate and facilitate nature development: hydro- and morphodynamics induce a series of interactive ecological processes of vegetation growth, benthos development and species establishment.

Fig. 1: Hedwige-Prosperpolder- Design concept

With the available sediments, a primary flood defense dike of about 5 km is built inland. Extensive earth works create channels and creeks in the polder area, levels the existing and realize a dedicated primary flood protection more inland. Dedicated nature development works (including breeding bird islands) are fully explored in the flood plain.
Only a small part of the total sediment balance volumes is removed as contaminated and/or unusable soil. All excess "good" soil is used for the construction of a panorama hill inside the polder.
As a final stage, the existing Scheldedijk is dug away – restoring a direct connection between tidal river and its floodplain.

Results: Bringing together different key enablers facilitates a successful fully integrated approach of the project: flood protection, nature development, recreational use and research facilities (living lab) cover highly relevant social challenges in the estuarine environment of this part of the river Scheldt – targeting an efficient working together on a more safe, accessible and natural Scheldt.
Given the specific transboundary sensitivities, stakeholder engagement was crucial to implement political treaties into practical site realization and current operational collaboration to monitor and manage the tidal nature reserve "Grenspark Groot-Saeftinghe" (together with the nearby nature reserve Drowned Land of Saeftinghe).

Fig. 2: Hedwige-Prosperpolder connected to the river Scheldt.

References:

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[2] De Vlaamse Waterweg (2023) Nieuwsbrief "Eindfase in het Hedwige-Prosperproject".

The impact of damming in sediment delivery to coastal zones – case of mainland Portugal

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Conference theme number(s): 3

Introduction:
Coastal sediment budget is highly dependent on the supply from fluvial solid discharge. The amount of sediment capable of reaching the coast is dependenton the productive capacity in relation to water erosion and the efficiency of transferring the produced sediments to the coast. Nowadays, the fluvial systems are, in general, heavily intervened. Dams constitute one of the most limiting alterations to the normal functioning of the fluvial systems in what concerns sediment supply to the coast. This work aims at detailing and updating the work done by [1], within the scope of characterising the state of fluvial sediment considering the impact of dam construction, where a reduction of more than 85% of the area that drains to the Portuguese coast was estimated.
This exercise was conducted to the coast of Portugal and this work intends to present the results and implications of such quantification.

Methods:
The delimitation of the area draining to the Portuguese coast with and without dam interference was conducted with the following procedures: 1) the drainage network and individual watersheds were estimated using a Global Digital Elevation Model with 30 m resolution [2] and the methods used in [3]; 2) dams were identified using the information provided by [4], using only the ones located further downstream of the drainage systems. A total of 58 dams were identified (57 in Portuguese territory and 1 in Spain – Chanza).

Results:
The results obtained (**Fig.1**) show that from a total area of 297 000 km^2 draining to the Portuguese coast (which includes watersheds in both Portuguese and Spanish territories), only 40 000 km^2 (13%) is free from the interference of dams. This means that only about ~10% of the potential sediment is capable of reaching the coast. Regarding the different sediment cells (SC), SC1 presents the biggest reduction in area with a 91% reduction of the original area, representing a loss of 120 000 km^2. In contrast, SC3 that does not show any signs of dam influence.

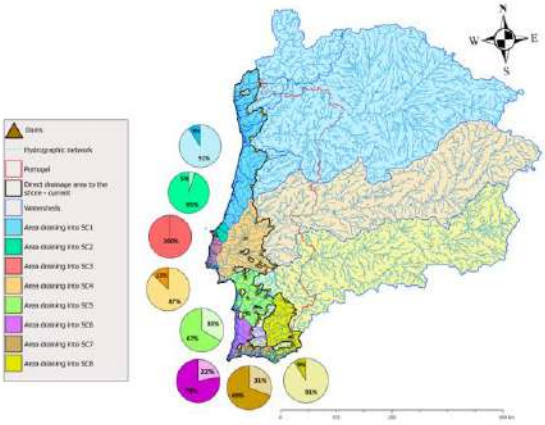

Fig. 1: Changes in the drainage areas before and after the construction of dams.

Discussion and Conclusion:
The influence of dam construction in the study area reveals a decrease in the potential area for sediment production of about 87%, which is quite considerable when comparing the current scenario with the undisturbed one. Also, one of the most productive watersheds in terms of sediment compatible with beach sediments that drains to SC1 – North of Portugal presents a reduction of 91%. This result confirms the link between the reduction delivery to severe coastal erosion problems (hotspots of erosion) that have already been suggested by previous authors (Santos *et al*, 2014).

Acknowledgements:
This work was funded by the Portuguese Fundação para a Ciência e a Tecnologia (FCT) I.P./MCTES through national funds (PIDDAC) – UIDB/50019/2020.

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[3] Lira *et al*. (2014), *IEEE International Geoscience and Remote Sensing Symposium* 6340–6343, 6352710.
[4] SNIAmb. 2022. Sistema Nacional de Informação Ambiental: https://sniamb.apambiente.pt/.

Decadal evolution of an intensely nourished coast

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Conference theme number(s): 3

Introduction: Coastal protection for sandy coasts is best done by artificial nourishments if sand is available. Such is the case of the Belgian coast where volumes between 0.5 to 1 million m^3 are supplied to weak spots along to its 65 km length every year. In the center of this coast, Middlekerke – Ostend area was in the past vulnerable to storms causing floods. However, starting early 2000's the active beach volume was increased by successive nourishments. The largest nourishments were carried out in 2013 – 2014 when over 2 million m^3 of sand was deployed on both the dry beach and the shoreface [1]. In 2018 and 2021, another 1.25 million m^3 were supplied to this coastal stretch (Fig. 1).

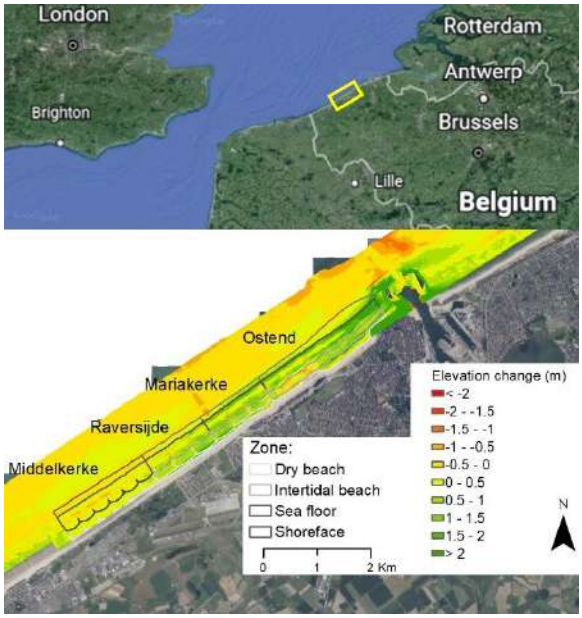

Fig. 1: Difference of DEMs 2013-2022.

Methods: The Belgian coast is intensively monitored with topographic surveys twice a year and bathymetric surveys once a year. Additional surveys are performed on the areas where interventions are carried out, such as the area of Middelkerke – Ostend. Based on these surveys, Digital Elevation Models (DEM) were generated for every year and difference of DEMs indicate how the nourished sand is re-organized along and across the active beach. Field observation, in situ measurements and sand budgets were also used to better understand and quantify the sediment circulation in the study zone.

Results: The study zone rapidly reacted to the nourishments especially after 2013, when in less than one year sand started to migrate in the net alongshore direction, towards the Ostend harbor. The harbor's jetties, perpendicularly to the shore trapped much of the sand generating significant accumulation at Ostend beach. Simultaneously, sand was re-organized cross-shore by strengthening the beach bar systems in the shoreface. The intertidal area lost part of the nourished sand which was transported to the shoreface and the dry beach.
The efficacy of the nourishments is remarkable, the majority of the sand being still present on the active beach after almost a decade.

Discussion:
The nourishments performed at the Middelkerke – Ostend coast in the last decade were a success, largely increasing the beach capacity to withstand extreme storms. Apart from the large volumes supplied to a relatively short coastal stretch (approx. 9 km), other important factors for the sand retention in the system were the local configuration (e.g. harbor's jetties), alongshore transport and a rather gentle submerged beach slope which limits the sediment loss in cross-shore direction. The re-organization of the sand in the area is ongoing and it is expected that the submerged sand bar system will continue to migrate back-and-forth. In contrast, the intertidal and dry beaches stay rather stable, which is also due to the human intervention. However, the large sand accumulation at Ostend beach can bypass the harbor jetties in the future with implications for the local sediment management.

Acknowledgements: The authors acknowledge Agency for Maritime and Coastal Services, Coastal Division and Flanders Hydraulics Research for supporting the present study.

References: [1] Dan et al. (2019). Beach versus shoreface nourishment experiment, *Coastal Sediments, Tampa/St. Petersburg, Florida, USA*, pp. 287–295.

Managing sediments in the Wadden Sea and the role of the research programme BenO Wadden Sea

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Conference theme number: 3. Sediment in coastal and marine management

Introduction:
The Wadden Sea. The largest connected tidal flat in the world with a unique ecosystem, thanks to the largely undisturbed hydro- and morphological processes that continuously (re)shape the landscape [1]. This UNESCO world heritage ecosystem is highly valued worldwide and is (jointly) protected and managed by the Netherlands, Germany and Denmark. The Wadden Sea is also of great value for its ecosystem services such as flood protection, fisheries, recreation and navigation. In the Netherlands, Rijkswaterstaat (the executive agency of the ministry of infrastructure and water management) is responsible for the management of the shipping lanes from the mainland to the islands as well as for the protection of nature [2].

Fig. 1: Area of the Wadden Sea World Heritage site (source: Common Wadden Sea Secretariat).

The dynamics of the system do not only form its key value, it is also a challenge for management as shipping lanes silt up while on the long term the tidal flats may drown due to accelerated sea level rise.
As such, Rijkswaterstaat needs a thorough understanding of the sediment system. For this reason, a small research programme on morphology and sediment management started in 2016, which now fulfills an important role. This paper highlights some of the work done over the years, and the lessons-learned for management practices.

Results: Research programme BenO Wadden Sea focuses and invests in five research pillars:

1. Bring/keep system knowledge up to date
2. Invest structurally in knowledge & tools
3. Investigate approaches to sediment management & sustainable dredging
4. Develop knowledge for nature conservation
5. Share knowledge & create common language

The abiotic dynamics of each basin is summarized for practitioners and managers, building upon existing research and data. These reports and accompanying website aid in addressing management problems (1&5). Furthermore, long-term investments in system knowledge and tools are necessary to assess future scenarios and developments, such as developing a Delft3D model and studying the role of mud and better estimating dredging volumes (2&3).
Besides this knowledge 'foundation', two pillars (3&4) focus on direct management questions. It is the interplay between the knowledge foundation and application to management problems that is of great added value. All studies of the research programme are made publicly available here.

Conclusions: the BenO Wadden Sea research programme contributes to Rijkswaterstaat's management practices by having become a central point in the organization (and beyond) where knowledge is available on the complex sediment dynamics of the Wadden Sea, providing evidence-based advice for navigability and nature conservation, while also thinking ahead. We experience that it needs time and commitment to consolidate the knowledge foundation, connect to colleagues and gradually develop and improve our management practices.

Acknowledgements: We thank everyone involved in the different studies, specifically Herman Mulder and Nicki Villars as previous programme leaders.

References: [1] Wadden Sea Quality Status Report-geomorphology, Oost et al. (2017) link ;[2] Natura 2000-beheerplan Waddenzee periode 2016-2022, Rijkswaterstaat, (2016), link

The WoE approach applied to the sediments characterization to the lagoon environment: the Venice Lagoon case

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Conference theme number: 3 - Sediment in Coastal and Marine management

Introduction:
Venice Lagoon, measuring 500 square kilometres, is among the most extended ones in the Mediterranean basin. It is about a century that the lagoon has been affected by a progressive process of morphological degradation caused by the increased strength of the tidal currents, the relative sea level rise, and the erosive action induced by internal navigation. In order to reverse the degradation process several interventions have been done in the last 30 years aimed at the reconstruction of the salt marshes and mudflats by using sediments coming from dredging of lagoon channels. This was possible thanks to the adoption in 1993 of a protocol for managing sediments based on a chemical characterization carried out on reference values for about ten substances (heavy metals, PAHs, etc.). In 2017 a general review process of the protocol dated 1993 was undertaken with the aim of reaching a new protocol coherent with the more updated knowledge and in compliance with the EU Directives. Attention was then given to the possibility of adopting a WoE approach based on a chemical and ecotoxicological characterization. Bioaccumulation assessments was included in the of reallocation sediments in lagoon water bodies.

Methods: The sediment and bioaccumulation analytical, chemical and ecotoxicological results, available from the MODUS project implementing the Water Frame Directive in the period 2012-2016, and from the project HICSED in 2008, were used to build a database aimed at verifying the suitability of the chemical reference values L1 and L2 adopted in 2016 for the Italian marine environment.

As for the chemical characteristics overall 7124 data were used unevenly distributed among metals and trace elements, IPA, and other relevant organotin compounds. As for the ecotoxicological aspects, the results related to 892 biological samples, divided in two types of batteries, were inserted into the database. Totally, 7 organisms with 8 different protocols were used so to gain a good ecological representativeness of the studied environments in terms of taxa, tested matrices, and measured points.

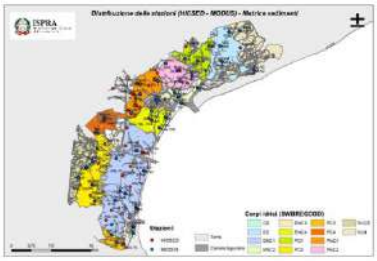

Fig. 1: Location of the sampling stations of the projects MODUS e HICSED.

Results: L1 values, largely coincident with the standards of environmental quality (SQA) required by the Italian legislation for transitional waters in coherence with the Water Framework Directive (WFD). Their adoption is also supported by the available bioaccumulation data. As for the L2, the low concordance with the collected chemical and ecotoxicological dataset shows a poor adeguacy for the management of lagoon sediments in case of handling. The consequent process of statistical derivation of chemical values with a local reference according to the Probable Effect Level criterion, enabled the identification of alternative limits, overall more realistic than the specific characteristics of lagoon sediments [1], [2]. The chemical and ecotoxicological evidence is expressed through Hazard Quotients and specific indexes provide a quantative estimate of the environmental hazard [3] [4] [5]. The indexes are put within hazard classes taking into account both the chemical evidence and the eco-toxicological evidence. In this way, 5 classes of sediment were definied compatible management options inside to the lagoon.

Discussion: To complete the definition of those values for which the dataset features did not enable the derivation of local L2, the database should be implemented by means new chemical and ecotoxicological characterisations of sediments sampled within those areas with higher levels of contamination and toxicity. For those parameters having local values lower than L1 deep analyses are necessary to consider the hypothesis of the SQA value review, i.e. the possibility of readjusting the

environmental standard according to the value of natural background.

Up to the dataset completion, for the scientific profile of the substances for which it was not possible to identify L2 values, an approach was adopted according to the precaution criteria established by the WFD that fixes a 20% tolerance for the SQA values.

This approach ensures coherence both with the evidence so far ascertained through the present study and the general setting of the proposal of a new protocol for the management of the Venice Lagoon sediments.

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Effects of Re-circulation on Sediment Properties: A Case Study in the Seaport Emden

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Conference theme number(s): 3

Introduction: To maintain nautical bottom depth at Port of Emden (Germany) re-circulation has been employed for more than three decades [1]. Utilising a trailing suction hopper dredger, fluid mud (FM) can be recirculated. During re-circulation, dredged sediment is first collected by a dredging vessel and then released back into the water creating a navigable FM layer. The main goals of this technique are to keep rheological properties, density and settling rate of FM low making the FM layers navigable [1], [2]. This study aims to investigate the effects of the re-circulation on rheological properties, consolidation and organic matter degradability, in FM to determine the most optimal frequency of port maintenance.

Methods: To investigate the effects of the re-circulation on FM properties and hence the efficiency of maintenance dredging, a number of field surveys were conducted in 2 locations of the Port of Emden. Measurements of in-situ density, in-situ rheology, acoustic measurements and oxygen saturation were carried out before and after re-circulation. Additionally, physical samples of FM were gathered from three different depths per location and analysed for rheological properties (yield stress and structural recovery), density, and organic matter degradability in the laboratory. Furthermore, settling and consolidation properties of mud were measured in order to select the most optimal frequency of port maintenance.

Results: The first findings showed that the effects of re-circulation on FM properties could be detected in-situ. Particularly, the density and the yield stress of the FM layer decreased after re-circulation by about 5% and 29%, respectively. Fig. 1 indicates the difference of field yield stress between before and after re-circulation. Fig. 2 shows that after re-circulation, the aerobic release of carbon (respiration) over time is less than in the sample before dredging. It is hypothesized that FM recirculation enhances organic matter degradation which reflects in reduced degradability of the remaining FM organic matter (sampled after dredging).

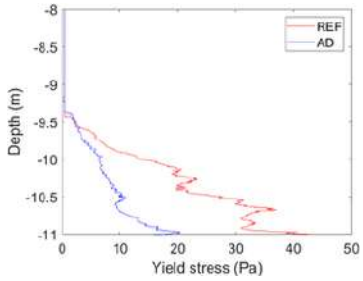

Fig. 1: FM in-situ yield stress vertical profile before (REF) and after re-circulation (AD).

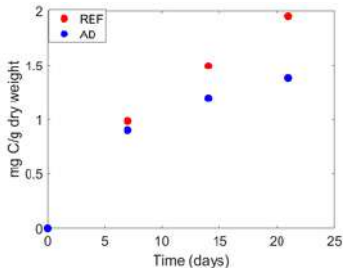

Fig. 2: Carbon released by degradation of organic matter before (REF) and after re-circulation (AD).

Summary and outlook: Different rheological characteristics and densities of the FM layers have been measured before and after re-circulation. After re-circulation, yield stresses, density and organic matter degradability of FM were reduced.
This study will support better understanding of the link between the properties of FM such as rheological properties, density, consolidation, oxygen saturation and the efficiency of port maintenance (sustainability of desired properties in terms of navigability) by means of re-circulation dredging. Thereby, the findings will aid in optimising strategies and reducing environmental impact of port maintenance.

This study is funded by NPorts. The research is carried out within the framework of the MUDNET academic network. https://www.tudelft.nl/mudnet/. The authors would like to acknowledge Deltares for the use of FCL laboratory.

References: [1] Wurpts et al. (2005) Terra et Aqua 99:22-32; [2] Gebert et al. (2022) WODCON XXIII.

Testing Conditioning Methods for Maintenance Dredging in Ports

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Conference theme number(s): 3

Introduction: There are several maintenance methods that are typically used for sediment conditioning in ports. For instance, the sediment re-circulation is used by the Port of Emden (Germany) for reducing the strength of the sediment [1]. Another example of sediment conditioning is applying Water Injection Dredging (WID) in port areas with low energy regions. The Port of Rotterdam (the Netherlands) tested WID for conditioning the sediment in the Calandkanaal [2]. The WID-induced fluid mud layer can be then used by vessel for navigation in the Calandkanaal by adapting the density of 1.2 t/m^3 as the critical criterion for navigation. Finally, sediment conditioning can be done by, for instance, hydro jet at the suction head, bed leveller and underwater plough. These methods has been also considered for reducing the strength of the sediment and thus increasing the under keel clearance (UKC) in the port area by adapting the nautical bottom approach.
This laboratory study compares the effect of different maintenance methods and frequencies on sediment properties as a basis for possible future adaptation of maintenance strategies in the Port of Hamburg (Germany).

Methods: First, sediment conditioning by WID, bed leveller and re-circulation was conducted using a field sediment sample collected from the Port of Hamburg in the laboratory. The sediment properties, namely rheology (yield stress), structural recovery, settling, oxygen saturation and redox potential were measured before and after conditioning to study the effect of these methods on mud properties. The rheological protocols developed by [3] were applied in this study. Conditioning was conducted with different frequency (once a week and 3 times a week) in order to investigate the frequency of maintenance for keeping mud fluid. Secondly, the results of the laboratory experiments were compared to the results of field trials, were WID, bed levelling and re-circulation were tested for port maintenance dredging.

Results: The effect of all conditioning methods can be replicated in the laboratory. Both laboratory and field tests showed that WID has the most pronounced impact on mud properties. Bed levelling and re-circulation had similar impact on rheology and density of mud. The effect of all methods was influenced by the frequency of conditioning, but differences were smaller than differences resulting from the different methods. The results also showed that WID is the most oxygen consuming condition method.
Future investigations will optimise lab replication of dredging techniques and further investigate the effect of dredging frequency on mud properties.

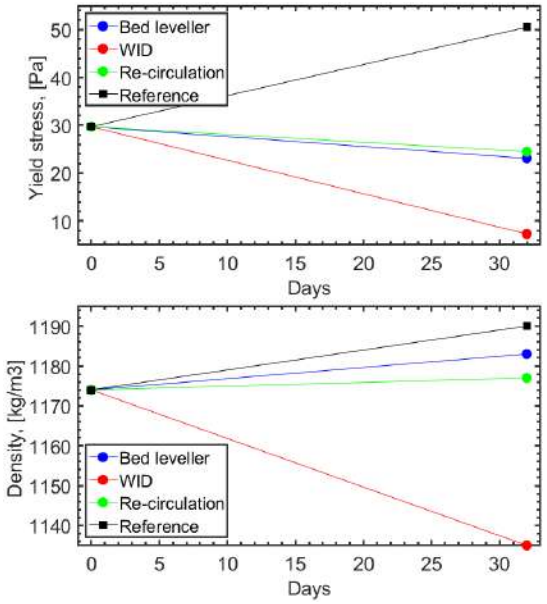

Fig. 1: Effect of conditioning methods on (fluidic) yield stress (shear strength) and on density of mud.

This study is funded by Hamburg Port Authority. The research is carried out within the framework of the MUDNET academic network. https://www.tudelft.nl/mudnet/. The authors would like to acknowledge Deltares for the use of FCL.

References: [1] Wurpts et al. (2005) Terra et Aqua 99:22-32; [2] Kirichek & Rutgers (2020) Terra et Aqua 160:16-26; [3] Shakeel (2022) PhD thesis, TU Delft.

The Impact of Contaminated Sediment in the Estuaries of Elbe and Odra

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Conference theme number(3): Sediment in Coastal and Marine management

Introduction: Estuaries rank among the most heavily impacted aquatic systems on Earth. Because of their exceptional resources and economic value, these coastal systems are sites of intense human activity and are subject to high levels of disturbance from multiple stressors [1]. Industrial and mining activities in the Elbe catchment area have a very long history, and caused contamination of sediments for centuries [2]. While the Elbe has been intensively studied in terms of historic chemical contamination, relatively little is known about the Odra. One objective within the Blue Estuaries project (BluEs) is to estimate the ecological stress from sediment-bound contaminants in the Elbe and Odra estuaries. To our knowledge, this is one of the few studies that has addressed the chemical contamination and the ecotoxicological assessment of sediments in the Odra delta.

Methods: Surface sediments were sampled 12 times in the Elbe Estuary and 6 times in the Odra delta at several sites over the course of two years. The sampling sites were chosen along a presumed contamination gradient in both estuaries. To detect the ecotoxicological effects of the sediment samples, a biotest battery was applied comprising assays in direct sediment contact and with elutriates. The meiobenthos composition was determined via the Nema-Spear-Index at some freshwater sites. Sediment samples were chemically analysed for metals and organic historic contaminants.

Results: The results of the chemical analyses confirmed higher concentrations of historic contaminants in the Elbe estuary than in the Odra for all contaminants except PAHs which were higher in the Szczecin Lagoon. In both estuaries, concentrations of historical contaminants decreased downstream. The bioassays responded differently to the sediment samples, probably reflecting different contamination patterns. In the Elbe estuary, the algae growth inhibition test showed a moderate inhibition at the upstream Elbe stations, which are more strongly contaminated. In the Odra estuary, the algae growth inhibition test did not show any effects. But the bacteria in the direct sediment contact test were strongly inhibited in some samples from the Szczecin Lagoon. The other tests did not show any effects.

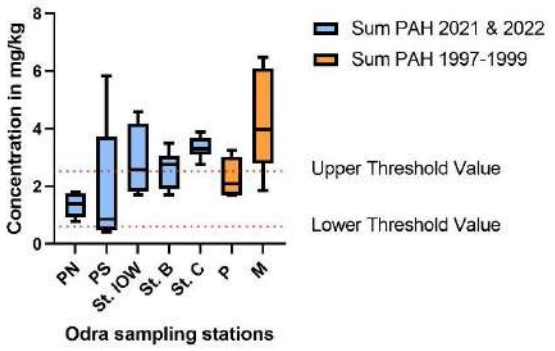

***Figure 1**: PAHs concentrations in the Odra estuary. A total of 16 PAHs were measured. The stations PN & PS are located in Peenestrom. St. IOW to M are located in the Szczecin Lagoon. Station P is close to St. IOW, B and C. Station M is located further upstream.*

Discussion: While contamination with historic contaminants in the tidal Elbe Estuary is continuously decreasing, PAH concentrations in 2021 & 2022 have remained similar to data from 1997-1999 in the Szczecin Lagoon [3]. Based on the Ant/(Ant+Phe) ratio, the PAH contamination in the Odra estuary can be attributed to pyrogenic sources. The decreasing trend in the concentration is reflected in the bacterial direct contact test. The two eluate tests (with microalgae und with luminescent bacteria (microtox)) did not show any effects, indicating either that contaminants may not be remobilized from the sediment during elutriation, or a lower sensitivity of the test organisms to the substances. The sensitivity of the test organisms to single substances to determine the respective toxic units, especially to PAHs, is currently looked into and will be elaborated upon during the presentation.

Acknowledgements: The authors gratefully acknowledge the support of the Federal Ministry of Education and Research (BMBF) for this project.

References: [1] Kennish (2002) Environmental Conservation 29:78-107; [2] Netzband et al. (2002) JSS – J Soils & Sediments 2 (3) 112 – 116. [3] Müller et al. (2001) International Odra Project Subproject 7.

Enhanced bioremediation of contaminated sediments in coastal areas of ex-industrial sites

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Conference theme number(s): 3

Introduction: Environmental contamination by polycyclic aromatic hydrocarbons (PAHs) and toxic metals is reaching a global dimension and represents a serious risk for the sustainable provision of ecosystems' goods and services and human wellbeing. In Europe, environment contamination is often linked to intense industrial activities, that in many cases, are located near the coast, representing a high ecological risk for both terrestrial and aquatic environments, especially after the end of the industrial exploitation. Among the most polluted coastal areas in Italy there is the Bagnoli site, located in Naples. This area is considered at high risk of environmental crisis in Italy and it has been included in the list of polluted sites of National interest. The site, now dismissed since 1990, was characterized by steel industry, asbestos processing, fertilizer, and concrete production. Knowledge on benchmark contamination is well developed and a complete characterization of the contamination in this area (14 Km^2) is available thanks to ISPRA (and to the ABBACO project recently concluded). Bagnoli's sediments contamination is characterized by high levels of PAHs and toxic metals, such as Pb, Zn, Cd, Cu and Hg [1]. These values not only tremendously exceed the thresholds of the chemical quality of marine sediments, but also have major detrimental biological and ecological consequences. Conventional remediation practices by mechanical dredging of the contaminated marine sediments can be highly costly and could cause environmental damage. The LIFE SEDREMED project [2] will demonstrate for the first time the cost-efficiency of *in-situ* bioremediation of different types of toxic contaminants, present in the Bagnoli's sediments, through the adaptation, combination, and field implementation of 2 innovative *in-situ* remediation technologies (EKO and IDRA), provided by the industrial partners.

Methods: The project proposes the (1) installation of an electro-kinetic system (EKO) and the (2) application of biofixed microorganisms (IDRA) (Fig. 1) to run bioremediation of contaminants in two selected Bagnoli's areas with different contamination level. The solution will be complemented by an innovative and up to date monitoring methodology to investigate the efficiency of the remediation technologies and the effect on the local biodiversity.

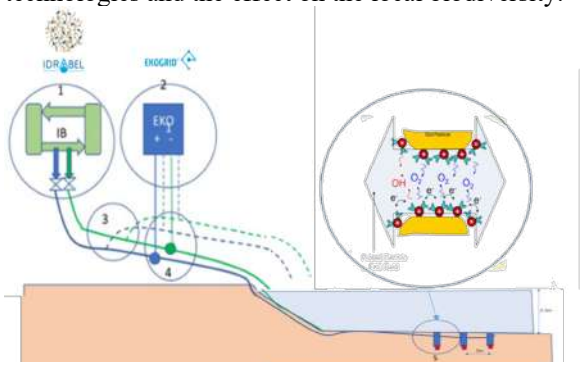

Fig. 1: *1. Pumping unit. Delivery IDRABEL; 2. EKO unit. Output cables, 3. Number of pipes; 4. The electric cables will go inside the injection pipes; 5. Electrode shall have the active tip (electrode) deep in the soil. The tip has perforations to allow injection.*

Expected Results and Discussion: For the first time a holistic approach to remediate a polluted area of 2 hectares will be implemented, combining two innovative technologies. We expect to reduce the concentration of toxic metals and hydrocarbon contaminants up to 80% and to save up to 6-times of remediation costs compared with the ex-situ remediation approaches. Finally, the plan will be delivered at project end with the extent to set the basis for a successful continuation, replicability, and transferability roadmap.

Acknowledgements: The LIFE SEDREMED project is co-funded by the LIFE Program of the European Union under contract number LIFE20 ENV/IT/000572.

References: [1] Morroni et al. (2020) *Marine environmental research* **160:** 104984. [2] https://life-sedremed.eu/

Environmental life cycle assessment of the innovative ejectors plant technology for sediment management in harbours

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Conference theme number(s): 3-4-6

Introduction: Preservation of a good navigability is a challenging issue, since port and harbour access and waterways are often hampered, as the vast majority of 10,000s of ports and harbours worldwide suffer from sedimentation. Traditionally, the sediment that causes the problem is excavated, removed and relocated through maintenance dredging. Nevertheless, dredging is not effective in keeping navigability over the time and also has considerable environmental impacts, since dredging operations can: i) destroy or greatly modify underwater habitats and resident flora and fauna, ii) resuspend sediments and contaminants already present in the seabed, thus increasing the Suspended Solid Concentration (SSC) in the water column with negative effects for the ecosystem, iii) impact locally on greenhouse gas (GHG), pollutants and noise emissions, iv) generate a waste to be disposed, i.e. the dredged material. The "*ejectors plant*" technology has been developed as a sustainable alternative to maintenance dredging and has been tested in the first demo application in the Marina of Cervia (Italy) [1]. The demo plant operated from June 2019 to September 2020 with the final aim of keeping water depth at the Marina entrance over 2.5 meters.

Methods: An environmental life cycle assessment (LCA) has been performed accordingly to with ISO 14040/14044 standards to evaluate the sustainability of Cervia ejectors demo plant, which is the functional unit of the analysis. Due to the goal of the paper, the choice of system boundaries considered only emissions related to raw materials processing and plant operation phases. The other phases of plant construction (components manufacturing, transport and assembly) as well as decommissioning phase was not included. The emissions comprehend various pollutants (CO_2, NO_x, particulate matter, SO_x, ...) and specific emission factors for each pollutant were found in the following different official publications [2-5]. ReCiPe2016 methodology has been applied as characterization model for the calculation of the impacts at a midpoint and endpoint levels.

Results: Table 1 summarizes the impacts on CO_2 emission of the ejectors plant construction and operation referred to the functional unit and by considering three different scenarios (Ss), that are i) current scenario (i.e. measured energy consumption and realistic emission impact), ii) optimized scenario (i.e. optimized energy consumption and realistic emission impact), and iii) best scenario (i.e. optimized energy consumption and low emission impact).

Tab. 1: CO_2 emission (in ton) over 20 years.

Boundary	Source	S1	S2	S3
Construction	Material	58	29	29
Operation	Energy	3498	970	65
	Material	5	3	3

Table 2 shows the results of midpoint characterization factor for assessing climate change impacts through Global Warming Potential (GWP).

Tab. 2: Midpoint characterization.

Midpoint parameter	S1	S2	S3
GWP100 (ton CO_2 to air)	3561	1002	96

Discussion: Table 1 confirms that the plant operation produces much higher CO_2 emissions than plant construction. Nevertheless, construction scenario is much relevant in terms of other impacts (not shown in this short abstract). Moreover, while in S1 and S2 the impact on CO_2 emission of ejectors plant operation is, respectively, 98% and 97%, in S3 the weight of operation reduces to 67%. Therefore, it is anyway relevant to work on the assessment of ejectors plant construction phase impact to reduce the related impacts moving towards more sustainable solution. The minimum impact is achieved in S3, in which the power consumption of the plant is hypothesized to be satisfied only by renewable energy. This is a relevant aspect since the electrification of sediment management through the adoption of the ejectors plant technology can be beneficial in terms of air emissions reduction only if the power source is renewable (generated locally, for example by photovoltaic panels, wind-turbines and/or wave energy converter, or purchased by the grid).

Acknowledgements: Activities financed by STIMARE and LIFE MARINAPLAN PLUS projects.

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The new breakwater of the Port of Genoa: monitoring and reuse of the dredged sediments

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Conference theme number(s): 3

Introduction: The Port System Authority of Genoa has planned the construction of a new breakwater (Fig. 1) to allow the entry and maneuvering of the latest generation of vessels (longer than 400 m). To achieve this, the Port Authority has also planned a new capital dredging (the first one carried out from 2009 to 2014) to further increase the depth of the port basin. In the initial phase of the dredging, the sediments are discharged into the channel protecting the Genoa airport; in the second phase of the project, the dredged sediments will be placed inside the caissons that will form the structure of the new breakwater.
The Italian Ministry of Ecological Transition has requested the creation of an Environmental Monitoring Plan (EMP) to ensure the protection of the marine-maritime environment outside the port basin, which boasts valuable sites such as protected marine environments and activities of high tourist interest. The University of Genoa therefore drafted the PMA in full compliance with the European Marine Strategy Framework Directive (MSFD) and formed the multidisciplinary team of researchers to implement the monitoring activities.

Fig. 1: Rendering of the new breakwater of the Port of Genoa.

Methods: In the *ante-operam* phase, the working group checked the health state of the port environment and surrounding areas by studying all the MSFD descriptors to follow their evolution during all phases of the breakwater works.
To provide continuous coverage and optimize the work of the researchers, a fixed automatic monitoring system was created for the sediment dredging and discharge phases consisting of instrumentation for the continuous measurement of turbidity and marine dynamics (Fig. 2). In order to follow the evolution of the system "environment" in detail during the different work phases, an additional on-site mobile monitoring is carried out weekly by boat.

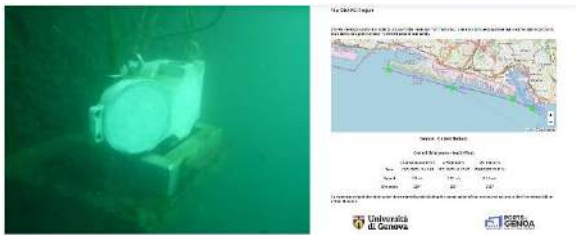

Fig. 2: Monitoring system of the current dredging.

Results: A first result of the monitoring can be seen on the dedicated S4SINAPSI internet page (https://s4sinapsi.it/Stazioni/en/#/adcp02) where an automatic value control system allows operators to check the status of the work at any time, even remotely.

(Re-) Evaluating the Role of Microbes for Fluid Mud Rheology and Settling

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Conference theme number(s): 3

Introduction: Organic matter interacts with charged mineral surfaces and thereby influences sediment properties relevant for port navigability, such as rheological characteristics [1], [2], and settling and consolidation behavior [3], [4]. Microbially produced extracellular polymeric substances (EPS) have been thought to enhance suspension and thereby the desired low yield stresses of fluid mud (FM) [5]. This study investigates the relationship between concentration and composition of EPS, particle size distribution, mineralogy, settling rates and yield stresses in fluid mud from the ports of Emden and Hamburg.

Methods: Concentration and composition of EPS, microbial biomass, rheological parameters, settling rates, microbial community composition and standard solids properties were measured over several years in Port of Hamburg and over one year in Seaport Emden. Single analyses of clay mineralogical composition were carried out on samples from both ports.

Results: The fine-grained fraction (< 63 µm) in FM exceeded 90% in both ports. The microbial community at both sites was highly diverse and total EPS concentration significantly lower in the saline inner harbor of Seaport Emden than in the freshwater Port of Hamburg (Fig. 1, left). Here, FM at downstream site KH with the lowest ratio of biomass to clay (Fig. 1, right) featured hindered settling behaviour. Yield stress increased exponentially with density (Fig. 2, left), with a similar relationship for the two Emden locations and a more scattered one for the Port of Hamburg, in relation varying organic matter content [6]. Settling rates were inversely related to density, as shown by Emden data (Fig. 2, right).

Discussion: The favourable properties of fluid mud in Seaport Emden appear to result from the low density achieved by recirculation dredging and not by particularly high concentrations of EPS, which are also subject to strong seasonal variation. Comparative results from different sites within the Port of Hamburg show that a low ratio of biomass to clay experience promotes hindered settling, likely due to a lesser extent of floc formation. These results support the relevance of fresh, biomass-derived organic matter for particle-particle interactions [7], flocculation and settling behavior, but shed doubt on the assumption that EPS contribute to keeping FM in suspension. The latter appears to be accomplished by the density window generated from recirculation dredging, with densities that are low enough to enable low yield d stresses but high enough to allow for low settling rates.

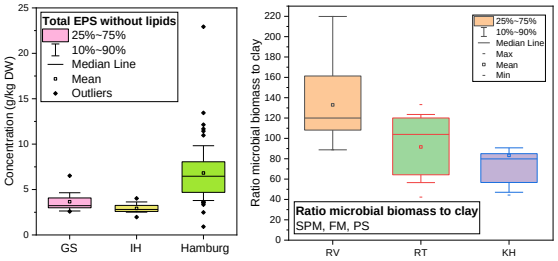

Fig. 1: Left: EPS in Seaport Emden (sites GS and IH) and in Port of Hamburg. Right: Ratio of microbial biomass to clay at three sites in Port of Hamburg.

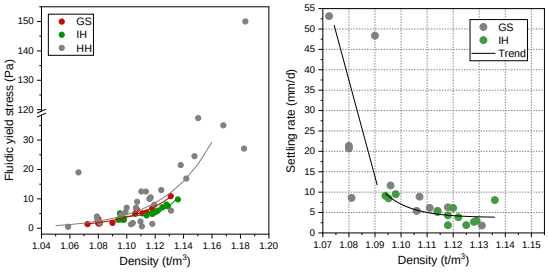

Fig. 2: Relationship between density and fluidic yield stress in fluid mud from Emden and Hamburg (left) and settling rate (Emden, right).

This study was funded by Niedersachsen Ports and Hamburg Port Authority and was carried out within the framework of the MUDNET academic network. https://www.tudelft.nl/mudnet/.

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Evolution of submerged large transversal bedforms in a shallow nearshore area along a macrotidal sandy coast.

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Conference theme number(s): 3

Introduction: Nearshore channels and sandbanks play an important role in nearshore hydrodynamics especially in relation to the coastline. Shallow morphological bedforms including sandbars, shoreface-connected ridges and large submerged dunes can result in feedback with tidal flow and wave action in the surf zone [1]. Unlike most other macrotidal coasts, a shoreface-connected ridge is present at the Belgian coast at Koksijde. Intriguingly, the shallow ridge is covered by large, compound hydraulic dunes, with wavelengths of 100-200 m and > 1000 m long crests (Fig. 1). This work presents results from a series of high resolution bathymetric surveys. Their morphological change and migration are documented over the longer term (> 1 year).

Methods: Koksijde beach is located on the west coast of Belgium. The coastline is oriented SW-NE and consists of broad, gently sloping sandy beaches up to 600 m wide at low tide. The tide along the Belgian coast is subject to moderate wave energy and is macro-tidal, ranging from 3.5 m at neap tides to 5 m at spring tides. The net longshore sediment transport is estimated to be 200,000 m^3/year in an eastward direction. High-resolution nearshore bathymetry surveys were conducted with multibeam in 2013, 2018, 2021, and 2022. Bathymetric surveys were converted to a Digital Elevation Model (DEM) of 1 m cell size. Hillshade raster, an illuminated representation of the surface, was also derived for each survey.

Results: The surveys indicate the presence of sandy bedforms in the nearshore zone between -0.5 and -4 m TAW (Belgium Ordnance Datum corresponding to the low spring tide in Ostend). They are transverse to the coastline, up to 1500 m in length and 1-2 m in height (Fig 1). Typically, the lee face is steeper than the stoss slope. Their spacing is in the range of 125-250 m. Some parts of the crests emerge at low tide. Repeated surveys of the bedforms field over 9 years revealed significant changes in morphology and their position. The large bedforms are very active, adapt to changing meteo-hydrodynamic conditions and migrate at rates of 20-25 m/year to the east.

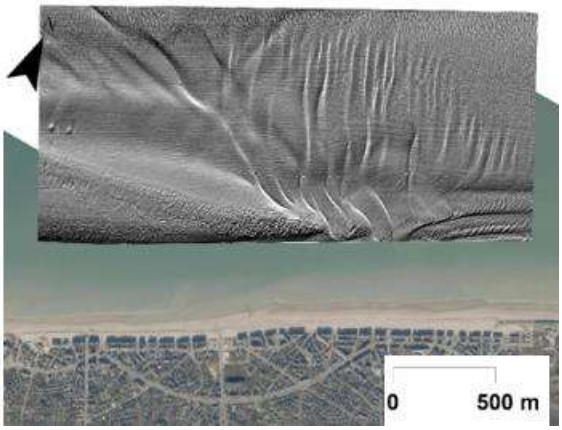

Fig. 1: *Hillshade raster of the bedforms in 2022.*

Discussion:
The morphological bedforms at Koksijde beach are singular features for sandy tidal beaches and they are not expected to occur so close to the coast and in very shallow water. They are very dynamic and migrate in the direction of the longshore sediment transport. The morphological characteristics of the submerged large transversal bedforms suggest that they are complex hydraulic dunes with a high degree of response with tide. Their role and presence is not well understood. It is intended to further analyze the available bathymetric surveys and to perform dedicated hydrodynamic measurements.

Acknowledgements: The authors acknowledge Agentschap Maritieme dienstverlening en Kust, Afdeling kust for access to data.

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13th International SedNet Conference on "*Sediment continuum: applying an integrated management approach*", 6-8 September 2023, Lisbon, Portugal

Title and Authors of the research work

SEDIMENTOLOGIC INFLUENCE OF TORRENT CHECK DAM SYSTEMS ON SHORELINE CHANGES IN SEMI-ARID MEDITERRANEAN AREA: A SUB-REGIONAL ANALYSIS IN CALABRIA (SOUTHERN ITALY)

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Abstract of contents

The evolving shoreline asset represents the dynamic synthesis of the sediment mass balance at watershed mouths as depending on natural agents (mainly floods and sea storms) and anthropogenic interventions both on inland areas and coastal strips. Many coastal areas around the world show a significant trend to shoreline retreat. Torrent control works, such as check dam cascades, usually addressed to face the hydro-geological instabilities and disorders (often driven by land-use changes) typical of the semi-arid Mediterranean environment, may represent one significant acting factor over the history of the so-called *sediment continuum*. The Calabria region, Southern Italy, with its 750 km coastline, can represent a reference case with respect to the concerned matter, given that the watershed geomorphological, hydrological and sedimentological characteristics have brought to the implementation, since 1954, of intensive programmes of torrent control accompanied by coastal control structures.

The research work aims to extrapolate the influence of check dam systems on the shoreline evolution at watershed mouths. Based on a methodological approach already developed by the same Authors, the monitoring surveys in five historical windows (years 1954, 1970's, 1980's, 1990's and 2019-2021) and the subsequent data elaboration and analysis were extended to 8 Calabrian watersheds (of 39,2 to 160,3 Km^2), distributed between the opposite sides (Tyrrhenian and Ionian) of the Aspromonte Massif, classified, according to the linear density of control structures in the main torrent reaches, as "medium-highly structured" (5 cases) and "lowly structured" (3 cases) watersheds.

The investigation, involving about nine hundreds check dams (completely filled just a few years after their construction), explored the relationships between the trapped sediment volume in the "mountain", "intermediate" and "valley" main torrent reaches and the shoreline changes. Although the other processes explaining the complexity of the sedimentary shoreline dynamics are not taken into consideration, the analysed observations allowed to recognise the influence of check dam systems and related sediment transport control on the shoreline evolution and, according to a comprehensive and integrated approach to the management of the *watershed-coast continuum*, suggests to pay a careful attention to check dam systems within the valley torrent reaches of the watershed. The achieved results, supported by cause-effect evidence, should tribute to a general debate on the inter-relationships and integrated evaluations between the relevant need of hydraulic control structures within the watershed and its complex hydro-geomorphology and the parallel consistent need to guarantee a stability of the desired shoreline asset, also to minimise supplementary financial investments in coastal protection measures.

Project funding reference

Research work financially supported by the Italian Ministry of University and Research (ex Decree 10th August 2020 n. 442 – art. 11) within the project "*Development of a service activity network for soil conservation in Mediterranean area*".

Variability of Fallout Radionuclides in River Channels: Implications for Sediment Residence Time Estimations

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Conference theme number(s): 1

Introduction: Fine sediment plays an important role in the health of river ecosystems, providing nutrients and contributing to habitat functioning. However, excessive sediment supply into rivers has several detrimental impacts on water quality and it causes sedimentation in river channels, reservoirs and estuaries. In addition, silts and clays are geochemically active and consequently are responsible for the transport of contaminants, including trace metals, phosphorus, pesticides and radionuclides among others which have high sorptive affinity for fine-grained particles. Hence, quantifying the timescales of sediment transfer throughout river systems is critical for understanding river basin sediment dynamics and the fate of their associated pollutants.

Methods: The River Avon (Devon, UK) is a 40 km long gravel-bed river, draining rough moorland and with a catchment area of 110 km^2. The mean annual flow is 3.7 m^3 s^{-1} and is moderated by managed discharges from a reservoir upstream. Suspended and channel bed sediments were sampled in a 5 km section of the river during four seasonal surveys (January, March, July and November 2022) and suspended sediments were also sampled during a stormflow event. Samples were allowed to settle overnight, dewatered, centrifugated and subsequently freeze-dried. Dried sediments were then gently disaggregated and sieved across a 63 µm mesh.

Dried sediment samples were packed and sealed into containers for at least 21 days to allow the development of equilibrium between ^{222}Rn and its parent ^{226}Ra. Activity concentrations (Bq kg^{-1}) of Fallout Radionuclides (FRNs) were then determined using a calibrated well HPGe gamma spectrometer, by counting samples for ~170,000 s. The isotopes ^{137}Cs and ^{7}Be were determined from gamma emissions at 662 and 477 kev, respectively and $^{210}Pb_{ex}$ was determined by subtraction of ^{226}Ra activity using ^{214}Pb gamma emissions (295 and 352 keV) from total ^{210}Pb (46.5 keV). Activities were decay-corrected to the collection date. Particle size distribution and Total Organic Carbon (TOC) analyses were also performed.

Results: FRN activity concentrations of channel deposited sediments varied substantially within and between river bars and seasonally. Suspended sediment activity concentrations varied within the stormflow hydrograph and also seasonally. ^{137}Cs and $^{210}Pb_{ex}$ did not show significant correlation with sediment storage, particle size or TOC ($R < 0.4$, P-value > 0.05) whereas strong and significant seasonal relationships between ^{7}Be activity concentrations and both sediment storage and TOC total organic carbon were found ($R > 0.4$, P-value < 0.05). Channel sediment residence times obtained using $^{7}Be/^{210}Pb_{ex}$ activity ratios ranged between 0 to 110 days, reproducing the high variability found in activity concentrations.

Discussion: The wide range of residence times can be attributed to various fluvial and geomorphological processes that dominate sediment dynamics in the river channel, including sediment resuspension through stormflow events, sediment deposition/infiltration during low-flow conditions and changing sediment sources in the wider catchment. In addition, particle size distribution and organic matter might influence FRN activity concentrations due to changes in seasonal riverine conditions affecting sorption/desorption dynamics. Future work will assess the influence of sediment sources on $^{7}Be/^{210}Pb_{ex}$ ratios and the relationship between sediment storage dynamics and sediment-bound contaminants. Sediment residence time modelling will provide an improved understanding of sediment dynamics in gravel-bed rivers which is essential to inform management decisions and prediction of the timescales of transfer and fate of associated contaminants.

E. Munoz-Arcos would like to acknowledge the support by the Agencia Nacional de Investigacion y Desarrollo (ANID) through the PhD scholarship ID 72210264. Dr. Ruppert Goddard, Miss Alice Kalnins and Miss Jess Kitch are gratefully acknowledged for fieldwork assistance.

Valorization of chestnut shell for the removal of heavy metals under real conditions

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Conference theme number(s): 8.Zero pollution in the soil-sediment-water nexus; Supported by IAEA TC project RER7015

Introduction: Sediments as the source and storage of heavy metals plays a significant role in their migration and as well transformation [1]. Heavy metals pollution is a worldwide problem through their migration and hazardous effect on the normal functions of rivers and lakes.So, it is of great importance to find suitable method for their removal from contaminated waters. The current study aimed to investigate removal of Cu(II), Cr(III, Pb(II) and U(VI) by means of biosorption. As a medium from which removal of metal ions was performed was used modelled solution to mitigate real conditions. As a novel biosorbent was used chestnut shellwhich characherization was performed by FTIR, EDXRF, physico-chemical analysis, Boehm's titration and determination of point of zero charge (pHpzc). Experimentally obtained data were analysed using Langmuir's, Freundlich's and Temkin's isotherm models. Used kinetics models were: pseudo-first order, pseudo-second order and interparticle model of diffusion.

Methods: Individual and simultaneous removal of heavy metal ions (Pb^{2+}, Cu^{2+}, Cr^{3+}andUO_2^{2+})using chestnut shellwere investigated in stationary conditions by batch method. The selected process parameters were optimized: pH values, sorbent mass, contact time, and initial metal concentration. Concentration of U(VI) was determined by UV-Vis spectrophotometric method and of other heavy metals by FAAS method. Removal efficiency (R_e) were determined by Eq.(1) [3]:

$$R_e = \frac{c_i - c_f}{c_i} \times 100\ \% \qquad (1)$$

Results: Point of zero charge was determined with the value of 4.64 and pH value of the powdered chestnut shell suspension was 4.49. Boehm's titrations showed that total content of acidic and basic functional groups was 2.91 mmol/g and 0.12 mmol/g. By EDXRF analysis, it was determined that chestnut shell contains heavy metals such as Mn, Fe, Ni, Cu, Zn and Pb, with the highest concentration of Fe (243.40 ppm). Optimal conditions for the removal of heavy metal ions with chestnut shell-based biosorbent were pH 5, sorbent mass 100 mg, contact time 30 minutes and initial concentration of each of the analyzed metals 20 mg/L. Adsorption isotherm models showed the best agreement with the Langmuir model for all metals.

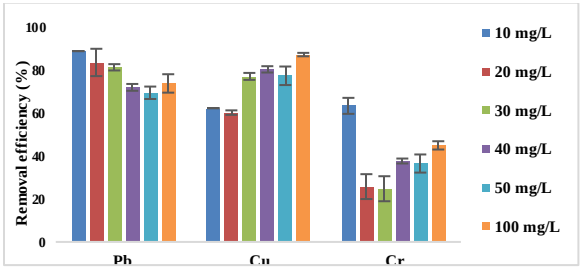

Fig. 1: Change in the value of removal efficiency with the initial concentration of Pb, Cu and Cr ions from a multicomponent solution during the biosorption process on the chestnut shell biosorbent.

Discussion: Analysis of the structural composition of chestnut showed that biosorbent is mainly composed of cellulose and lignin, which provides mechanical and chemical stability to its structure biosorbents. The cellulose content was 18.66% and lignins 36.20%. According to the pHpzc value obtained for chestnut shell (4.64), it can be concluded that it has a cation exchanger properties in a wider pH range.Additionally, characterization by FTIR spectroscopy revealed characteristic bands (C-O, O-H,C-H) attributed to cellulose, lignin and phenolic compounds [5]. Through kinetic modeling of the adsorption process, it was established that the sorption mechanism of the mentioned ions is based on a chemical reaction.The addition of U(VI) in a concentration of 10 to 50 mg/L shows an inhibitory effect on the removal efficiency of Cr ions. Chestnut shell proved to be an excellent biosorbent for the removal of Pb ions from a monocomponent solution, and for the removal of Pb and Cu from a multicomponent system, while it does not show significant affinity for Cr and U ions for investigated process parameters.

Acknowledgement: The authors are grateful for the financial supports from the IAEA RER7015 project.

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Assessment of Natural Radioactivity and Radiation Hazards in Coastal Sediments of Durres, Albania

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Abstract

With the increasing concerns about the potential environmental and health effects of ionizing radiation exposure, it is necessary to assess radiation levels in different areas. This particular study focused on Durrës, a well-known coastal city due to its thriving tourism industry and its proximity to industrial zones.

The research approach involved systematic measurements of gamma radiation using two advanced devices: the Inspector 1000 device and the Gamma radiation detection unit backpack. These portable radiation detectors are recognized for their accuracy and sensitivity. Over the past year, measurements were carried out four times annually to gather comprehensive data on radiation levels. Multiple sampling points were strategically selected along the Durrës coast to gain a complete understanding of radiation distribution patterns.

Preliminary findings suggest that radiation levels in the coastal area of Durrës fall within the acceptable range defined by international radiation safety standards. However, specific locations with high radiation, known as hotspots, were identified near industrial facilities. This emphasizes the potential influence of human activities on radiation distribution.

This study provides valuable insights into the current radiation conditions along the coast of Durrës, emphasizing the importance of ongoing monitoring to ensure the safety of residents, tourists, and the environment.

Keywords: Sediment, Durres, Albania, Natural radionuclides, Gamma ray spectrometer, Radiation hazards.

A case study on PFAS in different matrices downstream a waste processing company at River Nieuwe Kale, Belgium.

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PFAS, or per- and polyfluoroalkyl substances, are chemically, highly inert substances that once released into the environment remain there forever. They cause risks to humans and the environment. This study involves the monitoring of PFAS contamination at the discharge point of a waste treatment company, located on the river Nieuwe Kale, Belgium. The objective is to determine the impact of the PFAS discharge on surface water, sediment and biota.

The study showed that PFAS concentrations in both surface water, sediment and biota are significantly higher than the recommended limits at the discharge point and downstream of the company. Short PFAS chains such as PFBA are found more in wastewater and surface water, while longer PFAS chains such as 6:2 FTS, PFOA and PFOS are found in the sediment. In biota, PFOS dominates the measured PFAS. The difference between the matrices can be explained by water solubility and the degree of accumulation in the sediment and fish tissue.

Despite the company discharging within its permits, the PFAS pollution has an actual risk on the aquatic ecosystem of the Nieuwe Kale.