# Bioessays with the European amphipod *Gammarus fossarum* to assess freshwater sediments toxicity

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**Conference theme number(s): 1. Zero pollution**

**Introduction:** Freshwater sediments act as sinks for pollutants like metals, PAHs, PCBs, PPCPs[1], per- and polyfluoroalkyl substances[2] which can affect benthic organisms and complicate sediment management. *Gammarus fossarum*, a European freshwater amphipod, is widely used in France to assess water quality[3], [4]. And so, *G. fossarum* is a promising model for sediment toxicity assessments and could help making decisions for the management of contaminated sediments[5]. This study evaluates the toxicity of sediments by measuring feeding rate and reproduction in exposed organisms and complementing these with physico-chemical analyses. From these data, threshold values and bioassay guidelines are proposed to improve sediment quality assessments.

**Methods:** Sediment stations were selected using French water agency data, categorising them as reference (uncontaminated), contaminated, or random. Bioassays were based on standardised protocols, with feeding rate and reproduction tested on 140 and 84 sediment samples, respectively. Control tests used artificial sediment, and statistical analysis was performed in R Studio.

**Results and discussion:** Preliminary findings show granulometry and organic carbon contents have minimal impact on endpoints, allowing threshold proposals. Artificial control sediments performed worse than uncontaminated sediments, raising questions about their suitability. Feeding rate (Fig. 1) was more sensitive than reproduction but both endpoints are complementary for assessing sediment toxicity.

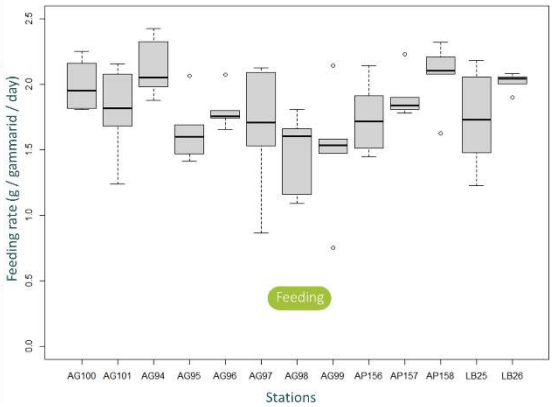


**Fig. 1:** *Feeding rate (g of MUG/gammarid/day, n = 5 replicates x 15 gammarids per condition) measured in G. fossarum males exposed to 13 environmental sediments.*

**Conclusion:** *Gammarus fossarum* can be used for sediment toxicity assessment, allowing sediment discrimination based on biological endpoints. These bioassays could help defining what is a healthy sediment.

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# Ammonium in marine sediments: from a confounding factor in ecotoxicological assessments to a contaminant?

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**Conference theme number(s): theme 1, platform presentation**

**Introduction:** The ecotoxicological approach is an essential component of the environmental quality evaluation of marine sediments, also in relation to the presence of new emerging contaminants. Particularly bioassay batteries are a predictive tool and a reliable indicator of the biological effects of mixtures of substances contained in the sediments, not predictable by chemical analysis alone. For these reasons, in recent years, bioassays have been introduced in a multidisciplinary Weight of Evidence (WOE) approach to evaluate the environmental quality of marine sediments. The use of the WOE integration, which quantitatively combines and weights different kinds of raw data (i.e. sediment chemistry and biological responses like ecotoxicological bioassays) also called Lines of Evidence (LOEs), allows to better discriminate the environmental impact due to the presence of contaminants [1]. The importance of the application of WOE models is particularly evident in complex environmental scenarios where seemingly conflicting results are provided by various LOEs [2].
In this context, the use of embryonic stages is fundamental to evaluate sublethal effects, but embryo bioassays are also sensitive to the presence of ammonium and other confounding factors, which can cause adverse effects in addition to those attributed to contaminant mixtures. The overestimate of toxicity due to confounding factor has practical implications, as it affects management options related to the sediment quality classes determined by the WOE approach.
The aim of this study is to define a tiered framework for assessing the environmental quality of marine sediments using the WOE model, minimizing the influence of ammonium as a confounding factor in bioassays, while considering its relevant chemical concentration in those cases where it can be regarded as a contaminant.

**Methods:** The WOE approach has been included in a quantitative user-friendly model (SediqualSoft ®, free software), that has been validated in several case studies [1, 2]. In SediqualSoft® different LOEs are elaborated independently, using specific criteria for each data, weighting the typology of chemical pollutants and the toxicological relevance of the measured endpoints. Synthetic and quantitative hazard indices are calculated for each LOE, before their overall inclusion in the WOE assessment: the calculated risk level is assigned with a value between class 1 and 5 which classifies the risk from absent to serious [3]. This tool was modified and integrated after the procedure reported in ISPRA guideline n. 16/2021 [4] related to the preparation of elutriate. In particular specific toxicity thresholds of ammonium were assigned to each bioassay, considering the results of embryotoxicity tests on elutriate of marine sediments prepared using a sediment/water ratio of 1:10. When ammonium exceed acceptability limits of bioassays, the tool assigns a lower weight to ecotoxicological battery, introducing a chemical reference level for ammonium.

**Results and discussion:** Preliminary results of the application of this approach showed a more accurate estimate of toxicity when the ammonium is considered a confounding factor. In these cases, the toxicity was overestimated using a classical criterion, Moreover, in some cases, ammonium masks the effects of some traditional contaminants, more persistent in the environment and with higher weight in chemical evaluation. For these reasons this new approach could be a promising tool to be adopted in future guidelines for the management of marine sediments

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# Assessment of Rare Earth Elements (REEs) Toxicity in Sediment Environments Using Caenorhabditis elegans

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**Conference theme number(s): 1**

**Introduction:** Rare Earth Elements (REEs) are increasingly recognized as emerging environmental contaminants due to their critical roles in renewable energy, electronics, and defense technologies. Their extensive use and subsequent release into aquatic systems have raised concerns about their accumulation in sediments and associated ecological risks. Sediments serve as dynamic reservoirs that influence the mobility, speciation, and bioavailability of REEs through complex microenvironmental interactions. Despite their ecological significance, the effects of sediment physicochemical conditions on REE bioavailability and their toxicological implications for benthic organisms remain insufficiently understood.

**Background:**
REEs have a complex chemistry and low solubility in natural waters, where they readily form complexes and precipitates. While also dissolved hydroxides are assumed to cause toxicity to some extent, as with other metals it is the free ions that are expected to be available and toxic [1]. Revel, Medjoubi [2], however, showed that presumably precipitated La and Gd both accumulated in the gut of daphnids, and had calculated killing rates of 0.28 mg/L/d (Gd) and 0.07 mg/L/d (La). This leads to the hypothesis that oral uptake of REE-precipitates by invertebrates may contribute to REE toxicity. As precipitates eventually end up and accumulate in sediments, their toxicity in the presence of rare earth elements should be investigated. This study will be among the first sediment contact tests with rare earth elements [3] and therewith provide insights on the effects to this previously neglected compartment.

**Methods:** This study is going to employ an integrative approach to investigate the effects of sediment microenvironmental factors, such as pH and organic matter, on the bioavailability and toxicity of REEs (specifically of the light element lanthanum (La) and heavy element gadolinium (Gd)) towards the nematode *Caenorhabditis elegans*. Experiments will be carried out using spiked artificial sediments and modifying the concentrations of organic matter and pH. Diffusive gradients in thin films (DGT) passive sampling will be used to quantify the activity of free REE ions. Ecotoxicological endpoints of concern will comprise growth, reproduction and fertility. Bioaccumulation will be determined by total x-ray fluorescence spectrometry. ROS generation will be visualized microscopically.

**Outlook:** These findings will elucidate the critical interplay between sediment composition, REE speciation, and bioavailability, and will offer new insights into the ecological risks posed by REEs in sediment environments.

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# Preliminary ecotoxicological analysis to optimize sediment quality characterization of the Ravenna Port, Italy.

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**Zero pollution**

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**Introduction:** In Italy, the Ministerial Decree 173/2016 regulates the management of dredged marine sediments. This decree outlines the procedures for assessing sediment quality and authorizing dredging management options in marine and coastal environment (e.g. nourishment, disposal at sea or storage in confined disposal facility). Assessing sediment quality is complex. In line with this decree, it involves physical, chemical, and ecotoxicological analyses. The presence of pollutants, such as heavy metals, and the sediment's composition (e.g., clay content) can influence toxicity to marine organisms. The unique characteristics of Italian sediments make assessment even more challenging. The geographical variability of sediments, with different mineralogical and organic compositions, requires a tailored approach for each site. In this context, preliminary studies are essential to optimize ecotoxicological analyses. This ensures a more accurate assessment and prevents misclassification of sediments, with direct implications to the different management options.

**Methods:** The ecotoxicological tests and the physical analyses were conducted on representative samples from different depths (0-50 cm and 50-100 cm) to represent the natural variations within the study area, under UNI CEI EN ISO/IEC 17025:2018 accreditation. Species for ecotoxicological test were selected according to the guidelines of D.M. 173/2016. Two test species were employed for each of the three assay types specified in the D.M. 173/16 (Type I - Sediment; Type II - Elutriate; Type III – Elutriate- larval development) following EPA and/or UNI EN ISO methods.

**Results:** This preliminary study allowed to select the species that provide the most objective representation of the sediment quality at the Port of Ravenna, leading to more accurate environmental risk classifications. The principal findings are that each species suggested in D.M. 173/16 may not always be suitable for all environments, and natural factors (clay content, metals, ammonia levels) can influence test results and generate false positives (i.e. *P. lividus*). The addition of a fourth species to the test battery (i.e. *A. fischeri* in the liquid phase) is recommended in some cases, e.g. in estuarine harbours. The addition of a more realistic picture of ecotoxicological risks beyond the fourth species does not significantly change the overall hazard assessment (**Figure 1**).

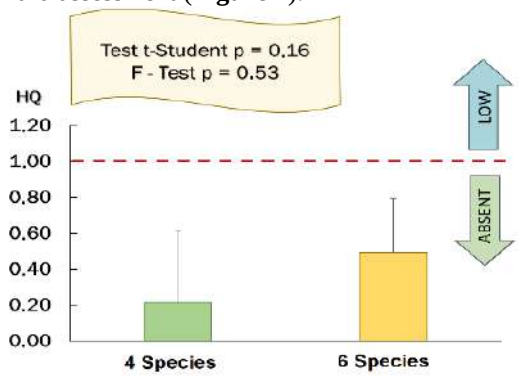


**Fig. 1***: Comparative t-Student test for the number of species tested.*

**Discussion:** A representative classification of sediment quality is crucial for determining sediment management and reuse options. A preliminary assessment is instrumental to defining the analyses methodology that best suits the specificity of the site.

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# Potantial Ecological Risk Assesments in the Gediz Delta derived by $^{210}$Pb and $^{137}$Cs sediment dating

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**Conference theme number(s): 1 and 2**

**Introduction:** Gediz Delta is under the pressure of urbanization of the Izmir metropolis. In the last 10 years, with the expansion of housing and industrial zone in Sasalı and Seyrek, the density of buildings and population has increased. The leading factors that pose a threat to environmental ecology and health are the industrial wastes carried by the Gediz River and the pollution caused by agricultural chemicals. These threats significantly affect not only the basin but the entire delta.

**Methods:** Activity concentrations were measured by using two gamma spectrometers, one of them was planar HPGe detector with low energy and the other was p-type coaxial HPGe detector with medium and high energy. The gamma activity of $^{210}$Pb with 46.5 keV energy in sediment samples was measured with a gamma spectrometer system containing a low energy (3-300 keV) planar HPGe detector with a crystal diameter of 36 mm, a crystal length of 13 mm, an active volume of 13 cm$^3$ and a vertical detector output. P-type coaxial detector has a horizontal output. The HPGe gamma spectrometer system consists of a 184 cc HPGe detector (detector efficiency: 25%, FWHM: 1.83 keV for 1.33 MeV gamma energy of $^{60}$Co and peak/compton ratio: 57:1), Ortec Model-671 spectroscopy amplifier and Canberra PC based MCA (8K) Wilkinson ADC and is shielded with 100 mm lead [1]. In sediment samples $^{226}$Ra; $^{214}$Bi's 609, 1120 and 1764 keV, $^{137}$Cs; 661.66 keV gamma energies are used to analyze. Gamma spectra of the samples are taken for 1-2 days and background spectra are recorded regularly [1].
Two models utilized for determining sedimentation rates in $^{210}$Pb dating are CRS, and CIC. The CRS model is better suited for scenarios where the profile distribution of unsupported $^{210}$Pb concentrations shows a non-monotonic decrease and specific geological conditions [2]. If there is the monotonic decline with depth, and in sediment cores that obtained from same area, total cumulative residual unsupported $^{210}$Pb concentrations more or less vary proportionally the mean sediment accumulation rate, CIC model will give the reliable chronology [3].


**Fig. 1:** Sampling points of the study area.

**Results:** The sediment accumulation rates calculated in the Homa, Homa-1A core taken from the study area, vary between 0.02 and 3.20 cm y$^{-1}$. According to the CIC model, it was understood that the layer sixteen centimeters below the surface was formed in 1986 within the error limits. The dating was confirmed by observing the 1986 peak (Chernobyl) at the same depth in the $^{137}$Cs vertical distribution graph obtained in this core.

**Discussion:** Up to now, redox potentials, porosities and organic matter ratios were obtained in the sediment cores (HM-1, HM-2, Homa-1A, Homa-3A and Homa-7A). Persistent organic pollutants (organochlorine pesticides and 16 PAH compounds) and heavy metals analyses in the sediment cores are still ongoing

**Acknowledgements:** This study was supported by Scientific and Technological Counsil of Türkiye (TUBITAK) under Grant Number 123Y091 authors thank TUBITAK for their support.

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# Title: Reconstruction of historical events by studying radionuclides and chemical concentrations in a sediment core at North Cretan deep basin, Greece

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## Abstract

Deep ocean basins are considered adequate laboratories for the study of the cycle of basic physicochemical quantities and tracers. They play a decisive role in better understanding environmental processes and ecosystem functioning. Sediments are also adequate marine matrices for studying the evolution of any quantity of interest, such as the relevant pollutants discharged or to reconstruct past events due to natural hazards. A 31cm sediment core was collected from the northern Crete basin, at a depth of 1500m, using the box corer method, in order to determine the sedimentation rate, measure the levels of 137Cs radioactivity due to the Chernobyl accident and investigate possible radiotracers. The radionuclide activity concentrations were measured in the laboratory using gamma spectroscopy and a high purity germanium (HPGe) detector at the Institute of Oceanography of the Hellenic Centre for Marine Research (HCMR). The sedimentation rate was calculated using radiodating models using both the $^{210}$Pb and $^{137}$Cs methods. The signals of the nuclear tests as well as from the Chernobyl accident were not resolved for validating the $^{210}$Pb model. The time marker of the Kolumbo volcano eruption that took place in 1650 A.D. it was also used to optimize the geochronology results.

# Environmental characterization for sediment management: the case of the Port of Civitavecchia (Rome, Italy)

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**Conference theme number: THEME 1 - poster presentation**

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**Introduction:**
The North Central Tyrrhenian Sea Port Authority, in order to guarantee the safety of navigation and commercial operations taking place in the Port of Civitavecchia (Rome, Italy) planned a maintenance dredging in the commercial docks and in the ship's turning circle. This in order to be able to restore the original bathymetry foreseen by the current harbor master plan: -15m above sea level in the turning circle and -13.50m above sea level in the remaining watersheeds.
In Italy, the management options for dredged sediments are 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 work summarizes the results of environmental characterization studies carried out in the port of Civitavecchia. It should be noted that the marine area outside the port of Civitavecchia is characterized by the presence of protected habitats (Habitats Directive) such as *Posidonia oceanica* meadows and coralligenous reefs [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 according to the strategy defined by M.D. 173/2016, providing a total of 78 samples. For each sample, grain size, chemical and ecotoxicological analysis were carried out. Data were elaborated using Sediqualsoft 109.0® software to identify the overall quality classes for management.

**Results:** Most sediment samples showed an overall quality classified as B and C, with only a few samples classified as A. 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.
Only 8 samples showed a worse quality D, suitable for disposal in a waterproofed CDF and, to a limited extent, class E for sediments that have to be safely removed from the marine environment.
The main responsible parameter for classification is provided by aliphatic hydrocarbons C>12, characterized by a lower toxicity than PAHs

**Discussion:** The characterization of the sediments to be dredged highlighted the presence of a number of samples that cannot be disposed in a CDF without isolation and handled with particular care.
In order to better discriminate the quality of materials classified in class E and guide their management, the Severe Effect Level (LEG) was calculated. The LEG is defined as "the concentration of the contaminant at which serious ecotoxicological effects are expected (i.e. higher than the average ecotoxicological risk) with a probability of 95%". The samples classified as class E, showing chemical concentrations of C>12 aliphatic hydrocarbons lower than the calculated LEG, can be managed according to the options provided for class D sediments, such as disposal in waterproofed CDF.
The application of the LEG allowed to simplify the management of dredging sediments promoting their reuse in line with the principles of circular economy, ensuring the protection of the marine environment.
Moreover, the resulting quality classification of sediments was fundamental to establish proper mitigation measures (to prevent or reduce the spreading of contaminated resuspended sediment) and monitoring plans, paying attention on nearby protected habitats and species.

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# Metals and phosphorus in riverine sediments from catchments under distinct environmental pressures: potential availability assessment

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**Conference theme number(s): …..**

**Introduction:** Metal accumulation and transport within sediments has been investigated over the past decades, but still represents a concern and a challenge regarding the development of River Basin Management Plans (RBMPs), under the implementation of the Water Framework Directive (WFD). In catchments where the agricultural, urban and industrial pressures interact, phosphorus coexists with metals in sediments, in which can be retained by the same geochemical components. The resulting interactions between P and metals at the sediment-water interface may lead to secondary pollution, due to the release of metals from sediments.
The Northern region of Portugal shows contrasting land uses, and land management practices infer differences in the factors that contribute to non-point source pollution. Recent studies support concerns related to soil losses and land use conflict, high levels of P, metals and organic contaminants in the regional fluvial systems. This study aims to recognize the pattern of distribution and the potential availability of metals and P in streambed sediments from two catchments, Vilariça and Vizela, with distinct geomorphology (and connectivity), land use and environmental pressures, located in the mentioned region.

**Methods:** The sediment samples were collected in September, at the end of the Dry Period (DP) and in May, at the end of the Wet Period (WP); the 63µm fraction was studied for As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn and V. To assess the contents and potential mobility of metals and P, aqua regia digestion, a modified Tessier method, water extractable P, anion exchange membrane extractable P, and the Chang and Jackson P fractionation methods were used.

**Results and Discussion:** The metals that showed the highest levels (above TEL and PEL reference values), in both catchments, were As, Cd, Cu, Pb and Zn. Of these, Cd, Cu and Pb occur in percentages ranging from 45 to 90% in the most unstable fractions (most labile fractions - #1, bound to Mn oxides - #2, bound to Fe amorphous compounds – #3). In the Vizela catchment the contents of Zn were also high in these fractions. The metal(oid) showed no affinity with fraction #4 (forms bound to organic matter). This distribution indicates the contribution of anthropogenic activity and a high potential for mobility and risk to river waters. The higher contents Cr, Fe, V and Ni presented in the residual fraction, express a significant contribution from a lithological source.
Between DP and WP, there was an increase in Pt in most of the samples, more pronounced in some sampling stations. Higher P-MTA contents were registered in the WP sampling period at most of the sampling stations in Vilariça and a few stations in Vizela. Yet, it was also observed a decrease in the Pi/Po ratio, revealing significant increases in Po between DP and WP. The distribution of P among the most active fractions shows that the Vilariça sediments are dominated by Ca-P, Fe-P and CBD-P. Between sampling periods, the high increases in P associated with Fe in the WP stand out, implying a susceptibility to P losses. In the sediment samples from Vizela, the distribution of the most active forms of P differs from that recorded in Vilariça, registering higher amounts of Al-P and lower amounts of CBD-P. When the variation between DP and WP is considered, there is some redistribution of P between the studied fractions.
The results of this study revealed a large variation in available metals and P from sediments of both catchments, and some samples reached levels that may present an environmental risk to the watercourses.

**Acknowledgments:** This work was supported by the Portuguese Foundation for Science and Technology (FCT) in the framework of the Strategic Funding, with UIDB/00073/2020 and UIDP/00073/2020 projects of the I&D unit Geosciences Center (CGEO); and the project UIDB/04033/2020 of the Centre for Research and Technology of Agro-Environmental and Biological Sciences, CITAB, Inov4Agro.

# Mercury contamination: from sediments to the terrestrial ecosystem. The case study of the Toce River (Northern Italy)

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**Conference theme number(s): 1. Zero pollution**

**Introduction:** Mercury is still considered a contaminant of concern in freshwater ecosystems, due to accumulation in sediments and biomagnification in trophic chains. About 50% of European surface water bodies fail to achieve the good chemical status because of mercury concentrations in water and/or biota [1]. Mercury bioavailability was assessed in the Toce River (Northern Italy), were residual contamination deriving from the activity of a chlor-alkaly plant is present in sediments. The aim was to assess the transfer of mercury from sediments to higher trophic levels, both in the aquatic (up to predator fish) and in the terrestrial ecosystem (insectivorous birds) and potential risks.

**Methods:** Total mercury (THg) and methylmercury (MeHg) were analyzed in sediments of the Toce River, in native benthic invertebrates belonging to different taxonomic/functional groups and in different benthofagous fish species (*Salmo trutta*, *Telestes muticellus*, *Squalius squalus*). To assess the transfer to terrestrial trophic chains, THg was analysed in adult macroinvertebrate insects and in different body tissues (feathers, blood, eggs) of the resident insectivorous passerine great tit (*Parus major*).

**Results:** THg in sediments showed values up to 100 µg $kg^{-1}$ d.w., slightly declining in time, while MeHg represented <1% of THg. Among benthic invertebrates, collectors, shredders and predators exhibited higher concentrations (up to 253 µg $kg^{-1}$ d.w. for THg and 88 µg $kg^{-1}$ d.w. for MeHg) than grazers, confirming that exposure is mainly due to the ingestion of contaminated food resources (sediments or preys) [2]. Fish showed values up to one order of magnitude higher than preys, and almost 100% of mercury was in the organic form (MeHg). THg concentrations in adult insects were close to those in aquatic stages, proving active mercury transfer to terrestrial food chains. Here, analysis of body tissues of resident great tits showed the presence of mercury in feathers and blood of adult females (THg up to 2 mg $kg^{-1}$ d.w. and 0.28 mg $kg^{-1}$ w.w., respectively) and its transfer to their offspring (THg up to 0.04 mg $kg^{-1}$ w.w. in eggs), as proved by significant correlations between Hg levels in eggs and maternal blood (r=0.91) or feathers (r=0.76, p<0.05).

**Discussion:** Active cycling of mercury stored in sediments has been observed in the Toce River, with values in benthic invertebrates – organisms at the basal levels of the aquatic trophic chain - and in fish exceeding the European Environmental Quality Standard for biota ($EQS_{biota}$=20 µg $kg^{-1}$ w.w. THg in fish) (Fig. 1). This threshold is aimed to protect top predators from risk of secondary poisoning. Based on these data, the chemical quality of the Toce River stretch should be classified as "not good". However, as in other mercury-contaminated ecosystem, further research is needed to determine the extent to which Hg exposure may cause significant impacts on wildlife.

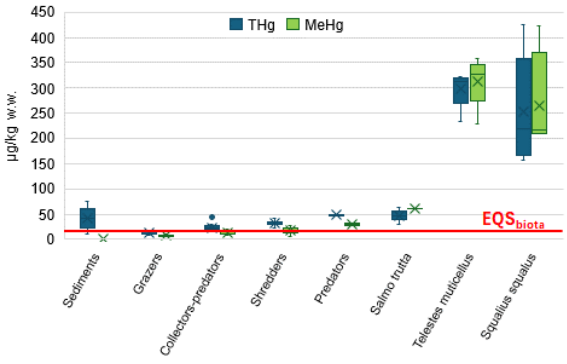


**Fig. 1:** THg and MeHg concentrations in sediments, benthic invertebrates (functional feeding groups) and fish collected in the Toce River, in comparison to the EQS for Hg in biota.

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# The NRRP Return Project: Environmental integrated monitoring plan for both traditional and emerging contaminants

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**Conference theme number: 1 – Zero pollution**

**Introduction:** The Italian NRRP (National Recovery and Resilience Plan) RETURN (multi-Risk sciEnce for resilienT commUnities undeR a changiNg climate) Project aims to improve understanding of environmental, natural and anthropogenic risks within the context of climate change. RETURN includes the proposal of a new integrated monitoring plan for traditional (metals and hydrocarbons) and emerging contaminants (asbestos fibers, organic microcontaminants, drugs, etc.) in seawater and sediments and their ecotoxicological effect in port sea environment. The first application of the monitoring plan was carried out in the Port of Genoa (Italy) for the first time between 15 December 2023 and 8 January 2024.

**Methods:** The monitoring plan included measures of physical-chemical parameters of the water column and dynamics by fixed and mobile instruments; sampling of sediments and water by Van Veen grab and Niskin bottle; sampling of traditional and emerging contaminants by passive samplers (DGT, POCIS and SPMD)[1]. Moreover, ecotoxicological evaluation of water and sediments was performed by tests on *Dunaliella tertiolecta* and *Artemia salina*. Sediments were sampled throughout the port basin, while two sites (Site 1 and Site 2) with different characteristics in terms of marine dynamics, port activities, stream inputs and vessel traffic were chosen for contaminant determination.

**Results:** Results made it possible to both characterize the port basin from a geological point of view and determine the distribution of major elements and trace elements. Significant differences between the two monitoring sites were found, including, for example, different sea dynamics (Site 2>Site 1), and metal concentrations in seawater (Fe in Site 1>Site 2), sediments (Site 1>>Site 2), and DGT (Site 1>Site2). Caffeine, cocaine and some drugs such as naproxen (an anti-inflammatory) were detected at both sites, while other compounds such as sucralose and benzophenone-3, which is a UV filter found in creams, were only detected at the eastern site (Site 2), the one closer the city of Genoa. Notable differences in toxicity levels between seawater and sediment elutriates were highlighted, but no differences between monitoring sites.

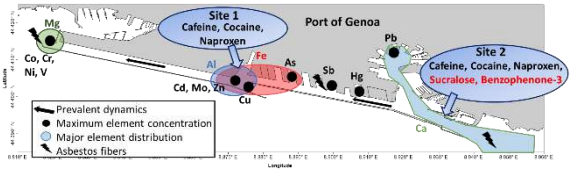


**Fig. 1:** Scheme of the results obtained in the Port of Genoa with the first application of the RETURN integrated monitoring plan.

**Discussion:** The proposed plan proved to be valid for the characterization of the port basin and the further sampling and measurement campaigns will allow us to refine the chosen methodology and better understand the results obtained.

**Acknowledgements:** The Authors would like to thank the Port System Authority of the Port of Genoa for having granted the use of the port areas as pilot site for their research activities. The present study was funded by the Italian NRRP (National Recovery and Resilience Plan) RETURN project (CUP D33C22001290002).

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# Organic ultraviolet filters (OUVFs) in sediments of freshwater bathing areas in Southern Poland: Current sink and future risk?

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**Conference theme number(s): Theme 1 (Zero Pollution)**

**Introduction:** Organic ultraviolet filters (OUVFs) are essential components in sunscreens and personal care products [1], designed to protect the skin by absorbing UV rays [2]. Despite their protective benefits, the environmental impact of OUVFs cannot be overlooked, as these compounds are directly released into ecosystems through recreational activities, wastewater treatment plant effluents, and illegal dumping [3]. As emerging contaminants, OUVFs pose a significant threat to the environment due to their high concentrations, frequent detection, chemical stability, resistance to biodegradation, persistence, potential toxicity, and endocrine-disrupting properties [4]. To our knowledge, no studies have yet examined OUVF concentrations in freshwater sediments in Poland. Therefore, this study aimed to determine the concentrations of the most used OUVFs in the sediments of recreational freshwater reservoirs in Southern Poland.

**Methods:** Sediment samples were collected in April and July 2024 from the popular freshwater reservoirs in Southern Poland, namely Kryspinów, Chechło, and Balaton, as well as from the Dobczyce reservoir that as the primary drinking water source for the Krakow's inhabitants was selected as the reference site. The determination of OUVFs followed the modified procedure described in [5]; briefly, 20 g sample of air-dried sediment was subjected to ultrasonic-assisted extraction using 20 mL of methanol (MeOH) for 30 minutes. Following extraction, the sample was centrifuged at 5000 rpm, and the supernatant was decanted. The extract was then evaporated to dryness using a CentriVap vacuum concentrator and reconstituted in 0.25 mL of MeOH. Organic UV filters were determined using an ultra high performance liquid chromatography (UHPLC) system (Vanqiush Flex Thermo Scientific), coupled to a triple quadrupole mass spectrometer (TSQ Altis Plus, Thermo Scientific).
Environmental risk associated with the analyzed OUVF concentrations in sediment samples were assessed using the risk quotient (RQ) methodology originally designed by the US Environmental Protection Agency [6]. RQ values were calculated as the ratio of measured environmental concentrations (MECs) to predicted no-effect concentrations (PNECs) for each investigated OUVFs. The mean concentrations of UV filters detected in each reservoir were used as MECs. The worst-case scenario was also considered, with maximum measured concentrations used as MECs. PNEC values were obtained directly from the ECHA Chemical Database [7] or, when unavailable, from relevant scientific literature.

**Results:** The concentrations of seven investigated OUVFs, namely benzophenone-3 (BP-3, oxybenzone), octocrylene (OC), 4-methylbenzylidene camphor (4-MBC), ethylhexyl methoxycinnamate (EHMC, octinoxate), butyl methoxydibenzoylmethane (BMDBM, avobenzone), homosalate (HMS), and isoamyl p-methoxycinnamate (IAMC) will be presented. Additionally, changes in the concentration of investigated OUVFs between spring (before the swimming season) and summer (during the peak of the swimming season) will be discussed. Finally, the estimated environmental risk as RQ values calculated for mean OUVF concentrations as well as for the worst-case scenario, represented by the maximum OUVF concentrations will be considered.

**Discussion:** As the first study investigating OUVFs concentrations in inland freshwater sediments in Poland, the findings of this research fill a critical knowledge gap and offer valuable insights. These results will also support the development of future pollution control strategies and enhance sediment quality monitoring efforts.

**Funding**: Research project was supported by program „Excellence initiative – research university" for the AGH University of Krakow.

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# Historical analysis of micro plastics and heavy metals from the sediment records in İzmir Bay

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**Conference theme number(s): I ve II**

**Introduction:** The province of Izmir is an important settlement area where the concept of urbanization has been experienced throughout history for more than 3000 years. Today, the metropolitan city of Izmir is the third largest city in Turkey in terms of urbanization with a population of approximately 5 million and the second busiest port of Turkey. The Gulf of Izmir is heavily affected by both natural micro-oceanographic and anthropogenic effects caused by intensive industrial-commercial activities, maritime traffic/shipyard activities and population density [1]. Therefore, the aim of the presented study is to examine the historical analysis of micro-plastics and heavy metals in the sediment records of İzmir Bay by $^{210}$Pb and $^{137}$Cs dating .

**Methods:** This study deals with the sediment cores from Izmir Bay /Aegean Sea within the scope of the ongoing project" Potential Ecological Risk Assessments in the Izmir Bay-Gediz Delta". One-day sampling expedition was conducted on 26th August 2024, onboard of R/V Marmara.

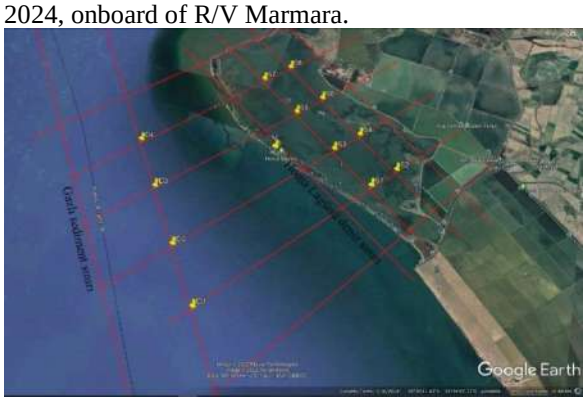


**Fig.1:**The sampling stations in the Izmir Bay-Gediz Delta

The sampling has been performed using Box-Corer sampler. The sampling stations (Fig.1) were selected based on recent preliminary information as shown in Fig.2. Four sediment cores from the inner Bay were sliced at 1-cm intervals for further analyses. In this study, the quantitative determination of the $^{210}$Pb and $^{137}$Cs was carried out by HPGe gamma spectrometry. Heavy metal analyses are carried out by Wavelength Dispersive XRF Spektrometers. Micro-plastic analyses are performed using well-known defined methods [2].

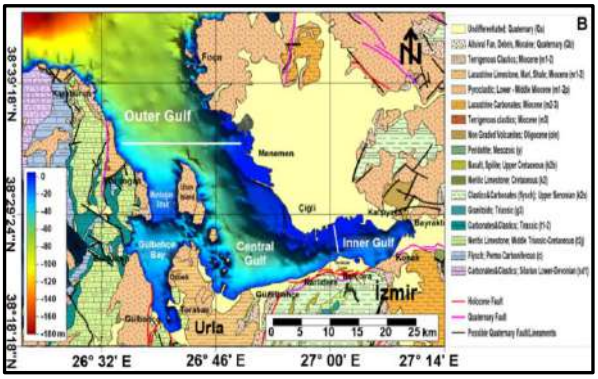


Fig.2 Bathymetric map of the Izmir By[1].

**Results:** It was derived from $^{210}$Pb dating that the sedimentation rates of the region were in the range of 1,71- 3,54 cm.yr$^{-1}$. There is not a significant discrepancy between CRS and CIC Models [3-4] and give the almost same results. Furthermore, the validity of the proposed methodology is confirmed by $^{137}$Cs chronology. After all analysis of heavy metals and micro plastics are completed, pollution history of the studied marine region will be evaluated within the established chronology.

**Discussion:** Sediments are a fundamental, complementary and dynamic part of the aquatic environment and serve as an archive for understanding the environmental processes and fates of pollutants in the aquatic systems.

**Acknowledgements:** This Project (Contract No: 123Y091) is financially supported by the TUBITAK (The Scientific Technological Research Council of Turkey).

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# MEASUREMENT OF MICROPLASTICS IN SAND SAMPLES TAKEN FROM AZERBAIJAN COASTS OF THE CASPIAN SEA.

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**Conference theme number(s): 1. Zero Pollution**

**Introduction:** Plastics are synthetic organic polymers, which are derived from the polymerisation of monomers extracted from oil or gas [1]. Since the mass production of plastics began in the 1940s, microplastic contamination of the marine environment has been a growing problem. Microplastics are both abundant and widespread within the marine environment, found in their highest concentrations along coastlines and within mid-ocean gyres [2]. Due to their small size, microplastics are widespread pollutants that can permeate various environments, posing risks to both ecosystems and human health. Microplastics have emerged as a significant environmental problem worldwide, particularly affecting unique ecosystems such as the Caspian Sea. The Caspian Sea is the largest lake on Earth both in terms of area and volume. It has a surface area of 371,000 square kilometers (143,000 sq mi). Its volume is 78,200 cubic kilometers (18,800 cubic miles). The Caspian Sea has 40-44% of the world's total lake waters. The Caspian Sea is an endorheic water body. It borders with Russia, Azerbaijan, Iran, Turkmenistan and Kazakhstan. Although research on microplastics is increasing globally, research focused on the Caspian region is still limited, especially regarding their potential effects on human health. This gap in research indicates the need for targeted research in this area. Research works on the study of microplastics in the Caspian region were mostly carried out in Iran, located on the southern shores of the Caspian Sea. In this study, sand samples taken from the Azerbaijani shores of the Caspian Sea were analyzed to determine contamination with microplastics.

**Methods:** The microplastics were analyzed using the IAEA's NUTEC protocol in samples taken from the Azerbaijani coast of the Caspian Sea. In the study, sand samples were collected from two distinct coastal areas of Caspian Sea in Azerbaijan, Novkhani and Shikhov (Figure N:1), with particular attention given to the surrounding environmental conditions and weather during the sampling process. Analisis process of samples include Drying, Fractionating, Density Separation, Filtration, Microscopic analysis of samples and Calculation of microplastic particles.

**Results:** A certain amount of microplastics were detected in the samples taken from both areas - Novkhani and Shikhov.


**Fig. 1:** Sampling stations along the coastline of the Caspian Sea in Azerbaijan (Absheron peninsula)

In particular, 94 MP/kg microplastics were found in the 4 mm-1.6 mm fraction in the Novkhani area, and 117 MP/kg in the same fraction in the Shikhov area. After calculations for each fraction, the total number of microplastics found in the Shikhov and Novkhani samples was divided by the weight of the dry sample, and approximately how many microplastics were present per 1 kg of sand was calculated .The discovery of a large amount of microplastics (150–290 particles/kg) in the coastal areas of Novkhani and Shikhov confirms that plastic pollution is widespread in the region.

**Discussion:** These results provide an estimate of the microplastic concentration in sand samples collected in the Novkhani and Shikhov coasts of the Caspian Sea, which help to understand the distribution of microplastics in different size fractions. Based on these results, it is possible to say that plastic pollution exists.This indicates that microplastics are present in significant quantities on the coasts.

The amounts of microplastics in different fractions demonstrate that microplastics vary in size and quantity across sites, and that overall plastic pollution is a problem in both sites. Based on this, the presence of plastic pollution on these shores of the Caspian Sea is confirmed.

**Acknowledgements**. This work was funded by the Institute of Radiation Problems, Ministry of Science and Education of the Republic of Azerbaijan.

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# Microplastic pollution in a special protection area for migratory birds

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**Conference theme number(s): 1**

**Introduction:** Plastic pollution in Special Protection Areas (SPAs) for migratory birds and in Sites of Community Importance (SIC) is a growing environmental concern. These areas, often designated to safeguard migratory bird species, are increasingly threatened by plastic waste. This study presents the first assessment of microplastics (MPs) pollution in beach sediments along the coast of the Strait of Messina (Central Mediterranean Sea) to evaluate the ecological risk.

**Methods:** Microlitter samples were collected from two sandy beaches, Montorsoli and Pylon beach, with a different anthropogenic impact. Microparticles were identified using Raman spectroscopy and Fourier Transform Infrared Attenuated Total Reflection Spectroscopy (FTIR-ATR). To evaluate the risk, the Polymer Hazard Index (PHI) and Polymer Load Index (PLI) were calculated.

**Results:** A total of 80 beach sediment samples were collected, with an average of 52.1 MPs/kg. At Montorsoli beach, 321 MPs were detected (80.2 MPs/kg), while Pylon beach had 96 MPs (28 MPs/kg). The dominant polymer at Montorsoli beach was PMMA (91%), followed by PE (2%) and PTFE (1%), with natural fibers, including cotton, accounting for 3% of the findings. In contrast, at Pylon Beach, the most common microparticles were cotton (49%) and cellulose-based fibers (35%), followed by PP (9%), PE (5%), and PET (2%). Based on PHI values, the overall risk of MP pollution at Montorsoli beach was categorized as hazard level V, whereas Pylon beach (PHI = 84) was categorized as hazard level III. Montorsoli beach was characterized by a PLI > 20 (Risk Level Category III), while Pylon beach was characterized by a PLI > 10 (Risk Level Category II).

**Discussion:** The Strait of Messina is one of the most important European migration flyways, supporting raptors, storks, and many other bird species. This study provides the first data on the MPs contamination of the beaches along the Strait of Messina. Despite not being a popular tourist destination, Montorsoli Beach was the most polluted, primarily by PMMA pellets. In contrast, Pylon Beach which is, a highly touristic area, was relatively clean. This baseline assessment provides critical insights into the current state of microplastic pollution and serves as a valuable foundation for effective management and conservation efforts.

**Funding**

This study was funded by the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4 - Call for tender No. 3138 of 16 December 2021, rectified by Decree n.3175 of 18 December 2021 of the Italian Ministry of University and Research funded by the European Union – Next Generation EU. Award Number: Project code CN_00000033, Concession Decree No. 1034 of 17 June 2022 adopted by the Italian Ministry of University and Research, Project title "National Biodiversity Future Center - NBFC".

# eDNA metabarcoding for the assessment of benthic macroinvertebrate biodiversity in Mediterranean coastal lagoons

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**Conference theme number(s): 1**

**Introduction:** Benthic invertebrates are invertebrate animals inhabiting the sediments of water bodies. They have a role as suspension feeders by capturing organic particulate from the water column and introducing it to the bottom. Benthic macroinvertebrates also act in the sediment to accelerate the decomposition processes of organic matter. They are suitable as ecological indicators of transitional water ecosystems for their critical role in the food web as well as being sensitive to the pollution conditions of the ecosystems due to their relatively sedentary life, long life cycles, and space use behaviour.. Moreover, the biodiversity reduction of benthic macroinvertebrates can impact the ecosystem functioning as demonstrated for different freshwater ecosystems. The application of molecular methods, such as environmental DNA (eDNA) metabarcoding, is improving the analysis of benthic macroinvertebrate biodiversity (1,2). eDNA metabarcoding refers to the analysis of DNA molecules present in an environmental sample, such as water or sediment, through PCR amplification of specific gene markers, high-throughput sequencing of amplicons, and taxonomic classification of DNA sequences comparing them with DNA barcodes deposited in the reference databases.

**Methods:**

The study area is a coastal lagoon included within the NATURA 2000 Site "Aquatina di Frigole" (IT50003) located in southeastern Italy. During the spring of 2021, three replicates of 1 L of surface water were collected in seven sampling sites and DNA was extracted. A region of COI gene marker was amplified and the amplicons were sequenced by NGS. The sequences were clusterized in OTU and taxonomically assigned to benthic invertebrates.

**Results:** High throughput sequencing of the COI amplicons and OTUs annotation highlighted the specific benthic macroinvertebrates communities composition throughout the Aquatina Lagoon (Fig.1). Overall, 49% of the OTUs belong to the Mollusca phylum, 16% to the Annelida phylum, 13% to the Gastrotricha phylum, 8% to the Chordata phylum, 7% to the Arthropoda phylum, 3% to the Cnidaria phylum, 2% to the Porifera phylum, and the remaining 2% to the Echinodermata and Nemertea phyla. The analysis also demonstrated that benthic macroinvertebrate communities structure is correlated to the temperature and salinity gradient of the lagoon.

**Discussion:** This research demonstrated the validity of eDNA metabarcoding as an efficient tool for the assessment of benthic macroinvertebrate biodiversity in coastal lagoons. The results suggest that peculiar features of this ecosystem, such as shallow waters and limited currents, facilitate the assessment of benthic macroinvertebrate communities through environmental DNA analysis from surface water samples, opening for more rapid and accurate monitoring programs for these animals inhabiting the sediments.

**Acknowledgement:** This research was supported by the PRO-COAST project funded by EU HORIZON-CL6-2022- BIODIV-01 to Maurizio Pinna; post-doc grant of F. Zangaro was supported by the National Biodiversity Future Center (NBFC) project CN_00000033 funded under the National Recovery and Resilience Plan (NRRP, Mission 4 Component 2 Investment 1.4) of Italian Ministry of University and Research (MUR) funded by the European Union—NextGenerationEU.

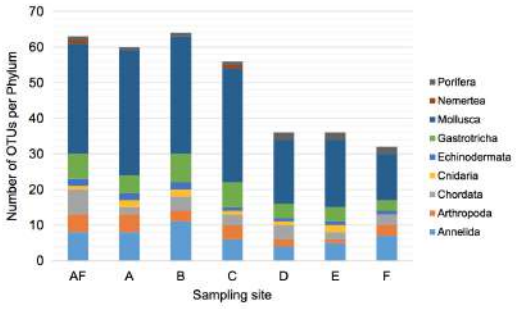


**Figure 1.** Benthic macroinvertebrates biodiversity among sampling lagoon sites

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# The new breakwater of the Port of Genoa (Italy): a complex marine environmental monitoring strategy

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**Conference theme number: 1 - Zero pollution**

**Introduction:** Thanks to the realization of the new breakwater and the modernisation of the inner port areas, the Port of Genoa (Italy) is a candidate to become a centre of gravity for large ships and a great logistics hub for trade in Southern Europe, to keep pace with Northern European ports and the rapid growth of North African, Middle East and Black Sea ports [1]. The new infrastructure will allow ultra-large container vessels (over 400 m long and 60 m wide) and bigger cruise ships (over 300 m long) to enter safety the Port of Genoa.
To ensure the sustainable use of marine waters and resources, the European Union has developed a strict system of environmental regulations, including the Marine Strategy Framework Directive (MSFD 2008/56/EC), which defines the general framework of environmental objectives to be applied in all European marine regions [2][3].

**Methods:** Under the indications and requests of the Italian Ministry and other government and control agencies, the monitoring plan of the construction of the new breakwater has involved a large group of researchers of UNIGE, each involved for their own specific skills in marine environmental monitoring.
All 11 descriptors of MSFD were taken into consideration, and UNIGE was responsible for characterizing Descriptors 1, 2, 3, 4, 5, 6, 7, 9 and 10 "in and around" the works area, and follow their evolution during the works as requested. Given that, the project in question foresees the dredging of the seabed of the port basin and of the inlet channel to the east of the Port, the spillage of the dredged material into the modular caissons of the new breakwater, the preparation of the embankment with gravel spillage and the consolidation of the foundation soils by creating gravel columns, i.e. all activities that may create turbidity along the water column, it was decided to add to the MSFD descriptors also the monitoring of turbidity and water mass dynamics.

**Results:** Figure 1 is a summary of the monitoring activities planned for each individual MSFD descriptor and for water turbidity and dynamics.

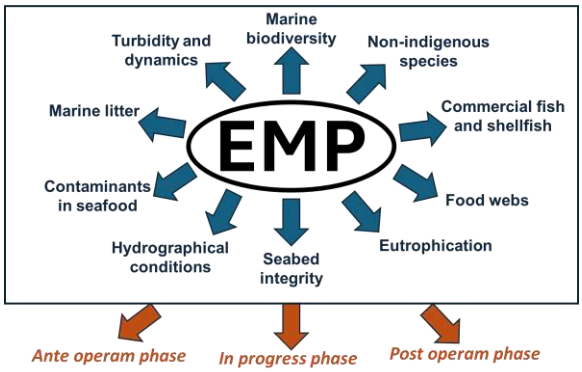


**Fig. 1:** Scheme of the Environmental Monitoring Plan (EMP) subjects (blue) and phases (orange).

**Acknowledgements:** This research has received funding from the construction of the new breakwater of the Port of Genoa project within the research agreement between DISTAV of the University of Genoa and the Port System Authority of the Western Ligurian Sea—Port of Genoa (Project 3062 CUP C39B18000060006).

**References:** [1] Haralambides (2019) *Maritime Economics & Logistics* **21**:1–60. [2] Paramana et al. (2023) *Marine Policy* **155**:105733. [3] Puharinen (2023) *Marine Policy* **155**:105712.

# Rock-glacier springs as key water sources for the future: is trace element contamination a risk?

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**Conference theme number(s): 1. Zero pollution**

**Introduction:** Rock glaciers - landforms indicating the past/current presence of ice-rich permafrost - are considered key water storage for the future, since the melting of ground ice is generally slower than the melting of surface glacier ice and because of their role as shallow groundwater reservoirs [1]. Moreover, rock glaciers can be important refugia for cold-adapted species. However, rock-glacier sediment transfer and ice melting can impact surface waters located downstream, since enhanced weathering in rock glaciers may favour the release of trace elements into the outflowing water [2,3]. Our aim was to analyze trace element concentrations in sediments and water of different rock-glacier springs in the Eastern Alps (North Italy) and to evaluate potential (eco)toxicological risks for native aquatic communities and for human health.

**Methods:** Sediments and water were collected in summer 2024 in springs (Trentino-Alto Adige, North Italy, 1800-2800 m a.s.l.) originating from rock glaciers (n=7) with different degree of activity (from intact to relict ones) vs. non-rock glacier springs (n=6). Trace elements were analyzed by ICP-OES and ICP-MS. Benthic macroinvertebrates were collected with kick-nets and identified to the finest taxonomic level.

**Results:** The results revealed that sediments of rock-glacier springs located in paragneiss-dominated catchments are characterized by high concentrations of some trace elements, e.g., Ni (Fig. 1) and Cr, exceeding Probable Effects Concentrations [4]. These values mirror concentrations in water, proving potential concern also for human consumption. To evaluate potential ecotoxicological effects on benthic invertebrates, the study will involve analysis of community structure, and of bioaccumulation and incidence of morphological deformities in larvae of Diptera Chironomidae.

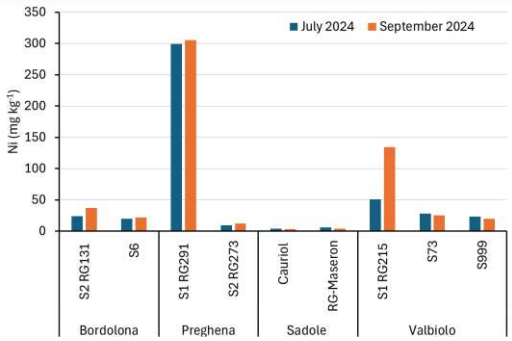


**Fig. 1:** Concentrations of nickel in sediments of springs originating from rock-glaciers ("RG" in spring code) vs. non-RG, in different areas.

**Acknowledgement:** This study was carried out within the project PRIN 2022 "SUBSURFICE – Ecohydrological and environmental significance of subsurface ice in alpine catchments" (code no. 2022AL7WKC, CUP: B53D23006910006), which received funding from the European Union NRRP (Mission 4, Component 2, Investment 1.1, D.D. 104 2/2/2022).

**References:** [1] Carturan et al. (2024) *The Cryosphere* **18**:5713-5733 [2] Colombo et al. (2020) *Catena* **194**:104700; [3] Brighenti et al. (2024) *STOTEN* **953**:175706; [4] MacDonald et al. (2000) *Arch. Environ. Contam. Toxicol.* **39**:20-31.

# *Gammarus fossarum* as European amphipod species for substance toxicity assessment using spiked sediment

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**Conference theme number(s): 1**

**Introduction:** As part of the evaluation of the chemicals' toxicity via the sedimentary phase in non-vertebrate aquatic species, an OECD test guideline on freshwater amphipods is currently under validation through interlaboratory assay ("Sediment-Water Amphipod Toxicity Test Using Spiked Sediment", Project 2.68). The protocol assesses toxicity of persistent chemicals in sediment and comprises both sub-chronic and chronic toxicity tests that measure the effect of exposure to spiked sediment on juveniles' growth and adults' reproduction, respectively [1-2]. The test guideline proposal focuses on the North-American amphipod *Hyalella azteca* but also includes the possibility to use alternative amphipod species. Here, we aim at highlighting the interest for including the European freshwater amphipod *Gammarus fossarum* as second model species. As a proof study of feasibility, we focused on the sub-chronic toxicity test: an experiment was conducted with *G. fossarum* to assess juvenile's growth in control conditions (i.e. without contaminated sediment).

**Methods:** Pairs of sexually-mature gammarids were isolated and maintained during 24h in the laboratory in two aquaria at 16°C until juveniles were spawned. Adults were then removed to allow the neonate gammarids to grow without risk of cannibalism. After 7 days (day 7), ten pools of thirty 7-day-old juveniles were sampled from the aquaria, sacrificed in ethanol and dried in an oven (24h, 80°C) to measure mean individual body mass. The remaining juveniles were introduced in new aquaria for 14 days. At day 21, ten pools of thirty 21-day old juveniles were sampled from the aquaria, sacrificed in ethanol and dried to measure mean individual body mass (Fig. 1).

**Results:** Our analyses showed that juvenile gammarids grew significantly during the 14-day experiment (t-test: $t_9$ = -8.45, P < 0.001; Fig. 1). Juveniles body mass doubled between day 7 (mean ± SE: 0.03 ± 0.001 mg) and day 21 (0.06 ± 0.003 mg).

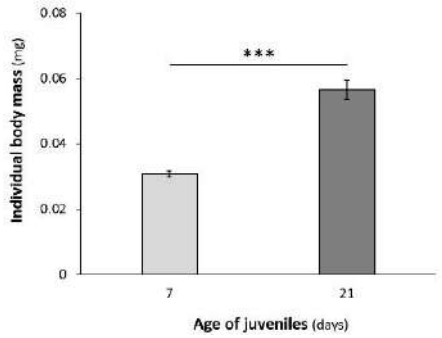


**Fig. 1:** Mean (± SE) growth of 7-day old juvenile gammarids during the 14-day sub-chronic toxicity test in control conditions (i.e. without contaminated sediment).

**Discussion:** By determining growth of 7-day old gammarids after 14 days, we demonstrated that validity criteria of the sub-chronic toxicity test was fulfilled (i.e. significant growth in control conditions). These results look promising regarding the Sediment-Water Amphipod Toxicity Test protocol applicability to *Gammarus fossarum*, a European amphipod species. To support these results, an interlaboratory assay is planned in early 2025 with several European countries to determine during sub-chronic toxicity test the effect of two molecules (bifenthrin and pyrene) spiked in sediment.

Acknowledgements: We thank M. Claitte, C. Arcanjo, S. George, A. Racher and D. Galaman for their technical assistance.

**References:** [1] Norberg-King et al. (2003) *ETC: An International Journal* **25**:2662-2674; [2] Environment and Climate Change Canada (2017) *Third Edition*. *RM.33*.

# Exploration of sediment research by water authority HHNK within its Water Framework Directive Impulse Program

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**Conference theme number(s): 1**

**Introduction:** The current goals of the Water Framework Directive (WFD) for water quality are not going to be met for all waterbodies in the Netherlands in 2027. Dutch water authorities, like Hoogheemraadschap Hollands Noorderkwartier (HHNK), play an important role in the acceleration of the improvement of water quality, both ecological and chemical. This is why HHNK launched its own WFD Impulse Program (WFD-IP), which contains supplementary measures in order to speed up the implementation of the WFD goals. The ambition of HHNK is that all the waterbodies within its management area will be clean and healthy according to the WFD standards by 2027 [1]. However, this is a very though challenge and might not be entirely achievable. HHNK conducted in 2023 a WFD review which revealed that 27 chemical substances do not meet the water quality standards in one or more WFD water bodies[2]. HHNK conducted a monitoring program all substances not meeting the WFD standard. Based on the outcome of the monitoring an action plan was determined by HHNK. One approach was to perform research and monitoring of WFD specific substances, problem substances and (upcoming) substances of concern in relation to the sediment quality. In preparation for dredging work, HHNK already carries out standard water bottom surveys[2]. HHNK will now also take the additional chemical substances into account in this process. This will give HHNK a better understanding of sediment as a source and possible impact of dredging on the chemical water quality. The goal is to use data from monitoring of the WFD-IP and link it and coordinate it to the dredging work. By determining the role of dredging and the local sediment quality on the water quality, dredging can be assessed as part of other possible actions that can be taken by HHNK for improvement of the overall water quality.

**Methods:** HHNK performs several experiments in relation to the WFD-IP sediment research. Here we focus on an experiment that is being performed with the assistance of Deltares; Monitoring WFD specific substances, problem substances, and substances of concern in sediments at five locations along the motorway N9 (Fig. 1) . Duplo samples will be taken according to guidelines at undisturbed silt rich points. They will be taken either from shore, a bridge, or by boat. A 500 gr. (mixture of 3 monsters) sediment sample will be taken with a piston sampler from the top layer (up to 30 cm). The samples will be stored in the dark around 4 degrees. An additional third sample will be taken for a leaching test (liquid to solid ratio of 10 L $kg^{-1}$, NEN-EN 12457-2 [3]). Abiotic factors like the weather, pH, temperature, oxygen, and suspended matter will be measured. Samples will be prepared and analyzed by the inhouse laboratory of HHNK, Stichting Waterproef.


***Fig. 1:*** *Indication of sampling locations in the province North-Holland. Modified from A. Wijdeveld.*

**Outlook:** We would like to further elaborate on this study and present preliminary results in the poster. Some questions we would like to focus on are: 1) What are the possibilities of subsequent delivery from the sediment for various WFD specific substances?, 2) How does this impact these substances reaching our WFD goals?, 3) What are the possible follow-up actions for HHNK that can be implemented in the WFD-IP in relation to sediment contaminated with problematic WFD substances?, and 4) How can we as HHNK improve sediment research within the WFD-IP in a cost-effective way? We will also discuss challenges and lessons learned, and hope to gain insight from experts in the field.

**References:** [1] HHNK (2024) https://www.hhnk.nl/deltares-onderzoek-dinoterb. [2] HHNK (2024) *Bijlage 1 24.0673636*; [3] NEN (2002) *NEN-EN 12457-2*.

# Sediment pollution, chronic toxicity and metal bioaccumulation in freshwater macroinvertebrates from Pb/Zn mining districts

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**Conference theme number(s): 1**

**Introduction:** Mining activities for the extraction of metals have usually resulted in the disposal of soil tailings, which can leach metals to rivers and pose a significant risk for aquatic communities. Sediment and biota have been recognized as suitable monitoring matrices for long-term changes in water quality of European water bodies, but environmental quality standards, for both sediment and biota, have been developed only by some State Members. In present study, the assessment of two abandoned Pb/Zn mining districts was carried out through the integration of three lines of evidence (LOEs) to conduct a risk assessment using a weight of evidence (WOE) framework through a reference condition approach. The LOEs were sediment pollution, sediment chronic toxicity and metal bioaccumulation in field macroinvertebrate biomonitors.

**Methods:** The river catchments studied are located in in the Cantabrian region (northern Spain), and seven sites in two metal districts were studied: Arditurri Pb/Zn mining district in Gipuzkoa (Basque Country, 5 sites: END, OIA1, OIA2, ARD, OTS) and Reocín Pb/Zn mining district (Cantabria, 2 sites: SB013 and SB014). The LOE of sediment chronic toxicity was assessed through sediment *Tubifex tubifex* 28-day bioassay [1]. The LOE for risk of metal bioaccumulation was assessed using the INTISS score (Integrative Tissue concentration, [2]) calculated by means of several *in situ* biomonitors. For the sediment pollution LOE, and in the absence of sediment quality guidelines for the region, ecological backgrounds and thresholds for Cd, Pb and Zn were estimated from a database of 31-55 sites as representative of the reference (unpolluted) condition for Cd, Pb and Zn, in sediments from northern Spain, following the methodology proposed by [3]. The decision matrix developed for the WOE was made by ranking the three LOEs used.

**Results:** Comparing the Cd, Pb and Zn sediment concentrations with the ecological background values, they were more than 10 times higher at OIA2, ARD and OTS and more than 6 times higher at SB014 for Zn.

The three LOEs showed impairment due to sediment pollution and chronic toxicity in all test sites, and only in one test site the hazardous levels of bioaccumulation were not attained (SB013).

**Discussion:** Sediment ecological thresholds proposed for Cd, Pb and Zn are comparable to other thresholds proposed in other geographic areas, and have been proved to be an useful tool for the pollution assessment in areas affected by historical Pb/Zn mining activities in northern Spain. Sediment chronic toxicity and tissue residues in field macroinvertebrates have demonstrated that the sediment pollution poses a risk for the benthic communities, due to the toxicity and the bioaccumulation of hazardous metals in most sites, related to the Arditurri and Reocín historical mining activities. This assessment suggests applying management programs for reducing the source of metal pollution at these sites.

**References:** [1] ASTM E1706-05, 2005. [2] Rodriguez et al., 2021. *Aquat Toxicol* 238: 105918. [3] Méndez-Fernández et al. (2019) *Environ Pollut* 245: 1000-1013. [4] MacDonald et al. (2000) *Arch Environ Contam Toxicol* 39: 20-31.

# Ecotoxicological assessment of river sediments downstream of a firefighting training site

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**Conference theme number(s): 1**

**Introduction:** The use of firefighting foams, which are known to contain per- and polyfluoroalkylated substances (PFAS), can result in the dispersion of these contaminants into the environment during training exercises. As a result, training sites contribute to hotspots of PFAS contamination. This study reports on the PFAS contamination and ecotoxicity of sediment samples collected in two rivers downstream of a firefighter training site in Switzerland. It's a follow-up to previous studies conducted by the corresponding regulatory authorities which confirmed the spread of PFAS in the surrounding area, with elevated concentrations in both soil and water compartments.

**Methods:** Five sediment samples, one upstream and one downstream in each river, and one after their confluence, were collected for both chemical and ecotoxicological analyses. A total of 20 PFAS were analyzed on dry sediment sieved at 2 mm. Fresh sediments sieved at 2 mm were tested with the ostracod *Heterocypris incongruens* [1]. Growth inhibition and mortality rates after six days of exposure were compared to toxicity thresholds [2].

**Results:** For the bioassay, both mortality and growth inhibition were higher at the downstream sites (A2, B2) compared to the upstream sites (A1, B1) for both rivers (Fig. 1). The mortality rate was above the toxicity threshold of 20% at the two B sites and at the site downstream of the A/B confluence (A3).

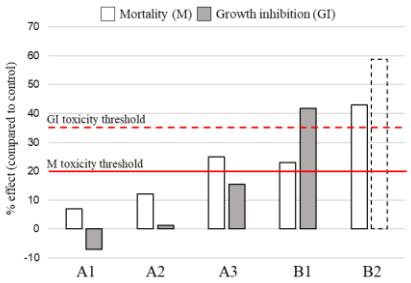


**Fig. 1:** *Effects measured in* H. incongruens *after 6 days of exposure to sediment samples from rivers A and B.*

For B2, the mortality reached the highest value of 43%, while the upstream site B1 showed significant sublethal effects with growth inhibition exceeding the toxicity threshold of 35% (Fig. 1).

Of the 20 PFAS analyzed, PFOS, PFDA and PFOA, were detected in all samples, except the control blanks. The risk assessment was carried out according to the PFOS sediment quality criteria (SQC) for the protection of benthic organisms from direct toxicity of 2.7 µg/kg dry weight (dw, 1% TOC), and according to the PFOS SQC to protect top predators from secondary poisoning of 1.85 µg/kg dw [3] (Tab. 1).

**Tab. 1:** Risk assessment for PFOS. Blue, RQ < 0.1; green 0.1 ≤ RQ < 1; yellow 1 ≤ RQ < 2; orange 2 ≤ RQ < 10, red, RQ > 10.

| Risk quotient (RQ) / Site | A1 | A2 | A3 | B1 | B2 |
|---|---|---|---|---|---|
| RQ - PFOS_benthic organisms | 0.01 | 0.33 | 0.52 | 0.07 | 5.91 |
| RQ - PFOS_secondary poisoning | 0.05 | 1.97 | 2.11 | 0.22 | 18.4 |

A maximum RQ of 5.91 (concentration of 34.1 µg/kg dw) was calculated for B2, classifying the sediment quality as unsatisfactory (orange). If we consider the SQC derived to protect top predators from secondary poisoning, the sediment quality is downgraded to poor (red, RQ 18.4). The two sites upstream of the study site (A1 and B1) are of very good (blue) or good (green) quality, depending on the protection objective.

**Discussion:** Both the risk assessment based on chemical analyses and the bioassay converge in showing an impact on sediment quality downstream of the firefighting training site. Ostracod mortality showed a clear upstream-downstream response in both rivers, with the highest mortality was observed in the sediment with the highest concentration of PFOS (and ∑PFAS). This suggests that ostracod mortality is sensitive for detecting effects related to the presence of PFAS in complex sediment samples. Further studies are needed to rule out other potential sources of PFAS in these rivers and to determine how far the contamination spreads.

**References:** [1] ISO (2012) ; [2] Casado-Martinez et al. (2016) *Chemosphere* **151**:220-4; [3] Casado-Martinez (2020) *Swiss Centre for applied ecotoxicology*.

# On the importance to test sediment toxicity in rare earth element enriched waters

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**Conference theme number(s): 1**

**Introduction:** Rare earth elements (REE) are essential metals for different components of our modern technology (e.g. smart phones, wind energy and electric cars). Enrichments of individual REE concentrations in rivers due to emissions from mining activities, fluid cracking catalyst production, fertilizer plants, wastewater treatment plants etc. have been found all over the world. Since the 1990s, the number of papers on rare earth toxicity has multiplied reflecting the growing concern, that increased concentrations could harm the environment. Due to their high tendency to form complexes with carbonates, hydroxides and phosphates, however, dissolved concentrations in the environment are mostly minor and the risk to aquatic organisms is often considered to be low. Insoluble complexes will precipitate and attach to organic material or sink to the sediments where they are considered not to be effective. But while some studies have demonstrated an elevated toxicity in REE contaminated environmental sediments (e.g. [1]), very few toxicity studies have been performed on REE-spiked sediments to support that assumption [2]. This presentation will base the argument for testing the toxicity of rare earth elements in sediment on a number of experimental results, mainly from the Panorama Project, and summarize what progress has been made in this regard up to the conference. A plea will be made not to dismiss REE as minor contaminant until this has been confirmed by sediment toxicity testing.

**Methods:**
Tests of toxicicty of REE (lanthanum, gadolinium) for

- nematodes in water phase acc. to ISO 10872 (mod.)
- daphnia in water phase acc. to ISO 6341 and modified; avoidance studies with sediment
- *Myriophyllum aquaticum*; sediment, ISO 16191

Synchrotron studies at Nanoscopium, Soleil, in Paris, France

**Results:**
Effects on nematodes: Comparing toxicity of La in media with and without precipitation revealed lower EC50 values, when precipitates were present.


Effects on daphnids: After 7 days of exposure, both metals had been accumulated in the intestinal tract and showed toxicity [3].
In a two-phase sediment-water system, Gd-enriched sediment led to an almost complete reduction in the residence time of daphnids on the sediment surface at concentrations of 1 µg/kg (van Drimmelen et al., in prep).

**Fig. 1:** Accumulation of La in the intestinal tract of D. magna after 72 hours of exposure.

Effects on the benthic plant Myriophyllum aquaticum: Gd spiked sediment strongly affected photosynthetic activity at 50 mg/kg, followed with higher concentrations by an impact on growth and development

**Discussion:**

- REE-Precipitates can be taken up and may become available in the gut of organisms
- Spiked sediments can impact the photosynthetic efficiency of benthic plants
- sublethal effects to REE-contaminated sediments may be ecologically relevant

**Acknowledgments:** funding: Marie Skłodowska-Curie Grant Agreement N°857989. Special thanks go to Ann-Christin Häder, Sebastian Höss, Lucas Janssen Nieto, Lisa Tamminga.

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[2].Revel, M. et al. Critical Reviews in Environmental Science and Technology. 2024:1-42. 10.1080/10643389.2024.2406992.
[3].Revel, M. et al. Chemosphere. 2024;353:141509. 10.1016/j.chemosphere.2024.141509.

# Emerging contaminants (ECs) in inland water sediments of the anthropogenically affected areas in Poland. A One Health perspective.

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**Conference theme number(s): Theme 1 (Zero Pollution)**

**Introduction:** Recognizing the interconnections between human, animal, plant health, and the environment has led to the adoption of an integrated perspective on health, known as the One Health approach [1]. Additionally, One Health approach emphasizes the need for collaborative efforts to address emerging contaminants (ECs) issues. ECs refer to newly identified synthetic or naturally occurring chemicals in the environment whose hazardous effects on humans and natural ecosystems are not yet fully understood, or to chemicals recently recognized as posing risks to human and environment [2]. The continuous introduction of ECs into the environment undermines global environmental protection efforts, as substances once hailed for their beneficial properties have increasingly become recognized as pollutants of significant concern. Water sediments, functioning as a critical sink for pollutants, play a pivotal role in the long-term storage of contaminants [3]. Therefore, this study aimed to investigate the ECs contents in the various inland water sediments in Poland and to determine the related cumulative environmental risk.

**Methods:** Sediment samples were collected from various inland water reservoirs in Southern Poland, each influenced by various anthropogenic activities, as well as from a reference site – a drinking water reservoir serving the inhabitants of Krakow. Organic ECs were determined using an ultra high performance liquid chromatography (UHPLC) system (Vanqiush Flex Thermo Scientific), coupled with a triple quadrupole mass spectrometer (TSQ Altis Plus, Thermo Scientific). Inorganic ECs were measured using inductively coupled plasma – mass spectrometry (ICP-MS) system (Thermo Scientific) and inductively coupled plasma - optical emission spectrometry (ICP-OES) system (Optima 7300DV Perkin Elmer).
Environmental risk associated with the analyzed ECs concentrations was evaluated using the risk quotient (RQ) methodology, as developed by the US Environmental Protection Agency [4]. RQ values were determined by calculating the ratio of measured environmental concentrations (MECs) to predicted no-effect concentrations (PNECs) for each of the investigated ECs. The average concentrations of the investigated ECs were used as MECs for environmental risk calculations. Additionally, the worst-case scenario was evaluated by using the highest measured EC concentrations as MECs. PNEC values were obtained directly from the ECHA Chemical Database [5] or, when unavailable, from relevant scientific literature.

**Results:** The concentrations of investigated ECs, belonging to the following classes of substances: bisphenols (BPs), per- and poly-fluoroalkyl substances (PFAS), pharmaceuticals and personal care products (PPCPs), and heavy metals (HMs) will be presented. Additionally, the relationship between changes in EC concentrations and sediment properties across different locations will be discussed. Finally, the environmental risk, as represented by the Risk Quotient (RQ) values for both mean and worst-case scenarios, will be assessed.

**Discussion:** These preliminary results offer new insights into the presence of emerging contaminants (ECs) in aquatic sediments. They may also contribute to the development of future, comprehensive monitoring plans for sediment catchments, particularly in relation to the cumulative effects of emerging contaminants.

**Funding**: This work was supported by the EFSA EU-FORA Program (Cycle 2023/2024 and 2024/2025).

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# Red mud: hazardous waste or secondary raw material with potential?

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**Conference theme number(s):** THEME 1: Zero Pollution
**Supported by IAEA TC project RER7016**

**Introduction:** Disposal and storage of industrial waste (red mud) is a growing problem today, considering that most of it endangers the environment [1]. The physicochemical characterization of red mud answers the question of whether it is exclusively hazardous waste or can be used as a resource for certain metals or even possibly for other purposes [2]. The current study gives insight into the main properties of the red mud samples from „Dobro Selo" abandoned landfill, Čitluk (Bosnia and Herzegovina) based on the comprehensive characterization.

**Methods:** The "pseudo-total" content of Cr, Cu, Mn, Fe, Co, Ni, Cd, Pb and Zn in acid digested (*aqua regia)* red mud samples was determined by the AAS-flame technique. Calculation of the metal content per kilogram of dry sample was performed according to the Eq.(1): $\frac{mg}{kg} = \frac{(C_S - c_{bl}) \text{ x V}}{m} \cdot \text{CF}$ (1)
where $C_s$ and $C_{bl}$ are the metal concentration in sample and blank; V is the sample volume; m is the sample mass and CF is a correction factor for moisture content.
Oven-dried (105°C for 24 hours), homogenized and sieved (500 μm) red mud samples were subjected to gamma spectrometric analysis in order to determine the concentration of radionuclides activity following the Eq. (2): $A_s = \frac{N}{\varepsilon \, m \, p(\gamma) t} \, 1000 \, (\frac{Bq}{kg})$ (2)
where A is specific activity of the radionuclide; N is pure or net number of pulses; Ɛ is detector efficiency; m is mass of the sample; t is measurement time and p(γ) is percentage of gamma-ray emission of the radionuclide.

**Results:** The experimental results for the red mud samples (n=6) include the following: pH values ranging from 8.04 to 9.16, a point of zero charge (pHpzc) of 8.7, moisture content between 20.08% and 37.21%, granulometric composition with the most abundant fraction being <0.25 mm, mineral substance content ranging from 12.45% to 17.77%, and bulk (1.01 g/cm³ to 1.58 g/cm³) and true (2.74 g/cm³ to 3.31 g/cm³) densities. The results for heavy metals average content are presented in Figure 1, and were as follows: Fe>Mn>Cr>Ni>Zn>Pb>Co>Cu>Cd, while the order for radionuclides was: $^{232}$Th (411.3 Bq/kg) > $^{226}$Ra (134.1 Bq/kg) > $^{238}$U (71.9 Bq/kg). Energy dispersive spectroscopy revealed $Fe_2O_3$, CaO and $Al_2O_3$ as the main components (that make up 85.62%-92.35% of the red mud). Moderate amounts of $TiO_2$ (3.82%-5.97%) and $SiO_2$ (1.29%-5.42%), as well as certain amounts of $V_2O_5$, $Cr_2O_3$, MnO, NiO, $K_2O$, SrO, ZnO, $As_2O_3$, $ZrO_2$ were determined. The analyzed red mud shown to be a source of some trace rare earths elements (REE) such as: $Ir_2O_3$, $Y_2O_3$, NbO and $Ga_2O_3$. *Fourier* transform infrared spectra confirmed the presence of carbonate ions, asymmetric stretching vibrations of Si-O and Al-O bonds and bending vibrations of Ti-O-Ti bonds in $TiO_2$.

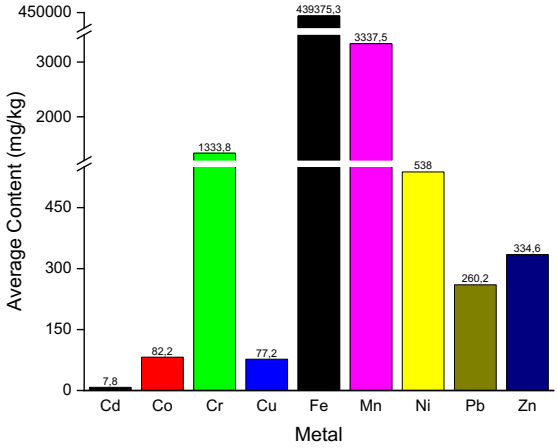


**Fig. 1:** Average content of nine metals in red mud.

**Discussion:** The overall characterization results imply that the red mud from "Dobro Selo" landfill can be used as secondary raw material. In that meaning, this waste can be used as the source of heavy metals, precious metals (REE, Zr and Ti). Moreover, according to pHpzc, this red mud can be enrolled as solid adsorbent for anions removal from waste water in wide pH range, as well as a raw material in construction, etc. Similar potential usage of this sort of waste has been reported in literature [3, 4].

**Acknowledgement:** The authors are grateful for the financial supports from the IAEA RER7016 project.

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# A regional systemic approach to assess spatial distribution, transfer, exposure and remediation of wide-spread PFAS pollution in Willebroek

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**Conference theme numbers: 1, 6**

**Outline:** Extreme persistence of PFAS and their environmental toxicity and bioaccumulation capacity, and adverse human health effects make PFAS a top priority pollutant group. Current 'one substance, one assessment' approaches to measure the risks and propose appropriate remediation for PFAS are difficult to apply through the different compartments given the extensive group of precursors and metabolites that can arise in the environment. Current knowledge is insufficient to understand the risks posed by diffuse pollution to both people and the environment ('one health' approach) and has not yet been translated and integrated into management nor remediation practices. The recently started LIFE PFASTER (PFAS systemic regional approach to Assess Spatial distribution, Transfer, Exposure and Remediation of wide-spread pollution in Willebroek, Flanders) project, aims to improve soil, sediment and water quality by developing a regional systemic remediation approach to reduce diffuse pollution with PFAS of soil, sediment, water and biota, including innovative, cost efficient methods to assess the spatial distribution and identification of exposure routes of the contaminants and the design and piloting of a replicable remediation approach beneficial for biodiversity and human health.

**Project site**: The project site considers the area that has been impacted by a former paper mill factory located in Willebroek, Flanders (Belgium), an exemplary case for a heavily PFAS contaminated area, characterized by a very diverse pattern of land use types.

Considering the long period of industrial activity and the shutdown of the plant more than 20 years ago has changed the context to a rather diffusely present contamination in terms of assessment and approach to tackle the contamination.

In this case it is not feasible to aim for a complete destruction of the contamination. We pursue an overall containment approach that optimizes long-term strategies for managing and remediating risks, with the attention for safe sinks and proposing the best available technique per location.

**Methods**: We aim to develop this holistic and systemic approach to be replicable in other situations with complex contamination and multiple stakeholders involved. A GIS-data platform, where different relevant data can be clustered, is a crucial element of the approach. In the PFASTER project it is used to share the measurement data amongst the partners. For the remediation approach it will be an essential tool where information is shared with the stakeholders.

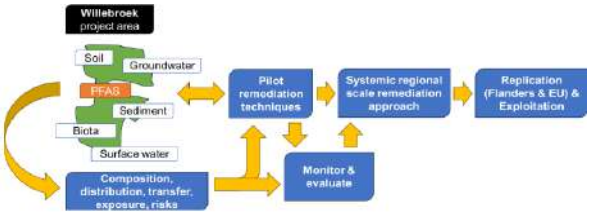


**Fig. 1:** *Different steps in the LIFE PFASTER project.*

**Role of sediments**: Sediment is an elementary link in the entire system. Wastewater has been discharged in one of the main streams and has spread over the entire hydrological network. Sediment removal and disposal on the banks of the different streams has spread the contamination on land. Also, certain peat pits in the nature reserve Broek de Naeyer have been used for a long period of time as settling basins for the paper mill. The characterization of contamination in sediment, the relevant posed risks and the different pathways from and to sediment are part of the project objectives. Moreover, this integrated approach will be guidance to the piloting of certain remediation techniques for PFAS in sediment.

Visit www.life-pfaster.eu for more information.

# Study of PFAS contamination in the Garonne and its watershed

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**Conference theme number(s): 1**

**Introduction:**

Per- and polyfluoroalkyl substances (PFAS) comprise more than 5,000 distinct compounds currently in use. These compounds are extensively employed worldwide from decades and spread in the environment. The toxicological, persistent and bioaccumulative properties of PFAS have been demonstrated in numerous studies. However, the behaviour of most PFAS is not fully understood, and there is a paucity of scientific data on their occurrence and fate in the environment, especially for emerging polyfluorinated ones.

The Garonne River is the fourth longest river in France. This 530-kilometre-long river has its source in the Pyrenees mountain range at the French-Spanish border and is subject to a variety of anthropogenic influences. Its watershed is home to a number of urban centers, including Toulouse and Bordeaux, as well as a diverse range of industrial facilities, from airports to nuclear power plants. The purpose of this study is (i) to document the spatial distribution and patterns of PFAS in the Garonne Basin sediments and water using both targeted (47 PFAS including long and short-chain carboxylates and sulfonates as well as selected perfluoroalkyl acid precursors, pre-PFAAs); and (ii) to assess the PFAS transfer towards the first link in the food chain, i.e., the biofilm.

**Discussion:**

A representative overview of the Garonne River watershed and the activities conducted along its course from source to estuary was obtained by collecting sediments, biofilms and water samples from the river and its tributaries. Twenty-three sites were sampled during two campaigns under low- and high-flow conditions.

Microwave assisted extraction was employed to facilitate the extraction of PFAS from the sediments and biofilm, with methanol and 50 mM of ammonium acetate as extraction solvent. Subsequently, samples were filtered through glass wool prior to purification on a graphite cartridge (Envi-Carb, 250 mg)[1]. Water samples were treated following USEPA1633 recommendations. Targeted analysis was conducted using high-performance liquid chromatography coupled with electrospray ionisation and tandem mass spectrometry (HPLC-MS/MS). The total oxidisable precursor assay (TOP assay)[2] was also conducted on sediment, biofilms and water samples. This step convert pre-PFAA (targeted and non-targeted ones) into PFAAs that can be measured via targeted analysis. This allows us to estimate the potential reservoir of non-targeted pre-PFAAs present in the water, sediments and biofilm. Results are currently be exploited and will presented.

In conclusion, this study will fill the gaps in the assessments and understanding of PFAS contamination in an anthropogenized watershed such as the one of the Garonne River. Our contribution is expected to demonstrate the impact of the different facilities and cities present in this basin on the occurrence of PFAS in sediments, further document the differences in PFAS pattern between sediment and biofilm, and further highlight the usefulness of the TOP assay to provide more extensive characterization of the PFAS contamination.

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to Perfluoroalkyl Acids in Urban Runoff », *Environ. Sci. Technol.*, vol. 46, nº 17, p. 9342-9349, sept. 2012, doi: 10.1021/es302274g.

# Quantitative analysis of PFAS distribution in aqueous environmental samples of the Hungarian section of the Danube River

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**Conference theme number(s): Theme 1 - Zero pollution**

**Introduction:** The abundance of Per- and polyfluorinated alkyl substances (PFAS) has become a global concern due to their persistence, bioaccumulation, and toxicity. They are characterized by their strong thermal and chemical stability, high polarity, and non-biodegradability, which makes them useful as coatings for textiles, papers, consumer products and lithium-ion accumulator batteries (LIB) [1].

**Methods:** This study focuses on investigating the occurrence of PFAS and the quantitative analysis of the Inorganic Fluoride (IF) and Adsorbable Organofluorine (AOF) compounds in water and sediment samples collected along the Danube River including the locations at the LIB factory in Komarom and Vadja paper factory in Dunafoldvar. Samples were analysed alongside grain size analysis of the sediments for 6 months to ascertain their spatial distribution, evaluation of their temporal trends and comparison of concentration obtained in both phases.

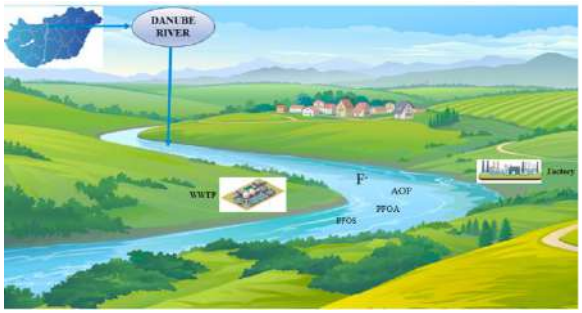


**Fig. 1:** PFAS distribution in the Hungarian section of the Danube River.

**Results:** A comprehensive study conducted on the Danube in 2015 revealed perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) concentrations in the range of 5-40 and 5-30 ng/L, respectively, with measurements in the Hungarian section ranging from 5-20 and 5-15 ng/L [2]. In this study, the concentrations along the Hungarian stretch were 0.7-2.3 ng/L and 0.7-1.7 ng/L respectively. The concentration was 28 to 76 µg/L (average 45.1 ± 7.7 µg/L, median 45.3 µg/L), and 0.22 to 12.15 µg/L (with an average of 3.19 ± 2.62 µg/L and a median of 2.43 µg/L) for IF and AOF respectively.

**Discussion:** Due to the high average water yield (2350 m3/s) of the Danube River in its Hungarian stretch (417 km), the concentrations of fluoride anions, total adsorbable organofluorines, PFOA, and PFOS exhibit minimal fluctuation in the water phase. Sediment concentration is expected to exceed these limits. A correlation between AOF levels and sediment properties was also noted, indicating that fine-grained, organic-rich sediments are key sinks for PFAS.

**Acknowledgement:** The research presented in the article was carried out within the framework of the Sz´echenyi Plan Plus Program with the support of the RRF 2.3.1 21 2022 00008 project.

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# The current situation with TBT in Sweden – contamination situation, sources, transport pathways and ongoing research

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**Conference theme number(s): 1**

Organotin compounds have had a broad use as e.g. biocides and stabilisers in plastics. Release of organotin compounds are associated with e.g. ports and marinas, sewage treatment plants, wood-, paper- and pulp industries, and textiles production. Notably tributyl-tin (TBT) is associated with wide-spread harm to aquatic environments. TBT was used in antifouling paints to prevent the fouling of a broad range of organisms. Due to contamination of the marine environment and impacts on marine life its use as an antifouling agent was banned globally in 2008.

The current contamination situation in coastal and freshwater environments was investigated in a nation-wide survey comprising 70 sites impacted by ongoing environmentally hazardous activities as well as contaminated sites. Concentrations of TBT in surface sediment (0-5 cm) was found to be generally higher at sites where maritime industries, *i.e.* harbours or marinas, are present compared to sites with no maritime industries present. Concentrations of TBT in deeper sediment (15-20 cm) were generally higher compared to surface sediment at sites with maritime industries, whereas no such difference between surface and deeper sediment was apparent at sites without maritime industries (average and median concentrations in surface vs. deeper sediments were 42.8 and 3.7 (n=76) vs. 207 and 11.6 (n=49) at sites with maritime industries, and 9.4 and 1.8 (n=51) vs. 9.3 and 2.5 (n=42) at sites without maritime industries). This demonstrates that concentrations of TBT in sedimenting materials have decreased at sites with maritime industries following the ban of TBT in antifouling paints. Results from monitoring of offshore sediment also show decreasing concentrations of TBT in surface sediment, and thus the situation appear to be improving on both larger scales (i.e. sea basins) and smaller scales (local).
In contrast concentrations of TBT and other organotin compounds were similar in surface- compared to deeper sediment at sites without maritime industries, indicating that emissions of TBT from other sources continue.

Despite the improving situation, maritime industries are highlighed as significant pressures that prevent achieving good chemical status with respect to TBT in many coastal water bodies under the water framework directive. In the nation-wide survey concentrations of TBT exceed the effect-based quality standard for sediment at 13 of the 14 surveyed sites with maritime industries. In the 80 samples from these sites, concentrations of TBT exceed by an average of 34 (median 3.6, maximum 1177) the sediment quality standard of 1,6 microg/kg DW (at 5 % TOC). Results from the national marine monitoring programme on biological effects shows that impacts from exposure to TBT on marine molluscs are common. It is therefore necessary to continue preventing further inputs to aquatic environments.

Land and sediments in the vicinity of boatyards, ports and marinas are sources to secondary pollution of aquatic environments. In Sweden most leisure boats are stored on land over the winter season, and there are several thousand such sites spread across the country. The soil at these sites often contains very high concentrations of TBT and other pollutants that have accumulated there over time from maintenance work such as abraisive blasting and painting of hulls. The storage sites are typically situated close to aquatic recipients, and contaminants may be transported through different pathways. Particle-bound emissions can occur from wind erosion and dust that is deposited in surface waters, or transport via storm water. Or, if the surface is not hardened, leaching and transport via groundwater. Local conditions influence which pathways are more important, and thus which measures may be the most cost-effective. Higly contaminated sediments close to marinas may also serve as a source to wider TBT contamination of the recipient, either by leaching of soluble fractions to the water-phase, or resuspension and transport of sediment particles by currents or propeller movements. Ongoing research on measures to prevent emissions from marinas with boat storage sites on land will be presented and discussed.

# Long-Term Monitoring of Chemical Sediment Composition in the German Bight: Insights into Past and Future Trends and Changes

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**Conference theme number(s): 1. Zero Pollution**

**Introduction:** Sediments are an important sink for organic and inorganic pollutants. They can reflect the current "health status" of the surrounding environment and act as a record of chemical composition and pollution levels in the past. Using sediment as an archive alongside regular monitoring activities is therefore an important tool in tracking the evolution of the environmental status as required for the Marine Strategy Framework Directive (MSFD).

**Methods:** The German Federal Maritime and Hydrographic Agency (BSH) has conducted continuous annual monitoring activities in the North See (German Bight) for several decades. The aim of this ongoing monitoring is to systematically collect data on the chemical and physical state of the North Sea, enabling long-term assessments on environmental changes. This presentation outlines the monitoring activities and provides insights from the chemical data collected over the past decades, along with additional data from current research projects.

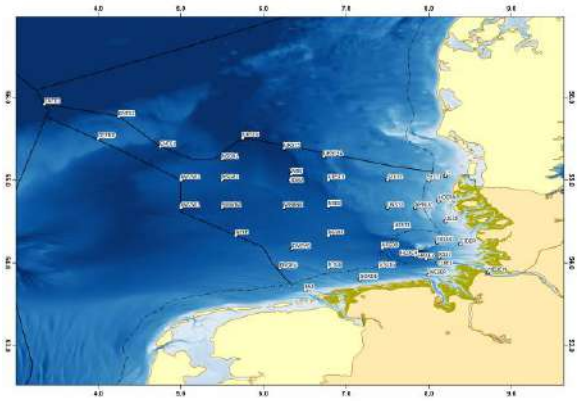

**Fig. 1:** BSH monitoring stations

**Results:**
The long-term monitoring data reveal changes in pollution levels in the German North Sea for various substances, including both organic and inorganic pollutants. For some substances, a decreasing trend in concentrations in surface sediments is observed (e.g. Hg, Pb), while others show no clear trend or even an increasing trend [1, 2, 3]. Furthermore, the data provides insights into the environmental impacts of substance bans and regulations illustrating how these regulatory measures are reflected in the monitoring data. Current data also help to assess potential new sources of emissions to the marine environment, such as those from offshore energy production (e.g. from corrosion protection) [4].

**Discussion:**
Continuous sediment monitoring offers valuable time-series data that reveal trends and changes in pollution levels. These data are instrumental in identifying emerging pollutants, which enables the implementation of timely mitigation measures. To achieve this, monitoring efforts must not only be sustained over time but also regularly updated to address evolving concerns. The list of substances monitored should reflect the current environmental priorities (e.g. PFAS), and new sources of emission, such as offshore energy production, should be integrated into monitoring strategies. Developing adaptive monitoring strategies will help to ensure pollution control and to develop actions to maintain healthy sediment conditions.

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# The Rhône Sediment Observatory (OSR) monitoring network for suspended sediment and contaminants long-term assessment

**Marina Coquery[1], Fabien Thollet[1], Jérôme Le Coz[1], Hugo Lepage[2], Jérôme Labille[3], Aymeric Dabrin[1], Matthieu Masson[1], Cécile Miège[1], Hugo Delile[1], Bertrand Morandi[4], Olivier Radakovitch[2]**

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**Conference theme number(s): 1**

**Introduction:** The Rhône Sediment Observatory (OSR), created in 2009, aims to provide scientific knowledge for promoting a sustainable management of channel forms and sediment processes of this river [1], the largest by mean discharge in France and one of the largest tributaries of the Mediterranean Sea. We propose here a summary of the major developments and findings obtained on the monitoring of suspended sediment and associated priority substances in the Rhône River basin. We also focus on the evolution of the techniques and tools developed and applied for research and diffusion to stakeholders.

**Methods:** Monitoring of concentrations and fluxes of suspended particulate matter (SPM) and contaminants is based on continuous measurements of water discharge and turbidity/SPM, coupled with integrative sediment traps collected monthly for contaminants analyses. The OSR network includes 12 permanent stations in the Rhône River and major tributaries (Fig. 1, [2]). Different geochemical methods and models have also been developed and tested at various temporal and spatial scales to estimate the sources of SPM and associated contaminants.

**Results:** This comprehensive network has permitted to establish event-related, annual and interannual SPM and contaminants mass budgets across the entire Rhône River basin [3]. Sedimentary export to the Mediterranean was on average 5.21 Mt per year for the period 2009-2023, with very high annual variability (between 1.8 and 12.8 Mt). Nonetheless, on average, the Rhône system has a balanced sediment budget (inputs from tributaries versus outflow to the sea). In contrast, for contaminants (e.g., polychlorobyphenyls - PCBs, aromatic polycyclic hydrocarbons – PAHs, trace metal elements – TMEs, radionuclides), the annual outputs are often lower than the tributary inputs, suggesting that other sources must be taken into account. The various tributaries show very contrasting levels of contamination according to the contaminants studied, which can be explained by past or present activities on their watersheds. Overall, in the Rhône River, the concentrations of particulate contaminants have generally decreased or remained stable over the past 10 years and over the longer term. Nonetheless, contaminants concentrations remain higher in the Rhône River at the outlet than upstream.

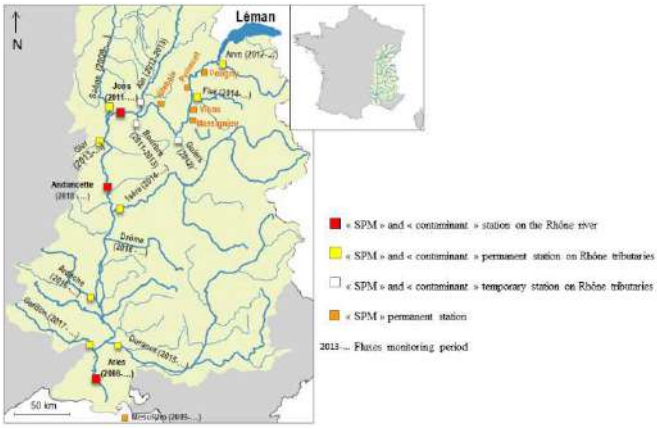


**Fig. 1:** The OSR monitoring network of SPM and associated contaminants along the Rhône River [2].

**Discussion:** Some sources of contaminants have yet to be characterized for budget that are not balanced. These sources include smaller mountain tributaries that could be highly contaminated by TMEs or direct discharges to the Rhône from urban areas (major sources of PAHs). Maintaining such a comprehensive monitoring network over a long period is essential to confirm or inform the trends observed, and to evaluate the policies implemented for the management of these contaminants.

**Acknowledgments:** This study was conducted within the OSR multi-partner research program funded through the Plan Rhône by the European Regional Development Fund (ERDF), AERMC, CNR, EDF & 3 regional councils (ARA, PACA & Occitanie).

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# Trends of per- and polyfluoroalkyl substances recorded in sedimentary archives upstream and downstream of the Lyon metropolis

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**Conference theme number(s): 1**

**Introduction:** Concerns about per- and polyfluoroalkyl substances (PFAS), known for their highly stable carbon-fluorine bonds, have sparked a global socio-environmental crisis. South of the city of Lyon (France), significant levels of contamination have been detected in various environmental matrices around the Pierre-Bénite industrial platform, which has synthesized, used, and released PFAS for several decades. Initial studies emphasize the role of this source, whose very specific molecular profile is marked by the predominance of long-chain carboxylates [1]. Sediment analyses conducted in the early 2000s revealed the evolution of discharges, with historical contributions up to 20 times higher than current levels [2]. In this context, the aim of our study is to better assess the level of sediment contamination at key sites along the Saône-Rhône river corridor. We also aim to determine the spatial and temporal extent of this pollution and identify the different phases of contamination throughout history.

**Methods:** The data used in this study originate from surface sediments and the analysis of six sediment cores encompassing the Lyon metropolitan area and documenting over four decades of river pollution. The sampling strategy was refined from 2012 to 2022, adapting to evolving scientific questions, public policy needs, and growing citizen concerns. In total, 3,874 PFAS concentrations distributed across 200 samples were compiled into a database suitable for geo- and chrono-statistical analysis.

**Results and Discussion:** In the Rhône River upstream of Lyon, PFAS concentrations in sediments are relatively low compared to other sediment cores. A trend of decreasing contamination levels is observed over the period covered by the archive (early 1980s–2022). The concentration levels do not exceed 2 ng/g for the sum of all measured PFAS. The compositional signature of PFAS is relatively similar to that reported at the national level [1], and sediment characteristics (organic matter content and grain size) may be key factors explaining the subtle variations within the sediment column.

Downstream of Lyon, at least three contamination phases can be identified over the period covered by the sedimentary archives (1980s–2022):

- The earliest phase is associated with PFOS and its precursors in the mid-1980s. This phase peaked in the early 1990s before decreasing sharply.
- The second phase is dominated by PFDA and PFDoDA, two long-chain PFCAs. Concentrations were already high in the 1980s, but the peak occurred in the late 1990s, followed by a rapid decline. The PFAS compounds present in the highest concentrations were PFDA, PFDoDA, and PFTeDA, with maximum levels reaching 23.3, 15.4, and 6.06 ng/g, respectively [2].
- The most recent phase is primarily characterized by PFUnDA and PFTrDA, also long-chain PFCAs. This phase began in the early 2000s, peaked in the early 2010s, and then declined rapidly, ending around 2017. These findings establish a link with PFAS compounds used in workshops at the industrial platform, which utilized Surflon® between 2013 and 2016 [3]. Notably, these same compounds have also been detected in soils and dust near or within this industrial site [4].

**Conclusion:** The contamination of sediments by PFAS, particularly long-chain PFCAs, poses a long-term challenge for managing contaminated sediment stocks. This issue also represent a strategic challenge for drinking water production and the ecological restoration of the river. Indeed, the biological compartment is severely contaminated locally, with bioaccumulation phenomena observed in fish and benthic invertebrates [5].

Finally, these results highlight a disconnection between the socio-political "crisis" surrounding PFAS and the measured contamination levels in the environment, despite the data being public and readily accessible.

**References:** [1] Munoz G et al. (2015) *Sci Tot Environ*, 517: 48-56; [2] Mourier et al. (2019) *Environmental Pollution*, 253, 1117-1125; [3] Ramboll (2023) *Arkema - Historical and Documentary Study*, excerpt; [4] ANCES (2023) *Technical note* 27 pp.; [5] Babut et al (2016) Research report, Irstea, 75 pp. hal-02603445

# Coastal microplastic monitoring: Harmonized protocols for sampling and analysis

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**Conference theme number(s): THEME 4**

**Introduction:** The explosion of research on microplastics (MPs) pollution in recent years has led to a better understanding of the extent of the spread of these contaminants. Many studies have shown that both humans and wildlife are potentially exposed, suggesting a need to better characterize the occurrence, distribution, sources and risk of exposure to MPs. Knowledge of the extent of MPs exposure, spatial and temporal trends, and the potential risks of MPs to human health is an essential prerequisite for the definition of protection and mitigation measures against MPs.

**Method:** There is no harmonized approach to MPs data collection, analysis and interpretation among the International Atomic Energy Agency (IAEA) member states (MSs). The IAEA project RER7016 aims to provide MSs of the European Technical Cooperation Region (TCEU) with the competencies to produce inter-comparable, reliable data that will enable MSs to improve their coastal management by effectively addressing the effects of climate change and pollution, including MPs. The first survey on MSs capacity to monitor MPs pollution showed that MSs were not sufficiently aware of the advantage of nuclear technology applications in monitoring MPs pollution.

**Results:** The focus of presented study is on the investigation of MPs in surface seawater and beach sediment on a European scale. It is well known that beaches are hotspots for MPs due to sea washing and the impact of tourist activities. The first step was to conduct a survey on the capabilities of the MSs involved in the RER7016 project to monitor MPs ranging in size from 0.3 mm to 5 mm in beach sand and surface water. According to their capabilities to monitor MPs, laboratories were classified from basic to advanced level by the criteria defined within the IAEA initiative "NUclear TEChnology for Controlling Plastic Pollution" (NUTEC). The second step was to develop harmonized sampling and analysis protocols through the exchange of expertise and best practices.

**Discussion:** The results of the survey have shown that although the MPs research is very important for studying marine pollution, it is still one of the most immature areas of monitoring. MSs that already have experience in MPs analysis, mostly do not conduct regular MPs monitoring. The need for harmonized methods and protocols has been clearly identified. The study presented here addresses this gap and presents the protocols for sampling and analysis of MPs in surface water and beach sand. The harmonization of protocols for sea sediment and biota are in preparation. This will enable the building of a European regional database for sharing and comparison of marine MPs pollution data. This database will allow researchers to analyze, consolidate and integrate their data at the regional level, which is important for evaluating the results of remedial actions taken at the global level. Ultimately, policymakers, researchers, and the public will benefit from not only the collected dataset but also from comparable data. This data have the potential to contribute to the achievement of SDG 14, the UN Ocean Decade Goal.

**Acknowledgment:** This work has been done within the framework of the IAEA RER7016 "Enhancing Coastal Management in Fresh and Saltwater Bodies by Using Nuclear Analytical Techniques, Including Monitoring of Microplastics". The IAEA Marine Environmental Laboratories are grateful to the Government of the Principality of Monaco for the support provided to the Environment Laboratories.

# Emissions - The long-term memory of sediments

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**Conference theme number(s): Theme 1 – Zero Pollution**

**Introduction**: Sediments are the long-term memory of anthropogenic (human caused) spills of chemicals. In many cases this has buffered the water quality, sediments remove contaminants from the water by sorption and settling. Alas, the reverse is also true, when the water quality improves sediments can become a source of contaminant emissions. We address the timescale of this impact and the relation with the Water Framework Directive (WFD) water quality standards.

**Methods:** This study consists of two parts. In *part one* we extrapolate the timescale to reach a good chemical status for chemicals with a historical background, TBT and PFAS, based on monitoring data and model extrapolation. In *part two* we calculate the potential impact of clean soil and sediment on the water quality when backfilling a deep lake connected to the river.

**Results:** *Part 1:* The use of the anti-fouling chemical TBT has been completely banned in the EU since 2008. Since the ban the TBT concentration in the water improves. However, the new Environmental Quality Standard $(EQS)_{sediment}$ is not yet reached. Extrapolation shows it takes at least till 2040 before the sediment is considered clean (Figure 1).

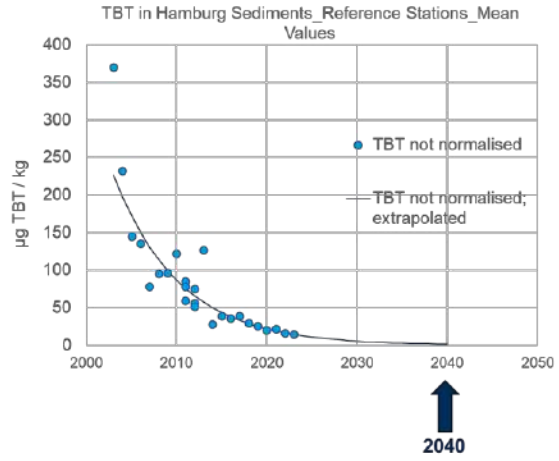


*Figure 1 Extrapolation of the observed TBT concentrations in Hamburg sediments to the moment the $EQS_{sediment}$ (proposal for directive on EQS, 2022) is reached (in 2040).*

*Part 2:* Based on the contaminant levels in soil and sediments suitable for beneficial use, the impact of backfilling a deep lake with soil and sediment on the WFD water quality can be estimated. To test if the impact on the water quality is acceptable the Netherlands uses an immission screening tool based on discharges (https://www.immissietoets.nl) Table 1 gives an impression on the impact of soil/sediment backfilling on the water quality impact for metals and PFAS.

*Tabel 1 Impression on the impact of backfilling on the water quality in the lake and bordering river.*

| | Does the emission from the soil/sediment meets the immission target (= have an acceptable WFD water quality impact)? | | | |
|---|---|---|---|---|
| | In the Lake | | In the river | |
| | during backfilling | after backfilling | during backfilling | after backfilling |
| **Metals** | | | | |
| antomony | ja | ja | ja | ja |
| arsenic | nee | ja | ja | ja |
| barium | ja | ja | ja | ja |
| cadmium | ja | ja | ja | ja |
| chroom | ja | ja | ja | ja |
| cobalt | nee | nee | ja | ja |
| copper | ja | ja | ja | ja |
| mercury | nee | nee | nee | ja |
| lead | ja | ja | ja | ja |
| molybdenum | ja | ja | ja | ja |
| nickel | ja | ja | ja | ja |
| tin | ja | ja | ja | ja |
| vanadium | ja | ja | ja | ja |
| zinc | ja | ja | ja | ja |
| **PFAS** | | | | |
| PFOS | nee | nee | ja | ja |
| PFOA | ja | ja | ja | ja |
| Mefosaa | ja | ja | ja | ja |
| Etfosaa | ja | ja | ja | ja |

**Discussion:** The lessons learned is that it can take decades after the use of chemicals has been stopped before the water quality improves sufficiently to meet the WFD water quality standard. The application of relative clean soils and sediment can have a negative impact on the water quality, especially during the backfilling. For many chemicals, even when their spill into the water is stopped today, it will take decades to reach background levels in the water quality due to the long-term memory of sediments.

**Acknowledgements:** We want to thank the Hamburg Port Authority for providing the data and the Ministry of Infrastructure and Water Management and RWS in the Netherlands for funding the research.

# Sediment risk assessment in Europe: comparison of environmental regulations

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**Conference theme number(s): 1 Zero pollution**

**Introduction:** Environmental regulation of chemicals in the EU was implemented to protect the environment against potential adverse effects caused by their use. Sediments are recognized as an integral part of aquatic ecosystems and, as such, sediment risk assessment is foreseen as part of the prospective risk assessment (before a substance is authorized for use and released into the environment) and retrospective risk assessment (once released) performed for the aquatic environment. As the chemical structure of a substance, and hence its mode of action, may allow its use for different commercial purposes, different regulations may apply for the same chemical.

The environmental assessment schemes that evolved during the last decades under the different regulations differ from each other. For many years, these differing assessments have been of no consequence, because there were mostly no points of contact between the different regulations that could have flagged inconsistencies. During the last decade though, surface water monitoring campaigns have been performed that have indicated risks for substances that are deemed safe for use.

This discrepancy has led the European Commission to set one of the objectives of the 'Chemicals Strategy for Sustainability' to move towards the introduction of the 'one substance, one assessment' approach. The aim is to improve efficiency, effectiveness, coherence and transparency of safety assessments across all relevant legislations. To support this EU strategy and the EU Green Deal, the EU funds a 7-year partnership under the Horizon Europe program (PARC, 2021-2028). In the context of PARC, we compared the environmental risk assessments for the aquatic ecosystem under prospective regulations and under the retrospective Water Framework Directive (WFD). Here, we would like to present the results of the comparison for the sediment compartment and reflect on whether current practice is aligned with the zero pollution ambition of a toxic-free environment by 2050.

**Methods:** We analysed the procedure, the protection goal and the conceptual approach for the following regulations: (EC) No 1107/2009 for the authorisation of plant protection products, (EU) No 528/2012 for biocides, (EU) 2019/6 for veterinary medicines, and (EC) No 1907/2006 for industrial chemicals (REACH), as well as for retrospective assessments, e.g. for surface water bodies under Directive 2000/60/EC (WFD).

**Results and discussion:** For the regulations with a mandatory aquatic risk assessment, usually the requirements for sediment risk assessment are less strict than for other environmental compartments (surface waters, soil) and the risk assessment is only required if certain conditions are met. The common approach across all regulations to trigger sediment risk assessment is the potential accumulation of the chemical in sediments. While partitioning (i.e. Log Koc/ow>3) seems determining for sediment consideration, there is ample room for flexibility in the consideration of additional criteria that should cover substances that may not be appropriately targeted through the Log Koc/ow trigger such as the indication of accumulation in sediments from environmental fate studies or high ecotoxicological potential. The hazard assessment for the sediment compartment, while similar under most regulations, follows a tiered approach but most often only lower tier approaches based on partitioning modelling are completed. Furthermore, aggregate exposure resulting from uses in different regulations is not effectively implemented. Surface water monitoring has expanded, can be very useful but is hardly ever done for sediments.

**Acknowledgements:** This project was financed by the EC under the Horizon Europe program (PARC, 2021-2028) and the Swiss Federal Office of the Environment (FOEN).

# Changes in trends of the seawater column parameters and concentration of elements in sediments from 2005 to 2024 in marinas located in the eastern Adriatic Sea

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**Conference topic: Theme 1 - Zero pollution**

**Introduction:** Marinas play an important role in Mediterranean tourism, extending the tourist season. However, there are many environmental challenges that need to be addressed in order to ensure that marinas remain sustainable and continue to provide recreational boating while minimizing the impact on the marine ecosystem. The greatest environmental challenges posed by marinas are associated with the application of antifouling paints to boat hulls that often contain toxic chemicals (such as copper and zinc). The antifouling paints are designed to constantly release biocides into the seawater at low doses, but over time these biocides accumulate in the sediment, harming marine ecosystem. There are strict regulations on boat maintenance, wastewater disposal and antifouling paint content that must be implemented in marinas as environmental protection measures. It is crucial to constantly monitor the quality of seawater and sediment in marinas to assess the effectiveness of these protective measures.

This study examines temporal trends in physico-chemical and microbiological parameters of seawater and element concentrations in surface sediments from 2005 to 2024 across 15 marinas in the Adriatic Sea. Seasonal analyses were carried out to assess improvements and/or deteriorations in marine environmental quality.

**Methods:** The trends in temperature, dissolved oxygen, pH and salinity in the bottom and surface layer of the seawater column are shown for two Adriatic marinas over a period of 15 years (2009-2024). In addition to the in-situ measurements, laboratory samples of 0.5 L were taken from the bottom and surface layer for microbiological analyses (total coliforms, faecal coliforms and faecal streptococci) and 1 L was taken from the surface layer for the analysis of hydrocarbons.

The sediments from the 15 Adriatic marinas were analyzed to evaluate trends in Fe, Cu, Zn, As and Pb concentrations before and about 10-15 years after the installation of the plant for the removal of metals from marinas' wastewater. Of these 15 marinas, two were studied in detail over a period of 19 years (2005-2024). Approximately 1 kg of surface sediment was sampled using the sediment grabber. The analysis was carried out using energy dispersive X-ray fluorescence (EDXRF).

**Results:** The trends of quality indicators for seawater and surface sediments (pH, dissolved oxygen, conductivity, microbiology, mineral oils and concentrations of selected elements) were evaluated for 15 Adriatic marinas over the last 2 decades. The results show a decrease in pH values and oxygen levels in seawater which is primarily attributed to climate change and increased sea primary production. On the contrary, environmental quality has improved in terms of microbiology and mineral oil concentrations. The treatment of wastewater from the service areas in most cases led to a decrease in Fe, Cu, Zn, As and Pb concentrations in the sediments as shown by the analysis of sediments 10-15 years after the installation of wastewater treatment plants. The diagram in Figure 1 shows a comparison of the results for sediments taken in marina Punat pier and service area before and after installation of the wastewater treatment plant.

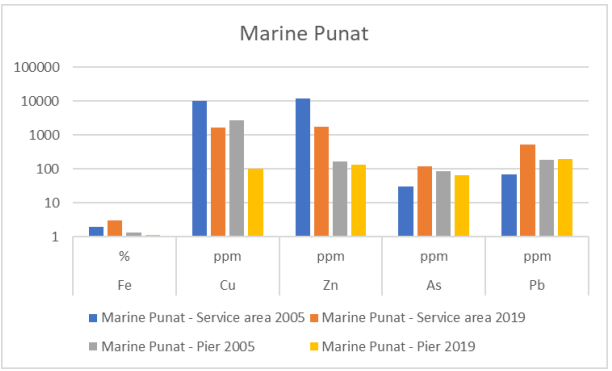


**Fig.** *Comparison of Fe, Cu, Zn, As and Pb contractions in sediments collected in Marina Punat at marina pier and marina service area in 2005 and 2019 (6 years after installation of the wastewater treatment plant).*

**Discussion:** The evaluation of the marine environment quality in the Adriatic marinas can be summarized as follows. The quality of sediments has improved in most marinas compared to the situation in 2005. In addition, a significant improvement has been observed with regard to the reduced input of mineral oils (petroleum hydrocarbons). As the main environmental risk is currently Cu input from antifouling paints, the solution could be to replace Cu-based antifouling paints with Si-based ones, which are substantially less toxic to marine organisms [1].

**Conclusion:** It has been shown that it is possible to improve and maintain a reasonably good seawater quality, and to slow down the accumulation of biocidal metals in sediments by careful implementation of environmental protection measures.

**Acknowledgments**: This study was carried out as part of the TC Project RER7016/IAEA "Enhancing Coastal Management in Fresh and Saltwater Bodies by Using Nuclear Analytical Techniques, Including Monitoring of Microplastics".

**References:**

[1] Science for Environment Policy (2023) European Commission DG Environment News Alert Service, edited by the Science Communication Unit, The University of the West of England, Bristol.

# Scaling complexity: novel hydraulic flume experiments on the interaction of sediments with nutrients and pollutants

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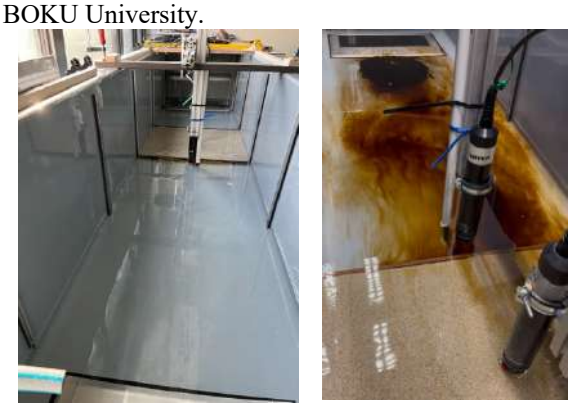
**Conference theme number(s): 1, 4**

**Introduction:** Aquatic ecosystems have been severely altered and disturbed by human influences. The result is a sharp decline in biodiversity in rivers. Despite existing research results, there is a knowledge gap regarding the local effects of nutrient and pollutant inputs in modified river systems and how these affect transport, deposition, and remobilisation [1]. Closing this gap is important for improving aquatic ecology and water management in general. A novel method for analysing nutrient and pollutant transport in hydraulic flumes is presented. The aim is to improve our process understanding of the interaction between sediments, nutrients, and pollutants.

**Methods:** The novelty and originality of the flume experiments compared to conventional approaches are: (i) adjustable hydraulic conditions; (ii) regulation of the water temperature; (iii) specification of physico-chemical parameters; (iv) controlled addition of nutrients in liquid form (e.g. fertiliser, manure) and particle-bound (e.g. arable soil); (v) reproduction of natural morphological aspects of a river (e.g. surface and subsurface layer of a river bed). ISE probes in the water and sediment were used to record the distribution of ammonium over time. Water and sediment samples were analysed for nutrient distribution in a certified chemical laboratory at BOKU University.



(a) (b)

**Fig. 1:** Hydraulic flume for investigating the interaction between sediments and chemical substances: (a) before the experiment: one sediment core and filled with tap water; (b) start of an experiment with animal manure.

**Results:** The initial results show clear differences in the temporal and spatial distribution depending on whether the nutrients are added in a particle-bound or liquid form. It was shown that the addition of animal manure produces an initial peak and then releases nutrients more evenly. When adding soil, variations in the concentrations and the time course were recorded. There were also differences regarding the structure of the sediment body (layers with different grain sizes) and the release of nutrients from these sediment bodies. The time course of the ammonium concentration is clearly different when finer substrate ($d < 0.8$ mm) is placed on coarser suspended sediment ($d < 8.0$ mm) than when the two layers are installed in the channel in reverse order.

**Discussion:** The novel approach of using adapted hydraulic flumes aims to investigate the hypothesis that particle-bound nutrient input and pollutant transport is also strongly influenced by the morphological characteristics of the river and the substrate composition. Consideration on a local scale is particularly important for the benthic environment [2]. In addition, this study investigated the hypothesis that temporal factors, such as sequential nutrient supply, may lead to an under- or overestimation of particle-bound nutrient dynamics in rivers, depending on when and where samples were taken in nature. This method offers the possibility to verify the previous findings (under optimum laboratory conditions) on pollutant binding (e.g. distribution coefficient Kd) in adjustable physico-chemical and hydraulic complexity. This allows the transport and fate of pollutants in rivers to be investigated and a deeper understanding of these processes to be gained.

**Acknowledgements:** The project is funded by the Disruptive Innovation – Early Career Seed Money funding programme of the Austrian Academy of Sciences (ÖAW) and the Austrian Science Fund (FWF).

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# Electrokinetic decontamination of Tributyltin (TBT) in dredged sediment

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**Conference theme number: 1 (Zero Pollution)**

**Introduction:** Tributyltin (TBT), an organotin compound used in antifouling paints, has caused significant environmental contamination. TBT strongly binds to sediment, limiting its degradation. The European Commission (DG-ENV) plans to set strict Environmental Quality Standards (EQS) for TBT in sediments, often close to or below the detection limits of current analytical methods. This necessitates the development of effective remediation techniques. This work investigates the electrokinetic decontamination of a marine dredged sediment using different setups and enhancing solutions.

**Methods:** Two types of reactors were used: a single-compartment flow reactor and a concentric two-compartment reactor. We tested different energy sources to facilitate desorption, along with various electrode configurations and enhancing solutions. In total, we conducted 24 different treatments. Before and after each experiment, we analyzed TBT and its degradation products (dibutyltin - DBT, and monobutyltin - MBT) using the method described in [1].
Freeze-drying of the samples for 24 hours was used to remove water. Approximately 0.2 grams of each sample were weighed and placed it in a focused microwave extraction tube. A known amount of $^{119}$Sn-labeled MBT, DBT, and TBT (a certified tracer mixture from ISC-Science) was added. 4 ml of an acetic acid/methanol mixture (3:1) was also added. The samples were then extracted for 4 minutes at 80°C in a focused microwave oven.
For the analysis 1.5 ml of the extract were transferred to a glass vial. Then, 4 ml of an acetic acid/acetate buffer (pH 5.4), 0.2 ml of a 1% (w/w) sodium tetraethylborate solution and 1 ml of hexane were added. The vial was capped and shaken for 5 minutes. The hexane layer was separated from the aqueous layer. Most of the hexane extract was transferred to a gas chromatography vial using a Pasteur pipette. The hexane was then evaporated under a gentle stream of nitrogen. For GC-MS Analysis 1 µ of the final extract was injected into a gas chromatograph coupled to a triple quadrupole mass spectrometer equipped with an electron ionization source (Agilent model 7000).

**Results and Discussion.** The highest extraction efficiency was achieved using the flow reactor. Optimal conditions included an applied electrical current of 0.15 A for 2 hours, the application of ultrasound, and the use of 0.25 M citric acid as the electrolyte (see Figure 1).
After treatment, TBT concentrations were below the detection limit of the analytical method. DBT concentrations decreased by 65%, and MBT concentrations decreased by 23%.
To assess the overall reduction of the entire organotin family (TBT, DBT, and MBT), we conservatively assumed that the TBT concentration was equal to the detection limit (0.3 ng/g). Based on this assumption, the overall decontamination efficiency was 47.6%.
These results demonstrate the potential of electrokinetics as a promising technique for decontaminating TBT-contaminated sediments under specific treatment conditions.

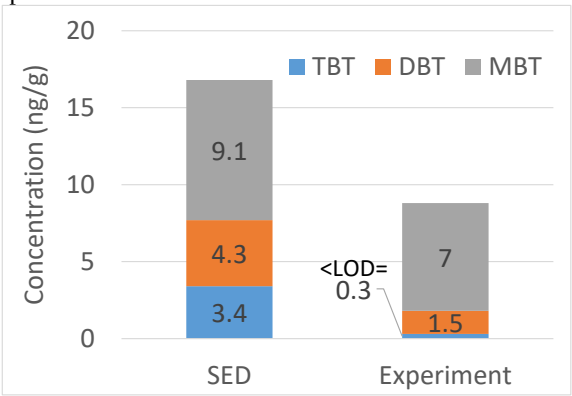


**Fig. 1:** *Concentration of TBT, DBT and MBT in the raw sediment (SED) and after the experiment which showed the maximum removal efficiency.*

**Acknowledgements:** This study was funded by MCIN/AEI/ MCIN/AEI/10.13039/501100011033 and the EU "NextGenerationEU"/PRTR through the Project TED2021-129950B-I00 (UNIDEC).

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# Assessing the impact of dredge disposal on different ecosystem components in the Belgian part of the North Sea

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**Conference theme number(s): 1**

**Introduction:** Harbours and navigation channels are dredged throughout the year to prevent siltation. In the Belgian part of the North Sea (BPNS), dredged material is disposed at five designated areas, located in three different benthic habitats (fine muddy sand *Abra alba*, muddy *Macoma balthica* and sandy *Nephtys cirrosa* habitat). Possible effects of dredge disposal are burial of benthic organisms and habitat changes due to sediment changes [1]. The Marine Strategy Framework Directive requires monitoring to check how this type of pressure influences the good ecological status of the marine benthic ecosystem.

**Methods:** The study covered 15 years (2005-2019) of monitoring in the BPNS, including three different ecosystem components (macrobenthos, epibenthos and demersal fish). The Benthic Ecosystem Quality Indicator (BEQI, www.beqi.eu) scores were calculated for the three benthic habitats, in which diversity, species composition, density and biomass were compared between the five impact areas and the control sites. These Ecosystem Quality Ratio scores (EQR) range between 0 and 1, where values below 0.6 imply that the benthic system in the impact area deviates significantly from the respective reference sites. Linear mixed-effects models (LMM) were performed to investigate the relationship between the amount of dredge disposal (pressure) and the EQR scores (impact) in the three habitats for the three ecosystem components.

**Results:** The highest impact was observed for the macrobenthic community in the *Abra alba* habitat, a site that received high and continuous dumping (on average 5.3 million tonnes dry matter per year). The LMM for the *Abra alba* habitat shows a significant decrease in the EQR scores for macrobenthos with increasing pressure (Fig. 1). The LMM shows a similar trend for macrobenthos within the *Macoma balthica* habitat, although the higher EQR scores suggest a smaller impact, even when receiving a relatively high amount of disposed material (Fig. 1). Most probably, the composition of the disposed material was not that different from the muddy sediment in the receiving habitat. For the *Nephtys cirrosa* habitat, the impact on the macrobenthic community was low, as overall high EQR scores were calculated, independent of pressure (Fig. 1). However, only limited amounts of dredged material were disposed at the sites in this habitat, which might influence the impact-pressure correlation. Also, the epibenthic and fish communities in the *Abra alba* habitat were affected, probably related to changes in the macrobenthic community at the impact site. For the other habitats, the impact on the epibenthic and fish communities was much lower, probably related to the higher mobility of these species groups. This is reflected in the LMMs for both ecosystem components (not shown). Although it was statistically not possible to detect a different impact, this did not imply an equal impact in the three habitats.

**Discussion:** The impact of dredge disposal varied with pressure (i.e. amount of dredged material), ecosystem component and habitat type. The EQR scores decreased with increasing pressure in all three habitats, though the impact was most clear in the *Abra alba* habitat for all three ecosystem components. The present study shows that benthic indicators of different ecosystem components are very useful to assess human pressure.

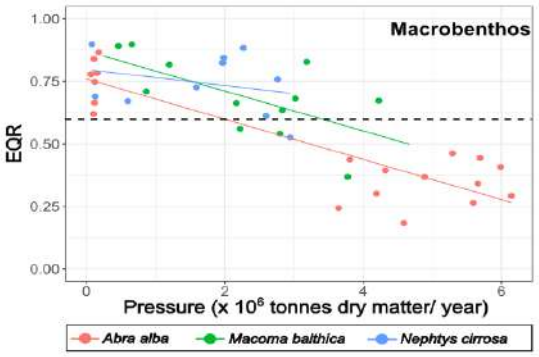


**Fig. 1:** Average EQR scores in function of pressure for macrobenthos in the three benthic habitats. The dashed line represents the threshold EQR score 0.6.

**References:** [1] Bolam and Rees (2003) *Environmental management* **32**: 171-188.

# Tribochemical decomposition of aromatic pollutants in dredged sediment

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**Conference theme number: 1 (Zero Pollution)**

**Introduction:** Over the past years, enormous efforts have been made in order to find new paths of chemical reactions, that could lead to the highly desirable thermodynamic and kinetic targets in various applied chemical processes. The nonconventional approaches involve non-thermal ways of activation of chemical reactions, many of which can have unusual reaction trajectories and products. Recently, the concept of a new technology for processing polychlorinated biphenyls waste through mechanically activated chemical treatment was proved (triboREMEDY project).
Our studies were focused on deep understanding of fundamental mechanisms underlying tribochemical activation for different classes of materials including metals, ceramics, polymers, surface coatings and liquids using a combination of advanced and original techniques including Mechanically Induced Gas Emission Mass Spectrometry. In this work, we explore the potential of tribochemical approach to solving challenging problems in decontamination of dredged sediments.

**Methods:** A model system consisting of a quartz sand as the main mineral component of sediments and various polycyclic aromatic hydrocarbons (anthracene and phenanthrene) and aniline, which simulated the contaminants. Sand and contaminants were loaded with various proportions into steel mechanochemical vial containing steel balls. The mixture was subjected to high-energy milling for 1 to 5 hours. After the test, milled sand was added to DMSO-d6 and solid fraction separated from the liquid phase. The obtained liquid was analysied using Nuclear Magnetic Resonance spectrometry ($^{1}H$ and $^{13}C$).

**Results and Discussion:**
NMR spectra showed that chemical transformations in all model contaminants initiated during the first hour of treatment and intensified after 5 hours (Fig. 1). In aniline, mechanochemical degradation started at amine group and continued at bencene ring. Similar degradation of aromatic structures were found for polyaromatic compounds. The resonance peaks became less intense and widened indicating possible distortions and tensions.

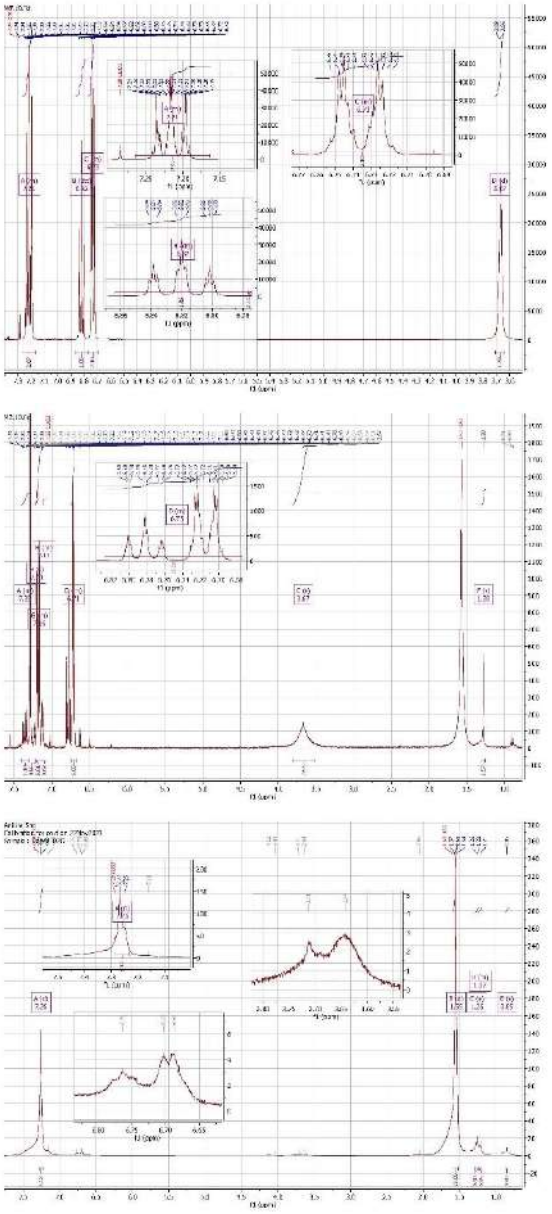

**Fig. 1. Top – pure aniline, middle – after 1 h treatment, bottom – after 5 h treatment.**

**Acknowledgements:** This study was funded by MCIN/AEI/ MCIN/AEI/10.13039/501100011033 and the EU "NextGenerationEU"/PRTR through the Project TED2021-129950B-I00 (UNIDEC).

# Spatial distribution of $^{40}$K, $^{137}$Cs, $^{226}$Ra and $^{238}$U in the coastal and shelf sediments of the western Black Sea

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**Conference theme number(s): Theme 1 Zero Pollution**

**Introduction:** Sediments play a significant role as sensitive indicators in realization of monitoring and control of the marine ecosystem. Important stage in realization of the monitoring is receiving relevant information for radionuclide and toxic element concentrations [1-3]. The main goal of this study is to fill the gaps of the few contemporary radionuclide data for the western Black Sea sediments. For that purpose, the results of the concentration measurements of the technogenic ($^{137}$Cs) and natural ($^{40}$K, $^{226}$Ra, $^{238}$U) radionuclides in sediments collected in the coastal and shelf sediments of the west Black Sea are represented.

**Methods:** Sediments were collected in the period 2018-2021, predominantly from shallow water but also from the deep water of the Black Sea in a depth range from 14 to 104 meters below the sea level. One part of the cores were collected on WFD (Water Framework Directive) monitoring stations. Sediment samples were sampled using a Multi corer (4 x Ø60 mm) equipment. Measurements were made by Low level Gamma Spectrometry using an HPGe-GMX 50P4 Coaxial Photon Detector System with a Beryllium window (Ortec) with an energy resolution of 2.3 KeV at 1332 KeV (60Co) and 50 % counting efficiency.

**Results:** Results show that all the measured $^{137}$Cs activities vary between 4.2 and 96.5 Bq.kg$^{-1}$. The both maximum and minimum $^{137}$Cs concentration values in the entire studied range are observed in the southern costal sediments from Burgas and Vromos, respectively. (Fig. 1). The obtained mean value is 26.4 Bq.kg$^{-1}$. The $^{137}$Cs specific activities in the surface layer (0-1/1.5) of the sediments vary from 9.5 to 96.5 Bq.kg$^{-1}$. The measured values for natural radionuclides are in the intervals 119 - 1053 Bq.kg$^{-1}$ for $^{40}$K, 29 - 71 Bq.kg$^{-1}$ for $^{238}$U and 12 - 128 Bq.kg$^{-1}$ for $^{226}$Ra. The mean values are 565 Bq.kg$^{-1}$ for$^{40}$ K, 44 Bq.kg$^{-1}$ for $^{238}$U and 35 Bq.kg$^{-1}$ for $^{226}$Ra. An exception is observed in the sediment collected from Vromos Bay (situated in the southern part of Burgas Bay), where the mean values are higher than those obtained for all other samples - 682 Bq.kg$^{-1}$for $^{40}$K, 183 for $^{238}$U Bq.kg$^{-1}$ and 208 Bq.kg$^{-1}$for $^{226}$Ra. Unlike natural radionuclides, the content of $^{137}$Cs in the sediment of Vromos Bay is significantly lower. The mean measured value is 8.2 Bq.kg$^{-1}$, and the concentration variations found range from 4.2 to 9.5 Bq.kg$^{-1}$.

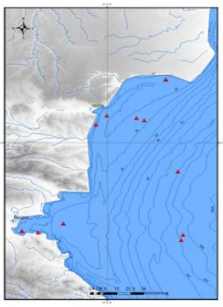

**Fig. 1:** Sampling stations in the Bulgarian Black Sea area

**Discussion:** The obtained values of the radionuclides content in studied sediments are in accordance to the published literature data [4-5]. The obtained results expand a database on the concentrations of radionuclides in sediments from the Bulgarian Black Sea coastal and shelf zone and can be used for assessment of the ecological status of the marine environment along both zones.

**Acknowledgements**: This study was carried out as part of the TC Project RER7016/IAEA *"Enhancing Coastal Management in Fresh and Saltwater Bodies by Using Nuclear Analytical Techniques, Including the Monitoring of Microplastics".*

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# Field Measurement of Greenhouse Gas Emissions and Gas Mediated Contaminant Dispersion from Fiberbanks

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**Conference theme number(s): 1,2,5**

**Introduction:** Large volumes of cellulose-rich material, also called fiberbanks, are frequently found in aquatic environments near paper and pulp industries. Because of the high organic content, they produce large volumes of greenhouse gas (GHG). Fiberbanks are often contaminated by semi-volatile persistent organic pollutants and mercury. The objective of this study was to quantify the gas composition and gas-mediated semi-volatile pollutants.

**Methods:** Several fiberbanks were investigated in the county of Västernorrland, Sweden (Fig. 1). Two different field sampling approaches were developed: (i) passive sampling to measure the long-term gas flux, gas composition, and the gas-mediated particle transport; and (ii) forced sampling, to measure the gas-mediated semi-volatile pollutants, where iron rods were attached beneath the sampler to penetrate the sediment and to collect larger gas volumes in shorter time intervals.


**Fig. 1:** Sampling at three fiberbanks.

**Results:** HCB and Hg(0) concentrations in gas were 6.5 (n=11) and 10.6 ng/m$^3$ (n=15) respectively, corresponding to 3.2 and 2.6 ng/m$^2$/year. Gas-mediated particle transport was > 200 mg/m$^2$/day. The average gas flux using passive sampling was approximately 0,7 L/m$^2$/day of which 52% was methane. Based on the gas flow and composition using passive sampling at Väja, the area estimate of the entire Väja fiberbank and the size of the sampler, the annual carbon footprint of this site is estimated to range between 55 - 300 tonnes of $CO_2$ equivalents.

**Discussion:**
The gas phase HCB flux during undisturbed conditions was 80 times lower than in previously measured sediment-to-water diffusive flux [1]. In our study, the Hg flux was quantifiable (2.6 ng/m$^2$/year), whereas in a previous measured sediment-to-water diffusive flux it was not [2]. Our results confirm that fiberbanks emit significant amounts of GHG as suggested by [3]. However, in [3] they most likely overestimated the total GHG release ($3.67 \times 10^6$ tons $CO_2$ eq./year, or 7% of the Swedish GHG emissions). This number was calculated from the estimated total fiberbank volume in Sweden and gas release from the studied volume of fiberbank material in the laboratory. However [4] observed that the methane generating degradation processes primarily occur in the uppermost decimeters of fiberbanks eventhough fiberbanks often are several meters in depth. When using data from [3] but assuming that only about 3 decimeters are involved in the gas production, the estimate was in much better agreement with our estimate based on in situ flux results. Nevertheless, we estimate that Swedish fiberbank production of GHG could range between approximately 3 – 18 % of the Swedish landfill emissions.

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# Abrasion in nature
# a single particle analysis

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**Conference theme number(s): 2**

**Introduction:**
Measuring abrasion of bedload material in nature is a challenging undertaking, resulting in limited availability of field data. Consequently, laboratory experiments have traditionally served as the foundation for understanding abrasion and developing formulae. Abrasion of bedload material is important as it describes the rigidity of the bedload material and marks the transition to smaller grain sizes and thus to suspended load. This study makes use of RFID tracers not only to locate single particles, but also to recover them in an alpine stream in Austria, for further analysis. This study seeks to enhance our understanding of natural abrasion behavior.

**Methods:**
Over a period of three years, 500 river own bedload material (limestone) with a b-axis ranging from 17 mm to 101 mm were equipped with passive RFID tags. This facilitated the identification, recovery and retrieval of some of the tracer stones after placing them into the Urslau stream. Combining three different mobile RFID antennas, designed specifically for this purpose, detection range of the mobile RFID antenna can be stepwise reduced until the tracer is localized. While reducing the detection range the sediment cover is removed, if the tracer is buried. The transport length of recovered tracer stones ranges from 0.09 km to 9 km. The a-, b- and c-axes, as well as the weight of the stones, were measured prior to the insertion and after recovery. The burial depth at which the tracer stones were located in the riverbed during recovery was also documented.

**Fig. 1:** a) tracer recovery, b) recovery antenna

**Results:**
The abrasion study revealed that mass loss was measured even with stones with low mobility (0-2km). Further, the mean abrasion rate as percentage of mass reduction per km decreases with increasing transport length as shown in Figure 2. The spikes in the Boxplot of Figure 2 are the result of stone fractures. The mean abrasion rate of all transport distances is 2.7 %.
The burial depth varied greatly along the search route and no correlation could be established in regard to transport length, total time in the river or the magnitude of the previous events. The burial depths ranged from 0-0.6m.

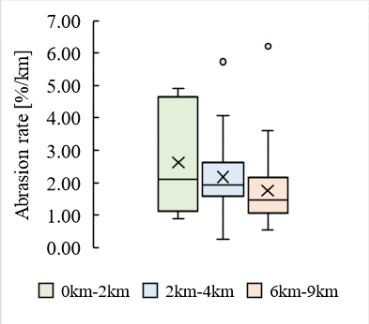


**Fig. 2:** *boxplot of abrasion rate of mass% per km*

**Discussion:**
The mobile recovery antenna designed for this study enabled the localization and identifying RFID tracers within the riverbed. The mean abrasion rate is slightly higher as the lab-based rates from literature [1,2]. The nature-based abrasion rates on the other hand have a good correlation [3].

**Acknowledgments:**
The authors thank the Austrian Federal Ministry of Agriculture, Forestry, Regions, and Water Management and the Department of Torrent and Avalanche Control in Salzburg for funding and supporting this study

**References:** [1] Mikoš (1993); [2] Attal, Lavé (2006) Geological Society of America; [3] Surian (2002) Geomorphology 43(1-2): 137 – 149

# Morphological changes after sequential experimental floods: the case study of the Spöl River, Switzerland

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**Conference theme number(s): 2**

**Introduction and goals:** Floods significantly reshape rivers´ morphology, causing channel avulsions, riverbank and widening [1], changes in conveyance capacity, and sediment redistribution [2]. These transformations may persist long after the flood water recedes and may accumulate after several flood events, leading to complex responses. Although these changes create habitats and sustain rivers´ health, they may also pose hazards to adjacent infrastructure and population [3]. Despite its importance, predicting these changes is still quite difficult for both managers and scientists. Understanding river morphological dynamics better is crucial for preventing flooding [4], protecting infrastructure, and encouraging river restoration. This knowledge is essential for reducing the likelihood of future floods and safeguarding ecological and human systems. This is the aim of this work, to shed light on the morphological response of rivers after several floods, quantifying the patterns of erosion and deposition combining high-resolution topography and geo computation techniques.

**Study Area and Methods:** This study analyzed the geomorphological changes in the Spöl River, an alpine river partially regulated by two dams, Punt dal Gall and Ova Spin. The study site is located in the lower reach of the Spöl River, where it receives additional flow and sediment input from unregulated tributaries, contributing to its dynamic geomorphological processes. Experimental floods are released annually as part of a restoration program making the River Spöl a natural laboratory for studying and analysing river morphological changes after floods [5].
We employed high-resolution digital surface models (DSMs) derived from structure from motion based on drone-acquired data to assess the geomorphic changes during a series of floods, in terms of sediment erosion and deposition using the Geomorphic Change Detection 7.5.0 standalone software [6]. Between 2018 and 2024, these DSMs have been obtained using pre- and post-drone surveys. For our area of interest, we were able to quantify the volumetric and areal changes brought about by erosional and depositional processes by computing Digital Terrain Models of Difference (DoD).

**Results:** The Spöl River experienced substantial morphological transformations that affected both area and volume. The results from 2023 showed about 24% of the entire region had a positive elevation change (deposition) while 16% had a negative elevation change (erosion). In the area of interest, sedimentation outweighed erosion, according to areal and volumetric changes. While the downstream region exhibits a general pattern of deposition, the upper portion of the reach showed significant erosion.
The study emphasizes continuous monitoring and adaptive management to balance restoration goals with infrastructure protection and flood resilience, with future research focusing on predictive models.

**Acknowledgements:**
This study has been partially supported by the Swiss National Science Foundation (PCEFP2_186963), the Universities of Lausanne and Bern (Switzerland) and the Research Commission of the Swiss National Park (SNP) of the Swiss Academy of Sciences (SCNAT).

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# Influence of pre-existing bed on diluted turbidity current propagation

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**Conference theme number(s): 2**

**Introduction:** Turbidity currents are a subclass of gravity currents where a particle-laden fluid flows through a relatively lighter fluid under the effect of gravity. The particles in this case are mostly suspended by the turbulence created due to the forward motion of the current along the boundary of the domain [1]. Turbidity currents are an inevitable part of any dredging or deep-sea mining activity. They have a potential impact on the local ecosystem [2]. They have the tendency to propagate further from the area of operation before settling down.
This study examines the behavior of turbidity currents which are quite dilute in nature, as they flow over different bed types both pre-existing and freshly deposited ones. The pre-existing bed here refers to the ocean, river or channel bed while the freshly deposited bed consists of a layer of materials deposited from previous run, which has loose materials on its surface.

**Methods:** Experiments were carried out in a lock - exchange flume of 3m*0.4m*0.2m dimension (see Fig 1). A bed of 5mm was laid on the flume bottom using quartz flour. All the experiments were run on top of this bed which was renewed after every run. The experiments were conducted using illite clay and sediments from the Clarion Clipperton Zone (CCZ) in the Pacific ocean. Additionally, a synthetic organic matter (polyacrylamide flocculant Zetag 4120) was also used to form flocs with illite clay as it does not form flocs on its own.

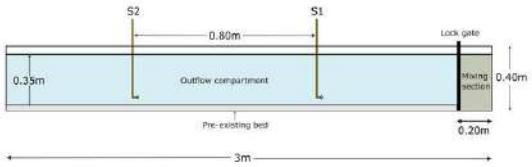


**Fig. 1:** Lock exchange flume with pre-existing bed.

An Ultrasonic Velocity Profiler (Met-Flow) and a Go Pro camera were used to measure particle velocity and record the front velocity of the turbidity currents, respectively. Two siphons were installed to collect samples from the body of the turbidity current to analyze flocs. The samples were analyzed using FlocCAM and Malvern Mastersizer 3000.

**Results:** The effect of a pre-existing bed on the turbidity current propagation was evident from the video analysis. The bed with a layer of illite clay on top of it reduced the front propagation velocity of turbidity current compared to both the no-bed condition and quartz bed (see Fig 2). Beds with traces of Zetag alone or a combination of illite and Zetag further reduced the front velocity of the propagating turbidity currents, thus highlighting the influence of organic matter. Additionally, floc analysis also proved that larger flocs were formed in presence of a bed.

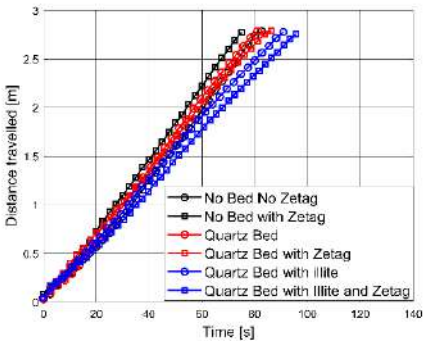


**Fig. 2:** Front position of Turbidity current under different bed conditions for 5g/L sediment concentration

**Discussion:** The results highlight the relationship between turbidity current velocity under varying bed conditions while taking flocculation into account. In case of CCZ sediment cases, the presence of a bed reduced the propagation speed significantly especially in cases of lower sediment concentrations. These findings emphasize the importance of bed roughness imparted by the freshly deposited sediments to the turbidity currents, thus reducing their velocities.

**Acknowledgement:** The authors would like to acknowledge Deltares for the use of their facilities. This work has been performed under the framework of PlumeFloc (NWO: TMW.BL.019.004, Topsector Water and Maritiem: Blauwe route) within the MUDNET academic network (https://www.tudelft.nl/mudnet/).

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# Investigating Sources and Transport Dynamics of Suspended Sediments in a Mediterranean Forested Catchment

**Diletta Chirici[1], Ilenia Murgia[1], Matteo Verdone[1], Lorenzo Innocenti[2], Matteo Nigro[1], Francesca Manca[1], Andrea Dani[1], Federico Preti[1], Giacomo Belli[3], Duccio Gheri[3], Luca Mao[4], Emanuele Marchetti[3], Luca Solari[2], Daniele Penna[1]**

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**Conference theme number: 2. Sediment Flows**

**Introduction:** Suspended sediment is vital for stream morphology and ecology, and its concentration is essential for catchment management and risk assessment (Ghimire et. al, 2024). However, its transport dynamics and spatial sources in forested mountain catchments remain poorly understood (Matos et. al, 2024). Therefore, this study aims to investigate the main sources and the space-time dynamics of suspended sediment transport in a small forested mountain catchment.

**Methods:** This study was carried out in the Re della Pietra experimental catchment located in the Tuscany Apennines, Central Italy, characterized by a Mediterranean climate. The catchment area is 2 km², with elevations ranging from 643 m to 1320 m a.s.l..
Suspended sediment was measured at the catchment outlet using a turbidimeter set at 5-min temporal resolution coupled to a water level logger for the stream stage. Soil moisture was measured at two depths on a hillslope nearby, while key meteorological variables were recorded from a weather station in the upper part of the catchment.

**Results:** Preliminary results reveal a significant correlation ($p<0.05$) between cumulative turbidity per event, runoff event duration ($\rho=0.65$), storm duration ($\rho=0.63$), and peak stream stage ($\rho=0.59$). Pronounced turbidity peaks during moderate to intense storms occurred during wet conditions (Fig. 1). From the analysis of the hysteretic loops between turbidity and stream stage, excluding the complex loops (70%), clockwise events were the most frequent (16%; anticlockwise 5%; figure-of-eight 9%), suggesting that the main sources of suspended sediment are local (Long et. al, 2024).

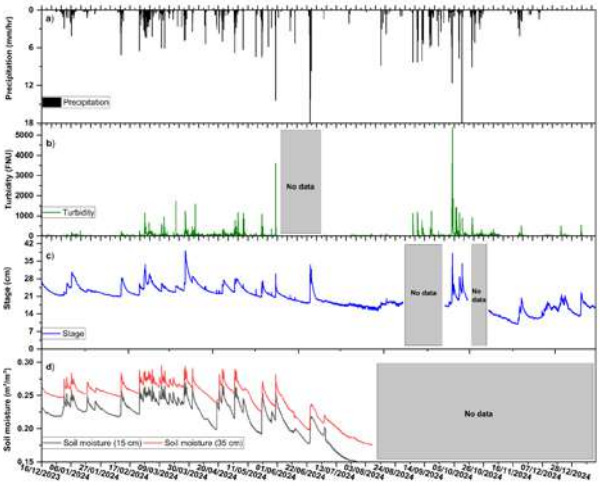


**Fig. 1:** *Time series of rainfall, turbidity, stream stage and soil moisture at 15 cm and 35 cm of depth data.*

**Discussion:** Preliminary findings highlight that the characteristics of rainfall-runoff events, as stream stage, rainfall intensity, and peak stream stage, strongly influence both amount and dynamics of suspended sediment in this catchment. Meteorological variables alone did not fully explain turbidity peaks, suggesting that other controls (e.g., localized bank failures or erosion scars, failure of log steps) influence short-lived turbidity peaks. Future work will convert raw turbidity data into suspended sediment concentration and a flow rating curve is currently under development.

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# Continuous Sediment Transfer – Restoring Sediment Continuity in impounded Waters

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**Conference theme number(s): 2,3**

**Abstract**: The retention of sediment in reservoirs exacerbates issues related to sediment balance, leading to a deficiency of sediment in the lower reaches. This deficiency affects nutrient levels for fish and other organisms, diminishes silt for alluvial forests, disrupts sediment equilibrium, and ultimately impacts river deltas.

As of now, sustainable sediment management in reservoirs is almost non-existent. 'Sustainable' in this context denotes a solution that benefits both the environment and reservoir use. Traditional practices involve recurrent dredging, permanently removing sediment from the river course and resulting in a negative sediment equilibrium. Flushing, while removing small sediment quantities around the bottom outlet, is unsustainable, often leaving a substantial amount below the dam to the detriment of ecology.

Ensuring technical passability of the reservoir for sediment would be sustainable, similar to a scenario without a dam element. This necessitates a large-scale, managed, and controlled transport of sediment from upstream to downstream waters to restore the natural sediment balance. Continuous sediment transport emerges as a technical and sustainable solution for sediment continuity.

In this approach, sediment is continuously and automatically transferred from headwaters to lower reaches in a parameter-controlled process using fully automatic dredges. The operation is feasible 24/7 and requires no personnel. Real-time measurement and monitoring of volume, mass flow, and other parameters enable precise control of sediment transport. This ensures removal by the downstream water flow, preventing direct sedimentation in the water. Due to the unique nature of each reservoir, ongoing technological development is essential to address new challenges and find tailored solutions.

As a prospect for further development of this process, research is currently being carried out on an integrated methane gas collector to collect, separate, and utilize the methane gas bound in the sediment. This can reduce the negative impact of methane gas on the climate, which can be released during desedimentation.

The presentation will delineate the environmental impact of sediment retention, introduce desedimentation methods, and elucidate the continuous sediment transport approach and the integration of a methane gas collector.

# Assessment of bioavailable metal/loids in metal-rich estuarine sediments using passive samplers and sequential extraction techniques

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**Conference theme number(s): Theme II Sediment Flow**

**Introduction:** Diffusive Gradient in Thin-Films (DGTs) are increasingly recognized as an alternative to conventional methods for assessing metal(loid) exposure in benthic organisms. By simulating the absorption of metal(loids) through biological membranes, DGTs offer sensitive and reliable measurements of DGT-labile metal species. This study aims to analyze the distribution of metal(loids) in estuarine sediments of the Ria of Huelva and evaluate their bioaccessibility using DGT devices alongside sequential extraction procedures.

**Methods:** Sediment cores were collected from the margin channels at selected sampling point using 25 cm PVC tubes. The cores were sealed, transported to the lab, sliced into 3 cm layers, frozen at -80°C, and freeze-dried before analysis. Pore water samples were also analyzed. DGT passive samplers were installed in each point. These devices retain the labile metal fraction through a Chelex-100 resin, where free cations and labile metal complexes diffuse through a filter and gel before being trapped by the resin. The LSPX-NP Loaded DGT used in this study features a mixed binding layer of Chelex and Ti oxide, designed to measure up to 40 metals. After 24 hours of sediment exposure, the devices were retrieved, rinsed, and taken to the lab. Resin gels were segmented, acid-treated, and shaken before dilution for metal analysis. Sequential extraction was performed to study the labile metal/loid fraction in sediments. Acid-extractable metals were obtained using 0.11 M acetic acid, while the exchangeable fraction was extracted with 1M $MgCl_2$ at pH 7. After centrifugation, supernatants were filtered, acidified, and preserved for analysis.

**Results:** The estuarine sediments are mostly silty loam (60% silt, 36% sand, 4.8% clay), except at the outer part, which has a sandy loam texture due to coastal influence. They contain high metal concentrations, with Fe averaging 9.0% and peaking at 18%. Al, $S_2O_3$, and $P_2O_5$ also show notable variations, with maximum values of 15%, 5.7%, and 3%, respectively. Sediment porewaters are characterized by high contents in Fe, with maximum concentrations of 5826 µg/L, followed by Mn (470 µg/L), Zn (210 µg/L), Al (189 µg/L), Cu and As (22 µg/L). DGTs accumulated high concentrations of Fe (maximum value of 24090 µg/L) and other metal/loids such as Al (1601 µg/L), Mn (1186 µg/L), Zn (684 µg/L), Cu (193 µg/L), Cr (35 µg/L), Pb (22 µg/L) or As (5.5 µg/L). Labile fractions obtained by sequential extractions also provide high concentrations of metal/loids such as Al (maximum of 31503 µg/L), Fe (17715 µg/L), Zn (1990 µg/L), Cu (1330 µg/L), Mn (668 µg/L), Pb (183 µg/L) or As (55 µg/L)

**Discussion:** The elevated Fe concentrations in porewater could be attributed to predominant Fe-reduction processes occurring under low-oxygen conditions. Iron oxides and oxyhydroxysulfates carried by the river settle and become buried in the sediment, where they undergo microbial dissolution in these reducing environments. The interaction between dissolved ferrous Fe and sulfide results in the formation of Fe monosulfides and pyrite, which serve as the ultimate sink for both elements in the deeper, oxygen-depleted sediment layers. During these reactions there is a flux of metals between reduced and oxidized phases. The elevated concentrations observed in DGTs for Fe and Al suggest that colloids may pass the membrane and contribute to this pool. Labile fractions observed by DGTs and sequential extractions were not well correlated in this study, suggesting further investigation.

**Acknowledgements:** CR Cánovas and MD Basallote thanks the Spanish State Research Agency (AEI) for the RYC2019–027949-I and RYC2022-035326-I grant funded by MICIU/AEI /10.13039/501100011033 and FSE+. This work was funded by the project DYNAMICO (PID2023-151504OB-I00) funded by the Spanish Ministry of Science, Innovation and Universities and the Spanish Research Agency.

**References:** [1] Menegario et al. (2017) Anal. Chim. Acta 983, 54–66.

# Past, present and future suspended sediment transport in large German rivers

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**Conference theme number(s): 2**

**Introduction:** Suspended sediment transport is an integral part of river systems and provides important services for ecological functioning and human use of river channels.
Suspended sediment transport has been strongly altered by human activity in many parts of the world. While deforestation and agricultural land use strongly increased soil erosion and sediment supply, dam construction for hydropower production, waterlevel control, and irrigation purposes disconnects downstream sediment transport with often negative effects for downstream river ecology and human wellbeing. Restoring disturbed sediment balances of river systems requires detailed knowledge of past, present and future trajectories of sediment transport.
This study aims to present the state of the art of suspended sediment monitoring in large German river systems, which represent an important logistics transport routes for the German economy.

**Methods:** Suspended sediment in German waterways is monitored at ~ 62 monitoring stations by the Waterways and Shipping Authorities starting in the 1960s. The dataset provides valuable information on the long-term development of suspended sediment transport in Germanys major rivers. We use suspended sediment rating [1] analysis to understand event-based and seasonal suspended sediment dynamics and to infer sources of suspended sediments. Past trends were derived for suspended sediment concentrations [2]. Climate change impacts were evaluated using convection permitting climate simulations [3], which allow for a better representation of rainfall induced soil erosion events for the calculation of future rainfall erosivity scenarios. Finally, we compared recent loads with long-term rates derived from stratigraphical evidences.

**Results:** The results indicate that river systems in Germany have witnessed strong increases of suspended sediment transport in response of large-scale deforestation during the Bronze age. After reaching maximum suspended sediment loads during the last 200 years, suspended sediment concentrations have strongly declined between 1990 and 2010. Since 2010, the decreasing trend of suspended sediment concentration has stopped. Global warming leads to higher atmospheric moisture fluxes causing an increase in the intensity and frequency of heavy rain events, globally as well as in Central Europe [e.g. 4]. Especially in summer, convective, high-intensity precipitation is increasing. The observed past and expected future increase in extreme precipitation suggests an increase in soil erosion and suspended sediment supply in the near and far future. This expected trend is supported by increasing rainfall erosivity in Central Europe for the near and far future, of up to 80%.

**Discussion:** The presented trajectory of suspended sediment transport in German river systems provides valuable insights for sustainable sediment management in these systems. The results are discussed in light of past (natural) reference conditions for suspended sediment in German rivers and expected future developments, which require climate-resilient sediment management solutions.

**References:** [1] Hoffmann et al. (2020) *Earth Surface Dynamics* **8**: 661-678*;* [2] Hoffmann et al. (2023) *Earth Surface Dynamics* **11**:287-303; [3] Uber et al. (2024) *Hydrology and Earth System Sciences* **28**: 87-102. [4] Allan et al. (2020) *Annals of the New York Academy of Sci.* doi.org/10.1111/nyas.14337

# Tracing gravel in the German Upper Rhine using radio acoustic transmitters – findings from a preliminary study

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

**Introduction:** The Rhine is Germany´s most important inland waterway. Downstream of its last barrage near Iffezheim it is free-flowing. Construction of this barrage resulted in the retention of all sediment fractions larger than sand, which in turn requires ongoing bed load nourishment since 1978, in order to prevent river bed incision.
The effectiveness of these nourishment measures can only be assessed through a thorough monitoring which in turn enables appropriate adjustments to be made, if necessary, to counteract undesirable developments of the river bed morphology. Regularly conducted echo-soundings, along with bed load transport measurements and river bed samplings help to inform about the development of the river bed. However, open questions remain regarding the conditions required for bed load transport to occur and its extent during various discharge conditions. Apart from an improved assessment of the effectiveness of the nourishment measures and a generally better system understanding, answering these questions would provide valuable input parameters for the validation and calibration of bed load transport models.
With the aim of obtaining better insights into the bed load dynamics of the Upper Rhine in the future, we tested an elsewhere proven method for this river reach in this preliminary study.

**Methods:** We used artificial tracer stones consisting of a distinctive radio acoustic transmitter incorporated into resin material and added lead balls to obtain the density of natural gravel (Liedermann et al., 2013). Production of the tracers using a mold of a representative stone ensured the identical shape of all tracers in a size group. A total of 22 tracers, ranging in size from 24.5 to 67.3 mm, was added to the river within one cross-section, just downstream of the nourishment reach. The size of the tracers covered the range from median grain size up to the 99$^{th}$ percentile for this river reach. Additionally, 4 tracers ($d_{90}$-size: 49.7 mm) were positioned at different depths of a depth profile.
Individual positions were determined from a boat using a directional antenna, with searches taking place every 3 weeks, on average, for the first 15 months, and after 21 months.
With the aim of reducing the work effort, we are also working on ways to automate the detection process.

**Results:** Overall detection rates of the tracers were at 73%, significantly dropping at water levels ≥ 5 m, especially for the two smaller tracer sizes, while the larger tracers could be reliably detected during most conditions. Additionally, increasing dispersion over time made searches more time-consuming.
Average tracer velocities over the 21-month period were between 9 m/day ($d_{99}$) and 20 m/day ($d_m$), with the fastest tracers moving at 13 m/day ($d_{99}$) and 27 m/day ($d_m$). During high discharge conditions, average velocities ranged up to 38 m/day ($d_{99}$) and 102 m/day ($d_m$), respectively, while during low-flow conditions only very little to no transport occurred.
Similar to transport velocity, transport probability generally increased with increasing discharge conditions throughout the tracer size range, while it decreased with increasing tracer size. However, even during low-flow conditions, transport probability was at least 40%, even for the larger tracers. Once tracers moved, they often showed laterally alternating patterns within the fairway between point bars.

**Discussion:** Using radio acoustic tracer stones proves to be feasible to investigate bed load dynamics in the Upper Rhine, especially for larger grain sizes in the coarse gravel range – due to stronger signals – and for flow condition even above mean flow. However, large efforts to detect most of the small number of tracers at adverse conditions reveal the need for further improving the method, e.g. through automation.
Size- and discharge-specific transport probabilities hint towards conditions for incipient motion. Together with transport velocities and pathways, these insights provide valuable data for the improved validation and calibration of bed load transport models, which in turn help to better inform sediment management measures.

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# Landscape Reading of River Systems: Exploring the Geological History of Alpine Rivers

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**Conference theme number(s): 2**

**Introduction:** Understanding a river's morphology requires examining its geological history: Fluvial development is controlled by changes in climate as well as tectonic processes and sediment dynamics [1, 2]. Glaciation processes, for example, are majorly responsible for reshaping landscapes by eroding older sediments and reorganizing river pathways [3, 4, 5]. The relationship between the geological history and morphological characteristics of selected Alpine rivers is analyzed, incorporating the findings of [6].
We illustrate how river morphology reflects the evolutionary history of different stretches along selected rivers [6].

**Methods:** We applied a hybrid approach [7] to the 'landscape reading' concept [8] to differentiate between the selected rivers' sections. This method uses three parameters: Active Channel (AC), Active Floodplain (AF), and Morphological Floodplain (MF). These were determined through a GIS survey (ASTER GDEM v3; AC, MF) and a hydraulic 1D step-backwater model (HEC-RAS) of a five-year-recurrence interval flood scenario (HQ5; AF), based on [7]. Channel sinuosity, including hydraulic and topographic sinuosity [9], was also evaluated.

**Results:** Analyses of landscape reading elements, hydraulic vs. topographic sinuosity, and longitudinal profile, confirm how the upper Biya (Siberia), formed in the late middle Pleistocene, contrasts with the older, well-developed valley downstream [10] (Fig. 1). The upper Biya has a linear longitudinal profile (associated with sediment equilibrium [11]), while the rest of the river follows a concave shape (indicating downstream fining and channel aggradation [11]).

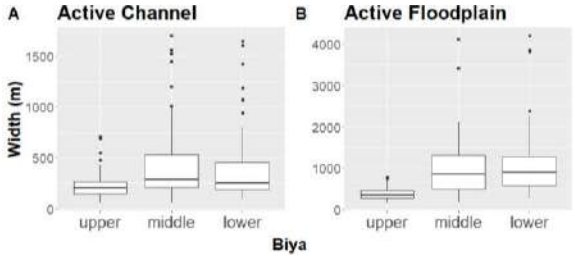


**Fig. 1:** *Biya: Selected landscape reading elements.*

**Discussion:** The shape of natural rivers is mainly a result of geological factors as well as climatic and hydrological controls. If these boundary conditions change at any point in space or time along a river, it is likely to exhibit changes in its morphology.
The example from the Biya precisely demonstrates this: Its upper valley shows evidence of a past glacial lake outburst flood. Moraine dam failure caused the catastrophic Biya debris flow (BDF) which initiated major valley incision processes that led to the development of the upper Biya about 37.5 ka before present [10, 12].
The relatively simple landscape reading approach, [7] effectively accounts for such differences in the evolutionary history between river sections. This method already yielded similar findings at the Vjosa [7].

**Acknowledgements:** Lisa Schmalfuss is supported by the Doctoral School "Human River Systems in the 21st Century (HR21)" of the University of Natural Resources and Life Sciences.

**References:** [1] Vandenberghe et al. (2018) *Quaternary* **1**: 14; [2] Anderson & Konrad (2019) *Journal of Geophysical Research: Earth Surface* **124(4)**: 902-919; [3] Sokołowski et al. (2021) *Geografiska Annaler: Series A, Physical Geography* **103(3**): 223-258; [4] Comiti et al. (2019) *Earth and Planetary Science Letters* **520**: 77-86; [5] Fildani et al. (2018) *Scientific reports* **8(1)**: 1-8; [6] Schmalfuss et al. (2022) *Geography, Environment, Sustainability* **15(4)**:196-213; [7] Hauer et al. (2021) *Catena* **207**: 105598; [8] Fryirs & Brierley (2012) *Geomorphic analysis of river systems: An approach to reading the landscape*, 368pp.; [9] Mueller (1968) *Annals of the Association of American Geographers* **58(2)**: 371-385; [10] Baryshnikov et al. (2016) *International Geology Review* **58(14)**: 1780-1794; [11] Rice & Church (2001) *Water Resources Research* **32(2)** : 417-426; [12] Baryshnikov (2016) *Geography and Tourism*, **4(2)**: 75-81.

# Sediment Dynamics in an Alpine River: A Case Study from the Ötztal, Austrian Alps

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**Conference theme number(s): 2**

**Introduction:** By the end of the 21st century, the Alps are predicted to be largely ice-free [1]. This reduction in glacier area raises many critical questions about the impact on high alpine (glacio-)fluvial processes and associated sediment dynamics [2, 3]. Particularly in formerly glaciated catchments, there is a considerable need for research to understand how glacier loss affects sediment fluxes and storage. This study addresses this issue by analyzing the long-term effects on sediment transport in an alpine river system. The focus is on the Vent/Rofenache monitoring station in the Austrian Ötztal, a representative example of a high alpine, formerly heavily glaciated catchment**.**

**Methods:** Sediment transport has been systematically analyzed at the Vent/Rofenache monitoring station since 2007. Both direct and indirect measurement methods are used (Figure 1). An indirect system, the plate geophone system (Figure 1 a, b), is used, which is based on the recording of seismic signals induced by the movement of bedload particles over the steel plates [4]. The direct methods include the use of a mobile basket sampler (Figure 1 c), which allows bedload material to be collected and quantified during specific discharge conditions [5]. The calculation of bedload transport can be achieved through an integrative approach, which involves a combination of direct and indirect measurements [6].

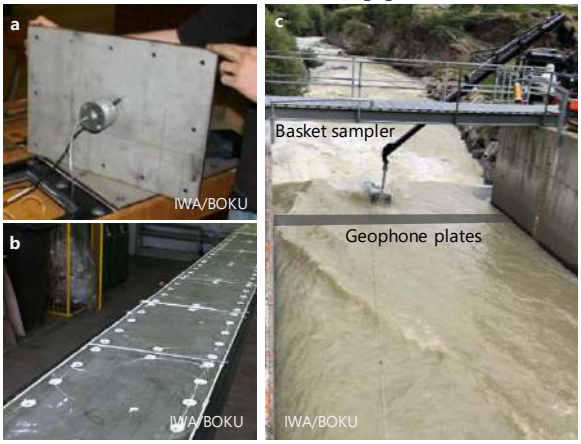


**Fig. 1:** (**a**) Steel plate with geophone sensor underneath; (**b**) geophones plates [6]; (**c**) direct bedload measurement with mobile basket sampler downstream of the geophone plates.

**Results:** The results so far show a clear dependence of sediment transport on hydrological conditions, which in turn are strongly influenced by glacier retreat. As glaciers retreat, the sources and amounts of sediment change. While in other catchments increased sediment release from formerly glaciated areas was observed in the early years after deglaciation, there are now signs that sediment flows are stabilizing [7]. This is still under investigation for the Rofenache catchment area. The measurements also show that extreme weather events, such as heavy rainfall or intense snowmelt, play a crucial role in sediment transport and strongly characterize interannual variability.

**Discussion:** The results highlight the complex relationships between glacier retreat, hydrological changes and sediment dynamics in high alpine catchments. Glacier retreat not only changes the availability of sediment sources, but also influences transport pathways and processes [3]. These changes have far-reaching consequences for the management of alpine water resources, the ecological stability of rivers and the infrastructure in the affected regions. Future studies should focus on modelling long-term developments in order to develop scenarios for the sediment budget under different climate projections.

The authors gratefully acknowledge the funding provided by the Austrian Research Promotion Agency (FFG) for the FRAGILE project under the Austrian Climate Research Program (ACRP) and the Tyrolian Hydrological Service.

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# Glacio-fluvial sediment connectivity: A catchment-scale perspective in a rapidly retreating glaciated area in the Austrian Alps.

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**Conference theme number(s): 2**

**Introduction:** What will be the consequences to high alpine rivers if glaciers disappear and the Alps become almost ice-free? The scientific community widely acknowledges that the ice-free Alps are a likely scenario by the end of the century [1,2]. This ongoing transformation prompts the question: How formerly glaciated catchments will influence high-alpine glacio-fluvial processes, downstream sediment yields, and sedimentological conditions?

Sediment is transported through a catchment via various processes, passing through different compartments of the sediment cascade in a glaciated catchment. Each subsystem of the sediment cascade can act as a (temporal) sediment sink or sediment source [3,4]. The catchment (dis)connectivity between subsystems is highly dynamic and crucial whether sediment reaches the glacio-fluvial system [3] and is thus one decisive parameter for transport-limited or supply-limited conditions at reach scale [4]. Controlling factors for the subsystem connectivity are, e.g., geology, slope angle, confinement, sediment texture, grain size, vegetation, or magnitude-frequency flows [5].

The study aims to outline, from the glacio-fluvial perspective, the (i) sediment connectivity and sediment supply throughout the catchment of the *Rofenache River* and (ii) longitudinal, lateral, and vertical (dis)connection at the reach scale. The study site is located in the Austrian Alps (Fig. 1), characterized by a high relief (1889 – 3763 m a.s.l.) and continuous glacier retreat since the end of the Little Ice Age (LIA) around 1850 – totaling $\Delta A_G$= 34.5 km² [6] – with yearly ablation records in the recent decade [7].

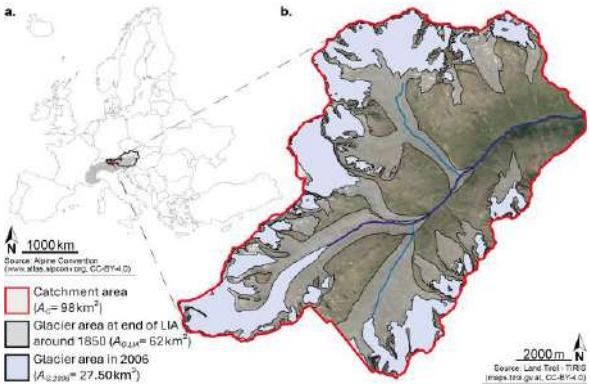


**Fig. 1: (a.)** Location of the study area in Europe and the eastern Alps in Austria; **(b.)** catchment area illustrating the glacier loss since LIA around 1850 [6].

**Methods:** The study area is defined by (i) LIA glacier margins and (ii) active bedload-bearing tributaries. The data used to detect (dis)connections within this spatial boundary were obtained by (i) multitemporal, multispectral aerial surveys using a UAV (DJI Mavic 3M) at different flight levels and (ii) documentation of granulometric data on the sediment along the proglacial rivers. High-resolution digital terrain models and orthomosaics were generated from the survey data. The characterization of the catchment area was done by (i) geodata analysis and (ii) hydraulic modeling. This combined approach allows a detailed connectivity analysis, mapping the (partly disconnected) sediment supply chain within the catchment, and identifying erosion and deposition zones in the reach scale.

**Results:** Within the studied catchment, hierarchical levels of subsystems were identified. The primary sediment load of the main proglacial river *Rofenache* is supplied by various tributaries. Each tributary subsystem is further divided into several proglacial sub-subsystems, predominantly characterized by a large quantity of glacially deposited sediment. The detailed sediment connectivity analysis revealed (temporal) sediment storages across different landform types in all spatial directions (lateral, longitudinal, and vertical).

**Discussion:** The study findings indicate that glacio-fluvial sediment connectivity and reworking is highly affected by time-varying controlling parameters, driving the recurring shifts between supply-limited and transport-limited conditions at the reach scale. Glacier retreat enhances sediment connectivity within a catchment in several ways [8]. However, the downstream sediment yield is primarily determined by the (subsystem) connection to the proglacial river system.

The authors thank The Austrian Research Promotion Agency (FFG) for funding the project FRAGILE and acknowledge the project partner *GeoSphere Austria*.

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# Urslau case study: A comparison of transport equations with long-term monitored bedload data

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**Conference theme number(s): 2**

**Introduction:**
The need for natural measurement data on bedload transport is crucial for implementing sustainable engineering measures and improving process understanding. Measured data are indispensable for the validation and calibration of transport formulas. This study is based on a long-term bedload data set from an alpine stream and offers valuable insights for analyzing bedload transport process and comparing it with commonly used transport equations.

**Study Site:**
The Urslau stream is situated in the province of Salzburg, within the alpine region of Austria. In 2011, an integrative bedload monitoring station was installed. The upstream catchment area covers 56 km², stream width is 8m and bed slope is 0.021.

**Methods:**
The integrative bedload monitoring station combines direct and surrogate measuring devices and therefore compensates for shortcomings and limitations of individual methods [1]. It enables a continuous and holistic monitoring of the process. Direct measurements are performed at the measuring site using a slot sampler (Birkbeck type) and an adapted mobile net sampler. Seven plate geophones are distributed across the stream cross-section, which have been continuously recording the transport process since 2011. The geophones are calibrated by correlating the results of the direct measurements and the geophone impulses [2, 3]. Fig.1 shows a basket sampler measurement at the measuring site.

**Results:**
In contrast to single-point measurements, a long-term, continuous, and integrative bedload dataset captures a broad spectrum of bedload transport characteristics (e.g., temporal variability, sediment availability, bedforms, the influence of previous flow events, fluctuations in sediment availability) in gravel-bed streams. This article deals with the comparison of this integrative measured data with commonly used transport equations. A key aspect of this evaluation is the classification of bedload transport events into different event types, which are linked to sediment availability [2, 3].
Fig 1 b presents exemplary for the results of this study measured versus calculated (using the Meyer-Peter Müller formula) bedload volume of events. The volumes of large, extraordinary events, which are associated with high sediment availability, are better described than those of ordinary events.

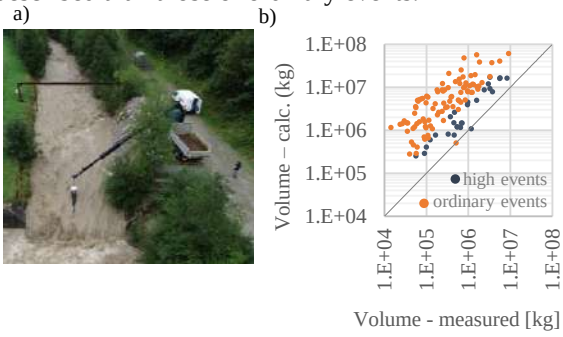


**Fig. 1:** *a) basket sampler measurement at the study site, b) Calculated vs. measured volumes*

**Discussion:**
The use of bedload transport formulas is crucial in practice, but recent research has raised questions about their reliability, given the highly variable and complex nature of the bedload transport process. The benefit of the current study is the availability of a long-term integrative bedload data set at a steep downstream section of a mountain stream. The study suggests that, depending on the specific question and the choice of the appropriate formula, improved calculation results for practical applications can be achieved.

**Acknowledgments:**
The authors thank the Austrian Federal Ministry of Agriculture, Forestry, Regions, and Water Management and the Department of Torrent and Avalanche Control in Salzburg for funding and supporting this study

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# Exploring the role of sediment availability in the morphological response during floods: the case of the Tenetra stream (Marche, Italy)

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**Conference theme number(s): 2**

**Introduction and goal:** Predicting geomorphic changes in rivers after floods remains a significant scientific challenge due to the complex interplay of hydrodynamic forces, sediment supply, and sediment availability. These factors play a crucial role in determining how rivers respond to extreme events, including channel morphology, sediment transport, and deposition patterns. Exploring these aspects is the primary objective of this study. Effective sediment control and management are increasingly recognized as critical to promoting the sustainable use of natural resources and mitigating environmental impacts.

**Study site:**
On 15-16 September 2022, the Marche region experienced an exceptional meteorological event, with localized rainfall reaching 419 mm in twelve hours—a record intensity over the past decades. This huge amount of rain water was derived by a self-regenerating storm system and led to the overflow of watercourses and widespread flooding, with peak rainfall intensities of up to 90 mm/h [1]. In the municipal territory of Cantiano, one of the most severely affected areas, intense soil erosion led to the mobilization of substantial amounts of mud and debris, exacerbating damage to built-up areas. The research focuses on a sub-basin of the Burano River, which experienced profound morphological changes due to the mobilization of coarse sediments during the event. This study seeks to advance understanding of these processes to improve predictive models and inform sustainable river management practices.

**Methods:** The Iber model [2], a two-dimensional numerical tool designed for simulating free surface flow in rivers, is employed to investigate erosion and deposition processes in Tenetra Creek. Iber solves the full depth-averaged shallow water equations to compute water depth and velocity. These equations are resolved using an unstructured finite volume solver explicit in time. The sediment transport module within Iber is used to model bedload transport, applying the Meyer-Peter and Müller equation [3]. Rainfall and topographic data were incorporated to refine the simulations, capturing critical aspects such as flow velocity, depth, critical shear stress, and erosion potential. Peak flow conditions were defined based on hydrodynamic modelling scenarios, with maximum discharge values derived from rainfall data during the considered event.
The model used a sediment inlet with bedload capacity, to dynamically calculate sediment inflow, ensuring sediment transport was based on the flow's capacity to mobilize material rather than imposing arbitrary quantities. The transport capacity was determined using hydraulic parameters such as velocity, shear stress, and sediment grain size, employing a combination of theoretical models and empirical equations. Multiple scenarios were developed to analyse the river's response to erosion and sedimentation processes responsible for morphological changes in the riverbed. The modelling incorporated various (d_{50}) values to explore the dynamics governing the coarse sediments' transport and better understand the underlying mechanisms driving these changes.

**Results:** The results of the above-mentioned applied methods are expected to provide critical insights into the role of sediment availability and its influence on morphological changes during flood events, not only in the studied river but also in analogous fluvial systems. This enhanced understanding will contribute to developing more effective flood management and river restoration strategies, aiding in designing of sustainable measures to mitigate flood impacts and improving sediment management practices across similar geomorphic contexts.

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# Analysis of sediment transport in Ebro Delta channels to optimise the irrigation network efficiency in diverting sediment to vulnerable areas.

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**Conference theme: Healthy Sediments**
**14th International SedNet Conference 6–10 October 2025, Madrid, Spain**

**Introduction:** The Ebro Delta is one of the most valuable delta systems in the Mediterranean, where a Ramsar protected wetland coexists with an extensive rice production area supported by a complex network of irrigation canals. Sediment supply to the delta has drastically declined in recent decades due to sediment trapping within the upstream reservoirs system of Mequinensa, Riba-Roja, and Flix. The sediment deficit, combined with natural land subsidence and accelerated coastal erosion driven by climate change, poses a significant threat to the delta's land availability. In response, the Confederación Hidrográfica del Ebro is exploring a pilot project in the Riba-Roja reservoir to develop a bypass system that would release trapped sediments and restore their transport to the delta. However, this approach may lead to increased sediment loads in the irrigation network, potentially causing sediments to accumulate in the channels rather than being effectively distributed across the delta. This project aims to analyse the sediment transport capacity of the irrigation canals and optimize the network's operation to direct sediment toward areas most vulnerable to land subsidence and coastal impacts.

**Methods:** Using a numerical model of the irrigation network, the Consortium will analyse the transport of fine sediment under different hydraulic conditions, sediment concentrations and particle sizes to estimate the sediment volumes reaching vulnerable areas. By simulating the scenario of the Riba-Roja bypass system, the project aims to evaluate its potential to mitigate land loss in the Delta. Finally, the study will assess the operational feasibility of the irrigation network under these conditions and propose management strategies to direct sediment to the most vulnerable areas.

The methodology uses a coupled 1D hydraulic and sediment transport model applied to various irrigation channel scales with different section geometries and discharge ranges, all within a unified simulation domain. The IBER tool's 1D urban drainage module is adapted for open channel flow with variable hydraulic conditions and depth-averaged convection-diffusion sediment transport. Calibration involves a field campaign measuring hydraulic variables (flow velocity and depth) and conducting sediment injection tests with different particle sizes.

Calibration of the model will be carried out through a field campaign where hydraulic variables (flow velocity and depth) and suspension matter, including suspended sediment, will be measured. These experiments determine the appropriate sediment transport formula for the model (between Ariathurai, Ariathurai-López, Smith-McClean, or van Rijn), calibrate the channel roughness coefficient, and validate model performance in various flow and concentration scenarios, which are also field-tested.

**Results:** After model validation, scenarios of channel discharge, sediment concentration, and particle size are simulated to generate transport efficiency curves (relationship between flow conditions and sediment particle diameter) for each channel typology. The expected results include defining particle size thresholds for transport and deposition, estimating sediment volumes reaching vulnerable areas, and identifying sediment-prone locations within the irrigation network.

**Discussion:** In collaboration with the Ebro Delta farmer-irrigation communities, this project will provide a user-friendly modelling tool to optimize channels operations and reduce sediment-related maintenance costs. Using numerical methods validated by field experiments, the study will evaluate whether the irrigation network can enhance resilience by directing sediment to areas vulnerable to land subsidence and climate-driven sea impacts.

**Acknowledgements:** This study is commissioned by the Catalan Agency of Water (Agència Catalana de l'Aigua - ACA) and funded by the Next Generation EU initiative. The project is part of the environmental restoration efforts of the Ebro River and its Delta, aligned with Investment 2 of Component 5 of the Spanish Government's Restoration, Transformation, and Resilience Plan. It contributes to achieving the objectives outlined in the CID 77 milestone, 'Restoration of Riverbed and Bank Protection against Flood Risks.

# Sediment Transport and Metal Dynamics in an Acid Mine Drainage-Affected Estuary: Insights from the Ria of Huelva

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**Conference theme number(s): Theme II Sediment Flow**

**Introduction:** The Ria of Huelva estuary is a severely Acid mine drainage (AMD)-affected system, which receives the inputs of two strongly metal polluted rivers, the Odiel and Tinto, which drain the Iberian Pyrite Belt (SW Spain). Consequently, enormous concentrations of potentially toxic elements (PTE) are transported to the estuary and through it to the Atlantic Ocean. Although the mixing of waters in estuaries results in the presence of a salt wedge and a progressive decrease in salinity inland, the Ria of Huelva also experiences a water pH gradient, ranging from acidic values (2.5 to 3.5) to alkaline values typical of the seawater. As a result, the sediment of the estuary of Huelva, which reflect the polluted river discharges, have been classified as one of the most metal polluted estuaries worldwide [1].

**Methods:** Water and sediment samplings have been conducted under different hydrological conditions (e.g., during rainfall-induced flooding event, before and after the summer period) and along the estuary to reflect the sharp hydrochemical gradients. Filtered and unfiltered water samples has been collected for the study of dissolved and total contaminants concentrations. Whereas surface sediments have been sampled at tidally influenced sites using PVC tubes, separated in different aliquots, frozen at -80 °C in sterile plastic bags and freeze-dried (Telstar LyoQuest, -40 °C and 0.2 mbar of pressure) before acid digestion. Trace elements concentrations have been determined by iCAP TQ ICP-MS (Thermo Scientific ®) at the AETE-ISO Platform (OSU OREME, Université de Montpellier).

**Table 1.** Metals and metalloid concentrations of reference for water and sediments and measured concentrations.

| (*) Surface Water | | Tinto-Odiel Rivers Water average | Sediments (mg/kg) | | | Tinto-Odiel estuary |
|---|---|---|---|---|---|---|
| Element | (µg/L) | | ERL[a] | ERM[b] | (**)Nature concentration | |
| As | 25 | > 70 | 8.2 | 70 | 10 | 2900 |
| Cd | 0.2 | 30 | 1.2 | 9.6 | 0.18 | 5 |
| Cr | 5 (Cr(V)) | 5 | 81 | 370 | 30 | 106 |
| Cu | 25 | > 5 000 | 34 | 270 | 14 | 2400 |
| Ni | 20 | > 200 | 20.9 | 51.6 | 19 | 56 |
| Pb | 7.2 | > 75 | 46.7 | 218 | 23 | 1800 |
| Zn | 60 | > 2 000 | 150 | 410 | 60 | 3500 |
| Fe | - | 1 000 -15 000 | - | - | 66 300 | 144 000 |
| Al | - | > 10 000 | - | - | 170 000 | 70 000 |

*Environmental Quality Standards expressed as an annual average value (NCA-MA)

(**)Concentration ranges of heavy metals in coastal marine sediments free of anthropogenic influence (CEDEX 2021)

[a]ERL (effects range-low): represents **values below which biological effects are**

[b]ERM (effects range-median):represents values above which biological effects are

**Results:** Contaminants transported from mining areas exhibit different behaviors in the estuary: non-conservative elements, mainly Fe, Al, and Cu, are removed from the water through mineral precipitation during the neutralization of AMD. In other words, they tend to become part of the particulate matter that deposits in the bottom sediments. On the other hand, conservative elements like Zn, Mn, Ni, and Co remain in solution throughout the estuary, reaching the Atlantic Ocean. Finally, elements with an ON-OFF behavior, mainly arsenic, are initially retained through processes of adsorption or mineral coprecipitation (OFF) and later released back to the water column (ON), also reaching the ocean along with conservative elements. Sediments from the study site turn out to be highly polluted with PTE concentrations surpassing Spanish guidelines and international sediment quality guidelines, especially for As (300 – 1300 mg/kg), Cu (300 – 3500 mg/kg) and to a lesser extent Zn (100 – 1400 mg/kg) and Cd (0.2 – 5.8 mg/kg) (Table 1).

**Discussion:** Environmental impact associated with mining-affected water discharges as well as industrial activities are the major threats for the degradation of the high ecological value of the estuarine/coastal system of the Ria of Huelva, which include several environmental protected areas (e.g., Biosphere Reserve and RAMSAR site Paraje Natural Marismas del Odiel, Natural Reserves Marismas El Burro and Isla de Enmedio and Special Areas of Conservation (SACs) Marismas y Riberas del Río Tinto and Estuario del Río Tinto.

Acknowledgements: MD Basallote thanks the Spanish State Research Agency (AEI) for the 410 RYC2022-035326-I grant funded by MICIU/AEI /10.13039/501100011033 and FSE+.

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# Wet season sediment plume distribution across northern Australia; primary productivity and climate change.

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**Conference theme number(s): 2**

**Introduction:** Northern Australia is home to some of the world's most expansive and ecologically significant river systems. These river catchments, which drain into the Gulf of Carpentaria and the Timor Sea, deliver sediments and nutrients that are vital to both the health of the region's coastal ecosystems and its commercial fisheries[1]. This study investigates the relationship between wet season river flows, sediment plume extent, and primary productivity in adjacent coastal seas, with a focus on understanding potential impacts from climate change and water extraction on these dynamics.

**Methods:** Hydrological data from 2003 to 2023 was analysed for the Flinders, Gilbert, and Daly Rivers to determine peak wet season flow events and the corresponding sediment plume extent using MODIS satellite imagery. Primary productivity following each event was determined using ocean colour algorithms. Future plume extent under climate change anomalies was determined from ensemble climate projections.


**Fig. 1:** Sediment plume in the Gulf of Carpentaria, northern Australia, following a peak wet season flood event.

**Results:** The study found that flood plumes were highly variable across the 20-year period, with significant events recorded in 2019 and 2023 and strong relationships between 7-day river flows and plume extents for all rivers.
Primary productivity, measured through chlorophyll-a concentration, was significantly associated with plume size in the southern Gulf of Carpentaria and Anson Bay, specifically for tertiary plumes from the Flinders, Gilbert, and Daly Rivers. Future climate projections indicate potential reductions in rainfall by 2070-2099, which could lead to decreases in flood plume extent and associated primary productivity.

**Discussion:** This research highlights the critical connection between river flows, coastal flood plumes, and marine productivity in northern Australia. The findings underscore the importance of maintaining environmental water flows to sustain coastal ecosystems and fisheries, particularly in the context of increasing water allocation pressures and the potential impacts of climate change on regional rainfall patterns.

**References:** [1] Burford, M. A., & Faggotter, S. J. (2021). Comparing the importance of freshwater flows driving primary production in three tropical estuaries. *Marine Pollution Bulletin*, *169*, 112565.

**Please submit your abstract before the 29th of November 2024 to the SedNet secretariat: secretariat@sednet.org.**

# Sustainable navigation in Malamocco-Marghera navigation channel (Venice Lagoon)

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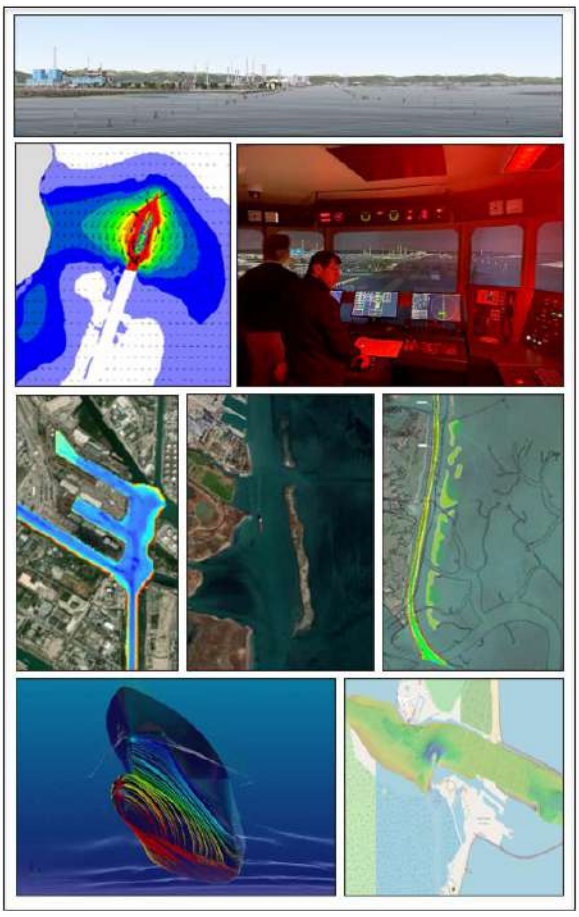
**Conference theme number(s): 3**

A thorough and multi-disciplinary study has identified sustainable solutions to enhance navigation capacity along the Malamocco-Marghera Channel, in the Venice Lagoon, at the same time mitigating the erosion processes affecting the tidal flats surrounding the Channel, thus guaranteeing safe navigation conditions. Moreover, seeking synergies between port sustainability and mitigation of human and climate change impacts on endangered habitats is part of the challenge.

The study activities have been carried out within the "Channeling the Green Deal for Venice", a CEF European funded project that tackles the limited nautical accessibility of the port of Venice, fully respecting the environment and the UNESCO protected site of the Venice Lagoon. Following Public Tender procedures, Port of Venice awarded the study to a Consortium led by DHI S.r.l. and formed by DHI A/S, Force Technology, HS Marine S.r.l., Cetena S.p.a. and Around Water S.r.l..

To achieve the ambitious goal, a complex and structured combination of navigation and hydrodynamic/ sediment transport models have been planned and implemented. For the first time hydrodynamics, real time navigation and morphological models mutually interact to identify the best solutions.

The development of the design solutions moves within a series of needs and constraints of different nature: functional, environmental and economic, and involves alternating phases of study and analysis of the results with phases of confrontation with the Port Community. The most critical phenomenology, i.e. the displacement wave induced by passing vessels, is in fact directly linked to the dimensional relationship between the section of the Channel, the submerged hull of the ship and the speed with respect to the water. The first step aimed at defining the proper study of the geometry of the Channel suitable for ensuring the safety of navigation; consequently, the 3D hydrodynamic simulations have been replicated, with special focus on the displacement wave and its potential impact on the morphological response of the tidal flats around the Channel. After proper quantification of the local bed shear stresses in the various areas of interest, both large scale and local design solutions aiming at preventing the erosion of the tidal flats and Channel banks have been identified. The result is complete framework of solutions, both infrastructural and management-led, that balance environmental and port performance needs.



# Transforming Sediments into A Sustainable Material for Blocks Production

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**Conference theme number(s): Theme 3**

**Introduction:** The construction industry faces increasing pressure to adopt sustainable practices that minimize environmental impacts and reduce reliance on non-renewable resources. Sediments, often regarded as waste or a by-product of dredging activities, present a unique opportunity for reuse in infrastructure applications.
This study explores the potential of transforming sediments into durable pavement stones through the patented GEOWALL compression technique. By utilizing sediments as a primary raw material, this approach addresses two key challenges: managing excess sediment sustainably and reducing the demand for traditional paving materials.
The research focuses on optimizing the compression process, evaluating the mechanical properties and the durability of the resulting stones, and comparing their performance with conventional alternatives. This innovative use of sediments demonstrates their viability as a sustainable construction material while supporting circular economy objectives. These stones can be used for various applications such as pavement stones, artificial reefs, sound barriers, dyke reinforcement …

**Methods:** Sediments were collected, and tested for their chemical and physical characteristics. The results were then analyzed to check whether they were contaminated or not and to optimize the particle size distribution.
The sediment content was maximized, typically using more than 50% of the total material mass in order to emphasize sustainable reuse.
Optimization of Moisture Content:
Tests are conducted to ensure that optimum moisture content is determined through preliminary testing to achieve the best workability and compaction results.
Particle Packing and Mix Design:
Particle packing was optimized using a custom-developed model based on hundreds of data points collected from the NETICS database. This model ensured an efficient distribution of particles, improving block density and strength.

Binder Selection and Incorporation:
For each application and sediment type, binders are selected to meet environmental. strength and durability requirements, balancing performance with sustainability.
Block Production:
The mixture was compacted under controlled pressure to form blocks, ensuring high density. The patented GeoWall press is used with compression from two sides. Fibers could be added to improve the flexural strength.
Testing and Validation:
Produced blocks were tested against the required standards for the specific, including compressive and flexural strengths, durability, erosion, and water absorption, to ensure compliance with industry requirements.

**Applications:**

**Fig. 1:** Different application of the blocs (from left to right: artificial reefs, pavement stones, dyke revetment, sound barrier)

**Discussion:** This methodology emphasizes optimizing sediment use, advanced particle packing, and the incorporation of fibers and effective binders, providing a framework for creating sustainable and high-performance stones. NETICS is working on creating a more commercialized approach and process of making blocks with a higher TRL level while upscaling aspects like production rates but also shapes and the possibility of creating openings.

# Sustainable reuse of posidonia oceanica fibers and dredged marine sediments for lightweight and eco-friendly mortars

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**Conference theme number: 3. Nature Based Solutions**

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**Introduction:** Marine sediments and *Posidonia oceanica* (PO) present significant environmental challenges that must be evaluated and managed. Dredging marine sediments is necessary to maintain navigable waterways and requires sustainable management to minimize ecological impacts. Similarly, PO, a key Mediterranean seagrass, bioindicator of water quality, shows specific challenges: during colder months, decaying PO accumulates along shorelines due to adverse weather, requiring effective management strategies. Balancing ecological preservation with economic and environmental needs is crucial to addressing these issues. Several studies have demonstrated that the addition of PO fibers to concrete mixes positively affects properties such as thermal conductivity and mechanical strengths. [1] At the same time, marine dredged sediments have shown potential for concrete development due to their mineralogical and chemical properties. [2] This study investigates the reuse of PO fibers and dredged marine sediments in cement mortars, evaluating their workability and mechanical performances to promote sustainable practices through the reuse of marine waste.

**Methods:** The mixes were based on cement, water, sand, PO fibers, and dredged marine sediment, used with different percentages. The cement used for the mortar samples was CEM II A-LL 42.5 R, a type II Portland cement characterized by very high normalized strength and high initial strength. The sediments, dredged from the port basin of Mola di Bari, were sandy, with a representative particle diameter of 0.35 mm; these were used in substitution of the sand in different proportions (1:3, 1:1, 3:1). The sand was a conventional silica sand with a diameter of 0.8 to 1.2 mm. The PO collected from the shores of Mola di Bari had a grain size between 2 mm and 0.063 mm, representative of the sand class, with an average particle size of 0.57 mm. Different PO fiber weight fractions (2.5% to 7.5% with respect to sand weight) were used. The water-to-cement ratio for all mixes was 0.5. Fresh properties were investigated by the flow test, which allowed to detect the workability of the samples. After 28 days of curing under conventional conditions, the uniaxial compressive and flexural strengths of the specimens were evaluated.

**Results:** The experimental investigation yielded good results for both workability and mechanical strength tests. The flow test showed promising outcomes: as the percentage of sediment and PO increased, workability decreased. Notably, mixes with 2.5% PO demonstrated workability comparable to that of traditional sand-based mortar. As PO content increased, specimen density decreased, leading to lower mechanical strengths. However, the compressive and flexural strength tests revealed satisfactory results for all mixes (2.5%, 5%, and 7.5% PO fiber content with respect to sand weight). While mechanical strengths decreased by approximately 50% compared to a traditional mortar, with a result of approximately 25 MPa, the highest strengths were observed in mixtures with 2.5% PO, reaching a value of 30 MPa. Failure modes became increasingly ductile as PO content increased.

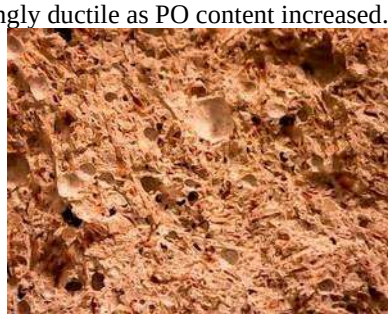

*Fig. 1 - Broken specimen, optical microscope*

**Discussion:** The addition of PO fibers and dredged marine sediments affected both the fresh-state properties and the 28-day mechanical properties of the mortars. These findings are significant, as the workability and mechanical strengths of the composite mortars are comparable to standard mortars, with additional benefits such as reduced weight and increased ductility, which traditional mortars do not offer. Further experimental research will focus on extended curing times, exploring new mixes composition, and evaluating thermal properties.

**References:** [1] Benjeddou et al. (2022) *Effect of Posidonia oceanica Fibers Addition on the Thermal and Acoustic Properties of Cement Paste*;
[2] Chuet al. (2020) *A strength model for concrete made with marine dredged sediment*.

# Valorization of Dredged Materials as Sustainable Construction Resources: An Overview

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**Conference theme number(s): 3- Nature Based Solution**

**Introduction:**
Globally, each year, an enormous quantity of dredged materials (DMs) is generated for the maintenance of navigable activities including harbors, rivers, and reservoirs. In recent years, DMs disposal on-land has increased due to the evolution of the regulations that eliminated the disposal in the oceans. The management of those materials has become a serious problem. On the other hand, the construction industry knew an important increase and request for raw materials to produce concrete and its derivatives. As a sustainable solution for this issue, several research studies attempted to recycle DMs in the field of civil engineering. Interest in DMs as construction materials has increased as noticeable from the large amount of published literature. This work presents a literature review on the reuse of DMs as sustainable construction resource (295 literatures) and constitutes a practical guide for the seeker of valorizing DMs. The findings presents: (i) a detailed state-of-the-art-review based on the published papers; (ii) Overview on recycling DMs in a non-structural application such as road construction, functional soil, and ceramics; (iii) Overview on recycling DMs as filler and aggregates including fine aggregates and artificial lightweight aggregates; (iv) Overview on the valorization of DMs as cementitious resource i.e., supplementary cementitious materials, binder for geopolymer, and a raw material for clinker production; (v) Overview on the industrial chairs and projects on valorizing DMs. The review revealed that extensive research works have been done on valorizing those materials in different civil engineering sub-fields. Encouraging findings on the different remediation pathways were reported. However, absence of in-depth research for large-scale application and long-term durability were noticed, as well as the absence of life cycle assessment on DMs as construction materials. However, despite the variability of DMs worldwide, the presence of metallic and metalloids trace elements, chemical instability, and most of the cases, DMs need to be treated before direct use, and even when DMs are not totally inert, the end-products are always under the required environmental limits. The evaluation of the vast experimental research showed that DMs are qualified to be considered as construction material resources. The recycling of those materials will decrease the natural resources consumption in the civil engineering field alongside resolving their environmental problems.

**Keywords:** Dredged Materials; Recycling; Review; Sustainability; Valorization; Waste Management.

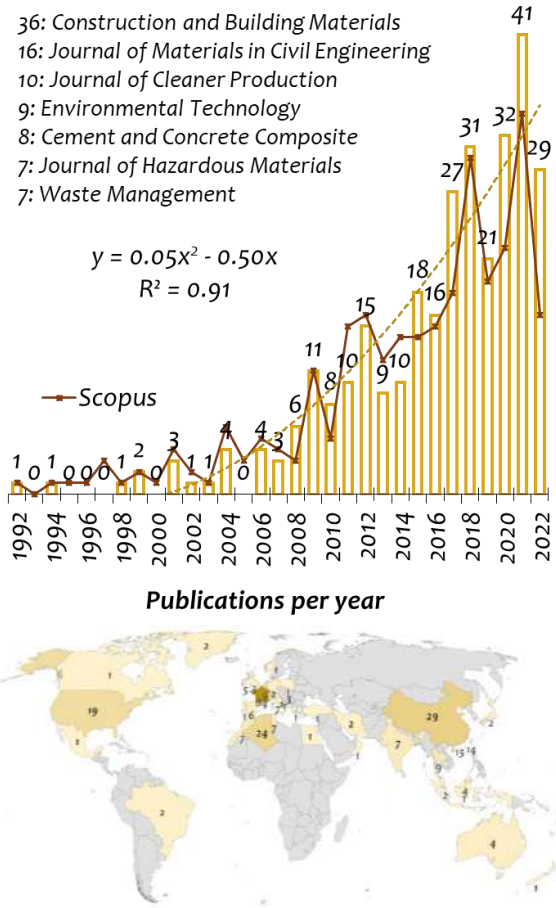


**Fig. 1:** Studies on recycling DMs in civil engineering: publications per year, and per the origin of the studied sediments.

**References:**
Safhi A. (2023), Valorization of dredged sediments as sustainable construction resource, CRC Press, ISBN 9781003315551

# Enhancing Dike Safety with Ripened Dredged Sediment

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**Conference theme number(s): 3**

**Introduction:** The use of ripened sediment in dike reinforcement is an innovative approach addressing both water safety and environmental sustainability. Furthermore, it represents an opportunity to support the transition to a circular economy (CE) in the construction of flood defenses. The ripening process, including dewatering and other physical and biochemical processes, makes it suitable for use in critical infrastructure like dikes. This presentation, which is part of the *Rivierwerken* (River Works) research [1], explores key projects that demonstrate the benefits and challenges of incorporating ripened sediment in dike reinforcement.

**Recent projects in the Netherlands:** The Brede Groene Dijk (BGD, Wide Green Dike) project explores how water safety, ecological improvements in the Ems estuary, and CE principles can be integrated. Unlike traditional dike reinforcement, which typically uses hard materials, the BGD employs a gently sloping, green embankment, allowing for a more natural transition between the existing salt marsh and the dike. This innovative design requires a substantial amount of material. For the 750-meter stretch of the dike, 70,000 m³ of dredged sediment was used, sourced from the Ems-Dollard estuary. The material was ripened into clay in a deposit (Kleirijperij project) before application in dike strengthening.

The concept of the Meegroeidijk [3] (MGD, Growing Dike) is based on the natural geological process where deltas grow over time through the gradual deposition of sediments by rivers and the sea. Inspired by this process, the MGD project aims to use locally dredged sediment to strengthen dikes incrementally. The dredged sediment is directly placed on the dike, where it ripens.

**Older projects worldwide**: The reuse of dredged material for dike reinforcement has been tested in various projects worldwide. EcoShape (2020, [3]) provides a comprehensive inventory of past projects. Notable examples include:

- Afsluiting Lauwerszee (1970, Netherlands): Dredged material was used as a covering material for the dike after it had ripened on the dike itself, with grass planted afterward.
- Wijdewormerringdijk (Netherlands): Area-specific sediment was used to reinforce the inner slope of a dike along a polder, which was drained in the 17th century.
- Garmerwolde (2015-2018, Netherlands): Sediment and sand were used to raise the dike along the northern side of the Eemskanaal.
- Rostock (2010-2015, Germany): A test dike was built to assess the behavior of ripened dredged material in dike construction, part of the EU project DredgDikes.
- Bremerhaven (Germany): A 900-meter-long dike was reinforced using dredged material from the harbor, replacing the original sand core with the dredged material.

The application of ripened sediment has also been tested in other international locations, including Gdansk (Poland), Antwerp (Belgium), Avilés (Spain), and Harwich (UK), showing the broad applicability of this technique.

**Conclusion:** Using ripened sediment for dike reinforcement is a sustainable solution. By transforming dredged sediments into high-quality construction materials, projects like BGD and MGD demonstrate the potential of CE approaches in flood protection. This method reduces the need for material transport and disposal while offering an eco-friendly way to strengthen dikes against rising sea levels and increasing extreme events. In addition to increasing dike height and strength to cope against extreme highwater, the sediment helps mitigate drying during extreme dry periods. Combining sediment recycling with dike maintenance also helps lower greenhouse gas emissions, creates job opportunities, and offers significant cost savings.

**References:** [1] Barciela- Rial & McLeod (2023). Report., [2] Gamberoni et al. (2024). Land+ Water, [3] EcoShape (2020). Report.

# Open field ripening reduces shrinkage and increases compactibility of dredged sediment

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**Introduction**:
Increase of sea level and land subsidence necessitate heightening and strengthening of dikes and embankments, creating large material demands. On the other hand, maintenance of fairways, harbor basins, sluices, barrages and water reservoirs generate large volumes of dredged sediment. Physical and biogeochemical properties of freshly dredged, saturated sediment differ significantly from those of ripened, unsaturated soil. Beneficial use of sediment as earthen construction material therefore requires dewatering and further biogeochemical and physical ripening. If repurposed for dike construction, particularly the shrinkage potential of the material and hence its susceptibility to crack formation is of interest. Further, compactibility of the material determines key mechanical properties such as shear and tensile strength. Here, we investigate the effect of field ripening of partially dewatered dredged sediment (METHA material) on these parameters.

**Methods:** In December 2022, Elbe sediment partially dewatered in the METHA plant (Hamburg, Germany) using high intensity (HIP) and multi-compartment filter (MKFP) presses was deposited into 9 stockpiles of 1,000-2,200 $m^3$, which were managed differently in terms of turning frequency (0, 2 and 4 times per year). Shrinkage, tensile strength, and compactibility were investigated over a 2-year period using the Coefficient of Linear Extensibility COLE[1], the Brazilian Splitting Test [2] and the Standard Proctor Test [3].

**Results**: The original, not yet ripened material (high-intensity press, HIP), showed the lowest Proctor density and the highest optimum water content, which increased (density) and decreased (opt. water content) with continued field ripening, also without stockpile turning (Fig. 1, top left). Turning, and hence enhanced exposure to air, increased compactibility, with turning four times yielding a greater effect than turning twice annually (Fig. 1, top right, and bottom). Field ripening strongly reduced the material's shrinkage potential, also found previously for laboratory-ripened material [4]. The greatest effect was seen after the first summer period (Fig. 2, cp. Mar and Nov 2023). In contrast to compactibility, shrinkage potential was not sensitive to stockpile management with no difference detected between the control (SP2, 4) and other stockpiles.

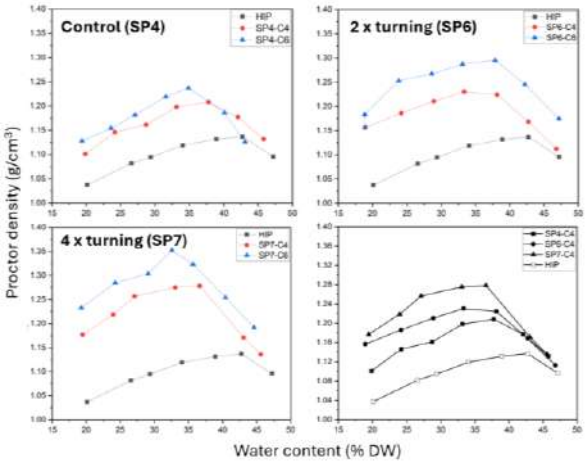


**Fig. 1:** Proctor curve in relation to time and stockpile turning frequency. C4 = Sept 2023, C6 = March 2024.

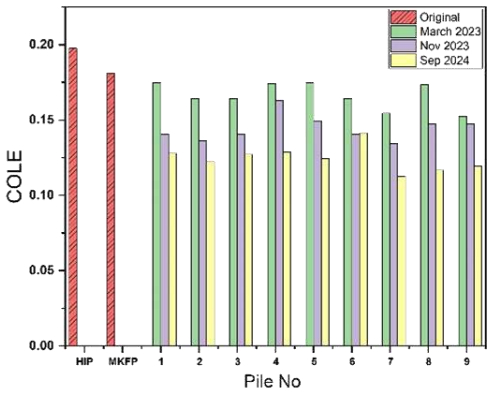


**Fig. 2:** Shrinkage potential (COLE) over time for original material (red) and 9 stockpiles.

**Conclusions**: Field ripening increases compactibility and reduces shrinkage and significantly enhances geotechnical properties of dewatered sediment for use in earthen constructions.

**References:** [1] Schafer & Singer (1976), https://doi.org/10.2136/sssaj1976.03615995004000050050x; [2] Akin & Likos (2017): https://doi.org/10.1520/GTJ20160180; [3] ASTM (2021), https://doi.org/10.1520/D0698-12R21; [4] Oing et al. (2019), https://doi.org/10.1007/s11368-019-02384-6

# Rheology and settling processes of mud for defining critical limits for navigability in the Port of Felixstowe

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**Conference theme number(s): 3**

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**Introduction:** The UK's largest container port at Felixstowe, faces significant sedimentation challenges, with approximately 2.4 million m³ of sediment requiring management annually [1]. To optimize maintenance strategies and enhance navigability, Harwich Haven Authority is exploring the implementation of PIANC's nautical bottom concept [2], which relies on understanding the rheological and settling behaviour of muddy bed in the port.

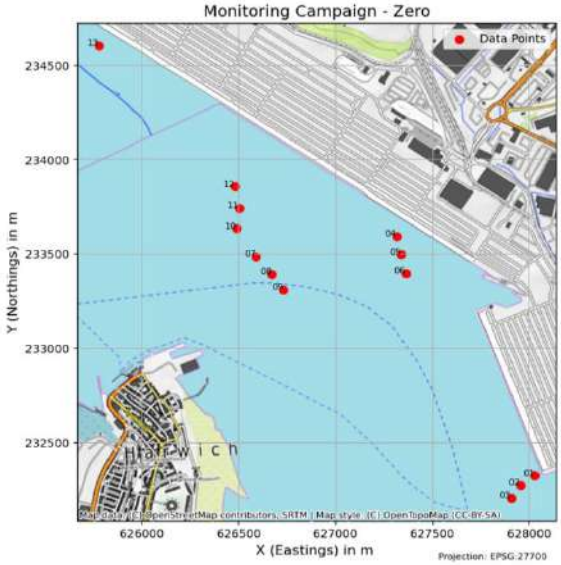


**Fig. 1:** Sampling and surveying locations at the Port of Felixstowe.

This study examines the shear strength (yield stress) evolution of soft mud layers by investigating their physical properties (e.g., density, organic matter, salinity, etc.), rheological behaviour such as yield stresses and thixotropy, and how these properties develop over time. By linking these temporal changes due to sediment settling and consolidation processes, the research aims to identify critical thresholds for navigability.

**Methods:** In this study, the analysis of both in-situ measurements and laboratory characterization on sediment samples was carried out. Sediment core samples were collected in the Port of Felixstowe using one-meter core sampler (the Frahmlot). The samples were subsampled into suspended particulate matter, fluid mud, pre-consolidated sediment and consolidated sediment at various depths per location (see Fig 1). The bulk density, particle size distribution, organic matter content, minerology, settling properties and rheology of sediment samples were determined in the laboratory. To identify the rheological characteristics of fluid mud and their development over time, in-situ measurements of density and yield stress, acoustic surveys to map the lutocline and mud-bed interface were conducted using the Rheotune and dual-frequency echosounder which are commonly used for determining the nautical bottom [3].

**Results:** The analysis conducted on in-situ data and collected sediment samples revealed the following results:
1) The bed of the port consisted of predominantly silt and clay with slight variation of sediment's particle size, organic matter, minerology and salinity suggesting that the density and strength variation of bed were predominantly driven by settling and consolidation of mud.
2) The analysis of settling behaviour showed a special variation in gelling concentration (structural density) of mud.
3) Strong thixotropic behaviour of mud was observed on mud with yield stresses above 50 Pa, which was in line with previous studies (e.g., [4]).

**Discussion:** The correlation of the in-situ and lab yield stress data could be potentially improved by generating a broad rheological dataset for calibration of the in-situ measurements.

This study is funded by Harwich Haven Authority. The research is carried out within the framework of the MUDNET network. The authors would like to acknowledge Deltares for the use of FCL laboratory.

**References:** [1] Spearman and Benson (2022) *WODCON XXIII*; [2] PIANC (2014) Harbour Approach Channels - Design Guidelines; [3] Kirichek and Rutgers (2020) *Terra et Aqua* **160**:16-26; [4] Shakeel et al. (2020) J. Soil and Sed. **20**: 2553–2562.

# In-Situ capping of contaminated sediments in Puddefjorden, Bergen Harbour, Norway, using rock materials from tunnel boring machine (TBM)

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**Conference theme number(s): 3**

**Introduction:** The harbour of the ancient Hansatic city of Bergen, in western Norway, has been a centre of trade and travel since the 14th century. Since the 19th century, industry and shipping has dominated the city centre, releasing pollutants into the harbour and the nearby fjords. The fjord "Puddefjorden" close to the city centre, has housed several shipyards and different industries up until recently. This has contributed to heavily polluted sea sediments. During the last decade, however, residential housing projects have transformed the area from industrial activity to public access space. The outer part of Puddefjorden has still a lot of traffic by large vessels that could erode and move pollutants.

**Methods:** A sediment remediation project was carried out in Puddefjorden during 2017-2018. The project required a substantial amount of capping material. Infrastructure projects in and around Bergen were many at the time, one being the construction of a new railway tunnel. The project used a tunnel boring machine (TBM) which drilled through hard gneissic rock producing mainly sand and gravel, along with approximately 10 % silt, making the material susceptible to frost actions, and thus useless for many purposes. The sediment remediation project used the TBM material as capping material to isolate the contaminated sea sediments in Puddefjorden. The results from this project have been monitored and evaluated in 2019 and 2022.

**Fig. 1:** Puddefjorden in the 1990s while shipyards were still present.

**Fig. 2:** A small part of Puddefjorden in 2019 after the completion of the remediation project.

**Results:** An area of approximately 500 000 $m^2$ was in part dredged (minor areas) with subsequent capping between June 2017 and December 2018. The 50 cm thick cap in Puddefjorden has proved efficient in isolating contaminants in the underlying sediments and resisting erosion. The big vessels have not affected the cap significantly by propellor erosion.

**Discussion:**
The beneficial use of a low value material has proved very efficient as capping material of a polluted seabed in an active harbor. There is however need for detailed planning, sampling and monitoring in order to secure the needed quality of the capping material to prevent or reduce the environmental risk for mixing of grease used for lubrication of the cutters and also to test the TBM-material for chemical composition and grain size compatibility after excavation. Environmental monitoring show a minor recontamination of the remediated area in Puddefjorden, but the cause of the recontamination is believed to be the spread of contamination from land (urban runoff) or from the seabed outside the remediated area.

**References:**
In-situ capping of contaminated sediments in Bergen Harbour, Norway, using rock materials from Tunnel Boring Machine (TBM). Poster (C2_80) Ninth International Conference on Remediation and Management of Contaminated Sediments Batelle, New Orleans, January 2017.

# Organic Matter Decomposition During Sediment Ripening

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**Introduction**: Dredging produces large sediment volumes with organic matter (OM) from natural and industrial sources, which even in small amounts, can significantly affect sediment properties [1]. For beneficial use of dredged sediment, OM stability is paramount. Sediment ripening aims to reducing and stabilizing the organic fractions [2], [3]. This study examines OM degradation in mechanically dewatered dredged sediment (METHA plant, Hamburg, Germany) during ripening, analyzing sediment respiration and the Tea Bag Index [4]. Together, these methods provide a comprehensive understanding of the dynamics of organic matter transformation during biological ripening of dredged sediment.

**Methods:** The dewatered sediment originating from Elbe river in the area of the port of Hamburg was deposited into 9 stockpiles of 1,000-2,200 $m^3$. OM stability and the decomposition activity of the microbial community were investigated over a 2-year period by measuring $CO_2$ evolution and $O_2$ consumption during soil respiration using a gas chromatograph, and by determining the Tea Bag Index (TBI), a standardized approach to assess breakdown of labile and recalcitrant OM. Data from the ripening stockpiles are compared to the properties of ~60 years old historical sediment used as soil amendment (HS).

**Results**: The original material (high-intensity press, HIP) showed the highest cumulative carbon release, steadily declining from March to November 2023, reaching ~33% of the highest value within the first year of ripening (Fig. 1, left). A slight increase in March 2024 was followed by a sharp drop in September 2024 to below the "HS" sample level. The top layer consistently released more carbon than the bottom layer (Fig. 1, right), but appeared to become more similar to the bottom layer over time. The stabilization factor (S) increased during the early ripening phase (March to November 2023), then slightly decreased in March and September 2024 (Fig. 2, left), with the "HS" sample displaying less stabilization. The decomposition rate (k) decreased steadily throughout the ripening process, (Fig. 2, right). Complementary to the stabilization factor, k values of HS samples were higher than for ripening material.

**Discussion:** Ripening begins with drainage and ingress of atmospheric air, where oxygen enters the sediment, triggering chemical reactions and initiating OM mineralization [2, 3, 5]. Cumulative C release steadily declined, reflecting the depletion of labile organic matter as ripening progressed. Increased C release indicates a higher share of degradable OM and suggests environmental changes, such as higher precipitation [6, 8] or input of carbon by the vegetation [7]. The top layer, receiving more oxygen than the bottom, showed enhanced OM decomposition, especially in the beginning [9]. The decomposition rate (k) decreases over ripening, indicating labile OM depletion, while the stabilization factor (S) increases as recalcitrant OM becomes more dominant [4, 9].

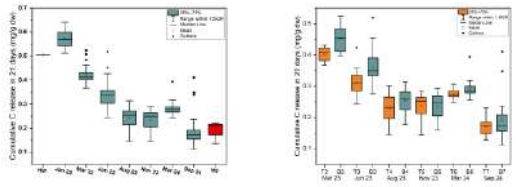

**Fig. 1:** Cumulative carbon release (left) and differentiation by top (T) and bottom (B) stockpile layers (right) over 21 days.

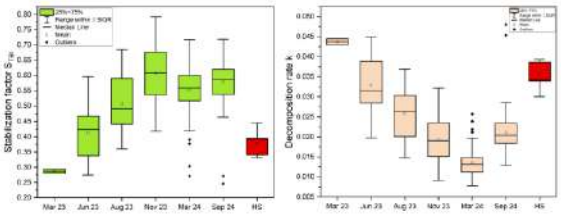

**Fig. 2:** Left: Stabilization factor (left) and decomposition rate (right) for tea bags incubated for 21-days.

**References:** [1] Hamouche and Zentar (2020) Waste Biomass Valori 11, 389-401; [2] Brouwers et. al. (2007) J Haz Mat 145, 8-16; [3] Pons and Zonneveld (1965) Veenman; [4] Mori et al. (2023) Ecol Indic 152, 110358; [5] Vermeulen et al. (2007) Toxicol Chem 26, 2540-2549; [6] Li et al. (2023) Catena 228, 107175; [7] Jansson and Hofmockel (2020) Nat Rev Microbiol 18, 35-46; [8] Chen et al. (2020) Sci Total Environ 714, 136787; [9] Williamson and Johnson (1990) Plant Soil 128, 241-247.

# Capillary Suction Time: Assessing the Potential of a Rapid, Small-Scale Method for Determining the Material Properties of Dredged Sediment

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**Conference theme number(s): 3**

**Introduction:** The use of dredged sediments and nature-based solutions is increasing. However, designing end products or structures requires knowledge of sediment properties and mechanical behavior, highlighting the need for efficient methods to determine these parameters.

**Materials and methods:** This study used sediment from Lake Markermeer, Netherlands, within the Marker Wadden Building with Nature project. Three natural bulk materials were analyzed: bulk clay (SW1B), bulk sandy silt (NE1B), and sandy clay (NE2B), along with their fine fractions (SW1BF, NE1F). The reliability of a Triton 304M Capillary Suction Time (CST) device in determining material parameters was tested. The CST device consists of a metallic sample ring (radius R, height H) surrounded by concentric rings on filter paper. Water is drawn from the sample, creating a diffusing front. The experiment records the time taken for the water to reach the inner and outer rings, linking this time to sample properties. The analysis is based in the Gibson equation [2]:

$$\frac{\partial \phi_{\text{corr}}}{\partial t} - \frac{\partial}{\partial z}\left(\frac{(\rho_s - \rho_w) k \phi_{\text{corr}}^2}{\rho_w}\right) - \Gamma_c \frac{\partial^2 \phi_{\text{corr}}}{\partial z^2} = 0$$

where $\phi_{\text{corr}}$ is the corrected volumetric concentration of solids [1] , $\rho_s$ the particle density, $\rho_w$ the density of water, $k$ is the hydraulic conductivity and $\Gamma_c$ the consolidation coefficient, which can be defined as:

$$\Gamma_c = \frac{2}{3 - n_f} \frac{K_k K_\sigma}{g \rho_w}$$

where fractal dimension $n_f$, permeability factor $K_k$ and effective stress parameter $K_\sigma$ are material parameters. They can be used to determine $k$ and the effective stress $\sigma_{\text{eff}}$ as a function of $\phi_{corr}$ as follows:

$$k = K_k \phi_{\text{corr}}^{-\frac{2}{3-n_f}}$$

$$\sigma_{\text{eff}} = K_\sigma \phi_{\text{corr}}^{\frac{2}{3-n_f}}$$

Material parameters were experimentally determined for replicates of each sediment type as follows: To determine $K_\sigma$ and $\Gamma_c$ samples were preconsolidated in steps before performing the CST test (at 3 bar for 5 minutes in a filtration vessel). To determine the permeability factor $K_k$ and fractal dimension $n_f$, the same initial sample used in the preconsolidated CST test was diluted in steps with 10 mL of Markermeer water before the CST measurement.

**Results:** Tab. 1 shows the material parameters for all analyzed materials and their replicates.

**Tab. 1:** *Fractal dimension $n_f$, permeability factor $K_k$, effective stress parameter $K_\sigma$ and consolidation coefficient $\Gamma_c$ for all the replicate samples studied*

| Replica | $n_f$ [-] | $K_k$ [m/s] | $K_\sigma$ [Pa] | $\Gamma_c$ [m²/s] |
|---|---|---|---|---|
| SW1B-I | 2.68 | 6.6E-14 | 6.3E+09 | 2.7E-07 |
| SW1B-II | 2.71 | 2.3E-14 | 1.1E+10 | 1.8E-07 |
| SW1B-III | 2.68 | 4.2E-14 | 6.5E+09 | 1.8E-07 |
| SW1F-I | 2.43 | 2.1E-11 | 3.4E+07 | 2.5E-07 |
| SW1F-II | 2.29 | 8.6E-11 | 9.4E+06 | 2.3E-07 |
| SW1F-III | 2.22 | 2.4E-10 | 2.0E+06 | 1.3E-07 |
| NE1B-I | 2.68 | 8.6E-13 | 1.5E+08 | 8.1E-08 |
| NE1B-II | 2.68 | 9.1E-13 | 2.0E+08 | 1.2E-07 |
| NE1F-I | 2.45 | 3.0E-11 | 1.2E+07 | 1.3E-07 |
| NE1F-II | 2.40 | 6.4E-11 | 7.4E+06 | 1.6E-07 |
| NE2B-I | 2.44 | 3.4E-11 | 5.9E+06 | 7.3E-08 |
| NE2B-II | 2.49 | 1.4E-11 | 7.9E+06 | 4.6E-08 |
| NE2BF-I | 2.22 | 2.1E-10 | 1.4E+06 | 8.1E-08 |
| NE2BF-II | 2.27 | 1.1E-10 | 3.1E+06 | 9.4E-08 |

**Discussion:** All replicates of the same samples yielded similar results, which were consistent with the orders of magnitude reported in the literature. This demonstrates the potential of the CST test as a rapid method for determining material parameters in nature-based or beneficial sediment use projects.

**References:** [1] Barciela-Rial et al. (2022) *Frontiers Earth Sciences* **10**: 786108

[2] Barciela-Rial et al. (2024) *Frontiers Earth Sciences* **11**:1466650

# Towards carbon neutral construction using Olivine and Calcined Sediment

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**Conference theme number(s): Theme 1 or 3**

**Introduction:** Sediments, a natural byproduct of geological and hydrological processes, are abundant and often treated as waste, particularly in dredging activities. However, these materials hold significant potential as a valuable resource for sustainable construction.
This research focuses on transforming sediment into a valuable component for construction by calcining it to enhance its pozzolanic properties. This allows sediment to partially replace traditional Portland cement. By doing so, sediment becomes an integral part of a sustainable binder formulation, addressing both sediment management challenges and the construction industry's environmental footprint.
Olivine, a magnesium-iron silicate, is incorporated into the formulation to further enhance sustainability. Olivine replaces fractions of both sediment and cement, while actively absorbing carbon dioxide—up to its own weight—during its lifecycle. This dual approach leverages the synergy between calcined sediment and olivine to create a high-performance, low-carbon product. The study explores the binder's material properties, environmental benefits, and potential applications, offering a pathway to innovative sediment reuse while contributing to global carbon reduction goals.

**Methods:** To explore the potential of calcined sediment and olivine as potential sustainable binder components, a systematic experimental approach was adopted:
Sediment Calcination:
Samples of sediments with varying compositions were collected and calcined at 850°C. This process was designed to activate the sediment's pozzolanic properties, enabling it to act as a partial cement replacement.
Block Preparation:
The calcined sediments were used to produce test blocks. The formulations included varying proportions of calcined sediment and cement to evaluate the performance of each combination.
Olivine was incorporated as a partial replacement for either cement and/or sediment, taking advantage of its carbon sequestration capability.
Testing and Evaluation:
Blocks were tested for compressive strength at 7, 28, and 56 days to monitor their early strength as well as development over time.
Relative indices such as the Relative Activity Index (RAI) were calculated to quantify the reactivity and performance of the calcined sediment and olivine blends.

**Results:**

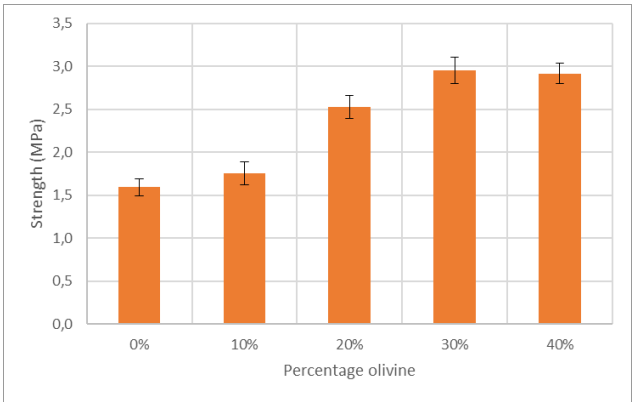


**Fig. 1:** Compressive strength blocks with different olivine percentages

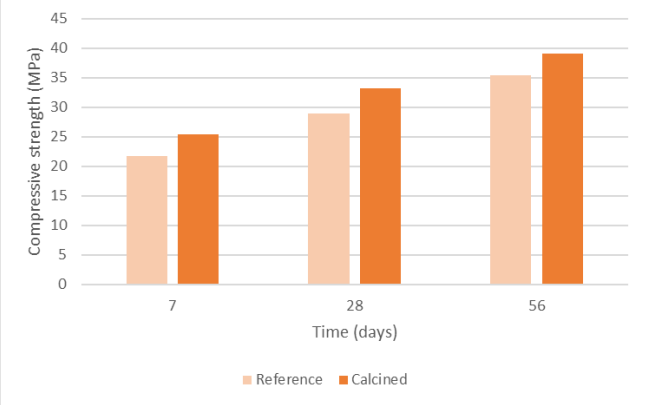


**Fig. 1:** Compressive strength of blocks with 10% calcined sediment

**Discussion:** These experiments will guide the development of a binder formulation that combines calcined sediments and olivine, aiming to maximize both sustainability and performance, the way for innovative and sustainable binder technologies.

# Beneficial use options for dredged sediments: circular economy and climate change-based assessment and classifications

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**Conference theme number(s): 3**

**Introduction:** Dredging of sediments is a requirement for waterborne transportation, creating one of the biggest material flows in the world. At the same time, sediments present a valuable mineral resource, the use of which would significantly reduce consumption of primary raw resources. The potential contribution of sediments towards achieving circularity led to the creation of a dedicated SedNet working group in 2018. Beyond minerals reuse, sediments have a broader role in the beneficial use (BU) of materials for a circular economy. Case studies encouraged by INTERREG, PIANC, CEDA and USACE led to the uprise of the Building with Nature (BwN) concept. Key applications of sediments within BwN include climate change adaptation works (flood and shoreline protection), natural habitat restoration (like wetlands), use on agricultural land, river restoration works, and civil works (like dike construction). This contribution provides an overview and analysis of the current global BU projects.

**Methods:** Structured data sheets of case studies published by CEDA and USACE, were classified along the main applications categories, thereby providing partial but significant statistics on beneficial use options, and recent trends. More projects identified by literature scans were added.

**Results:** A total 78 projects and pilot projects [1] provided data on the beneficial use of 725 $Mm^3$ of raw sediments. Climate change impact applications accounted for 80.5% of the total, while 20.6% for agricultural or landscape applications and 2.5% for raw minerals applications. This result is unexpected when referring to circular economy applications as outlined around 2000-2010, in which sediments were mainly proposed as beneficial substitutes for minerals from primary extraction [2]. In the meanwhile, the fast growing needs for sustainable building material [3] of climate change adaptation [4] works acted as a driver for cost-effective beneficial use [5].

**Discussion:** One of the main issues with sediments as substitutes for raw minerals applications was, and still is, social acceptance and potential liabilities for the end user, either long term performance or contaminants contents. On the opposite, climate change adaptation works are perceived as positive regardless of potential issues, and the material costs implied by their massive size can be reduced by sediments reuse. Besides this, most of these works are implemented along or nearby the water body the sediments were dredged from, hence reducing the environmental suitability constraints and transportation costs. With the growing urgency of such works, they provide a sustainable alternative to the current landfilling or disposal at sea practices. This implies revisiting enablers and barriers for circular economy options, such as regulations, incentives or standards, and opportunities, such as priority works.

**References:**

[1] CEDA Beneficial use of sediments: Case studies (https://dredging.org/resources/ceda-publications-online/beneficial-use-of-sediments-case-studies).
[2] Laboudigue et al. (2011) *SedNet conference*.
[3] UNEP 2022. Sand and sustainability: 10 strategic recommendations to avert a crisis. GRID-Geneva, United Nations Environment Programme, Geneva.
[4] EPA, 28-05-2024, Climate Adaptation and Erosion & Sedimentation.
[5] Wijdeveld et al. (2024) *J Soils Sediments* https://doi.org/10.1007/s11368-024-03811-z.

**Fig. 1:** Sediments beneficial use for dike construction, Germany.

# River Works: Soil-Based Programming in the River Area

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**Conference theme number(s): 3**

**Introduction:** Many functions converge in the river area: water safety, shipping, nature, water quality, freshwater availability, living, working, and recreation. Yet, the space for the major rivers has steadily decreased over the centuries. Since the dawn of humanity, people have settled close to rivers, which have served as lifelines for societies. For centuries, rivers flowed freely through the landscape, with channels silting up and shifting, and adjacent areas regularly flooding. In the 19th century, large-scale river normalization projects were undertaken in many rivers to benefit navigation and flood safety.
In the Dutch context, floodplains have silted up over the last centuries due to flood events and space narrowing caused by dikes. As a result, floodplain nature restoration in the Netherlands requires excavation. Meanwhile, around 2000 km of dikes in the Netherlands must be reinforced before 2050 to comply with safety requirements. Therefore, linking soil supply (nature restoration) with demand (e.g., dike strengthening) seems logical from a sustainable river management perspective. This approach not only provides sustainable material that can be used locally but also potentially leads to cost savings and reductions in CO2 footprint and environmental nuisance. This method, referred to as soil-based programming, was the focus of the Rivierwerken (River Works) project, which concluded at the end of 2024.

**Materials and methods:** River Works was organized in three work packages: 1) Sustainable Resource Extraction, 2) Circular material use and 3) Soil-Based programming.
The consortium, led by HAN University, included other 20 partners (public, private, knowledge): two ministries (Infrastructure, and Agriculture and Nature), a nature management agency (Staatsbosbeheer), three waterboards (Limburg, Rijn en Ijssel, and Rivierenland), two provinces (Limburg and Gelderland), two foundations (Smart Rivers and EcoShape), three additional knowledge institutions (Deltares, TU Delft and Van Hall Larestein), a multidisciplinary group of private companies (Fugro, Van Oord, K3 Delta, Netics, Aveco de Bondt, Witteveen+Bos, and Arcadis) covering both consultancy and contractors role.

**Results and conclusions:** The project's outcomes are summarized in Tab.1. These results provide valuable support to technical managers, designers, risk managers, project managers, and administrators of dikes and floodplains, contributing to a more sustainable approach.

**Tab 1.** Output per work package

| **Output WP1** |
|---|
| -Tool for estimating soil volume extracted in nature development projects based on river DNA and validated with an expert-based system approach<br>-Opportunities for local sediment replenishments to counter river bed erosion<br>-Designing nature restoration projects that follow the DNA of the river |
| **Output WP2** |
| -Soil treatment techniques review<br>-Improving the mechanical properties by mixing different clay types and analysis of a case of study<br>-Compositional effects and suitability for dikes<br>-Soil-based dike design |
| **Output WP3** |
| -Methodology for an integrated approach to soil<br>-Evaluation of existing tools<br>-Developing of a new improved tool to match soil offer with demand |

**Fig. 1:** Screenshot of the tool developed in WP3

This presentation will explain in a summarized way all the lessons learnt from River Works, which contribute to the mainstreaming of soil-based programming, and explain how these lessons link with ongoing national and international initiatives and policy.

**Acknowledgements:** This project was conducted with the support of all the partners mentioned, and not solely by HAN University of Applied Sciences. Due to space constraints, only the name of the project leader, main researcher, and presenter is explicitly mentioned as author.

# Field labs sustainable use of sediments in the Rhine-Meuse delta

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**Conference theme number(s): 3 (NBS)**

**Introduction:**
In the period from 2019 to 2024 we developed three field labs for sustainable use of sediments in the Rhine - Meuse delta ("Proeftuin Sediment Rijnmond"). The target of these field labs is to understand and innovate the approaches for better and circular (re)use of non-contaminated sediments, and to keep these sediment in the estuarine system.

Every year, a huge amount of material is dredged in the Rhine – Meuse delta to guarantee navigability. Most of this sediment is not contaminated, but is relocated offshore to the North Sea. However, the Rhine – Meuse delta also needs sediment for erosion protection, nature development, recreation and water safety. Balancing the supply and the demand of sediment will give great opportunities for circular and sustainable use of dredged sediment, and to better satisfy the needs of sediment in the delta.

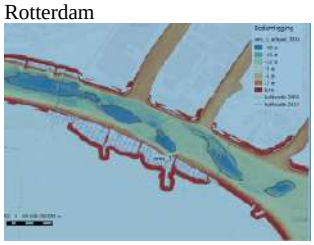
The field labs are a cooperation between suppliers of sediment (RWS, WSHD, PoR), contractors (DEME), Nature conservation organizations (World Wildlife Fund, ARK rewilding) and knowledge institutes (Deltares, WMR).

**Methods:**
Important issues for the field labs were research, demonstration, sharing of knowledge, working together and learning by doing.

The first step was to quantify and locate the supply (dredging) and demand of sediment in a sediment atlas. The sediment atlas also provides insight into the environmental quality of the sediment. Outcome of the sediment atlas was that there is a huge amount of sediment available for circular and sustainable sediment management but that there is a mismatch between the need (demand) of sediment and the supply of the sediment.

The field labs provided execution of three pilot projects. The first pilot is located in the port area, whereby sediment was used for nature development in a groyne field instead of relocating the sediment to the North Sea. The second pilot is located in the river channel of the Oude Maas, whereby the (sandy) sediment was used for filling up and stabilize deep scour holes and creating a 'sand engine', instead of selling it on the 'sand market'. The third pilot is located in a partially closed estuary (Hollands Diep) where very fine sediment also will be used to improve ecology in bank zones.

Pilot 1: field lab "Groene Poort" at entrance channel of Port of Rotterdam



Pilot 2: Filling of deep scour holes

Pilot 3: Nature development in estuary bank zones

**Results:**

The results of the field labs were presented last November. The shared vison and ambition connect the partners and they will continue the cooperation.

It results in an approach for the future:

1. Develop locations for circular / sustainable use of sediment, and connect them to sediment sources;
2. Organize the cooperation;
3. Keep opportunities for experiments, research and monitoring

The final target will be the circular /sustainable use of sediment as a daily business

# Reuse of dredged sediments from hydropower reservoirs in France: Recent experiments highlighting current enablers and barriers

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**Conference theme number(s): 3**

**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 dredged sediments become waste by regulation in Europe (cf. Waste Framework Directive 2008/98/EC).

**Methods:** This paper will present a methodology developed by EDF with several stakeholders, using dredged sediments from several reservoirs for different recovery ways (i.e. mineral and agricultural valorisation paths). First the context and main current issues are presented in France (sediment characteristics and volumes, analyses required, arising issues, …). Then the method to address them, with the different stakeholders and possibles recovery purposes are described issuing dredged sediments as an alternative to raw materials. Then main results of these different experiments are summarised in the context of climate change mitigation and adaptation (an alternative to raw materials for concrete, terracotta, agricultural soils, …). And finally main current enablers and barriers are highlighted assuming the current state, and possible future publication of guides could make sediments a nature-based solutions to contribute for a real circular economy.

**Fig. 1:** Dredging sediments for reuse.

**Fig. 2:** Drying sediments is essential for recovery.

**Fig. 3:** Recovering sediments for agricultural uses.

**References:** [1] CIS document. (2022) *Integrated sediment management - Guidelines and good practices in the context of the Water Framework*

**Please submit your abstract before the 29th of November 2024 to the SedNet secretariat: secretariat@sednet.org.**

# Description of and criteria for nature-based solutions involving sediments that reduce erosion as well as slope instability

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**Conference theme number(s): 3**

**Introduction:** International organizations such as UN, OECD and EU have their own, although quite similar, definitions and descriptions of what a nature-based solution (Nbs) is. A common denominator is that a Nbs should contribute positively to biological diversity and strengthen ecosystems. Since these definitions and descriptions are very generalized, we have aimed to define, describe and list criteria to be used or considered when a solution is designed, implemented and used to be classified as a nature-based solution involving sediments and reducing erosion as well as slope instability. Experiences and comparisons of pilot studies of Nbs solutions that reduce the risk of erosion in rivers based on the descriptions and criteria are also presented.

**Methods:**
The International Union for Conservation of Nature's (IUCN's) and the Swedish Environmental Protection Agency's descriptions have been the base for the descriptions and list of criteria that have been developed and adapted to Nbs solutions involving sediments and reducing erosion as well as slope instability.
Evaluations, follow-ups and comparisons with the descriptions and lists of criteria for existing Nbs solutions that are reducing erosion in the Göta river, located in southwestern Sweden, are also performed.

**Results:** These eight criteria should be met or considered when a solution is designed, implemented and used to be classified as a nature-based solution that involves sediments and prevents problems and damage caused by erosion and landslides:

1. the function and strength of the technical solution works.
2. is adapted to the conditions of the area.
3. promotes biological diversity and strengthens the functioning of ecosystem services.
4. is resource efficient, i.e. that the measure, for example, is designed energy-efficiently and that a sustainable use of materials is applied.
5. is designed in cooperation, i.e. that relevant interests, competences and stakeholders are identified, considered and involved in relevant parts of planning
6. balances different interests, clarify different interests and take them into account in as fair and inclusive way as possible, both in time and space.
7. creates value and provides synergies with other sectors, i.e. that different interests are made clear and synergies with other sectors can be identified. A well-designed Nbs can create more values and benefits and do not cause other problems, geographically and in time, as remobilizing and transporting polluted sediments. An Nbs do not increase emissions of pollutants to air, soil and water. An Nbs do not create unhealthy sediments.
8. is followed up, maintained and adapted to new conditions. An Nbs must be able to be adapted to meet new conditions, such as changed environmental and social conditions.

One riverbank protection consisting of core logs, logs and timber built in 2021 and one that consists of logs and cut-down trees built in 2021 are compared and evaluated with regards to the list of criteria and sediments.

**Discussion:** The Nbs consisting of core logs meets and fulfills criteria 3 and 4. However, criteria 4 is in some respects not fulfilled, since the core logs are imported from Asia. Criteria 1 and 7 are not fulfilled because the core logs were eroded and wiped away. The function was deficient and cause a risk of remobilizing polluted sediments. The Nbs solution consisting of logs and trees fulfills criteria 1, 2, 3 and 4, and in some respects criteria 6, 7 and 8. This Nbs solution also reduces sediment dynamics and the effects of erosion. One main experience for both Nbs is that criteria 5 should be more considered. That is, for example, ecologists and biologists to follow up the biological diversity and ecosystem services, with regards to the sediments, that the Nbs solutions provide.

# LIFE NARMENA: Nature based remediation techniques for heavy metals in sediment – results of a constructed wetland in the Winterbeek site

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**Conference theme number(s): 3, 1**

**Introduction:** The industrial legacy of western Europe has caused several problems with contamination. One particular issue that will be targeted in the LIFE NARMENA project is contamination with heavy metals in small watercourses that flow through nature reserves. While the source activities are often no longer present, the contamination remains in the sediment and on the banks of the stream. The sediment and banks act as secondary source zones, gradually causing further spreading of the stored contamination, exacerbating the problems caused by this heavy metal contamination. Beside human exposure, ecological exposure is an important issue not only in the streams itself but also in nature reserves through which they flow. Traditional remediation techniques for contaminated sediment typically rely on the removal of contaminated material. While this might be an effective technique in residential or agricultural settings, it is often not desirable in areas with a high nature value as significant ecological damage can be caused by such conventional techniques.
The objective of the LIFE NARMENA project is to demonstrate less intrusive, nature-based remediation techniques to manage heavy metal contamination in flood-prone watercourses.

**Methods:** The remediation concept will be aligned with the general water and nature management and requires an integrated approach to deal not only with the environmental issues but also the economic and social implications. To facilitate this, the LIFE NARMENA project brings together a diverse consortium of stakeholders: relevant public organizations, nature NGO's and technical partners.

The project consists of three test sites where different nature-based remediation concepts will be demonstrated.
Two of the sites will be used to demonstrate the use of free water surface constructed wetlands. Both sites are primarily contaminated with cadmium, and additionally contain lower traces of other metals (mainly mercury and arsenic). The contamination on both sites was caused by a combination of historical sediment deposition on the banks and significant seasonal flooding. The remediation concept consists of controlled inundation of the sites, hereby altering the geochemical conditions in the top of the soil/sediment, which results in a decrease in bioavailability and overall mobility of the contaminants.

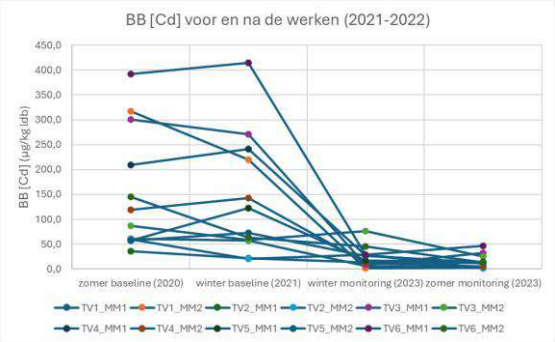


**Fig. 1:** Bioavailability of Cadmium in sediment before and after inundation.

**Results:** For one of these two cadmium-contaminated sites, called the "Winterbeek", the works started in the fall of 2022 and the constructed wetland will be finished in 2023.

**Discussion:** In the first year of monitoring post works, decreases in the bioavailability of Cadmium of more than 90% have been observed in some of the monitored areas, as well as significant declines in toxicity. At the conference, we will be able to share more details about the positive results of the use of constructed wetlands as efficient nature-based remediation technologies.

# Soil carbon and nutrient addition from dewatered sediment application to agricultural land –benefits and synergies for dredging and Net Zero

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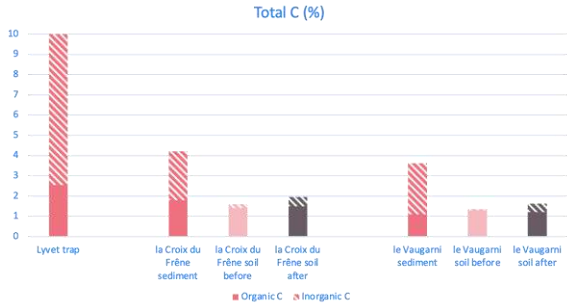
**Conference theme number(s): 3 Nature Based Solutions.**

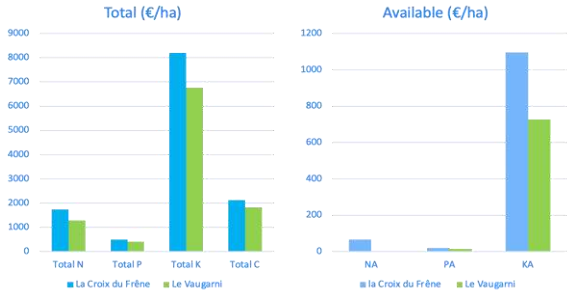
**Introduction:** Beneficial use of sediment on agricultural land is a common reuse option for uncontaminated, freshwater or desalinated estuarine sediments. Their favourable mixture of particle sizes and decaying organic matter content provide the basis of a loamy soil texture and a slow-release source of major nutrients, including nitrogen, phosphorous, and potassium, together with neutralisation potential from biogenic carbonate. What is less clear is the fate of the organic carbon, its residence time and future storage potential as soil carbon. If the whole system carbon footprint of dredging is to be considered under net zero targets, then this must also be compared to the likely counterfactual, including the offset greenhouse gas emissions from the *in situ* sediment before removal, or any negated contribution to blue carbon stores if the sediment had been left in place.

**Methods:** In September 2022 as part of the Interreg NWE Suricates Project (Sediment Uses as Resources in Circular And Territorial EconomieS) the receiving soils at two agricultural sediment application sites, near la Croix du Frêne and le Vaugarni, were sampled together with the stockpiled dewatered La Rance Estuary sediment delivered to the sites from the La Hisse treatment facility ready for spreading. At both sites the soils were resampled in May 2023 following incorporation of the sediment into soil by the respective farmer and continued rotational or cover crop planting.

**Results:** Our soil analyses confirm that the placed sediment, which had been stored at La Hisse since January 2020, has broadly similar levels of organic matter (2-3%) and soil organic carbon to that of the receiving soils (2.2-2.4 %), and roughly half that in samples of fresh sediment collect from near to the Lyvet sediment trap. However, the sediments also contain significant inorganic carbon content, presumably from the marine shells observed while sampling. For the 500m$^3$/ha application rate this corresponds to 18-20 t of total biogenic C addition per hectare (or 68-77t $CO_2$ equivalent). If this total amount of C could be considered as stored this would represents a value of over €2K/ha (OECD C price 2018-21).




The placed sediments also contain significant total major nutrients in rank order K > N > P. Measured available nutrients were <3 % for N and P, compared to 14 % for K. However, the total equivalent value of mineral fertilizers (UK prices January 2023) for the total nutrient addition present in the sediment would be €6.5-8K/ha..




**Discussion:** Further work is required to ascertain the long-term C dynamics and nutrient release of organic matter contained in sediment place on land. However, assuming complete decomposition will occur over the 10 year interval between permitted spreading, the loss of temporary soil C storage will be replaced by the much larger value of nutrients released, which together exceed the actual cost of sediment application.

**Acknowledgements:** The SURICATES Project was funding through the INTERREG NWE programme from the European Regional Development Fund (ERDF).https://vb.nweurope.eu/projects/project-search/suricates-sediment-uses-as-resources-in-circular-and-territorial-economies/

# Aquaforest: a Nature-based-Solutions for restoring and developing new mangrove habitats through eco-engineering

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**Conference theme number(s): 3.**

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**Introduction:** Human activities, rising sea levels, and more frequent severe storms have drastically reduced mangrove habitats, putting over half of the world's mangrove ecosystems at risk of collapse, according to the IUCN Red List of Ecosystems. This loss is catastrophic for nature and people, as mangroves provide vital services such as coastal protection, carbon storage[1], and fisheries support.

Meanwhile, vast volumes of dredged sediments are discarded annually during waterway maintenance, though these sediments could support mangrove growth in tropical and subtropical regions. Addressing this opportunity, the Aquaforest project explores and demonstrates the reuse of dredged material to create new mangrove habitats. Initiated by the Jan De Nul Group, the project is managed by a consortium of eight partners (Haedes, Mantis, SouthPole, ESPOL, VUB, UAntwerp, and Calisur), with financial backing from G-STIC and IUCN. Located in Ecuador's Guayas Delta, the project leverages sediment from the maintenance of the Access Channel to the Port of Guayaquil, managed by Jan De Nul since 2018.

**Methods:** Aquaforest is an innovative project that repurposes dredged sediments sustainably to create mangrove habitats in the Guayas Delta. After extensive investigations and eco-engineering studies, a 50-hectare landmass was designed on an intertidal flat near the Access Channel, enclosed by a J-shaped sand bund and semi-permeable structure filled with silty sediments. Hydrodynamic modeling confirmed the habitat's stability, and sediment analysis validated its suitability for mangrove growth.

The project combines eco-engineering with community involvement through capacity building and sustainable management. By fostering assisted natural regeneration, it enhances biodiversity and ecosystem resilience. Aquaforest integrates key stakeholders at every stage, ensuring the long-term ecological and socio-economic sustainability of the newly created mangrove habitat.

**Results:** Haedes utilized its NESEV tool (Ecosystem Services network model) to evaluate ecosystem services for the AquaForest project. NESEV provides a holistic valuation framework, identifying a wide range of ecosystem services and actors (nodes), allowing to create a matrix and visualize the values in the network. It enables multi-currency valuation based on client needs (€ per area) and highlights the benefits nature provides to human society, bridging ecosystems and human well-being[2].

Key ecosystem actors identified in this study include fisheries, mangroves, local businesses, local population, and tourism. NESEV was applied to analyze different scenarios: baseline, one year post-plantation (Scenario 1), 10 years post-plantation (Scenario 2), and 20–25 years post-plantation (Scenario 3). The results show that the new island will significantly enhance the ecosystem after 25 years, when the mangrove forest matures.

NESEV predicts an increase in biodiversity, with new species populating the island. The mangroves will also improve water and air quality, contributing to a higher standard of living for the local population. Overall, the analysis indicates that the mangrove-covered island will generate an added ecosystem value.

Some Sustainable development goals (SDGs) were evaluated in NESEV for the baseline situation and the scenarios of island creation. The process was assessed to see the SDGs achieved by the project due to the newly created mangrove ecosystem.

**Acknowledgements**:AquaForest is supported by the Government of Flanders (NL: "Departement Omgeving") through the G-STIC Climate Action Programme 2022, and The International Union for Conservation of Nature (IUCN) through the 'Blue Natural Capital Financing Facility'

**References:** [1] Suello, R. H., et al. 2022. Mangrove sediment organic carbon storage and sources in relation to forest age and position along a deltaic salinity gradient: Biogeosciences, v. 19, no. 5, p. 1571-1585.;[2] Reid W., Mooney H., Cropper A., Capistrano D., Carpenter S. and Chopra K. (2005). Millennium Ecosystem Assessment. Ecosystems and human well-being: synthesis

# First morphological response of a large nearshore nourishment project using fine sand, Knokke, Belgium

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**Conference theme number(s): 3**

**Introduction:** Sandy nourishments are a common and successful engineering solution to mitigate coastal erosion. They make the coast more resilient as the supplied sand creates a larger beach to accommodate the natural dynamics, storminess associated to climate change and rising sea level [1]. Nearshore nourishments have usually a lower cost, while providing an improved protection from waves. The largest nearshore nourishment with fine sand (150 µm) project ever in Belgium was completed between 10/2023 and 02/2024. A volume of 1.2 million $m^3$ was placed in Knokke below the low water line and extending 650 m from the coastline. The aim of this study is to assess the efficiency of a nearshore nourishment with fine material as well as its incipient morphological evolution.

**Methods:** Knokke is located on the east coast of Belgium. It is characterized by a moderate wave energy and a macro-tidal regime. The coastline is oriented WSW-ENE and consists of a gentle sloping sandy beach up to 400 m wide back by a seawall. The coast suffers from long-term erosion due to the offshore presence of the Appelzak tidal channel at -8 m TAW (Belgian Ordnance Datum corresponding to low spring tide) [2]. High-resolution nearshore bathymetry surveys were conducted with multibeam.

**Results:**
An accretion up to 2.5 m was observed surrounding the groynes between the low waterline and the depth contour of -4.5m (Fig 1).

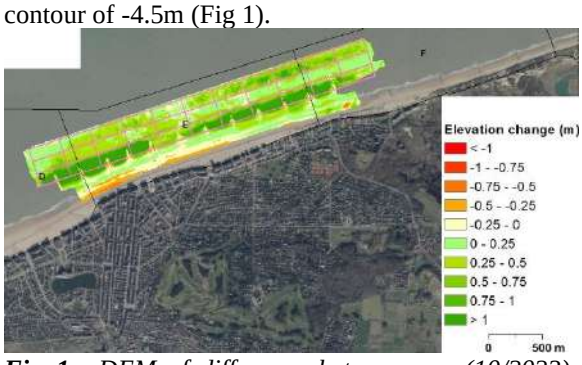


***Fig. 1:*** *DEM of difference between pre (10/2023)-post (03/2024) nearshore nourishment surveys.*

The channel floor just off the shoreface was subject to a vertical gain by on average 0.4 m. A few concentrated spots that accreted by up to 1.7 m were direct remnants of nourishment ship dumps. In contrast, negative morphological changes ranging from -0.05 to -0.7 m characterized the beach especially in the west part of the resort. This was likely due to the spreading of the beach nourishment carried out in 02-04/2023.

**Discussion:**
Knokke coast is liable to erosion by fast hydrodynamic processes causing alongshore and cross-shore sand transfers. The 'efficiency' of the nearshore nourishment characterized by fine sand ranges from 61% to 72%. At the end of the nearshore nourishment, the immediate environment inside of the Appelzak channel also showed a significant sedimentation. It is hypothesized that the nearshore nourishment might have induced a reduction in tidal currents by blocking of the part of the tidal channel just in front of the shoreface and diverting flows more offshore inside the channel. This would have engendered deposition in the alongshore relatively sheltered parts of the channel bed. Thus, most of the supplied sediment would still be present at the immediate environment of the nourishment area. The evolution of the nearshore nourishment and its effect on the beach-shoreface morphology will further be monitored in 2025.

**Acknowledgements:** The authors acknowledge Maritime Access Division and Coastal Division of Flemish Maritime and Coastal Services Department for access to data.

**References:**
[1] Brand, E. et al. (2022) Dutch experience with sand nourishments for dynamic coastline conservation, an operational overview, *Ocean and Coastal Management*, **217**; [2] Houthuys, R. et al. (2022) Morfologische evolutie van de Vlaamse kust tot 2019: Evolutie van de Vlaamse kust tot 2019. Versie 2.0. WL Rapporten, 18_142_1. Waterbouwkundig Laboratorium: Antwerpen.

# Dewatering of Dredged Sediment by Natural Solutions

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**Conference theme number(s): 3, 6**

**Introduction:** Dewatering of dredged sediment often relies on chemicals and heavy machinery, which increase fossil fuel use and emissions [1]. Traditional sediment dewatering methods only worsen the financial and environmental burdens associated with sediment management. When the slurry eventually dries at dewatering fields, it is perceived that the biological quality of the resulting sediment does not meet the standards of healthy soil, meaning it is rarely reused. It is also important to note that none of the existing commercial dewatering methods improve the environmental quality of the final product; they only address its physical properties.


**Fig. 1:** One of the dewatering ponds after having been filled with dredged sediment.

Over the past decade, more nature friendly innovative methods have been developed [2]. These methods use only endemic fauna and flora to significantly accelerate the dewatering process for various types of slurry. Additionally, the treated final product resembles closely biological properties of soil. Soil is a valuable resource, which would otherwise need to source it from the commercial soil market, a process that is both expensive and environmentally harmful due to operations-related emissions.

**Methods:** The goal of this research is to demonstrate that dewatering can be sped up without increasing the financial and environmental costs of sediment management, while also improving the quality of the dried product so it can be reused after the treatment. This can be achieved through the application of natural technologies. To achieve these objectives, the City of Rotterdam and Medeina conducted a pilot project. In this pilot, natural dewatering technologies were implemented after filling in dewatering ponds with dredged sediment (see Fig 1). Three dewatering ponds, each approximately 15m x 15m, with a total capacity of around 250 m³ were filled with slurry. One pond (Vak4A) was treated with worms and plants, one pond was only dewatered with worms (Vak4b) and one pond was used as a reference (no treatment). During the pilot, an intensive monitoring was conducted to capture the changes in solid content and strength of soil for a period over 4 months. This pilot marks a pioneering effort of using natural solutions for sediment circularity and reuse.

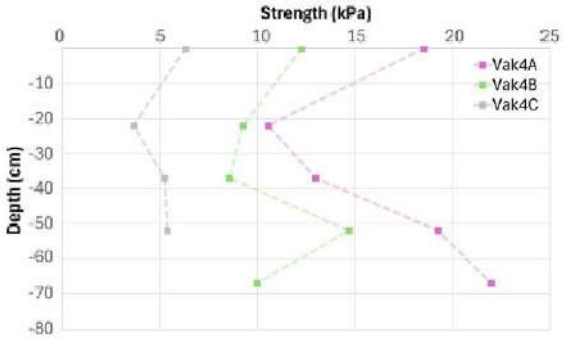


**Fig. 2:** In-situ soil strength measured 3.5 months after filling dewatering fields. Vak4A was treated by worms and plants, Vak4B was dewatered by worms and VAK4C was used as a reference (no treatment).

**Results:** The solid content of the slurry was increases by 15% over three months by suing natural solutions, while the reference depot showed virtually no average increase in solid content. Looking at the soil strength (see Fig 2), natural solutions exhibited strengths ranging between 10 and 20 kPa after 3.5 months, with the reference remaining around 5 kPa. This explains why the two depots that were treated with Medeina were accessible up to 80% of their surface, whereas only a quarter of the reference depot could be walked.

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# Adaptive Management for environmental aspects of dredging and reclamation projects: Reactive and Pro-Active

**Boudewijn de Crop[1], Marc Kindermann[2], Alessandra Feola[3], Sina Saremi[4], Marc Huygens[5], Iolanda Lisi[3], Marc Brouwer[6], Robrecht Schmitz[7], Pierre-Yves Belan[8], Volker Steege[9], Wouter Schiettecatte[10]**

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**Conference theme number(s): 2, 3, 5**

**Introduction:** A number of publications, among which the CEDA information paper on Adaptive Management (AM), published in 2015 [1], contains a high-level description of the different aspects of AM. The descriptions are often generic and do not include details of AM of specific parameters yet. In this fast-evolving topic, a number of information gaps and subjects that require revision have appeared the past years. For instance, a topic which has undergone a considerable evolution in recent years is pro-active adaptive management of turbidity.

The CEDA Environment Commission (CEC) has therefore decided to establish a Working Group to prepare a CEDA information paper on (Pro-active) Adaptive Management in dredging and land reclamation projects [2]. The paper provides an overview of existing tools and platforms to implement AM and recommended best practises. Also, a questionnaire on the awareness and experience with AM was launched in the industry and a significant number of responses was received from all different types of stakeholders in dredging and reclamation projects. It was found that significant awareness of the concept of Adaptive Management exists in the industry, but that the benefits of Pro-Active AM for environmental management are less known. Therefore, this aspect was covered in more detail in the paper. Finally, case studies demonstrate that (Pro-active) AM can help to guarantee environmental compliance.

**References:** [1] CEDA (2015): Integrating adaptive environmental management into dredging projects. CEDA Position Paper; [2] CEDA (2024) : ADAPTIVE MANAGEMENT FOR ENVIRONMENTAL ASPECTS OF DREDGING AND RECLAMATION PROJECTS: REACTIVE AND
PRO-ACTIVE.

# Dredging project and environmental monitoring programme in the O Burgo Estuary (A Coruña, Spain)

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**Conference theme number(s): 1, 3**

**Introduction:** The O Burgo estuary has been the recipient of numerous discharges for years that deteriorated the quality of its waters and created a layer of polluted sediments from industrial and urban discharges. The removal of contaminated materials from the estuary and their partial restitution by new zero polluted sediments will improve the quality of the waters and the bottom of the estuary, thus promoting the recovery, productivity and quality of the shellfish banks located there, as well as the recreational uses of the area.

This project includes a dredging of 583,337.04 $m^3$ in the estuary and a total investment of approximately €40 million. The complexity of this dredging is conditioned by three factors: 1) it is an environmental dredging, not designed to get sand or increase draft. To do this, it is necessary to remove only the upper layer of polluted sediments (which constitute a thin layer 50 cm width) and replace them with clean sediment; 2) the Ria de O Burgo is a closed estuary with a very shallow draft, subject to large tides with tidal range up to 4.5 m, with suspended mud that lacks bearing capacity and can disperse pollution while dredging. In addition, there are large areas very shallow even with high tides; 3) it has great environmental consequences, being an estuary of high environmental value, with a great wealth of wintering birdlife, seagrass meadows and where shellfishing is an important socio-economic activity.

**Methods:** The dredging of material with the highest contamination levels, involves a treatment that allows the retention of the materials to later be confined close to the project location, generating green spaces and giving continuity to paths and walkways. The material with the lowest contamination was initially thought to be dumped to the sea.

The discharge of the lixiviated water was carried out in the Fonteculler lagoon ensuring, by means of sensors, measurement systems and periodic analytical controls, rigorous environmental control. Following the environmental monitoring programme, special attention was paid to the control of water and environmental quality and the use of continuous measurement sensors for the different parameters. Once the dredging was completed by mid 2024, clean aggregates were provided for the recovery of the intertidal zone, restoration of channels, improvement of shellfish banks, regeneration of the bottom of the Culleredo lagoon and Santa Cristina beach. After the end of the project 70,000 $m^2$ of public spaces will be recovered.

**Fig. 1:** Areal view of the confined dredging facility in Culleredo.

**Results and discussion**: The Culleredo marshes, of more than 227,000 $m^2$, have been excluded from the intervention in order to preserve the seagrass meadows and the main habitats of wintering birds. Other activities carried out in the field of environmental conservation have been the periodic analytical control and collection of the affected shellfish species before the start of the work and their subsequent replanting with seeds from hatcheries and the transplantation of the protected marine phanerogam *Zostera noltii* and the elimination of invasive exotic species such as the pampas reed "*Cortadeia Selloana*". mainly present under the bridge of the A9 motorway located close to the dregding site. In all these works, we have had the expert collaboration of the shellfishmen of the estuary, great connoisseurs of the terrain and the special circumstances of their work for the improvement of the environmental quality of the O Burgo estuary.

Investment made by the Directorate-General for the Coast and the Sea (co-financed by the European Regional Development Funds 2014-2020)

# A Citizen Science Method: Engaging non-experts in monitoring river sediment and morphological changes.

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**Conference theme number(s): 4**

**Introduction:** The DANUBE4all project aims to develop a strategic Danube Basin Restoration Action Plan (DBRAP), integrating environmental, economic, and social objectives for sustainable river basin management. Acknowledging that the success of measures in a River Basin highly depends on the involvement of citizens, local communities, businesses and other stakeholders, the project deals with the development of several new Citizen Science (CS) monitoring methods that empower citizens to become active observers of the changes in connectivity that occur as a result of restoration measures planned in this project and beyond. [1]

**Methods:** We are developing these CS methods as a tool that enables citizens to systematically observe and document river sediment and morphological changes, contributing to both local and scientific understanding of river dynamics. We will include the following **(Fig. 1)**.


**Fig. 1:** Tools for Monitoring

The CS methods will be piloted at the Upper Danube Region around the Vienna area. The initial idea is to split the toolbox into two parts.

1. Physical Toolbox: This includes measurement instruments like the one developed in [2], aimed at interested and involved citizens who will receive training and guidance from the project team. This ensures both data quality and participant safety, as measurements will take place within (smaller) rivers.
2. Erosion monitoring: Focused on broader citizen engagement, this only requires a smartphone, allowing a larger group to contribute data on any river size through a simple, accessible method. A similar method was used within [3].

How intensively a HYMO survey will be included in either part is still under discussion.

**Results:** As the CS methods are still in its early development stage, extensive tests are planned for spring 2025. The mini sieving tower already went through a first testing phase, Pouwels [3] tested the reliability of this CS method compared to the lab method. First tests showed promising results, including statistical analyses.

**Discussion:** These CS methodologies have strong potential to strengthen citizen involvement in monitoring river sediment and morphology, providing valuable data that complements professional assessments. The initial tests will evaluate the reliability of citizen-collected data and show the need for necessary quality control measures. Ultimately the CS methods will be adapted for the whole Danube River Basin and other river basins.

**Acknowledgements:** The DANUBE4all project is funded by the European Union's Horizon Europe research and innovation program under grant agreement no. 101093985. The authors would like to thank Philipp Gmeiner, Marlene Haimann, Mario Klösch, Rolf Rindler and Marcel Liedermann from BOKU University for their valuable support and contributions to this work.

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# Citizen Science and Macroinvertebrate Monitoring: Key Learnings from the CS4Rivers Project

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**Conference theme number: 4**

**Introduction:** Rivers provide habitat for a diverse range of aquatic organisms, including fish, benthic organisms, phytoplankton and zooplankton [1]. However, the alteration of riverbed habitats and disruption of natural flow dynamics pose direct threats to the survival of various aquatic species [2]. Monitoring water bodies is a significant challenge for relevant authorities due to the extensive length of stream networks and the substantial resources required in terms of time, labor, and finances.. Consequently, citizen science (CS) is becoming increasingly important in environmental research and monitoring, including studying river environments [3].
In this context, a CS project - CS4Rivers - has introduced a new approach to monitoring habitat Quality throughout the analysis of macroinvertebrate communities used as an indicator to assess sediment healthy.

**Methods:** CS4Rivers guided by the University of Siena (Italy), within the NBFC with NRRP funds, is active in the Ombrone river basin (South Tuscany, Italy), throughout various monitoring activities, including assessment of chemical water quality, macroinvertebrate community and riparian vegetation.
For macroinvertebrates, CS4Rivers employs a new protocol called IBS (Simplified Biotic Index), a simplified version of the Italian IBE (Extended Biotic Index). Following a specific protocol, citizen groups collect samples twice a year at the same sites. Data Quality is verified by comparing volunteers-collected data with expert assessment. To support volunteers, detailed training and support material have been developed.

**Results:** Preliminary results indicate that the IBS effectively identifies critical or valuable conditions in macrobenthic communities. Volunteers will be interviewed using tailored surveys to further evaluate the project's strengths and challenges.

**Discussion:** After this initial phase of data collection and survey analysis, adjustments to the methodology can be made to enhance accuracy and inclusiveness. These steps will also help improve the perception and engagement of volunteers.

**Acknowledgements:** The authors would like to thank all the volunteers participating in the project and all the stakeholders involved in supporting CS4Rivers.

**References:**
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[2] Damseth, et al. (2024) *HydroReaserch* **7**:122-130;
[3] Kelly-Quinn et al. (2020) *Hydrobiologia* **850**:3419–3439

# Remediation of polluted marine sediments in Bergen city harbour; a collaborative approach to environmental conservation

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Conference theme number(s): 4

**Introduction:** City of Bergen is Norway's second largest municipality, located on the west coast which has several harbour areas polluted from historical industrial activities. Project Clean Harbor, managed by Agency for Urban Environment, attempts to improve the condition of some of these areas. Several major seabed restauration projects situated in the inner city has been carried out. The project removes pollution and restores the sea bottom, but to ensure that the remediated areas will be kept in good condition a collaborative approach is needed. The project strongly encourages and facilitates efforts to monitor effects of the restored sea bottom. All these extra efforts are communicated with the aim to increase both public awareness and scientific interest, with the overall aim to increase awareness of the collaborative effort needed to preserve the inner-city fjord.

**Methods:** To assess the level of pollution and condition of the marine environment, thorough sampling and monitoring programs are applied. This includes traditional sampling and analyses of sediments, biota and water, but also the use of USV, drones, and tracking of organisms. Clean Harbour Bergen is involved in both national and international research projects that present a novel approach over the effect of urban sediment remediation on fish communities [1, 2].

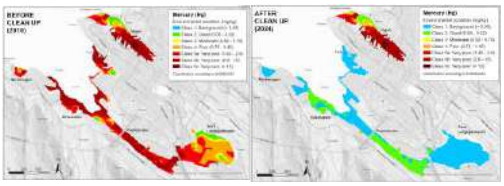

**Fig. 1:** Marine Seabed restoration in Bergen inner harbour greatly reduces the levels of several damaging toxins, here showing mercury (Hg) before and after.

**Results:** The Clean Harbor project in City of Bergen has managed to engage various NGOs, companies, researchers, startups and public managers to collaborate and make the most of what could "just" have been capping of polluted marine sediment. This highly collaborative approach to environmental conservation has several upsides both within public awareness of harbour diversity but also increased scientific and management understanding of how urbanization affects coastal marine habitats and how restoration potentially can mitigate ecosystem services. The knowledge gained within this cluster of different actors has been communicated both using media and the city's official channels for public communication and also through large exhibition at the city's aquarium.

**Discussion:** A well-functioning coexistence between needs, considerations and interest in society and industry activities demands cross sectorial involvement of both research, industry and regulatory bodies.

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[2] Fossum, TO, Sture, Ø., Norgren-Aamot, P., Hansen, IM, Kvisvik, BC., Knag, AC. Underwater autonomous mapping and characterization of marine debris in urban water bodies. arXiv (2022). DOI:10.13140/RG.2.2.20080.74249

**Please submit your abstract before the 17th of January 2025 to the SedNet secretariat: secretariat@sednet.org.**

# Sediment Literacy: Empowering Future Generations for Sustainable Interactions with Natural Resources in an Increasingly Complex World

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**Conference theme number(s): 4**

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**Introduction:** Sediments are fundamental to ecosystems and human development. As demands on rivers, oceans, and coastal areas grow - from transportation and hydropower to fisheries and cooling networks - conflicts over their use grow, driven by climate change and competing interests. At the same time, misinformation, the lack of willingness to engage deeply with complex topics, and the rapid spread of polarizing narratives through social media hinder public understanding of these challenges. To address this, basic sediment literacy is not only essential for understanding processes that enable informed and sustainable decisions in the management of rivers and oceans. It empowers individuals and communities to engage critically in decision-making, fostering sustainable interactions with natural resources in an increasingly complex world.

**Methods:** Education plays a vital role in addressing these issues, aligning with the principles of good governance. Institutions have a responsibility not only to ensure transparency and accessibility of information but also to actively disseminate and contextualize this information for diverse audiences. Knowledge transfer between scientists, policymakers, stakeholders, and citizens must be prioritized to foster shared understanding and collaboration.

This contribution draws on the author's background in risk communication and disaster risk reduction to propose strategies for fostering sediment literacy. International examples of successful formats for promoting risk literacy and geological literacy - including interactive workshops, community engagement initiatives, and participatory learning models - are explored [1]. These examples provide a framework for developing literacy programs that are both impactful and adaptable to various contexts.

The potential of artificial intelligence (AI) to deliver tailored educational content is also emphasized. AI can be leveraged to create age-appropriate materials, analyze learning outcomes, and adjust content to meet the needs of different demographics. This technology holds promise for enhancing engagement and ensuring that educational initiatives resonate with their intended audiences. Additionally, the role of digital platforms such as Instagram and TikTok is critically evaluated. While these tools have the potential to engage younger audiences, their effectiveness depends on their integration with other educational approaches, such as museum exhibits and school curricula development. Questions remain about how these methods can complement one another and whether their combined use can create a more comprehensive educational strategy.

**Results:** The proposed approaches demonstrate significant potential for equipping individuals with the knowledge required to navigate the complexities of sediment management. By integrating AI-driven tools with traditional and digital educational platforms, these initiatives create accessible and engaging content tailored to diverse audiences. International case studies illustrate how participatory learning can deepen understanding and prepare society to address the challenges associated with water body management and sediment dynamics. These strategies provide actionable frameworks for fostering public awareness and improving decision-making processes in various contexts related to sediments as a natural resource.

**Discussion:** Education is a cornerstone in all sustainable resource management, bridging the gap between technical expertise and public engagement. In addition to advancing understanding of sediment dynamics, effective educational strategies align with the principles of good governance. Institutions have an obligation to provide transparent, accessible, and contextualized information, ensuring that the public can actively participate in sustainable decision-making processes. By emphasizing their responsibilities, institutions can build trust and collaboration among stakeholders. Without such efforts, even the most robust management measures risk failure due to public resistance. Leveraging AI and innovative educational methods, sediment literacy becomes a pathway to informed decisions and sustainable practices.

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# Dirt or no Dirt, that is the Question - Improving Citizens Sediment Literacy

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**Conference theme number(s): 4**

**Introduction:** This presentation will summarize the work within the citizen science and communication work package of the national project "Improvement of Ecosystem Services in the Reinfeld Ponds" (VerTe). The Reinfeld ponds are an interconnected system of artificial lakes in the center of the German city of Reinfeld, that is used for leisure activities (rowing, swimming stand-up paddling) but also for raising carp. The ponds receive drained surface run off from nearby agricultural fields, and effluents from domestic sewage treatment plants. When local politicians observed the ponds silting up, the prevailing opinion in the political committees of the city of Reinfeld was that dredging would be the appropriate solution. The project VerTe was then initiated to broaden the spectrum of possible measures. Its objective is to identify sustainable solutions that mitigate sediment accumulation while preserving and improving biodiversity of the water bodies. The diversity of interests that come into play when considering the future development of the ponds required a work package dedicated to information, education and participation for stakeholders and the community, including citizen science activities. In Germany, the term "citizen science" has a broad meaning from developing the scientific question to the development of a project, data collection, scientific evaluation and the communication of results [1]. In this project, citizen science is used not only for communication but also for experiencing nature and research in nature.

**Methods:** Target groups within the Citizen Science work package in the VerTe project are on one site children (3 to 10 yrs) and on the other site adult stakeholders such as farmers, city citizens, city council members, representatives of leisure activity groups etc. For children, events are organized that comprise 1. A story about the life of Lilly the dragonfly or – for sediment-related events Sam, the pond snail. 2. Feeling different types of sediment in a barefoot path, 3. Discovering and examining different pond inhabitants, 4. Artistic processing of the experience. Primary school pupils are asked afterwards to evaluate the event via a standardized online survey with regard to gaining of knowledge and awareness about the problems with sediment as a habitat and questions concerning the knowledge about importance, benefits and problems of biodiversity Adult stakeholders are engaged in (1) a series of interactive workshops with the aim to cooperatively perform to a system analysis, and (2) in a field work event on sediment focusing on endo- and epibenthic life.

**Results & Discussion:** Since August 2022, 24 events with children were held with a total of 400 participants. 5 work shops were organized for adult stakeholders, with 20 to 30 participants each, some of them taking part in several of the meetings. Next to a system analysis, the workshops resulted in a conceptual plan for measures to improve the biodiversity of the ponds.
The experience with the different events will be shared during the presentation, and the participants' evaluation of the workshops and children's events will be discussed in the light of sediment literacy of the participants, the perspective of children and their inspiration for further scientific research in nature.

**Fig. 1:** *Children`s program*

**Acknowledgements**: The project is funded by the Federal Agency for Nature Conservation Germany in the Federal Program for Biological Diversity. Thanks go out to the colleagues who contribute to the implementation of the workshops and all participants.

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# Evaluation of a Continuous Sediment Ebullition Monitor

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**Conference theme number(s): 5**

**Introduction:** Understanding occurrence, frequency and distribution of gasses released from subaqueous sediments into the overlying water column (ebullition) can play an important role in contaminant flux and transport to the surface. Gasses are produced by microorganisms decomposing organic matter under anoxic conditions in the sediment. These processes occur naturally in the environment, in addition to contributions from degradation of organic contaminants that may contribute to the overall gas release from aquatic ecosystems. Hydrophobic contaminants located within the sediment bed can adhere to the surface of the gas bubble and may result in transport and redistribution to the surface water column. Accurate monitoring of gas flux from the sediments is used to support risk evaluations, remedy decisions and remedy design. Various methods have been employed to monitor this phenomenon, each with unique advantages and limitations. As the production and ebullition of gasses is driven by many dynamic factors, a continuous in-situ method is ideal for developing a process-based understanding of ebullition to be included in site-specific or global models. An autonomous sediment ebullition monitor was developed by Eosense, designed to continuously monitor gas flux from sediment and capture temporal variability.

**Methods:** The sediment ebullition monitor was designed and developed based on previous work by Varadharajan et.al.[1]. The main instrument components consist of an inverted funnel and gas collection column, stabilized by a tripod system that rests on the sediment bed. There is an auto-siphon in the gas column to allow for continuous operation of the instrument. Sensors to measure the gas volume inside the chamber are included along the length of the column, along with peripheral sensors to measure water temperature and water depth. The system is supported by a datalogger and solar power at the water's surface. Two different iterations of the design were deployed as pilot projects in diverse environments, including 1) a rain basin located within an industrial facility, and 2) a publicly owned waterway. The pilots were designed to test the operation and instrument performance over a continuous and extended monitoring duration, and to evaluate variable influences (such as air temperature, water temperature, barometric pressure, water levels) on measured ebullition rates.

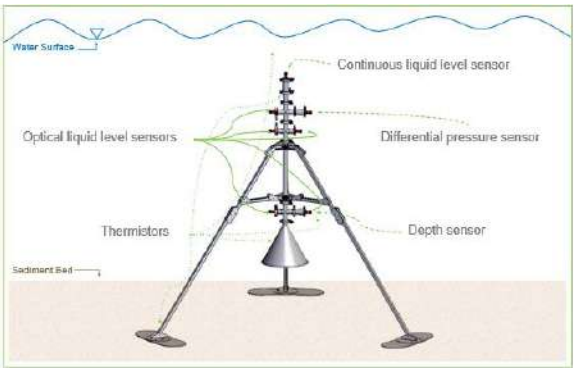


**Fig. 1:** *Schematic of the sediment ebullition monitor*

**Results:** The performance of the sediment ebullition monitors for each field pilot will be presented. Design improvements that were made from the first iteration to the second, based on challenges encountered in the pilots will be reviewed for efficacy. A continuous ebullition flux dataset will be presented, and a comparison of ebullition fluxes measured by the instrument over an extended period relative to historical manual short-term measurements. These data will be compared to previous flux data from similar waterways, as an alternative approach to traditional ebullition measurement tools and practices. Recommendations will be given for best practices in continuous sediment ebullition monitoring.

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# On-site sediment toxicity monitoring using a field operable biosensor (SUNDANSE)

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**Conference theme number(s): 5**

**Introduction:** In light of the fact that sediments can be a critical source of bioavailable toxic contaminants affecting both the environmental biogeochemical of water bodies, as well as its biodiversity. Their remediation can have a detrimental effect on aquatic life when dredging or other techniques are used. The present study thrives to provide policy makers with hard data in terms of providing a picture over the course of a river such as the Danube in terms of its toxic potential. For this we propose a field-enabled biosensor.

**Methods:** Genetically engineered E. coli cells were im-mobilized on a fiber optic tip using a calcium alginate matrix. This method enhances detection sensitivity by placing the bacterial cells in direct contact with the fiber optic surface, maximizing the bioluminescent signal in response to genotoxicants[1, 2]. Sediment samples were collected from six different sites around Israel, that are suspected to be contaminated. The sediments were placed in Eppendorf tubes containinSg DDW. Alginate immobilized tip of a multimode optical fibres, SFS400/440 (Fibreguide Industries, Inc., USA), was placed inside the sediment suspention, while the other tip of the fiber was connected to a photon-counting PMT detector HC135-01 Hamamatsu Photonics, Japan). The PMT detector was interfaced with an in-house developed board for signal acquisition. This setup was placed in a light-proof case, that was sealed during measurements.

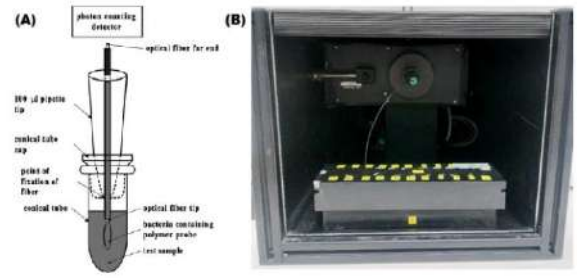


***Figure 1:*** *(A) Instrument set-up demonstrating the components used in the experiments for the bioluminescent measurements using the optical fiber tip optrode whole-cell biosensor (B) A photo of the biosensor system.*

**Results:**

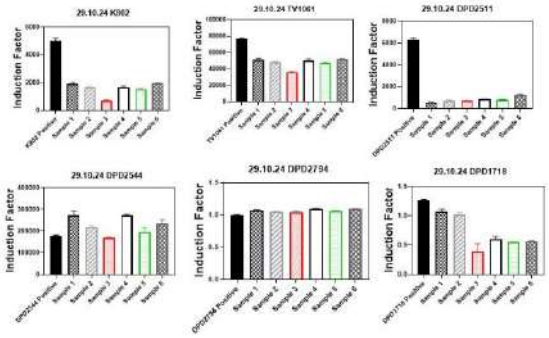


***Figure 2:*** *Bioluminescent response of six bacterial strains (DPD2794, TV1061, DPD2544, DPD1718, K802NR, DPD2511) to sediment samples from six different sites measured using the biosensor system.*

**Discussion:** The results demonstrate the effectiveness of the fiber optic-based bioluminescent biosensor in detecting sediment toxicity across multiple sites, with variations in bacterial strain responses indicating differing sensitivities to specific toxins. Spatial variability in toxicity likely stems from diverse pollution sources, sediment composition, and hydrodynamic conditions. These findings align with previous studies, reinforcing the utility of bacterial bioreporters as a rapid and reliable tool for environmental toxicity assessment[1-4].

**References:**[1] B. Polyak, E. Bassis, A. Novodvorets, S. Belkin, R.S. Marks, Sensors and Actuators B: Chemical, 74 (2001) 18-26.
[2] B. Polyak, E. Bassis, A. Novodvorets, S. Belkin, R.S. Marks, Water Science and Technology, 42 (2000) 305-311.
[3] E. Lior, T. Axelrod, E. Eltzov, A. Kushmaro, R.S. Marks, The EuroBiotech Journal, 2 (2018) 47-58.
[4] A. Ivask, T. Green, B. Polyak, A. Mor, A. Kahru, M. Virta, R. Marks, Biosensors and Bioelectronics, 22 (2007) 1396-1402.

# Enhancing Harmful Heavy Metal Contamination Profiling in Coastal Sediments: A Modified Geochemical Index Approach

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**Conference theme number(s): 2, 5, 6**

**Introduction:** Sediment contamination by harmful heavy metals (HHMs) poses significant risk to ecosystems and human health. Historical mercury (Hg) data from Cartagena Bay (CB), Colombia (1996-2024) were analyzed. A modified geochemical index ($mP_d$) is proposed for improving sediment vertical contamination profiling for a more accurate sediment contamination than traditional approaches, surface-level assessments. Numerical results suggest its potential applicability to various coastal areas.

**Methods:** The proposed index builds on existing geochemical indices: pollution degree ($P_d$) [1], contamination factor ($CF_n$) and geo-accumulation index ($I_{geo}$) [2]. Empirical Hg data from CB validated the approach. Hg was selected as target HHMs due to its persistent impact on CB over the last three decades. The existing indices $P_d$ and $CF_n$ are mathematically equivalent since $P_d = CF_n - 1$. $I_{geo}$, a logarithmic scale of $CF_n$, aligns with $P_d$ and $CF_n$, but with a rescaled value:

$$I_{geo} = \ln\left[\frac{C_n}{B_n}\right] / \ln(2), \quad (1)$$

where $I_{geo}$ ln(2)=Dh, $D$ being diffusion in a sediment layer of thickness $h$. The vertical concentration profile is $C_n(z)=B_n\ exp(Dz)$ for $z \in [0,h)$; with $h(t) = b_0 + wt$, where $b_0$ is the initial thickness and $w$ the sediment accumulation rate. Using the molecular diffusion equation:

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial z^2}. \quad (2)$$

where porosity and tortuosity limit diffusion, the boundary conditions are defined as:

$$C(z=0) = B_n \text{ and } C(z = b_0 + wt) = C_n. \quad (3)$$

Solving (2) and (3) yields:

$$C(z,t) = B_n + (C_n - B_n)\left[1 + \text{erf}\left(\frac{z - wt - b_0}{2\sqrt{Dt}}\right)\right]. \quad (4)$$

Integrating over z from 0 to h(t) normalizing by $h$ and $B_n$, gives the modified pollution index:

$$mP_d = P_d[1 + F/h]. \quad (5)$$

where $F$ is the integral of the solution. As t→∞, F/h=1/2, and $mP_d$ varies from $P_d$ to 1.5 $P_d$.

**Results:** Hg contamination of CB varied significantly from 1996 to 2024. The highest index values were near urban areas in regions influenced by the Dique Channel, reflecting significant anthropogenic inputs from industrial discharges. The central and southern regions had much lower index values indicating less Hg contamination. Results highlight the importance of including sediment transport processes in future studies to better understand Hg distribution and long-term effects in this ecosystem.

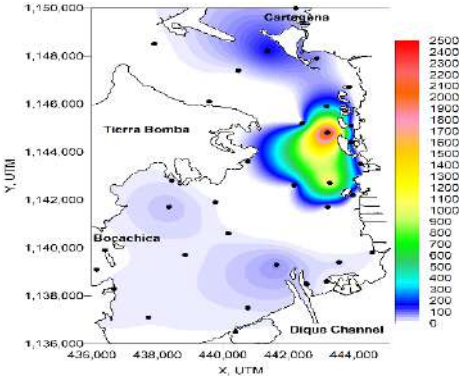


**Fig. 1:** Results of the $mP_d$ in sediments of CB.

**Discussion:** Hg concentrations decrease from the industrial zone toward Bocachica and Tierra Bomba, influenced by suspended sediment transport driven by a pycnocline and bedload transport, which redistributes sediments and supports pro-delta growth near the levee channel. The sediment dynamics and release of particulate Hg obscure the link between proximity to the Dique Channel and contamination levels. By accounting for processes like diffusion and sediment interactions, this approach provides an accurate assessment of HHM distribution, overcoming limitations of traditional geochemical indices and aiding environmental remediation. The $mP_d$ reliably evaluates HHM in vertical sediment profiles.

Additional sediment quality issues in CB will be presented during the 2025 SedNet conference.

**References:** [1] M. Fukue et al. (1999) *Eng. Geol.* **53**: 131-137. [2] L. Hakanson (1980) *Water Res.* **14**:975-1001. [3] W.T. González Cano, K. Kim (2022) *Sustain.* **14**: 14821.

**Acknowledgements:** This research was supported by the Korean Institute of Ocean Science and Technology, (PEA0201 and KIMST-20220027), Korea (Rep. of).

# LandSeaLot: improving (also sediment dynamics) observation capacity in the land-sea interface area

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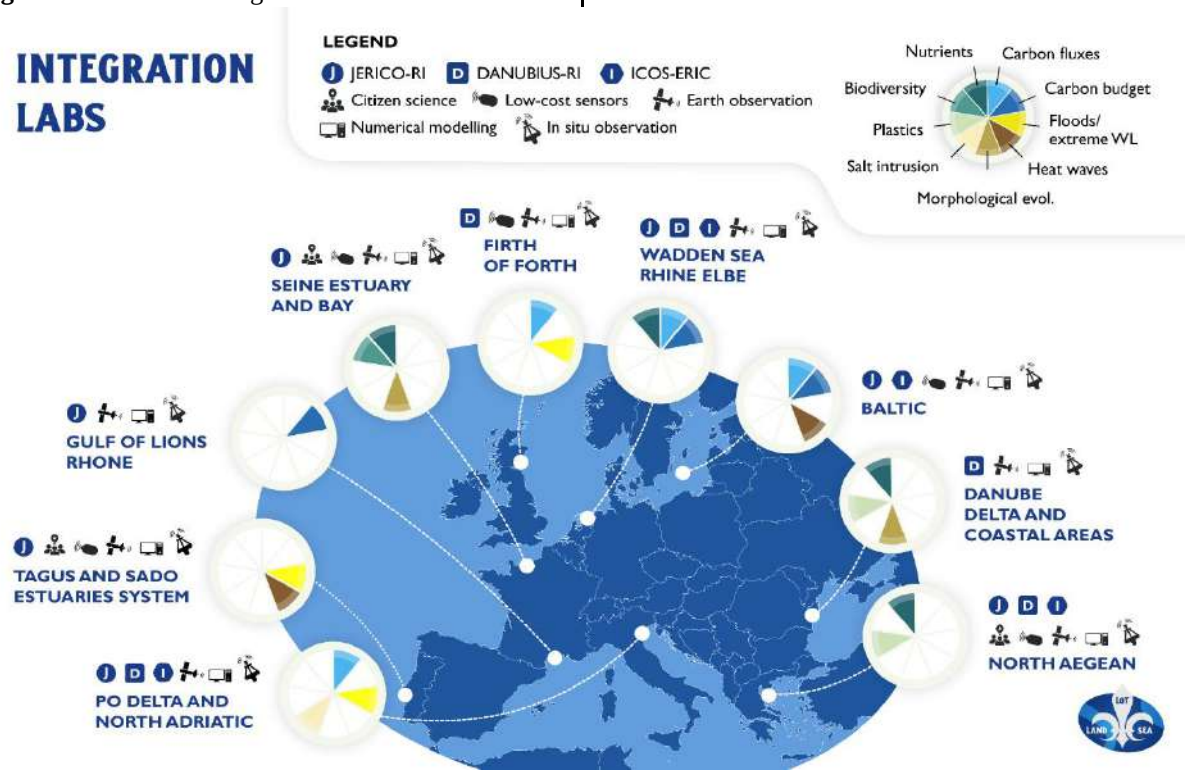
**Conference theme number(s): 5. Data Collecting, Sharing and AI**

The Horizon Europe funded project LandSeaLot (February 2024 – January 2028) links *in situ*, model and earth observations (EO) together and connects related communities, citizens and initiatives such as Copernicus, ESA, EEA, GEOSS, EMODnet and the European Digital Twin of the Ocean. All engage in a gap analysis used to co-design a joint and common land-sea interface observation strategy and its implementation plan.

LandSeaLot experts simultaneously work on improving: *in situ* and EO capabilities, models to reduce the model/observations gap and the integration of model, *in situ* and satellite data. Observation capacity is mainly increased through tested, improved and guided use of low-cost sensors by citizens, facilitated by the network of European marinas. The sensors identified are piloted in Integration Labs (Ils) together with improved and integrated in situ and EO observations techniques and model outputs.

LandSeaLot ILs cover strategically selected areas in the Black, Aegean, Mediterranean, Atlantic, North and Baltic Seas, with a range of catchment, tidal and meteorological regimes (see Fig. 1).

**Fig. 1:** LandSeaLot Integration Labs




In LandSeaLot experts and citizen science initiative leaders will work in the ILs together with JERICO-RI, DANUBIUS-RI and ICOS-RI and with regional policy makers and managers to tailor integrated observations that will provide them information to manage societal challenges. These include assessment of morphological evolution (**sediment dynamics**), the lateral carbon fluxes and stocks, plastics transfer, nutrients impact on primary production and eutrophication, supporting biodiversity conservation, improving modeling capability and supporting climate change adaptation (storm surge, floods, heat waves, **coastal erosion**, saltwater intrusion).

Data generated in the ILs will be made FAIR available via EMODnet and interoperability and semantic solutions for existing, international data flows will be developed.

Relevant communities are engaged by workshops, conferences, trainings, a high-tech summit and by a communication strategy including videos and policy briefs to ensure LandSeaLot's legacy.

**References:** https://landsealot.eu

# Introducing the Sediment Management Framework Application

**Claire Mason[1], Roi Martinez[1], Sylvia Blake[1], Kirsty Clarke[1], Joe Perry[1], Jemma-Anne Lonsdale[3] & Richard Heal[2]**

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**Conference theme number(s): 5**

**Introduction:**
Shifting the perception of sediment disposal from a waste stream to a potential beneficial material use presents many challenges [1]. Chief among these is the need for an understanding of the contaminants within sediments at extraction and potential disposal sites. A key element to achieving this is accurate and reliable historical data, a need for the operator and the regulator alike.

In England (and Northern Ireland) the Marine and Coastal Access Act 2009 [2] requires that anyone wanting to perform a dredging activity must apply for a Marine Licence Application (MLA) through the Marine and Maritime Organisation (MMO). Applicants are required to ensure adequate sediment analysis is performed and results are supplied by the applicant via a bespoke results template along with the other MLA documents. Despite these results being publicly available via the MLA public register, no single repository for the data for England was available. Here we describe a purpose-built database and web-based application, the Sediment Management Framework Application, that makes quality-checked contaminants data freely available and adopts the FAIR principles (Findability, Accessibility, Interoperability, Reuseability).
In a complementary paper, we detail a sister web-based application that ensures up-to-date, quality assured data is added to the contaminants database in a controlled and audited manner [3].

**Methods:** Dredge sediment contaminant concentrations, including trace metals, organotins, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides (OCs), and polybrominated diphenyl ethers (PBDEs) data collated under the Action Level Review Project (ME5226/ C7590) by Centre for Environment, Fisheries and Aquaculture Science (Cefas) [4]. The purpose of this study was to determine potential impacts of proposed action levels in the assessment of dredged sediment for licensing of disposal at sea. A bespoke database was created to host quality checked sediment data and potential action levels for their use. To visualize the data, and provide guidance on their collection and potential use, a web-based app was created in R-Shiny that connected to the database and allowed easy to use spatial and temporal analysis of the data and the application of action levels.

**Results:**

**Fig. 1:** *Sediment Management Framework Dashboard*

The application can be found at https://rconnect.cefas.co.uk/content/692515e9-65a5-41d8-9117-79a9798a0519 and a screen shot is shown in Fig. 1. Users can select and download dredge sediment contaminant concentrations from a dashboard, apply action levels, as well as find out more about the licensing process for dredge sediment assessment.

**Discussion:** Ensuring all stakeholders have sight of the available data is essential to progressing more sustainable use of dredge material, and will support restoration initiatives [5].

**Acknowledgements**: Cefas colleagues & involved in the Action Level Review Project (ME5226/ C7590).

**References:** [1] USAR (Sediment Recycling Strategy) (2018); [2] Marine and Coastal Access Act (2009) [3] Heal et al, SedNet 2025 [4] Mason, C. et al. (2022) Reviewing the UK's Action Levels for the Management of Dredged Material. Geosciences 2022, 12, 3. https://doi.org/10.3390/geosciences12010003 [5] Manning WD, Scott CR, Leegwater E. 2021. Restoring estuarine and coastal habitats with dredgedsediment: A handbook. Bristol, UK: Environment Agency https://catchmentbasedapproach.org/wp-content/uploads/2021/10/Restoring-Estuarine-and-Coastal-Habitats-with-Dredged-Sediment.pdf

# Using a web application to ensure quality-assured data entry into an open access sediment contaminant database

**Richard Heal[1], Sylvia Blake[2], Kirsty Clarke[2], Joe Perry[2], Jemma-Anne Lonsdale[3] & Claire Mason[2]**

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**Conference theme number(s): 5**

**Introduction:** Shifting the perception of sediment disposal from a waste stream to a potential beneficial material use presents many challenges [1]. Chief among these is the need for an understanding of the contaminants within sediments at extraction and potential disposal sites. A key element to achieving this is accurate and reliable historical data, a need for the operator and the regulator alike.

In England (and Northern Ireland) the Marine and Coastal Access Act 2009 [2] requires that anyone wanting to perform a dredging activity must apply for a Marine Licence Application (MLA) through the Marine and Maritime Organisation (MMO). Applicants are required to ensure adequate sediment analysis is performed and results are supplied by the applicant via a bespoke results template along with the other MLA documents. Despite these results being publicly available via the MLA public register, no single repository for the data for England was available. In a separate paper we describe a purpose-built database and web-based application [3] that makes quality-checked contaminants data freely available and adopts the FAIR principles (Findability, Accessibility, Interoperability, Reuseability).

In this paper, we detail a sister web-based application that ensures up-to-date, quality assured data is added to the contaminants database in a controlled and audited manner. In doing so, the application also supports the marine advisors during the process of vetting the Marine Licence Application.

**Methods:** The Disposals Database Quality Control app was developed as web-based R-shiny application [4] and employs the packages *openxlsx* [5] to upload the MMO Licence application, *pool* [6] for database connectivity, *sf* [7] for manipulation of spatial data, and *leaflet* [8] for mapping of sample sites.

**Results:** A web-based app was designed to fit within the marine advisor vetting process. The app is linked to the sediment contaminant database to ensure quality control of the data prior to its inclusion (see Fig. 1). Under this workflow the marine advisor uploads the applicant's MLA Application form, and a series of automated checks are performed. The outcome of these checks is presented to the advisor. Any automated changes made, and potential areas for consideration, are highlighted and presented for manual editing if necessary (e.g. data using incorrect units). The approach is advisor led allowing them to make their own informed edits to the data, and all edits are recorded in an audit trail. Furthermore, the advisor can download a copy of the MLA template with any new changes or additions which they can return to the applicant for further work. Once complete the data is uploaded to the database, along with the audit information. This data is then immediately publicly available and searchable.

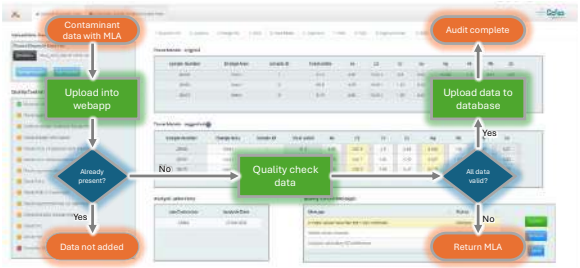


**Fig. 1:** *A web-based app for quality-assurance of sediment contaminant data.*

**Discussion:** We present here a workflow and application developed to ensure that the sediment contaminant database for England is routinely updated with the latest, quality-assured data that has been checked and audited by an expert advisor. Using this methodology, applicants for marine operations applications have the best and latest evidence available thus enabling them to plan and cost out the best options for beneficial use of any sediment resource created.

**Acknowledgements**: Cefas colleagues & involved in the Action Level Review Project (ME5226/ C7590).

**References:** **[1]** USAR (Sediment Recycling Strategy) (2018); **[2]** Marine and Coastal Access Act (2009); **[3]** Mason et al. SedNet 2025; **[4]** Chang et al Shiny: Web Application Framework for R (2024); **[5]** Schauberger et al (2024). _openxlsx: Read, Write and Edit xlsx; **[6]** Cheng et al. Pool: Object Pooling (2024); **[7]** Pebesma et al (2018) *The R Journal* **10**:439–446; **[8]** Cheng et al. (2024) Leaflet: Create Interactive Web Maps with the JavaScript "Leaflet" Library.

# Tools to Inform Sediment Assessment, Management, and Regulation: Book Update

**Richard J Wenning [1], Sabine E. Apitz [2]**

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**5.Data Collecting, Sharing and AI**

**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.

However, considerable progress has been made in establishing SQGs internationally for the prospective and retrospective assessment of sediments. National environmental agencies have advanced the understanding and value of their jurisdiction's unique marine and freshwater ecosystems. New monitoring tools for passive sampling, in-situ field monitoring, ecotoxicity testing, and eDNA provide deeper insights to healthy and poor sediment conditions. Further, significant developments have been made for assessing other lines of evidence required to inform sediment management in the 21st century.

**Need to Review Current State of Practice Involving Sediment Assessment to Support 21st Century Management:** The consensus recommendation from 2005 remains unchanged; current SQGs are useful for screening purposes and should not be applied as definitive determinations of sediment risk or cleanup goals [1]. Still, there is a strong desire to use SQGs for sediment monitoring, management, and regulatory purposes. A review of this practice is needed—where and why are SQGs used, and how old and new analytical and assessment tools can better inform decision-making.

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. Further, there is a need for a critical assessment of how various lines of evidence (LOEs) should be integrated to inform a range of management and regulatory decisions. New approaches and tools can help account for biodiversity, climate change, chemical mixture interactions, and different sediment management objectives.

Among the new sediment management tools quickly evolving in recent years are ecosystem-based approaches that consider non-chemical stressors. Approaches have been developed for evaluating previously un-assessed or sensitive species, predicting sediment mobility and transport, and *in situ* chemical and toxicity testing, and addressing adverse outcome pathways (AOP).

In this new edition of the SQG book, 17 chapters prepared by 65 experts working worldwide will discuss their work and collaborate to define a practical and meaningful future for sediment management. The book is planned in three parts: (1) a summary of current sediment assessment and toxicity testing methods used to determine sediment quality; (2) a review of the new and emerging methods for assessing healthy and poor-quality sediments in different aquatic ecosystems; and (3) a discussion of how sediment data are interpreted using tools such as SQGs, WOE, and statistical methods to inform different sediment management approaches. External peer review of this collaborative work before publication will strengthen its value for the academic, governmental, and professional communities.

The theme throughout this book effort is the question of whether both "classical" and emerging approaches are fit for the management of sediments in the 21st century. Global conditions, from sea level rise and increasing extreme events, to changes in population, production, consumption and pollution, are changing at increasing rates. Emerging contaminants, not generally assessed or regulated just two decades ago, are being detected in sediments globally. A drive towards circularity, including the valorization of sediments as a resource, rather than a waste, all have the potential to change "standard" thinking about how sediments should be managed. Are the assessment regulations and tools still fit for purpose? Do decision-makers have access to the data essential for modern, sustainable sediment management? What is the state of science in support of such goals, and what developments in science, engineering, and policy are needed?

Progress and highlights emerging from content of the book will be presented, along with a call for reviewers to get involved in this process, which, ideally, will be completed by the end of 2025.

**References:** [1] Wenning et al. (eds.) (2005) SETAC Press, Pensacola FL

# Time-integrated sediment quality monitoring in large rivers. Temporal variations in suspended and floodplain sediments in the Drava River.

**Samdandorj Manaljav[1], Gyozo Jordan[2], Zsófia Kovács[3], Katalin Dudas[4], and the SIMONA Team**

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**Conference theme number(s): 1 / 5**

**Introduction:** Sediments act as an important sink and secondary source of contamination for many hazardous chemicals as a major carrier of pollutants in rivers through geochemical processes at the sediment-water interface [1]. The study was carried out within the framework of the EU Interreg SIMONA project, which aimed at establishing appropriate sampling, analytical, and evaluation techniques, as well as time-integrated (quasi continuous) monitoring tools for sediment quality monitoring and assessment in the Danube River Basin countries.
This study aimed to evaluate temporal variations of examined elements in both suspended and floodplain sediments over a one-year monitoring period at the Barcs station in the Croatia-Hungary border section of the Drava River.

**Methods:** The sampling approach used two ISO standard sediment trap boxes (Joint Danube Survey 4; JDS4), originally developed for large rivers and adapted by the SIMONA project for shallow rivers. One JDS4 sediment trap box was submerged in Drava River, while other one was installed on the overbank of the river [2]. Suspended sediment trapped in the boxes were collected every months. The concentrations of the studied elements in sediment samples (<2mm) were analysed using inductively coupled plasma mass spectrometry (ICP-MS) after aqua regia digestion [3]. In addition, loss on ignition (LOI), total organic carbon (TOC) and total inorganic carbon (TIC) were measured.

**Results and Discussion:** The concentrations of TOC, Na, K, Al, Fe, P, in addition to Ni, Cr, Co, Cu, and Ba were significantly higher in floodplain sediments (high flow conditions) than those in river suspended sediments channel (baseflow conditions). This chemistry originates from soils and pollution sources eroded from the catchment slopes during heavy rainfall and related flood events. However, the concentrations of Ca, Mg, Sr, Li, Mn, in addition to Pb, Zn, Cd, and As, Hg, were higher or the same in river channel suspended sediments than those of floodplain sediments. This chemistry originates from groundwater draining the overwhelming calcareous rock in the Alpine hinterland and associated Pb-Zn Mississippi-type mineral deposits and historic mines, thereby defining a geochemical background.
Consistently, the time-integrated monthly suspended sediment concentrations of Ca, Mg, Sr, Li, Mn, Pb, Zn, Cd, and As, Hg remained constant during the monitoring experiment, while all the other analytes showed a statistically significant (95% confidence level) increasing trend from the beginning of the 2021 monitoring year.
Monthly peak concentrations for most studied elements were detected in March, May, and during the period from September to December.
Among the EU-defined hazardous substances, only Zn concentrations exceeded the Environmental Quality Standards (EQS) in both sediment types.

**Acknowledgements**: This research was co-funded by the European Union Fund, ERDF, IPA, ENI (DTP2-093-2.1 SIMONA project), and by the DanubeSediment_Q2 (DRP0200029), an Interreg Danube Region Programme project co-funded by the European Union.

**References:**

[1] Schubert et al. (2012) Trends in Analytical Chemistry 36: 58-70; [2] Šorša et al. (2019) EU Interreg Danube Transnational Programme SIMONA Project Output 4.1 45p; [3] Čaić Janković et al. (2019) EU Interreg Danube Transnational Programme SIMONA Project Output 4.2 37p.

# Suspended Sediment Load Prediction using Machine Learning models

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**Conference theme number(s): 5**

**Introduction:** Precise estimation of Suspended Sediment Load (SSL) is crucial, as it plays an important role in river management and is also associated to pollution, water quality, and ecosystem degradation. (K. Khosravi et al. 2022)
In recent years, numerous studies have demonstrated the ability of machine learning (ML) (D. Gupta 2021) models to accurately predict SSL, often outperforming traditional models due to their ability to capture implicit relationships within the data. As part of the Rhône Sediment Observatory (OSR), we propose an approach that considers streamflow and rainfall data collected from multiple stations to predict SSL across multiple tributaries of the Rhône River (France).

**Methods:** We used a Random Forest (RF) model to predict hourly SSL data from 2014 to 2024 based on observations from various streamflow and rainfall stations across each river basin. Two strategies are implemented: one considers the variables at the same time instance as the SSL, while the other uses variables at the time lag that maximizes their correlation with the SSL. Additionally, we developed a neural network model (CNN-LSTM) that considers sequences of lagged observations of the input data to capture temporal dependencies. The lag is treated as a hyperparameter, established within a window based on the correlation analysis performed in the RF model. To assess the performance of our methodology, the ML models are compared with a rating curve approach, namely the SiRCA model (M. Sadaoui et al. 2016), using coefficient of determination ($R^2$, ranging from 0 to 1, with the latter being the perfect score) and Root Mean Squarred Error (lower values indicate better performance). Moreover, we established and evaluated a Transfer Learning (TL) strategy using the proposed CNN-LSTM model to predict SSL in tributaries with limited data. For this approach the model was pre-trained on a *source river* identified as similar to the *target* river using clustering methods based on the statistical properties of the data. Then the first layer of the pre-trained model was frozen and the remaining ones were fine-tuned on the target data.

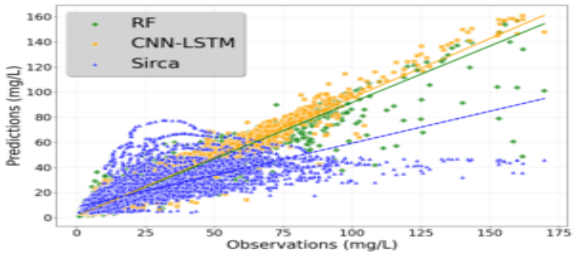


**Fig. 1:** Comparison of models: Saône river case

**Results:** While the empirical model (SiRCA) already demonstrates good performance for some tributaries with values ranging from 0.5 to 0.7, the performances are significantly improved by the RF and CNN-LSTM models ($R^2$ values around 0.9). For the tributaries where the SiRCA model does not perform well ($R^2$ values bellow 0.3), the ML models achieve $R^2$ values close to 1. Overall, the CNN-LSTM model outperforms the RF model across most tributaries by closely aligning with measured values and successfully reproducing hysteresis effects. Furthermore, while only using a small portion of data for training, the TL can achieve enhancement of performances up to 0.3 gain in $R^2$.

**Discussion:** The ML models consistently outperform the rating curve approach across all tributaries. Furthermore, variable importance analysis reveals that rainfall data contributes minimally to the models, suggesting that streamflow data from different stations is sufficient. The TL methodology proves to be effective, enabling significant performance gains when data availability is limited. However, one could argue that the variables used for classifying the rivers are not fully explanatory. More work can be done to get better clusters thus enabling more performance gain using TL.

**Acknowledgement:** I would like to express my deepest gratitude to the OSR team for ensuring the availability of data.

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# Streamlining erosion and sediment transport modelling: the 'pywatemsedem' package

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**Conference theme number(s): 5**

**Introduction:** A standardized model and scenario development procedure is crucial for effective use of simulation models for water erosion and sediment transport management [1]. The erosion and sediment transport model WaTEM/SEDEM [2], developed by KU Leuven, serves as a valuable tool for scientific research and soil management, offering a spatially distributed framework for assessing erosion and sediment dynamics. Its key strengths include the capability to compute net erosion and deposition in two dimensions, as well as its rapid computation time. However, the extensive data processing required and the numerous extensions available can pose challenges, making the transition from a base model to specific scenarios labour-intensive. To address this issue and operationalise WaTEM/SEDEM in Flanders, the government of Flanders has been financing the development of a Python API, 'pywatemsedem' aimed at providing data scientists with a tool to automate and standardize the data processing workflow for WaTEM/SEDEM.

**Methods:** The pywatemsedem package is designed to enable users to implement customized workflows for WaTEM/SEDEM using their specific source data. The package provides tools for clipping and transforming spatial data, generating and validating WaTEM/SEDEM inputs, and performing advanced post-processing and analyses. An example of user interaction is provided in a Jupyter Notebook. This example guides users through defining source data, setting up static model elements (e.g. an elevation model), selecting scenario options and processing functions, and executing data processing and model runs.

**Results:**
The development of the pywatemsedem package aims to enhance clarity in the methodology for processing data related to erosion and sediment transport modelling, thereby improving traceability and transparency in model usage. The package is developed to facilitate the implementation of WaTEM/SEDEM for policy and practice in Flanders, but is also generally applicable worldwide. An example application for different catchments in Flanders illustrates the key differences in erosion and deposition rates, and subsequent loads transported to the river (Fig. 1).

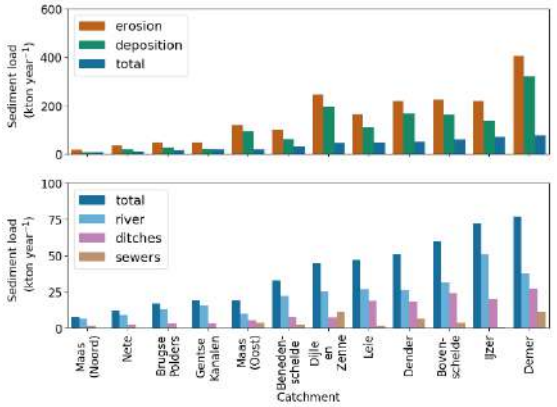


**Fig. 1:** Comparison of results for different catchments in Flanders (year: 2022).

**Discussion:** The package has been rigorously tested by the government and stakeholders in Flanders, generating valuable feedback to guide improvements and investments in user-friendly infrastructure. Future efforts will focus on expanding its user base to include academics, policymakers, and managers, while applying the package to regions beyond Flanders. Planned updates include advanced processing options for land use, erosion control, and transport coefficients, enhancing flexibility for diverse modeling needs. The WaTEM/SEDEM's source code is available on GitHub [2], with pywatemsedem to follow soon.

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[1] Choi, et al. (2021) *Environ. Model* **135**: 104888.
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# The synergistic use of bathymetric measurements and ADCP for the hydromorphological monitoring of waterways

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**Conference theme number(s): 5**

**Introduction:** This study aims to determine the complex relationship between river bed morphology and hydrodynamic forces to ensure safe navigation in river environments [1]. Using multibeam integrated bathymetry and Acoustic Doppler Current Profiler (ADCP) data, we aim to identify and analyze critical navigation hazards such as sediment deposition and erosion. High-resolution bathymetric maps are combined with ADCP-derived flow velocities to identify riverbed dynamics and predict changes over time[2]. The multi-beam bathymetric measurements are aimed at mapping the bed of the navigable waterway, and combined with the flow currents, flow rates and flow speeds, optimal solutions can be identified to reduce sediment transport, erosion, as well as the application of measures leading to the maintenance of the navigable channel.

**Methods:** The monitored site is located on the Danube River, with a length of 25 km. The alluvial riverbed is composed of different types of sand size. Approximatively 90% of sand is medium sand type with a $D_{50}$=0.36 mm. During the November 2024 survey campaign, with a low flow condition, multibeam bathymetric (MBES) and discharge and water velocity (ADCP) surveys were done. The MBES used was the EM 2040C by Kongsberg for the navigable channel and GeoSwath 250 kHz interferometric sonar for a very shallow section of river. The ADCP survey was made with Riversurveyor M9 ADCP by Sontek. With the aims of computing the combined measurements technique and comparing the results and overcoming the referencing errors, the original and the filtered bathymetries were resampled along the 25-km-long thalweg with a 1-m spacing.

**Results:** The multibeam bathymetric survey revealed a dynamic riverbed with features such as thalwegs, sandbars, and scoured pools. The main channel depth varied between 0.5 in shallow sandbar regions to 9 m in scoured pools. Sand dunes with crest heights of 0.5–1.2 m and wavelengths of 5–25 m were detected along the channel bed, particularly in regions of high flow velocity.

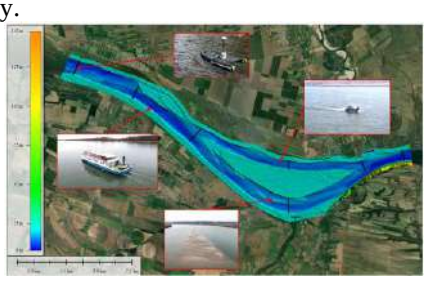

**Fig. 1:** November 2024 MBES, ADCP and SS from survey

**Discussion:** The combined survey of MBES and ADCP is very important for monitoring the sediment deposition, in terms of quantity and quality. In meander bends, secondary flow structures were evident, with velocity vectors forming helical patterns. These flows were strongest at outer bends, contributing to localized erosion [3]. High velocities and shear stresses in outer bends led to erosion and sediment entrainment, while depositional zones were identified in inner bends and downstream sandbars.

**Acknowledgments:** This work was supported by a grant of the Ministry of Research, Innovation and Digitization, CNCS/CCCDI - UEFISCDI, project number PN-IV-P8-8.1-PRE-HE-ORG-2024-0212, within PNCDI IV

The project PN-IV-P8-8.1-PRE-HE-ORG-2024-0212 is implement within the REXDAN Infrastructure.

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# Rivers do not only transport sediment: Monitoring and quantifying the instream large wood regime combining field and drone surveys and AI techniques

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

Rivers not only convey water and sediment from the mountains to the oceans but also transport and store large instream wood (i.e., downed trees, trunks, branches, and root wads laying on the river). Large wood's essential physical and ecological roles in channels and floodplains have been largely proven [1, 2]. The instream large wood, together with the flow and sediment, create habitats supporting abundant and diverse biotic communities, sustaining river´s health [3]. On the other hand, like sediment, large quantities of wood can be entrained (e.g., uprooted trees from riverbanks) and transported during floods, which can pose a danger to infrastructures such as bridges e.g., [4]. This has been the reason why instream large wood has been traditionally removed from rivers, without considering the potential environmental impacts [5], and although it continues to be indiscriminately removed, the practice of wood reintroduction as a river restoration measure has spread across Europe [6].

Therefore, like for sediment, assessing the quantity of instream wood is very important to diagnose river status and evaluate the potential success of restoration measures and the potential hazards and risks. However, the current legislation rarely considers wood management in its effort to support environmentally sustainable rivers.

Similarly to the flow and sediment regime, the wood regime is characterised by frequency, magnitude, timing and mode, considering supply, transport and deposition [1]. However, unlike the water and sediment regimes that have been intensively studied over the past decades, the instream wood regime has only recently been defined and remains rarely quantified [6]. Compared to flow or sediment, we are still unable to monitor or measure the wood regime with the same level of accuracy due to several limitations. The lack of long-term observations, monitoring networks, and data are the most crucial gaps. The significant temporal and spatial variability of wood supply and availability, and transport processes contribute to this data scarcity.

The amount of wood stored in rivers (referred to as wood load and measured in volume of wood per area) is a critical value to quantify the wood regime. How much wood is being entrained and transported during floods, the so-called wood flux (e.g., the number or volume of pieces per time), is another essential variable. Different approaches have been developed to estimate wood loads and fluxes [6]. This contribution summarises the most recent advances to quantify these elements of the wood regime, providing exemplary cases from ongoing research. For example, we show how using sensors like radio transmitters can help to track wood displacement; or how machine learning algorithms can be trained to identify, map and quantify instream wood load stored in rivers using high-resolution imagery acquired by drones and wood fluxes from footage recorded by cameras.

The information gathered by these monitoring frameworks is key for river restoration and flood management.

**Acknowledgements:** This study has been supported by the Swiss National Science Foundation (PCEFP2_186963), the Universities of Lausanne and Bern (Switzerland).

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# Impacts of Sterilization and Organic Matter Removal on the Rheology and Settling Behavior of Fluid Mud

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**Conference theme number(s): 6**

**Introduction:** Mud is a fine-grained cohesive material which contains mineral particles (predominantly clay and silt), organic (and inorganic) matter, and water. Understanding mud's rheological and settling behaviour is critical for sustainable sediment management in ports [1, 2]. A systematic analysis of the effect of clay minerology on the rheological and settling behaviour of mud has been conducted previously [3, 4]. In contrast, literature on the impact of organic matter on physical properties of sediment is scarce. Our previous work [5] demonstrated the impact of microbial inactivation via gamma radiation, revealing a significant increase in settling rates. Current research incorporates chemical sterilization ($NaN_3$) and organic matter removal (NaOCl), to systematically differentiate between effects of microbial activity and effects of organic matter on the physical properties of fluid mud (FM).

**Methods:** FM samples from the Port of Emden (Germany) were sterilized to inactivate microbial activity and chemical treated to remove organic matter. Each experiment was conducted in duplicate to ensure reproducibility. Microbial inactivation was achieved through several sterilization techniques:
1. A 500 ml FM sample was irradiated with 10 kGy Co-60 gamma for 24 hours. This dosage inactivates microbial life while preserving the physical structure of the sediment [6].
2. Sodium azide ($NaN_3$) was applied (1 mg per 1 g of dried sediment) to inhibit microbial activity (chemical Sterilization, [7]). A respiration test using gas chromatography was conducted at the beginning of the experiment and repeated after three weeks to confirm the sustained inactivation of microbial life.
Organic matter removal will be conducted using sodium hypochlorite (NaOCl), with TOC measurements confirming the effectiveness of carbon removal. For NaOCl treatment, samples will be exposed to a 1 M solution with a sediment-to-solution ratio of 1:50 (w/v), followed by centrifugation and washing to remove salts before restoring the original water content.
Reference samples were maintained without any treatment to allow comparison with treated samples. The physical properties of the FM e.g., density, yield stress, and settling behavior were measured after treatments.

**Results:** Microbial inactivation using $NaN_3$ treatment and gamma radiation did not alter the density or yield stress of FM significantly (Fig. 1). However, the settling behavior was significantly affected, with a 3.25 and 2.5 times increase in the initial settling rate (within the first 20 hours) observed in irradiated and $NaN_3$-treated samples compared to the reference sample (Fig. 2). While both treatments increased settling rates during the linear phase, $NaN_3$ treatment demonstrated a slightly slower initial (17%) settling behaviour compared to gamma radiation. After 20 hours, treated and reference samples settled similarly, although treated samples reached lower final height.

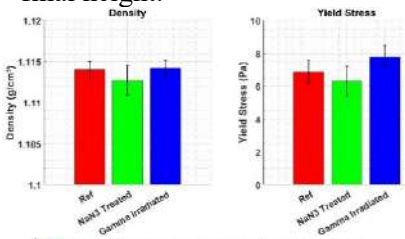


**Fig. 1:** *a) Density and yield stress for reference, $NaN_3$-treated, and gamma-treated samples (error bars: variation in duplicates)*

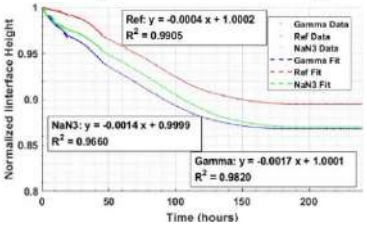


**Fig. 2:** *Settling rate for reference, $NaN_3$-treated, and gamma-treated samples*

**Discussion:** Inactivating microbial life in FM increased settling rates, presumably through the removal of buoyancy effects from microbial byproducts like $CH_4$ and $CO_2$ bubbles. These findings highlight the role of active microbiota for physical properties and hence the navigability of fluid mud in ports and waterways.

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# AMORAS sediment treatment: Estimate of sediment import through lock exchange at the right-bank port of Antwerp

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**Conference theme number(s): 1, 2, 6**

**AMORAS:** Sediments that are dredged within the docks of the right-bank within the port of Antwerp suffer from historical contaminants and therefore cannot be disposed back into the estuary. Since 2011 AMORAS contributes to a sustainable treatment and storage of the dredged sediments, Fig. 1. When dredged material is brought to the underwater cell, first the sand content is separated (1). The mud content is then pumped (2) to the AMORAS dewatering installation (3) and the dry material is stored on land for reuse as construction material in the future (4). The drained water is purified and pumped back to the docks.


**Fig. 1:** AMOARS dewatering installation: 1) Underwater disposal cell and sand separation, 2) piping system, 3) dewatering and water treatment site, 4) storage.

**Sediment sources**: It is estimated that there is enough accommodation space for at least the next 15 years. Nevertheless, an accurate prediction of the future need for sediment treatment is required. Therefore, it is necessary to understand the different sediment sources within the port. Principal sources of dredged sediments are (1) import of fresh sediment from the Lower-Seascheldt through lock exchange, (2) the removal of sediments of historical backlog of maintenance, (3) local deepening and construction works (limited), and (4) through water exchange between the docks and the Albert-canal (limited) and the docks and the Lower-Seascheldt through culverts.

**Density driven sediment exchange through lock operation:** The exchange of water, salt and sediments is driven by the density difference due to the salinity difference between the docks and the estuary. Every time the lock doors are open, either on the estuary side or on the dock side, the water starts exchanging resulting in a net import of fresh sediments into the port. Within the docks there is hardly any currents which allows the sediments to settle in the vicinity of the lock complexes.

**Estimation of annual sediment import:** The import of fresh sediment through the lock complexes is estimated by analyzing different dredging registration databases of the last nine years. The trailing suction hopper dredgers directed by the division of DMOW Maritime Access are equipped with a BIS-system, registering the location and dredging volumes during operation. Figure 2 visualizes the dredging activity of the period 2016-2024. Near the Zandvliet- and Berendrechtlocks (1) a clear pattern of dredging tracks is visible indicating the preferred settling locations of freshly imported sediments through lock exchange. For the Boudewijn- and Van Cauwelaertlocks the pattern is less obvious (4). In this area other parties, amongst which the Port of Antwerp-Bruges, execute dredging works as well (eg. local deepening near some of the quay walls). Therefore the BIS data will be combined with other databases to estimate the net sediment import through the locks.

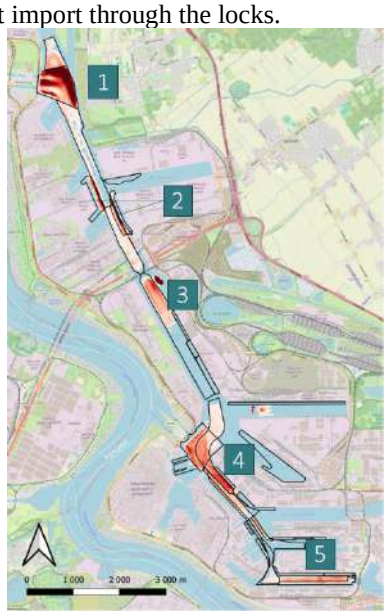


**Fig. 2:** Dredging intensity of the trailing suction hopper dredgers 2016-2024.

# High concentrations of certain trace metal elements in Martinique port sediments.

## *A natural or anthropogenic origin?*

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**Conference theme number(s) : 1 / 6**

**Introduction:** The concentrations of certain heavy metals in Martinique port sediments regularly exceed the regulatory thresholds for the management of dredged sediments. Several studies have shown that the volcanic nature of these sediments may be the cause of these high levels, particularly for copper. The objective of this study is, based on existing data, to assess whether the observed exceedances of the dredged sediment management thresholds (N1 and N2) are linked to the geology of the island or to anthropogenic inputs.

**Methods:** The analysis of the metal contents of sediments in Martinique is based on the following data:
- Port sediment quality monitoring network (REPOM),
- sediment analyzes carried for dredging operations,
- existing data on geochemical backgrounds in Martinique.

Thus, the studies of Castaing et al. [1], Pons et al. [2] and Pujos et al. [3], which define the concentrations of heavy metals in the alterites, were averaged in order to establish indicative values of pedo-geochemical backgrounds.
In order to avoid grain size variations, the measured concentrations were normalized with respect to an aluminum content of 5%.
Port activities and different releases may generate heavy metal intakes were identified : careening area, stormwater discharges, refueling stations…
To determine the natural part and the anthropogenic part of exceeding the dredged sediment management thresholds, the measurement results were analyzed using two indices: the enrichment factor and the geo-accumulation index [2] :

| Enrichment factor | Interpretation |
|---|---|
| < 1,5 | Natural geological composition |
| 1,5 à 3 | Low enrichment |
| 3 à 5 | Moderate enrichment |
| > 5 | Important enrichment |

**Fig. 1:** Interpretation of sediment enrichment factor values.

Finally, the concentrations of elements for which an anthropogenic contribution is suspected were correlated with the concentrations of contaminants of exclusively anthropogenic origin (TBT, PCB...).

**Results:** The level of the natural pedo-geochemical background of copper in Martinique is very close to the N1 threshold, which may explain some exceedances of the regulatory thresholds. Thus, the levels measured at certain ports are mainly of natural origin. However, concentration peaks observed at certain port basins indicate the presence of anthropogenic inputs. This is confirmed by the significant correlations observed with anthropogenic contaminants and the context of these ports (particularly careening areas). For lead and zinc, the indicative levels of the natural pedo-geochemical backgrounds are lower than the N1 level. The observed exceedances therefore result from inputs of anthropogenic origin.

**Discussion:** The threshold values for the management of dredging sediments in France are established on the basis of metropolitan data and therefore do not take into account the geological specificities in Overseas France. A similar study was conducted by Cerema on the port sediments of La Réunion and made it possible to partially adapt the regulatory framework to the high nickel and chromium pedo-geochemical backgrounds of this territory. A similar reflection could be conducted for copper in Martinique, but the significant variations in the contents within the Island could complicate this work. However, it appears necessary to adapt the regulatory thresholds for dredging operations to the pedo-geochemical backgrounds of the different territories. But for this, more data on the pedo-geochemical backgrounds would have to be acquired.

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# Flanders policy continues to focus on an integrated approach of contaminated sediments : legislation and code of good practice.

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**Conference topic: 6 Sediment Management Concepts and Policy**

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**Introduction:** *The European Water Framework Directive states that a good status of surface water and groundwater must be achieved. The remediation of contaminated sediments is indispensable linked on this. After all, contaminated sediments prevents the improvement of water quality and the ecological recovery of the watercourse.*

*In Flanders, the remediation of contaminated sediments falls within the scope of the soil remediation regulation, but given the specific environmental characteristics of sediments makes the application of the existing decree procedures not evident. The remediation of contaminated sediments requires a unique approach.*

*The Flemish Soil Decree contains specific regulations for the investigation and remediation of contaminated sediments (Articles 124-135 of the Soil Decree). The Soil Decree defines the concept of 'waterbed' by referring to the Decree on the Integrated Water Policy, which defines the concept of 'waterbed' as: 'the bottom of a surface water body that is always under water or for a large part of the year'.*

**Methods:** *Since it is not possible to immediately remediate all waterways, priorities are determined by a tool "Sedimentexplorer" and the most urgent waterways with contaminated sediments are tackled first.*
*There are various ways in which contamination can come to light.*

*If the waterbed has been examined in a sediment assessment in accordance with Chapter 12 of the Soil Decree, the remediation obligation only arises after the Flemish Government has designated the watercourse as a priority for remediation. The watercourse manager is the person who has the obligation to conduct the investigation.*

*The investigation of the discharge point will be mandatory when carrying out an preliminary soil investigation of a company. If contamination is identified, this contamination will not prevent the transfer of the site, but agreements will have to be made between the transferor and the acquirer.*

**Results:** *The OVAM works together with soil remediation experts, research institutions and other experts on a code of good practice: Assessment of contaminated sediments and banks - Code of good practice. Guidelines for investigation of contaminated sediments in the context of a preliminary soil investigation are also being developed.*

*This code of good practice is a manual for the assessment of contaminated sediments for accredited soil remediation experts and watercourse managers.*

# Comparison of Freshwater Sediment Quality Guidelines (SQGs) for potentially toxic elements (PTEs): Gaps and Needs

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**Conference theme number(s): 6**

**Introduction:** The EU Water Framework Directive (WFD) employs a comprehensive strategy for waterbody management by integrating sediment quality guidelines (SQGs) to protect aquatic ecosystems. SQGs are essential for evaluating sediment contamination levels, establishing threshold values to differentiate uncontaminated sediments from those requiring remediation [1]. This synergy aligns SQGs with the WFD's benchmarks for mitigating sediment toxicity, promoting a unified, science-based approach to waterbody preservation across Europe [2]. This study examines the evolution of SQGs since the 1970s, demonstrating a transition from simple contaminant concentration comparisons to advanced assessments incorporating ecological impacts. Initial reliance on background values overlooked biodiversity and potential harm to aquatic organisms.

**Methods:** Freshwater SQGs from different national and regional agencies were collected and categorized into threshold effect concentrations (TECs) and probable effect concentrations (PECs). These categories aim to protect sediment-dwelling organisms in freshwater ecosystems [3].

**Results:** Statistical analyses reveal significant variability in PECs among metals. Ranking shows chromium has the least variable SQG (11%) while mercury has the most variable SQG (52%) among the 28 national and international SQG systems compared (figures in brackets show the MAD/Median relative variability in percent [4]). Statistical comparison also identified that mercury is the most toxic metal and zinc as the least, corresponding to the lowest and highest SQG values, respectively. For TECs, lead and copper exhibited the lowest (11.4%) and highest (37.1%) variability, respectively.

**Discussion:** These findings highlight the importance of refining SQGs to account for metal-specific toxicity and variability. The variability of the SQGs values among different metal(loid)s underscores the importance of refining these guidelines for effective environmental protection. By selecting SQGs with minimum variability, the study ensures precise and consistent evaluations of heavy metal contamination across diverse environmental contexts. Integrating these guidelines into the implementation of the WFD framework enhances sediment quality management by consistent application of threshold values across borders, hence fostering ecological sustainability and improved waterbody health.

**Acknowledgements:** This work was funded by the DanubeSediment_Q2 Project (DRP0200029), an Interreg Danube Region Programme project co-funded by the European Union, and supported by Stipendium Hungaricum Scholarship Programme

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# Using sediment samples to assess substances in relation to the Water Framework Directive (WFD)

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**Conference theme number(s): 6**

**Introduction:** In Denmark, the permission for dredging and disposal of sediment from the sea is based on a hierarchy. 1. Bypass of sediment, 2. Utilization of sediment, and 3. Dumping. In connection with all three forms of disposal, an assessment of substances in relation to the Water Framework Directive (WFD) must be conducted. The ecological status is assessed based on a range of quality elements, including nationally specific substances, while the chemical status is assessed based on EU-prioritized substances.

**Methods:** Before dredging, the concentrations of various substances are necessary to carry out in order to perform an environmental assessment (EA). At the same time, sediment spreading, and release is essential. Prior larger dredging tasks, numerical modeling can be used, while for smaller dredging and dumping operations, simpler models may be applied.

Step 1: In Denmark, sediment samples are taken prior an environmental assessment. Review of the substances on the OSPAR/HELCOM primary and secondary lists are performed.

Step 2: The analysis of these substances is always carried out by laboratories that are accredited to perform such analyses.

Step 3: Using different sources, concentrations in sediment is compared with EQS. 1st priority: Environmental quality standards are established in legislation. 2nd priority: Environmental quality criteria set out in fact sheets from the Environmental Protection Agency, and 3rd priority: EU predicted no effect concentrations (PNEC)

Step 4: There are only a few environmental quality standards for sediments and biota; the remaining environmental quality standards are for water. Analyses are conducted from a national list and EU-prioritized substances list. Concentrations in sediment need to be converted to concentrations in water and then compared to the water quality standards. Here are several choices and assumptions that can affect the outcome. It is important to be conservative due to the precautionary principle, but the assessments should also be realistic.

Step 5: At the same time, several guidelines are used. The Environmental Protection Agency has created several guidelines [1], but guidelines from HELCOM [2] and OSPAR, as well as EU guidelines (Common Implementation Strategy (CIS)) [3], are also used.

**Results:** By using a combination of conservative calculation methods along with an assessment of sediment spreading, it can be evaluated whether EQS is being met and does not lead to a deterioration of the status of the surface water area and does not hinder the achievement of the established environmental objective, including through the measures specified in the action program.

**Discussion:** It is sometimes difficult to determine when there is a local and/or temporary impact and whether this falls under the WFD (Water Framework Directive). How are requirement values determined for a given substance in an emission when the environmental quality standards for that substance have already been exceeded in the surface water? Is it sufficient to look at the concentration of individual substances and the increase in the concentration of the substance in sediment, or should a calculation of the release to the water phase and the increase in the water phase also be made? Should the assessment be carried out across the entire water area, or is there a deterioration if there is a very local and temporary increase in concentration? What about the time perspective? AA-EQS is the EQS expressed as an annual average value. MAC EQS is the EQS expressed as a maximum allowable concentration.

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# Assessment of dredged sediments in the light of the WFD-EQS. Justified trouble due to advanced assessment tools?

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**Conference theme number(s): 6**

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**Introduction:** As approach to Germany's most important seaport, Hamburg, the Elbe estuary is a waterway of great nautical importance, in which regular maintenance measures on a considerable scale are required to maintain the safety of shipping. In the context of the use and approval of different options for the disposal of dredged, mostly more or less contaminated sediments, the environmental impacts of the use of various disposal sites in the Elbe estuary and in the German Bight have been assessed in recent years. In preparing the respective impact assessments, a collaboration between the German authorities Federal Institute of Waterways Engineering (BAW) and the Federal Institute of Hydrology (BfG) has been established. On the one hand, a continually improved hydraulic numerical model for the transport and fate of the disposed sediments provide an essential basis for the impact forecasts. On the other hand, the requirements of EU directives like the water framework directive (WFD) have to be considered with increasing detail. The contamination of the dredged sediments as well as existing concentration gradients between the sediments of the North Sea and the Port of Hamburg make estimates of the pollutant input into the sediments and the surface water of the disposal area of considerable importance. Due to very low environmental quality standards (EQS) for some contaminants according to the WFD, problematic assessments arise for some ubiquitous pollutants whose concentrations in the dredged sediments were previously considered to be largely uncritical.

**Methods:** From the results of the hydraulic numerical modelling (carried out by the BAW), expected deposits of dredged material on the riverbed as well as expected discharge-related suspended matter inputs into the surface water of individual sub-areas are derived. With regard to WFD requirements estimates for the pollutant input into surface water are derived from these forecasts on suspended matter input, considering the quality of the dredged sediments since the assessment of organic pollutants according to the WFD takes place in the total water phase. For parameters for which a sufficiently good database has been collected as part of the surface water monitoring, furthermore, expected average and maximum concentrations are estimated. These expected average and maximum concentrations were finally evaluated based on criteria for the analytical detectability (measurement uncertainty, coefficients of variation of the measured concentrations) and the EQS according to WFD (annual averages and maximum allowable concentrations). In our view of the WFD, results appear problematic when the expected average and maximum concentrations exceed both the corresponding EQS (annual averages or maximum allowable concentrations) and the criteria for the analytical detectability. In this case, either a first-time exceedance of the EQS or the introduction of a pollutant that already exceeds the EQS on a measurable and observable scale is to be feared. Both would represent a potential violation of the prohibition of deterioration.

**Results:** Against this background, in the impact assessments in the Elbe estuary problematic results arise in addition to tributyltin, especially for the PAHs benzo(a)pyrene, benzo(g,h,i)perylene and fluoranthene, which already exceed the corresponding EQS more or less extensively in the study area (tidal Elbe and German Bight). In contrast uncritical assessments are obtained for most of the parameters that so far caused concern in connection with the disposal of dredged sediments and the assessment of these based on other assessment criteria in the Elbe estuary (e.g. cadmium, zinc, hexachlorobenzene, p,p`-DDE, p,p`-DDD, p,p`-DDT).

**Discussion:** The presentation will emphasize that advanced assessment tools, together with the very low EQS of some parameters, lead to legal uncertainties in connection with the relocation of dredged sediments. Critical results are obtained mainly for ubiquitous substances without their concentrations having increased significantly. On the contrary, decreasing pollutant levels are observed in the sediments of the tidal Elbe. At the end the extremely low EQS may threaten the maintenance of waterways although these contaminants are ubiquitous and do not represent the most severe contamination of the respective sediments.

# The sediment's role in the management of beach and recreational use of water

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**Introduction:** The recent challenges caused by global climate and environmental changes are making us rethink human health as something inseparable from the state of natural resources and environmental variables, converging on the "one health,, principles. The global recreational use of water in coastal areas, determines the need to guarantee increasingly better quality status. The EU Directive 2000/60 regulates the management of bathing water quality through monitoring and preventing pollution, to achieve a "good" environmental status, protecting human health, water resources, natural ecosystems, and biodiversity. The PNC ACeS Project (Water, Climate, and Health: from the Environmental Protection of Resources to Access to Water, to Safe Use) considers more environmental matrices (water, beach and marine sediments, biota) to understand their correlation with some chemical contaminants better, but also emerging pathogens (including antibiotic-resistant ones) in the bathing areas. Understanding how different environmental interactions can affect the bacteria tracer (i.e. adsorption/desorption processes) in the water column is also useful to validate numerical transport models that generally treat bacteria as free-living in current [1].

**Methods:** Two recreational coastal areas of the Tyrrhenian and Adriatic Seas (Italy) were selected for the physical, chemical, microbiological, and ecotoxicological characterization of all the environmental matrices. In each area, five sampling stations affected by industrial, urban, and agricultural discharges, plus a control one, were selected for the collection of water, beach and marine sediments, and filter-feeding bivalves during three campaigns (before, during, and after the bathing season) for two years. Marine sediments and organisms were sampled at 1 m water depth. Beach and marine sediments were analyzed for grain size, trace metals, PAHs, and PCBs, to which the analysis of *Escherichia coli*, faecal Streptococci, *Salmonella* spp. and, in addition for marine sediments a battery of three ecotoxicological tests were added.

**Results:** The analytical activity is still in progress, but the early results highlighted for all sediment the exclusive presence of the sandy fraction in both areas, without seasonal variations except for minimal changes probably due to seasonal events. The microbiological analyses revealed the absence of pathogenic bacteria in both areas in May and low values in July, at a few stations close to drainage channels.

**Discussion:** Microorganisms (i.e. bacteria, fungi, parasites, and viruses), significant in beach sands and some of this potential pathogens, have all been isolated. Accordingly, a concern is that this matrix may act as a reservoir or vector of infection, as well as a source of water contamination [2,3,4]. The location of marine sampling stations on the submerged beach justifies the sandy texture, devoid of fine fractions that are transported far from the coast. Contaminants are normally associated with clay fraction due to its mineralogical features and this was also demonstrated for bacteria [5]. However, it was found that they may also live in the pores of sand [6]. The absence of contamination before the tourist season and the peak after it let us suppose pathogenic bacteria may accumulate in sandy fraction which is a sink for this contamination for some months. The presence of breakwaters in the Adriatic coastal area may favor this process.

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# Spanish Framework for coastal sediment management. Regulatory conditions and impact on sediment balance

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**Conference theme number(s): 2, 6**

**Introduction:** Sediment Management in Spanish coastal waters is regulated by three national laws: the Coastal Law, the Port Law and the Marine Environment Protection Law. The implementation of these laws has led to the development of technical instructions that regulate the extraction, placement and disposal of materials in coastal and transitional waters in accordance with the European Directives and International Conventions to which Spain is a Contracting Party.

The entry into force of this legislation has had a major impact on the evolution of sediment volumes according to their destination and on the quality of sediments that can be placed or disposed of in the marine environment without containment measures.

CEDEX, through the Centre for Port and Coastal Studies, has been deeply involved in providing technical and scientific advice to the Spanish administration, primarily to the General Directorate of of the Coast and the Sea and the State Port System.

**Methods:** Since the 1980s, CEDEX has carried out many studies to characterise dredged materials including management options, which have culminated in the development and proposal of Recommendations and Guides for approval by the competent Ministries to guarantee sustainable management of dredged materials, as well as beach restoration. Methodologies for classifying marine sediments are addressed by these guidelines including National Action Levels (NAL) for establishing the most appropriate management alternatives. Additionally, a procedure has been developed for dumping sites evaluation where the potential impact to protected areas has been considered in depth.

In addition, CEDEX is responsible for updating an inventory compiling volume sediment data and other associated parameters of all extraction works in Spanish coastal and transitional waters, including the destination of these materials.

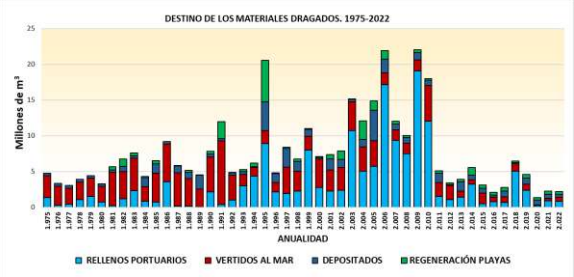


**Fig. 1:** Destination of dredged materials in Spain 1975-2022. Source: Inventory of dredged material in Spanish ports 2022 (CEDEX).

**Results:** Since 1975, 357 million of cubic meters of dredged material has been removed from ports in Spain. More than 200 million have been classified according to the Dredged Material Guidelines. 125 million have been dumped into the sea and 25 million have been used as beach fill material. The rest has been used in port landfills or placement in confined disposal facilities.

**Discussion:** The adoption of various pieces of legislation has had a strong impact on the reduction of the volumes of dredged material dumped into the sea, especially the most polluted ones, and has favoured a greater use of the best quality sediments in beach nourishment. The establishment of NAL for the classification of marine sediments has been based on many technical studies and on a discussion process in which scientific and technical personnel and the competent administrations have participated.

Acknowledgements: To the General Directorate of the Coast and the Sea and to State Ports Authority for their support in maintaining this line of activity, including its financing.

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# Optimization of Sediment Restoration Through Combined Remedy and Risk Management

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**Conference theme number(s): 3, 6**

**Introduction:**
In ongoing international efforts for sustainable management of impacted sediments, the decision-making process includes site investigations, exposure and risk assessment, development of risk management strategies, selection and implementation of a remedy followed by site monitoring to evaluate performance of sediment restoration.
The state of the practice of sediment restoration techniques include removal of impacted sediments from the aquatic environment, covering with clean material, in-situ treatment and/or natural processes while monitoring the sediments to ensure that contaminant exposures and risk to environment and human health is in decreasing trend. In majority of the contaminated sites, a combined remedy optimizes the process to achieve the remedial goal.
This paper presents the sediment restoration process utilized at a site to optimize restoration of impacted sediments through utilizing a combination of restoration technologies based on risk to environment and human health. The main objective of the optimization efforts is to manage further degradation of the health of sediment to achieve a balance between the protectiveness and long-term effectiveness of the risk management strategies.

**Methods:**
Sediment at a site in the USA mid-Atlantic region is impacted with PCBs, PAHs and metals. Multi-parameter decision analysis tools were used to facilitate final remedy selection, which included a multi-component remedy, including removal and in-situ treatment. In-situ treatment was proposed as sustainable restoration option to reduce removal, sediment disturbance, dewater and disposal of impacted sediment. Coordinated communication efforts were required to obtain regulatory approvals, the informed consent of stakeholders and the general public. Treatability testing was employed to document the effectiveness of proposed in-situ treatment amendments. Treatability studies demonstrated that the effectiveness of activated carbon application at doses of 2.5% and 5 % dry weight of the sediment resulted in 95% reduction in porewater concentrations and invertebrate bioaccumulation. As the project went from treatability study to implementation, the site became one of the largest in-situ treatment of PCBs in sediment to date with 5.5 hectare.
Multi-component remedy in the creek portion of the site included select removal followed by habitat restoration to reduce erosion and migration of contamination from upland.


**Fig. 1:** Combined remedy in a cove.

**Results:**
Risk monitoring results show reductions in sediment porewater PCB concentrations and invertebrate tissue PCB concentrations. The total dissolved PCB concentrations in sediment porewater had reductions greater than the 80% target and reductions in tissue PCB concentrations were greater than the 70% target established for the project. Near sediment surface water concentrations were reduced by approximately 80% from baseline. Five-year monitoring of habitat restoration areas showed that functional goals of erosion protection, nutrient removal, and creating ecological diversity have been achieved.

**Discussion:** In-situ treatment of contaminated sediments is a sustainable risk management approach to restore the health of sediment if applicable to the site conditions. A well-designed habitat restoration is a nature-based solution to restore health of sediments by reducing erosion and promoting natural recovery.

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# Sediment management concept of the River Elbe (Germany) – implementation status and an example for supporting research

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**Conference theme number(s): 6 Sediment Management Concepts and Policy**

**Introduction:** Sediments are an integral part of water bodies and aquatic ecosystems, thereby fulfilling fundamental functions as a stream bed, habitat and with regard to biogeochemical cycles and ecosystem services. Sediment quantity and quality can vary and sediments interact with other environmental media - this is thus relevant for achieving the objectives of the European Water Framework Directive (WFD). Sediments and their management are also important for various utilisations of watercourses, such as navigation. The Elbe River Basin Community (RBC Elbe) and the International Commission for the Protection of the Elbe (ICPER) therefore identified the need to develop a sediment management concept in the first River Basin Management Plan for the WFD in 2009, as the directive itself only takes sediments into account to a limited extent. Such a concept was then developed nationally and internationally in the following years and published in 2013 and 2014. The central aim was to provide suggestions for good sediment management practice in the Elbe catchment area in order to achieve supra-regional action goals. Specific recommendations for action and management options were formulated based on an integral consideration of the aspects of quality, quantity and hydromorphology as well as navigation.

**Current approach:** The implementation steps of the sediment management concept to date with regard to qualitative sediment management will be discussed in this presentation, including the obstacles identified. To strengthen and improve the implementation process, an ad-hoc working group was established in the RBC Elbe in 2020, which is now established as a permanent sediment management expert group to continuously and actively accompany the further process. In addition, two sediment workshops of the German Federal Government and the German federal states were held in 2019 and 2023 to intensify the process, resulting in both a position paper (2020) and, as an update, a declaration of intent (2024) for joint action in the Elbe river basin district.
One important task of the sediment expert group is the prioritisation and estimation of effectiveness of measures. This likely can be supported by methods developed during research projects. In this presentation, examples of results from the still ongoing research project SOURCE, conducted at the Federal Institute of Hydrology (BfG), are shown. The aim of the project is to develop a methodological framework for identifying the pollutants responsible for ecotoxicological effects and their sources of input into federal waterways focused on the River Elbe and its tributary River Saale. This will be achieved by combining chemical analytical procedures, modelling of toxic effects and effect-based methods. For this purpose, cause-effect relationships between observed ecotoxicological effects and the pollutant load of waterways are considered.

**Outlook:** An important objective of the declaration of intent is that all necessary, proportionate, sediment-related and at best near-source measures to achieve the requirements of the WFD and also the European Marine Strategy Framework Directive (MSFD) should continue to be realised in the German Elbe catchment area. It was noted that the required reduction of sediment-related pollutant discharges and displacements will be achieved in particular if the necessary environmental policy weight is given to the sustainable reduction of pollutant loads (also internationally) and if there is a timely joint identification and realisation of measures, which are sustainably effective throughout the river basin.
Concerning the identification and prioritisation of these measures, methods applied and developed by projects such as SOURCE also allow for considering the high number of known and unknown pollutants as well as possible mixture effects to facilitate a more realistic sediment risk assessment and sediment risk management in the future.

**Acknowledgements:** The project SOURCE is financed by the German Federal Ministry for Digital and Transport.

# iNNO SED - Innovative Sediment Management in the Danube River Basin

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**Introduction:** Effective sediment management is vital for maintaining the health and functionality of river systems. In the Danube River Basin (DRB), human interventions such as river regulation, hydropower plants, and other human impacts have disrupted sediment continuity, resulting in sediment imbalances. The iNNO SED project addresses these challenges by delivering innovative, sustainable solutions to improve sediment quantity and quality within the DRB.

**Objectives:** The primary objective of iNNO SED is to establish the Danube Sediment 'Lighthouse' Knowledge Centre together with providing a Sediment Management Toolbox with transferable solutions for sediment challenges in large river basins. Key goals include: i) Enhancing sediment continuity and mitigating erosion in free-flowing sections; ii) Reducing sedimentation in impoundments while improving sediment quality; iii) Developing innovative sediment monitoring and modelling techniques; iv) Empowering stakeholders and the public through participatory tools and training.

**Methodology:** The project employs a holistic, interdisciplinary approach, integrating scientific, socio-economic, and environmental aspects of sediment management. Highlights include: i) Development of novel monitoring methods, such as AI-based sediment quality assessment and Earth Observation (EO) techniques; ii) Creation of Digital Twins for complex regions, including the Iron Gates and Danube Delta, to simulate sediment dynamics and inform management decisions; iii) Implementation of innovative, preferably nature-based solutions (NbS) at eight demonstration sites, addressing sediment-related challenges such as continuity restoration and pollutant reduction.

**Expected Results:** i) A comprehensive Sediment Management Toolbox, including a Sediment Atlas and actionable guidelines for replication and scaling; ii) Demonstrable improvements in sediment management at key demonstration sites, enhancing ecosystem health and reducing pollution; iii) Increased stakeholder capacity through targeted training, public engagement, and Citizen Science initiatives.

**Impact:** By improving sediment conditions across the DRB, iNNO SED supports biodiversity, sustainable inland navigation, and hydropower production. The project aligns with the European Green Deal and the Water Framework Directive, contributing to global sustainable development goals and serving as a model for sediment management in other large river basins worldwide.

**Conclusion:** The iNNO SED project exemplifies transnational collaboration and innovation in sediment management. Its integrated solutions and comprehensive approach aim to transform sediment-related challenges into opportunities for environmental restoration and sustainable development.

# DanubeSediment_Q2 - Sustainable, Integrated Transnational Sediment Quantity and Quality Management in the Danube River Basin

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**Introduction:** Sediment management is a critical issue in the Danube River Basin (DRB), as disturbances in sediment balance—both in quantity and quality—affect river morphology, ecosystems, flood risks, and navigation. The DanubeSediment_Q2 project addresses these challenges by aiming to achieve harmonized sediment management practices to support environmental objectives across the DRB.

**Objectives:** The primary goal of DanubeSediment_Q2 is to develop the first Integrated Sediment Management Plan (ISMP) for the DRB. This plan will include recommendations for sustainable sediment management and upscaling solutions to be adopted in future iterations of the Danube River Basin Management Plan and the Flood Risk Management Plan.

**Methodology:** To achieve its goals, DanubeSediment_Q2 employs an innovative co-design approach involving 14 project partners and multiple stakeholders across all across the Danube Region. The project develops and tests sediment management measures using data from an extended sediment monitoring network, modelling tools, and case studies in nine pilot sites. Key outputs include a new hydromorphological assessment method, a sediment risk assessment method, and practical solutions for sediment quantity and quality improvements. The development of the Integrated Sediment Management Plan will be done based on the procedure outlined in the Common Implementation Strategy for the water framework directive [1] and applying a co-design and co-creation to involve stakeholder.

**Expected Results:**
The project will develop the first Integrated Sediment Management Plan for the Danube River Basin which is expected to improve sediment balance, ensure continuity at barriers, reduce sedimentation in impoundments, mitigate riverbed and coastal erosion, and control polluted sediment transport. In the long run, this will contribute to dynamic river morphology, reduced flood risks, enhanced groundwater levels, and improved conditions for ecosystems, navigation, and hydropower.

**Impact:** The project will have a long-term impact by facilitating the adoption of harmonized sediment management practices, contributing to better flood risk control, reduced erosion, and improved water quality. Its outputs will influence the Danube River Basin Management Plan and Flood Risk Management Plan, benefiting governments, stakeholders, and local communities.

**Conclusion:** DanubeSediment_Q2 represents a vital step towards sustainable sediment management in the Danube River Basin. The project's collaborative approach and innovative methodologies will support the restoration of a healthy sediment system, essential for ecological balance and flood risk reduction in the region.

**Acknowledgements:**
DanubeSediment_Q2 is supported by the Interreg Danube Region Programme co-funded by the European Union under the grant number DRP0200029.

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# Data-driven approach to implement an integrated water and sediment management strategy in Flanders

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**Conference topic: 6 Sediment Management Concepts and Policy**

**Purpose:** In line with the European Water Framework Directive, Flemish authorities face significant issues with respect to the impact of pollution from urban wastewater and industry on surface and groundwater at the level of river basins. Historically 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. Flanders invested (since 2018) in the development of a data-driven approach to achieve an actionable policy. The project aimed 1) to develop a public tool where different authorities and stakeholders can consult data on sediments to streamline operational activities with respect to water and sediment management and 2) to set up a regional prioritization and financial support system to initiate concrete remediation projects across Flanders. The approach has been put to practice in a collaborative project between VITO, OVAM (the public waste agency of Flanders), VMM (the Flemish Environment Agency) and DOV. We present the web-based tool and it's implementation by the Flemish Government to prioritize their actions in the field.

**Methodology:** 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. The Sediment explorer collects data from different local and regional authorities. A multi-criteria approach is used to derive the remediation priority of streams and are presented alongside maps with relevant environmental and policy data to support area-specific strategies. Additionally, 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. The regional prioritization builds on the Sediment explorer and cost-benefit analysis to list those water courses with highest policy priority for 1) sustainable remediation and 2) those up for remediation due to immediate health risks.

**Results/Discussion:** About 40% of measured sites have a physico-chemical contamination with significant ecological risks but often sustainable remediation is possible if appropriate measures are taken. A series of cost-benefit scenarios indicates that only 60-90% of all costs can be compensated by the benefits of remediation. Limited direct benefits of remediation suggest that additional incentives need to evoke remediation. It is therefore a strong plea for targeted prioritization and an area-specific approach. The Flemish government exemplified this by listing those water courses with the highest policy priority and provided financial support to remediate those waterbodies. As a result concrete actions have been initiated in several streams across Flanders.

**Significance:** Local and regional authorities use the web-based tool 'Waterbodemverkenner' to help streamline operational activities. The cost-benefit analysis result corroborates the concept of 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. The data-driven approach allowed the Flemish government to set up financial incentives to kickstart remediation projects.

# Banning the dumping of polluted sediments - The French choice

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**Conference theme number(s): 6**

**Introduction:** Since January 1, 2025, the discharge of polluted sediments and dredging residues at sea has been banned in France [1]. To make this ban effective, new content thresholds qualifying sediments as polluted have been defined, in addition to the N1 and N2 levels already available in French regulations. This study presents the choices that led to their establishment.

**Methods:** Based on a literature review of international regulations and practices relating to the management of dredged sediments, three ban threshold scenarios were proposed and assessed in terms of environmental and socio-economic consequences:

- "N2" scenario : setting the L2 guide values of current French regulation as the thresholds for prohibiting immersion.
- "ALT1" scenario: alternative 1 of the International Maritime Organization (IMO) study, corresponding to the 75th percentile of level 2 values available worldwide, all greater than or equal to N2, as thresholds for prohibiting immersion.
- "N*" scenario simulating the implementation of a 'triad' approach, including the use of ecotoxicological tests, likely to prohibit the dumping of part of the dredged sediments.

A flow chart describing the fate of sediments brought ashore has been drawn up. It presents the various stages of onshore management, distinguishing between: a possible granulometric separation of sand from silt brought ashore, re-drying of sand and/or dewatering of silt, followed by possible treatment prior to reclamation or disposal in storage facilities. Based on this flow chart, a calculation algorithm was created using quantitative parameters characteristic of sediments and their management method. The algorithm was transcribed into Excel® in order to automate the step-by-step calculations and thus obtain the financial cost (€) and environmental balance (GHG, land consumed, potential danger to the marine environment avoided) for each proposed scenario. The model's output is thus a decision-making tool, depending on the scenario chosen.

**Results:** According to the data collected in this study (CEREMA database), the volume of sediment dredged in France, exceeding the N1 threshold, is estimated at 14.3 million m3 per year, of which 400,000 m3 is currently brought ashore and managed. Simulations indicate that implementation of the new scenarios would lead to an increase of +87,600 m3 per year for scenario N2, +28,600 m3 per year for scenario ALT1, and +157,700 m3 per year for scenario N*. A hazard score was calculated for each dredging operation listed, and used to define a score for each scenario studied. Systematically, scenario N2 - which brings the largest volume of poor-quality sediment ashore - offers the greatest gain in terms of impact on the marine environment. However, the differences induced by the choice of scenario appear to be small on a national scale, indicating that sediments currently dumped are on average of fairly satisfactory quality, with disparities depending on the port and dredged area.

**Discussion:** In comparative terms, scenario N2 is the most protective for the marine environment according to the indicator used in this study, but would generate almost 5,000 tonnes of CO2 per year more than the current situation. Scenario ALT1, on the other hand, generates lower additional costs, emits fewer GHGs and consumes less land than scenario N2. It offers a more limited, but still significant, gain in terms of protection of the marine environment. For this reason, it has been selected by the French Ministry as the new threshold for prohibiting the dumping of sediments considered polluted.

**References:** [1] Article 11 de l'arrêté du 27 mars 2024.

# Circular management of dredged sediments from port maintenance

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**Conference theme number(s): 6**

**Introduction:** The concept of circularity is used as an alternative to linear flow materials in order to protect the environment from potential damage. To determine to what extent a sediment management project contributes to circularity practices, it is necessary to quantify how much of the dredged material is maintained within the system. Hence, defining boundaries for the system and circularity indicators for dredged material plays a vital role in measuring the circularity level of a certain project [1]. This study concentrates on defining circularity indicators for sediment management projects when a certain amount of material is diminished during the pre-processing stage. Besides, the perspectives of different stakeholders (e.g. port authorities, and dredging contractors) influence the selection of strategies for circular maintenance dredging [2].

**Methods:** To determine how the sediment management project contributed to a circular economy, the total amount of loss in the amount of sediment is measured during the pre-processing phase. The pre-processing operations might include washing, de-watering, treatment, desalination, degradation, etc. A certain tonnage of dried sediment (or cubic meters of slurry) is lost during each stage which reduces the circularity of the system. Figure 1 shows a simple schematic approach for sediment loss.

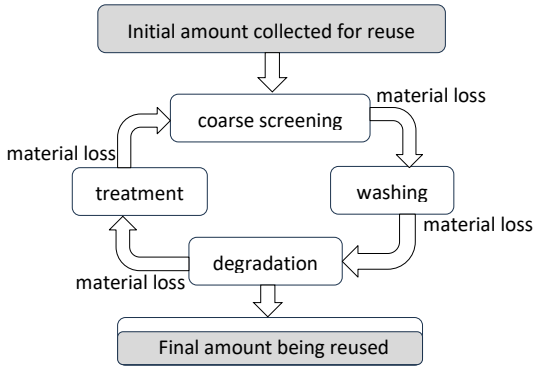


**Fig. 1:** Circular dredged sediment management [1]

The initial amount of collected sediments diminishes during each stage of pre-processing; therefore, the final amount being reused is relatively lower. As a result, the total contribution of the sediment management project to circularity practices is decreasing during each stage of pre-processing [3].

**Results:** Case studies of port maintenance are discussed to determine the impact of sediment pre-processing on the total loss before being re-used and the contribution of each project case to circularity practices. First, the pre-processing operations required to be specified for each case to monitor the sediment loss. Second, the amount of sediment loss in each stage is determined by tracking the input and output of each compartment. Third, the initial and final amounts are compared to measure to what extent the project is circular. Meanwhile, the circularity is also affected by sediment reusability and life cycle that are dependent on the sediment properties. Thereafter, other scenarios for dredging are discussed to provide a detailed insight into the optimal sediment management in each case. The scenarios focus on using different types of dredging vessels or vessels of the same type but with different properties. A discrete-event simulation is used to quantify a comparison between different dredging scenarios regarding efficiency and emissions.

**Discussion:** Scenario comparison is connected to trade-off quantification and the circularity index is studied along with other criteria such as emissions and the time needed to dredge the whole area. This trade-off can help stakeholders with different viewpoints to understand which strategies can be chosen for a certain case. Besides, the theoretical and managerial implications of this study are elaborated.

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# Sediment management in hydropower reservoirs on Drava river

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**Conference theme number(s): 6**

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**Abstract**

Eight large and three small hydropower plants on the River Drava generating approximately 2.8 TWh of electricity per year, represent one of the most important pillars of electricity production in Slovenia, as the total production accounts for about a quarter of the electricity generated in Slovenia.

Like in many other hydropower reservoirs around the world sediment deposition reduces the energy potential of reservoirs, decreases good ecological potential of the reservoirs, reduces flood control, irrigation possibilities and impede other functions that the hydropower operator is obliged to provide.

Based on the yearlong bathymetry survey results of the reservoirs on the River Drava, it is evident that the amount of sediment deposited in the live storage is increasing rapidly and reducing the daily production capacity of the hydropower plants. The capacity of the total volume has been reduced by 29% by 2023 from the original 108.99 million $m^3$ of sediment deposited in the useful volume to 108.99 million $m^3$ of sediment deposited in the useful volume by 2023. From a sediment management perspective, this represents 544,000 $m^3$ of sediment in the useful volume of all reservoirs that would need to be relocated or removed for full energy recovery.

A number of measures can be applied to mitigate the effects of sedimentation, from flushing to removal and treatment of sediment for re-use in construction. To be optimally effective in the long term, these measures require a holistic approach, ranging from the development of hydraulic models for the entire hydropower chain, the preparation of a sediment management plan and an action plan for the implementation of the measures, taking into account the legal framework and seeking compromises with stakeholders. The paper will present how Dravske elektrarne Maribor d.o.o. approached the problem.

# Regional Geochemical Baseline for the Southern Madeira Island: Challenges and Implications for Environmental Assessments

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**Conference theme number(s): 6**

**Introduction:** The term "geochemical baseline" was first introduced over three decades ago, but a universally accepted and concise definition remains lacking. In this context, we define it broadly as concentration levels of metals in the sediments of an environmental system for a defined timeframe.
Geochemical baseline values vary regionally due to geological settings and locally based on the influence of external geodynamic processes. Moreover, the applied analytical methods can significantly affect the observed metal concentrations. Different geochemical baselines may be defined depending on factors such as sediment fraction size (e.g., <2 mm vs <63 µm), composition (e.g., total vs lithogenic), or extraction method (e.g., total digestion vs partial extraction). Establishing these values is critical for environmental management and legislative decision-making.
In Portugal, sediment dredging is regulated by a decree that aligns with OSPAR environmental protection guidelines, classifying sediments into five classes based on contamination levels based on the concentrations of seven key metals and metalloids, along with three group of organic compounds. However, this criterion does not account for regional geological variability, particularly the differences between mainland and insular Portugal, posing challenges for its effective application. For example, Madeira Island has high metal and metalloids contents in its outcropping basaltic rocks, often exceeding the Class 1 threshold for non-contaminated sediment. This is particularly evident for nickel and chromium, whose concentrations frequently exceed or match Class 3 levels, indicating at least slight contamination.
These naturally higher concentrations highlight the need for a region-specific geochemical baseline reflecting Madeira's geology. Therefore, this study aims to establish baseline concentration values or upper thresholds for chromium (Cr), nickel (Ni), copper (Cu), and zinc (Zn) on Madeira's southern shelf for the early 21st century, considering sediment characteristics and environmental conditions. This approach will ensure accurate contamination detection, support policy decisions, and provide a robust framework for assessing contamination levels tailored to this island.

**Methods:** Surface sediment samples were collected in the southern shelf of Madeira using a Smith-McIntyre grab: 166 in 2002/2007 and 20 in 2017/2019. Metal concentrations were determined by AAS after total digestion of the <2 mm sediment fraction. Calcium carbonate ($CaCO_3$) content was estimated using NDIR spectrometry. Sediment texture was classified based on median grain-size, determined through mechanical sieving (>500 µm) and laser diffraction (<500 µm).

**Results & Discussion:** Two distinct sectors were identified along the southern insular shelf based on the spatial distribution of $CaCO_3$ and metal contents. While a textural gradient reflecting hydrodynamic conditions is observed, it does not significantly affect metal distribution. The eastern sector, sheltered from wave action, consists of very fine to coarse sands, with a wide range of $CaCO_3$ (6-82%) and metal contents (Zn: 19-140 mg/kg, Ni: 30-282 mg/kg, Cr: 64-731 mg/kg, Cu: 7-66 mg/kg). In contrast, the western sector, more exposed to the Atlantic swells, features sediments ranging from coarse silts to coarse sands, with less than 50% of $CaCO_3$ and narrower metal concentrations ranges (Zn: 67-178 mg/kg, Ni: 75-332 mg/kg, Cr: 225-1145 mg/kg, Cu: 2361 mg/kg). The compositional differences are attributed to variations in the bioclastic component, predominantly composed of carbonate minerals, which dilute elemental concentrations. This highlights how contrasting hydrodynamic conditions influence the sediment type (lithogenic vs biogenic) and therefore the metal concentrations across the study area.

**Future Work:** Baseline values for Cr, Ni, Cu, and Zn concentrations in the southern Madeira shelf sediments will be determined using statistical methods (e.g., iterative 2σ-technique and cumulative distribution function) based on their concentration distribution (unimodal vs. polymodal, normal or log-normal) from samples collected in the first decade of the 21st century. These values will be compared with current legislation and samples from the late 2010s.

**Acknowledgments:** Thanks to the Regional Government of Madeira for the data used in this study.

# Phosphorus recovery from dredged sediments: Case of Malmfjärden Bay, Kalmar

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**Abstract**
Sediment dredging is important for ensuring an adequate navigation depth of harbours and flood prevention. Despite having several beneficial uses, sediments are often considered waste and disposed of in open oceans or landfills. Metals and nutrients can be extracted and recovered from the sediments for re-use. The aim of the current study is to extract phosphorus (P) from dredged sediments from Malmfjärden bay through chemical extraction, using several extractants and concentrations, targeting to determine the best conditions to extract phosphorous from the studied sediments with minimal contamination with metals. The chemicals used for the extractions include citric acid ($C_6H_8O_7$), sulphuric acid ($H_2SO_4$), sodium hydroxide (NaOH) and ethylenediaminetetraacetic acid (EDTA) at 0.01M or 0.1M. The acids were at pH 5, and NaOH at pH 12. pH was also varied for 0.01M EDTA at pH 2, and 0.1M $H_2SO_4$ at pH 1. Single extraction was carried out with each reagent at the varying concentrations and pH. One test had a combined treatment of EDTA as a first step, followed by $H_2SO_4$ as a second step. The results showed that extraction efficiencies were significantly higher at 0.1M than 0.01M of the reagents, as well as at more acidic conditions for the reagents with varied pH, in most cases. $H_2SO_4$ at pH 1, extracted the most P (46.4%), together with most of the other elements. EDTA also exhibited a high extraction efficiency for the elements and can be used as a pre-step to remove metal before extraction with $H_2SO_4$. Alternatively, although it had lower P extraction efficiencies, NaOH can be used as the extractant, since it extracted less of the other elements. Hence, the recovered P will be less contaminated. Further research will be done on recovering the P from the extractant with higher P purity and less contamination from metals/metalloids, taking into consideration economic feasibility.

Keywords:

Dredged sediments, phosphorus extraction, metal contamination, circular economy