TU Delft

Delft University of Technology

Document Version
Final published version

Citation (APA)
Kirichek, A., de Lucas Pardo, M., Freymuth, H., & Lehman, K. (2026). Nature-based technologies for dewatering of dredged material. In *Tagungsband 13. Rostocker Baggergutseminar: Kompetenztreffpunkt Baggergut* (pp. 23-30). Universiteitsdruckerei Rostock.

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Copyright
In case the licence states “Dutch Copyright Act (Article 25fa)”, this publication was made available Green Open Access via the TU Delft Institutional Repository pursuant to Dutch Copyright Act (Article 25fa, the Taverne amendment). This provision does not affect copyright ownership.
Unless copyright is transferred by contract or statute, it remains with the copyright holder.

Sharing and reuse
Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy
Please contact us and provide details if you believe this document breaches copyrights.
We will remove access to the work immediately and investigate your claim.

*This work is downloaded from Delft University of Technology.*

*Alex Kirichek, Miguel de Lucas Pardo, Heye Freymuth, Karsten Lehman*

# Nature-based technologies for dewatering of dredged material

## Introduction

Dewatering of dredged material traditionally relies on chemical conditioning and energy-intensive mechanical processes. Although these approaches can effectively reduce water content and improve the physical handling properties of dredged material, they may involve substantial fossil-fuel consumption, greenhouse-gas emissions and operational costs. Moreover, conventional dewatering primarily targets the physical properties of the sediment and does not necessarily improve its biological quality, which can limit its subsequent reuse in applications requiring a biologically functional soil or sediment.

In contrast, nature-based technologies use naturally occurring organisms and ecological processes to promote sediment dewatering and consolidation while simultaneously improving sediment quality. In natural aquatic environments, including lakes, rivers, estuaries and coastal systems, vegetation and benthic fauna are integral components of sedimentary ecosystems. These organisms continuously interact with the sediment matrix through processes such as root growth, bioturbation, nutrient uptake, organic-matter turnover, and pore-water exchange. Such biological–sediment interactions can substantially modify the physical, hydraulic and biogeochemical properties of sediment (de Lucas Pardo et al, 2020).

Vegetation can contribute to the dewatering and consolidation of water-saturated sediments through a combination of root water uptake, evapotranspiration, and modification of sediment structure (Barciela Rial, 2019). Plant roots extract pore water from the sediment to support transpiration, thereby reducing sediment water content and potentially increasing effective stress within the sediment matrix. Root growth can also alter sediment porosity and hydraulic conductivity by creating preferential flow pathways, thereby facilitating pore-water drainage and promoting consolidation. The magnitude of plant-mediated dewatering depends on plant species, root density and depth, sediment texture, initial water content, salinity, groundwater conditions and atmospheric demand. Evapotranspiration is generally the dominant water-loss pathway at the system scale, while root-induced changes in sediment structure can regulate the availability and transport of pore water. In coastal and estuarine environments, halophytic vegetation may therefore contribute to sediment consolidation and stabilization while simultaneously modifying sediment hydrodynamics and biogeochemical conditions.

Benthic fauna can provide an additional mechanism for accelerating sediment dewatering. In particular, oligochaete worms have been shown to enhance the dewatering of freshly deposited, soft sediments in Dutch water bodies (de Lucas Pardo, 2014). Through their vertical

migration and feeding activity, worms create an interconnected network of burrows and channels within the sediment. These structures provide preferential pathways for pore-water drainage, thereby accelerating dewatering and consolidation and enabling the sediment to reach a more compact final state over a shorter timescale (de Lucas Pardo and Kirichek, 2020). In addition to their physical effects, bioturbating organisms can modify the geochemical conditions within the sediment through respiration, organic-matter processing, and particle reworking, potentially contributing to changes in sediment strength and stability.

Oligochaetes are widely distributed in muddy freshwater, estuarine, and coastal environments, and some species exhibit high tolerance to anoxia and elevated concentrations of contaminants and heavy metals (Yang et al., 2020). Their ability to survive and function under conditions characteristic of dredged material makes them promising biological agents for sediment dewatering and conditioning. Accordingly, the application of oligochaetes for the treatment of dredged material has been investigated in several countries, including the Netherlands, Chile, Brazil, Canada and Northern Europe. This paper presents the main findings from these nature-based dewatering projects.

## Methodology

The implementation of nature-based technologies follows a sequential pathway, beginning with small-scale laboratory investigations and progressing through controlled container tests to the upscaling of results in in-situ pilot studies, ultimately leading to full-scale deployment during the operational dewatering phase of the sediment management cycle (see Figure 1).

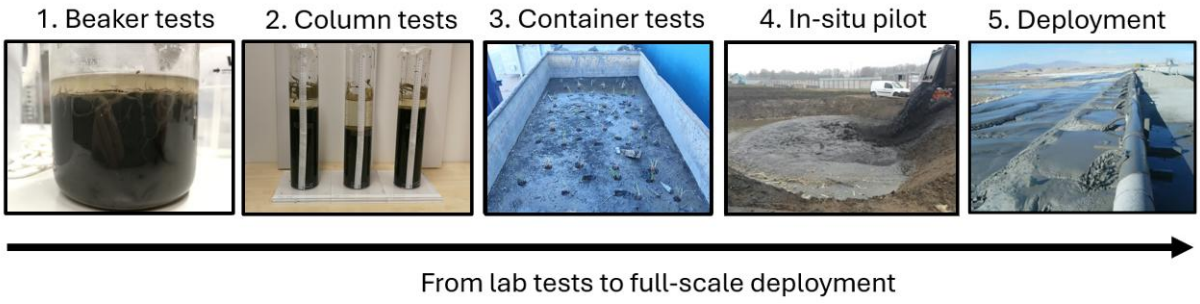



Figure 1: Implementation pathway: optimizing the performance of nature-based technologies before full-scale deployment in sediment management strategies.

The first adaptability assessment of the nature-based technologies is conducted through beaker tests. Nature-based agents are initially selected based on the physical and geochemical properties of the sediment, as well as the characteristics of the pore water. These experiments identify the most suitable nature-based agent (e.g., worm species, plants, or bacteria) that is compatible with the local sediment conditions and/or capable of accelerating

the dewatering process. For contaminated sediments, a systematic series of experiments is conducted to identify nature-based agents with potential for decontamination.

Once suitable nature-based agents have been identified, column tests are conducted to optimize their concentration or dosage. This phase provides an initial estimate of the dewatering timescale, enables comparison with conventional dewatering practices, and supports the identification of combinations of nature-based agents that achieve the best dewatering performance for dredged material, as measured by key parameters such as solid content and undrained shear strength.

In the next phase, the best-performing nature-based agents and dosages identified during the column tests are evaluated in container-scale experiments at the problem owner's site. This allows the selected agents to be exposed to local climatic and site-specific conditions, providing an important intermediate step before an in-situ pilot is undertaken. Container tests can also provide insight into the lateral migration and spatial distribution of worms and bacteria, as well as the development of root systems in vegetated systems. These insights can be used to optimize agent concentrations and inform subsequent cultivation, farming, and harvesting requirements.

The in-situ pilot is conducted once the nature-based agents and their optimal concentrations have been established through the preceding research phases. The selected agents are introduced into a defined segment of the sediment dewatering chain within the sediment management cycle. Their performance is monitored using key performance indicators (KPIs), e.g., dewatering time, emissions and costs, is evaluated against a baseline or conventional practice.

The implementation pathway culminates in full-scale deployment, in which the selected nature-based agents are integrated into the operational sediment dewatering process. This phase considers the characteristics and requirements of the production line, the business case, the availability and supply of the nature-based agents and applicable regulatory requirements.

## Results

The proof-of-concept beaker tests provide a rapid assessment of the suitability of different nature-based agents for a specific type of dredged material. By considering key sediment characteristics, including particle size distribution, organic matter content, salinity, pH, and contamination levels, these tests enable the rapid screening and selection of suitable nature-based agents. An example of the beaker tests is shown in Figure 1, where the adaptability and reproduction of worms species were tested with various organic and inorganic additives in tailings.

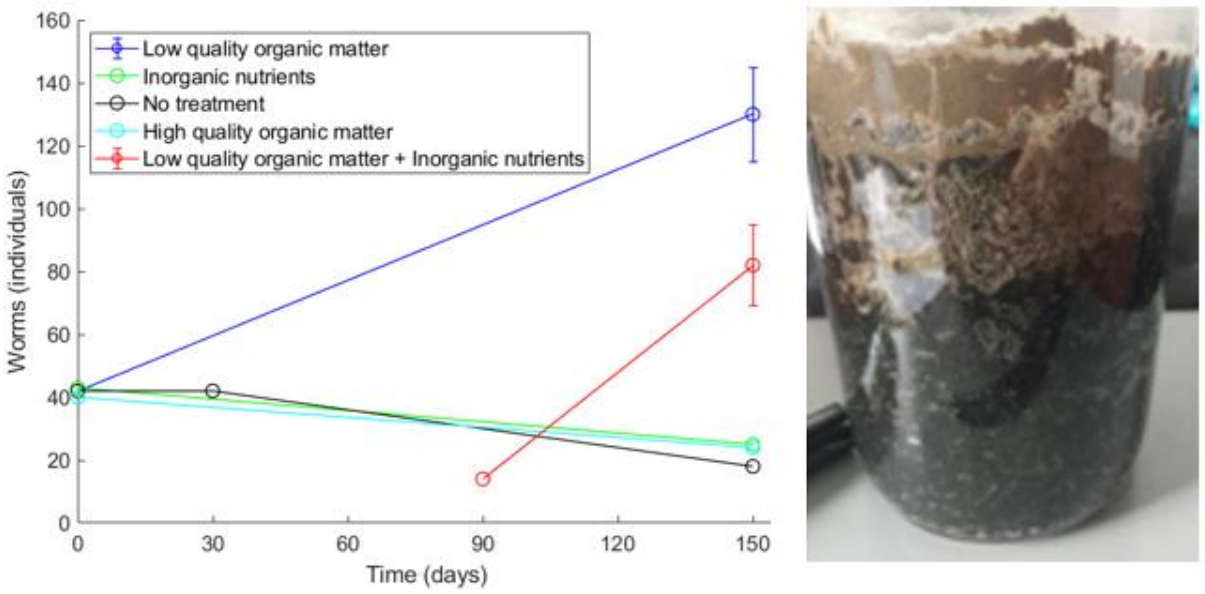



Figure 2: Testing adaptability of worms with organic and inorganic additives in tailings using the beaker tests.

Column tests provide more detailed insights into the dewatering efficiency of nature-based agents as the dredged material undergoes settling and consolidation. They also enable optimization of the agent concentration using columns with a typical height of 0.5–1.5 m, representative of the thickness of dredged material in dewatering fields. An example of worm concentration optimization is presented in Figure 3. All tested worm concentrations resulted in faster dewatering compared with the baseline (see left panel). However, doubling the worm concentration from C2 to C1 did not result in a significant further increase in the development of solid content across the samples with the initial solid contents of 0.5 (right panels). This indicates that the lower worm concentration was sufficient to achieve optimal dewatering performance.

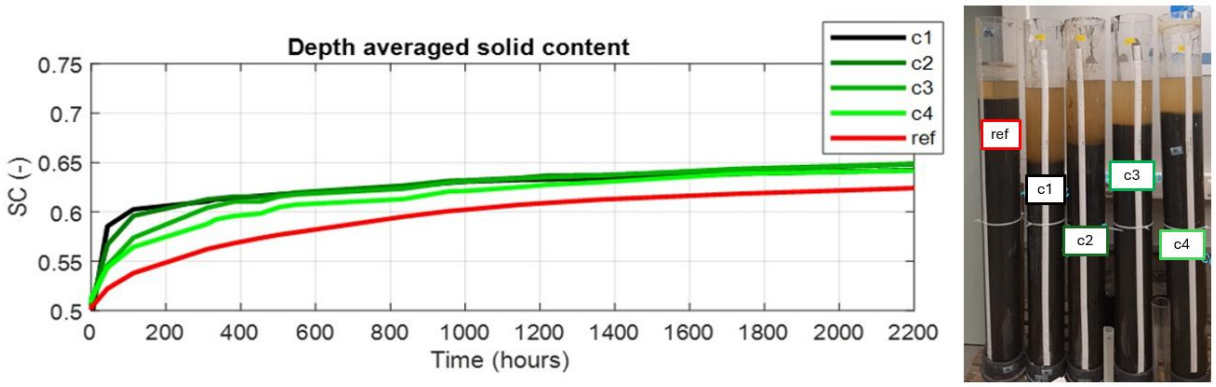



Figure 3: Optimizing concentrations of worms for dewatering tailings based on the solid content (left panel) and selling measurements (right panel) for the worms concentrations c1-c2 24 hours after setting up the column tests.

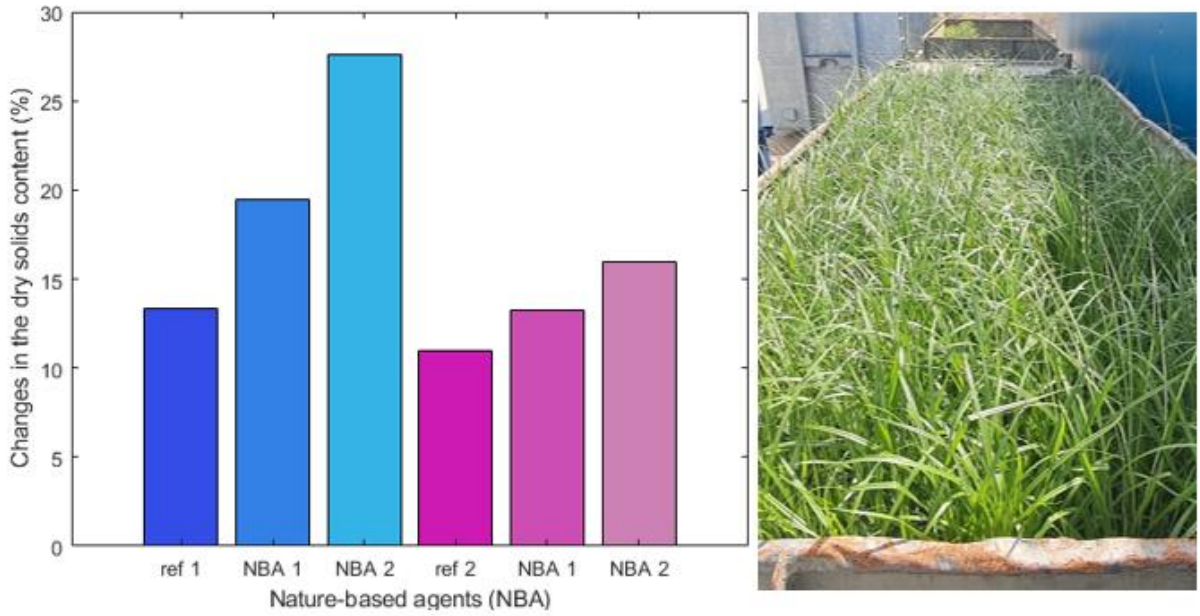



Figure 4: Changes in dry solids content of 2 dredged materials with different composition (ref 1 and ref 2) from the Rotterdam region following application of 2 nature-based agents (NBA 1 and NBA 2), after 1.5 months of container testing. Both materials had an initial solids content of approximately 0.25.

Container tests enable nature-based agents to be evaluated under conditions that closely resemble those of the in-situ environment, as the experiments are typically conducted in proximity to the dewatering fields. Figure 4 shows the percentage changes in dry solids content of 2 types of dredged material from the Rotterdam region, which had different compositions but similar initial solids contents of approximately 0.25, following the application of local plants and worms after 1.5 months of container testing.

All knowledge gained from the controlled laboratory and container tests, including the selection and combination of nature-based agents, deposition strategies, methods of introduction, and optimal conditions and concentrations, is used to design and conduct the in-situ pilot. Monitoring the KPI's is the key to understanding the performance of the nature-based agents compared to the baseline. For example, the strength of the dredged material is one of the KPIs, that can be monitored in the field. Figure 5 shows the strength measurements of dredged material in the 3 dewatering compartments 3 months after initiation of the in-situ pilot in Rotterdam. Worms were used as nature-based agents for dewatering in the 1$^{st}$ compartment, while a combination of worms and plants was applied in the 2$^{nd}$ compartment. The 3$^{rd}$ compartment served as the baseline condition (without nature-based agents). Furthermore, contamination levels can serve as a KPI in case of the dewatering of the contaminated material. Figure 6 shows the heavy metal decrease after introducing a combination of nature-based agents in the dredged material during the in-situ pilot in Rotterdam.

Finally, full-scale deployment of the selected nature-based agents requires a comprehensive assessment of the sediment dewatering chain and a comparison of KPIs. Figure 7 presents a comparative analysis of time, emissions, and costs for passive dewatering in dewatering fields

(I), dewatering using the selected nature-based agents (II) and mechanical dewatering using different types of equipment (IIIa–IIIc) in the city of Rotterdam. These KPIs are also compared with the alternative of sourcing suitable soil from the market, providing a broader basis for evaluating the technical, environmental, and economic performance of the different approaches.

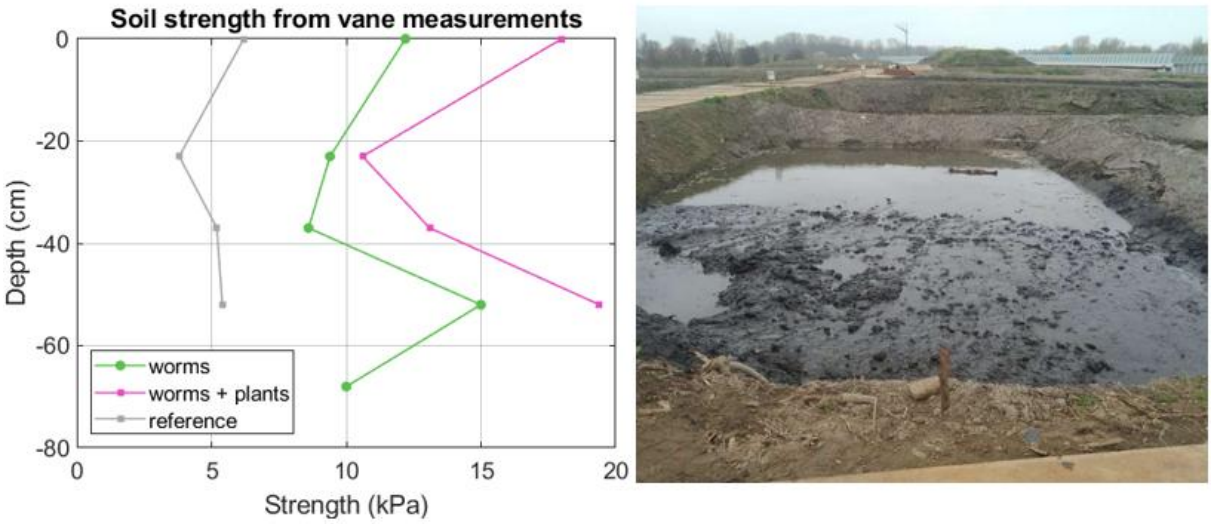



Figure 5: Strength of the dredged material in the dewatering of 3 dewatering compartments (one with worms, one with plants and one without nature-based agents) 3 months after initiation of the in-situ pilot in Rotterdam.

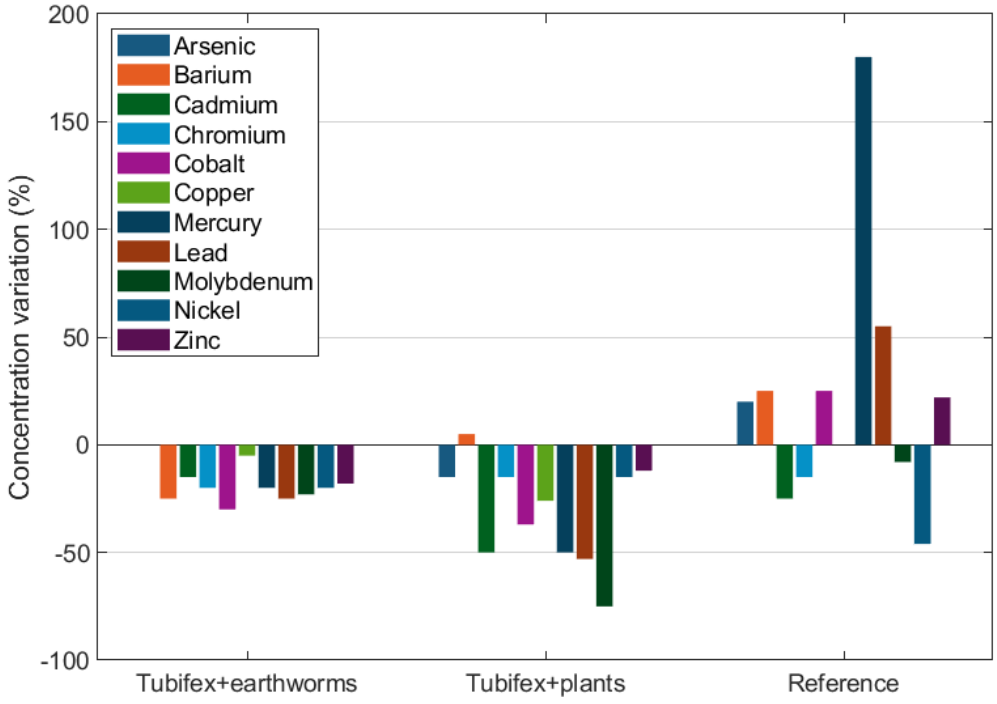



Figure 6: Heavy metal decrease due to introducing nature-based agents in the dredged material during the in-situ pilot in Rotterdam.

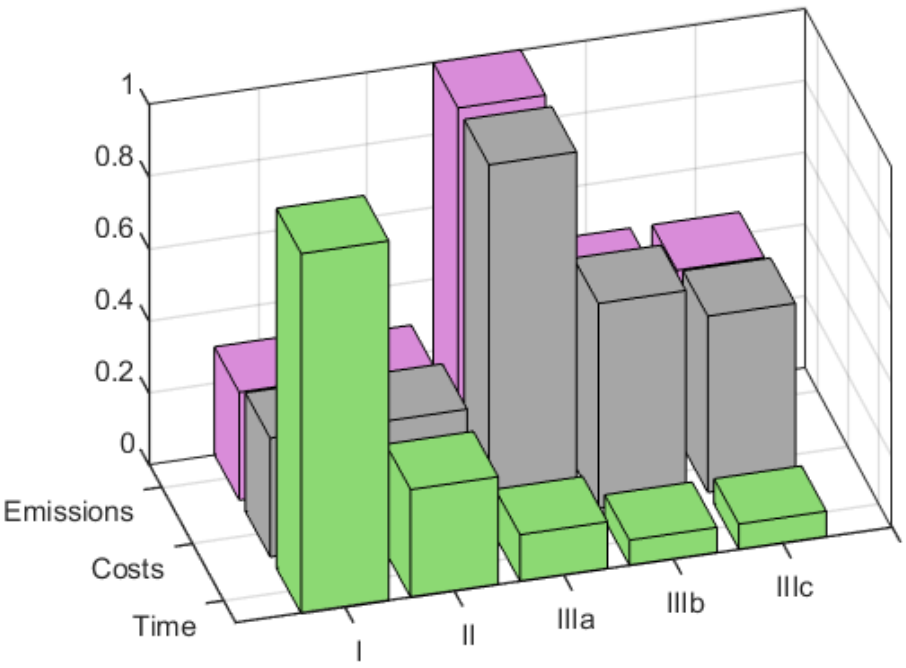



Figure 7: Comparing dewatering KPIs (time,costs and emissions) for full-scale deployment of the tested dewatering agents in sediment strategies in Rotterdam.

## Conclusions

Nature-based technologies accelerate dewatering without added costs and produce higher-quality soil suitable for reuse, supporting a more sustainable sediment management. Ongoing research focuses on optimizing this technology for field-scale applications and identifying the boundary conditions required for its effective integration into the problem owners' sediment management cycles.

The integration of vegetation and benthic fauna can provide a multifunctional approach to dredged-sediment management, in which dewatering and consolidation are coupled with biological conditioning and the development of a more functional sediment matrix. Such nature-based technologies can therefore offer an alternative to conventional dewatering technologies while potentially reducing energy consumption and emissions and increasing the suitability of treated dredged material for beneficial reuse.

## Acknowledgement

We thank Gemeente Rotterdam, Port of Rotterdam, Hamburg Port Authority, Rijkswaterstaat, Province Zuid-Holland, COSIA, Deltares and the MUDNET community for supporting the development of the nature-based technologies.

## References

Barciela Rial M. (2019). Consolidation and drying of slurries: A Building with Nature study for the Marker Wadden. PhD thesis. Delft University of Technology.

de Lucas Pardo M.(2014). Effect of Biota on Fine Sediment Transport Processes: A Study of Lake Markermeer. PhD thesis. Delft University of Technology.

de Lucas Pardo M., Kirichek A., Kox M. and van Rees F. (2020). Terra et Aqua 161:6-19.

de Lucas Pardo M. and Kirichek A (2020). Land/Water 8/9.

Yang X., de Lucas Pardo M., Ibanez M., Deng L., Sittoni L., Ulrich A. and Chen, Q. (2020). Improving engineering properties of mature fine tailings using Tubifex. Canadian J. of Civ. Eng., 47(7), 812-821.

## Contact

Dr. Miguel de Lucas Pardo

Medeina Engineering B.V.

E-Mail: m.delucas@medeina.nl

Internetseite: www.medeina.nl