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

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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.

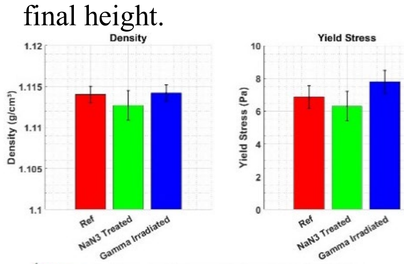

Fig. 1: *a) Density and yield stress for reference, NaN_3-treated, and gamma-treated samples (error bars: variation in duplicates)*

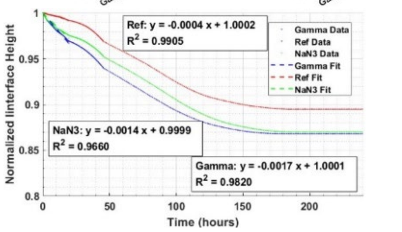

Fig. 2: *Settling rate for reference, NaN_3-treated, and gamma-treated samples*

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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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.

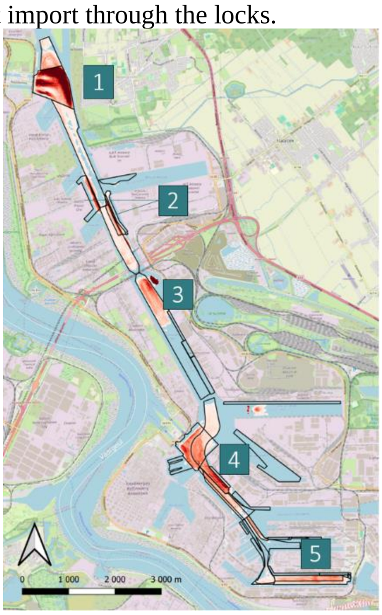

Fig. 2: Dredging intensity of the trailing suction hopper dredgers 2016-2024.

High concentrations of certain trace metal elements in Martinique port sediments.

A natural or anthropogenic origin?

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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.

References: [1] CASTAING et al. (1986) *Qualité des eaux et des sédiments dans la baie de Fort-de-France (Martinique), Université de Bordeaux 1 ;*
[2] PONS et al. (1988) *Teneurs en métaux lourds des sédiments fins de la baie de Fort-de-France, Martinique.*
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