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An experimental study on dredge spoil of estuarine sediments in the bay of seine (France): A morphosedimentary assessment

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ABSTRACT

Studies on the consequences of dredging on estuarine morphology and its sedimentary dynamics are common, but the impacts of dumping dredge spoil in coastal open settings are rarely found in scientific literature. An experimental study was conducted over the period 2012-2013 to monitor the physical impacts of dredged material dumped at two adjacent sites (one million cubic metres at each) on the inner shelf of the Bay of Seine in France (eastern part of the English Channel, La Manche). As recently reinforced in the EU Marine Strategy Framework Directive (MSFD), knowledge on the location and intensity of human impacts (e.g. on marine ecosystems) is critical for effective marine management and conservation. So, two methods of disposition were tested to evaluate the impacts of dumping on the environment and thus propose recommendations for future dumping. The strategy is based on a Before-After-Control-Impact (BACI) approach, in which the spatio-temporal variability was studied by analysing the morphological and sedimentological characteristics over a period of 28 months, from November 2011 to April 2014, also including recovery of the seafloor after cessation of the dumping activities. The first experimental dumping operation (**MASED**) was carried out regularly for 8 months at a single point and generating a conical deposit of 5 m in height, while the second dumping (**MABIO**) lasted for 12 months involving four steps in the dumping process. In the second case, a wider area was covered, leading to the formation of a smaller deposit of 2 m in height. The dumped deposits consisted of muddy fine sand, whereas the inner shelf seafloor in this area is covered with fine to medium sand. As a result, muddy fine sand accumulated at or near the two dumping sites, with a maximum mud (i.e. particles < 63 μm or > 4 Φ) content of 50% compared to $< 5\%$ before dumping operations. Videos obtained from a LVB200 Seabotix ROV, highlighted the heterogeneity of the sea floor around the dumping areas. Due to hydrodynamic forcing (wave climate and tidal currents), about 50% (**MABIO**) and 75% (**MASED**) of the volume of dredged material remained at the end of the dumping periods. After dumping ceased, a further 5% of material for MABIO and 20% for MASED, was transported out of the study area. For the latter, a spreading of fine particles was observed extending from the conical deposit towards the south west. To favour long-term exploitation, a more dispersive dumping over a wider surface area is recommended (e.g. MABIO)

1. Introduction

To enable their economic development, harbours are required to have good and permanent access. The improvement of shipping facilities in harbours necessitates that navigation channels should be regularly maintained to ensure sufficient depth for vessels with deep drafts. Every year, large amounts of sediment are dredged in the access channels; these amounts vary widely, depending on the size and geographical location of harbours. According to the risks for the environment, dredged materials can be disposed of at sea by; overflow during dredging, dumping in authorized reference areas, or by being brought ashore for storage or treatment. The latter approach remains an alternative, but requires extensive

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storage and involves high costs to provide large areas for potentially polluted sediments. Dredged material can be used for the creation of artificial wetland areas or for beach nourishment. However, for economic reasons, most dredged material is disposed in offshore areas (Engler et al., 1991). Dredged material disposal is required, it is inevitably linked to good environmental status (GES) of the marine environment. This is the 2020 goal of the Marine Strategy Framework Directive (MSFD, 2008/56/EC). Appropriate assessments are needed of any plan or project that may affect such sites. To allow monitoring of the evolution towards GES, a series of descriptors have been defined. Related to physico-chemical seabed attributes, descriptor 6 on seafloor integrity and descriptor 7 on hydrographic conditions are both relevant in the context of physic impacts. GES for seafloor integrity refers to the structure and functions of the ecosystems that need safeguarding, without adversely affecting benthic ecosystems, whilst GES for hydrographic conditions implies that permanent alteration of hydrographical conditions does not adversely affect marine ecosystems (Van Lancker et al., 2013).

Numerous studies have focused on the environmental impact of dredging activities (e.g. De Jonge et al., 2004; Van Raalte, 2006; Van Maren et al., 2014) or their morphological consequences (e.g. Monge-Ganuzas et al., 2013), but few authors have addressed the impact of spoils in the open marine environment. The dumping of dredged materials is one of the most important problems in coastal zone management (O'Connor, 1998), can produce a major disturbance to the environment (Essink, 1999). The physical impact of dredge spoil on coastal ecosystems depends on the methods of dumping, the amount and manner of disposal (Newell et al., 1999), as well as the oceanographic conditions at the deposition site (Cole et al., 1999). Several studies have addressed the effects of the disposal of dredged material in offshore environments, but only few have considered the short- and long-term effects ($>$ 1 year) of the disposal of uncontaminated dredged material (Du Four and Van Lancker, 2008).

The Grand Port Maritime de Rouen (GPMR, the harbour authority), which is the most important French inland harbour, is situated 120 km from the sea. Its access is ensured by regular maintenance and permanent dredging of the outer navigation channel. Each year, up to 4.5 million cubic metres of sediment are extracted and dumped at the disposal site called "Kannik", to the north of the Seine mouth. Kannik was commissioned in 1977, and has so far remained the authorized dumping site for material dredged from the navigation channel. However, it will reach saturation in 2016. To replace this site and optimize the future dumping of sediment, the GPMR is searching for a new site outside the Seine estuary (Marmin et al., 2014). Therefore, an experimental study was carried out in the proximal eastern Bay of Seine to

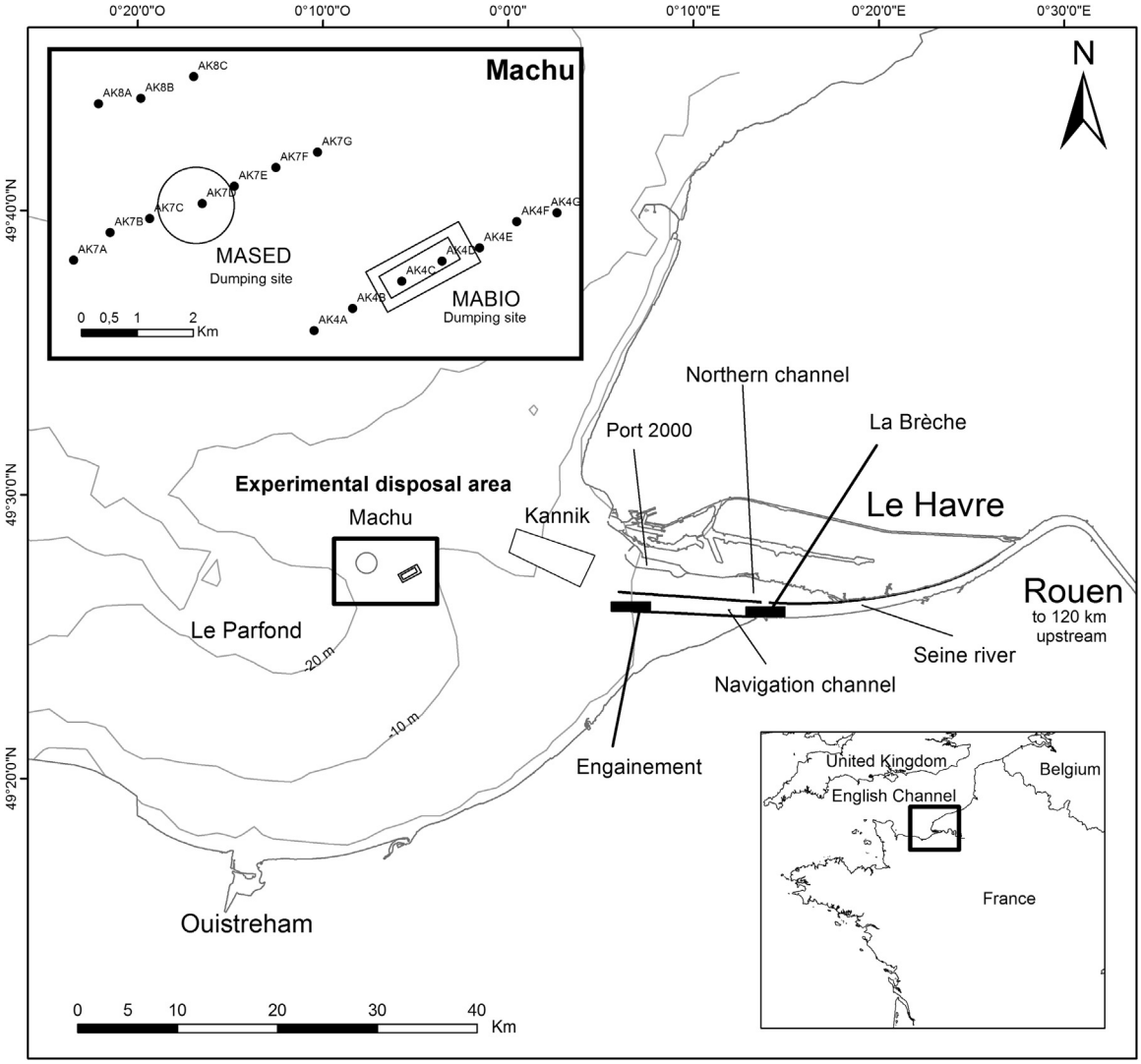

Fig. 1. Map of the eastern Bay of Seine showing the location of the present-day dumping site (Kannik) and the experimental disposal area (Machu). The sampling stations distributed over the two dumping sites (MASED and MABIO).