Dispersion and deposition of sediment plumes, resulting from intensive marine aggregate extraction.

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Abstract

Marine aggregate extraction activities, using small (2.500m^3) to large (> 10.000m^3) trailer suction hopper dredgers, pressurize quasi-continuous the marine ecosystem of the Belgian part of the North Sea. Since the concession zones are within a Habitat Directive Area, or nearby, potential near- and far-field impacts need investigation. Results indicated that, after 2-yrs of intensive extraction along the far offshore coarse-grained sandbanks, some fining trend was observed in the upper seabed. In the Habitat Directive area, mud enrichment has been observed over 3 consecutive years. Hitherto, no direct link can be made with the extraction activities, though the area is further monitored to assess changes in seafloor integrity.

Keywords: environmental monitoring; suspended particulate matter; plume modelling; European Marine Strategy Framework Directive

1. Introduction

With the increasing demand of marine aggregates, the Belgian State recently opened 4 new extraction sites on sandbanks, 40 km offshore (Fig. 1). Up to 2.9 million m^3 sediments can be taken over 3 months with a maximum of 35 million m^3 over a period of 10 years. This is the highest amount ever extracted in the Belgian part of the North Sea (BPNS). The present paper focusses on the main extraction site (Sector 4c Oosthinder; Fig. 1), where since 2012 intensive extraction took place. The main objective was to assess the dispersion and deposition of sediment plumes arising from the overflow of trailing suction hopper dredgers (TSHD). The term ''overflow'' refers to the release of a mixture of water and sediments from the hopper of the TSHD, forming a plume of sediments in the water column. The coarser portion of the initial plume deposits close to the dredger, the so-called dynamic plume. The portion remaining in suspension contributes to a passive plume of which the dispersion can reach some km distance from the vessel (Jones et al., 2010; Spearman et al., 2011). With the implementation of the Marine Strategy Framework Directive (MSFD; Directive 2008/56/EC; Zampoukas et al., 2012), European Member States need to arrive at a 'Good Environmental Status' of their marine environment by 2020. Since the extraction takes place at 2.5 km northward of a Habitat Directive area (Council Directive 92/43/EEC; Fig. 1), where ecologically valuable gravel beds occur, appropriate assessments are needed. Particularly, there are concerns that the intensive aggregate extraction can lead to increased deposition of fines that might smother the gravel beds on the longer term.

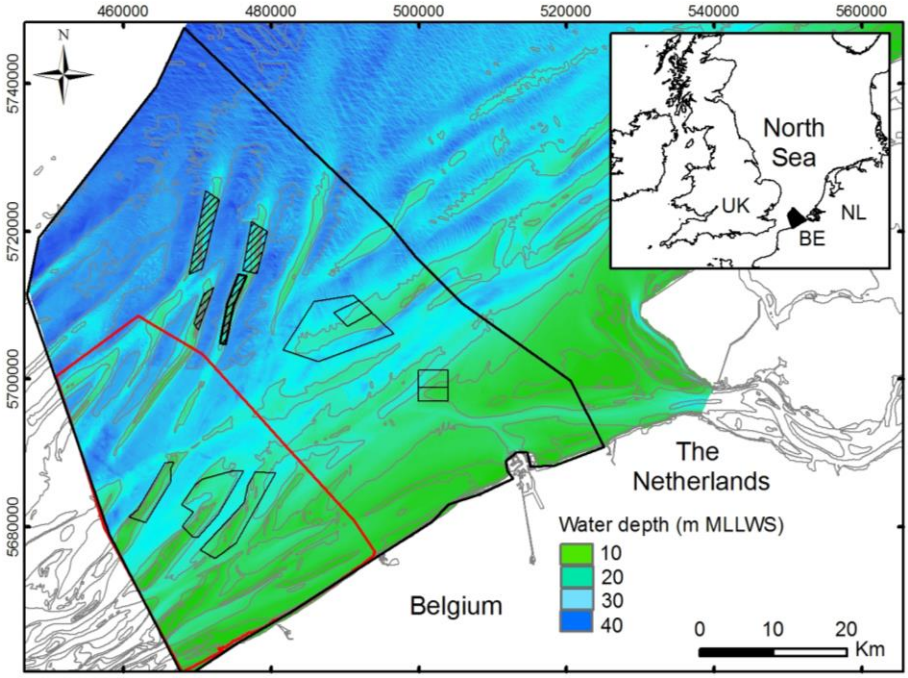

Fig.1 Bathymetry of the Belgian part of the North Sea. Red boundary illustrates the Habitat Directive Area. Black polygons represent the sectors on each sandbank where marine aggregate extraction is allowed. Hatched polygons indicate where intensive extraction took place since 2012; the bold polygon is Sector 4c, Oosthinder sandbank.

2. Materials and methods

First, the intensity of marine aggregate extraction activities was assessed based on data from the Electronic Monitoring System (EMS) of each TSHD. EMS recorded the position of the ships, as well as their pump status. Secondly, to validate the dispersion and deposition of sediment plumes in the near- and far-field, *in-situ* sampling and observations were conducted (RV Belgica, 24-28 March 2014). ADCP data (RDI, 300 kHz, 1m bin size) were recorded and converted to suspended matter concentrations (following Deneis, 1999). SPM of the water column for both the extraction site and Habitat Directive area was determined from water samples, respectively from the water surface, using a centrifuge purifier, and from close to the seabed. 16 Reineck cores, sliced at 1-cm interval, were taken in the vicinity of the extraction site to characterize the sediment composition and to characterize the depositional pattern of the overflow release. Additionally, 3 Hamon grabs were taken along the gravel beds in the Habitat Directive area to reveal any potential fining trend in the far-field. All cores were analysed for total organic matter content (TOM %), as well as for carbonate content by using the Loss-on-ignition method (Dean 1974; Heiri et al., 2001). Grain-size analysis were conducted using a Malvern Mastersizer 3000 laser particle analyser. Finally, models were used to predict the overflow release of sediment fractions for each TSHD using TASS 4.0 software (Ecoshape, 2013; www.ecoshape.nl), in combination with sediment transport models (Van Lancker et al., 2014). The model ran on a two dimensional ± 250 x 250 m resolution, hydrodynamic model, coupled to a ± 5 x 5 km resolution wave model (HYPAS; Van den Eynde, 1992).

3. Results

3.1 Dredging activity

EMS data revealed a clear increasing trend in the intensity of the dredging activities in the last three years (2012 - 2014) with varying practices: (i) use of larger TSHDs; (ii) longer dredge tracks; (iii) more dredging events (extractions up to 4 times per day); and (iv) simultaneous operations by small (± 2.500 m^3) and large (± 10.000 m^3) TSHDs. Table 1 illustrates the estimated total overflow of fine sediment release for each TSHD for the last three years.

Table 1. Estimate of the total amount of fine sediment fractions (16 µm and 63 µm) released from TSHDs extracting in 2012, 2013 and 2014. Calculations are based on TASS 4.0 software (Ecoshape, 2013).

TSHD	Capacity (m^3)	Year	Months	Extraction events	16µm (kg)	63µm (kg)
Small	± 2.500	2012	Feb-Mar	9	12000	6000
Medium	± 4.500	2012	Mar-May	83	380000	190000
Large	± 10.000	2012	May-Jun	63	500000	250000
Small	± 2.500	2013	Mar-Jun	76	86000	43000
Large	± 10.000	2013	Oct-Dec	78	110000	560000
Small	± 2.500	2014	Feb-Mar	56	63000	32000
Large	± 10.000	2014	Jan-Mar	143	2000000	1000000

3.2 Sediment composition of extraction site and Habitat Directive area

The sediment composition in the extraction site consisted of medium to coarse sands (250 – 665 µm). High amounts of shell fragments were found to be present in all cores. Fine fractions (silt/clay) were only observed along the western flank of the sandbank, with some fining towards the upper layer of the cores. TOM analyses did not reveal any significant high presence of organic material (0.5 to 2.7 %), whereas the high values of carbonate content observed were due to the high presence of shell fragments. The sediment composition of the Habitat Directive area consisted mainly of gravel and coarse sediments. However, unusual high percentages of mud were observed also, reaching up to 22 %. The mud fraction had modes of 8 to 9 µm (medium silt). TOM ranged between 1.7 to 2.7 % with a carbonate content of 7 to 10.8 %.

3.3 Plume observations

The descent of dynamic plumes, generated by a small-sized TSHD, was recorded with the hull-mounted ADCP. The width of the plume increased with depth, forming an up to 50 m wide plume close to the seafloor. Based on the ADCP backscatter, the SPM concentration within the plume reached up to 1 gl^{-1}. Grain-size analyses of water samples, taken within the passive-surface plume of the small TSHD, revealed modes of 6-10 µm. SPM concentrations within the passive plume ranged between 0.01 to 0.04 gl^{-1}.

3.4 Plume modeling

Sediment plume model simulations were run for both a small (± 2.500 m^3) and large (± 10.000 m^3) TSHD, for a period of 45 days. The total amount of overflow release of the fractions less than 63 µm was in the order of 2.500 tons and 12.500 tons, respectively. For both ship classes the model showed the potential for deposition of fines in the Habitat Directive area. However, stronger tides and waves would resuspend most of the material. Only the model results of the larger TSHD showed a remaining deposition after the 45 days of simulations.

4. Conclusions

Within the last 3 years (2012 – 2014), the marine ecosystem of the far offshore Belgian part of the North Sea was subdued to increasing pressure from aggregate extraction. Simultaneous activities, using small (2.500 m^3) and large (>10.000 m^3) TSHDs, already introduced some fining trend in the top surface of the seabed of the extraction site. Plume modelling confirmed that sediment plumes generated at the extraction sites can deposit in the Habitat Directive Area, though hydro-meteorological conditions would likely prevent permanent deposition. However, a mud enrichment (up to 22 %) has been observed over 3 consecutive years. Hitherto, no direct link can be made with the extraction activities, and needs further monitoring. Assessments will be made of potential adverse effects on seafloor integrity. To understand cause-effect relationships, model simulations will now include trapping mechanisms of fines in permeable coarser sands.

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