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Fast ferry traffic as a qualitatively new forcing factor of environmental processes in non-tidal sea areas

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Summary

The impact of wake wash from high-speed ferries on the coastal environment in non-tidal seas is analysed in terms of wave energy and power, and properties of the largest waves. Shown is that hydrodynamic loads caused by heavy high-speed traffic may play a decisive role not only in low-energy coasts but also in certain areas with high wind wave activity. Owing their unusual length combined with their severe height, waves from fast ferries may appear as a qualitatively new forcing component of considerable remote impact in certain semi-enclosed sea areas such as the Azov Sea or certain areas of the Mediterranean or the Baltic Sea.

Introduction

The importance of the contribution of the ship traffic to the local hydrodynamic activity in rivers, inland channels and narrow straits has been recognised for a long time. Ship wakes can essentially contribute to the shoreline erosion, cause an extensive erosion and resuspension of bottom sediments, trigger ecological disturbance, cause harm to the aquatic wildlife etc.

The introduction of high-speed vessels extended the above threats from inland waterways, particularly narrow straits, and archipelagos to much larger confined sea areas with low natural wave and tide activity [1]. These vessels have a high ratio of propulsion power to vessel displacement. They are able to sail at speeds comparable with the hump speed (that occurs when the half-length of ship waves is close to the vessel's length) or with the critical speed (that is, the maximum phase speed of surface waves in finite depths). Additionally to an increase of wave heights and periods with the increase of the sailing speed, the ship sailing at near-critical speeds may generate

a wave system that is non-dispersive and may remain compact for a long time.

Contribution of waves from large high-speed ships to natural wave activity

On the one hand, it has become clear that heavy ship traffic has a great damaging potential in the vicinity of waterways and the adjacent shoreline, in particular, in micro- or non-tidal areas that are sheltered from large wind waves (such as wetlands, low-energy coasts etc. [1,2]). On the other hand, it is generally believed that ship wakes are negligible and that their effect is sporadic in coastal areas that are open seawards and where natural waves are frequently much higher than the wakes [3]. This assumption is true for coasts exposed to high tides or large wind waves indeed.

We show that the share of ship waves in the total wave activity may be remarkably high in the vicinity of open sea waterways even in terms of wave energy. As a model case, the impact of wake wash from high-speed ferries on the coastal environment in non-tidal seas is analysed in terms of wave energy and power, and properties of the largest waves in Tallinn Bay, the Baltic Sea. This area may have very rough wave conditions [4]. Certain parts of its coasts are exposed to significant natural hydrodynamic loads and are already subject to intense beach erosion in natural conditions. However, ship traffic is so intense that ship-generated waves form, at least, about 5–8% from the total wave energy and about 18–35% from the wave power in the coastal areas of Tallinn Bay exposed to dominating winds [5,6].

The reason for such a high contribution of ship waves in total wave acitivity is a combination of specific features of (i) the existing hydrodynamic loads (that are restricted to a particular direction or to a certain frequency interval) and (ii) the coastal environment (that has reached a near-equilibrium stage of its evolution [7]) with (iii) particularly high anthropogenic wave loads that are qualitatively different from the natural wave loads [8].

Quality of energy in ship waves and wind waves

The periods of wake waves from high-speed ships frequently are much larger than dominating periods of wind waves in certain open sea areas. The leading waves typically have a height of about 1 m and a period of 10-15 s. Such waves extremely seldom occur in natural conditions in many regions of semi-enclosed seas [4]. Qualitatively, it has been demonstrated that wakes from high-speed ferries may trigger considerable changes of the existing balance of coastal processes [7]. They cause unusually high hydrodynamic loads in the deeper part of the nearshore not only because of their length and height but also owing to their nonlinear properties [9]. The fast ferry traffic thus is a qualitatively new forcing component of vital impact on the local ecosystem in certain open sea areas. In Tallinn Bay, literally, the contribution of ship waves to the

wave climate is comparable to those that would happen if open ocean swell from the North Atlantic reached the Gulf of Finland.

Environmental implications

Owing to their low decay rates combined with their exceptional compactness after crossing many kilometres of the sea surface, highly energetic ship wakes may cause considerable remote impact of the ship traffic. This feature has to be addressed in the analysis of the impact of harbours and associated ship traffic in the neighbourhood of vulnerable areas.

This new component of the local ecosystem causes severe concerns. An extensive reaction of fine bottom sediments at the deeper part of the nearshore is conceivable [7,10]. The accompanied reduced water transparency [10], besides of the impact of direct mechanical disturbances, may have suppressing feedback on the bottom vegetation. Suspension and re-sedimentation of finer sediments may considerably worsen fish spawning conditions. Another potential mechanical effect of ship waves is an enhancement of vertical mixing along the ship lane. This may intensify the eutrophication effects and influence harmful algae blooms due to the transport of nutrients from sediments into the euphotic layer.

Since the location of the harbours and vulnerable areas cannot be changed in practice, it has become necessary to introduce a new paradigm of treating the ship traffic as a potential source of remote influence. In particular, it is natural to extend the definition of pollution (that today commonly is interpreted as releasing certain substances or noise into the environment) towards including the releasing of energy in general into the marine environment [11].

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