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The Environmental Protection Aspects of Handling Dredged Material

Aspekty ochrony środowiska w postępowaniu z urobkiem czerpalnym

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Abstract: Extraction of dredged material may have a negative impact on the marine environment. Thus, an environmental control is necessary at all stages of implementing the investment; starting from the strategy of choosing a place for deposition of the material, through controlling the excavation and storing processes, and the practical use of the material, to monitoring the state of the environment in the place of deposition (also following its closure). In this work, there are presented the general rules governing actions taken within the Polish coastal zone to mitigate the negative environmental impact of dumping material in the sea. Polish legislation has been proven to lack any precise principles of selecting new dumping locations, very rarely their monitoring, and practical use of the material.

Keywords: Dredged material, dredging, prevent the negative impact on marine environment

Streszczenie: Wydobywanie urobku czerpalnego może mieć negatywny wpływ na środowisko morskie. Konieczna jest więc ochrona środowiska na wszystkich etapach tej inwestycji, począwszy od strategii odpowiedniego wyboru miejsca odłożenia urobku, poprzez kontrolę procesu wydobywania, składowania czy też praktycznego wykorzystania urobku, a następnie monitorowania stanu środowiska w miejscu odłożenia urobku (także po jego zamknięciu). W pracy przybliżono ogólne zasady podejmowanych działań w polskiej strefie przybrzeżnej aby złagodzić negatywny wpływ składowanego urobku w morzu na środowisko. Stwierdzono brak sprecyzowania zasad wyznaczania nowych klapowisk w prawodawstwie polskim, ich monitoringu oraz ograniczenia w praktycznym wykorzystaniu urobku.

Słowa kluczowe: Urobek czerpalny, prace pogłębiarskie, zapobieganie negatywnym skutkom na środowisko morskie

Introduction

Dredging works are performed in order to excavate seabed sediments (i.e. dredged material) so that an adequate navigable depth of a fairway roadstead and harbour basin is maintained. They also include transportation of the dredged material, its safe deposition in places designated for this purpose, and if need be, also its purification and/or practical use. To limit the negative environmental impact, a proper strategy is necessary at each stage of works.

Environmental control should encompass the pre-investment stages (suitable choice of the place for deposition of the dredged material), investment works (excavation and deposition of the material), as well as the monitoring of the state of environment in the dumping location (also following its closure). There are certain discrepancies in the way all the stages are monitored in the Polish Economic Zone of the Baltic Sea.

Currently, there are in the Polish Economic Zone 9 dumping locations which until now was deposited around 21 mln m^3 of dredged material [13]. In this paper, we focus mainly on the impact of the deposition of the dredged material in the sea on the marine environment. In this context, it discusses the necessary guidelines for environment impact assessment of this measure and existing shortcomings in the proceedings. It is not, however, a detailed discussion of the principles and scope of monitoring dumping location in the sea. As of today, there are no precise rules in the Polish legislation that would determine methods of marking out new dumping locations, nor are there any rules for their monitoring.

Pre-investment works – designating areas for dredged material's deposition in the sea

According to the Regulation of the Minister of Transport and Construction Engineering of January 26, 2006 on the mode of issuing the permits to dispose the dredged material and to sink waste and other substances in the sea (*Dz. U.* [Journal of Laws], no. 22 item 166) [10], it is necessary at the stage of planning the excavation works to **assess the impact of the excavation and deposition the material from the dredging works in the sea on the marine environment and the organisms living there**. Factors that should be taken into account are, above all, the geological and morphodynamic conditions; hydrodynamic and hydrological circumstances; elements of biological quality; presence of mineral deposits; landscape values and cultural heritage; air quality index; acoustic climate; areas given the national status of conservation occurring within the region of the planned excavation works and potential sediments dumping locations (Table 1) (*Tabela 1*). The above mentioned aspects of the environmental assessment are analysed for potential impairment of the parameters during and after the excavation and deposition of the sediments. They are also to help determine the best date for performing the works, and selecting the right strategic, technical, pro-ecological and economical solutions in order to limit the negative environmental impact of the spoils excavation, deposition, and practical use [3; 5]. Information collected in table 1 should be included in the next report on the environment impact assessment necessary when applying for a permit to sediment dredging in the sea.

The conditions tabulated in Table 1 (*Tabela 1*) may be considered a basis in selecting a dumping location for depositing spoils in the sea [5; 14]. It must also be consistent with the assumptions of The Water Framework Directive - WFD (2000/60/EC) and as well as not to violate the protected areas Natura 2000. WFD as the parent act is to just manage the environment to reduce the emission of harmful substances into the natural environment [15]. **However, there is no clear way of performing a variant analysis for depositing spoils in the sea.** In this respect, the integrated indicators (from 1 to 5) developed by the Maritime Institute may turn out to be useful, as they specify: 1-incidental (minute); 2-small; 3-medium; 4-high; or 5-very high impact of a dumping location variant on the biotic and abiotic environment [1; 2; 3; 4].

Strategy of deposition or practical use of the material

A decisive factor for deciding dredged material's further treatment is its chemical and microbiological quality. Most often, if a sediment is not contaminated, it is stored in the sea or onshore at the sites specifically designated for this purpose (silting fields). Should a contaminated dredging material be found, it has to be separated from the not contaminated material, and stored on an allotted part of the silting field secured against the contaminants' transfer into the groundwater and material's infiltration by rainfall. Storing the dredging material must not cause a deterioration in the ground's quality. Uncontaminated material may also find a practical use. **Unfortunately, practical use of dredging material is fairly limited on the Polish shores and coastal zone, as well as in the other Baltic States.** The dredged spoils are mainly used in the artificial nourishment of the shores (when having suitable parameters for example granulometry), rarely also in the modernisation of ports and quays [11; 12; 13]. In the years 1990-2008 the volume of dredging work in estuaries and open sea ports amounted to more than 6.85 mln m^3, of which only 43% was used to power the coastal zone. The remaining amount still put off in the sea [3; 13].

Generally further investigation of the dredged spoils depends on the physical, chemical and biological classification (granulometry, content of toxic substances) and financial and economic aspects and such kind of decision tree was already included in *Guide to appoint of new dumping locations*, a study carried out under the project ECODUMP [5].

Criteria for assessing sediments' toxicity

The general guidelines for examining toxic substances may be found in the Convention for the Protection of the Marine Environment in the Baltic Sea Area as drawn up in Helsinki in 1992, and in the HELCOM, 1993 – recommendation 13/1 based on the abovementioned convention [8; 9].

Enlisted there are: metals (As, Cd, Cr, Cu, Hg, Zn, Ni and Pb); polycyclic aromatic hydrocarbons (PAHs: na benzo(a)pyrene, dibenzo(ah)anthracene, benzo(k)fluoranthene, benzo(ghi)perylene, benzo(a)-pyrene, dibenzo(a.h)anthracene, indeno(1.2.3-cd) pyrene); and polychlorinated biphenyls (PCBs). Whereas in the HELCOM Guidelines for the Disposal of Dredged Material, adopted in June 2007 by the Helsinki Commission, Baltic Marine Environment Protection Commission, there is a list of substances, an examination of which is advisable in situations when their presence may be suspected due to local or/and historical sources [7]. Among others, these are organochlorine and organophosphoric pesticides, organotin compounds, petroleum hydrocarbons (PHC), polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F). What needs to be taken into account, however, is that the Convention and Helsinki Commission's guidelines do not specify what the maximum permissible concentrations of the above mentioned compounds are in the dredged sediments. Also WFD, despite to provide a list with priority hazardous substances, does not specify them to the sediments, and doesn't define maximum permissible concentrations [15]. This results in a **lack of clear normative references in the Baltic States that would deem sediment contaminated or not** [10; 11]. It should be noted, that the requirement to develop such a coherent indicators for the dredged sediments in European countries appeared in The Marine Strategy Framework Directive - MFSD (2008/56/EC) [16].

The minimum/maximum concentrations (mg kg^{-1} d.w.) of contaminants in the dredged sediments in the Baltic Sea countries depend on degree of contaminated area (less or more); kind of sediment (sand, mud) or size of sediment particles; established

Tab. I. Specification parameters necessary for performing an environmental assessment in the area of a potential dumping location [1; 2; 3; 4].

PARAMETER	DESCRIPTION
GEOLOGICAL AND MORPHODYNAMIC CONDITIONS OF AN AREA	
Geology and geomorphology	To be determined are: seabed type (abrasive, accumulative), seabed form (flat, on a slope); depth of the potential deposition locations; sediment type, hydrodynamic parameters influencing the spoils' displacement in the area where works are conducted.
Displacement of the debris	To be determined are: anticipated direction and range of the spoils' movement. In the dumping location, there should be no displacement of earth masses. It is advisable to use the results of a suspension diffuse modelling or to use the empirical interrelations to estimate the direction and distance to which dredged material would spread while being deposited.
Sedimentary environment	To assess the collected sediment, it is recommended to carry out basic physical and chemical tests (HELCOM, recommendation 13/1, 1992 [8]) i.e.: sediment's colour, its volumetric density (g/cm3), natural dampness (%), organic matter (%), granulometry (average grain size), depth to which oxygen is available in the sediment, and contaminants content. It is necessary to assess whether the sediments are harmful in relation to designated contaminants.
Morphodynamic processes of the shore and seabed	Excavation of dredged material often takes place near the coastal zone. It should be judged whether the extracted spoils may find application in artificial nourishment of the nearby beaches, in order to help protect the beaches and dunes against erosion, and the neighbouring areas - against floods from the sea.
HYDRODYNAMIC AND HYDROLOGICAL CONDITIONS	
Wind regime	To be determined is the changeability of wind's direction and its strength in a given area in order to choose the best period of time for performing the excavation and deposition works.
Variability of the sea level	To be determined are the fluctuations in the sea level as generated by the accumulating influence of the wind, and most of all, the frequency and length of storm situations in a given area.
Wave motion and currents	To be determined is the most frequent direction of wave motion. Waves' height and the currents are analysed in their horizontal layout (in the surface and bottom layers) as well as the vertical one.
Ice conditions	To be determined are: the frequency of the first and last ice; duration of the ice season; frequency of ice days; and the ice thickness. It is most advantageous to perform excavation and deposition works in the months, in which probability of ice days occurrence is but a slight one.
SEAWATER'S PHYSICOCHEMICAL PARAMETERS' STATE ANALYSIS	
Temperature; salinity; level of dissolved oxygen and biogenic salts concentration; water's transparency	Particularly vital information on the state of the environment at the site where excavation works are performed may be obtained due to the seasonal changes in waters' oxygenation and in the level of biogenic salts concentration. During the sediments' deposition, there may occur a hypoxia and a rise in the level of biogenic salts concentration in the water column. Thus, the excavation works should be carried out intermittently, in order for the environmental conditions not to be deteriorated.
BIOLOGICAL PARAMETERS' STATE ANALYSIS	
Elements of biological quality	Biological diversity is a proof of environment's richness and good state. There ought to be drawn a seasonal profile of qualitative and quantitative composition of species occurring on the various steps of the trophic ladder: phytoplankton, zooplankton, underwater vegetation – macrophytes, benthic fauna communities, microbiological characteristics, avifauna, ichtyofauna, and fisheries, marine mammals and seabirds. Species of biological and commercial "particular value" are also to be identified. It needs to be assessed whether given area is birds' place of living and feeding, whether it does not cross avifauna's main migratory routes, and whether it is not a part of a birds' Special Protection Area (SPA). If the result is positive, the report should contain an assessment of the degree to which the excavation works may probably disturb the birds' natural habitat and feeding place.
Areas protected by the Polish law	To be determined is: location of nature conservation areas in relation to possible location options. It has to be assessed whether excavation works would impact on the nature conservation areas including habitats, and species protected on the Natura 2000 sites, and under other forms of nature preservation, e.g. national parks, nature reserves. Dumping location must not worsen their conditions.

AIR AND ACOUSTIC CLIMATE	
Air quality index	To be determined are the background and estimated quantities of expected gaseous pollutants (hydrocarbons, CO2, CO, NOx, SO2), and dust released into the air due to the dredgers' activities.
Acoustic climate	To be determined is the noise level at the site where works are carried out, and its impact on residential, and recreation and rest areas. If there are planned any night works or/and works to be performed near the seaside residential areas, only modern vessels that use new excavation technologies and equipped with protection systems reducing the noise emission (suppressors, sound absorbing acoustic casings) should be chosen for the task.
SPATIAL DEVELOPMENT PLAN FOR THE MARITIME AREAS	
Human activity	It needs to be analysed if there are no potential conflicts with: - shipping activities, maritime transport, sports, tourism and recreation, - areas of military activity (zones closed to shipping and fishery), - potential collisions with the heavy fishery zones, - obstacles buried in the seabed, - already-existing and planned infrastructure.
Mining and energy industry	It has to be assessed whether a given area contains mineral deposits, mining areas covered by concessions, or areas with types of sands that may find application in artificial nourishment, which would all make it impossible to set there a dumping location.
Landscape value and the cultural heritage	An inventory of objects considered important from the point of view of culture, history, economy or natural sciences is to be carried out together with an assessment of the potential dumping locations' influence on these objects.
OTHER	
Accidents, breakdowns and chance events	If possible, the level of a site's exposure to accidents, breakdowns and chance events are to be assessed.

safety for human or environment and are different in each country (Table 2, *Tabela* 2). The most important for potential accumulation of pollutants are sediment particle size. In the finer particles, the levels of toxic substances are usually higher. Therefore, the limits concentrations for toxic compounds in the mud are mostly the highest (max value in Table 2.) [11].

The investment works – the environmental impact of dredging

Depending on the scale of the works carried out, the technologies and protection methods used in the process, character of the potential influence of the sediment dredging and deposition works on the marine environment shall be varied [2; 3; 4]:

- with respect to the range – local, supralocal,
- with respect to the extent of changes introduced to an environment – significant: observable through a lowering of an environment's quality standards; insignificant: observable through a deterioration of particular environmental components, without lowering its standard though,
- with respect to the duration: short-term (transient) and long-term,
- with respect to the type: direct, indirect (environmental impacts which are not direct results of an investment),
- accumulated: influence exerted simultaneously by several factors.

Dredging works may cause the following kinds of disturbances in the marine environment [2; 3; 4]:

- Physical: there may occur topographic changes in the seabed structure at the site of dredging and deposition, changes of the grain size, suspension and dispersion of the fine-grain fraction (often even over great distances), an imbalance between the sediment's accumulation on the seabed and their erosion,
- Chemical: resuspension of contaminants into the water column,
- Biological: directly burying individual organisms living on the seabed or destroying them, devastating the spawning grounds, disruption of the migration routes of fish, transfer of contaminants through the marine food web, which results from resuspended particles and dissolution of contaminants.

Potential physicochemical disturbances

Dredging works and dumping the dredged material at the designated locations exert primarily a short-term influence on the marine environment as they are being performed. The main physicochemical short- and long-term disturbances that occur in the water are listed in Table 3. (*Tabela* 3.) [2; 3; 4].

The short-term effects related to dumping the sediment like resuspension of metals to water column may be significant [6]. But in the longer time have no significant impact on the

Tab. II. The minimum/maximum concentrations (mg kg^{-1} d.w.) of contaminants in the dredged sediments in the Baltic Sea countries [11]

COMPOUND	MIN. LIMIT VALUE	MAX. LIMIT VALUE	COUNTRY	COMMENTS
Arsenic (As)	10	150	Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, Sweden	The limit value depends on: degree of contaminated area; kind of sediment; safety for human or environment.
Zinc (Zn)	60-100	1750		
Mercury (Hg)	0.1	10		
Chromium (Cr)	20	800		
Nickel (Ni)	10-20	500		
Cadmium (Cd)	0.3	20		
Lead (Pb)	10	600		
Copper (Cu)	10-40	500		
Iron (Fe)		40000	Sweden	
Vanadium (V)		20		
Tin (Sn)	1	300	Estonia, Sweden	
Cobalt (Co)	15	300		
PHCs (C10-C40)	20-200	5000	Estonia, Finland, Germany, Latvia, Lithuania, Russia	
Sum of PAHs (individual compounds)	0.1 (0.01)	200 (8)	Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia	
Sum of PCBs (individual compounds)	0.02 (1)	2 (30)	Denmark, Finland, Germany, Latvia, Lithuania, Poland, Russia	
TBT	3	200	Denmark, Finland, Germany, Latvia	
DDT	0.0025	5	Estonia, Finland, Germany, Latvia, Russia	
DDE	0.0025	3	Finland, Germany, Latvia, Russia	
DDD	0.0025	10		
α-HCH	0.0025	2	Estonia, Germany, Russia	
γ-HCH	0.00005	2		
HCB	2	25	Estonia, Germany	
PCP	1	3	Germany	
PCDD/PCDF (ng WHO-TEQ/kg)	20	500	Finland, Latvia	

life in the water column nor on the deterioration of the water purity status in the region of the nearest beaches and seaside resorts. In the regions that are too shallow, however, during the storm surges there may occur a re-deposition of fine-grained sands; especially if the works are not conducted properly. Such a transportation may result in a spread of the fine-grained sediments together with the accumulated contaminants over greater areas and to great depths.

Influence of the dredged material deposited in the sea on the marine environment depends on where the deposition takes place. In a dynamic environment eroded by natural processes, the impact of dumping the material is small, as the organisms living there are characterized by a natural capacity to adapt to their biotopes' instability, and the pollutants are dispersed over big areas.

Potential biological disruptions

The character of a potential impact on the marine plant and animal life depends on the distance from the sediment dumping location. In close proximity of the dumping field, the influence is varied, including a partial contamination of organisms in the water column and most of the seabed. As the distance from the central spoils dumping point grows, the influence decreases, and the possibility of harming the marine organisms is limited to their

Tab. III. The main short- and long-term physicochemical disturbances occurring in water and sediment during the dredging works [2; 3; 4]

DISTURBANCE TYPE	DESCRIPTION
Short-term	♦ Disturbances occurring in the water column due to e.g. resuspension of the material present in the sediment, ♦ Modification of the hydrodynamic processes due to conducting the engineering works, ♦ Short-term and local increase in the amount of suspension and in turbidity of water appearing at the site where works are performed, ♦ Local decrease in the transparency, which limits the primary production of the euphotic zone, ♦ Rise in the organic matter, organic and metals contaminants and soluble phosphorus and nitrogen compounds content in the water and sediments; eutrophication at the deposition site, ♦ Short-term lowering of the waters oxygenation level due to the increase in the suspension's amount and consumption of dissolved oxygen by the oxidation of organic matter and sulphides, ♦ Transport of harmful substances by waves, tides, and currents, ♦ Damages done to the recreational beaches by the increased water turbidity levels, fine material's depositing on a beach, worsening of the pollution indicators and sanitary status, ♦ Potential rise in the level of water's contamination level due to occurrences of emergency situations (oil spillages, leaks), ♦ Potential growth of the vessel traffic in the area, ♦ Inconveniences connected with the activities carried out by the dredging teams (noise, fumes), ♦ Hindrance to communication, or even temporary closing the extraction and deposition areas for the movement of vessels and fishing boats.
Long-term	♦ Permanent changes in the seabed topography, ♦ Change of sediments quality at the dumping location, ♦ Local change in the transported debris, which may – under extreme conditions – lead to damaging a shore, abrasion, or to a beach accumulation.

juvenile forms. In the far field of the site, there will occur disturbance of birds, and repulsion of fish (or marine mammals). In the close field, the first layers of dumped spoils may have a relatively heavy influence on the organisms in the water column, and on the seabed organisms, as well as on the fish migration. Among the short-term effects of the dredging works one must recognise a temporary deterioration of the living conditions of organisms within the territory on which the suspension and chemical substances released from the dredged material are spread. Among the long-term effects there should be listed a partial elimination of organisms at the site of sediments excavation; partial burial of the organisms at the site where material is deposited; risk of destroying the habitats of rare, sensitive or endangered species; hindrance to the demersal fisheries; damaging or destroying the fish spawning sites and habitats, thus leading to a decrease in fisheries productivity. If works are conducted during the non-vegetation season, the biological losses in the close field are not heavy. It has been estimated that it might cause losses equal a dozen or so kg of the wet mass of water column organisms per a single dredged material deposition [2; 3; 4].

Excavation works are usually of little impact on the phyto- and zooplankton. No species of conservation interest occur here. On the excavation works stage, an increase in the biogenic compounds concentration in the water column is bound to take place, which will cause the local and short-term growth of phytoplankton biomass and higher intensification of primary production.

Effect of the excavation works on the seabed fauna is negative. It is possible that great losses of macrofauna will occur on the seabed surface as a result of the mechanic disruption of the seabed sediments layer. In the macrozoobenthos of the coastal areas, there usually dominate species characterized by a high resistance to environmental stress. Considering a short period of dumping, a return to the original state – re-establishing the benthic fauna communities – will take place after a full life cycle of benthos organisms is finished at the latest, i.e. within a 2-3 years period [2; 3; 4].

In general, the process of depositing spoils in the sea does not disturb significantly any important birds' feeding and resting place. Birds are able to move quickly to nearby areas richer in nutrients. When it comes to the avifauna, no losses among the species occurring on the sea surface are to be expected. In the close field of the dumping location and neighbouring area, the dumping activities may have a destructive influence on individual diving birds (benthophags). Before it would come to that, however, birds would be scared away by a vessel and noise connected with the performed works [2; 3; 4].

Dumping the sediments may consist a threat to fisheries, interfering with the fish migration and spawning, increasing the young individuals' mortality, and scaring fish away from a given area. The most important species in the context of the South Baltic Sea is herring. The fundamental recommendation for the investor is to schedule the silting works taking into account the fish breeding period in the spring. No sooner should the works start than the spring herring spawning season is over (i.e. in June). Should the dumping start earlier, the spawning might be thwarted in the areas where the works take place. The activities should be finished by March, 31 – before the herring spawning season starts. It is hard to estimate losses in the fishing stock occurring during the excavation works. In relation to the basic consumable species (cod, herring, sprat in the water column, and flatfish on the seabed), the losses are assessed to be small, and estimated as 0.01% of the fisheries from a 1 km^2 of the area on which works are performed [2; 3; 4].

Activities limiting the dumped dredging material's negative impact on the environment

The scale of the negative impact exerted by the excavation works on the environment is related to frequency and duration of the works performed in a given area. Crucial are: choice of method of excavation or sediments' removal; amount of sediment extracted, and its physicochemical parameters (granulometry, contamination level), as well as the depth and water density at the site where the works are carried out.

To **limit the negative environmental impacts** of the performed excavation works, there have to be prepared detailed plans for the activities involving, among others [2; 3; 4; 5]:

- Scheduling the time for conducting the works, so that they do not collide with the fish spawning seasons, and using seines when fishing,
- The right selection of the dredging equipment, proper use of the high-performance machines and devices that ensure reduction of noise and pollution emission, all fully operational from the technical viewpoint and operated by persons authorised to do it,
- Observing the standards and safety procedures connected with the works performed on the high sea resulting from the separate provisions,
- Providing equipment and accessories for minimizing and absorbing the possible leakages of contaminants from vessels,
- Prohibition of dumping sewage into the sea,
- Dividing the dredging works into stages and plots, if great volumes of dredging material are expected,
- Providing an adequate standards of executing individual elements of investment from the companies implementing the dredging works and dumping the spoils in the sea by means of subjecting the workmanship to an internal control, in order to obtain a high quality of the works performed,
- Transportation of the dredged material to the dumping location only through the zones specifically designated to the purposes of transport,
- Complying with the probable necessity to clear the contaminations that will emerge on the water's surface due to the performed dredging works,
- If the works performed impact on the Natura 2000 sites, it is of great importance to take into account the value of animated nature resources while conducting the works; it is advisable to establish a regular or permanent cooperation with a specialist in the field of natural environment protection,
- To preserve the potential archaeological artefacts buried under the ground or a layer of bottom sand, it is necessary to conduct observations of the material dredged from the seabed while performing the ground works. Should objects of archaeological value appear, an archaeologist must be informed in order to document the site,
- Planning the strategy of preserving the officially protected modern era monuments,
- Obliging the Investor to maintain a website in order to present an information service dedicated to the progress in the investment's implementation, and the results of the monitoring environmental surveys,
- The activities' environmental impact should be monitored.

In order to minimize the adverse environmental impacts, the works should be conducted in a period of time when strong influence on the environment and marine organisms may be avoided. The worst time for the morphodynamic, hydrodynamic and hydrological processes is the autumn – winter period. From the point of view of the biological processes, the least favourable is the spring period of fish breeding. In the summer, an intensification in vessel traffic and other works at sea should be expected. If works are to be carried out in the vicinity of residential areas, they should be conducted alongside with ensure minimization of inconveniences connected with the emission of pollutants into the air and noise disturbances. With respect to the protection against noise obligation, the works should not be performed at night.

Undoubtedly, one of the most important aspects of performing dredging works are the economic conditions. They are a decisive factor in the selection of an extraction method (choice of the most economically optimal dredger), or a sediment storage/application manner. **The selected method of works implementation should be the one which is most advantageous in respect to the as little as possible, an interference in the marine environment and maintenance of the optimal economic conditions.**

Monitoring of dumping location

The monitoring surveys should encompass periods of time before and after the extraction works in a given area, so that it is possible to define the background in the area of the planned extraction and dredging material dumping works, as well as to document the changes occurring in the close and far field of the disturbances' centre. In case of an investment which assumes great extraction works expenditure and dumping the spoils in the sea, the environmental parameters should be monitored also while the investment is being implemented [3].

Scope of the monitoring survey should account for [2; 3; 4; 13]:

- a bathymetric survey of the dumping location field,
- photographic and film documentation of the sea surface and seabed surface in the region where the material is to be dumped, so that it is later possible to determine the direction and range of suspension spread after dumping the spoils (the implementation stage),
- basic sedimentological surveys (granulometry, sedimentation rate),
- benthic fauna research,
- biological and physicochemical surveys of water,
- physicochemical surveys of sediments,
- study of phytoplankton, zooplankton, and macrrophytes,
- ichtyofauna, and avifauna research,
- monitoring the presence of harbour porpoises,
- surveys of the changes occurring in the morphological forms on the stretches of shore near the planned extraction works area. In order to oversee the protection of seashore formations, the control encompasses the beach condition and dunes.

The monitoring surveys should be conducted by specialized teams of researchers. Marine environment monitoring in pelagial and benthal zones should be carried out in accordance with standard methodologies as recommended by the Baltic Marine Biologist, and with the marine environment monitoring methods recommended by the HELCOM and ICES Conventions. Methodological guidelines of the Water Framework Directive - WFD (2000/60/EC) and Marine Strategy Framework Directive - MFSD (2008/56/EC) and State Environment Monitoring Program should be implemented [15,16]. **It has to be stressed that in the Polish coastal zone, dumping locations have rarely been monitored so far** [3; 4; 5; 14].

Conclusions

Environmental control is a necessity at all stages of dredging works. It consists of assessing the impact of dredged material's extraction and dumping in the sea on the marine environment and organisms living in it, as well as of selecting the strategies of the works implementation which will prove optimal for minimizing the interference in the marine environment while at the same time maintaining the optimal economic conditions.

- However, there remain a few areas of activities employed at the dredging strategies, which still remain half-baked. It is, among other things, necessary to:
- specify in a clear way a unified method of assessing the variants of possible dumping locations in the sea in the Polish economic zone,
- develop the activities aimed at finding a practical use for the dredging material on the Polish coasts, and in the other Baltic Sea states. At present, the extracted spoils are mainly applied in the artificial nourishment of shores, and only occasionally in ports rebuilding and quays modernisation,
- specify unambiguous normative criteria for qualifying a sediment as contaminated or not on the Polish coasts, and in the other Baltic Sea States,
- introducing legal requirements of a monitoring of dumping locations within the Polish economic zone.

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