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# Sediment open water disposal in the aspect of environmental hazard. General trends. Current scientific literature review.

## Deponowanie urobku czerpalnego do otwartej toni wodnej w aspekcie zagrożenia dla środowiska. Ogólne trendy. Przegląd aktualnej literatury naukowej

mgr inż. Łukasz Zegarowski

Instytut Morski w Gdańsku, Zakład Ochrony Środowiska

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**Abstract:** Disposal into the open water body is the most common practice with dredged sediments from water objects. These actions may disrupt the balance inside and around dumping area. Accumulated in sediments anthropogenic pollution such as heavy metals and persistent organic compounds impact on the environment over a longer period of time. Dumping into aquatic ecosystems million tons of spoils from dredging causes a number of concerns in the international arena. A large number of global treaties and protocols were signed to minimize the negative environmental impact of contaminated sediment from dredging process. According to current scientific papers, the study shows the sources of environmental risks and general trends stemming from this practice. Furthermore, it indicates directions of activities aimed at minimizing the negative impact of human activities resulting from the excavation of waste material brought up from dredging.

**Keywords:** dumping site, sediment dumping, global problem, impact of dumping, polutions , general trends, minimazing the negative impact

**Streszczenie:** Deponowanie urobku czerpalnego z prac pogłębiarskich do otwartej toni wodnej jest najczęściej praktykowanym rozwiązaniem . Takie działania mogą zakłócić równowagę w środowiska wewnątrz oraz wokół obszaru klapowiska. Nagromadzone w osadach dennych zanieczyszczenia mające charakter antropogeniczny , takie jak metale ciężkie i trwałe związki organiczne, mogą oddziaływać na środowisko w dłuższej perspektywie czasu. Klapowanie milionów ton rocznie osadów, z pogłębiania obiektów wodnych, wywołuje liczne obawy na arenie międzynarodowej. Aby zminimalizować negatywne oddziaływanie urobku deponowanego na klapowiskach podpisano wiele traktatów oraz protokołów o wymiarze globalnym. W oparciu o aktualną literaturę naukową przedstawiono potencjalne zagrożenia oraz trendy wynikające z procesu klapowania osadów dennych z prac pogłębiarskich. Ponadto, wskazano kierunki działań mających na celu ograniczenie negatywnego wpływu działalności człowieka wynikających z klapowania do akwenów morskich.

**Słowa kluczowe:** klapowisko, deponowanie osadów dennych, globalny problem, wpływ klapowania, zanieczyszczenia, ogólne trendy, ograniczanie negatywnego oddziaływania

## Introduction

Continuous use of ports, shipyards, fairways, etc. contributes to dredging associated with bottom sediments excavation. Nowadays, deposition of dredged sediment into the water column is a common practice which is known in scientific literature as *Open Water-Disposal*. Thus, dredging and open water disposal are coexisting operations. Discharging into the seas, oceans, estuaries, bays, rivers and lakes is one of several alternative options for dealing with the dredged material. The most commonly used solution for sediment replacement is deposit in the open water column using the pipeline, barge or hopper

(Fig. 1). Most material is discharged with a depth <20 m, within a few kilometres from excavation place [1]. Furthermore, disposal of dredged material into the water body is often the most economical practice [2].

The aim of this study is to acquaint with basic issues related to disposal of dredged sediments into open water. According to current scientific papers, the study shows the sources of environmental risks and general trends stemming from this practice. The present study indicates directions of activities aimed at minimizing the negative impact of human activities resulting from the excavation of waste material brought up from dredging.

## Management of dredged material - a global problem.

Dumping into aquatic ecosystems million tons of spoils from dredging causes a number of concerns in the international arena. This process may disturb the homeostasis of the environment. Referring to the data from the International Maritime Organization (IMO), the scale of the problem is significant (Tab. I; Tab. II).

The table contains a summary report of permits issued in 2007 as part of the London Convention and London Protocol. Negative impact on the diversity and abundance of organisms living in particular ecosystems had been repeatedly reported.

A large number of global treaties and protocols were signed to minimize negative environmental impact of contaminated

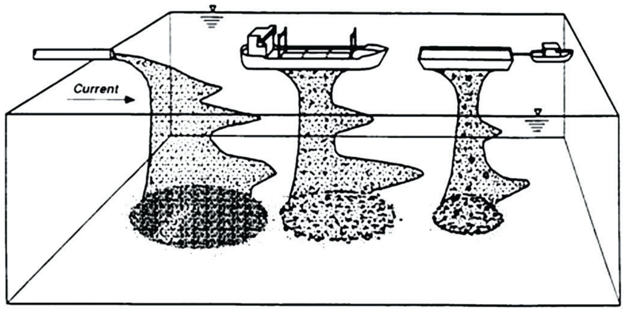


**Fig. 1.** Possibilities of sediment disposal into open water [3].

sediment from dredging process. The most important of them from a global point of view in this matter include:

- Ramsar Convention (1971) - Convention on Wetlands of International Importance, especially as Waterfowl Habitat,
- London Convention (1972) and London Protocol (1996) - Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter,
- Barcelona Convention (1976) – Convention for protection against Pollution in the Mediterranean Sea,
- UNCLOS (1982) – United Nations Convention on Law of the Sea,
- Basel Convention (1989) - Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal,
- AMAP (1991) - The Arctic Monitoring and Assessment Program,
- Bamako Convention (1991) - Bamako Convention on the ban of the Import into Africa and the Control of Transboundary Movement of Hazardous Wastes within Africa,

**Tab. I.** Summary list of dumping authorization. Final Summary Report 2007 [4].

| COUNTRY | NUMBER OF GENERAL PERMITS ISSUED | | NUMBER OF SPECIAL PERMITS ISSUED | | TOTAL NUMBER OF PERMITS ISSUED |
|---|---|---|---|---|---|
| | SEDIMENT | OTHER MATERIAL | SHIPS & PLATFORMS | OTHER MATERIAL | |
| Australia | 10 | 4 | | | 14 |
| Belgium | 2 | | | | 2 |
| Brazil | 21 | | | | 21 |
| Canada | 41 | 53 | | | 94 |
| China | 367 | | | | 367 |
| Hong Kong, China | 80 | | | | 80 |
| Denmark | 29 | | | | 29 |
| Ecuador | 1 | | | | 1 |
| France | 71 | | | | 71 |
| Germany | 72 | | | | 72 |
| Greece | | | | 1 | 1 |
| Iceland | 10 | | | | 10 |
| Ireland | 7 | | | | 7 |
| Israel | 10 | | | | 10 |
| Italy | 3 | | | | 3 |
| Japan | 1 | 9 | | | 10 |
| Latvia | 8 | | | | 8 |



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**Tab. II.** Summary list of dumping authorization. Final Summary Report 2007 [4].

| COUNTRY | NUMBER OF GENERAL PERMITS ISSUED | | NUMBER OF SPECIAL PERMITS ISSUED | | TOTAL NUMBER OF PERMITS ISSUED |
|---|---|---|---|---|---|
| | SEDIMENT | OTHER MATERIAL | SHIPS & PLATFORMS | OTHER MATERIAL | |
| Liberia | | | | 2 | 2 |
| Lithuania | 8 | | | | 8 |
| Malta | | | | 1 | 1 |
| Mexico | 6 | 19 | | | 25 |
| Netherlands | 9 | | | | 9 |
| New Zealand | 15 | 9 | | | 24 |
| Norway | 48 | 3 | | | 51 |
| Panama | | | | 1 | 1 |
| Philippines | 25 | 106 | | | 131 |
| Poland | 12 | | | | 12 |
| Portugal | 11 | | | | 11 |
| The Republic of Korea | 24 | 8 | | | 32 |
| Russian Federation | | | | 1 | 1 |
| South Africa | 13 | 4 | | | 17 |
| Spain | 26 | 39 | | | 65 |
| Sweden | 18 | | | | 18 |
| Ukraine | 37 | | | | 37 |
| United Kingdom | 101 | | | | 101 |
| USA | 64 | 1 | 1 | 2 | 68 |
| TOTAL | 1150 | 255 | 1 | 8 | 1414 |

- Bucharest Convention (1992) - The Convention on the Protection of the Black Sea Against Pollution,
- OSPAR (1992) - The Convention for the Protection of the marine Environment of the North-East Atlantic,
- HELCOM (1992) – Convention on the Protection of the Marine Environment of the Baltic Sea Area,
- Stockholm Convention (2001) - Convention on Persistent Organic Pollutants.

The guidelines resulting from the arrangements within the individual conventions do not provide direct answer how to proceed with contaminated bottom sediment originating from dredging. A significant problem is the lack of consistency in the interpretation of the guidelines in relation to their execution in different countries. The procedure that classifies sediment as contaminated (banned to open-water dumping) is varied in different countries that are parties to the convention. Thus, there is a high probability that the sediment with the same degree of contamination classified as highly contaminated in one country, receive a permit for dumping in another country which is part of the convention. There are a variety of guidance documents relating to dredged material management either at the state level or international level. Detailed procedures for treatment of dredged material within a particular country are contained in its legislation. Thus, from a formal point of view, the degree of contamination can be considered in various ways. Differences in sediment dumping may, therefore, be very significant, which is associated with the risk of balance disorders in the marine environment. The international SMOCS (Sustainable Management of Contaminated Sediments) project has been prepared to develop environmental policy and legislation in terms of dredged material treatment in the Baltic Sea ( Environmental Policy and Legislation on Dredged Material in the Baltic Sea Region) [5]. It lists the legislative requirements of dredged material management for countries such as Denmark, Estonia, Finland, Germany, Lithuania, Latvia, Poland, Russia and Sweden. It shows significant diversity within procedures to get permission for dumping into the open water body, however, most of the dumping operations take place in similar environmental conditions of the Baltic Sea. Separate legislation in each country has different criteria that must be met to obtain for sediment dumping.

## The differences may refer to:

- limit values and type of chemical compounds contained in the sediment samples,
- the method of analysis for individual chemical compounds,
- the amount of dumping material,
- suitable location of dumping site,
- monitoring methods,
- morphological classification of sediment,
- the administrative district of dredging (Finland)
- duration



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Below, they have presented chemical compounds and their limit values in sediment intended for dumping in Poland, Finland, Latvia and Germany (Tab. II; Tab. III). If the sediment contains substances which do not exceed the first permissible value specified in the legislation, it is considered to be harmless to the environment and may be dumped in the sea. If the concentration of particular compound will be contained between the first and second limit value, a permit issue to dump into the sea must be individually examined. Exceeding the limit value causes that sediment cannot be deposited in the marine environment, as is considered hazardous. Moreover, it should be taken into account that the methodology of determination (including conversion concentration values depending on the type of dredged material, etc.) is miscellaneous in each of these countries [5].

## The impact of sediment dumping in the marine ecosystem.

Dumping operations into the water column may adversely impact on the environment, especially in „sensitive areas". This situation takes place, when dumping site influence a detrimental effect on food chain structure among sea inhabiting organisms, or leads to the the release of large amounts of contaminants such as heavy metals or hydrocarbons [6]. Depositing large amounts of non-contaminated or low-contaminated sediment, may lead to physical and chemical changes in the water column as well as changes in bottom morphology. These actions may disrupt the balance inside and around dumping area. The scale of these impacts can vary greatly and depends on many factors. These issues are described in more detail later in this work.

### Physical and chemical changes in the environment, dumping result.

Dumping of large amounts of sediment into the sea forms a sandy mounds shaped structures. This structure is formed depending on many factors such as a method of dumping, the amount of material, composition of the sediment, the depth, the hydrodynamic conditions and weather (currents, waves and the wind, etc.) [7, 8, 9]. The lighter fractions fill the cavities formed between the hills. Processes such as erosion, transport and sedimentation contribute in the long term to smoothing created prisms and their slow disappearance. Quite significant factors affecting the magnitude of dumping impact are hydrodynamic conditions prevailing in the aquatic environment. The currents have an impact on suspensions drift, resuspension and sediment advection after dumping. Thus the range of the possible impact of dumping not always correspond to the range of drop zone [10]. The high affinity of anthropogenic pollutants into suspended particles causes an increase in contamination of sediments in estuaries and coastal areas located near industrial zones and urban areas [11]. Accumulated in sediments, contaminants such as heavy metals and persistent organic compounds impact on the environment over a longer period of time from the time of their accumulation to the appropriate critical value. This is the main reason for environmental engineers to create computer models that

**Tab. III.** Limits for bottom sediments deposited in the sea.

| NR | SUBSTANCE | UNIT ( D.W.) | I LIMIT VALUE | | | | II LIMIT VALUE | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Metals | | Finland | Germany | Latvia | Poland | Finland | Germany | Latvia | Poland |
| 1.1. | arsenic (As) | mg kg-1 | 15 | 30 | 20 | - | 60 | 150 | 30 | 30 |
| 1.2. | zinc (Zn) | mg kg-1 | 170 | 350 | 200 | - | 500 | 1750 | 400 | 1000 |
| 1.3. | mercury (Hg) | mg kg-1 | 0.1 | 1 | 0.5 | - | 1.0 | 5 | 1.5 | 1 |
| 1.4. | chromium (Cr) | mg kg-1 | 65 | 150 | 100 | - | 270 | 750 | 300 | 200 |
| 1.5. | nickel (Ni) | mg kg-1 | 45 | 50 | 20 | - | 60 | 250 | 50 | 75 |
| 1.6. | cadmium (Cd) | mg kg-1 | 0.5 | 2.5 | 1 | - | 2.5 | 12.5 | 3 | 7.5 |
| 1.7. | lead (Pb) | mg kg-1 | 40 | 100 | 100 | - | 200 | 500 | 200 | 200 |
| 1.8. | copper (Cu) | mg kg-1 | 50 | 40 | 100 | - | 90 | 200 | 200 | 150 |
| 2 | Polychlorinated biphenyls (PCBs) the IUPAC numbering | | | | | | | | | |
| 2.1. | 28 | μg kg-1 | 1 | 2 | 1 | - | 30 | 6 | 30 | |
| 2.2. | 52 | μg kg-1 | 1 | 1 | 1 | - | 30 | 3 | 30 | |
| 2.3. | 101 | μg kg-1 | 4 | 2 | 4 | - | 30 | 6 | 30 | |
| 2.4. | 118 | μg kg-1 | 4 | 3 | 4 | - | 30 | 10 | 30 | sum 0.3 |
| 2.5. | 138 | μg kg-1 | 4 | 4 | 4 | - | 30 | 12 | 30 | |
| 2.6. | 153 | μg kg-1 | 4 | 5 | 4 | - | 30 | 15 | 30 | |
| 2.7. | 180 | μg kg-1 | 4 | 2 | 4 | - | 30 | 6 | 30 | |

simulate the behavior of the deposited material in the water column during dumping process. In the years 1990-1995 48 850 cubic meters of sediment was dumped in the Black Sea during dredging in the Kerch Strait [12]. The operation resulted in a dramatic transformation in the composition of sediments within the deep-sea dumping site and in its surroundings. The estimated load of pollutants released into the waters of the Black Sea was respectively: > 200 kg Hg> 30t As, Pb ~ 30 t, Cu ~ 40 t, Cd ~ 400 kg,> 5000 t of oil products,> 200 kg organochlorine compounds. It was found simultaneously that the introduced load of contaminants is 10-1000 times lower than the load originating from waters with the rivers and sewage. Moreover, settling velocity of fine particles in formed suspension was also estimated (0.05 - 0.005 mm) at the rate of 0.002 - 0.07 cm/s, and thus settling of the particles at the depth of 50 m will be approx. 1.5 days and the extent of formed stains visible on the surface does not exceed 60 m. It was also found a significant correlation contaminants in the water to the amount of material deposited for Cu, and Hg. There was no similar correlation for bottom sediments from the dredging area. The effect of sediment contamination within the dump became apparent after 1 year for Cu, 2 years for As and Pb, Cd 3 years, 4-5 years for organochlorine compounds, and 5 years for petroleum substances.

The negative effects of contaminated sediment have also been reported on „Northwest" and „North" dumping sites from in Port of Rotterdam, in the North Sea [13]. There was observed an increased content of Cd, Hg, PAHs, PCBs and TBT compared to reference sites. Other pollutants measured values did not differ from the values measured around dumping site. It is worth mentioning that there has been a significant decline for PCB, Hg, Cd, PAHs and TBT in sediments throughout the year, despite the high mobility of fine fraction. The authors suggest that the strong dispersion of fine fraction in the coarse fraction of the sediment slowed the release process of these compounds.

International conventions prohibiting and restricting depositing of polluted excavated spoil certainly has influenced the improvement of the marine environment condition. However, there are illegal dumping sites which may release into the environment a significant amount of pollution. The situation is similar to many historical already closed dumping areas.

In 2005 research paper was published describing the study of dumping site functioning in 1950-1960, located in the Gulf of Mecklenburg, in the south-western part of the Baltic Sea [14]. It was dumping site for sediments and industrial waste heavily contaminated with heavy metals and PAHs. The study of inactive dumping site carried out in the mid-80s, and then in 1997 and 2001, providing a picture of the long process of „attenuation" adverse effects. Twenty years after dumping site inactivation, a significant portion of the deposited material dispersed inside the Gulf of Mecklenburg, as a result of resuspension and transport of sediment at a depth of 20-25 meters. Another result was the discovery of a place (hot spot) of highly increased content of heavy metals and PAHs (anthropogenic origin) at dumping place. The site was re-examined in terms of impurities dynamics in 1997 and 2001. Maps presenting the distribution of Pb concentrations in the bay in 1983-1985 and 1997 show considerable differences. Contaminated material from dumping site in 1985 spread to the area of 7x15 square nautical miles. Thirty-two years after the dumping site closure Pb concentrations in sediments began to decline toward the background values in the outer part of the bay, while "hot spot" contaminated by Pb and PAH is still noticeable. Fresh material and sedimentation processes „diluted" contaminated layers and covered the old with new. In 1985 and 2001, core samples were taken from the "hot spot". Contaminated sediment layer from the years 1950-1960 was covered with 5-10 cm layer of mud. It is a consequence of strong dynamic conditions at a depth of 20 m below sea level. It is possible that the mobile fractions of metals from the deeper layers of sediment transformed under anaerobic conditions into strongly bonded sulfide forms. Despite the passage of years and progressive „attenuation" process at the dumping site, there is still a high risk of resuspension and the further spread of contamination from buried material.

Another, negative observations of sediment dumping impact on the marine environment requiring discuss are possible changes in the content and forms of phosphorus due to increased concentration of suspensions in water. Violation of the natural phosphorus cycle may pose a significant risk to the sustainability of the environment since it constitutes one of the essential nutrients in the trophic chain. Calcium carbonate as a constituent of a suspension strongly adsorbs phosphate, which can be released in an environment under the condition of low pH value [15].

**Sediment dumping impact on living organisms.**

Anthropogenic contaminants contained in sediments may accumulate in subsequent layers of the food chain at dumping site and adjacent as well. In reports on the high level (relative to background values) of pollutants such heavy metals or persistent organic compounds some cases of bioaccumulation of mutagenic compounds in organisms were reported as well. Toxicity in the organism depends very much on the „bioavailability" of a chemical compound. Some indigenous species can be successfully used as bio-indicators of particular pollutions [10]. In the estuary of the Gota Alv (Sweden) mussel, Mytilus edulis was used to monitor organic compounds and heavy metals during dredging works. It was observed that the greatest concentration of contaminants occurred just after the start of work. Another interesting conclusion from this study were differences in toxicity occurring in the tissues of bivalve molluscs from the dredging area in relation to bivalve molluscs from the dumping area.

Biological effect of contaminated sediment on mussel Arctica islandica was tested on Mecklenburg dumping site (already discussed in this study). Furthermore, the answer to ecotoxicological test on contaminated sediment and sediment from the reference site was examined as well [14]. In contrast to the significant differences in sediments from each site, there were only minor differences in the concentrations of heavy metals in the studied bivalves from both zones. The soft tissues in the dumping area were only slightly enriched in Cu and Pb. There was also a large concentration of Cd in the shells in comparison to soft tissue and sediments. It was found that there were no other visible accumulations of heavy metals due to their low bioavailability in the top layer dumping site. It is difficult to speculate about acute toxicity during dumping site activity, however, the lack of older individuals may suggest the presence of these toxicities in previous years. Moreover, there was also a double increase in the concentration of chlorinated hydrocarbons in soft tissues in relation to those of the reference site. Therefore, it can be concluded, that organic contaminants much longer retain their assimilation than heavy metals. The positive response in 3 out of 5 „bioassay" clearly show an increase in the toxicity of contaminated dumping site in relation to the reference area. Starfish Asterias Rubens is another invertebrate occupying two discussed dumping sites „North" and „Northwest" in the North Sea, which was used for studies on the toxicity [13]. No acute toxic effects were observed, despite the high concentration of anthropogenic compounds in sediment and low accumulation of these compounds in the tissues. The level of Hg, Zn, PCBs and dioxins in Starfish examined tissues did not exceed double value from the reference area. It was found only a small pathological effect of flatfish species Limanda limanda. Therefore, it can be concluded that the presence of relatively small amounts of contaminants in deposited sediment does not strongly affect toxic effect on benthic fauna. Keep in mind, though, that the majority of tested organisms were invertebrates at the low level in the marine trophic chain. It can be assumed that contamination introduced with the spoils accumulate and affect toxic to the higher trophic levels.

The first and fastest vanishing phase during dumping, which may negatively affect the environment is a very significant increase in turbidity at the site of deposition, often described in the literature as a "stain". Light fraction released during dumping process causes a very significant increase of the suspension, which in turn disturbs the balance in both water and the near bottom zone. The negative impact of stain from uncontaminated sediments as well as sediments containing low amounts of contamination has been repeatedly proven. Released suspension may adversely affect the dynamics of nutrients in estuaries, increase water filtering organisms, phytoplankton productivity and impede food acquiring by predators using their eyesight (birds, fish, etc.). In addition, settling material covers the organisms living in the dumping area. Quite a detailed study of this phenomenon was performed on dumping site in Denmark (Wadden Sea) [15]. There was no increase in mortality or decline in the condition of organisms in fish and birds. Fears of a reduction in the efficiency of gas exchange via gills by increasing suspension in water is not confirmed. Reducing the visibility is rather quickly withdrawing local disorder. Increasing suspension of 10-20% did not cause growth disorders among filtering organisms due to changes in the composition of the filtered water (more organic matter, impurities). A much more serious situation was with increased sedimentation after discharge of material into the water. In the majority, there was reported a decline in benthos within 2-3 weeks after dumping activities. Benthos sensitivity to "burial" depends on the thickness of the settled material, and the ability to restore contact with the open water. Nematodes are organisms able to survive "burial" with a layer of sediment not exceeding 10 cm thick. Cover with 10 cm layer did not cause an essential impact on the mussel *Mytilus edulis*, *Ostrea sp.*, *Mya Arenaria*, some species of corals and starfish as well. Mortality among mussels was noticed for layers with a thickness of 20-30 cm. Benthic organisms demonstrated a greater tolerance in relation to the particulate material than the muddy material. Perhaps the silty material enhances the formation of anaerobic conditions and impedes the process of vertical migration. The study of benthic macrofauna in the estuary of the River Weser (Germany) led to similar conclusions [11]. A physical disorder caused by sediment disposal contributed to the vertical migration and increased mortality. Stability of the top layer, thickness, and material type are the primary determining factors for that phenomena. In addition, the increase in turbidity can lead to metabolic disorders, reducing the growth and production of larvae. Larger diversity and abundance of cnidaria, molluscs and polychaetes were noticed at the reference site. The author draws attention to the high sensitivity of *Mytilus edulis* manifested by bringing filtration to a stop under few millimetres top layer of sediment. Reducing the size of some organisms contributed to a drastic decline of *Asterias Rubens* starfish. Another important factor is the frequency of disposal. The lower it is, the more likely it is to re-colonize dumping area [11, 16].

A similar situation took place at the dumping site in the Gulf of Mecklenburg. Within 3 weeks after disposal ended, a significant decline in almost all organisms inhabiting the bottom was observed [2]. The author distinguishes 3 groups of organisms: those that are able to survive buried under sediments (mainly infauna), or those that able to survive because there is a high probability of escape in the upper layers or migrate to the nearby untouched zone. The third group consists of organisms with very low mobility or with very limited habitat. The reaction of organisms, within the same species, physical changes caused burial, changes in the sediment composition and increasing suspension may be varied for individual dumping sites. This is due to the characteristics of the disposal area, climate and hydrodynamic conditions as well as organisms condition. In all cases, with regard to the long-term impact on benthic organisms, a clear trend is visible. Revival to its original state takes within 6 months to 4 years after sediments deposit [2, 13, 16]. Full recovery of benthic environment takes place in stages. At first, a significant change in species structure in comparison with the pristine is observed. In the early stages of ecosystem restoring there is predominance of opportunistic organisms. Species characterized by high mortality rate need more time to recover. There are numerous advanced mathematical models that might be helpful tool with estimating the impact of the deposition material into the marine environment. However, the key on the predictive estimate dumping site impact is to determine the relationship between the stability of the ecosystem (or environmental stress) and inhabiting there living organisms susceptibility to changes (resulting from dumping) [17].

### Minimizing the negative impact of sediment disposal.

Dredged material dumping is a very common practice, should, therefore, follow in the way that exert the minimal possible impact on the environment. There were published scientific papers containing suggestions on the "proper sediment management". It is therefore necessary to consider whether the various guidelines describing "proper options" of management offer us the optimal outcome. A very important element of the project is the selection of a suitable place to deposit sediment. A major limiting factor in selecting the proper dumping location is the cost associated with the transport of sediment at the place of deposit. The authors of scientific publications and various guidelines collectively indicate that the force and type of dumping site impact depend on factors such as [6, 13, 15, 18, 19]:

- physicochemical properties of sediments,
- the volume of deposited material,
- the similarity of dumping sediment to sediment occurring in the dumping area,
- the degree of sediment contamination,
- the depth of water,
- the structure of bottom,
- hydrological and sedimentation conditions of disposal site,
- time of year,
- method of dumping,
- adaptability of organisms to changes occurring in the ecosystem in dumping site adjacent,
- interference in other spheres of human activity (recreation, fishing, places of cultural and historical value, oil industry, military work).

In the northern Adriatic Sea (Italy), the long-term impact of dumping site on macrozoobenthic communities was investigated. As a result of monitoring after 6, 8, 24 and 48 months, no apparent differences in the structure and population of this ecosystem were noticed [18]. The key to this success was the proper treatment of dredged material, leading to minimize the effects of burial and to reduce the concentration of suspension during sediment dumping process. Each disposal area was divided into 4 smaller square "subzones" with dimensions of 1km x 1km. Each time homogeneous sediment was discharged gradually, and the maximum volume was not exceeding 12,000 cubic meters in each sub-zone. In all four subzones, sediment disposal took place in a different time. Appropriate intervals, the amount of deposited material, prevailing hydrodynamic conditions, as well as the characteristics of the sediment and biological characteristics of the area allowed to assume that the impact of dumping will not induce significant adverse effects. Benthic zone was characterized by a strong hydrodynamics, high coefficient of sedimentation and resuspension. Bottom organisms have therefore been adapted to moderate instability in the structure of the bottom and periodically increasing sedimentation. The thickness of the deposited sediment in collected core samples did not exceed 2 cm. Gradually dumping of homogeneous and similar material on relatively large areas did not result in changes in macrozoobenthic structure and its abundance. During research on the Wadden Sea was found that the season of the year of sediment dumping may be a significant factor [15]. Increased turbidity may result in reduced abundance of phytoplankton, which is a very important element of the trophic structure. Therefore, it is recommended to carry out disposal activities in the autumn and winter, when biological activity and nutritional needs of filtrators decrease. However, winter period is the most abundant in the presence of certain species of fish such as herring or smelt. Compromise for phytoplankton and fish in that area is sediment dumping in the autumn.

In Greece, attempts were made to select the most suitable place of disposal ~ 1100 000 cubic meters of sediment [6]. The selection was primarily based on finding physicochemical similarities of sediments taken from 19 potential sites. Cluster analysis turned out relatively easy and helpful application method in order to find a close connection between deposited sediment with potential dumping point. The following criteria were used:

- the percentage of the various size fractions (clay, sand, silt)
- the concentration of major elements,
- the concentration of trace elements,
- the concentration of hydrocarbons (aliphatic, PAHs).

This activities have significantly reduced the imbalance in marine environment after dumping operations and time of recovery to natural condition.

## Summary.

There are many papers exploring the issue of a single dumping site impact. However, these researches are often limited. They frequently predict the probable impact of the planned dumping site. Combining data from different studies and comparing them helps to find the general trends in major ecological effects of depositing sediments into the marine environment. Comparing results of different individual dumping sites are limited to create the only conceptual model, whereby a variety of framework decisions could be based on [20]. Review papers present that some of the common trends may be related to all dumping site, but the selection of a new location dumping place and evaluation of its impact on the marine ecosystem should be considered in each case on an individual basis. Selection of new dumping site should include every important local factor mentioned in this study. The planned implementation should be preceded by a thorough data collecting concerning the future disposal area. To obtain a complete picture of dumping impact an appropriately designed environmental monitoring should be carried out at various time intervals.

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Corresponding author: lzegarowski@im.gda.pl