GC Revista Nacional de Gerenciamento de Cidades
National Journal of City Management

ISSN 2318-8472, v. 12, n. 86, 2024

Environmental and social impacts of underwater pits in the disposal of contaminated sediments: a case study of the Santos-São Vicente estuary

Sandra de Oliveira Soares Cardoso
Professora Mestre, UNISANTA, Fatec BS e PG, Brasil
s.oliveira61@ymail.com

Patrícia Gorisch
Professora Doutora, UNISANTA, Brasil
www.sociedadedeadvogadas.com.br

ISSN 2318-8472, v. 12, n. 86, 2024

SUMMARY
The installation of underwater pits is today a common procedure, adopted by several countries around the world for the disposal of contaminated sediments resulting from dredging and industrial activity. In Baixada Santista, more specifically in the Piaçaguera Channel, an underwater pit was built for the same purpose, despite the protests that arose. This dispute arises from the fact that these contaminated sediments can cause environmental and social damage in areas close to their installation. This article aims to evaluate the environmental and social impacts of underwater pits used for the disposal of contaminated sediments, focusing on the Santos-São Vicente estuary. By adopting a bibliographical research methodology, it was possible to verify that environmental impacts are related to the possible contamination of waters, marine fauna and, consequently, human beings. Considering that the communities carry out their activities in the region affected by the construction of the pit, in the event of any problem resulting from contamination, the social impact is also important.

KEYWORDS: Underwater Pit; Baixada Santista; Environmental and Social Impact

1 INTRODUCTION

One of the most important aspects of ports is the depth of the waters, because there is enormous competition when it comes to maritime container transport. Therefore, in order to accommodate larger cargo-carrying ships, the water areas of the ports must be dredged to remove excess sediment (Oliveira, 2010).

Dredging consists of the excavation and removal of soil and submerged decomposed rocks, regardless of the depth, using different equipment in different waters, such as the sea, estuary or river (Alfredini, 2014).

Dredging carried out close to the coast can cause erosion, resulting in the disturbance of naturally occurring coastal processes, changes in wave transformation patterns and a loss of sand from the coastal system. The impacts resulting from dredging are related to the depth, the amount of marine sediments that are extracted and the distance between the coastline and the place where the dredging is carried out (Brito, 2010).

From time to time, it is necessary to dredge the Port of Santos, due to the natural silting that occurs in the region. This is due to the fact that the channel is the maritime route through which vessels can access their docking locations and, due to this situation, it is necessary that its depth is maintained to allow navigation, as well as access for vessels. larger and maintaining activities in the region (Codesp, 2022).

Currently, the navigation channel at the Port of Santos is 24.6 km long, has an average width of 220 meters and a depth of 15 meters. The area made up of the Port of Santos extends from the bay of Santos to the Pier da Alemoa region, where the section that is under the responsibility and jurisdiction of the Santos Port Authority ends and the Piaçaguera Channel begins, which the Terminals of Private Use Tiplam and Usiminas use it as access (Santos Port Authority, 2023.).

In contrast to the scenario of economic prosperity that port activities provide, the surrounding activities such as the chemical, steel and petrochemical industries impact the ecosystems under which they were founded and, as a consequence, the communities that depend on it. Port activities, channel dredging, illegal sewage, industrial effluents and indirect

ISSN 2318-8472, v. 12, n. 86, 2024

sources such as atmospheric deposition, for example, are among the main causes of pollution of the delicate environments that make up the estuarine system and the mangrove that are characteristic of the pit construction area, so the objective is to associate the maintenance of the access road to the port facilities and the environmental repair of the Piaçaguera Canal (Parreira, 2012).

Due to this condition, companies operating in Santos and Cubatão were depositing their waste and sediments in this channel, posing risks to the environment and the riverside population, as this waste was composed of chemical materials, domestic waste and other materials (People of Cubatão, 2019).

It is in this context that underwater pits are built, precisely to reduce the risk of contaminated sediments polluting the entire area, storing and isolating this contaminated material resulting from dredging (Palermo, 2002).

Therefore, the questions that arise are: what are the direct and indirect impacts of underwater pits on local marine and coastal ecosystems? How do local communities perceive and are affected by underwater pits? Do underwater pits represent a sustainable and safe solution for the deposition of contaminated sediments?

As a general objective, we intend to evaluate the environmental and social impacts of underwater pits used to dispose of contaminated sediments, focusing on the Santos-São Vicente estuary.

The following were defined as specific objectives:

1) Investigate the effectiveness of underwater pits in containing contaminated sediments and preventing marine and coastal pollution;
2) Analyze the impacts of the construction and operation of underwater excavations on local ecosystems, especially on mangroves and marine biodiversity;
3) Evaluate perceptions and socioeconomic impacts on local communities resulting from the implementation of underwater excavations; and
4) Compare Brazilian practices for disposing of contaminated sediments with those of other countries that use similar techniques.

As a methodological procedure, bibliographical research was adopted with the collection of information in articles, books and other materials already published by different authors and related to the topic addressed.

2 CREATION OF THE SANTOS UNDERWATER PIT AND ITS FUNCTION IN THE FINAL DISPOSAL OF SOLID WASTE

The underwater pit was built to replace the so-called Ocean Disposition Polygon (ODP), an area used to confine sediments, as it was considered a better destination than the ODP. This conclusion arose from the perception that considering the volume that would be dredged, as well as the type of sediment originating from urban and industrial activity and, therefore, likely

ISSN 2318-8472, v. 12, n. 86, 2024

to contain contaminating elements, it would be indicated that there was no dispersion of the same, which made the construction of the underwater pit a more suitable option (Junior, 2019).

The capping (closing) of the pit, located in the Piaçaguera Canal, in Baixada Santista, carried out in 2020 was the culmination of work to clean the canal, where contaminating materials were removed from the bed and, subsequently, the safe disposal of the pit was carried out. even, complying with the standards of environmental legislation (Cava Subaquática, 2019).

> Underwater pits consist of a method of sediment disposal. A submerged area is created in a safe place, with little current and far from the beach, where sediments that were previously available in the sea current are confined. This method called environmental dredging is internationally recognized and used successfully in countries such as Australia, the United States, Spain, the Netherlands, Norway, the United Kingdom and Hong Kong, as well as Rio de Janeiro and Santos, in Brazil. (Cava Subaquática, 2019, s/p.)

The option for Cava results from the advantage in relation to its location because it was very close to the place of origin of the problem and also due to the speed of the intervention, which it allowed for shorter exposure time and the disposal of the material to be confined, away from the biotic exchange zone with the ecosystem (Marques, 2022).

Figure 1 – Santos underwater cave

Source: Mar Sem Fim, 2019

There are two underwater caves in Brazil that store contaminated sediments: one is the one in figure 1, located in the Santos-São Vicente estuary region (São Paulo coast) and the other in Rio de Janeiro, in Sepetiba Bay. The Baixada Santista underwater pit is 22 meters deep, 480 meters in diameter and has a capacity to store 4 million meters3 of sediment.

It should be noted, to give you a sense of its grandeur, that the Santos estuary pit is larger than the Maracanã stadium and is the only access to a terminal at the Port of Santos that is operated by private companies. In addition to this pit, two others were approved for construction: one in Santos, in Largo do Canéu and another in Cubatão, another industrial hub (Mar Sem Fim, 2019).

Although the pit only began to be built in 2016, the studies and analyzes for its implementation began in 2004 and were carried out by Companhia Siderúrgica Paulista (COSIPA). Before starting its construction, Cetesb (2019) required that the pit comply with some

ISSN 2318-8472, v. 12, n. 86, 2024

specific conditions, particularly with regard to dredging, which would have to be carried out with cutting-edge technology, meaning that a dredger Hopper type would have to be used so that the uplift of the material could be avoided.

The description approved in 2004 for the disposal of sediments in the area represented a CDF model structure, that is, a confined disposal facility, however the structure that was built is in accordance with the CAD model, that is, aquatic disposal contained, with differences in terms of the construction method and the values performed, as well as in terms of safety and indication of use for each of the models (Ferraz, 2023).

Additionally, Cetesb (2019) also determined that there would be a need to place a silt curtain along the entire perimeter of the pit, which should be inspected periodically and monitored 24 hours a day, to prevent sediments from being deposited in the pit. cava could disperse to the estuary.

Regarding this silt curtain, it is commented that:

> From above, what you can see is an enclosure, similar to a large fishing net, tracing a poorly arranged circle in the murky waters of the Piaçaguera Channel that flows into the Santos estuary, practically touching the mangrove area. It is located right on the border between Santos and Cubatão, in a region called Largo do Casqueiro, but goes almost unnoticed, so much so that most inhabitants of Baixada Santista probably do not know of its existence (Hiroshi; Vieira; Abreu; Rodrigues, 2021, s/p .)

The pit began to be filled in 2017, with sediments from dredging the channel and a tube was used to insert the sediments, connected to the dredger that pumped them into the pit.

However, both its construction and its use over the years have generated numerous discussions and also conflicts, especially environmental ones due to the possible impacts that the pit has on the region's ecosystem services (Contracava, 2021).

In addition to all this, a project to build a gas terminal was also implemented, with a gas pipeline to receive the product, which increased the climate of protest regarding the pollution and degradation of the estuary and the dangers for the future of communities. locations (Strupeni, 2022).

A diffuser attached to the tube was also used to prevent the sediments from dispersing when leaving the tube and, thus, preventing the tube from rising to the surface of the pit (Torronteguy et al., 2018).

Because it was deeper than that initially proposed (15 meters instead of 12 meters), the volume of sediment inserted into the pit was also significantly greater. In 2020, at the end of sediment deposition, the pit was also covered with a layer of almost 2 meters of sand, therefore a material without environmental risk, with the aim that, over time, the site can be reincorporated into the environment (Cava Subaquática, 2019).

2.1 Geographic and environmental characteristics of the Pit implementation region

The plateau in the Cubatão region, which is part of the Geomorphological Province of the Planalto Atlântico and whose area is part of the Planalto Paulistano, has a smooth relief,

ISSN 2318-8472, v. 12, n. 86, 2024

formed by spiers and hills with altitudes of up to 900 meters and which are drained by the Tietê River. It is in the central-north sector of this region that the São Paulo sedimentary basin is found.

The Baixada Litorânea and Serrania Costeira make up the coastal province and is an area whose drainage goes directly to the sea. The Cubatão River basin region is surrounded by the Serra do Mar to the north and the coastal plain and Atlantic Ocean to the south. Serra do Mar has an altitude of up to 900 meters and its rock formations include granite, quartz, gneiss and schist. A network of meandering channels is located there, which are interconnected to the Bay of Santos, with an opening to the south towards the ocean, between the two main channels that surround the Island of São Vicente and which are named after the two main municipalities: Santos and São Vicente (Parreira, 2012).

The area surrounding the Pit, that is, the Piaçaguera Channel, is located in the Santos Estuary, on the central coast of the coastal zone, being a transition zone between the Atlantic Ocean and the fresh water of the river basin that bathes the five municipalities which constitute the Metropolitan Region of Baixada Santista. The canal is located at the head of the estuary and has been used since 1969 to transport cargo ships.

This region is part of the Santos-Cubatão estuarine system, which presents the characteristic of high sedimentation, due to the Serra do Mar. Another relevant aspect is the existence of a break in relief, called the Cubatão Fault, which greatly contributes to the deposition of sediments (Silva et al., 2012).

According to the explanation, estuaries are coastal, transitional and semi-closed environments, meaning that they are influenced by both continental and oceanic origins, which means that the ecosystem is constantly changing to respond to the natural forces that act on it, therefore it is a very dynamic environment to enable the exchange of water and sediments between the coastal and oceanic regions. Therefore, any human interference in this process is a risk to its stability.

The region studied has an important and vast river basin in its territory, with the source located at the top of Serra do Mar and flowing into the Santos estuary. The flow of these waters is different due to ruptures and changes in slope between the coastal plain and the Serra escarpment. Thus, upon reaching the lowest part, the energy of the waters decreases, which results in the formation of many channels that give the rivers a meandering appearance and enable the development of mangroves (Santos; Furlan, 2010).

The Piaçaguera River channel is a natural channel, with an average width of 400 meters and along its axis an artificial navigation channel was developed with a length of 4500 meters, 100 meters wide and 12 meters deep. It also has an evolution basin 750 meters wide, 600 meters long and 12 meters deep, which makes it possible to connect the entrance to the Port of Santos with the Cubatão Private Maritime Terminal (Ferraz, 2023).

This is a mangrove region and, therefore, a provider of diverse ecosystem services, meaning that the ecosystems bring benefits to the human beings who live there, whether through forestry products, fishing, drinking water, or protection. against climate and erosion events (Almeida; Junior, 2018).

ISSN 2318-8472, v. 12, n. 86, 2024

This is a region that, in terms of climatic configuration, presents high levels of precipitation, with an annual average of 2830 mm and an average temperature above 15ºC, considering the coldest month. It is an area greatly influenced by moisture convergence zones in the spring and summer months and by anticyclones originating from the South Atlantic and the South Polar, during the autumn and winter months (Galvani; Novais, 2022).

It is these climatic and geological conditions that favor the transport of an important volume of sediments that end up being deposited on the banks and beds of the channels and that affect their navigability.

Estuaries are of great importance in the biological sphere as they are habitats rich in nutrients, as they are home to organisms originating in the marine and freshwater environments. Furthermore, they develop their own community, serving as a shelter, nesting, breeding, feeding and resting area for several species that are adapted to these environments (Dias, 2005).

2.2 Main waste dumped in the pit and potential impacts on environmental health

Environmental health is an element linked to factors such as climate change, pollution and poverty, thus being directly related to economic, social and environmental development. These are problems that, according to the World Health Organization, can be mitigated by reducing environmental contamination, improving water quality, basic sanitation, reducing pollution and correctly disposing of polluting waste (WHO, 2017).

Unacceptable sediments are those that have the potential to cause harmful effects, both to human health and the environment. Contaminated sediment is considered to be: soil, sand, organic matter or other minerals that accumulate at the bottom of different bodies of water and that contain dangerous or toxic materials at a level that could adversely affect the environment or human health. They can be found in rivers, streams, swamps, lakes, reservoirs, along the shores of the oceans, in ports and other bodies of water (Palermo, 2002).

Port activities, channel dredging, illegal sewage, industrial effluents and indirect sources such as atmospheric deposition are some of the main sources of pollutants in the delicate environments that make up the estuarine system and the mangrove in the Pit area (Parreira, 2012).

Dredging carried out close to the coast can cause erosion, resulting in the disturbance of naturally occurring coastal processes, changes in wave transformation patterns and a loss of sand from the coastal system. The impacts resulting from dredging are related to the depth, the amount of marine sediments that are extracted and the distance between the coastline and the place where the dredging is carried out (Brito, 2010).

In the case of the Santos estuary, it is in constant transition from brackish water, which causes a biogeochemical mixture of substances. It is a whole set of molecules of metal ions and organic materials that are dumped into the estuary and accumulate at the bottom, which is mainly composed of gravel, sand, silt and clay (Carmo; Abessa; Neto, 2011).

The disposal of various materials, which contain heavy metals such as mercury, nickel, lead, copper, cadmium, zinc, among others, have the capacity to contaminate soils through

ISSN 2318-8472, v. 12, n. 86, 2024

infiltration, also contaminating groundwater and, as a consequence, fauna and flora from nearby regions. These are metals that have bioaccumulative potential and when they are absorbed by the individual, they end up being deposited in bone and fatty tissue, which can cause various pathologies such as kidney and lung dysfunction and even brain injuries (Roa et al., 2009).

Waste deposition is responsible for environmental and sanitary degradation, receiving waste that ranges from those with low hazardous values, to more aggressive pollutants and a multitude of organic and inorganic compounds are transported by water, also compromising the soil and, consequently, the entire food chain, causing bioaccumulation in the most diverse environmental compartments (Araújo, 2015).

Water contamination is one of the main causes of environmental problems to which populations are exposed, as water is considered a source of transmission of various biological agents (Guedes et al., 2015).

The sediments that accumulate in the channel are rich in chemical elements and contaminants (Couto, 2003). It is important to note that over the decades, the Canal received waste and sediments that were deposited by various companies that operated in that region. This material was, until then, in an inadequate environment and spread over an area equivalent to 460 thousand m2 and which put marine life, flora and the population at risk (Povo de Cubatão, 2019).

Considering the existence of the mangrove:

> The harmful toxicological potential of these residues is impressive. For example, in relation to Dibenzo(ah)anthracene, Benzo(a)pyrene and Benzo(a)anthracene, there are sufficient scientific studies to characterize them as genotoxic, mutagenic and carcinogenic, that is, causing damage and mutations of different orders in genes. Due to these characteristics, these toxic compounds, aggressive to fauna, flora and humans, could never be confined in underwater pits – a toxic liability abandoned, without any treatment, at the mercy of the tides (Fonasc, 2018, s/p).

Among the various problems that arise from the underwater pit are the contamination of rivers, mangroves and fish, the possible dispersion of polluting elements to the beaches by the movement of the tides, in addition to the possible recontamination of the estuary resulting from the dredging process and the arrangement of polluting elements placed in the pit (Araújo, 2022).

Toxic waste such as mercury, arsenic, cadmium, nickel and other polluting metals were identified as existing in the underwater pit and the levels reached are considerably above the values that are established as acceptable by the resolution of the National Environmental Council (Conama).

In addition to mercury and cadmium, other heavy metals are also present in the sediment from the Santos underwater pit, such as lead, zinc and copper. These metals are released by various industrial activities and can cause harm to human health and the environment (Marques, 2022).

Among the effects of these heavy metals, damage to the central nervous system, cardiovascular system, kidneys and liver stands out. Furthermore, they can also be carcinogenic

ISSN 2318-8472, v. 12, n. 86, 2024

and mutagenic, increasing the risk of cancer and genetic changes in humans and animals that come into contact with these substances. (Marques, 2022)

Metals are substances that are easily installed in the organism of animals such as fish and invertebrates, but which, on the other hand, are difficult to excrete, as they are hydrophilic substances and which, in their ionic form, mix with the molecules of water and when in excess, they accumulate and gather in the sediment. These are substances that do not dissolve in water and can be carcinogenic and toxic (Pereira Neto et al., 2000).

The fact is that these sediments deposited in confined areas, if exposed, can promote the contamination of bodies of water (in this case, the Piaçaguera Canal) due to their transport by rainwater. This is a negative impact that can harm aquatic communities, since when removed, these habitats are suppressed and because they play a fundamental role in the food chain of the estuarine system, everyone involved in the process ends up being affected, albeit indirectly.

For fishermen who live in the region, the benefits do not seem to be so many. The fishing village is located just two kilometers from the pit and the fishermen consider that the pit is a threat to the mangrove, influencing the survival of fish, molluscs and crustaceans in the region, which has guaranteed the livelihood of this community for decades (Hiroshi et al., 2021).

2.3 Equipment similar to the Underwater Pit located abroad

The need to control contaminated dredged materials that present parameters above the required limits of chemical or toxic substances resulted in the development of techniques for the deposition of these materials, with specific characteristics that allow minimizing the environmental damage that this contamination may cause (Monteiro, 2010) .

The technologies used for these purposes are diverse, but in all of them, the basic principle in terms of operation of the installation is the same, that is, the confinement and containment of the material to prevent harmful substances from being made available, preventing negative consequences for the local environment (Monteiro, 2010).

Confined disposal corresponds to the deposit of material that has been dredged and is contaminated, in a structure that allows this disposal area to be isolated from any adjacent water surfaces. These confinement sites can be built above or below sea level, in areas close to the coast or on islands (Almeida, 2004).

Sedimentation of waste in the aquatic environment is a practice adopted in many different countries, although different methods are used for this process. While in Brazil and more specifically in Baixada Santista, the Underwater Cave technique was used, also called Contained Aquatic Disposal (CAD), while in other countries, the most used method is the Confined Disposal Facility (CDF) or Installation of Confined Disposition.

> Disposal in Confined Disposal Units (UDC) is the most widespread and applied alternative in the United States and in some European countries, being an option that brings together solutions to environmental and financial issues. This alternative consists of allocating the dredged material inside structures, such that they isolate said material, forming a true walled island in the final disposal environment (Monteiro, 2010, p.52).

ISSN 2318-8472, v. 12, n. 86, 2024

The confined disposal facility is an artificially constructed area, surrounded by dikes and intended to contain contaminated dredged materials, aiming to prevent their leakage into the environment. The dredged material is generally disposed of in hydraulically confined areas, either through pipes or pumping systems on self-transported dredgers or barges (Goes Filho, 2004).

In relation to Contained Aquatic Disposal, this alternative involves the controlled disposal of dredged materials and contaminated underwater caves, with clean material to isolate the surface contaminated material released. This is a method similar to in situ caulking, with the difference that the sediments are contained laterally to prevent their spread. Underwater caves or contained aquatic disposal (CAD) can be strategically placed in natural environments or depressions excavated in previously studied locations (Parreira, 2012).

According to a document prepared by the National Academy Press (National Research Council, 1997), confined disposal has to do with the placement of dredged materials in confined disposal facilities in locations close to the coast, on islands or on land. This CDF is surrounded by dikes or confinement structures, above the water level to isolate the dredged material from adjacent waters. The purpose of this installation is to receive these contaminated sediments, providing adequate storage capacity and, at the same time, meet the requirements of maximizing efficiency in controlling the release of contaminants.

Contained Aquatic Disposal or CAD involves placing the contaminated material in an open water location and then covering it with clean material. There are some similarities between this method and in situ leveling, with the most relevant difference being that in the CAD method, the contaminated material is relocated and contained laterally, in order to minimize the spread of contamination from the bottom. Unlike the CDF option, the chemical environment surrounding the contaminated material remains unchanged since the sediment ends up remaining in the waters from which it originated (National Research Council, 1997).

In the case of the CDF, they indicate that this is a model that can be easily coated, depending on the hydrological and geological conditions, as well as the degree of contamination of the materials previously dredged and that must be deposited. This is a more expensive model, but it may be the only option for containing moderately and highly contaminated sediments (Agerschou, 2004).

> Water discharged from CDFs must meet applicable suspended solids standards and contaminant criteria within a specified mixing zone, and CDFs are designed to perform this rudimentary “treatment.” The size and design of CDFs can range from simple earthen structures with passive dam systems to sophisticated disposal facilities with lining, leachate collection systems, and other controls designed to prevent migration of contaminants from the site (PALERMO; AVERETT, 2000, s/p.).

In the case of the CAD model, its use is more restricted to the deposition of materials whose contamination is milder or moderate (Agerschou, 2004).

Considering the literature, it seems clear that the criteria for installing this type of structure abroad takes into account not only the financial aspects related to its construction, but also the type of sediment and the best suitability depending on the location. In the case of

GC Revista Nacional de Gerenciamento de Cidades
National Journal of City Management

ISSN 2318-8472, v. 12, n. 86, 2024

the Baixada Santista underwater pit, what was verified, considering the reading of the different texts, is that some guidelines were not respected.

3 CONCLUSION

The underwater pits used to dispose of contaminated sediments in the Santos-São Vicente estuary have direct and indirect impacts on local marine and coastal ecosystems. Among the direct impacts, water contamination stands out, which can release pollutants into the water column, directly affecting the health of marine organisms. Marine fauna, especially benthic organisms such as mollusks and crustaceans, are particularly vulnerable to contamination, and bioaccumulation of toxins can occur that affect the entire food chain, including fish consumed by humans. Additionally, the construction and operation of pits can destroy critical habitats, such as mangroves, which are breeding and feeding grounds for many marine species. Pits can also alter current and sedimentation patterns, negatively impacting the ecological processes that support the productivity of marine ecosystems.

Indirect impacts include effects on the food chain, where contamination of marine organisms leads to the bioaccumulation of toxins in higher species, resulting in adverse effects on predatory fish and marine mammals. Habitat degradation and contamination can lead to a decline in biodiversity, affecting the resilience and functionality of marine and coastal ecosystems. Additionally, mangroves and other coastal habitats provide important ecosystem services, such as protection from coastal erosion, water purification, and support for fisheries, and degradation of these habitats can compromise these services, directly impacting the human communities that depend on them.

Local communities generally perceive underwater pits with suspicion and concern, influenced by the lack of clear and transparent information about the risks and benefits of pits, past experience with industrial pollution and economic dependence on fishing activities. These communities face significant health and economic risks. Fishing activities, a crucial source of livelihood, can be negatively affected by fish contamination and habitat destruction, resulting in loss of income and increased food insecurity. Exposure to contaminants through the consumption of contaminated fish and shellfish can lead to public health problems, including chronic diseases and acute poisoning. Environmental degradation and the loss of natural resources can generate social conflicts, increase forced migration and reduce the quality of life of local communities.

Although underwater pits offer a technical solution for disposing of contaminated sediments, their long-term sustainability and safety are questionable. The effectiveness of pits depends on the use of advanced technologies for containment and monitoring, but long-term maintenance and ensuring that contaminants remain confined are significant challenges. Pits can mitigate some immediate risks, but long-term environmental impacts, such as persistent contamination and degradation of ecosystems, compromise the sustainability of this solution. More sustainable alternatives, such as in situ remediation and treating contaminated sediments before disposal, can offer more effective solutions. Habitat restoration and pollution source reduction are complementary approaches that increase sustainability.

ISSN 2318-8472, v. 12, n. 86, 2024

The safety of underwater pits requires continuous monitoring to detect leaks and dispersion of contaminants, resulting in high costs and the need for cutting-edge technologies. Robust regulation and strict oversight are essential to ensure pits operate to high safety standards. The participation of local communities in inspection can increase transparency and effectiveness. However, continued sedimentation and the potential for extreme weather events pose risks to the integrity of underwater pits, which in the long term could compromise safety and require additional remediation solutions.

The environmental impacts identified include possible water contamination and the impact on marine fauna, especially mangroves, which are sensitive ecosystems and vital for local biodiversity. The dispersion of heavy metals and other contaminants, even if confined, can result in prolonged adverse effects on the health of aquatic ecosystems. These effects can manifest themselves in the form of bioaccumulation of toxins in marine species, with potential consequences for the entire food chain, including humans.

To mitigate these impacts, the research suggests implementing comprehensive strategies that include continuous monitoring of water and sediment quality, as well as the use of advanced technologies to prevent the spread of contaminants. The creation of buffer zones and the restoration of degraded habitats are additional measures that can help mitigate environmental damage. Furthermore, the active participation of local communities in the decision-making process and transparency in communication about the risks and benefits of underwater pits are crucial to building trust and cooperation. Robust public policies, which incorporate international best practices and ensure strict compliance with environmental regulations, are essential for the effective management of underwater pits.

Compared to international practices, it is observed that many countries have adopted more rigorous measures and more advanced technologies in the management of contaminated sediments. Adapting these practices to the Brazilian context can offer significant improvements in the sustainability of underwater pit operations. The issue of contaminated sediment deposits is something that all countries have to deal with and there are countless examples of confined pits around the world. Spain, the United States and Canada are examples of countries that adopt this method to confine toxic waste, varying only in terms of the laws that each country adopts to allow this type of installation. The issue of environmental and social impacts when related to the deposit of toxic sediments means that, in these countries, underwater pits are built according to safety and financial impact criteria.

In conclusion, although underwater pits offer a practical solution for the disposal of contaminated sediments, their effectiveness and safety depend on integrated management that considers both technical aspects and socio-environmental impacts. Effective mitigation of impacts requires a continuous commitment to technological innovation, environmental sustainability and social inclusion, thus ensuring a safe and prosperous future for the Santos-São Vicente estuary and its communities.

4 BIBLIOGRAPHIC REFERENCES

4.1 Books

ISSN 2318-8472, v. 12, n. 86, 2024

ALFREDINI, Paolo.; ARASAKI, Emília. **Engenharia portuária**. São Paulo: Blucher, 2014.

ALMEIDA, Renato; JUNIOR, Clemente. **Atlas dos Manguezais do Brasil**. Ministério do Meio Ambiente, Instituto Chico Mendes de Conservação da Biodiversidade, Brasília, 2018.

ALMEIDA, S. **Subsídios para o gerenciamento ambiental de projetos de dragagem em portos**. Rio de Janeiro, 2004

AGERSCHOU, H. et al. **Planning and design of ports and marine terminals**. 2004. Disponível em: https://pt.scribd.com/document/625588104/Agerschou-Et-Al-2004-Planning-and-Design-of-Ports-and-Marine-Terminals-2nd-Ed. Acesso em: 24.nov.2023.

BRITO, Pedro. **Muito a navegar: uma análise logística dos portos brasileiros**. Rio de Janeiro: Topbooks, 2010.

NATIONAL RESEARCH COUNCIL. **Contaminated Sediments in Ports and Water-ways: Cleanup Strategies and Technologies**. Washington, DC: The National Academies Press, 1997. https://doi.org/10.17226/5292

4.2 Dissertation, thesis and academic work – Print

ARAÚJO, Tiago. **Avaliação de impactos em um lixão inativo no município de Itaporanga – PB**. 48 f. Trabalho de conclusão de curso (TCC) do Curso de Engenharia Sanitária e Ambiental da Universidade Estadual da Paraíba, Campina Grande, 2015.

COUTO, M. J. **Entre Estatais e Transnacionais: O Polo Industrial de Cubatão**. Tese (Doutorado em História Econômica) - Instituto de Economia da Universidade Estadual de Campinas. Campinas. 2003.

DIAS, C. B. **Dinâmica do sistema estuarino Timonha/Ubatuba (Ceará - Brasil): considerações ambientais**. 2005. 146 f. Dissertação (Mestrado Ciências Marinhas Tropicais) – Instituto de Ciências do Mar, Universidade Federal do Ceará, Fortaleza, 2005

FERRAZ, Ana. **Cava é cova: desdobramentos socioambientais da dragagem do Canal de Piaçaguera em Cubatão – SP**. 2023. Monografia (Bacharelado em Geografia) – Universidade de São Paulo, São Paulo, 2023

GOES FILHO, Hildebrando. **Dragagem e gestão dos sedimentos**. Pós-Graduação (Engenha-ria) – Rio de Janeiro, 2004

JUNIOR, Sérgio. **Estudo conceitual da dragagem de aprofundamento para a implantação do projeto de expansão do terminal público da Alemoa**. Trabalho de Conclusão de Curso, Faculdade de Engenharia, Universidade Santa Cecília, 2019. Disponível em: https://cursos.unisanta.br/civil/arquivos/dragagem-estudo.pdf. Acesso em: 16.01.2023

MARQUES, Raquel**. Avaliação do uso da cava subaquática em Cubatão (SP) para a colocação de sedimentos contaminados como uma eventual forma de remediação**. Trabalho de Conclusão de Curso – Bacharel em Ciência e Tecnologia do Mar – Universidade Federal de São Paulo, Santos. 2022. Disponível em: https://repositorio.unifesp.br/handle/11600/66376. Acesso em: 17.04.2023.

MONTEIRO, Analucia. **Estudos das técnicas de disposição de sedimentos contaminados de dragagem**. Dissertação (Mestrado em Engenharia de Transportes) – Instituto Militar de Engenharia. Rio de Janeiro, 2010. Disponível em: file:///C:/Users/USUARIO/Downloads/Analucia%20Meyrelles%20Monteiro%20.pdf. Acesso em: 28.dez.2023.

PARREIRA, Caroline. **Avaliação da hidrodinâmica e da poluição no Canal de Piaçaguera, no Estuário de Santos - São Vicente (SP), a partir de informações ambientais e modelagem numérica**. Tese de Doutorado. Universidade de São Paulo, 2012. Disponível em: https://www.teses.usp.br/teses/disponiveis/90/90131/tde-04072012-140310/pt-br.php. Acesso em: 18.04.2023.

STRUPENI, Giulia**. O impacto das recentes atividades antrópicas nos serviços ecossistêmicos na região do Canal de Piaçaguera – SP**. Trabalho de Conclusão de Curso – Cientista do Mar – Universidade Federal de São Paulo, Santos, 2022

4.3 Works published in events

ISSN 2318-8472, v. 12, n. 86, 2024

PALERMO, M. **Dredging Operations and Environmental Research: Focus on Contaminated Sediment**," Proceedings of the Third Specialty Conference on Dredging and Dredged Material Disposal Dredging'02 Key Technologies for Global Prosperity, 58 May 2002, Orlando, FL. Stephen Garbaciak, Jr., ed., American Society of Civil Engineers

SANTOS, A. L. G.; FURLAN, S. A. **Manguezais da Baixada Santista, São Paulo - Brasil: uma bibliografia**. In: VI Seminário Latino-Americano de Geografia Física, II Seminário Ibero Americano de Geografia Física. Universidade de Coimbra. 2010.

TORRONTEGUY, M.; MENEGUCCI, J. M.; SARAIVA, A.; CAMARA, F.; CASTRO, N.; MARQUES, A.; COELHO, L. **Piaçaguera chennel dredging case: confined aquatic disposal – CAD as an alternative for the destination of sediments not available to the ocean disposal**. VLI Logística, 2018.

4.4 Periodical Article

CARMO, Carolina; ABESSA, Denis; NETO, Joaquim (2011): **Metais em águas, sedimentos e peixes coletados no estuário de São Vicente-SP, Brasil**. Revista O mundo da saúde, v. 35, n 1, São Paulo. Disponível em: https://revistamundodasaude.emnuvens.com.br/mundodasaude/article/view/576. Acesso em: 14.04.2023

GUEDES, Gilvan; SIMÃO; Andréa; DIAS; Carlos; BRAGA; Eliza. **Risco de adoecimento por exposição às águas do Rio Doce: um estudo sobre a percepção da população de Tumiritinga, Minas Gerais, Brasil**. Cadernos de Saúde Pública, Rio de Janeiro, v. 31, n. 6, p. 1257-1268, jun, 2015. Disponível em: https://www.scielo.br/j/csp/a/rXLryPdc9dkbb8nyPyMvykw/abstract/?lang=pt. Acesso em: 12.04.2023.

PALERMO, M.; AVERETT, D. **Confined disposal facility (CDF) containment measures: A summary of field experience. DOER Technical Notes Collection**. ERDC TN-DOER-C18. Vicksburg, MS: U.S. Army Engineer Re-search and Development, 2000. Disponível em: http://el.erdc.usace.army.mil/elpubs/pdf/doerc18.pdf. Acesso em: 16.nov.2023.

PEREIRA NETTO, Annibal; DIAS, Josino; ARBILLA, Graciela; OLIVEIRA, Luiz; BAREK, Jiri. **Avaliação da contaminação humana por hidrocarbonetos policíclicos aromáticos (HPAS) e seus derivados nitrados (NHPAS): uma revisão metodológica**. Química Nova, n. 23, 2000. Disponível em: https://www.scielo.br/j/qn/a/5nRS3W39cCpVXcc8vYM5gtJ/?format=pdf&lang=pt. Acesso em: 29.dez.2023

SILVA, Wanilson; MATOS, Rosa; MACHADO, Wilson; NIZOLI, Érico Casare. **Taxas de Sedimentação em Estuário do Sudeste do Brasil, baseadas em Assinatura Geoquímica e Histórico Industrial**. São Paulo, UNESP, Geociências, v. 31, n. 1, p. 69 – 78, 2012.

4.5 Electronic documents, websites

ARAÚJO, Leandro. **ALESP – Relatório Alternativo CPI da Cava Subaquática**, 2022. Disponível em: https://acpo.org.br/wp-content/uploads/2022/05/realtorio_cava-.pdf. Acesso em: 25.nov.2023.

CAVA SUBAQUÁTICA. **Desmistificando**. 2019. Disponível em: https://cavasubaquatica.com/#desmistificando. Acesso em: 18.nov.2022
CETESB. Companhia Ambiental do Estado de São Paulo. **Assessoria Parlamentar -Requerimento de Informação nº 06/2019 sobre a Cava Subaquática do canal de Piaçaguera**. Processo SMA nº 13.781/02, São Paulo, 2019

CODESP. **Dragagem do Porto de Santos, Economia, sustentabilidade e educação ambiental**. Disponível em: <https://dragagem.portodesantos.com.br/portal/dragagem> Acesso em: 18.nov.2022.

CONTRACAVA. **O que é a cava subaquática**? Informativo do Movimento contra a cava subaquática, 2021. Disponível em: https://contracava.confianti.com.br/o-que-e-a-cava-subaquatica/. Acesso em: 18.nov.2022

FONASC. **Fonasc Cbh denuncia implantação de cava subaquática** (lixão submarino químico tóxico) no estuário santista.2018. Disponível em: http://fonasc-cbh.org.br/?p=18907. Acesso em: 19.04.2023

ISSN 2318-8472, v. 12, n. 86, 2024

HIROSHI, João; VIEIRA, Victor; ABREU, Lívia; RODRIGUES, Marcela. **Cava ou cova? O dilema de conciliar qualidade de vida e desenvolvimento**, 2021. Disponível em: https://viralunisanta.wixsite.com/viral2021/cava-subaqu%C3%A1tica. Acesso em: 18.nov.2022

MAR SEM FIM. **Cavas subaquáticas: projeto que proíbe construção avança**. 2019. Disponível em: https://marsemfim.com.br/cavas-subaquaticas-projeto-que-proibe-construcao-avanca/. Acesso em: 18.nov.2022.

OLIVEIRA, Ulysses. **A dragagem e os impactos ao meio ambiente**.2010. Rio de Janeiro. Disponível em: www.uezo.rj.gov.br/tccs/capi/UlyssesOliveira.pdf. Acesso em: 16.04.2023.

POVO DE CUBATÃO**. Cava submersa no canal de Cubatão recupera ecossistema regional**. 2019. Disponível em: http://povodecubatao.com.br/cava-submersa-no-canal-de-cubatao-recupera-ecossistema-regional/. Acesso em: 19.nov.2022.

ROA, Katia; SILVA, Gilson; NEVES, Leonardo; WARIGODA, Massuko (2009): **Pilhas e baterias: usos e descartes x impactos ambientais**. Disponível em: http://www.cienciamao.usp.br/dados/aas/_indefinidopilhasebateria.arquivo.pdf. Acesso em: 16.05.2023

SANTOS PORT AUTHORITY. **História, 2023**. Disponível em: https://www.portodesantos.com.br/conheca-o-porto/historia-2/. Acesso em: 19.04.2023.

WHO - World Health Organization**. Inheriting a sustainable world?** Atlas on children's health and the environment. WHO, Switzerland.2017. Disponível em: https://www.who.int/publications/i/item/9789241511773. Acesso em: 15.05.2023.