Research on harbor channel dredging project under the concept of environmental protection

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Abstract*:* In port and waterway dredging projects, traditional construction methods have many adverse effects on the water environment and ecosystems, and with the enhancement of environmental protection awareness, the concept of environmental protection has gradually become an important guiding principle for dredging projects. Based on the concept of environmental protection, this paper systematically analyzes the impacts of dredging projects on the ecological environment and proposes strategies for pollution control, waste resource utilization, ecological restoration and green management applicable to dredging projects. This paper discusses the innovation and application of environmental protection dredging technology, and analyzes the implementation effect and successful experience of environmental protection measures through typical cases, which provides theoretical support and practical references for future dredging projects in port and waterway under the requirements of environmental protection.

1. Introduction

Dredging of port waterways is a key infrastructure project to ensure the smoothness of waterways, the enhancement of port capacity and regional economic development[1]. However, the traditional dredging construction process is often accompanied by sediment suspension, pollutant dispersion and damage to the ecological environment, which poses a serious threat to the aquatic ecosystem[2]. Against the background of increasing global awareness of environmental protection, the integration of environmental protection concepts into the design and implementation of dredging projects has become an important development direction for port construction and waterway maintenance in various countries.

In recent years, a great deal of research has been carried out at home and abroad on environmental protection dredging technology, pollutant control, ecological restoration and other aspects, and significant results have been achieved[3]. Environmental protection dredging technology can not only reduce the impact on the water environment, but also realize the effective use of dredged material through the waste resourceization and other ways to enhance the sustainability of the project. How to effectively apply the concept of environmental protection in dredging projects and take into account the economic and ecological benefits has become a key issue of concern in the field of port and waterway dredging at present[4].

This paper will systematically explore the application strategies of environmental protection concepts in dredging projects, analyze the specific measures in pollution control, waste treatment and resource utilization, ecological restoration, etc., and demonstrate the implementation effect of environmental protection dredging technology with case studies[5]. Through the study of these contents, this paper aims to provide theoretical support and practical reference for harbor channel dredging projects in order to promote the green development and ecological sustainability of the project[6].

2. Overview and current status of harbor channel dredging projects

Dredging of port waterways is an important basic project to ensure smooth shipping, port development and economic growth[7]. Maintaining the water depth and width of the channel through

regular dredging ensures the safe passage of ships and creates conditions for ports to increase their throughput capacity[8]. Such projects cover a wide range of aspects, such as excavation, dredging, transportation and disposal of dredged material, and their implementation is directly related to the operational efficiency of ports and the development of the regional economy. Pollution Concentration Formula:

$$C_t = \frac{C_0}{(1+k \cdot t)^n} \tag{1}$$

The global demand for dredging of ports and waterways is increasing, especially in the context of the rapid development of coastal cities, and the frequency and scale of dredging projects are further expanding[9]. However, traditional dredging techniques often generate large amounts of suspended sediment and other pollutants during the construction process, leading to increased turbidity in water bodies, the spread of heavy metals and hazardous substances, and significant damage to aquatic organisms and the surrounding ecosystem[10]. This negative impact has prompted the industry to explore more environmentally friendly dredging technologies and methods,showed in Figure 1 :

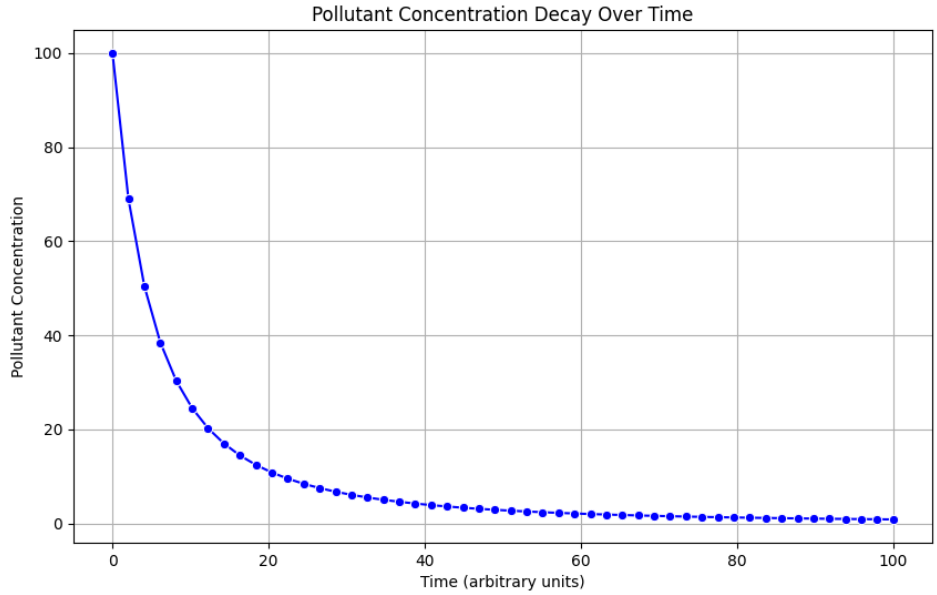

Figure 1 Pollutant Concentration Decay Over Time

Driven by the concept of environmental protection, in recent years, countries have gradually emphasized the research and application of green dredging technology, trying to reduce the impact on the natural environment during dredging construction[11]. For example, low-disturbance dredging equipment, real-time water quality monitoring, and control of the construction area have been adopted to maximize the protection of the ecological balance of the water body. Governments have also introduced stricter environmental regulations and standards to guide and standardize the green transformation of dredging projects[12]. Environmentally friendly dredging projects still face technical challenges and economic pressures in practical application, such as higher R&D costs for environmentally friendly equipment and greater construction difficulties. How to optimize the dredging construction process under the premise of cost control and achieve a balance between pollution prevention and control and resource recycling is still a pressing issue for the green transformation of dredging projects.

3. Strategies for the application of environmental protection concepts in dredging projects

Under the guidance of the concept of environmental protection, dredging projects have gradually shifted from traditional construction methods to a green construction mode that pays more attention to ecological protection and resource utilization. In order to achieve this goal, it is necessary to start

from the three aspects of pollution control, waste resource utilization and ecological restoration, and to comprehensively apply advanced technology and scientific management measures to reduce the impact of construction on the environment and effectively utilize dredged material to protect and restore the balance of the aquatic ecosystem.

3.1. Pollution control

In dredging projects, pollution control is a central aspect of reducing environmental impacts. Dredging operations are often accompanied by the suspension and spread of large quantities of sediment and pollutants, which can cause water turbidity to rise and threaten the living environment of aquatic organisms. The use of low-disturbance dredging equipment to reduce sediment suspension has become one of the key measures to control pollution. The impact of construction on the water body can be further reduced by optimizing the construction process and operation procedures.

Real-time monitoring of water quality during dredging operations is critical. Through the introduction of a water quality monitoring system, data such as suspended solids concentration and pollutant diffusion in the water body can be obtained in real time during the construction process. Timely warning and adjustment of construction programs for exceeding data can help control pollution within reasonable limits, thus better protecting the surrounding ecological environment. The establishment of a sound pollution control monitoring mechanism can also provide data support for the evaluation of the effectiveness of environmental protection dredging technology.

The collection and disposal of contaminants is also a key part of pollution control. Pollutants and hazardous sediments generated during dredging need to be properly treated to avoid secondary pollution. Physical methods such as filtration and dewatering can be used to remove pollutants from the water, while sediments containing heavy metals or other hazardous substances can be centrally transported to suitable treatment sites for harmless treatment or resource utilization in order to reduce long-term impacts on water bodies.

Strict environmental management and construction supervision play a safeguarding role in pollution control. Formulate clear environmental construction specifications, require dredging companies to follow environmental standards in operation, and ensure that pollution control measures are put into place through on-site supervision. This management mechanism can not only effectively improve the environmental protection of the construction process, but also lay the foundation for the long-term sustainable development of the dredging project.

3.2. Waste Resource Utilization

In dredging projects, waste resource utilization is one of the key strategies to achieve environmental goals. Dredging operations produce large amounts of mud and sediment, which, if not handled properly, can occupy a large amount of land and cause secondary pollution to the environment. Transforming dredging waste into renewable resources through resource utilization can not only effectively reduce the amount of waste stockpiled, but also create economic value. Some of the sediment can be used as construction material, roadbed filler or soil conditioner. Sediment Transport Equation:

$$Q_s = \alpha \cdot u^3 \cdot (S - 1) \tag{2}$$

For the resource utilization of dredging wastes, dredged material needs to be classified and treated. Dredged material in different waters and construction environments has different compositions and properties, with some containing high levels of organic matter or nutrients, while others may contain heavy metals and other pollutants. Through chemical analysis and separation techniques, dredged materials are classified into usable and unusable categories for more efficient resource utilization. At the same time, dredged material containing pollutants needs to be harmlessly treated to ensure the safety of subsequent resource utilization.

Converting waste into ecological restoration materials is an effective way of utilizing resources. Part of the dredged waste can be used for wetland restoration, ecological dam construction or water body habitat improvement after treatment, which can play a role in promoting ecological restoration. The use of organic matter-rich dredged sediment as a substrate for vegetation restoration can improve

the survival rate of aquatic plants, thus helping to repair the structure and function of the ecosystem and promote the sustainable development of watershed ecology. In order to promote the resource utilization of waste, it is crucial to establish sound policies and incentive mechanisms. The government can introduce relevant regulations and incentive policies to provide technical and financial support for the resource utilization of dredging waste, and establish an assessment and regulatory mechanism to ensure that the resource utilization process meets environmental requirements. Through policy guidance, the popularization and standardization of dredging waste resource utilization will be further promoted, providing a win-win situation for both ecological environmental protection and economic benefits,showed in Figure 2 :

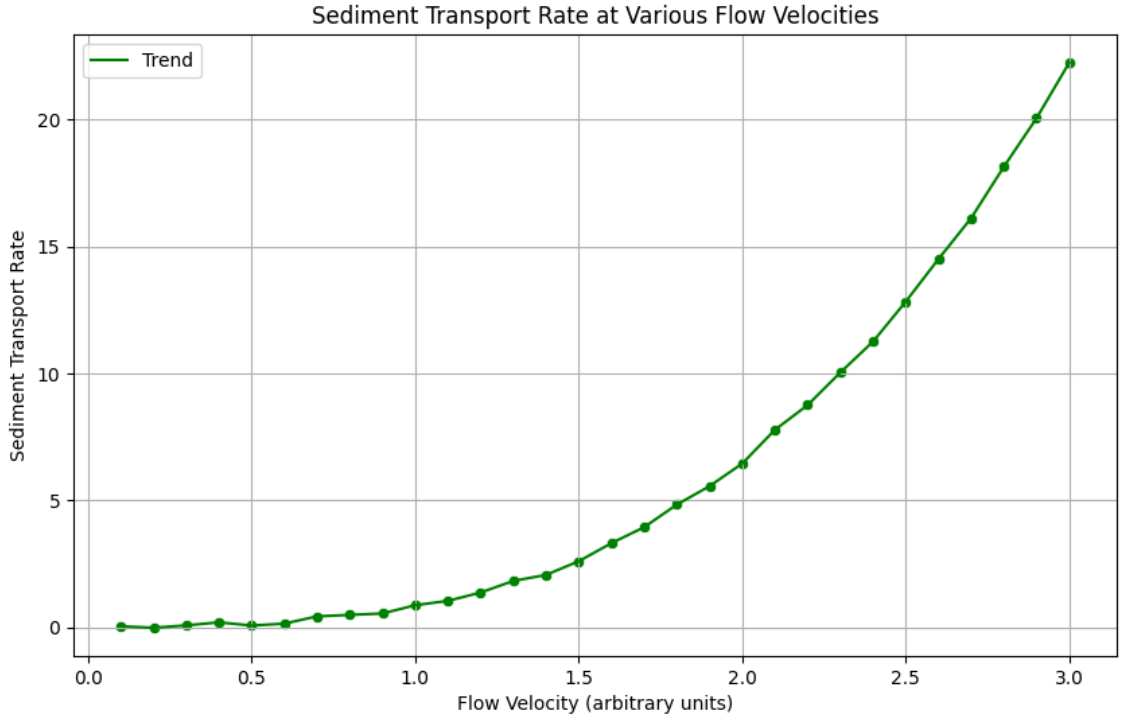

Figure 2 Sediment Transport Rate at Various Flow Velocities

3.3. Ecological recovery

Ecological restoration is an important part of the application of environmental protection concepts in dredging projects, aiming to minimize the long-term impact of dredging construction on the environment by restoring the ecological balance of the waters. After the completion of the dredging project, the ecosystem of the waters is usually damaged to varying degrees, such as the reduction of aquatic plants and the destruction of the habitat of water organisms. To cope with these problems, ecological restoration measures need to prioritize the re-establishment or improvement of aquatic organisms' habitats. Ecosystem restoration can be accelerated by planting native aquatic plants to improve the self-purification capacity of water bodies.

Water quality management is an important part of ecological restoration. Dredging works may lead to an increase in suspended solids and pollutants in the water body, affecting the quality of the water body. Therefore, it is very important to carry out water quality regulation and purification after the construction is completed. The concentration of harmful substances in the water can be gradually reduced and the cleanliness and stability of the water quality can be restored by means of putting water purification microorganisms and setting up water quality restoration devices. At the same time, through regular water quality monitoring, the restoration effect can be assessed in a timely manner to ensure that the water quality meets the target standards for ecological restoration.

The construction of facilities such as artificial reefs is an effective method of restoring biodiversity in waters. Dredging projects may destroy the habitats of some aquatic organisms, leading to a decrease in biodiversity. In the restoration process, new habitats for fish and other aquatic organisms can be provided by installing artificial reefs, fish nests and aquatic planting areas. These facilities not

only help restore biodiversity, but also enhance the stability of the ecosystem and form a sustainable ecological environment. Ecological restoration requires long-term management and continuous monitoring to ensure the effectiveness of restoration measures. Ecosystem restoration usually takes several years or even decades, so it is necessary to monitor the water quality, biological communities and habitats in the restoration area on a regular basis to observe the progress of ecological restoration. At the same time, by dynamically adjusting the restoration strategy and continuously optimizing the restoration measures based on the monitoring results, it is possible to effectively respond to the challenges posed by environmental changes and ensure the sustainability and effectiveness of ecological restoration.

4. Innovation and Application of Environmentally Friendly Dredging Technology

The innovation and application of environmentally friendly dredging technology is the key to improving the environmental friendliness of dredging projects. On the basis of traditional dredging technologies, green dredging equipment and low-disturbance technologies are emerging. The use of environmentally friendly winches, bubble barriers and low-energy mixing technologies can effectively reduce the suspension of sediment and pollutants during the construction process, reduce the turbidity of the water body, and minimize the damage to aquatic habitats. The application of these innovative equipment not only improves dredging efficiency, but also provides strong technical support for environmental protection.

The introduction of real-time monitoring and intelligent management systems is an important development direction for environmentally friendly dredging technology. During the dredging construction process, factors such as water quality, sediment content and pollutant diffusion range need to be strictly monitored. By adopting IoT technology and a data analysis platform, environmental data from the construction site can be collected in real time and construction parameters can be dynamically adjusted according to the monitoring results, thus minimizing the risk of pollution. This intelligent management effectively enhances the environmental friendliness of the dredging project, and also improves the accuracy and responsiveness of the construction. Green treatment and recycling technology of dredged material is an important part of environmental protection dredging. While traditional dredging often involves the simple disposal of dredged material, current technological advances allow dredged waste to be converted into resources such as construction materials and soil conditioners through separation, purification and sorting. This recycling method not only reduces waste stockpiling and secondary pollution, but also brings certain economic benefits to the project, realizing a win-win situation for both the environment and economic benefits.

The promotion and application of environmentally friendly dredging technologies cannot be separated from policy support and the development of technical standards. Governments should introduce relevant regulations and provide policy incentives to encourage the research and development and application of environmental dredging technology. Formulate industry technical standards to provide scientific guidance for environmental dredging projects, standardize the construction process and environmental requirements. Through the joint promotion of policy guidance and technological innovation, environmental dredging technology will be more widely used, contributing to the protection of the aquatic environment and ecological sustainable development.

5. Conclusion

The application of environmental protection concepts in port channel dredging projects not only promotes the green transformation of engineering methods, but also promotes the multifaceted development of pollution control, waste resource utilization and ecological restoration. By optimizing the construction technology and implementing effective water quality management and ecological restoration measures, the dredging project can minimize the impact on the ecology of the waters while ensuring the smooth flow of shipping. These environmental protection measures have shown good results in practical application, providing strong support for the construction of sustainable dredging

projects.

With the continuous innovation of environmentally friendly dredging technology and enhanced policy support, green dredging is expected to be popularized and applied in more ports and waters. By improving technical standards and strengthening management, environmental protection dredging projects will more effectively realize the dual goals of ecological protection and resource recycling, thus laying a solid foundation for the economic development of ports and the long-term protection of the watershed environment, and promoting a good situation of harmonious coexistence between the port economy and the ecological environment.

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