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The Negative Impact of the Three Gorges Dam on Its Area and the Middle and Lower Reaches of the Yangtze River after Its Construction

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Abstract: The Three Gorges Dam (TGD) is one of the largest construction projects all over the world. The construction of TGD causes significant and far-reaching consequences on the Yangtze River basin (YTR basin). It has brought numerous benefits, particularly with regard to the flood control, the development of hydroelectric power, the shipping industry, and tourism. Yet, it has also resulted in environmental destruction and geological catastrophes. This research investigates the detrimental effects of the TGD on the ecological environment as well as geological disasters through a review of relevant literatures. In general, the positive aspects of the TGD far outweigh its drawbacks, particularly as a consequence of the establishment of monitoring stations and the restoration of the ecologically degraded areas.

Keywords: Three Gorges Dam, ecological environment, geological disasters, Middle and Lower Yangtze River

1. Introduction

The Three Gorges Project is located in Sanduoping Town, Yichang, Hubei province. It is the largest water conservation hub project in history [1]. In addition to the power generation, the dam is also beneficial to the floods control, shipping, and aquaculture. However, the construction and operation of the TGD also lead to a series of negative impacts on the YTR basin and its riparian. For example, the destruction of riparian soil led to a landslide tsunami at Qianjiangping region. The change of environmental at reservoir region resulted in the decline of the population of Chinese sturgeon. Despite studying the enormous benefits, the detrimental effects of the TGD should also be studied. A significant number of studies have been conducted with the majority of attention on the ecological environment and geological disasters, but there's a lack of study to summarize their results. Therefore the goal of this study is to provide an overview of the detrimental effects of the TGD on the natural environment and the geology of the surrounding area during the construction and operation period, as well as to describe the efforts that have been taken to reduce the severity of those effects.

2. Negative Impacts on the Ecological Environment

Ecological environment is the sum of ecological elements and ecological relationships [2]. The development and operation of large-scale projects usually harm local ecology since they may change local environment significantly.

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The TGD changed water ecology in the YTR basin. At upstream the reservoir's hydrological conditions have changed and sediment deposition changes bait organisms [3]. Some fish decreased or disappeared as they are not able to adapt to the changes in habitats and food sources, decreasing population size, altering food chains and food webs, and changing the dominant population.

The dam's impounding and interception impacts have modified sand content, water temperature, water level, and water flow rate to the middle and lower reaches. The dams congests a lot of sediment, reducing sediment density, increasing transparency in the middle and lower reaches, and encouraging algae growth and fish populations. The Three Gorges reservoir level fluctuates between 145m and 175m year-round, affecting fish eggs spawning and their survival. Fry are retained in the upper reaches and reduced in the lower reaches due to the shifting of river channel and riverbed morphology [3]. The TGD also harms Chinese sturgeon and albino dolphins. Chinese sturgeon populations have declined largely due to changes in spawning ground flow during the breeding season induced by the TGD water storage and other anthropogenic influences [4]. Noise from shipping and urban developments along the Yangtze River has also harmed its gonads. The construction of the TGD, urbanization, the development of the fishing industry and shipping have damaged albino dolphin habitats and increased the chance of motorised vessel propellers killing them [3].

The TGD raised the water level in the upstream of the Yangtze River, flooding significant sections of land along the river and severely destroying the original habitat. The migration project compounded this situation. The TGD also encouraged coastal city expansion, which increased human-caused environmental issues. To a certain extent, it has also altered the seasonal variation law of climate in the Three Gorges reservoir.

First, after the reservoir fills and the water level rises, different elevation zones experience varied depths and durations of flooding for terrestrial plants [5]. Due to less flooding stress, higher elevation zones had a higher survival rate, more species, and richer plant diversity than lower elevation zones, where many plants died and only flood-tolerant plants survived. Nonetheless, human activities have definitely altered species diversity in the reservoir area, with higher species diversity in tributary areas where human activities are less intense and worse species diversity in riverine urban areas [6].

Second, the dam have affected reservoir wildlife to varied degrees. Rare bird species with high-elevation habitats are less affected. The reservoir impoundment has enhanced water area and number of migratory birds in winter, supplying amphibians with food and habitat [3]. Hence, humans have had a stronger impact.

Third, the TGD altered local climate and water quality. Its significant increase began in the 90s, and the increase was more obvious after 1997, with some annual average temperatures exceeding 15.7°C, and the annual average temperature increasing from 14.7°C to 15.3°C, an increase of 0.6°C, a significant change. After the water storage in 2003, the average annual temperature was still 15.3 °C, which was no obvious change from the annual average temperature before the water storage, indicating that the construction of the reservoir did not change the trend of large-scale climate change. The annual average temperature increase rate in the Three Gorges Reservoir area is positively correlated with the elevation, that is, the higher the altitude, the faster the warming, but at the same altitude, the higher the forest cover, the slower the annual average temperature rise [7].The overall water quality index of dry and tributary streams in the Three Gorges reservoir area is rising, however the water quality during abundant water periods is poorer than during dry and flat water periods [8].

Fourth, induce drought. El Niño affects Asian climate change. The subtropical monsoon region of the YTR basin, with hot and humid summers, cold and dry winters, four distinct seasons, and simultaneous rain and heat. As a result, the YTR basin is prone to flooding in summer, such as the 1998 summer flood, which was an extremely serious basin disaster. Several studies have linked these extreme weather events to global climate change-induced anomalous precipitation [9]. However,the TGD is an essential factor.

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The construction and operation of the Three Gorges Project has changed the seasonal variation pattern of dry and wet periods in the downstream of Three Gorges area, i.e., drought is more severe from mid-summer to mid-winter and wetter in late winter and spring; hydrological drought has obvious sudden change characteristics, and sudden change years have a greater correlation with the water storage stage in the reservoir [10]. After the construction of the Three Gorges Project, the middle and lower Yangtze River had severe and protracted droughts in 2004, 2006, 2007, and 2011, which hurt the local economy, society, and ecosystem [10-12]. The water storage and operation of the Three Gorges Project have changed the seasonal distribution of drought conditions in the lower reaches. The severity and risk of hydrological droughts increase in mid-summer, autumn and early to mid-winter, while decreasing in late winter and spring [13].

3. Geological Hazards

Geological hazards refer to geological effects or geological phenomena formed under the action of natural or man-made factors that cause losses to human life and property and damage to the environment. The distribution and change of geological disasters in time and space are not only subject to the natural environment, but also related to human activities, and are often the result of the interaction between human beings and nature [14]. The Yangtze River's Three Gorges reservoir is one of China's most geologically dangerous places. Large-scale geological hazards cause economic losses, human casualties, and landslide surge and weir cascade hazards. Because of global climate change, human activity, urbanization, and reservoir storage of the TGD, Three Gorges geological hazards have increased [15].

3.1. Landslides

The biggest geological hazard in the Three Gorges reservoir region is landslides. Included among the factors that influence landslide stability are stratigraphic lithology, proximity to faults, reservoir water level variations, vegetation cover, and human activities, among others. Among these, stratigraphic lithology, which primarily impacts the physical and mechanical qualities of bedrock, is a key internal cause of landslide hazards. Meanwhile,the closer one is to a fault, the greater the likelihood of a landslip occurring.

The fluctuating water level in reservoirs is another significant aspect influencing landslide stability. When the reservoir water level drops rapidly, the soil particles within the landslide body impede its internal groundwater infiltration, a big hydraulic gradient is frequently generated inside and outside the landslide body, and there is a large super-pore water pressure within the landslide body. When the groundwater within a landslide drains outward, the surface of the soil particles will be subjected to a greater infiltration force, hence rendering the landslide unstable. As the reservoir water level rises rapidly or remains stable at lower water levels, landslide stability is increased. On the other hand, the stability of landslides is reduced when the reservoir level declines rapidly or remains steady at higher water levels [16].

The impact of human actions cannot be overlooked either. Owing to the need for economic development, the degree to which humans have altered the natural geological environment has become increasingly severe. The development of houses, roads, and trash piles on slopes increases the slope load and can easily trigger landslide tragedies. The unreasonable discharge of waste water is easy to infiltrate into soft mud stone, which causes the slide body and slide zone, which are originally in unsaturated water, to be in a state of full water with reduced mechanical strength, resulting in a lower safety factor of slope instability and a resurgence of landslide deformation. At the same time, certain regions of the YTR basin are rich in mineral resources, and local residents engage in irresponsible mining activities to meet the energy demand, resulting in the formation of a number of

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dangerous rock masses, which reduces the soil's resistance to slipping and becomes a major cause of disasters [17]. In 2003, the Qianjiangping landslip occurred. The Qianjiangping landslide was the first extremely big rocky landslide to occur in the reservoir area following the impoundment of the Three Gorges reservoir. This landslip was caused by both reservoir storage and rainfall. The reservoir water soaked the rock bridge at the leading edge of the landslide, thereby reducing the slip resistance of the slope; the rainfall preceding the landslide increased the slip force of the slide-promoting section of the slope; and the rock bridge was eventually sheared off and the slope became unstable [18]. After instability, the rock began to slide. The rock slips into the Yangtze River as a result of destabilisation, generating surges and weirs.

3.2. Other Geological Hazards

First, collapsed shore. During water storage in the Three Gorges reservoir region, wind and wave erosion of the embankment becomes increasingly severe. Continuous wave erosion destabilises and even causes shore failures. After the completion of the Three Gorges project, the reservoir level fluctuates between 145m and 175m by up to 30m on a periodic basis. During the storage period, wind and wave heights may surpass 1m, indicating that wind and wave influence on the stability of the reservoir bank cannot be ignored. When waves propagate towards a slope, they transfer their energy to the slope, resulting in slope erosion [19]. Simultaneously, the periodic rise and fall of the reservoir bank water level causes the slope of the reservoir bank to be subject to the infiltration and erosion of water for an extended period of time, and the intact slope geotechnical body continuously generates cracks that become deeper and wider, and a portion of the rock body is gradually weathered, softened, and disintegrated under the action of dry and wet conditions. Simultaneously, during the reservoir water reduction process, the unloading impact will cause the rock body of the slope to create rebound effect, thereby generating the unloading fissure zone and further widening the fissure in the slope of the reservoir bank. Geological hazards, such as landslides, may result if part of the fractures penetrate the surface, which is already structurally fragile.

Second, reservoir-induced earthquakes. These changes have a significant effect on seismic activity and geological hazards.The area where the TGD is located is characterized by a typical weak seismic environment, with no active faults traversing the dam site area and reasonably stable tectonics. Seismic context before reservoir storage in the Three Gorges region, there were 179 earthquakes in the Three Gorges reservoir area.Much more earthquakes occurred after impoundment compared to before it, and there was a link between seismic activity and water level variations. Before 2010, the majority of reservoir-induced earthquakes were of the quick reaction type, meaning that the massive water load promoted the development of earthquakes instantly. However, this instantaneous effect no longer predominates after 2010. Long-term seepage has a greater effect in triggering earthquakes. The influence of time lag is clear [20].

Third, debris flow. Heavy rainfall is the primary cause of mudslides in this region. Severe and extremely heavy rainfall frequently raises the groundwater level, leading in anomalous pore water pressure or dynamic water pressure and pushing landslip revival. When the debris flow reaches the location of the landslide, it continuously erodes the slope bank and causes damage to the landslide. The loose landslide body flows downward with the debris flow, providing the debris flow with a new source of material. Effects on the safety of both residents and structures, etc. [21].

4. Measures to Mitigate the Impact of Dams

Before beginning construction on water conservancy and hydropower projects, the environmental impact assessment system is put into action. This system involves making a detailed prediction and evaluation of a number of impacts that the proposed project will have on the environment of the

surrounding area. These predictions and evaluations are done before main construction begins. Performing research to determine whether or not the proposed location is situated in a crust that is stable, as well as whether or not there are fracture zones in the surrounding area. Throughout the process of building, the construction itself is regulated, while other types of monitoring, such as landslide monitoring and management, seismic monitoring, and so on, are carried out in order to lessen the likelihood that a danger will arise. After the project is finished, afforestation is carried out to improve vegetation coverage and enhance slope stability. At the same time, measures to protect the soil and water are strengthened in order to restore ecology to the greatest extent possible, and monitoring stations are constructed in order to provide long-term geological hazard monitoring and early warning. For instance, the Three Gorges reservoir area has constructed a group measurement and group prevention monitoring and early warning system. This system makes use of early warning models, RS, GIS, GPS, and other technologies in order to form a monitoring network between each monitoring station. This significantly lessens the impact that geological hazards have on the people who live in the reservoir area.

5. Conclusion

The TGD is a world-renowned engineering feat that has contributed significantly to the industries of power production, flood control, shipping, and aquaculture. However, its harmful impact on the biological environment and the geological hazards it has produced cannot be overlooked, particularly the irreversible repercussions, such as the decline of rare animal populations such as the Chinese sturgeon and albino dolphins. In general, the building and operation of the TGD have produced certain negative effects. This study is based on a thesis review methodology and lacks experimental data and field surveys. Due to a lack of personal expertise, the conversation was incomplete. Future research will focus more on field surveys and the collection of field data in order to make the study more exhaustive and compelling. In the future, the limitations of this study and how they might be remedied, such as the lack of a survey or the inadequacy of the study's scope, will be investigated further.

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