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The Impact of Chinese Tunnel Engineering on Groundwater in the Past 40 Years: A Review

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Abstract. Tunnels play a crucial role in facilitating human activities, yet the potential impact of their construction on groundwater is often overlooked. With this in mind, this study delves into an investigation of 18 tunnels in North and South China. A thorough literature review and analysis uncover that the variance in hydrogeological conditions between the two regions during tunnel construction is the primary factor influencing differing levels of groundwater pollution. In South China, the groundwater condition is closely intertwined with surface water and is susceptible to the influence of tunnel construction. Conversely, the impact in the northern region is relatively limited due to slower groundwater flow and stable water quality. The investigation also highlights that the release of pollutants during tunnel excavation is the primary cause of groundwater pollution, leading to disruptions in both groundwater flow and quality. To mitigate these issues, it is essential to implement environmental protection measures and construction practices aimed at reducing the impact on groundwater resources, particularly in the southern region. This approach is vital for addressing the potential risks and minimizing the negative consequences associated with tunnel construction on groundwater

Keywords: Groundwater pollution; Tunnel engineering; North and South of China; Water environment protection.

1. Introduction

Tunnels are underground or underwater constructions used for the passage of motor vehicles, which have greatly improved transportation efficiency, alleviated traffic congestion, and promoted economic and tourism development in various regions. However, tunnel construction and operation can also lead to groundwater pollution problems due to the discharge and leakage of pollutants such as sewage, explosive materials, oil, and chemical grouting.

In areas with karst landforms, such as southwest China, the construction of highway tunnels through karst caves can cause issues such as groundwater level decline, surface water depletion, and ground collapse, which seriously affect the normal life and production of local residents. Similarly, in arid regions like northwest China, tunnel excavation can disrupt the equilibrium of the seepage field, affecting the groundwater circulation and the survival of plants.

The impact of tunnels on groundwater varies depending on geological conditions, location, and pollution sources. Different degrees of groundwater pollution and geological disasters can occur during the tunnel construction process. Pollutants from domestic sewage, grouting, and engineering blasting directly affect groundwater quality.

While some research has focused on the environmental impact of tunnel construction, limited studies have specifically addressed the impact on groundwater. Some studies have assessed the ecological effects of building bridges/tunnels on lake ecosystems, while others have investigated the hydrogeology and hydrochemistry of urban groundwater affected by underground tunnels.

Various studies have highlighted the impact of tunnel construction on groundwater quality. For example, the Xuefengshan tunnel was found to discharge dust, tunnel wall materials, and pollutants such as Fe^{3+}, Zn^{2+}, NO_3^{2-}, K^+, Na^+, Ca^{2+}, and SO_4^{2-}, resulting in serious water pollution. In Italy, groundwater discharge from tunnels caused damage to tunnel covers, water resources, agricultural lands, and infrastructure, leading to changes in groundwater quality and socioeconomic losses.

However, domestic research in China has mainly focused on analyzing the groundwater pollution caused by tunnels in specific regions, with limited systematic analysis and summarization of groundwater pollution caused by tunnels nationwide. Therefore, this paper aims to provide a comprehensive review of the impact of tunnel construction on groundwater pollution. It will analyze the causes of groundwater pollution using examples from the southwest and southeast regions of China, and summarize the general characteristics of groundwater pollution caused by tunnels in different areas. Finally, engineering guidelines and policy suggestions will be proposed to address these issues.

2. Data Collection

In the past 20 years, the number of tunnel engineering has developed rapidly and become an essential link in China's economic construction. By the end of 2020, mainland China had built 21316 road tunnels. Furthermore, the imbalance between the construction numbers of tunnels in the north and south area can be found in Figure 1, and this imbalance's possible environmental impact needs to be explored. Therefore, in this study, we selected 18 typical tunnel projects from north to south to analyze their impacts on the local groundwater environment (Figure 3). They included southern China (10): Swallow Cave Tunnel (Honghe Hani and Yi Autonomous Prefecture, Yunnan Province), Moon Mountain Tunnel (Huanggang, Hubei Province), Geleshan Tunnel (Yuhuai Railway, Chongqing City), Xuefengshan Tunnel (Huaihua, Hunan Province), Ba Gu Amo Tunnel (South of Sichuan Province) Zi Zhi Tunnel (Hangzhou), Xu Lingguan Tunnel (Luzhou, Sichuan Province), Guangzhou Metro Tunnel (Luogang District, Guangzhou City), Chaoyang Tunnel (Libo County, Guizhou Province). And northern China (8): Taiyuan Metro Line 2(Taiyuan, Shanxi province), Liupan Shan Tunnel (Ningxia), Mila Mountain Tunnel (Lhasa, Tibet), Sichuan-Tibet railway (Qinghai-Tibet Plateau), Bailong River Tunnel (Tanchang County, Gansu Province), Shengli Tunnel (Ten-zan, Xinjiang), Qin Mountains long tunnel (Xi'an, Shaanxi), Quantai Tunnel (Liaoyuan, Jilin province).

The distribution of tunnel projects in China is marked, and the underground water quality distribution patterns in South and North China are shown (Figure 3). Moreover, Zheng (2015) reported that the groundwater resources are unevenly distributed between China's northern and southern areas. The southern part of the country accounts for 36.45% of the total land area, and the water resources reserve amounts to more than 80% of the national total, while the northern part accounts for 63.61% of the national total land area, water reserves are less than 20% of China's total (Zheng 2015). The distribution of water quality in the North and South is shown in Figure 2. During 2013-2017, 20 indicators in groundwater monitoring wells were detected to varying degrees. Figure 4 shows the over-standard rate of total hardness, total dissolved solids, sulfate, iron, manganese, and Triazo. It is a high-energy compound consisting of three nitrogen atoms that are dipolar repulsive to each other. Nitrogen decomposes easily at high temperatures or pressure, producing by-products such as nitrogen and nitrogen oxide, reaching 10% and some wells even reaching more than 20%. Mercury, arsenic, cadmium, chromium (hexavalent), and lead also exceeded the standard to varying degrees, especially in 2016. Therefore, the distribution of groundwater resources in the North and South is different, the water quality is different, and the tunnel project's environmental impact may also differ.

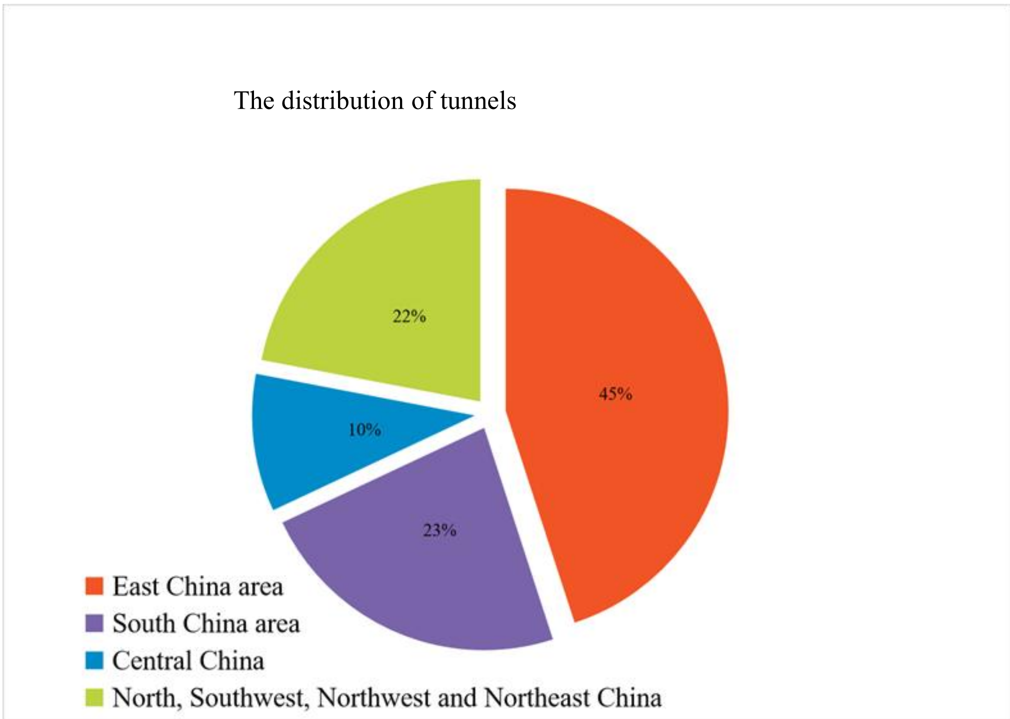

Figure 1. The pie chart of the distribution of tunnels across China

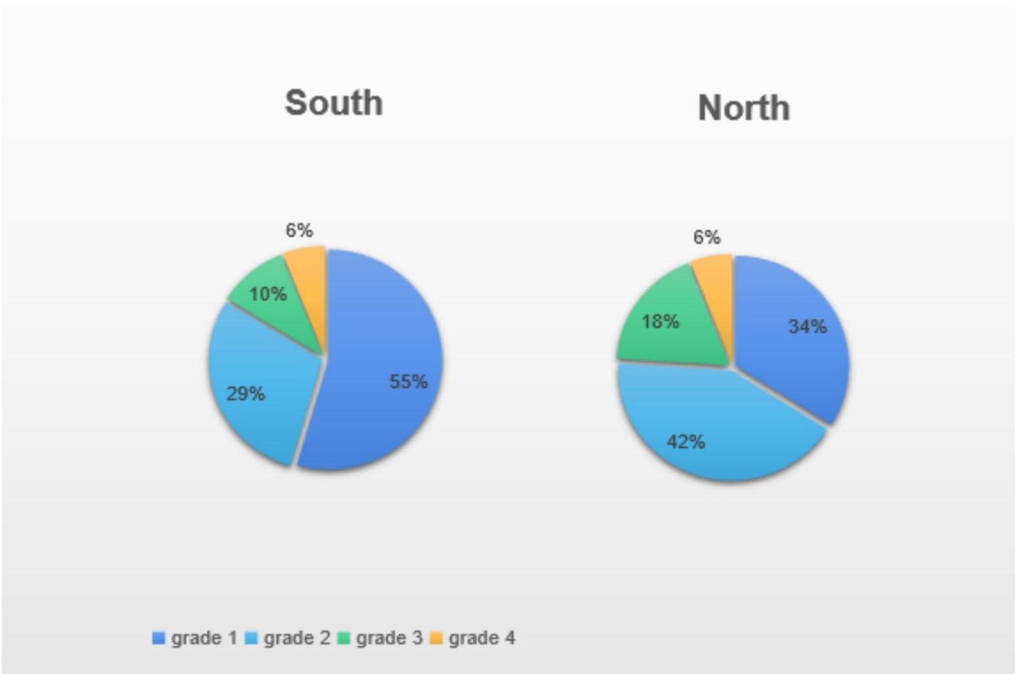

Figure 2. The pie chart of groundwater quality grades in North and South China

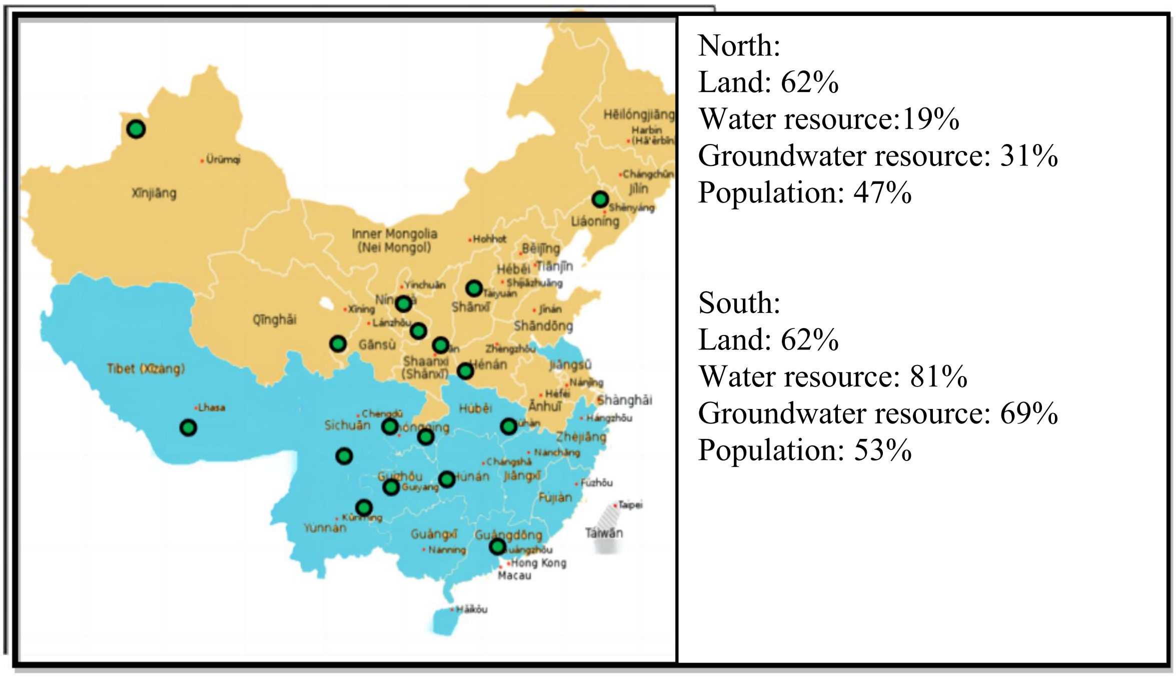

Figure 3. The distribution map of groundwater resources in China and 18 examples of tunnels' location

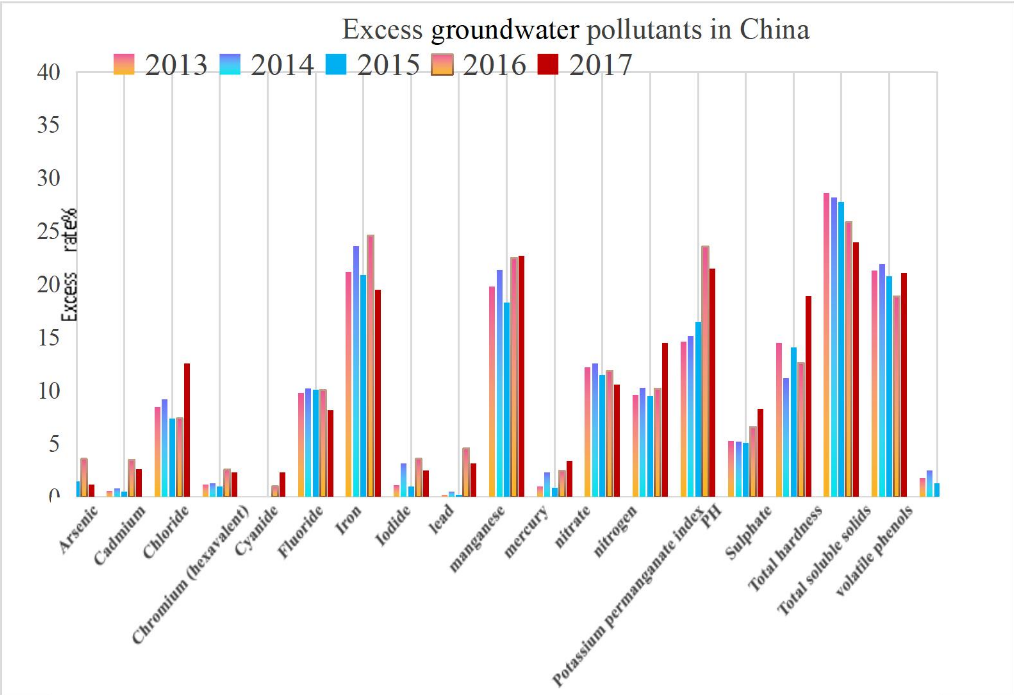

Figure 4. The groundwater pollution exceeds the standard value (Shengpin et al. 2019).

3. Tunnel engineering project in South China

3.1 Introduction to Tunnels

The Geleshan Tunnel in the Jialing River Basin, Chongqing, passes through Zhongliangshan, an area known for its high groundwater concentration. The construction of this tunnel presents significant challenges. It may disrupt the dynamic balance of groundwater, resulting in groundwater loss and the formation of underground funnels. These issues can lead to surface water supply depletion, water quality deterioration, and even surface subsidence. The destruction of the dynamic balance of groundwater and the formation of underground funnels can also have severe consequences for the natural ecology in the region.

Water transportation tunnel to Yanzi Tunnel Scenic Area (Yunnan): In Banshan-Datianshan hydrogeological unit. The tunnel discharges mechanical oil, waste residue, and other construction pollution into Yanzi Tunnel Scenic Area's surface water, polluting it (Ting 2015).

The dust and drainage generated by drilling, blasting, and vehicles at the face of the Xuefengshan Tunnel contain suspended solids and turbidity. Fe3+, Zn2+, Fe2+, and SO42- are dissolved in water and damaged surface water. Besides, the closed drainage system minimized groundwater pollution from vehicle exhaust gas. Tunnel crossing will deplete the rock stratum's groundwater reserves, destroying groundwater equilibrium (Yang 2007).

Table 1 presents the major pollutants found in the Geleshan Tunnel, Xuefengshan Tunnel, Yanzidong Tunnel, Shancheng Tunnel, Fuquanhoushuihe Tunnel, and Jinxinan Tunnel. The primary pollutants include suspended solids (SS), chemical oxygen demand with potassium dichromate (CODcr), petroleum compounds, nitrate groups, and nitrides. During tunnel construction, the flushing wastewater, containing petroleum residues, organic substances, and by-products of mechanical equipment, contribute to elevated levels of COD, biochemical oxygen demand (BOD), and SS in the discharged tunnel water. Additionally, pollutants, such as nitrides and sulfides, generated from tunnel drilling and blasting activities, can seep into the surrounding environment. The presence of explosives and oils during construction can pose a risk of surface and groundwater contamination. These anthropogenic factors contribute significantly to the most severe groundwater pollution during the construction phase. Nevertheless, after approximately two years, the solubility of the contaminants is expected to decrease.

Table 1. Pollutants and cause of Southern tunnel

Tunnel name	Main pollutants and concentrations	Possible source
Geleshan tunnel (Chongqing)	SS, CODcr, Petroleum, and nitrate base	Construction machinery oil and diesel leaked into the tunnel, and the tunnel drainage device was near farmland, so its waste residue leaked into the agricultural irrigation ditch with rainwater and polluted the crops.
Xuefengshan tunnel (Hunan)	High mineralization of water quality most of theFe^{2+}(0.031), Zn^{2+}, NO_3^{2-}(64.22), K^+(25.73), Na^+, Ca^{2+}, SO_4^{2-}	The dust from tunnel face drilling and blasting, engineering vehicle transportation, slag truck tail gas, and blasting substances and rock components dissolve in water, releasing a lot of heavy metal ions and polluting the water.
Yanzidong tunnel (Yunan)	After the explosion of toxic chemical grouting material explosives, many nitrogen compounds, sulfides, and other mechanical oil pollution, polluting organic substances, oily and flushing wastewater, domestic sewage, residual explosives, oil, and other pollution sources in waste residue under rainfall leaching.	1. Use chemical grouting to build lining and wall protection or leakage stoppage. 2. Tunnel drilling/blasting 3. Construction gear 4. Builders 5. Construction waste dump

Shancheng tunnel (Chongqin)	Nitrogenous organics, nitrogen fertilizers, sulfates, nitrate nitrogen, phosphates	Sewage from neighbors pollutes shallow groundwater. Domestic trash, agricultural fertilizers, untreated industrial and wastewater entering funnels, surface runoff, or rain washing pollutants into underground river systems.
Fuquanhhoushu ihe tunnel (Guizhou)	Total phosphorus, fluorine, and ammonia nitrogen exceed the standard	The pollution source is the phosphorus chemical storage yard on the east side of the river.
Jinxinan tunnel (Shanxi)	CO sulfate combined with gypsum in the tunnel accelerates the destruction and damage to the lining.	The change in groundwater quality and environmental water corrosion is lagging and hidden.
The main reasons	1. The source of groundwater is uncertain 2. Restrictions on tunnel construction technology and materials 3. Insufficient environmental monitoring	The geological conditions where the tunnel is located and the hydrogeological environment of the surrounding environment are very complex, and there may be multiple sources of groundwater. Some groundwater may contain high concentrations of harmful substances, leading to changes in water quality and delayed environmental corrosion.

Tunnel construction in South China is influenced by various geological factors, including fracture zones in the rock mass, boundaries between leakage and non-leakage layers, surface water systems, and karst areas. Joint cracks in these areas can impact groundwater and result in water inrush, minor collapses, and landslides during tunnel excavation. In regions with long-term rainfall, such as Karst Plateaus, cracks, pores, and pipelines accumulate significant amounts of groundwater. The disturbance of surrounding rock during tunnel construction can disrupt the balance of groundwater, particularly in areas with abundant rainfall or groundwater, such as karst regions, fault fracture zones, and rock contact zones. This may cause groundwater to flow into the tunnel, leading to the formation of confined water and potentially causing water inrush incidents.

The impact of water inflow during construction varies depending on its quantity. If the water inflow is excessive, construction may need to be temporarily halted, and in severe cases, it could endanger the safety of workers. Additionally, groundwater inflow into the tunnel may have a hydraulic connection with water sources in reserves, and large-scale seepage accidents can severely disrupt the original groundwater system's dynamic equilibrium. Improper technical measures during tunnel construction may result in excessive groundwater loss, leading to a decline in groundwater levels within the project area, a sharp reduction in spring water volume, and even complete drying up, significantly impacting the local water environment.

The geological conditions in southern regions are complex, making it challenging to assess the groundwater environment and design waterproofing and drainage structures for tunnels. Some strata in the south consist of granite, with varying permeability due to different degrees of weathering. Significant variations in tunnel burial depth further complicate the evaluation of the groundwater environment and design of appropriate waterproofing and drainage systems. Mining methods used in construction may cause damage to the surrounding rock of the tunnel, increase its permeability, and have adverse effects on the groundwater environment.

The southern region experiences active groundwater flow, prolonged rainy seasons with abundant rainfall, and ample surface water resources. The groundwater mainly comprises pore water in loose rocks and fissure water in block bedrock. Tunnel excavation can create a well effect, leading to a substantial collection of groundwater within the tunnel, negatively impacting the groundwater environment. (Wang 2022, Pan 2018)

4. Tunnel engineering project in North China

4.1 Introduction to Tunnels

Taiyuan Metro Line 2 Tunnel (Shanxi): Taiyuan distributes karst, fissure, and pore water. Taiyuan City's geological disaster is subsidence. Construction precipitation lowers groundwater levels during foundation pit excavation.

Gansu's Liupanshan extra-long tunnel is the Tianshui-Pingliang Railway's longest, which is a complex geographical environment. During tunnel construction, groundwater seepage, drip, stream, and large-scale water inrush will occur in the tunnel body, triggering a water inrush disaster. Rock blasting and vehicle emissions increase NO32-, NH4+, and SO42- concentrations. Water dissolves alkaline tunnel grouting, elevating pH and Ca2+. Three-sided blasting and reverse slope drainage construction dust is grouted and blocked, increasing SO42- concentration hardness.

Sichuan-Tibet Railway: The main project is on the Qinghai-Tibet Plateau, which has high ground stress (rock burst large deformation), deep and big active faults, high frequency and high-intensity earthquakes, high ground heat, and hazardous fumes. The natural conditions are very poor, and the line is located in a sparsely populated plateau with thin air, extremely inconvenient transportation, and a lack of infrastructure; it is upstream of many large rivers, with low vegetation coverage and a sensitive ecological environment; and the tunnel has a lot of spoil. Choosing, retaining, protecting, and transferring a lot of spoil is tough.

The north tunnel's unusual geology has highlighted tunnel mining's environmental damage to underground water (Table 2). High and cold areas have more tunnel lining, frost heave, ice hanging, and other reactions (Jian 2014, Xinxin, Bo et al. 2018). It causes diseases such as freezing drainage systems, ice accumulation of tunnel leaking water, cracking of lining structure, pavement icing, pavement swelling, and limit invasion, which undermines vehicle safety. Freezing damages the lining structure. Saturation weakness and water loss deformation of saturated soft loess pose environmental risks. Tunnel engineering practice mostly has surrounding environment damage caused by unreasonable groundwater control measures; water gushing, mud gushing, and collapse caused by poor groundwater control effect, unreasonable excavation and support, and risks like shield posture control difficulty caused by uneven soft and hard strata. Risk performance matches soil properties (Gang, Zuo et al.). The confluence of surface water and groundwater in the cold northeast causes water seepage and ice formation in the road and tunnel, reducing driving safety, shortening the project's lifespan, and increasing operating and maintenance expenses. Lining cracking, crisping, peeling, water leakage, and track bed muck are the leading northern tunnel problems.

Table 2. Pollutants and cause of northern tunnel

Tunnel name	Main pollutants and concentrations	Possible source
Muzhailin tunnel (Gansu province)	After two years, the pollution halo center reaches 100 mg/L: 2. A lot of ionic chemicals, including Ca2+, Mg2+, Na+, Zn2+, andFe3+, are released into the surface water body with the water and pollute the groundwater. CODcr	1. Tunnel construction machinery and earthwork vehicles pollute groundwater by releasing oil into drainage ditches. 2. Construction water can dissolve, soften and erode tunnel rock. Long-term drainage can accelerate groundwater pollution in the tunnel by driving aquifer water toward the tunnel at high hydraulic gradients.
Tunnel of Taiyuan Metro Line	Mechanical oil pollution, CMC, soda ash, residential sewage and depot, and comprehensive base wastewater.	Mechanical oil pollution that leaks into groundwater will pollute it.

2 (Shanxi)	The subway's aquifer water corrodes reinforced concrete, causing a chemical reaction.	
Liupanshan tunnel (Gansu)	Turbidity，NO32 -, NH4+,SO42-,concentration of total hardness , Ph and Ca2+concentration increase	The tunnel project's grouting, blasting, and vehicle exhaust greatly impacted groundwater quality, improving turbidity, SO42-total hardness, and other water quality indicators.
Sichuan-Tibet Railway		Tunnel development will drain groundwater, affecting people's ecological requirements for production and living water, wetland, and tunnel roof vegetation (Ci et al. 2021)1. The hydrogeological conditions are complex, with many valleys and gullies. 2. The distribution of rainfall has been uneven for many years, and the flow path of groundwater is complex. 3. High sediment content in groundwater and serious pollution of tap water 4.5%. Locomotive and rolling stock, construction equipment, etc.

4.2 Solutions

To prevent groundwater pollution during tunnel construction in both the North and South, several key measures should be implemented:

1.Conduct comprehensive geological exploration and hydrogeological surveys before site selection to fully understand the hydrogeological characteristics and potential pollution sources. This will help avoid selecting sites near sensitive groundwater areas or contamination sources.

2.Utilize low-impact construction techniques such as section construction or shield tunneling to minimize the impact of open-pit excavation on groundwater. Additionally, take measures to control soil erosion and prevent leakage.

3.Implement necessary retaining measures around the excavated foundation pit to prevent surface water from infiltrating into the groundwater system.

4.Monitor tunnel construction to detect and mitigate potential risks of large-scale deformation of surrounding rock and soil materials, which could lead to flood events and regional collapse disasters.

5.Enhance the design and construction of the tunnel drainage system, collect sewage, and adopt appropriate water quality treatment processes to reduce pollutant discharge and protect groundwater quality.

6.Implement rigorous tunnel management, conducting regular checks and clean-ups to prevent leakage and seepage that could negatively impact the groundwater environment. Controlling the water-solid ratio of grout slurry and its diffusion range can effectively reduce groundwater pollution caused by grout slurry.

7.Collect and centrally discharge production and domestic sewage from stations, vehicle depots, and comprehensive bases into the urban sewage pipe network to prevent them from entering the groundwater environment. Implement leakage-proof measures for toilets and septic tanks in stations to ensure the groundwater is not polluted.

In conclusion, reducing the impact of tunnel construction on the groundwater environment requires careful consideration of geological conditions, human activities, and other relevant factors, as well as the implementation of scientific and reasonable management measures to ensure the health and sustainable development of the groundwater environment.

4.3 Discussion

Based on previous research, this paper extensively discusses the pollution and influence of underground water in North and South China caused by tunnels. The study indicates that tunnels contribute to groundwater pollution in both regions, although the hydrogeological conditions and human factors vary, making the pollution levels different. The main focus of this paper is to acknowledge that tunnels do have a certain degree of impact on groundwater pollution. To mitigate this impact, it is necessary to implement scientific and reasonable management measures and construction techniques. Previous literature mostly concentrates on groundwater pollution caused by individual tunnel construction, while this paper not only considers construction factors but also incorporates hydrogeological environmental factors and summarizes the differences in tunnel impacts on groundwater in North and South China. Based on relevant research, the similarities in the causes of the tunnel's impact on groundwater are as follows: 1. Tunnel wall leakage: During tunnel construction, drilling and blasting can damage and loosen the surrounding strata, increasing the permeability and water permeability of the tunnel wall, which allows groundwater pollutants to enter the tunnel through the wall. 2. Groundwater flow: Underground tunnels in North and South China are influenced by the groundwater flow in the surrounding strata, which affects the migration and distribution of pollutants. The velocity and direction of groundwater flow play a crucial role in this process. 3. Types of pollutants: The types of pollutants around the tunnels in both regions are similar, including SS, CODcr, petroleum, nitrate, etc. However, there are also differences between the two regions: 1. Geological conditions: The tunnels in the South and North are situated in different geological environments. In the South, tunnels pass through various geological layers such as rock and sandstone, while in the North, they encounter different layers like loess and sandstone. These varying geological conditions impact groundwater flow and pollutant migration. 2. Differences in water quality: Groundwater quality around the tunnels differs between North and South China. In the South, groundwater is mainly affected by agricultural, industrial, and domestic pollution, resulting in poor water quality. In contrast, groundwater around the tunnels in North China is primarily influenced by agricultural pollution, resulting in relatively good quality. Possible reasons for these differences include: 1. Varied geological environments and locations of tunnels in the North and South regions. Geological disparities contribute to distinct groundwater flow patterns and pollutant migration. 2. Different pollution sources surrounding the tunnels: The economically developed South has a diverse range of tunnels affected by industrial, domestic, and agricultural pollution. The northern tunnels are primarily subjected to agricultural pollution. 3. Variances in groundwater flow rate: Groundwater flow rates differ between the North and South tunnels. In the South, the flow rate is slower, rendering groundwater more vulnerable to pollutants. In the North, the faster flow rate slows down the diffusion of groundwater pollutants. 3. Human activities are the main contributors to tunnel-induced groundwater pollution in both regions. During tunnel construction and operation, pollution from construction technology and mechanical equipment can affect the quality of the surrounding groundwater. Therefore, precautionary and environmental protection measures must be implemented. The disadvantage of this study is that its scope is broad, focusing mainly on the impact of tunnels in the majority of North and South China, thus lacking wide applicability. In the future, more attention should be given to safeguarding groundwater quality during tunnel construction and studying the specific mechanisms of groundwater pollution caused by human factors. Additionally, limited research on groundwater pollution in northern tunnels has been conducted, with greater emphasis placed on the impact of groundwater on the tunnels. As a result, more efforts should be directed towards monitoring and analyzing groundwater in the North, alongside implementing effective measures to control pollution and ensure the safety of the ecological environment, groundwater resources, and tunnel operation. Future research should expand the study's scope, explore the mechanisms of tunnel-induced groundwater pollution, and propose more effective countermeasures to achieve the coordinated development of tunnel construction and environmental protection.

5. Conclusion

This paper investigates and analyzes 18 representative tunnels in both northern and southern China, comparing the hydrogeological environment and pollution sources using charts. Drawing from extensive literature reviews, it examines the impact of tunnels on surrounding groundwater in various regions, and comprehensively assesses the common and differing influences of tunnels in the south and north of China on groundwater. The study also delves into the causes and reasons for pollution. The findings suggest that both the hydrogeological environment and human activities predominantly influence groundwater pollution in both the north and south. Commonalities are observed in tunnel wall leakage, groundwater flow, and types of pollutants. The investigation reveals that discrepancies in geological conditions manifest as variations in water quality and aspects. Different geological environments can impact the pollution status of tunnels on groundwater, for instance, with sandstone being susceptible to pollution, clay being difficult to permeate, and limestone being prone to acidification. Accordingly, in tunnel construction, tailored measures are essential for different hydrogeological environments, while concurrently enhancing control of pollution sources to mitigate tunnel-induced groundwater pollution. Ultimately, in the construction and operation management of tunnel engineering, heightened environmental awareness and focused attention on groundwater protection are imperative. Only through implementing scientific and rational measures can the smooth progress of tunnel engineering be guaranteed while safeguarding groundwater quality.

References

[1] Chiocchini, U. & F. Castaldi (2011) The impact of groundwater on the excavation of tunnels in two different hydrogeological settings in central Italy. Hydrogeology Journal, 19, 651.

[2] Ci, S., Z. Guangyu, W. Luoyun, W. Zhanbo, L.Jingji & X. Mong (2021) Ecological risk and protection countermeasures of groundwater drainage in a sichuan-tibet railway tunnel. Geological Hazards and Environmental Protection, 32, 104-108.

[3] Guozhen, Z., M. Ju & W. Fuping (2015) Study on water environment problems and countermeasures of tunnels in northwest China. Journal of Lanzhou Petrochemical Vocational and Technical College, 15, 68-70.

[4] Hui, L., J. Jun & L. Song (2019) Study on the influence of Yueliangshan tunnel construction on groundwater environment. Resource Environment and Engineering, 33, 92-97.

[5] Lifeng, Z. (2015) Research on water resources status and water resources security in China. Heilongjiang Science And Technology Information, 198.

[6] Naixia, L. 2004. Study on the influence of the Geleshan tunnel construction process on the water environment. Master’s thesis, Southwest Jiaotong University, 62Namin, F. S., H. Ghafari & A. Dianati (2014) New model for environmental impact assessment of tunneling projects. Journal of Environmental Protection,5, 21.

[7] Qi, L. Rui, G. Junfeng & H. Jiacong (2022) Environmental impacts and risks of bridges and tunnels across lakes: An overview. Journal of Environmental Management, 319, 115684.

[8] Shengpin, L., L. Wenpeng, Y. Xiulan & J. Aifang (2019) Distribution and change characteristics of groundwater quality in China. Hydrogeology and Engineering Geology, 46, 1-8.

[9] Shuaishuai, W., M. Jingbo, Z. Binbin, L. Yalong & Z. Honggang (2022) General construction technical scheme of Shengli Tunnel in Ten-zan of Wu-wei Expressway. Modern Tunneling Technology.

[10] Wenbin, W. (2021) Design and research of long-term monitoring system for Fangdoushan Tunnel. Gansu Technology, 37, 110-113.

[11] Xiao-Song, Z. (2018) The relationship between land use and water quality in Pengxihe modaoxi watershed of the Three Gorges Reservoir area, Master’s thesis, Southwest University, 68.

[12] Xiaobin, W. (2022) Treatment Technology and countermeasures for expressway tunnel passing through Karst cave. Property, 28-30.

[13] Yiheng, P. (2018). Construction of weathered granite tunnel using mining method Research on the Impact of Groundwater Environment China University of Geosciences., Doctoral dissertation,

[14] Yuandanduoji, Z. Ping & Cilang (2019) Summary of construction experience of lashan tunnel and connecting line project in Zhujiao, Tibet. Traffic Construction and Management, 92-94.

[15] Yuanfei, W. & L. Guojin (2014) Study on the site and Axis scheme of Balangshan Tunnel. Highway Tunnel, 16-20.

[16] Yuhan, Z., W. jianhua, G. Xingyu, G. Wenyu & C. Wenqian (2022) Hydrochemical Background Levels and Threshold Values of Phreatic Groundwater in the Greater Xi'an Region, China: Spatiotemporal Distribution, Influencing Factors and Implication to Water Quality Management. Exposure and Health, 1-15.

[17] Yunpin, L. 2018. Study on the evolution law of groundwater environment negative effect of tunnel engineering in Chongqing Karst Mountain area. Master's thesis, Chongqing Jiaotong University, 99

[18] Zhan, H., L. Baotan & P. Jianguo. 2011a. Impact Assessment of xuefengshan tunnel construction on groundwater environment, 77.

[19] Zhan, H., L. Baotan, P. Jianguo, D. Guohua, J. Chenghai & Z. Jinhua. 2011b. Impact Assessment of Xuefengshan Tunnel construction on groundwater quality environment. 162-165..

[20] Zhaowei, L. 2004. Mechanism of karst water inrush in Yuanliangshan Tunnel and its countermeasures. Beijing: China University of Geosciences, 156.