Protection Measures on Water Quality in Yellow-River-Crossing Tunnel

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Abstract. The Yellow-River-Crossing Project is a special symbolic water conveyance structure in the middle route of the main canal. Its scenic environment surface sensory and water quality safety are equally important. Under the guarantee of the water quality monitoring station network designed, the water quality of the inlet and outlet of the tunnel reaches environmental quality standards II for the surface water. The deterioration of organic matter seriously endangers the safety of water quality. Floating cleaning has become a part of the daily routine. In view of the shortcomings of traditional long-rod net fishing such as great difficulty, high operational risk factor and low efficiency, and the characteristics of many floating species, large volume and concentration in the catchment area in front of the safety barrier at the entrance of the Yellow-River-Crossing Tunnel Project, an automatic fishing barrier was developed and installed. An environmental-friendly floating operation platform was equipped at the outlet of the tunnel, considering the large difference between the platform and the water and as a window for external exchange and display. The floating mat can beautify the environment and provide an emergency operation platform for handling hydraulic oil leakage and accidents at the inlet and outlet of the tunnel. It provides a practical reference for the salvage mechanization of the Project and the floating materials cleaning of the inverted siphon and aqueduct structures in the Project.

1. Introduction
The safety of water source and total trunk channel of the South-to-North Water Diversion determines the benefit and success of the project. Whether the water quality can be guaranteed during the real-time operation of midline engineering is an important basis for evaluating its success. The main trunk channel of the midline adopts one-way single-line open channel water transmission, and the cross-building and control buildings are dense. The surrounding water quality has complex factors, and water pollution prevention and control faces severe challenges. To clean up the water, to ensure that the water along the way cannot be dirty, is the midline water protection facing two major difficulties. Since the construction of the project, the former State Council South-to-North Water Diversion Office, the South-to-North Water Diversion Division of the Ministry of Water Resources, and the Construction Administration Bureau of the South-to-North Water Diversion Middle Line Project have attached great importance to water quality protection work, and water quality safety has been studied as a major technical requirement. In addition to the study on water quality protection of water source in Danjiangkou reservoir area, Zuo Haifeng et al., Wang Xingwei and Chen Jiajun, Ren Zhongyu et al., the research shows that the inferior groundwater discharged into the channel has no effect on the quality of the drainage system. Wang Hao et al. In order to solve the...
technical problems of engineering scheduling, control and operation management, we put forward the scientific problems that need to be solved. The control system of "numerical simulation-evaluation-diagnosis-traceability prediction-emergency control-pollution disposal" was established; Zhao Rong et al. [10] Predictive study on the water quality of Guanhua in the Beijing section of the emergency project was carried out.

The trunk canal of the central line of the South-to-North Water Diversion has adopted engineering measures such as full interchange, isolation and protection, interception ditch, and anti-seepage membrane, combining daily inspections, daily monitoring of water quality, floating objects, pollution source management, and emergency response work. By strengthening the capacity of trunk water quality monitoring, forecasting and forecasting, improving the prevention and control of water pollution risks, and improving the emergency handling ability of water pollution accidents, a relatively complete and effective water quality protection system has been initially established [11].

As of 2400 hours on December 31, 2018, the South-to-North Water Diversion Middle Line Project transferred water from Taochaqu to the first channel of 16.47 billion m$^3$, and the water from the Yellow-River-Crossing tunnel to the channel reached 12.96 billion m$^3$. Water quality indicators are stable or better than the Surface Water Environmental Quality Standard (GB3838-2002) II standard. [12] At present, the main business of the water quality monitoring station network composed of fixed laboratories, mobile laboratories and automatic monitoring systems on the midline trunk channels is to monitor the 24 basic items such as ammonia nitrogen, permanganate index, dissolved oxygen, etc. specified in GB3838-2002 or including the replenishment of concentrated drinking water surface water sources. Or collect application information of water quality for a total of 109 indicators, including 5 items such as sulfate, nitrate, and specific items such as lindane and Lego.

Forecast channel water quality under sudden and non-sudden pollution conditions based on water quality change laws, water quality prediction theories and methods [13] and a lot of research has been done on the emergency handling capacity of sudden water pollution accidents [14, 15, 16]. However, the attention to the surface appearance, the visual environment, and the large volume of recurrent pollution sources that may lead to deterioration of water quality is not deep enough. At present, the research results of midline water quality mainly focus on automatic monitoring, forecasting and emergency treatment of sudden pollution accidents. In this paper, the water quality guarantee measures and the application of flotation salvage technology for important water conveyance buildings are studied.

2. Yellow-River-Crossing Tunnel Water quality profile

2.1. Yellow-River-Crossing Tunnel Engineering characteristics

Yellow-River-Crossing Tunnel is an important part of the middle line Yellow-River-Crossing Project. As an important water transmission building and key project across the Yellow River, the Yellow-River-Crossing Project is a landmark and control project of the entire South-to-North Water Diversion Line. It is located in Xingyang City on the south bank of the Yellow River and Wenxian County on the north bank of the Yellow River. The total length is 19.305 km. Including the Yellow-River-Crossing Tunnel (including the 3450m crossing river tunnel section and the 800m Mangshan tunnel section) and its entrance and exit buildings, water withdrawal buildings, the South Bank connection channel and the North Shore connection channel, among which the Yellow-River-Crossing tunnel project consists of Mangshan Tunnel, the river crossing tunnel and the north bank shaft. Since the Mangshan section belongs to the oblique section, the overall form of "large inverted siphon" is erected in the north of the South slope. See the figure 1.
Fig. 1 the longitudinal section of Yellow-River-Crossing Tunnel in the Middle Route Project

The general inverted siphon is a type of overpass hydraulic building that is often used when the channel crosses the road or the river or when the channel passes through the Valley. The working principle is to use the upstream and downstream water level difference to transport water downstream through pipelines or tunnels under the influence of gravity, and the length is 10-1000m; The difference between the two sides of the water level is within 0-1m, and both the upper and lower reaches are either sloping tubes or vertical wells. There is a 10m water level difference between the upper and lower reaches of the tunnel, a single hole length of 4250m, an upstream oblique tube type, and a downstream shaft type. The characteristics of the Yellow-River-Crossing Tunnel are obvious.

2.2. Yellow-River-Crossing Tunnel Status of Water Quality Protection

The safety of Yellow-River-Crossing Tunnel is great, and the safety and security of water quality should also be concerned. According to a total of 19 months of average water quality data analysis from December 2014 to June 2016, the water quality monitoring section before and after the Yellow-River-Crossing tunnel can meet the Class II standard of surface water environmental quality. However, the concentration of major basic items such as permanganate index, ammonia nitrogen, total nitrogen, and total phosphorus were all higher than the average of Henan Canal Section.[4] It shows that there are external factors that affect the water quality of the tunnel. At present, the water quality protection measures for Yellow-River-Crossing Tunnel are mainly the following four aspects.

2.2.1. Legal system guarantees

The operation and management of the South-to-North Water Diversion Project needs to ensure that the water quality meets the standards. In addition to the "Water Law of the People's Republic of China" and the "Water Pollution Prevention and Control Law of the People's Republic of China" and other laws, the administrative regulations of the "South-to-North Water Diversion Project for Water Supply Management" in 2014 are implemented. Strict water quality protection measures; "Measures for Emergency Management of Environmental Emergencies" (Order of the Ministry of Environmental Protection No. 34 of 2015), "Administrative Measures for the Release of Hazardous Substances for Reporting and Disposal of the Central Line of the South-to-North Water Diversion Project(Trial)", "Administrative Measures for Emergency Management of the Central Line of the South-to-North Water Diversion Project", "South-to-North Water Diversion" Integrated Emergency Plan for Central Route Project Emergency Response, Emergency Plan for Emergency Control of Central Route of South Water Transfer, Emergency Plan for Water Pollution Incident of Central Route of South Water Transfer, Technical Manual for Emergency Management of Water Pollution Incident of Central Route of South Water Transfer", "South Water North Line Main Line Algae Control Plan" and other departmental regulations and normative documents; In particular, the "Delineation and Improvement Plan for the Drinking Water Source Protection Area of the Hebei Section of the General Dry Canal of the First Phase of the South-to-North Water Transfer Line" and the "Protection Division of Drinking Water Sources on both sides of the General Dry Canal(Henan Section) of the South-to-North Water Transfer Central Line" are to prevent water quality pollution risks, effective prevention and control and removal hazards. And are important measures to ensure the safety of water quality in
South-to-North Water Diversion and Yellow-River-Crossing Tunnel.

South-to-North Water Diversion Central Line Piping Yellow-River-Crossing Project Management Office According to the "Administrative Measures for Engineering Inspection of the Operation Period of the South-North Water Diversion Central Line Project(Trial)"(No. 15, Quality Security[2015], and "Water Environment Daily Control Regulations of the South-North Diversion Central Line Construction Authority"(Q/NSBD) ZXJ012-2016), "Notice on Further Strengthening Water Quality Safety Management and Improving the Two-Level Water Quality Safety Management Framework"(No. 3 of the Central Bureau of Water Quality[2015]), "On Printing and Printing the Water Quality Monitoring Implementation Plan of Henan Branch of the Construction Bureau of the South-North Water Transfer Central Line Project Construction Bureau Notice of Water Quality(No. 15 of the Central Bureau of Water Quality[2015]), Notice on the Management of Water Quality Data of Henan Branch of the Construction Bureau of the South-North Water Transfer Central Line(No. 21 of the Central Bureau of Water Quality[2015]), and Water Quality during the flood season of the South-North Water Transfer Central Line Project The work plan for safety and security and the implementation plan for water quality safety and security during the large flow of total trunk channels are required. The regulations and rules such as the Water Quality Safety Inspection System of the Yellow-River-Crossing Project Management Office, the Measures for Inspection of Water Pollution Sources of the Yellow-River-Crossing Project Management Office, the Procedures for Cleaning Waste from the Yellow-River-Crossing Project Management Office, and the Algae Monitoring and Implementation Procedures of the Yellow-River-Crossing Project Management Office have been issued and effectively guaranteed the Yellow-River-Crossing project water quality safety.

2.2.2. Organizational staff security
The Yellow-River-Crossing Project Management Office set up a leading group for water quality safety management, clarified the leadership of water quality protection work and two water quality commissioners, and further improved the water quality safety management organization system; It has clarified the division of duties and responsibilities of the leading group for water quality safety management, and requires members to be familiar with the basic knowledge and management regulations for water quality protection management, so that water quality protection work can be reliably guaranteed in the organization, everyone has responsibility, and the work is in place. Ensuring water quality protection is foolproof. The Water Quality Commissioner summarizes the requirements every two months and reports to the Chief of Staff on the water quality protection work.

The director in charge of the management office and the corresponding personnel such as the water quality commissioner shall conduct supervision and inspection of the daily inspectors once a month, and the inspection results shall be used as the basis for the monthly assessment of the inspection units, and shall be binding on them to ensure the inspection and garbage salvage effects. Other duties of the Water Quality Commissioner are daily water quality sampling, daily inspection of surrounding pollution sources, and coordination with the water quality inspection or inspection arranged by the Central Construction Authority and the Henan Branch, and statistics, filling in or compiling various water quality statements or information.

2.2.3. Channel closed management
The water quality of drinking water sources on both sides of the channel shall be prevented from being artificially polluted by delimiting protected areas, setting up channel isolation belts, setting up cross-channel bridges, and road protection networks. The trunk line channel of the South-to-North Water Diversion is the only channel in the long-distance water diversion project at home and abroad. There are isolation fences on both sides of the channel, and a hob thorn wire is installed at the top; In addition, steel gates are installed at all four corners of each cross-channel bridge, and hob wire is also installed at the top of the steel gate: A large water delivery project designed to prevent outside unrelated personnel from entering the channel.

According to the "Administrative Measures for the Operation Period of the Central Line Project of
the South-to-North Water Diversion Project,” the workers ‘patrols are required to patrol all day long. The security personnel continuously patrol and report the abnormal situation to the management office in a timely manner and dispose of it quickly and properly.

Daily inspections mainly inspect the water quality risk sources such as cross-channel bridges, crossing buildings, and sewage into interception trenches. The focus is on inspecting whether there is any external water discharged through the bridge and whether there is any leakage of liquid immersion channels in the building through the canal. Daily inspectors make good record of water quality risk source inspection, record inspection time, inspection position, risk source status, form a "water quality inspection record sheet." If the inspection finds problems, it should be reported to the Henan Branch Water Quality Monitoring Center within 1 hour. At the same time, temporary disposal measures should be taken. After the disposal is completed, an incident report should be prepared for filing.

2.2.4. Water quality inspection monitoring

Water quality monitoring uses a combination of routine monitoring and automatic monitoring and emergency monitoring. When a sudden water pollution incident occurs, mobile laboratories are used to dynamically track and monitor water quality in order to actively respond to various emergencies. A total of 1 water quality laboratory, 12 water quality fixed monitoring stations and 3 automatic monitoring stations were set up in Henan Branch, and a mobile emergency monitoring vehicle was equipped to form a water quality monitoring system for Henan Branch. The fixed monitoring station is divided into 6 general monitoring stations and 6 key monitoring stations; The three automated monitoring stations use an automated water quality monitoring system to obtain monitoring data or results, and the general and key monitoring stations are recorded by the Water Quality Commissioner. The fixed water quality monitoring point before the Yellow-River-Crossing tunnel is a general monitoring station(K478+833), and the water quality monitoring point after the Yellow-River-Crossing tunnel(483+054) is located at the boundary between Zhengzhou and Jiaozuo areas and is a key monitoring station.

The automatic water quality monitoring system is a comprehensive online automatic monitoring system composed of modern sensor technology, automatic measurement technology, automatic control technology, computer application technology, and related specialized analysis software and communication network. Monitoring data can be counted and processed, and the results of monitoring can be printed, etc.. The implementation of automatic water quality monitoring can realize real-time continuous monitoring and remote monitoring of water quality, and achieve timely control of the water quality of key cross-sectional water bodies.

The Water Quality Commissioner mainly conducts daily inspections on the sensory characteristics of channel water bodies, records the overall conditions of water bodies such as color, odor, turbidity, etc.. If an anomaly in the color, odor, and turbidity of channel water bodies is found, 1 H will be reported to the South Water North Transfer Central Line Construction Bureau Henan Branch.

Since February 2015, the Yellow-River-Crossing Project Management Office has arranged for the Water Quality Commissioner to carry out the observation work on the collection of plankton nets at fixed water quality monitoring points before and after the Yellow-River-Crossing tunnel at 10:00 in the morning and 15:00 in the afternoon to record changes in the color and state of algae in water bodies. Before 17:00, the "plankton sampling report in the water" was submitted to the Henan Branch Water Quality Monitoring Center, and observation photos and original records were archived in electronic and paper versions.

The Water Quality Commissioner conducts inspections of the pollution sources once every two months in accordance with the "Measures for Inspection of Water Pollution Sources of the Yellow-River-Crossing Project Management Office" and fills in the "Water Pollution Source Inspection Record"; For the pollution sources in the isolation network, timely detection and timely treatment to avoid affecting the safety of water quality.

Establish a water quality pollution emergency material ledger, equipped with three types of WGV600, WGV700, WGV750, three types of oil barriers, and 10 kg felt, 200m hemp rope,
management, ready for emergency disposal.

According to the "Code of Waste Cleaning by the Yellow-River-Crossing Project Management Office", since the water was opened in December 2014, in order to maintain the clean and non-floater water surface, Security units are required to increase garbage removal work, to be responsible for filling in the "garbage removal log" and "garbage recovery records" and to supervise and inspect them, so as to ensure the safe and effective development of garbage recovery work.

3. Yellow-River-Crossing Tunnel entrance and entrance Float Clearance

The change trend of the water quality of the main trunk canal of the South-to-North water diversion line shows that most of the water quality indicators show the characteristics of the South, low, and high North. In recent years, the relevant index concentration of the Tao fork section of Danjiangkou Reservoir has remained stable, and the total nitrogen has decreased, indicating that there are still pollution sources along the total trunk channel. [4] Although the main channel has adopted antifouling measures such as isolation protection, interception ditch, and anti-seepage membrane, due to the characteristics of open channel water transmission and slow flow rate, there are still some potential pollution sources, which have a certain impact on water quality. In particular, it is very easy to gather water floaters at the entrance and exit of channel water delivery buildings, which not only affects the water surface environment but also can cause deterioration of water quality. Float cleaning has become the daily work of each operation management office of the South-North Water Diversion Line and the growth point of technical innovation and application. The Yellow-River-Crossing Project is a window for the exhibition and exchange of the central line of the South-to-North Water Diversion Project. It has special engineering, geographical and political significance. According to the water quality protection requirements of the Central Construction Administration Bureau and the Henan Branch, the surface flotation cleaning has become the main daily work. In order to effectively intercept and salvage the floaters entering and remaining at the entrance of the Yellow-River-Crossing Tunnel and the exit of the Yellow-River-Crossing Tunnel, to reduce the direct sensory effects and potential water quality hazards caused by the floaters, and to combine the actual working conditions on the site, the Yellow-River-Crossing Project Management Office has developed, designed, manufactured and installed itself. The automatic salvage grille is used on the south bank of the Yellow-River-Crossing Project, and the permanent polymer polyethylene flotation facility is added at the exit of the north bank of the Yellow-River-Crossing Project.

3.1. Entrance floater cleaning facilities on the Yellow-River-Crossing Project South Bank.

From the nearest dry river inverted siphon exit in the upper reaches of the Yellow-River-Crossing Tunnel to the Yellow-River-Crossing Tunnel, there are no other channels of hydraulic buildings in the 10.8km channel, and the water flow speed is 1-1.63 m/s, forming a catchment area at the entrance of the Yellow-River-Crossing tunnel. In the upper reaches of the channel, there is a large collection of float that flow into and fall around the area before the entrance security gate through the Yellow-River-Crossing tunnel. There are metals, glass, paper, plastics, fabrics, bone shells, food, wooden bamboo, aquatic plants, dead leaves, animal corpses, etc.. The original salvage work platform was narrow and could only accommodate one person. The salvage cost was high, the labor intensity of the personnel was high, the efficiency was low, and there was a risk of falling into the channel. The safety hidden danger was great. Installation of floater salvage facility-automatic containment grate, including containment grate and fixed hoist, before the entrance grille through the Yellow-River-Crossing tunnel. The materiact size and fabrication installation is shown in Figure 2.
Fig. 2 The automatic fishing barrier system on the inlet of the Yellow-River-Crossing Tunnel

At the same time, a stainless steel hollow tube is installed in the static area in front of the water retreat (see Figure 3), so that the floating material floats along the water to the entrance garbage salvage facilities, and then manually cleaned to effectively protect the water quality safety.

Fig. 3 The automatic fishing barrier system on the inlet of the diversion tunnel

3.2. Yellow-River-Crossing Project North Shore Exit Float Cleaning Facility

The surface of the catchment area formed by the outflow of two parallel tunnels through the north bank of the Yellow-River-Crossing tunnel is relatively calm, resulting in a large collection of drifts that flow out of the tunnel and fall into the area. As the image project of the central line of the South-to-North Water Diversion, the number and frequency of visits, inspections, and investigations to the platform are very large, and the clearance of floating objects for exit is particularly important. However, the exit through the Yellow-River-Crossing Tunnel has both a floater clearing platform and a height difference of 20 m from the surface of the water. There is a great security risk in the use of traditional long rod nets to salvage garbage, and the cleaning work is extremely difficult. Following environmentally friendly, aesthetic and practical considerations, flotation flotation facilities were added in early 2017, as shown in figure 4. The flotation is assembled from a polymer polyethylene float tube, and the flotation body is fixed with two sides of guardrails and reinforced bolts to strengthen safety and stability.
Fig. 4 The cleaning mat for floating materials on the outlet of the Yellow-River-Crossing Tunnel

Exit area flotation includes: steel ladders, fixed lifting pulleys, buoys, salvage boats. The steel climbing ladder facilitates the staff to operate the platform up and down, and the fixed lifting pulley ensures that the float does not leave the track when fluctuating or lifting with the water surface, and the salvage boat is used to salvage and collect floats farther away from the float. The float adopts a new type of environmental protection material made of high molecular polyethylene with anti-ultraviolet substances, which has strong toughness and high hardness and can withstand changes in the natural environment and low temperatures. It has the characteristics of light weight, high buoyancy, acid and alkali resistance, zero maintenance, flexible combination transformation, long life, bright and beautiful colors, anti-rot, anti-freeze, anti-ultraviolet, anti-aging, etc., and is not subject to the erosion of chemicals, pharmaceuticals, oil stains and aquatic organisms. There is no secondary pollution, the entire pontoon is seamless, no water seepage, no water storage problems, and recyclable recycling. The supporting equipment such as ship bolts, cable piles, anti-pool balls, guardrails, and landing bridges are complete, and they can automatically rise and fall with the water level. The staff is safe and comfortable on and off the ship.

The upper surface of the pontoon body adopts an Anti-Slip pattern design, which is safe and stable. The four corners are all arc obtuse shapes. The dangers of sliding, being crushed wood chips, and being stabbed by rust in common cement, wood, and iron facilities can be avoided. Water waves are used safely in level 5.

3.3. Effect of Entrancing and Exiting Float Clearance through Yellow-River-Crossing Tunnel

The installation and application of the facilities for cleaning up floating objects for entrance and exit through the Yellow-River-Crossing Tunnel have not only enhanced the image of the Yellow-River-Crossing Project on the central line of the South-North Water Diversion, improved the working environment of the operators, but also improved the mechanization and salvage efficiency of the floating objects and increased the safety operating coefficient of personnel. It embodies the spirit of courage to innovate and the people-oriented feelings.

3.3.1. Application Effect of Importation Automatic Blocking Grate in Yellow-River-Crossing Tunnel

The cleaning effect of channel flotation is obvious by using automatic blocking grille device.

1. Efficient and uninterrupted interception of various physical traits of flotation and in the water, filamentous algae and other organic organisms.

2. The efficiency of flotation cleaning is obviously improved, the labor volume of manual directly salvaging flotation in the water body is reduced, and the safety factor is increased, and the safety of flotation cleaning personnel is effectively guaranteed.

3. After flotation cleaning, the potential impact of flotation on water quality is reduced, and the sensory characteristics of water bodies are also improved.

4. The reduction of floating objects entering the tunnel effectively relieves the salvage work of floating objects at the exit of the tunnel.

3.3.2. Effect of using Yellow-River-Crossing Tunnel exit salvage flotation

The application of the Yellow-River-Crossing Tunnel exit flotation has the function of beautifying the environment and improving the flotation cleaning effect.
(1) The beautiful appearance of the floating platform adds to the scenery of the outlet catchment area and enhances the image of the Yellow-River-Crossing Project.

(2) Provide operation platform for floater cleaning personnel to improve personal safety factor.

(3) In order to prevent the leakage of hydraulic oil which affects the water environment quality of the tunnel exit, solve the problem of water launch in an emergency event, and provide an emergency operation platform.

4. conclusion

The water quality safety in the process of water diversion is the continuous protection of the middle line of the South-North Water Diversion Project in the present era and benefits from the thousands of years. Unlike the results of water quality protection studies such as the conventional water quality monitoring system and the emergency treatment of non-conventional sudden-onset water pollution incidents, insufficient attention has been paid to the physical characteristics of the potential water quality factors affecting the entrance and exit of the water supply buildings. The water quality guarantee measures of Yellow-River-Crossing Project are combed and analyzed.

(1) Data from fixed water quality monitoring sections before and after Yellow-River-Crossing Tunnel penetration show that the concentration of basic monitoring items is stable, and the physical and chemical indicators meet the water environment quality standard category II, but the efficiency of salvage of entranced floating objects and the risk coefficient of exit cleaning are large. The debris physical debris and decaying organic floaters have potential potential water safety hazards.

(2) The installation of the entranced automatic pollution control grid system and the outlet salvage flotation system through the Yellow-River-Crossing Tunnel has improved the engineering image, the surface sensory environment, improved the flotation cleaning efficiency, and increased the safety operating coefficient of the scavengers.

(3) It is of great practical significance for the clearance of floating materials in other hydraulic buildings with open water bodies, slow flow, and deep water surface, and provides practical reference for the clearance of floating materials in the water catchment area of other water transport buildings in the middle of the South-to-North Water Diversion Line. It can ensure the safety of water quality on the trunk line of the South-North Diversion. Play the comprehensive economic, social, and environmental benefits of the midline project to achieve the goal of "a channel of clean water to the North".

With the operation of flotation cleaning facilities, it is necessary to further study the impact of flotation cleaning facilities on the flow rate and water level, and the impact of water flow on flotation cleaning facilities.

References

[1] CHENG D H, SU X. Technical advancement and demand of Middle Route Scheme of South -to-North Water Diversion Project [J]. CHINA WATER RESOURCES, 2018(10):24-27.

[2] WENG L D, YE M, LOU B F, et al. Water quality protection in water source area of Middle Route Project of South to North Water Transfer [J]. Yangtze River, 2005,36(12):24-25,43.

[3] ZHANG D W. Research on the Key Technology of the Regulation of Water Quality and Quantity of the Middle Route of South-to-North Water Diversion[D].SHANG HAI: Donghua University,2014.

[4] LIANG J K, XIN X K, LU L, et al. Analysis of water quality variation and potential pollution sources in main channel of Middle Route Project of South to North Water Diversion [J]. Yangtze River, 2017, 48(15):6-9.

[5] ZUO H F, HUANG Y F, WEI J H, et al. Potential Risk Analysis for Impact of Contaminated Groundwater on Water Quality in Middle Route of the South-to-North Water Diversion Project [J]. South-to-North Water Transfers and Water Science & Technology, 2008, 6(5):1-3.

[6] WANG X W, CHEN J J. Impact of groundwater internal discharge on the water quality of open
channel in the Middle Route of South-to-North Water Transfer Project [J]. South-to-North Water Transfers and Water Science & Technology, 2015, 13(5): 858-861.

[7] REN Z Y, XUE X, GAO A H, et al. Groundwater Inflow of Check Value and Its Impact on main canal Water Quality in the Middle Route of S-N Water Transfer Canal [J]. South-to-North Water Transfers and Water Science & Technology, 2015, 41(2): 281-286.

[8] WANG H, ZHENG H Z, LEI X H, et al. Study on Key Technologies of Emergency Regulation and Treatment to Ensure Water Quality Safety of the Main Canal of Middle Routes of South-to-North Water Diversion Project [J]. JOURNAL OF SICHUAN UNIVERSITY (ENGINEERING SCIENCE EDITION), 2016, 48(2): 1-6.

[9] WANG H, LEI X H, SHANG Y Z. Key technologies of intelligent control and emergency regulation for the Middle Route of South-to-North Water Diversion Project [J]. South-to-North Water Transfers and Water Science & Technology, 2017, 15(2): 1-8.

[10] ZHAO R, LI Z H, ZHU Q M. Potential Risk Prediction and protection of water quality for emergency water supply project of the Beijing section of the Middle Route Project of the South-to-North Water Transfer [J]. Journal of China Institute of Water Resources and Hydropower Research, 2009, 7(4): 311-315.

[11] SUN Y P, TANG T. New technologies and equipment for dealing with water quality emergency accidents along the Middle Route of South-to-North Water Diversion Project [J]. CHINA WATER RESOURCES, 2018(8): 18-21.

[12] ZHAO Y P, TANG T. Water in the Middle Route of South to North Water Diversion reaches 15 billion cubic meters [N]. People's Daily, June 18, 2018 (01 Edition).

[13] WANG Z M. The Theories and Methods of Water Quality Prediction in the Middle Route of South to North Water Transfer Project of China [D]. Wuhan: Wuhan University, 2017.

[14] TANG C H, YI Y J, YANG Z F, et al. Water pollution risk simulation and prediction in the main canal of the South-to-North Water Transfer Project [J] Journal of Hydrology, 2014 (519): 2111-2120.

[15] FANG Y M, ZHANG D W, LEI X H, et al. Emergency control strategy for sudden water pollution accident in the main channel of middle route of the South-to-North Water Transfer Project [J] South-to-North Water Transfers and Water Science & Technology, 2014, 12(2): 133-136.

[16] LIAN J J, WANG X, LIU C Y, et al. Emergency Regulation for Sudden Water Pollution Accidents of Open Channel in Long Distance Water Transfer Project [J] Journal of Tianjin University (Science and Technology), 2013, 46(1): 44-50.