



Risk forecasting of pollution accidents based on an integrated Bayesian Network and water quality model for the South to North Water Transfer Project



Caihong Tang^a, Yujun Yi^{a,b,*}, Zhifeng Yang^{a,b}, Jie Sun^a

^a Ministry of Education Key Laboratory of Water and Sediment Science, School of Environment, Beijing Normal University, Beijing 100875, China

^b State Key Joint Laboratory of Environment Simulation and Pollution Control, School of Environment, Beijing Normal University, Beijing 100875, China

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ABSTRACT

For a long distance water transfer system, guaranteeing the safety of water transferred in a long open canal is a challenge. Potential pollution sources and locations are identified first. Bridges above the canal are considered as the typical location where pollution accidents could happen. Truck responses, road conditions, and human responses are the main factors resulting in sudden pollution accidents. A Bayesian Network model is developed to calculate the risk of water pollution and evaluate the effects of pollutants in water. The key causes (human judgment, truck condition) were determined to calculate the unfavorable accidental risk. Six types of hydraulic structures were included in this canal reach. MIKE 11, a one-dimensional hydrodynamic and water quality model, was used to simulate the fluid field and pollutants transportation process. The water quality situations of cyanide at four pollution loads (0.5 t, 5 t, 10 t, 20 t) were simulated. Emergent countermeasures and measures, including the management of diversion and check gate, have been proposed according to the calculate result.

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1. Introduction

Sudden water pollution accidents have characteristics of varied and complex pollution sources. The pollution pathway and pollution degree are changeable and unpredictable. Especially in China, rapid economic development encourages large demand for chemicals and petrochemical products, which lead to severe pollution in sudden pollution accidents. Sudden pollution accidents frequently happening in rivers, lakes, and groundwater, have significantly polluted local water resources and ecological environment. Consequently, these polluted water events dispute ecosystems (Mi et al., 2015) and are harmful to the local politics, economy and life safety (Shi et al., 2014; Zhang et al., 2012).

Aiming to alleviate the water resources shortage of northern China, the Middle Route of the South to North Water Transfer Project (MRP) was constructed. It provides drinking water to northern China (e.g. Beijing, Tianjing). Therefore, its water quality should

be guaranteed. Elevations of canal bed ranges from 139.38 m to 56.5 m from south to north for the MRP; therefore, the MRP significantly relies on gravity to transfer water in the open canal. Extra auxiliary power is provided in areas that contain hydraulic structures. Open canal decreases the construction costs, but the transferred water is exposed to the air which adversely increases the risk of water pollution. The emergent pollution accidents are the prominent threat to water quality, consequence threaten the health and life of the people in intake area. Bridges, especially high-way bridges that cross the canal are the most significant accident locations according to the identification and analysis of emergent pollution sources. The Dianbei Bridge, a typical cross-canal bridge, was selected as a representative bridge where emergent pollution accidents would happen. The prediction of accidental risk analysis provides support and suggestion for decision makers and managers.

Sudden pollution accidents have multiple complex causes, which makes difficult to ascertain the risk profile. Standard and dynamic fault trees, Markov chains, Petri nets, and Bayesian Networks (BN) are the primary research methods for determining risk probability (Kabir et al., 2015; Faghih-Roohi et al., 2014; Akgün et al., 2015; Convertino et al., 2011). Bayesian Networks are applied extensively in risk analysis of uncertain problems. It

* Corresponding author at: Beijing Normal University, Ministry of Education Key Laboratory of Water and Sediment Science, School of Environment, No. 19, Xijiekouwai Street, Beijing 100875, China. Tel.: +86 18810628449.

E-mail address: yiyujun@bnu.edu.cn (Y. Yi).

has strong inference function that can identify the relationship between each factor in a complex system, and determine the powerful factor. From governmental, academic, and industrial perspectives, BNs have been established to evaluate the consequences of the technical and socio-economical factors on typical system (Buriticá and Tesfamariam, 2015). 26% references connecting with BNs are focused on the risk analysis in recent years (Weber et al., 2012). A BN model, combining with Fault Tree Analysis, has been developed to calculate the impacts of organizational functions and regulations to research the risk of human and organizational factors in the maritime industry (Trucco et al., 2008). Bayesian Networks have experienced widespread application to complex ecological assets with large uncertainty and limited data. It is used to compare concentrations of Boron Nitride in fish and parameterize and evaluate the risk assessment of Boron Nitride to improve catchment management (Pollino et al., 2007). The Bayesian Network is also employed to assess the credible intervals resulting from pesticides reduction in constructed wetlands (Krone-Davis et al., 2013). Additionally, identifying the main factors contributing to the accident severity happening on the rural highways in Granada, Spain is another application (de Oña et al., 2013). A Bayesian Network model, considering six major factors (including truck type, truck status, visibility, road environment conditions, driver age, and driver gender) was developed in this study. It was used to deduce the accident risk of the MRP.

The MRP has a strict requirement for water quality that the transferred water must meet the water quality standard Class II of the Surface Water Quality Standard GB3838-2000 of China. Each pollutant has fixed critical values. Concentration of cyanide should be less than 0.05 mg/L, which means water quality meets Class II standard. This requirement indicates that water pollution accidents occurred in the canal severely pollutes the diverted water and the water quality cannot be guaranteed. Consequently, the forecast of sudden water pollution accidents is essential to ensure the water quality.

In this paper, all potential sudden pollution accidents and pollution sources are analyzed in the section of Beijing-Shijiazhuang canal. According to identifying pollution sources of canal, potential pollution factors are selected and bridges are recognized as the main locations of sudden accidents. The Dianbei Bridge is a representative location where sudden pollution accidents happen. Human judgment, road and environment factor, truck response are identified three direct factors, which are affected by six indirect factors, including driver gender, age of driver, weather, visibility, truck types, truck condition. A Bayesian Network has been built based on these identified factors. The accident probability is calculated and sensitive factors are selected based on the established BN. This study applies MIKE11 to the channel to establish a one-dimensional hydrodynamic and water quality model to simulate the change of cyanide concentration within the canal as a result of an accident. The cyanide, concentration of 100 mg/L, is leaked into the canal at loads of 0.5 t, 5 t, 10 t, and 20 t at the Dianbei Bridge. Finally, the regularity rules of polluted water at diversion are proposed.

2. Study area

The MRP has a long water conveyance distance with a total length of 1277 km and transfers water from Dianjiangkou Reservoir to Beijing and Tianjin (Fig. 1). The canal from the Shijiazhuang to the Beijuma River is selected as the research object in this paper, which is 158 km long and contains the hydraulic structures (diversions, check gates, exit gates, inverted siphons, bridges, tunnels and aqueducts) (Tables 1 and 2). The controlling and crossing structures are constructed to guarantee that the normal daily transportation and regulation of water. Security barriers are set on both sides of canal, which make the canal closed and prevent people and pollutants approaching the channels and water (Changjiang Institute of Survey Planning Design and Research (CISPDR), 2005). The different types of bridges crossing the canal are shown

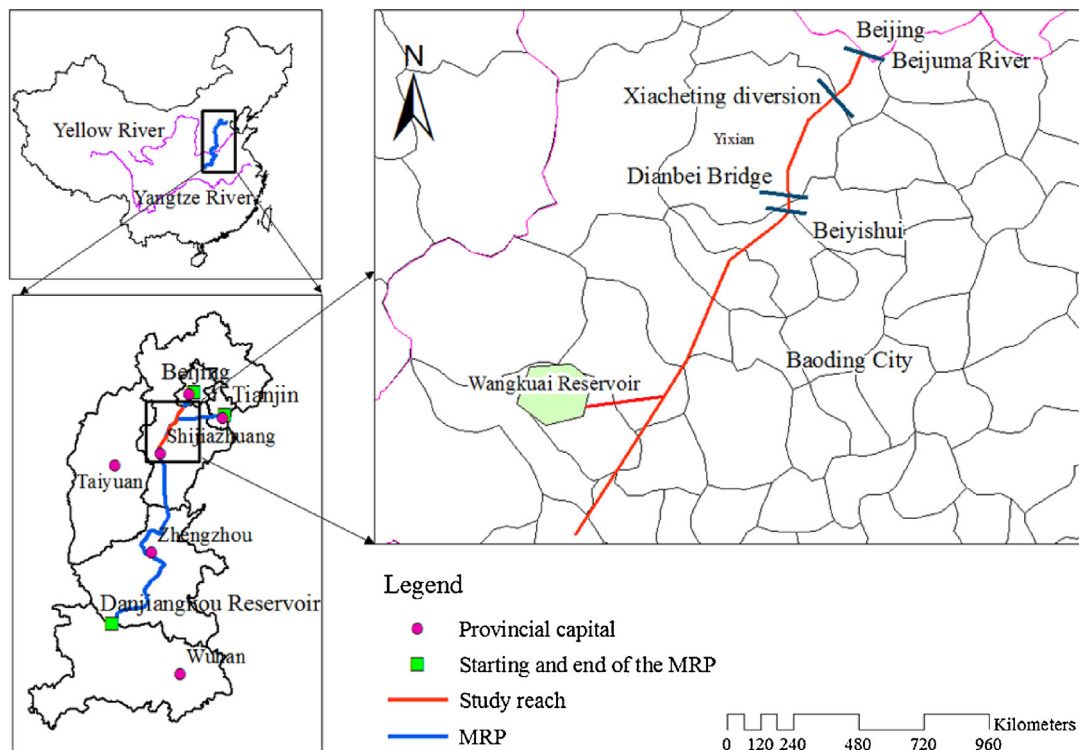


Fig. 1. Map of the Middle Route of the South to North Water Transfer Project (MRP) and the study reach.

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