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Risk factors analysis and risk assessment of sudden pollution from traffic accidents in the Middle Route of South-to-North Water Diversion Project

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Abstract. The traffic bridges along the route of South-to-North Water Diversion Project are numerous. Once a traffic accident occurs causing pollutants in the channel, the water safety, ecological environment and economic development of water receiving areas along the line will be affected .We investigate the bridges along the channel, focusing on the investigation and analysis of hazardous chemicals, nearby backwater gates and water inlets involving 173 cross-channel bridges with large traffic volume. The risk evaluation index system of sudden water pollution is established in this study, while the risk of different bridges is evaluated. We divide bridges in three risk grades, and delimit key prevention areas and key monitoring objects. And the stress of traffic risk factors on the water quality safety is summarized. It is significant for being regarded as basis for contingency plans, hierarchical responses and emergency material reserve for the middle line of the south-to-north water diversion project.

1 Introduction

The south-to-north water diversion project is the largest inter-basin water diversion project in the world. It is a significant strategic infrastructure to alleviate water shortages in northern China, achieve rational allocation of water resources, ensure sustainable economic and social development, and build an overall well-off society. The middle route project is the lifeline connecting the Danjiangkou reservoir with the four provinces of Beijing, Tianjin, Hebei and Henan, of which the average annual water transferred is 9.5 billion m^3, and the beneficiary population has reached 53.1 million. It is responsible for more than 70% of urban water supply in Beijing, and the proportion of water supply in the water area is growing. The water supply target of the Middle Route of the south-to-north water diversion project is mainly urban domestic and industrial water along the line, and the water supply network covers 97 outlets and 293 water plants with the high requirements for water quality.

The main canal adopts one-way single-line water transportation, with the water transportation distance of 1,432 kilometers. The cross buildings and control buildings along the road are dense, and the factors affecting water quality are complex.

There are about 1,238 cross-canal bridges along the main canal of the middle line, which has become an important risk point for vehicles to transport chemicals and throw into the canal. Since the water flowed on December 12, 2014, cross-canal bridge traffic accidents have occurred occasionally. Although there is no direct impact on the quality of the diverted water conveyance, the threat of sudden water pollution from traffic accidents has emerged and attracted attention. Therefore, for the purposes to make water pollution emergency strategy, take good measures to prevent water pollution and plan emergency material reserve layout, the sudden pollution risk factors of traffic accidents are investigated and analyzed. And it is necessary and urgent to put forward a set of index system to evaluate the risk of sudden pollution from traffic accidents in middle line. There are many risk assessments of traffic accidents and sudden water pollution in rivers at home and abroad, but less risk assessment on sudden water pollution from traffic accidents in the main canal of south-to-north water diversion middle route. Li Jiahui, Guo Liang[20], centered on the Hongze Lake in the south-to-north water diversion project, investigated the pollution source information of 22 factories in the surrounding cities, established an index system for river basin hazard source identification and evaluation, and conducted risk calculation. According to the analysis results of the main risk sources in the main canal of middle line, Shi Yueying[1] considered that the occurrence of traffic accidents risk was more probable than that of other risk sources, with weak controllability of risks, and performed spatial clustering analysis of risk sources for traffic accident risk.

Wang Huadong and Wang Fei[3] carried out environmental risk assessment on middle line water

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source of the south-to-north water diversion project, performed risk identification by analytic hierarchy process, estimated the risk probability by the fuzzy probability-- accident tree analysis method, estimated the risk consequences using the statistical analysis method and the analogy analysis method, and comprehensively evaluated the risk by gray correlation analysis method and comprehensive index method, making the conclusion that the main environmental risk accidents of the engineering and environmental composite system were dam breaks, and the extraordinary floods and destructive earthquakes were the main causes. Tian Weimin[2] analyzed the actual flood control safety situation of Beijing-Guangzhou Railway cross-buildings, compared the design indicators of the Beijing-Guangzhou Railway (Hebei Province section) and the main canal (Hebei Province section) and the river crossing buildings, and considered that the risk of water damage undertaken by the crossing buildings of main canal in middle line was quite low.

2.Methodology

2.1 Risk factors analysis

2.1.1 Possibility analysis of accident occurrence

There are various direct causes of accidents, such as vehicle mechanical failure, driver's carelessness or fatigue driving, environmental conditions, vehicle types, lighting conditions, and so on. The possibility estimation of accident occurrence on the bridge can be analyzed from three aspects, the frequency of vehicles passing through, the bridge attribute, and the number of surrounding chemical plants.

(1) The frequency of vehicles passing through bridges

The frequency of vehicles passing through bridges is directly related to the probability of sudden water pollution from traffic accidents. The frequency statistics are counted according to three time periods per day, 9:00-10:00 am, 15:00-16:00 pm, and 12:00 pm to 1:00 am. The arithmetic mean was taken as the frequency of vehicles passing per hour, and then the frequency of vehicles passing per day was obtained.

The frequencies of hazardous chemicals vehicles passing through in three days were ranked: Grade one, the total number of hazardous chemicals vehicles passing through within three days $\geq$ 50; Grade two, the total number of hazardous chemicals vehicles passing through within three days < 50 and $\geq$ 10; Grade three, the total number of hazardous chemicals vehicles passing through within three days < 10.

(2) Bridge attributes

Most of the bridges surveyed along the route are highway bridges, railway bridges, water bridges (aqueducts), foot bridges and other special bridges. Different types of bridges are divided into three types of risks: Class I risk bridges, highway bridges; Class II risk bridges, railway bridges; Class III risk bridges, foot bridges and other special bridges.

(3) Number of surrounding chemical plants

The number of chemical plants in the range of 10km around the bridge is investigated.

2.1.2 Estimation and analysis of pollution impact degree

In the cases of sudden water pollution caused by traffic accidents, the types of pollutants are mainly highly toxic chemicals and other chemicals that are harmful to the human body, facilities and the environment. The weight and toxicity of the chemicals carried by vehicles determine the size of the pollution hazard. The distance between the location of the pollution and the downstream water outlet is related to the impact on the water intaking.

(1) Weight of chemicals carried by vehicles

Counting the weight per vehicles carrying chemicals and the design load of the highway bridge during the survey and investigation period, the load per vehicle is averaged 3 tons. According to the frequency level of hazardous chemicals vehicles passing through, the weight of chemicals carried by vehicles are also divided into three grades: Grade one, the total weight of chemicals carried by vehicles within three days $\geq$ 150 tons; Grade two, the total weight of chemicals carried by vehicles within three days > 30 tons; Grade three, the total weight of chemicals carried by vehicles within three days < 30 tons.

(2) Type and toxicity of chemicals carried by vehicles.

27 types of typical chemicals are surveyed and investigated in this paper. The main chemicals carried by vehicles are divided into 7 categories, the categories and properties are as follows:

1. Benzene species

①Main common substances: benzene, toluene, nitrobenzene, 1,2-dinitrobenzene, 1,3-dinitrobenzene, etc.

②Chemical characteristics: colorless light yellow transparent oily liquid, strong fragrant smell, volatile to vapor, flammable and toxic. Benzene compounds have been identified as strong carcinogens by the World Health Organization.

2. Ethers

①Main common substances: methyl ether, ether, ethylene oxide, petroleum ether, methyl ether.

②Chemical characteristics: except for methyl ether and ethyl methyl ether which are gas, most ethers are flammable liquids with a special smell and a relative density of less than one. Generally, they are slightly soluble in water and soluble in organic solvents, more stable compound that can form salts with strong acids.

3. Aldehydes and acetals

①Main common substances: Formaldehyde, acetaldehyde, acrolein, glyoxal, succinaldehyde, glutaraldehyde, benzaldehyde, etc.

②Chemical characteristics: The compound containing an aldehyde group has two major classes of aliphatic aldehydes and aromatic aldehydes. The low molecular aldehydes are gases, while most of the aliphatic aldehydes are a liquid, and the high molecular aromatic aldehydes are a high-melting solid. Aldehydes are readily soluble in water, with a stimulating effect. The degree of stimulation decreases as the number of carbon atoms increases, by which the stimulation site also changes.

4. Alcohols

①Main common substances: Methanol, ethanol, n-butanol, 1-butanol, 2-methyl-1-propanol, etc.

②Chemical characteristics: generally, they are a colorless liquid or solid. Alcohols are chemically active, and both the carbon-oxygen bond and the hydrogen-oxygen in the molecule are polar bonds. Hydrogen-oxygen bond cleavage and carbon-oxygen bond cleavage can be carried out with the hydroxyl group as the center. Further, a carbon atom bonded to a hydroxyl group is easily oxidized to form an aldehyde, a ketone or an acid.

5. Petroleum

①Main common substances: Petroleum and its refined products, such as kerosene, diesel, gasoline, etc.

②Chemical characteristics: Mineral oil chemicals are mixtures of various hydrocarbons. Petroleum can be present in water in dissolved, emulsified and dispersed states. After entering the water environment, petroleum can form an oil film on the water surface, affecting the reoxygenation process of the water body, causing the water body lack of oxygen, endangering the life of aquatic organisms and the aerobic degradation of organic pollutants. The cyclic hydrocarbon chemicals in petroleum have significant biological toxicity.

6. Acids and alkalis

①Main common substances: Hydrochloric acid, sulfuric acid, nitric acid, phosphoric acid, hydrofluoric acid, phosphorous acid, hydrobromic acid, etc.

②Chemical characteristics: The acid chemically refers to a compound of which the cation generated when ionized in a solution is completely hydrogen ion, and the pH of their diluted solution is less than 7.

Alkalis chemically refer to a compound of which the anion generated when ionized in a solution is completely hydroxide ion, and the pH of their diluted solution is greater than 7.

7. Sulfides

①Main common substances: sodium sulfide, potassium sulfide, hydrogen sulfide, barium sulfide, calcium sulfide, etc.

②Chemical characteristics: sulfides refer to a class of compounds formed by strong electropositive metals or non-metals and sulfur. Most metal sulfides can be considered as salts of hydrosulfuric acid.

For the toxicity analysis of 27 types of chemicals, the toxicity values K1, K2...K27 were respectively assigned according to the difficulty of disposal, ranging from 0 to 100. The comprehensive toxicity of the chemicals carried by a car can be calculated by the following formula (1), and the comprehensive toxicity intensity can be calculated according to formula (2):

$$P_j = w_1k_1 + w_2k_2 + \cdots + w_ik_i \quad i = 1, 2, \cdots, 27 \tag{1}$$

$$U_j = \frac{P_j}{P_{\max}} \quad j = 1, 2, \cdots, 173 \tag{2}$$

where: Wi is the weight of the chemicals carried through the bridge in one day; ki is the toxicity value; i is the chemical type; Pj is the comprehensive toxicity value of the j^{th} bridge; P_{max} is the maximum toxicity value of the 173 bridges; Uj is the comprehensive toxicity intensity of the j^{th} bridge.

(3) Distance of downstream water outlet

Considering the interval time between inspections, the water outlets within 2000 meters from the point of the pollution occurrence are likely to be affected.

2.1.3 Predictive analysis of pollution disposal effect

After the accident, an emergency response is needed to ensure the lives and property safety of the people along the line, water supply safety, and engineering safety as the decision-making goals. Under the premise of ensuring the above objectives, the pollution groups will be discharged and disposed of as soon as possible. Therefore, the effect estimation of pollution disposal should be based on factors such as the locations of the effective backwater gates and the accident occurrence, the amount of water discarded, the location of the emergency reserve materials, and the degree of pollution received by the backwater area. The distance from the accident location to the downstream effective backwater gates determines the distance of the pollution group transferred and the scope affected by the accident. Pollutants are diffused and diluted during the transportation process, and the distance of the pollutants transporting affects the amount of discarded water. At the same time, when selecting the effective backwater gates, the location of the emergency reserve materials, the length of the backwater channel and the acceptance degree of pollution in the backwater area should also be considered, as well as considering whether the pollutants discharged into the backwater area in the backwater channel could decrease the pollution of the backwater area.

(1) Distance of effective backwater gates

After the pollution occurs, the pollution may not be discovered in the first time, so the nearest backwater gates from the point of the pollution occurrence may not be opened in time.

In the channel, the emergency materials can be used first to dispose before backwater. Therefore, the pollution occurrence time and response time should be considered in the selection of the effective backwater gates, and the appropriate distance of the backwater gates is selected as an indicator to measure the effect of pollution treatment. The transport distance of the pollutant at the peak concentration and the length of the pollution area can be calculated by the following formula[7].

$$D = 60vT \tag{3}$$

where: D is the transport distance of the pollutant at the peak, m; v is the average flow rate, m / s; T is the diffusion time, min.

The expression of the length S of the polluted area along the channel in the time of T:

$$S=\int_0^T vdt=2a\sqrt{2}D_L^{0.5}T^{0.5} \tag{4}$$

$$v=\frac{m\sigma}{t}=\frac{a\sqrt{\int 2E_x dt}}{t}=a\sqrt{2}D_L^{0.5}t^{-0.5} \tag{5}$$

$$D_L=\frac{1}{2}\frac{\partial\sigma^2}{\partial t} \tag{6}$$

where: D_L is the coefficient of dispersion, v is the longitudinal stretching speed of the pollutant.

(2) Emergency materials reserve

At present, the sites of emergency materials reserve near the bridges along the line are scarce.

Considering the time interval of pollution discovery and the time of emergency material release, the emergency reserve rooms at 1~2km from the bridge are the best, followed by those at 2~3km, and those at 0~1km are the most inferior, so the locations of the emergency material reserve room are divided into three grades.

(3) Degree of acceptable pollution in the backwater area.

Considering the situations of the backwater gates and the backwater area, the backwater gates can be directly opened for the acceptable pollutants in the backwater area. Taking the impact on the backwater area into account, pollutants cannot be accepted in some important backwater areas. For example, the Yellow River is responsible for the supply of the downstream water resource. After the upstream pollution occurs, the Yellow River backwater gate cannot open preventing the polluted water from the Yellow River main canal.

According to the length of the backwater canal (Figure 1, Figure 2), three types of pollution disposal methods can be adopted: after being disposed in the backwater canal, it is discharged into the backwater area; some of the polluted water bodies are disposed in the backwater canal, and some are disposed in the backwater area; All are discharged into the backwater area and disposed.

Figure 1.sand river dewatering area

Figure 2. white river dewatering area

Therefore, according to whether the backwater area can accept pollution and the conditions of the backwater area, the acceptable pollution degree of the backwater area can be divided into four levels: level 1, pollution cannot be accepted in the backwater area; level 2, the pollution is acceptable after being disposed in the backwater canal; level 3, part of untreated pollution and some of the pollution that has been disposed of in the backwater canal is acceptable; level 4, untreated pollution is acceptable.

2.2 Evaluation index system

Comprehensively taking the above risk factors into account, an index system of three-layer stepped structure is drawn up, as shown in Figure 3.

The first layer is the target layer *A*, which comprehensively reflects the assessment index system of water pollution from traffic accident in the middle line of the south-to-north water diversion;

The second layer is the criterion layer *B*, consisting of three subsystems, reflecting the possibility of accident *B1*, the severity estimation *B2* of pollution, and the degree estimation *B3* of pollution disposal;

The third one is the index layer *C*, and according to the actual situation of the main canal in the middle line, 9 indicators are selected: the number of surrounding chemical plants *C1*; the frequency of vehicles passing through *C2*; the bridge attribute *C3*; the weight of chemicals carried by vehicles *C4*; the toxicity of chemicals *C5*; the distance of the nearest water outlet *C6*; the distance of the effective backwater gate *C7*; the emergency material reserve *C8*; the acceptance of pollution by a backwater gate *C9*.

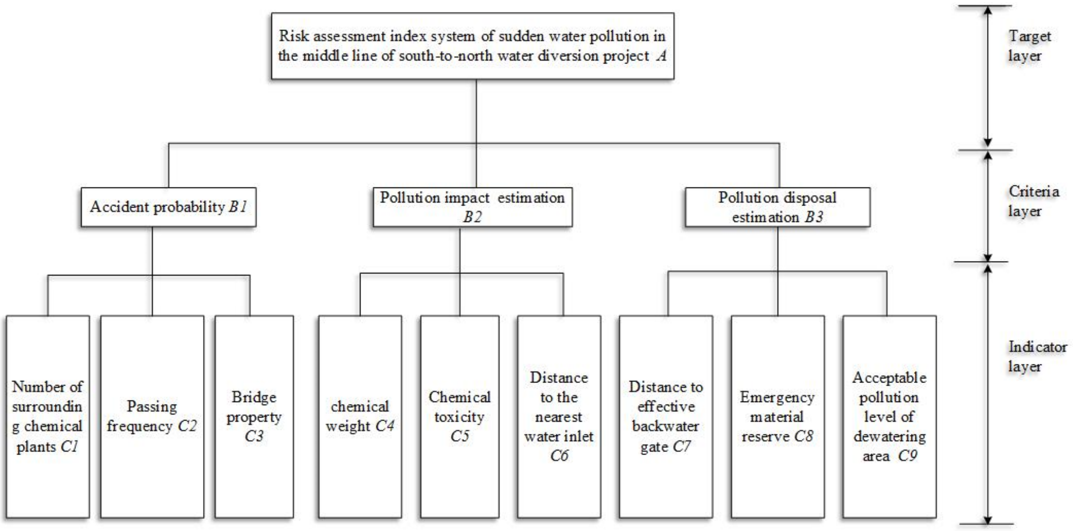

Figure 3. Risk assessment index system of sudden water pollution in the middle line of south-to-north water diversion project

2.3 Establishment of index weights

2.3.1 Judgment matrix

Since each indicator value belongs to a different type of judgment values, it is necessary to build a judgment matrix to reflect the weight of the factor of the same layer in that of the upper layer. In this paper, the judgment is quantified by the 1-9 scale method, and the importance between indicators in each layer is objectively evaluated, constructing the judgment matrix R according to the scale obtained from the evaluation. The meanings of the judgment matrix elements are shown in Table 1.

$$R = \begin{vmatrix} O_{11} & \cdots & O_{1n} \\ \vdots & \vdots & \vdots \\ O_{n1} & \cdots & O_{nn} \end{vmatrix} = \left[O_{ij}\right]_{n\times n}$$

$$i, j = 1, 2, \cdots, n \quad (7)$$

O_{ij} is the element of the judgment matrix.

2.3.2 Weight vector

A feature vector corresponding to the largest eigenvalue of the judgment matrix is regarded as the weight vector. Common methods of calculating the maximum eigenvalue and eigenvector are power method, sum method and root method. In this paper, the root method is selected to calculate the weight of the factors of the same layer in those of the upper layer, and this vector is called the weight vector. The product of the elements in the judgment matrix are calculated by rows and then extracted n roots (n is the order of the matrix), followed by the normalization of the obtained vectors, that is:

$$\tilde{\omega} = \sqrt[n]{\prod_{j=1}^{n} O_{ij}} \quad i, j = 1, 2, \cdots, n \qquad (8)$$

$$\omega_i = \tilde{\omega}_i \Big/ \sum_{j=1}^{n} \tilde{\omega}_j \quad i, j = 1, 2, \cdots, n \quad (9)$$

2.3.3 Consistency test

Consistency test is an effective method to test the size of the judgment error caused by the feature vector as the weight vector. The rationality of the eigenvector as the weight vector, that is, whether the consistency of the judgment matrix is within the allowable variation range, can be judged according to the value of the consistency judgment coefficient C_R[5]. When $C_R<0.1$, the consistency of the judgment matrix is within the allowable range, and its feature vector corresponding to the largest eigenvalue can be used as the weight vector; When $C_R\geq 0.1$, it is necessary to re-evaluate objectively the importance between the indicators, adjust the scale value in the judgment matrix, and redo the consistency test until $C_R<0.1$.

$$C_I = \frac{\lambda_{\max} - n}{n-1} \qquad (10)$$

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(\Re\omega)_i}{\omega_i} \qquad (11)$$

$$C_R = \frac{C_I}{R_I} \qquad (12)$$

C_I is the consistency index, and the larger the C_I value, the worse the consistency of the judgment matrix; $\lambda_{\max}$ is the maximum eigenvalue of the judgment matrix; R_I is the average consistency index, and its values depending on the order the judgment matrix are as shown in Table 2; $(\Re\,\omega)_i$ is the ith component of the vector $\Re\omega$.

Table 1. Elements and element values of the 1-9 scale method

Scaling O_{ij}	Relative degree	Scaling O_{ij}	Relative degree
1	O_i is as important as O_j	1	O_j is as important as O_i
2	O_i is as important as O_j ~ slightly important	1/2	O_j is as important as O_i ~ slightly important
3	O_i is slightly more important than O_j	1/3	O_j is slightly more important than O_i
4	O_i is slightly more important than O_j~ more important	1/4	O_j is slightly more important than O_i~ more important
5	O_i is more important than O_j	1/5	O_j is more important than O_i
6	O_i is more important than O_j~ very important	1/6	O_j is more important than O_i~ very important
7	O_i is more important than O_j	1/7	O_j is more important than O_i
8	O_i is more important than O_j~ absolutely important	1/8	O_j is more important than O_i~ absolutely important
9	O_i is absolutely more important than O_j	1/9	O_j is absolutely more important than O_i

Table 2. Average random consistency indicator

Matrix order	R_I	Matrix order	R_I	Matrix order	R_I
1	0.00	4	0.90	7	1.32
2	0.00	5	1.21	8	1.41
3	0.58	6	1.24	9	1.46

2.4 Risk classification

The risk value of each bridge is judged. According to the distribution of risk value, literature research and expert consultation, the risks are divided into three levels, shown as in Table 3.

(1) Level 1: It is expected that the normal water supply by the water outlet will be interrupted (seriously affected) for more than 24 hours. The large amount of abandoned water will cause greater economic losses and affect the water quality and ecological environment of the backwater area.

2) Level 2: It is expected that the normal water supply by the water outlet will be interrupted (seriously affected) for less than 24 hours, and a certain amount of water will be abandoned and cause large economic losses.

(3) Level 3: It is not expected that the water supply by the water outlet will be interrupted, but the gates need to be adjusted to treat the site.

Table 3. Risk values of each level

Risk level	Level I	Level II	Level III
Risk value（F）	$0.70\leq F\leq 1.0$	$0.45<F\leq 0.70$	$0<F\leq 0.45$

3 Conclusion

On the basis of the risk assessment system, the risks of the bridges along the line are evaluated and graded .Due to too much bridge information, the results of some bridge risk classification and related information are listed in Table 4.

Table 4. Risk grades of sudden pollution

Branch office	Management office	Bridge name	Stake number	level	Chemicals
Head branch	Dengzhou	Wang jia southwest highway bridge	K9+884.4	I	Gasoline, diesel, methanol, ethanol , explosive and toxic chemicals
	Dengzhou	Zhuying northwest highway bridge	K33+750	I	Gasoline, diesel, methanol, ethanol , explosive and toxic chemicals

	Nanyang	Manzi village northeast cross - channel highway bridge	109+996	I	Gasoline, diesel, explosive and toxic chemicals
	Fangcheng	Ma gang north highway bridge	144+372	I	Oil and toxic chemicals
Henan branch	Jiaxian	Shilipu highway bridge	K283+703.5	I	Gasoline, diesel, benzene, methanol, sodium hydroxide, asphalt, anhydrous ammonia, petroleum ether
	Xinzheng	Bei jing-Hong kong-Macao expressway	K384+128	I	Gasoline, diesel
	Xinzheng	Zheng xin road highway bridge	K376+335	I	Gasoline, diesel, natural gas, sulfuric acid
	Aviation port area	Four port linkage bridge	K411+886.49	I	Methanol, sulfuric acid, diesel oil, gasoline
	Aviation port area	Bei jing-Hong kong-Macao expressway	K412+640.71	I	Methanol, sulfuric acid, diesel oil, gasoline
	Xingyang	Science avenue bridge	456+725.47	I	diesel oil
	Wenbo	Ma zhuang southeast cross - channel highway bridge	k493+700.51	I	Methanol, diesel, gasoline
	Wenbo	Qi cun northeast cross - channel highway bridge	k518+140.50	I	Methanol, diesel, gasoline
	Hebi	Qibin road bridge	K665+116.38	I	Gasoline, diesel, methanol, propane, flammable liquids, corrosives, liquefied petroleum gas, compressed natural gas, sulfuric acid
Hebei branch	Cixian	Jiang wu cheng north bridge	3+490	I	Methanol, sulfuric acid, diesel, gasoline
	Cixian	Qinglan expressway bridge	25+170	I	Methanol, sulfuric acid, diesel, gasoline
	Handan	Xue Zhuang bridge	51+737	I	Gasoline, natural gas
	Shijiazhuang	Longquan bridge	225+640	I	Oil
	Tangxian	Shannan Zhuang bridge	332+420	I	Inflammable, explosive and corrosion products
Beijing branch	Yixian	Zhangshi highway bridge	183+150.8	I	Oil
	Laizhuo	Zhangye highway bridge	215+709	II	Inflammable chemicals and dust
	Laizhuo	Jingkun expressway bridge	219+069	II	Inflammable chemicals
Tianjin branch	Xiheisahan	Rongwu highway bridge	1119+391	II	Gasoline, diesel, benzene, methanol, sodium hydroxide, asphalt, anhydrous ammonia, petroleum ether, others

Note: The Stake numbers of the Hebei branch and the Beijing branch are based on the starting points of the first management offices of the branch offices; The Henan Branch and the Tianjin Branch start with the head of the line. Same as Table 5.

According to the results of risk assessment, the proportion of bridge risks at level one and level two is small, while the proportion of bridges at level three is relatively large. Precautions should be taken in the dense area of the bridges at level one and level two. The key prevention areas are displayed in Table 5. Geographically, Henan has the largest number of bridges, and its proportion of bridges at all levels is larger than those of other provinces and cities. Therefore, it should take a high degree of prevention for key prevention areas in Henan. The classification status of local bridges is presented in Figure 4, and the classification status of each branch bridges is shown in Figure 5.

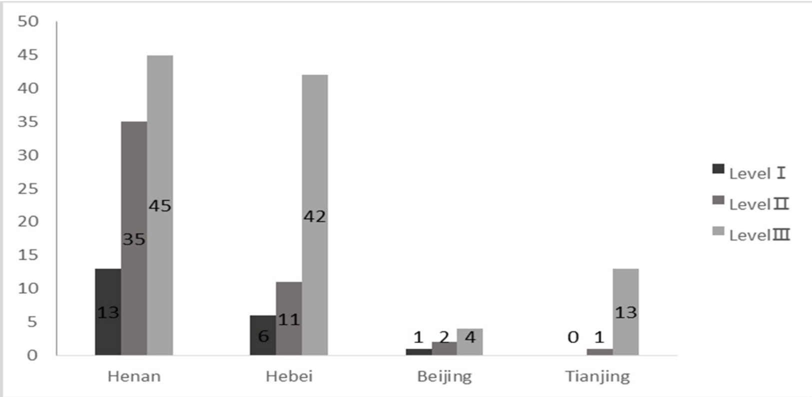

Figure 4. Bridge classification status map for each location

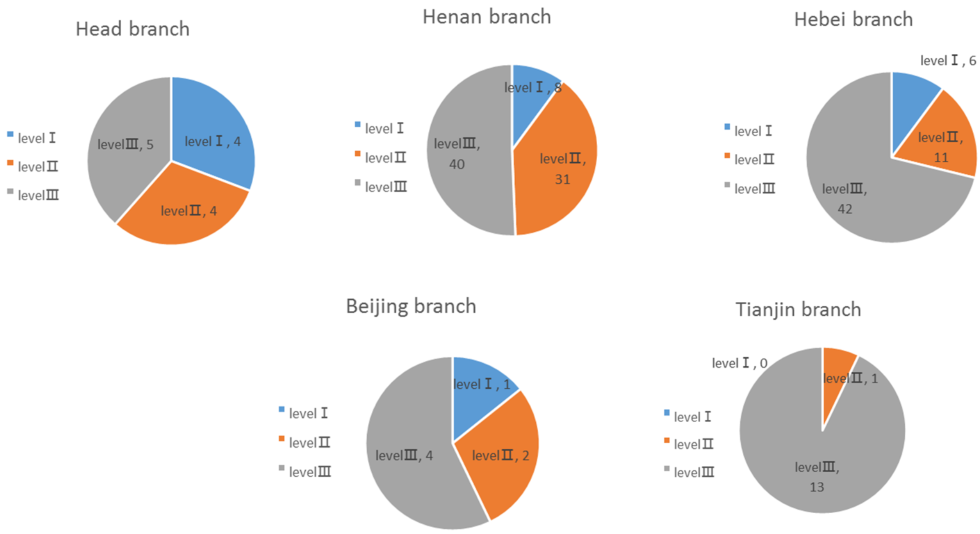

Figure 5. Classification status of each branch office

Table 5. Key prevention areas

Branch office	Stake number	Prevention area
Henan branch	K9+884.4～144+372	Wangjia southwest highway bridge ~ Magang north highway bridge
	k333+542.37~K412+640.71	Zhangnan highway bridge ~ Beijing-Hong Kong-Macao expressway bridge
	K665+116.38~k718+672.2	Qibin avenue highway bridge ~Bei Tuwang highway bridge
Hebei branch	3+490~59+323	Jiang Wucheng north bridge ~ Qinglan expressway bridge
	225+640~344+285	Longquan bridge ~ Baoyu expressway bridge
Beijing branch	183+150.800~219+069	Zhangshi highway bridge ~ Jingkun expressway
Tianjin branch	1119+169~1120+621	Zaoyuan bridge ~Xi Heishan highway bridge

In order to detail the prevention, after comprehensively considering the risk assessment results and the key prevention areas, special consideration should be given to the bridges that are closer to the water outlets and the ones that are farther away from the backwater gates. Considering the patrolling interval of patrollers along the line, the pollution may not be discovered in the first time. The flow velocity of the main canal along the line is fast, and the pollutants migrate and spread quite rapidly, so the bridges closer to the water outlets should be given certain emergency prevention and frequent inspection tours. For the bridges far from the backwater gates, emergency material reserves should be made in the middle route. According to the formula (3), considering that after the patrolling time, the pollution occurrence time is 60 minutes, the pollutant transport distance is calculated to be 2160 meters. Bridges within 2160 meters from the backwater gates and water outlets should be inspected and monitored emphatically, to avoid missing the optimal backwater time and affecting the water supply by the water outlets. Among them, the Dongzhuang west highway bridge, and the Zhengzhou southwest expressway bridge, etc., which are closer to the water outlet, need to be monitored intensively. Emergency material reserves need to make along the way for the Guandian north road bridge, and the Provincial road 314 South-to-North Water Diversion bridge, etc., which are closer to the backwater gates. The conditions of some bridges, water outlets and backwater gates can be seen in Table 6.

Table 6. Conditions of Bridges, water outlets and backwater gates

Name	Stake number	Distance（m)
Xu Pingnan expressway cross-channel highway bridge	K193+879	636
Xinzhuang water inlet	195+477	
Guandian north road bridge	k241+084	626
Shahe riverbackwater gate	241+710	
Manliu northeast highway bridge	k257+510	1517
Mazhuang water inlet	259+027	
107 national highway no.1 highway Bridge	K374+322	975
Li Wei water intlet	375+297	
Bohai road highway bridge	K440+224.68	2000.68
Jiayu river backwater gate	442+038	
Zhengzhou southwest expressway bridge	K453+897	258
Qian Jiangzhai water diversion	454+155	
Provincial road 314 South-to-North Water Diversion bridge	k478+027.55	878.58
Yellow river backwater gate	478+906.13	
Zheng Jiaojin highway bridge	K523+240	957
Fucheng water inlet	524+197	
Dapushui north highway bridge	K607+447.049	1569.951
Mengfen river backwater gate	609+017	
Yangzhuang north highway bridge	K647+125.02	1162.98
Yuanzhuang water inlet	648+288	
Xinxiang tunuxi highway bridge	K657+457.64	1267.36
Sanlitun water inlet	658+725	
Dongzhuang west highway bridge	k686+456.03	39.97
Dongzhuang water inlet	686+496	
Civilization avenue highway bridge	K711+035.2	1830.8
Nanliu temple water inlet	712+866	

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