Study on Water Environment Evaluation and Protection Measures During Highway Construction in Plateau Ecological Protection Area

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Abstract: Because the highway construction is located in the plateau ecological protection area, the change of water environment or environmental pollution is an important factor that needs to be grasped by the construction unit in time. Based on the analysis of water environmental pollution sources during highway construction, the water quality evaluation index factors were selected, which was aimed at the pollution characteristics of plateau ecological protection areas. Based on the entropy weight-extension matter-element theory, the water environment evaluation model was established, the corresponding protection and control measures were proposed, and the effectiveness of the measures was verified. The results show that: (1) The water environment evaluation index is selected, and the entropy weight-extension matter-element theory is based on the entropy weight and correlation degree calculated by the classical domain matter-element R_{0s}, the nodal domain matter-element R_p, and the matter-element R_i to be evaluated. Its comprehensive correlation degree is calculated, and then the quality level of the sample is obtained; the single factor index method does not consider the index weight problem in the evaluation process and the calculation method of the weight in the grey weighted correlation method is optimized, and the calculation accuracy is improved. (2) Based on the weight calculation results in the water environment evaluation model, the corresponding treatment measures were proposed, and the effectiveness of the treatment measures was verified. (3) The level of water environment can be reflected by the comprehensive correlation degree calculated by entropy weight-extension matter-element theory, and the distance between the determined water environment level and other levels can also be reflected. The construction unit can grasp the trend of water quality change in time and formulate corresponding wastewater treatment measures, which saves time and economic costs.

Keywords: highland ecological reserve; road construction period; entropy-entropy-topologic element theory; water environment evaluation model; water environment protection measures

1 Introduction

The Qinghai-Tibet Plateau is known as the ' roof of the world ', the ' third pole of the earth ', and the ' Asian water tower '[1]. It is an important plateau ecological reserve in China. In recent years, although the construction level of highway engineering has been continuously

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improved, in the highway construction period of the plateau ecological protection area, the problem of water pollution caused by earthwork excavation, tunnel construction and bridge construction is inevitable [2].

At present, there are few studies on the impact of domestic and foreign scholars on the water environment of the plateau ecological reserve during the highway construction period. Hu Lin [3] et al.believed that suspended solids (SS) is the main pollutant of land runoff in the plateau ecological reserve and the carrier of other pollutants. Li Leiming [4] and others believe that trace elements are the most dangerous pollutants because they are persistent, carcinogenic and environmentally toxic. Domestic and foreign scholars have not evaluated the current situation of water quality and paid attention to the trend of water quality change according to the construction characteristics of different regions.

A highway project in Qinghai Province is located in the National Forest Park Nature Reserve, and there are three secondary water source protection areas in the bid section, and the ecological environment is fragile. Based on a highway project in Qinghai Province, the characteristics of water environment in plateau ecological protection area and the pollution sources during highway construction were analyzed. Based on the entropy weight-extension matter-element theory, the evaluation index system and model that can reflect the pollution characteristics of the plateau ecological reserve were established, and the corresponding protection and control measures were proposed, and the effectiveness of the control measures was verified.

2 Evaluation index system of water environment during the highway construction period

2.1 Analysis of pollution sources during highway construction

2.1.1 Wastewater from living

According to the investigation, the domestic sewage produced by the construction camp is mainly the sewage and faecal water from the construction workers ' dining and washing. The main organic matter is grease, food residue, detergent, etc[5]. The main pollutant components and their concentrations are detailed in Table 1.

Table 1. Composition and concentration of domestic wastewater Unit:(mg/L)

key pollutant	SS	BOD_5	COD	TN	TP
concentration	60	100	240	15	4

2.1.2 Factory effluent

The production wastewater is mainly produced by washing wastewater of mechanical equipment in prefabrication yards and mixing stations, mechanical repair and oil spills during work[6]. The main pollutant components and their concentrations are detailed in Table 2.

Table 2. Composition and concentration of production wastewater Unit:(mg/L)

key pollutant	PH value	SS	oil contents
concentration	5~7	2500~4000	10

2.1.3 Construction wastewater

Construction wastewater is mainly caused by tunnel, bridge, and roadbed construction. In general, tunnel excavation, blasting, oil leakage of mechanical equipment and so on will increase the pollutant content of wastewater discharged from tunnel construction. Due to the influence of many factors, such as engineering geological conditions and construction progress requirements, the amount of discharged wastewater can range from several to hundreds per hour. According to the survey, the main pollutants in tunnel construction wastewater are petroleum and suspended solids (SS) [7]. The main pollutant components and their concentrations are detailed in Table 3.

Table 3. Composition and concentration of tunnel construction wastewater Unit:(mg/L)

Key pollutant	PH value	SS	NH_3-N	oil contents
concentration	9~10	500	3	11

In summary, the main pollution sources during highway construction are domestic, production, and construction wastewater; the main pollutants are petroleum and SS.

2.2 Selection of water environment evaluation index system

Based on the analysis of pollution sources during highway construction in plateau ecological reserve, six water quality evaluation index factors, such as petroleum, permanganate index, suspended solids (SS), pH value, total phosphorus (TP) and dissolved oxygen (DO), were selected as water quality evaluation system.

3 Water environment evaluation based on entropy weight-extension matter-element theory

3.1 Establishment of entropy weight-extension matter-element model

It is assumed that there are i sections of water environment that need to be classified by water environment during highway construction, and there are n factors that affect the classification of water environment. Therefore, the classification of water environment can be described by the following n-dimensional matter element:

$$R=(N_j,C_j,V_{ij})=\begin{bmatrix} N_j & C_1 & V_{i1} \\ 0 & C_{p2} & V_{i2} \\ \cdots & \cdots & \cdots \\ 0 & C_n & V_{in} \end{bmatrix} \tag{1}$$

In Equation (1), N_j represents the water environment to be classified in Section j; C_j represents the indicators that affect the classification of the water environment; V_{ij} denotes the value of the water environment concerning the index C_j (i =1, 2, ..., n).

According to the relevant specifications and evaluation criteria, the water environment is divided into s grades, and the classical domain matter element R_{os} of the water environment classification is obtained, namely:

$$R_{os} = (M_{os}, C_{oj}, X_{osj}) = \begin{bmatrix} M_{os} & C_{o1} & X_{os1} \\ 0 & C_{o2} & X_{os2} \\ \cdots & \cdots & \cdots \\ 0 & C_{on} & X_{osn} \end{bmatrix} = \begin{bmatrix} M_{os} & C_{o1} & \langle a_{os1}, b_{os1} \rangle \\ 0 & C_{o2} & \langle a_{os2}, b_{os2} \rangle \\ \cdots & \cdots & \cdots \\ 0 & C_{on} & \langle a_{osn}, b_{osn} \rangle \end{bmatrix} \quad (2)$$

In formula (2), M_{0s} denotes the sth level of the water environment; C_{oj} representation M_{os}'s the nth influencing factor（j=1， 2， …， n）； X_{pj}=<a_{pn}, b_{pn}> representation M_{os} correspondence the value range of C_{oj}. Quorum a_{osn} and b_{osn} represent the upper and lower limits of the range of grading index values for different water environmental levels. The joint domain matter element R_p is the value range of each factor corresponding to each water level, namely:

$$R_p = (P, C_{pj}, X_{pj}) = \begin{bmatrix} P & C_{p1} & X_{p1} \\ 0 & C_{p2} & X_{p2} \\ \cdots & \cdots & \cdots \\ 0 & C_{pn} & X_{pn} \end{bmatrix} = \begin{bmatrix} P & C_{p1} & \langle a_{p1}, b_{p1} \rangle \\ 0 & C_{p2} & \langle a_{p2}, b_{p2} \rangle \\ \cdots & \cdots & \cdots \\ 0 & C_{pn} & \langle a_{pn}, b_{pn} \rangle \end{bmatrix} \quad (3)$$

In formula (3), P represents all levels of the water environment determined by evaluation criteria; X_{pj}=<a_{pn}, b_{pn}> denotes the range of P values corresponding to C_{pj}.

The water environment to be evaluated, that is, the evaluation index factors of the water environment in the ith section, are expressed in the form of matter elements, and the matter element R_i to be evaluated for the classification of the water environment is obtained, that is:

$$R_i = (N_i, C_j, X_{ij}) = \begin{bmatrix} N_i & C_1 & X_{i1} \\ 0 & C_{p2} & X_{i2} \\ \cdots & \cdots & \cdots \\ 0 & C_{pj} & X_{ij} \end{bmatrix} \quad (4)$$

In formula (4), N_i represents the water environment to be evaluated in paragraph i; C_j represents each evaluation index factor of the water environment to be evaluated; X_{ij} indicates the value of the water environment in the first paragraph about the index C_j, that is, the specific value of a water environment grading index factor measured on site.

Because the value of each evaluation index factor is obtained through on-site monitoring, and the value range of each evaluation index factor is different. In order to facilitate the calculation and analysis, the linear range method is used to select the value of each evaluation index factor and normalize it. The calculation is as follows:

When the larger the evaluation index factor is, the more favourable the water environment level is:

$$r_{sj}^{*}=\frac{r_{sj}-\min r_j}{\max r_j-\min r_j} \quad (5)$$

When the smaller the evaluation index factor is, the more favourable the water environment level is:

$$r_{sj}^{*}=\frac{\max r-r_{sj}}{\max r_j-\min r_j} \quad (6)$$

In formula (5) (6), r_{sj}^{*} represents the dimensionless value of the jth evaluation index whose normalised water environment is the sth level; table r_{sj} shows the standard evaluation value of the jth evaluation index of the sth level of the water environment. $\max r_j$ represents the maximum standard value of the jth evaluation index; $\min r_j$ represents the minimum standard value of the jth evaluation index.

The water environment has s samples and each water environment level has n evaluation index factors are assumed; the normalized judgment matrix $R=(X_{ij})_{sn}$ is obtained. According to the concept of entropy, the entropy of each evaluation index factor is calculated, that is:

$$H_j=-\frac{1}{\ln s}\sum_{i=1}^{s}\frac{x_{ij}}{\sum_{i=1}^{s}x_{ij}}\ln\frac{x_{ij}}{\sum_{i=1}^{s}x_{ij}} \quad (7)$$

Then on the basis of the entropy calculation results, the entropy weight θ_j is calculated, namely:

$$\theta_j=\frac{1-H_j}{n-\sum_{j=1}^{n}H_j}\ 且\sum_{j=1}^{n}\theta_j=1 \quad (8)$$

The correlation function of the n th evaluation index factor of the s level of the water environment is assumed to be:

$$h_{sj}\left(X_{ij}\right)=\begin{cases}\dfrac{-\rho\left(x_{ij},X_{osj}\right)}{\left|X_{osj}\right|},x_{ij}\in X_{osj}\\[2ex]\dfrac{\rho\left(x_{ij},X_{osj}\right)}{\rho\left(x_{ij},X_{pj}\right)-\rho\left(x_{ij},X_{osj}\right)},x_{ij}\notin X_{osj}\end{cases} \quad (9)$$

Of which:

$$\rho\left(x_{ij},X_{osj}\right)=\left|x_{ij}-\frac{1}{2}\left(a_{osj}+b_{osj}\right)\right|-\frac{1}{2}\left(b_{osj}-a_{osj}\right)、\ \rho\left(x_{ij},X_{pj}\right)=\left|x_{ij}-\frac{1}{2}\left(a_{pj}+b_{pj}\right)\right|-\frac{1}{2}\left(b_{pj}-a_{pj}\right)$$

$$\left|X_{osj}\right|=\left|b_{osj}-a_{osj}\right|$$

The results of the above steps are synthesized, and the comprehensive correlation degree of N_i about grade s is calculated:

$$K_{is}(N_i)=\sum\theta_j h_{sj}(X_{ij}) \quad (10)$$

According to the identification principle in the maximum correlation theory, the formula of water environment grade utilization to be evaluated is described as:

$$K_{iso}(N_i) = \max\{K_{is}(N_i)\} \qquad (11)$$

The water environment grade to be evaluated is S_0.

3.2 Realization of entropy weight-extension matter-element model

3.2.1 Data selection and processing

Ten groups of monitoring samples from 10 typical sections of 'Environmental Impact Report of Jiading (Qinggan Boundary) to Haiyan (Xihai) Highway in Qinghai Province' (JGH (2016)-752) were selected, as shown in Table 4. The water environmental assessment standards are implemented in accordance with the ' Surface Water Environmental Quality Standard ' (GB3838-2002) [8] and the ' Groundwater Quality Standard ' (GBT14848-2017) [9].

Table 4. Sample data Unit:(mg/L)

Center pile number	oil contents	permanganate index	SS	PH value	TP	DO
K10+980	0.24	1.02	37	6.7	0.019	7.85
K60+350	0.04	0.91	34.2	7.0	0.079	7.93
K67+760	0.04	1.57	8.5	7.82	0.063	7.08
K74+730	0.04	0.84	13	7.1	0.017	6.23
K94+175	0.04	0.79	7.33	7.9	0.025	7.99
K107+830	0.04	1.63	10	7.6	0.021	6.14
K116+550	0.06	1.05	11.5	7.7	0.047	7.99
K156+070	0.04	2.2	22.5	7.9	0.023	7.03
K167+280	0.04	2.38	20.3	7.4	0.042	7.66
K181+560	0.04	0.74	11.67	6.9	0.013	7.73

3.2.2 Entropy weight method is used to calculate the weight of each evaluation index.

Based on the formula (2) ~ (6), the data in table 4 are normalized and the classical domain matter element R_{0s}, the nodal domain matter element R_p and the matter element R_i to be evaluated are calculated respectively. Since more sample sections are selected, K10+980 water environmental indicators are selected for specific introduction.

Based on formula (7) and formula (8), the weight value of each evaluation index factor is calculated, and its result is shown in table 5.

Table 5. The weight value of each evaluation index factor

index	C_1	C_2	C_3	C_4	C_5	C_6
weight	0.134	0.055	0.187	0.004	0.106	0.514

Based on formula (9), the correlation degree of each evaluation index factor with respect to each water environment level is calculated, as shown in Table 6.

Table 6. Correlation of each evaluation index factor on each evaluation level in section K10+980

	C_1	C_2	C_3	C_4	C_5	C_6
K_{1I}	-3.80	0.48	-0.90	0.38	0.05	0.13
K_{1II}	-3.80	-0.44	-1.92	-0.15	-0.01	-0.22
K_{1III}	-3.80	-1.55	-1.56	-0.83	-0.81	-1.93
K_{1IV}	0.42	-1.23	0.23	-1.83	-1.81	-1.41
K_{1V}	-0.52	-1.82	-0.26	-2.83	-2.81	-4.63

3.2.3 Determine the level of water environment

Based on Table 7, the correlation degree results of each evaluation index factor on each evaluation level are obtained, and the comprehensive correlation degree of each water environment on each water environment level is calculated by formula (10), as shown in Table 7.

Table 7. The comprehensive correlation degree of water environment in K10+980 section about each water environment grade

Center pile	K_I	K_{II}	K_{III}	K_{IV}	K_V	MAX
K10+980	-0.578	-1.008	-1.967	-0.887	-2.903	-0.578

Based on the identification principle in the maximum correlation theory, the water environment of K10 + 980 section is determined to be Grade I.

The water environment evaluation model based on entropy weight-extension matter-element theory was established. All samples in Table 3 were graded and evaluated. The results of grading evaluation are shown in Table 8.

Table 8. Environmental classification evaluation results of water in each section

Center pile number	KI	KII	KIII	KIV	KV	Level
K10+980	-0.578	-1.008	-1.967	-0.887	-2.903	I
K60+350	-0.315	-0.384	-1.295	-0.923	-2.940	I
K67+760	-0.198	-0.130	-1.371	-0.873	-2.583	II
K74+730	-0.137	-0.132	-0.798	-0.685	-2.210	II
K94+175	0.191	-0.537	-1.970	-1.165	-3.084	I
K107+830	-0.164	-0.231	-0.848	-0.666	-2.159	I
K116+550	0.031	-0.425	-1.819	-1.107	-3.044	I
K156+070	-0.125	0.296	-0.786	-0.807	-2.565	II
K167+280	-0.079	0.044	-1.190	-0.960	-2.859	II
K181+560	0.204	-0.330	-1.664	-1.085	-2.960	I

3.3 Comparative verification analysis

The classification results of the water environment evaluation model based on the entropy weight-extension matter-element theory are compared with the classification results of the water environment obtained by the single factor index method and the grey weighted correlation method [10] (the specific steps are not described). The applicability and accuracy of the classification results of the water environment evaluation model based on the entropy weight-extension matter-element theory are verified. The classification results of the three methods are shown in Table 9.

Table 9. Comparison table of the results of different water environmental evaluation methods

Center pile number	single factor index method		grey weighted correlation method	Entropy weight-extension matter-element method
	water quality classification	contaminant		
K10+980	I	oil contents, SS	I	I
K60+350	II	SS	I	I
K67+760	II	nil	II	II
K74+730	II	nil	II	II
K94+175	I	TP	I	I
K107+830	II	nil	I	I
K116+550	II	oil contents	I	I
K156+070	II	nil	I	II
K167+280	II	nil	II	II
K181+560	I	nil	I	I

It can be seen from Table 9 that the classification results obtained by the entropy weight-extension matter-element method are consistent with the classification results of the gray weighted correlation method in 9 places, and are consistent with the classification results of the single factor index method in 7 places. Its accuracy is 90% and 70% respectively.

The entropy weight introduced by avoids the subjectivity of weighting the evaluation index factors; the extension matter-element theory is used to effectively solve the problem of mutual influence between the evaluation index factors, and the water environment is qualitatively evaluated.

Therefore, the water environment evaluation model based on entropy weight-extension matter-element theory has good applicability and accuracy in the comprehensive evaluation of the water environment impact of the plateau ecological protection area during the highway construction period.

4 Study on water environment protection and control measures during highway construction

4.1 Treatment measures based on entropy weight-extension matter-element water body evaluation model

Based on the calculation of entropy weight and correlation degree in the article, it can be seen that the content of suspended solids SS and dissolved oxygen DO in this section has the greatest impact on water quality. Therefore, it is necessary to formulate corresponding treatment measures for this index: (1) The content of suspended matter SS is reduced: We use the physical principle to separate the suspended matter from the water. We use iron hydroxide to precipitate the suspended matter in water to the bottom by gravity, and use activated carbon filter to filter the suspended matter. (2) The content of dissolved oxygen in water is increased: the decomposition of organic matter in water can be promoted by increasing the number of microorganisms in water, so that the content of dissolved oxygen in water is increased. The specific methods include increasing the types of microorganisms in water and increasing the number of microorganisms in water.

Based on the entropy weight-extension matter-element theory, the K67+760 section of the water environment evaluation grade II was selected as the treatment sample. The water sample index after treatment was re-measured, and the correlation degree of each evaluation index factor with respect to each water environment level was calculated.

Table 10. K67+760 segment index content

Center pile number	oil contents	permanganate index	SS	PH value	TP	DO
K67+760	0.037	1.67	9	7.82	0.063	7.87

It can be seen from Table 10 that the corresponding control measures were implemented, and the changes of petroleum, permanganate index, PH value and TP index in K67+760 section were very small, but the content of suspended matter SS decreased, and the oxygen content DO increased significantly. Then the comprehensive correlation degree of K67+760 water environment about each water level is calculated (the calculation process is as above), and the results are shown in Table 11.

Table 11. The comprehensive correlation degree of water environment in K10+980 section about each water environment grade

Center pile number	K_{I}	K_{II}	K_{III}	K_{IV}	K_{V}	MAX
K67+760	-0.332	-0.438	-1.267	-0.877	-2.904	-0.332

Based on the identification principle in the maximum correlation theory, the water environment of K67+760 section is determined to be grade I.

4.2 Other sewage protection measures

4.2.1 Domestic sewage treatment measures

If the corresponding collection measures are not taken for the domestic sewage of the construction personnel, the generated wastewater may adversely affect the water environment near the construction camp. The domestic sewage in the construction camp contains COD, BOD, SS and grease, so the discharge of domestic sewage into the primary and secondary protection areas of the water source is prohibited. We recommend the use of mobile environmental protection toilets, which will not affect the area around the protection area. After the construction, the domestic sewage is treated uniformly.

4.2.2 Production and construction sewage treatment measures

The discharge of construction and production wastewater into the primary and secondary protection areas of water sources is prohibited. Construction flushing wastewater is treated: We use the precipitation method to treat the sand and gravel flushing wastewater. The sedimentation tank and the anti-seepage evaporation tank should be fortified by the construction site. After the sedimentation tank is treated, it is stored and recycled or evaporated in the evaporation tank. If necessary, the flocculant can be added, the precipitation is promoted, and the evaporation tank is cleaned and buried after the construction.

5 Conclusion

Based on the comprehensive evaluation of the impact of highway construction on the water environment of the plateau ecological protection area, the following conclusions are drawn:

(1) The pollution sources during the highway construction period were analyzed, and six water quality evaluation index factors such as petroleum, permanganate index, suspended solids (SS), PH value, total phosphorus (TP) and dissolved oxygen (DO) were selected as the water body evaluation system. The impact of highway construction period on the water environment of the plateau ecological reserve is comprehensively reflected by the water evaluation system.

(2) Compared with the single factor index method and the grey weighted correlation degree method, the entropy weight-extension matter-element theory is based on the entropy weight and correlation degree calculated by the classical domain matter-element R0s, the joint domain matter-element Rp, and the matter-element Ri to be evaluated. Its comprehensive correlation degree is calculated, and then the quality level of the sample is obtained. The single factor index method does not consider the index weight problem in the evaluation process and the calculation method of the weight in the grey weighted correlation method is optimized, and the calculation accuracy is improved. The applicability and accuracy of the method were verified.

(3) The water environment evaluation model based on entropy weight-extension matter-element theory is applied in practical engineering. The calculation results of weights show that petroleum, SS and DO account for a large proportion, indicating that petroleum, SS and DO play a decisive role in the surface water environment during the construction period of the highway. For SS and DO, we use iron hydroxide to precipitate the suspended matter in the water to the bottom by gravity, and use activated carbon filter to filter the suspended matter, increase the number and type of microorganisms in the water, and the water quality is obviously improved.

(4) The level of water environment can be reflected by the comprehensive correlation degree calculated by entropy weight-extension matter-element theory, and the distance between the determined water environment level and other levels can also be reflected. The construction unit can grasp the trend of water quality change in time and formulate corresponding wastewater treatment measures, which saves time and economic costs.

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