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Water Quality Monitoring and Evaluation of Four Rivers in Huadu District, Guangzhou

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Abstract: By collecting historical data, the water quality of four rivers in Huadu District was monitored, and the fuzzy comprehensive evaluation method was used to evaluate the water quality of the rivers. Introduce the concept of membership function and membership degree of the evaluation of water environment of river, establish the membership function of evaluation factor, the evaluation set, weight set and fuzzy set of subset, according to the size differences between pollution factor's influence on water quality to determine the weights, with fuzzy comprehensive evaluation method of huadu finally four major river water environment evaluation. The results show that the water quality of Tieshan River belongs to class II. The water quality of Xinjie River belongs to Class V, and the main pollutant is total nitrogen. The water quality of Tianma River and Tianmei River also belongs to Class V, with total phosphorus, total nitrogen and ammonia nitrogen as the main pollutants. The research results can provide scientific basis for source control and pollution interception and water environment safety in Huadu District.

1. Introduction

Water resources are an indispensable part of human survival environment. Water environment safety is closely related to human activities, world development and social stability, etc. [1, 2], and involves a huge system including population, economy, society and environment. However, in recent years, with the acceleration of urbanization, the growth of population and the development of industry and agriculture, the treatment of waste sewage lags, which makes the pollution of natural water intensified, and the contradiction between supply and demand of water resources have become increasingly acute, the importance of water quality control has gradually become prominent, and its safety problem has attracted the wide attention of governments and people at home and abroad. Thus, it promotes the development of water environment assessment. Water environment assessment refers to the objective qualitative and quantitative investigation, analysis, evaluation and prediction of water environment quality in a limited area according to the requirements of environmental hygiene and the prescribed evaluation standards and methods [3]. At present, there are many methods for water quality evaluation, such as the Nemerow pollution index method, grey clustering method, fuzzy comprehensive evaluation method and artificial neural network method [4]. There are a lot of fuzzy phenomena and concepts in the comprehensive evaluation of water environmental quality in the actual situation. The uncertainty of the monitoring value in the calculation of water quality classification is precise because of the interaction of a large number of factors and complex phenomena. Among them, it is more objective to describe the degree of water pollution by sampling membership of fuzzy comprehensive evaluation method [5-7]. By applying the synthesis principle of fuzzy relation, some water environment factors with blurred boundaries and difficulty to be quantified can be quantified, so as to carry out comprehensive evaluation and obtain evaluation results more in line with the actual situation [8, 9]. The fuzzy mathematics method has been used in the evaluation of surface water quality, groundwater quality, lake quality and drinking water quality.

In order to promote environmental improvement and ecological protection, 13 black and smelly river surges in Huadu District, including Tianma River, Huwu River, Tianmei River, Tieshan River, Daling River, Baini River and Xinjie River, have been listed on the list, according to the Task Book for the Remediation of Black and Smelly River Surges in Guangzhou (2016-2017) issued by the Guangzhou government. Since the document was issued by the municipal government, the government of Huadu District has made every effort to implement the work of water environment management and protection and has achieved considerable results. However, with the rapid development of urbanization and social economy, the confluence of rain and pollution has not been effectively solved, the composition of pollution sources is becoming more complex, and the comprehensive difficulty of control is still very great. Therefore, determining river water quality parameters and accurately evaluating river grades are of great significance to correctly understand the structure and function of the river ecosystem and tapping the potential of urban water resources [10].

2. Overview and Data Sources of the Study Area

2.1. Overview of the Study Area

Huadu District of Guangzhou City is located the north of Pearl River Delta, south-central Guangdong Province and north of Guangzhou City. Huadu is close to Qingyuan City in the north, Sanshui City in the west, Nanhai City in the southwest, Baiyun District in the south, and Conghua District in the northeast and east. Huadu District is located in the South Asian tropical monsoon climate zone, with long summers and short winters, high temperatures and high precipitation. The climatic changes in precipitation, wind direction, temperature, humidity and wind speed all have significant seasonal changes. Although the land resources are not rich, there are 18 kinds of minerals found, with high mining value and a large amount of savings are granite, limestone, kaolin and so on. There are many surface water rivers, but the river course is relatively short, the rainwater collection area is not large, the average annual diameter discharge is about 1.159 billion cubic meters, and 17 small and medium-sized reservoirs are built in the area. The surface runoff generated by rainfall is the main source of surface water.

2.2. Monitoring Regional River Profiles

Tianma River, one of the tributaries of Xinjie River, with a total length of 22.1 kilometers, is located in Xinhua Street, Huadu District.

The Tian Mei River is located in the middle of Huadu District and joins the Xin Jie River at the edge of Tai Tang.

Xinjie River, known as Hengtanshui in ancient times, is the boundary river between Guangzhou Baiyun District and Huadu District. Its mainstream from Tieshan River, Tonggukeng after the convergence, from east to west through Liantang, Xinhua Town, along the way Tianma River, Tianmei River into the water, the water quality changes fluctuate greatly.

2.3. Sample Collection and Analysis

2.3.1. Sampling Time, Frequency and Position

In order to make the water quality data more reliable and truly reflect the current water quality, it is necessary to select the sampling time, frequency and location reasonably. The sampling and analysis methods were carried out according to the relevant requirements of Surface Water Environmental Quality Standards [11] (GB3838-2002) and Technical Specifications for Surface Water and Sewage Monitoring [12]. The wet season of the four rivers was selected as the sampling time, and the sampling frequency was once a day. Sampling was carried out at the same point at the same time every day, and sampling was conducted continuously for one week. The time is from September 4th to 10th, 2017.

Table 1: Location of the monitoring section

River	Point	Longitude	Latitude
Xinjie River	D1	E113°26′19″	N23°39′24″
	D2	E113°22′84″	N23°37′52″
	D3	E113°20′14″	N23°36′34″
Tianma River	D4	E113°18′83″	N23°40′87″
	D5	E113°19′30″	N23°38′19″
	D6	E113°18′22″	N23°36′83″
Tianmei River	D7	E113°23′68″	N23°42′96″
	D8	E113°22′78″	N23°40′72″
	D9	E113°20′71″	N23°36′54″
Tieshan River	D10	E113°26′25″	N23°43′42″
	D11	E113°25′72″	N23°41′30″
	D12	E113°26′01″	N23°39′68″

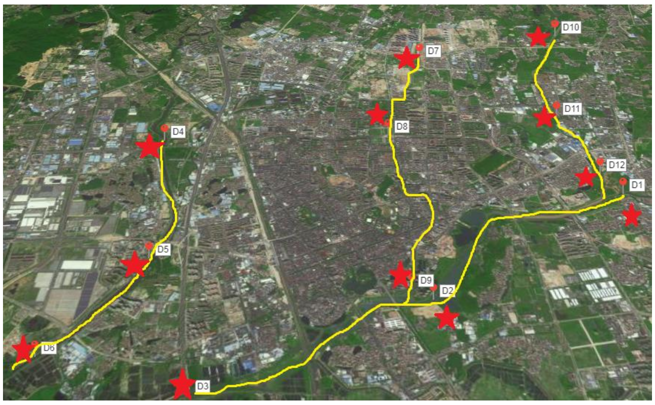

Figure 1: Schematic diagram of river monitoring points

According to the requirements of Technical Guidelines for Environmental Impact Assessment - Surface Water Environment (HJ/T2.3-93) [13] and the actual river site conditions, three monitoring sections are laid along each river according to the river hydrological conditions. The detailed locations of the sections are shown in Table 1 and Figure 1.

2.3.2. Water Quality Testing and Analysis

According to the "Surface Water Environmental Quality Standard (GB 3838-2002)", "chemical oxygen demand (CODcr), dissolved oxygen (DO), total nitrogen (TN), ammonia nitrogen (NH_3-N), phosphorus (TP)" total of 5 indicators as water quality parameters, as shown in Table 2. Its measurement method refers to the Environmental Quality Standard for Surface Water (GB 3838-2002).

2.3.3. The Data Analysis

Excel2007 and SPSS19.0 were used for statistical analysis, and the fuzzy comprehensive evaluation method was used to evaluate the environmental quality of these four major rivers.

3. Results and Analysis

3.1. Analysis of Water Quality Monitoring Data

According to the Technical Code for Surface Water and Sewage Monitoring (HJ/T 91-2002), the monitoring points of the four rivers were monitored, and the monitoring data after sampling and analysis were shown in Table 3.

Table 2: Environmental quality standards for surface water

serial number	project	Class I	Class II	Class III	Class IV	Class V
1	DO (mg/L)	7.5	6	5	3	2
2	CODcr(mg/L)	15	15	20	30	40
3	NH3-N(mg/L)	0.15	0.5	1.0	1.5	2.0
4	TP (mg/L)	0.02	0.1	0.2	0.3	0.4
5	TN (mg/L)	0.2	0.5	1.0	1.5	2.0

Table 3: Monitoring data of four rivers in Huadu District in September 2017

rivers	Point	DO (mg/L)	CODcr(mg/L)	NH3-N(mg/L)	TN (mg/L)	TP (mg/L)
New Street Surg	D1	6.24	17.83	0.41	1.58	0.18
	D2	4.99	25.33	0.91	2.89	0.26
	D3	2.51	23.33	2.69	4.68	0.30
	average	4.58	22.16	1.34	3.05	0.25
Tianma River	D4	5.14	22.83	5.82	9.8	0.38
	D5	3.18	20.83	5.83	8.94	0.36
	D6	3.41	19.17	4.86	8.89	0.30
	average	3.91	20.94	5.50	9.21	0.35
Tian Mei River	D7	4.84	21.67	0.62	2.53	1.58
	D8	5.45	30.5	1.47	4.09	0.31
	D9	2.86	25.5	2.97	5.08	0.27
	average	4.38	25.89	1.69	3.9	0.72
Iron Mountain River	D10	6.44	10.33	0.49	1.38	0.09
	D11	6.86	15.33	0.46	2.00	0.18
	D12	4.78	19.5	0.94	2.85	0.24
	average	6.03	15.05	0.63	2.08	0.17

Note: L indicates that the sample detection index is lower than the lower detection limit.

3.2. Fuzzy Comprehensive Evaluation Method

According to the uncertainty problem in the evaluation of the current water quality of surface water, a fuzzy subset is first used to replace various complex environmental factors of the water environment, and then the mathematical membership degree is used to describe the grading interface of the current water quality, in order to make each evaluation index quantitatively and clearly reflect the comprehensive state of the water quality of the corresponding water body when describing the water pollution level, different weights are assigned, and then the subset and membership degree can be obtained through the mathematical operation of the fuzzy matrix. The water quality category of the integrated water environment is judged according to the maximum value principle [14-16].

3.2.1. Fuzzy Comprehensive Evaluation Model of Water Quality

The mathematical model of fuzzy comprehensive evaluation is:

$$B=W\times R \tag{1}$$

By calculating the fuzzy relationship matrix R of single factors relative to each water quality level, and then calculating and multiplying the weight W of each factor in the comprehensive evaluation of water quality, it can be converted into the fuzzy relationship vector B [1] of the sample relative to water quality.

Factor set W = {X1, X2, X3, Xn }= {dissolved oxygen, chemical oxygen demand, ammonia nitrogen, total phosphorus, total nitrogen}; R= {$\{r_1,r_2,r_3,......,r_m\}$ = {I,II,III,IV,V}.

3.2.2. The Establishment of the Fuzzy Relation Matrix R

The fuzzy relationship matrix R is composed of the membership degree of each index relative to different rating classifications in the factor set, and the descending half-trapezoidal stepwise method is used to calculate the membership degree rij [17] of the participation factor xi in the corresponding water quality level. This paper sets a total of m levels for water quality categories, and Pij is the standard limit value of the item i entry factor in the corresponding water quality category j, and xi is the actual detected value of an evaluation factor [18]. In the evaluation of water environment quality, there is ambiguity between adjacent grades, while the fuzzy interval of the membership function belongs to the "first-level", while in other intervals, the degree of membership is constant at 1 or 0. For some indicators, the larger the value, the heavier the pollution, and its membership degree will be given by the following equation (2)~(4). The membership function of class I. water, when j = 1,

$$r_{i1}=\begin{cases} 1 & x_i\le P_{i1} \\ (x_i-P_{i2})/(P_{i1}-P_{i2}) & P_{i1}<x_i\le P_{i2} \\ 0 & x_i>P_{i2} \end{cases} \tag{2}$$

The membership function of class II, III and IV water bodies, that is, when j = 2, 3, 4,

$$r_{ij}=\begin{cases} (x_i-P_{i,j-1})/(P_{ij}-P_{i,j-1}) & P_{i,j-1}<x_i\le P_{ij} \\ (x_i-P_{i,j+1})/(P_{ij}-P_{i,j+1}) & P_{ij}<x_i\le P_{i,j+1} \\ 0 & x_i\le P_{i,j-1},\ x_i>P_i \end{cases} \tag{3}$$

The membership function of class V water, i. e. when j = 5,

$$r_{i5} = \begin{cases} 0 & x_i \leq Pi4 \\ (x_i - P_{i4}) / (P_{i5} - P_{i4}) & P_{i4} < x_i \leq Pi5 \\ 1 & x_i > Pi5 \end{cases} \quad (4)$$

Type: xi — the actual detected value of the item i indicator in the sample (i = 1, 2, 3, ..., m)

Pij— category j criterion for the item i indicator (j = 1, 2, 3, 4, 5)

The smaller the value, the more polluting the index (dissolved oxygen) has a different degree of membership calculation, and needs to replace "≤" with "≥" and ">" with "<" in Equation (2) and (4). For ammonia nitrogen (NH_3-N) the membership function for the five grading criteria is established as follows:

$$r_{i1} = \begin{cases} 1 & x_i \leq 0.15 \\ (x_i - 0.5)/ (0.15 - 0.5) & 0.15 < x_i \leq 0.5 \\ 0 & x_i > 0.5 \end{cases}$$

$$r_{i2} = \begin{cases} (x_i - 0.15)/(0.5 - 0.15) & 0.15 < x_i \leq 0.5 \\ (x_i - 1)/(0.5 - 1) & 0.5 < x_i \leq 1 \\ 0 & x_i \leq 0.15, x_i > 1 \end{cases}$$

$$r_{i3} = \begin{cases} (x_i - 0.5)/(1 - 0.5) & 0.5 < x_i \leq 1 \\ (x_i - 1.5)/(1 - 1.5) & 1 < x_i \leq 1.5 \\ 0 & x_i \leq 0.5, x_i > 1.5 \end{cases}$$

$$r_{i4} = \begin{cases} (x_i - 1)/(1.5 - 1) & 1 < x_i \leq 1.5 \\ (x_i - 2)/(1.5 - 2) & 1.5 < x_i \leq 2 \\ 0 & x_i \leq 1, x_i > 2 \end{cases}$$

$$r_{i5} = \begin{cases} 0 & x_i \leq 1.5 \\ (x_i - 1.5)/(2 - 1.5) & 1.5 < x_i \leq 2 \\ 1 & x_i > 2 \end{cases}$$

Similarly, membership functions of chemical oxygen demand, dissolved oxygen, total nitrogen and total phosphorus for the five classification criteria can be established. The membership function matrix of each evaluation factor for water quality at all levels is obtained according to the membership function of each evaluation factor and its measured value. Taking Xinjiehe D1 as an example, the corresponding fuzzy relation matrix can be obtained by the corresponding operation.

$$R_{D1} = \begin{matrix} 0.16 & 0.84 & 0 & 0 & 0 \\ 0 & 0.434 & 0.366 & 0 & 0 \\ 0.26. & 0.74 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.84 & 0.16 \\ 0 & 0.2 & 0.8 & 0 & 0 \end{matrix}$$

Similarly, the membership degree of indicators of other rivers to all levels of standards can also be obtained.

3.2.3. Determination of Factor Weight Distribution Vector W

In the comprehensive evaluation of water environment quality, the weight of each element reflects the influence of different factors on the comprehensive evaluation results of water environment quality, so different weights can be given according to the different effects of their influence on water quality namely:

$$Qi = xi/Pi (i = 1,2,......,m) \quad (5)$$

The weight Qi is normalized to get a new weight

$$Wi = Qi \Big/ \sum_{i=1}^{m} Qi \quad (6)$$

In the formula:xi— The measured concentration of a single factor;

Pi— Grade scale of single factor evaluation criteria. Here, the average concentration of the first 5 levels is taken;

Qi— The weight value of the ith factor in the sample before normalization

Wi— The weight value of the ith factor in the sample

The weight of dissolved oxygen (Q_{DO}) assignment can be obtained by the reciprocal of equation (5)

Table 4: Weight coefficient of water environment monitoring results of four rivers in Huadu District

The river	The weight	DO	CODcr	NH_3-N	TN	TP
New street River D1	Qi	0.75	0.74	0.40	1.52	0.88
	Wi	0.17	0.17	0.09	0.35	0.21
New street River D2	Qi	0.94	1.06	0.88	2.78	1.27
	Wi	0.14	0.15	0.13	0.40	0.18
New street River D3	Qi	1.87	0.97	2.61	4.5	1.47
	Wi	0.16	0.08	0.23	0.39	0.13
New street River average	Qi	1.03	0.92	1.30	2.93	1.23
	Wi	0.14	0.12	0.18	0.40	0.17
Tianma River D4	Qi	0.91	0.95	5.65	9.42	1.86
	Wi	0.05	0.05	0.30	0.50	0.10
Tianma RiverD5	Qi	1.48	0.87	5.66	8.60	1.76
	Wi	0.08	0.04	0.31	0.47	0.10
Tianma RiverD6	Qi	1.38	0.80	4.72	8.55	1.47
	Wi	0.08	0.05	0.28	0.51	0.09
Tianma River average	Qi	1.20	0.87	5.34	8.86	1.72
	Wi	0.07	0.05	0.30	0.49	0.10
Tian mei River D7	Qi	0.97	0.90	0.60	2.43	7.75
	Wi	0.08	0.07	0.05	0.19	0.61
Tian mei RiverD8	Qi	0.86	1.27	1.43	3.93	1.52
	Wi	0.10	0.14	0.16	0.44	0.17
Tian mei RiverD9	Qi	1.64	1.06	2.88	4.88	1.32
	Wi	0.14	0.09	0.24	0.41	0.11
Tian mei River average	Qi	1.07	1.08	1.64	3.75	3.53
	Wi	0.10	0.10	0.15	0.34	0.32
Iron Mountain River D10	Qi	0.73	0.43	0.48	1.33	0.44
	Wi	0.21	0.13	0.14	0.39	0.13
Iron Mountain River D11	Qi	0.69	0.64	0.45	1.92	0.88
	Wi	0.15	0.14	0.10	0.42	0.19
Iron Mountain River D12	Qi	0.98	0.81	0.91	2.74	1.18
	Wi	0.15	0.12	0.14	0.41	0.18
Iron Mountain River aveage	Qi	0.78	0.63	0.61	2.00	0.83
	Wi	0.16	0.13	0.13	0.41	0.17

Table 4 shows the weight statistics of water pollution factors of four rivers in Huadu District in September 2017.

3.2.4. Calculation of Fuzzy Comprehensive Evaluation Results

The factor evaluation matrix R and weight distribution vector W were multiplied. Taking Xinjie River D1 as an example, according to the principle of maximum membership, it can be determined that the surface water quality of Xinjie River D1 in September 2017 is Class II:

$$B = W \times R = \begin{matrix} 0.16 & 0.84 & 0 & 0 & 0 \\ 0 & 0.434 & 0.566 & 0 & 0 \\ 0.26 & 0.74 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.84 & 0.16 \\ 0 & 0.2 & 0.8 & 0 & 0 \end{matrix}$$

$$\times \{ 0.17, 0.17, 0.09, 0.35, 0.21 \}$$

$$= \{ 0.051, 0.325, 0.264, 0.294, 0.056 \}$$

The fuzzy comprehensive evaluation results of each sample, namely the membership degree of each influencing factor (Table 5), can also be obtained. The same can be said for the water quality of other rivers (Table 5).

Table 5: Water quality of four rivers in Huadu District in September 2017 (Comprehensive evaluation matrix)

The River	membership					Belongs to the category	Major contributing factors
	I	II	III	IV	V		
New street River D1	0.051	0.325	0.264	0.294	0.056	II	TN
New street River D2	0	0.023	0.388	0.189	0.400	V	TN
New street River D3	0	0	0.534	0.238	0.698	V	DO, NH_3-N, TN, TP
New street River	0	0	0.347	0.263	0.40	V	TN
Tianma River D4	0	0.007	0.079	0.314	0.880	V	NH_3-N, TN, TP
Tianma River D5	0	0	0.044	0.116	0.840	V	NH_3-N, TN, TP
Tianma River D6	0	0.008	0.058	0.154	0.790	V	NH_3-N, TN, TP
Tianma River	0	0	0.080	0.092	0.840	V	NH_3-N, TN, TP
Tian mei River D7	0	0.038	0.144	0.018	0.800	V	TN, TP
Tian mei River D8	0	0.045	0.081	0.420	0.464	V	TN
Tian mei River D9	0	0	0.074	0.247	0.700	V	NH_3-N, TN, TP
Tian mei River	0	0	0.110	0.183	0.717	V	NH_3-N, TN, TP
Iron Mountain River D10	0.212	0.398	0.094	0.296	0	II	TN
Iron Mountain River D11	0.097	0.322	0.161	0	0.042	II	TN
Iron Mountain River D12	0	0.029	0.413	0.089	0.410	III	TN
Iron Mountain River	0	0.433	0.154	0	0.410	II	TN

4. Conclusions and Recommendations

4.1. Conclusion

The water quality status of four rivers in Huadu District in September 2017, namely Xinjie River, Tianma River, Tianmei River and Iron Mountain River, was analyzed by the fuzzy matrix mathematics method. The comprehensive evaluation of water environmental quality was carried out, which objectively reflected the current environmental quality status of the main surface water in Huadu District. The following conclusions can be drawn:

1) Among the four rivers in Huadu District, Xinjie River, Tianma River and Tianmei River all belong to Category V, and the pollution is relatively serious. It indicates that the current Xinjie River, Tianma River and Tianmei River have not taken effective protection measures or the protection measures have not been completed. Only Tieshan River was classified as Class II.

2) Among the five conventional water quality parameters of the four rivers in Huadu District, the main pollution factors of Xinjie River and Tieshan River are total nitrogen, while the main pollution factors of Tianmei River and Tianma River are ammonia nitrogen, total nitrogen and total phosphorus.

4.2. Advice

In this paper, the fuzzy comprehensive evaluation method was used to evaluate the water environment quality of four rivers in Huadu District in September 2017. The results showed that the main pollutant in Xinjie River and Tieshan River was total nitrogen, followed by ammonia nitrogen. The Tianma River and Tianmei River are the main pollutants of total nitrogen, ammonia nitrogen and total phosphorus [19,20]. The ratio and load of nitrogen and phosphorus input into the water determine the growth of phytoplankton and algae in the water body and affect the eutrophication process of the water body. Eutrophication will lead to the explosive propagation of algae in the water body, and then lead to the decrease of dissolved oxygen in the water body, and the water body will be black and smelly. At the same time, a large number of toxic and harmful substances produced by dead algae directly threaten the survival of organisms and the balance of the whole water ecosystem [21,22].

The most polluted Tianma River and Tianmei River are located in the central urban area. Therefore, the main pollution factors of total nitrogen, total phosphorus and ammonia nitrogen are caused by the concentration of living areas and the discharge of a large amount of urban domestic sewage, such as catering industry wastewater, septic tank wastewater and the discharge of synthetic detergent. Xinjie River is also located in the central urban area, but since Xinjie River belongs to the confluence of Tianmei River and Tieshan River, all pollution factors have been diluted, even so, the total nitrogen exceeded the standard is still very serious [23,24]. Compared with the other three rivers, Tieshan River with better water quality is further away from the central city, and the main pollution source is non-point source pollution from agriculture. Therefore, the implementation of total amount control of pollutants is a top priority, on the one hand, to reduce the number of pollutants discharged, including accelerating the sewage treatment plants, urban pipe network construction, enterprise pollution, and the result of the cross-strait agricultural adjustment and reduce pesticide chemical fertilizer use, further strengthening sewage concentrated treatment, continuous improvement of denitrification and phosphorus removal method, Reduce the total amount of nitrogen and phosphorus nutrient pollutants [25,26]; On the other hand, river channel transformation, including river dredging, sewage interception and treatment, riverbank garbage removal, timely replenishment of fresh water, effectively improve the water environment quality of the four urban rivers, is very helpful to improve the quality of life of surrounding residents [27-29].

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