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An Ecological Compensation Model for Liuxi River Basin Based on Emission Rights

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Abstract

Researches on standards of ecological compensation will raise awareness of protecting the ecological environment in the basin and maintain the economy's and society's sustainable development. This paper constructed an ecological compensation model on the Liuxi River Basin in Guangzhou, China. Data and statistics were acquired from the statistical yearbook in Guangzhou Statistical Information Network, including the total GDP, total wastewater discharge amount and total population of Guangzhou for 13 years (1995, 2000, 2005–2015). Then, SPSS was used to fit the scatter plot of volume of wastewater discharged per capita and GDP per capita, and the most accurate regression equation was selected. Most importantly, an ecological compensation model was constructed based on emission rights and it was then used to calculate the annual eco-compensation fee for Conghua, where the river's upper part is located. The results showed that the amount of ecological compensation in 2017 was 33.821 billion Chinese Yuan, which should be used to compensate Conghua for the emission rights it had given up for protecting water quality of the Liuxi River. This study provided an effective reference to the government's decision on continuous improvement of the "Guangzhou Ecological Compensation Plan for Liuxi River Basin".

Keywords: emission rights, Liuxi River Basin, Conghua District, SPSS, ecological compensation model

1. Introduction

Since the Opening up and Reform, China's economy has achieved impressive growth, leaping from 13th place in 1980 to the 2nd largest economy in the world (Hu, 2012). However, such rapid growth had come at the expense of overexploitation of resources and wanton pollution emissions. The alarm was sounded when severe natural disasters like smog, sand storms, and floods ensued. At present, industrialization in the underdeveloped regions is to be brought about; yet meanwhile, they carry the burden to serve as water conservation areas and provide ecological services, which obstructed the regions' further development. The irrational utilization of water resources in river basins will lead to increasingly prominent ecological problems and can arouse ongoing conflicts between the upper reaches and lower reaches (Zhao, 2009; Chen et al., 2006). Ecological compensation mechanism was put forward to fully utilize the water resources and strengthen the ecological protection of river basins.

In recent years, researches on setting standards of ecological compensation have attracted the attention of many scholars (Geng, Ge, & Zhang, 2018; Wu et al., 2018; Chen & Cheng, 2018; Xiao, Shen, Wei, & Yong, 2018; Wen, Liu, & Wu, 2018). Numerous researches have already been done on discussing the model. It was defined as a type of assistance to ecological damage caused during development (Cuperus, Canters, & Piepers, 1996) and a remedy for the internalization of externalities (Li & Liu, 2010).

Zhang (1987) first presented the idea of eco-compensation in ecological terms. Subsequently, Gao and Huang (2003) proposed an eco-compensation model which focused on the issue of trans-boundary water pollution. The model suggested that the upper reaches should give subsidy to lower reaches for contaminating the water source, which has proven conducive to stimulating the effort of upper reaches administrators for treating pollution, promoting sustainable development for the entire river basin.

On the contrary, Zhang (2008) suggested that the policies which restrict pollution mainly in water sources and upper reaches of river basins generates additional costs due to the treatments of the contaminants. Therefore, he developed a different model in which lower reaches ought to subsidize the upper reaches to compensate for the economic losses caused by the reduction of pollutant rights due to restrictions.

The most updated works were overall data-based and multi-faceted. A research by Li and Fan (2017) presented a model of eco-compensation within Xin'an River basin in Zhejiang, China based on the local data of ecology and economy from 2005 to 2015. What's more, to calculate the reasonable payments of each province along the Yangtze River, Lu and Ke (2016) built a quantitative model of the basin based on the ecological footprint model, water resources overload index of the provinces, the ecological value, and regional compensation capability. Hu et al. (2011) discussed the measures to construct an ecological compensation model of Dongjiang River basin on an inter-provincial scale. When determining the sum of compensation, not only the analysis of the cost and benefits of ecological constructions was conducted, but also the economic development level and willingness to pay in different regions were taken into consideration.

As for worldwide, New York City purchased the eco-environmental services of the Catskills basin of the upper reaches in order to secure the quality of the water supply (Rosa, Kandel, & Dimas, 2004). To improve the water quality of the Elbe River, which flows through Germany and the Czech Republic, Germany, which is in the middle and lower reaches of the Elbe River Basin, established national parks and nature reserves in the area. What's more, Germany also compensated the Czech Republic (in the river's upper reaches) with collected sewage charges to build wastewater treatment plants near the river borders (Lindemann, 2008).

Guangzhou is the third largest city of China. The Liuxi River is of great significance to Guangzhou since it is the one of the city's main sources of drinking water and used to be the water source of Guangzhou Jiangcun Water Plant, Xicun Water Plant, and Shimen Water Plant. The length of Liuxi River in Conghua District is about 113 kilometers long, accounting for 72% of the total length of the river. And most parts of the river were water conservation areas and have always shouldered the responsibility of protecting the environment of the upper reaches of Liuxi River. Due to the adjustment of the zoning of Guangzhou Drinking Water Source Protection Area in 2017, the length of the protected area increased by 57.1 kilometers, which is an increase of 9.6%. Thus, the protection of the upper reaches and source areas of Liuxi River was further emphasized. Accordingly, stricter restrictions would be imposed for the development of the upper reaches to achieve better protection. If there are no appropriate economic compensation policies, it is evidently unfair for the upstream areas to suffer relative poverty, while the downstream areas enjoy the river's ecological benefits. Therefore, it is necessary for highly developed downstream areas to compensate the underdeveloped upstream areas through ecological compensation.

So far, the quantitative research on the ecological compensation standard of river basins in China is still in the preliminary phase. Although some models have been put forward, they are not flexible enough to adapt to all regions. In 2017, the Guangzhou Water Affairs Bureau published the "Guangzhou Ecological Compensation Plan for Liuxi River Basin". The scheme, which is the first of its kind in Guangzhou, proposed the calculation method for ecological compensation in various districts of the river basin. It is of great significance for the protection of the area's ecological environment.

In this research, the ecological compensation model of the upstream stream of the Liuxi River Basin in Guangzhou is discussed, based on the idea that the right to pollution is the right to development. Hence, the study is hoped to provide references for the improvements in ecological compensation method in this area.

2. Main Concepts

2.1 Emission Rights

Emission rights are the right of people to use resources and the environment. In essence, it is a pollutant discharge permit granted by the government to implement environmental management, allowing people to exercise the right to discharge pollutants within a reasonable range.

Emissions trading originated in the United States. American economist Dales first put forward the theory of emission trading in 1968 (Winch & Dales, 2002), and then Germany, Britain, Australia and other countries have implemented the emission trading in practice.

2.2 Basic Ideas

Wei and Shen (2011) put forward the idea that the right to pollution is the right to development, and Ding, Duan, Ge and Zhang (2009) proposed a similar contention. This paper agrees with the ideas and hold that the ecological protection quality of the upper reaches of the basin has a direct impact on the environments of the lower reaches.

Thus, the ecological protection's efforts and opportunity costs are to be compensated. However, if regions of the upper reaches polluted the rivers wantonly due to the neglect of ecological environment, compensation should be provided to the downstream areas, for water resources are shared by the whole basin.

This paper believes that the quality of environmental protection in the upper reaches of the basin has a direct impact on the downstream environment, and it is necessary to compensate for the efforts and opportunity costs of ecological protection. Due to the neglect of the ecological environment, upstream polluted rivers should provide compensation to the downstream areas so that the entire basin can share water resources.

2.3 Briefing of the Liuxi River Basin

Liuxi River originates from Guifeng Mountain in Lutian Town, Conghua District, the northern part of Guangzhou, and flows to the south. Its annual average flow rate is 90.1 m^3/s and its drainage area is 2300km^2. It exits Conghua from Taiping Town, flows through the Zhongluo Lake in Baiyun District, merges into the Baiji River, and finally flows into the South China Sea via the Pearl River Delta river network. Liuxi river a total length of 156 km. Its main tributaries are Niulan River, Yuxi River, Fentian River, Xiaohai River, Longtan River.

The Liuxi River Basin mainly includes three administrative districts: Conghua District, Huadu District and Baiyun District. The upper reaches of the river are all within the Conghua District, accounting for 64% of the total drainage area. The middle and lower reaches of the basin belong to Huadu District and Baiyun District. In the past 20 years, with the booming of Guangzhou's economy, the discharge of waste water has also been increasing rapidly. Due to the lack of the construction of sewage treatment plants in the basin, a large volume of sewage was discharged into the Liuxi River waters directly without having been treated effectively. The main water quality indicators in the lower reaches of the Liuxi River are at "Inferior to V-class level", the worst level on the chart, which is far below the legal standards. In 2017, the GDP of Conghua District, Huadu District and Baiyun District was 345.977 billion Yuan (Guangzhou Statistic Bureau, 2017).

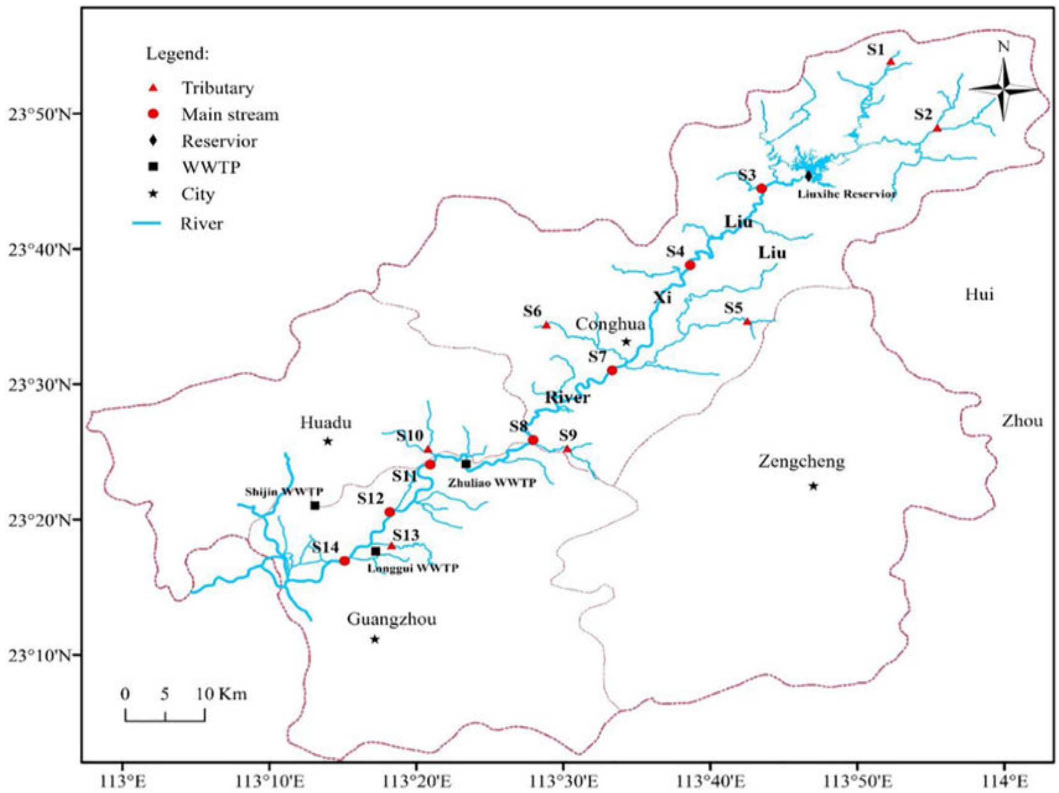

Figure 1. Map of Liuxi River Basin (Tang, Wang, Fan, Long, Wang, Tang, & Yang)

3. Modelling

3.1 Calculation of the Emission Rights

According to the theory in environmental economics, it can be hypothesized that there is a certain functional relationship between the GDP per capita (Gr) of the Liuxi River Basin and the annual amount of pollutant discharged per capita (Pr):

$$Pr = f\,(Gr) \tag{1}$$

Since the annual GDP per capita of each region of the basin (Gri) can be downloaded from the statistical information websites of each administrative region, the annual pollutants discharged per capita for the region (Pri), the theoretical emissions, can be calculated according to Equation (1). In addition, the actual amount of pollutant discharged per capita of each area of the basin (Prip) can also be obtained by consulting relevant statistics.

According to the theory of emission rights, the difference between the theoretical annual pollutants discharged per capita for the region (Pri) and the actual annual pollutant discharged per capita for the region (Prip) is defined as the emission right per capita (ERi), which is shown in Equation (2) below:

$$ERi = Pri - Prip \tag{2}$$

When Eri > 0, it indicates that an amount of pollutants is lost in the area due to the restrictions of protecting the river, thus the area should be compensated for the lost pollutants discharge; when Eri < 0, it indicates that the area over-discharged a number of pollutants due to economic developments, thus the area should compensate other regions for excess emissions.

Accordingly, the total amount of emissions (TER: Total Emission Right) that is lost or occupied in the region can be determined by the following Equation (3):

$$TER = ERi \times TPi \tag{3}$$

Among them, TER is the total amount of water pollutants lost or occupied in area i; TPi is the total population of area i.

3.2 The Eco-Compensation Model

Assuming that the price of a unit of emission rights is Pe (Price of Emission), the amount of ecological compensation (Mec) can be calculated by Equation (4):

$$Mec = TER \times Pe \tag{4}$$

3.3 Calculation of the Price of Emission Rights

As the emission rights of most pollutants cannot be traded through the market, it is difficult to determine the price of emission rights. So, its determination is still a hot topic in academia. Common calculation methods are the Recovery Cost Method, the Opportunity Cost Method and the Shadow Price Method. For instance, the price of discharging wastewater is calculated indirectly by accounting for the unit cost of wastewater treatment and the resulting GDP output.

3.4 Relationship Model Between Economic Development and Sewage Discharge in Guangzhou

3.4.1 Scatter Plot and Analysis

The GDP, wastewater discharge amount and population data for the past 13 years (1995, 2000 and 2005–2015) were obtained from the statistical yearbook in the Guangzhou Statistical Information Network (Table 1). SPSS was applied to draw the scatter plot and do curve fitting, with GDP per capita as the independent variable and wastewater discharge amount per capita as the dependent variable. The scatter plot is shown in Figure 1. The wastewater discharge amount per capita increases with the GDP per capita. But when the per capita GDP came to 120,000 Yuan, wastewater discharge amount per capita experienced fewer increases tends to stabilize. It can be deducted that the wastewater discharge amount per capita is approaching the inflection point, which is in line with the first half of the environmental Kuznets curve. This shows that with the continuous development of Guangzhou's economy, the awareness of environmental protection is being raised within citizens, whose ideological concepts and lifestyles are slowly changing.

Table 1. Economic development and Sewage Discharge Data of 1995, 2000 and 2005–2015 in Guangzhou

Year	GDP (Yuan)	Wastewater Discharge Amount (10000 tons)	Population (person)	GDP per capita (Yuan)	Wastewater Discharge Amount per capita (tons)
1995	24927434	91267	6467115	25626	141.12
2000	28416511	95434	7006896	28537	136.20
2005	32039616	125837	7505322	53809	167.66
2006	37586166	128302	7607220	62495	168.66
2007	44505503	111491	7734787	69673	144.14
2008	51542283	126156	7841695	76440	160.88
2009	60818614	119317	7946154	79383	150.16
2010	71403223	125662	8061370	87458	155.88
2011	82873816	141521	8145797	97588	173.73
2012	91382135	152747	8222969	105909	185.76
2013	107482828	157843	8323096	120294	189.64
2014	124234390	161484	8424169	128478	191.69
2015	135512072	161905	8541913	136188	189.54

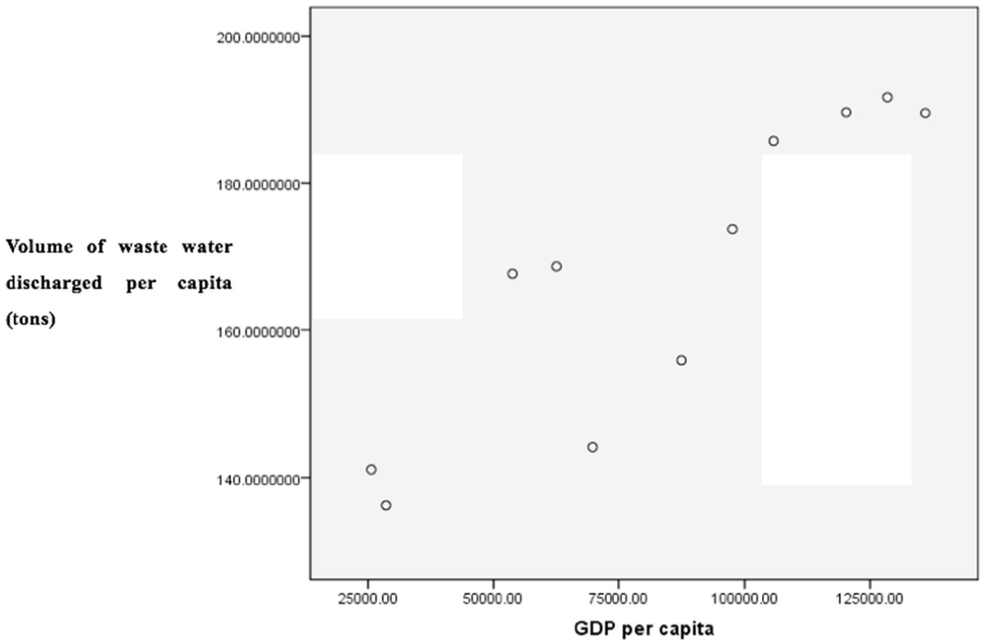

Figure 2. Scatter plot of the volume of wastewater discharged per capita and GDP per capita

3.4.2 Comparison of Different Curve Estimation Models

The SPSS is used to estimate the linear model, the quadratic model, the logarithmic model, the cubic model, the logarithmic model, the compound model, the power model, the growth model, and the exponential model in turn.

According to different models of R, R2, adjusted R2, standard error, F and Sig. F (Table 2), the optimal model is determined to fit Guangzhou's GDP per capita and Wastewater Discharge Amount per capita.

Table 2. The main statistics of the eight selected models

Models	Model summaries			Analysis of Variance		
	R	R2	Adjusted R2	Standard error	F	Sig. F
Linear	0.887	0.787	0.763	10.088	33.163	0.000
Logarithmic	0.863	0.745	0.716	11.033	26.249	0.001
Quadratic	0.887	0.787	0.734	10.684	14.794	0.002
Cubic	0.888	0.789	0.699	11.363	8.743	0.009
Compound	0.881	0.777	0.752	0.063	31.293	0.000
Power	0.866	0.750	0.722	0.067	26.971	0.001
Growth	0.881	0.777	0.752	0.063	31.293	0.000
Exponential	0.881	0.777	0.752	0.063	31.293	0.000

Among the eight models of the linear, logarithmic, quadratic, cubic, compound, power, growth and exponential model in Table 2, it could be seen that the adjusted R2 value of 0.763 in the linear model is highest and its Signif F value is less than 0.01, indicating that the linear model is statistically significant. So, the linear model is concluded to be the best match the relationship between GDP per capita and wastewater discharge amount per capita. Table 3 shows the Regression coefficients of the linear model.

Table 3. Regression coefficients

	Unnormalized coefficient		normalized coefficient	t	Sig.
	B	Standard error	Beta		
GDP per capita	0.000478	0.000083	0.886813	5.758743	0.000273
(constant)	127.809603	7.555749		16.9155434	0.000000

According to the linear model, the function of GDP per capita and wastewater discharge amount per capita in Guangzhou is:

$$Pr = 0.000478*Gr + 127.81 \quad (5)$$

Pr is the wastewater discharge amount per capita, while Gr is GDP per capita.

4. Calculation and Analysis

According to the Statistical Bulletin of the National Economic and Social Development of Conghua, Guangzhou in 2017, the GDP of Conghua District was 40.044 billion Yuan, and the total registered population of the district was 626,343. Meanwhile, the total amount of wastewater discharged was 25 million tons, 88% of which was treated. It can be calculated that the GDP per capita of Conghua District is 63,933 Yuan (RMB), and the wastewater discharge amount per capita is 45.343 tons in 2017

4.1 Calculation of the Total Emission Right of Conghua

Assuming that the wastewater discharge amount per capita of both the upper reaches and lower reaches of the Liuxi River Basin are consistent. According to the GDP per capita of Conghua in 2017 (63993 Yuan), the theoretical value of the wastewater discharge amount per capita in Conghua is calculated using Equation (5) to be 158.42 tons. The actual value of wastewater discharge amount per capita in 2017 is 45.343 tons, which indicates that 113.077 tons of sewage per capita were not discharged (Equation (2)). Therefore, according to Equation (3), the total emission rights (TER) lost from Conghua is:

$$TER = ERi \times TPi = 113.077 \text{ tons/capita} \times 626343 = 70824987 \text{ tons}$$

4.2 Determination of the Price of Emission Rights of Conghua

Li (2015), who adopted the Recovery Cost Method, processed data regarding the cost of treating water pollution in Guangdong Province from 2009 to 2013, and based on the loan interest rate of 6.25%. The price of the wastewater emission rights of Guangdong Province in 2013 was calculated to be 477.53 Yuan per ton.

Wei and Shen (2011) determined the functional relationship between economic development level and pollutants in Wenzhou according to the GDP per capita and the discharge amount of industrial wastewater per capita of consulting the Wenzhou Statistical Yearbook (2003–2008). He then estimated the amount of sewage discharged in Wencheng County, and concluded that 70% of the emission rights per capita in Wencheng are not used, which stated that the county gave up 70–178 million tons of industrial sewage due to the need to ensure its water quality. The annual loss was calculated to be 2.47 to 4.49 billion Yuan using the lowest output value of industrial wastewater. Therefore, the price of wastewater emission rights in Wencheng, Wenzhou is 252.25–352.86 Yuan per ton.

As the price of emission rights is in line with the region’s geographical and economical situations, in this paper the price of emission rights in Guangdong in 2013 is used as the price of emission rights in Conghua, which is 477.53 Yuan/ton.

4.3 Calculation of Ecological Compensation Value in Conghua

According to Equation (4), the ecological compensation value of Conghua is calculated as below:

$$Mec = TER \times Pe = 70,824,987 \text{ tons} \times 477.53 \text{ Yuan/ton} = 33.821 \text{ billion Yuan}$$

In 2017, the Guangzhou Water Affairs Bureau published the “Guangzhou Ecological Compensation Plan for Liuxi River Basin”. Although it contains the calculation methods of the ecological compensation values and fund allocation methods for each district in the Liuxi River Basin of Guangzhou, the annual budget for the compensation remains obscure. Therefore, it is impossible to calculate the ecological compensation value according to the plan. Also, the ecological compensation must be discussed on the premise of meeting the environmental emission standards. The ecological compensation value calculated in this paper may serve as a reference for the determination of the amount of funds for ecological compensation in the Liuxi River Basin of Guangzhou.

5. Discussion

The purpose of establishing an ecological compensation model is to estimate the reasonable amount of ecological compensation. The emission rights and the price of emission rights are the two key influencing factors of the amount of ecological compensation. In this paper, the amount of sewage discharge is used to indicate the emission rights of the region; yet, the types of sewage, including the difference in content and concentration of pollutant, are not included. Different types of sewage vary in their contributions to the GDP. The large difference in the types of sewage generated by different industries would result in deviations in the calculation of emission rights between the upper and lower reaches of the river,

In addition, due to difficulties in obtaining the data of sewage treatment cost of the Conghua District, this paper cited the price of the emission rights based on the water pollution control cost of Guangdong Province in 2009–2013 and banks' interest rate during the time period as the basis for calculating the amount of ecological compensation. As the amount and quality of sewage water can greatly influence the cost of treatment, there may be some error in the estimation of the price of the emission rights.

However, despite the potential errors, with the calculation method of the amount of ecological compensation presented, this paper is still significant in providing a reference for the determination of the amount of funding for ecological compensation in Liuxi River Basin of Guangzhou.

6. Conclusion

This paper, based on the emission rights, built the ecological compensation model of Liuxi River Basin in Guangzhou. According to the economic development data and waste water discharge data of Guangzhou and Conghua, the opportunity cost which Conghua gave up for the protection of the water quality of Liuxi River is calculated. The ecological compensation amount for Conghua in 2017 is determined to be 33.821 billion Yuan, accounting for 84.5% of the district's total GDP. The research aims to provide references for the continuous improvement of the "Guangzhou Ecological Compensation Plan for Liuxi River Basin". Yet, this study faces several shortcomings. As the pollutant discharge data of each district in the Liuxi River Basin is currently unavailable to the public, the data used during the construction of the model is not yet sufficient. Moreover, the subjective judgments are included in the determination process. These aspects are hoped to be improved in further studies.

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