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Water Safety Assessment of Drinking Water of Hanjiang River in Wuhan City, China

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Based on researching related literature information and considering the actual situation of Hanjiang river in Wuhan, this work took PSR model to construct the safety assessment of this district. We adopt expert consultation, AHP to determine weights and comprehensive index method to evaluate the safety status of water environment of Hanjiang river in Wuhan. The results show that the environmental safety of Hanjiang river in Wuhan is 0.572; the water environment is significantly lower than the national average in each subsystem, it is a vulnerable system to impact this region; Per capita food, engel coefficient of urban residents and percentage of river pollution, *etc.* are sensitive factor of Hanjiang river in Wuhan.

Key Words: Hanjiang river, Wuhan, Water safety, PSR model, AHP.

INTRODUCTION

In recent years, security issues in water environment have continue to appear frequently both nationally and internationally. Such as aluminum toxic waste spill in Hungary, the water bloom problem in Hanjiang river, the Zijin Mining pollution incidents in Tingjiang Fujian province and the oil spill in Dalian, *etc*. It indicates that the water environmental problems has constitute a serious threat to our people's production and living standard, to assess the existing water bodies of water environment safety is imminent. The study on current water environmental safety were focused on surface water resources and the water environment security assessment, analysis tools, the evaluation methods and contents and the index system are different[1]. The present work is aiming to establish an evaluation system from socio-economic system, environmental system and water environment system to ascertain a safety system of the water environment stress factors from an example of Hanjiang river in Wuhan, in order to provide scientific basis for management and water protection and to provide technical support for water safety evaluation in other areas.

It's length of 62 km in the Wuhan section of the Hanjiang river which contains Caidian district, east and west Lake, Hanyang and Qiaokou district in Hankou. Hanjiang river is not only an important source of drinking water in Wuhan, but also a receiver of the industrial and agricultural water use and some industrial waste water especially the cross-strait agricultural waste water, domestic sewage. Over the years, the Hanjiang river water quality is good and has remained at more than two categories. But in recent years, with the advance of south-to-north water diversion central line project, lead to reduction and a sharp decline of the downstream, coupled with the cascade development ongoing, will constitute a serious threat to the downstream water environment safety. As an first city in Hubei province, Wuhan City's economic output and development capabilities has an important influence to the surrounding countries. With the great relationship between water environment security and the around industrial enterprises and local residents, therefore, to evaluate the water environment safety is reasonably becoming very important[2].

EXPERIMENTAL

Water environment security index system: By taking science, operability, flexibility and timeliness as the principle and thingking of the full water environment situation, we selected 19 from a number of index indicators and constructed an index system from three leversof pressure-state-response (Table-1).

According to AHP theory, discussing, consulting, comparing and judging from the relatively important indicators, we obtain the index matrix and then summarized the results of expert evaluation. The results were satisfied with the consistency (Table-2).

Weight determination and calculation of safety: Comprehensive evaluation of the safety of the water environment is an process to quantitative the environmental safety of water.

TABLE-1
INDICATOR SYSTEM FOR ASSESSMENT OF REGIONAL WATER ENVIRONMENT SECURITY IN WUHAN

Pointer type/Field of evaluar	Pressure Indicators	Status Indicators	Response Indicators
Socio-economic	Population growth rate	GDP per capita	The number of people with high education
	GDP growth rate	Engel coefficient of urban	Rural per capita net income
	Per capita food	Urbanization	Average years of schooling
	Life expectancy	Gross Industrial Output Value	
Ecological Environment	Utilization of organic fertilizer	Green coverage	Industrial wastewater treatment rate
	Chemical fertilizer load	Diameter than the sewage	Urban sewage treatment rate
	Stocking rate	Urban green space per capita	Rate of land degradantion control
	Biodiversity	Area of soil erosion	Manure treatment rate
	Effective irrigation area /Arable land	Functional area of urban water quality compliance rate	The environmental protection investment – GDP Percentage
			Rate of soil erosion
Water environment	BOD concentration of water	Water resources per capita	Solution rate of drinking water fluorosis areas
	Funnel area	Water resource per mu	Environmental water
	Utilization of water resources	The daily per capita water	Compliance rate of groundwater quality
	The propotion of water quality and safety	Flood control standard	Compliance rate of groundwater quality
	Percentage of river pollution		Compliance rate of drought
	The extent of groundwater exploitation	The number of deaths caused by water problems	

TABLE-2
SECURITY LEVEL OF WATER ENVIRONMENT OF HANJIANG RIVER IN WUHAN

Subsystem	Indicators	Weight		Evaluation function
Socio-economic system	GDP per capita	0.163	0.368	$y = -0.134 + 0.005x^{1/2}$
	Per capita food		0.053	$y = -0.6 + 0.06x^{1/2}$
	Engel coefficient of urban		0.135	$y = 1.563-2.159x^{1/2}$
	Urbanization		0.135	$y = -0.462 + 1.462x^{1/2}$
	Rural per capita net income		0.235	$y = 0.01x^{1/2}$
	The number of people with high education		0.073	$y = 0.32 + 0.02x^{1/2}$
Ecological environmental system	Chemical fertilizer load	0.297	0.068	$y = 2.264-2.667x^{1/2}$
	Effective irrigation area /Arable land		0.068	$y = -2.789 + 3.789x^{1/2}$
	Diameter than the sewage		0.108	$y = 0.75-0.75x^{1/2}$
	Urban green space per capita		0.203	$y = -0.022 + 0.220x^{1/2}$
	Industrial wastewater treatment rate		0.127	$y = -2.789 + 3.789x^{1/2}$
	Urban sewage treatment rate		0.174	$y = -1.454 + 2.454x^{1/2}$
	Rate of soil erosion		0.148	$y = -0.775 + 1.775x^{1/2}$
	The environmental protection investment –GDP Percentage		0.278	$y = -0.209 + 0.66x^{1/2}$
Water environmental system	Water resources per capita	0.540	0.167	$y = -0.19 + 0.019x^{1/2}$
	Percentage of river pollution		0.167	$y = 0.885-0.885x^{1/2}$
	Utilization of water resources		0.167	$y = 1.40-1.266x^{1/2}$
	Compliance rate of groundwater quality		0.167	$y = -0.366 + 1.366x^{1/2}$
	The daily per capita water		0.167	$y = 0.339 + 0.027x^{1/2}$

After evaluation in determining the indicators, we firstly normalized the actual value of the index data and got a dimensionless index; what's more, empowered by AHP analysis, we weighted the dimensionless parameters of the unit index and the weight parameters and got the comprehensive evaluation index[3]; thirdly we divided it into levels according to a certain interval. The aim is to evaluate the safety of the water environment by using comprehensive index.

Dimensionless index values: This paper selects the function $y = a + bx^{1/2}$, where a and b as parameters in the model[4]. The reason for selecting the index 1/2 power function is because that this function is common and simple and at the same time the function of the growth meet the significance of safety index. If x take the worst value, then y take 0; if x take the passing value, then y take 0.6; if x take the optimal value, then y take 1. Each indicator's child safety evaluation function shown in Table-2.

Calculation of system level indicators: System level indicator value is weighted according to their respective values of the indicators and their product weight. System safety is calculated by the model:

$$E = \sum_{i=1}^{m} E_i \times W_i$$

where, E- the size of the system safety; E_i- the I indicators of the child safety values; W_i- the I weight indexes; m-number of indicators.

Calculation of comprehensive safety water safety: Comprehensive assessment of water environment safety index is the value used by the system safety after their added weight to evaluate the water environment safety. The weight of the system safety is obtained through the AHP. The following formula:

$$WES = \sum_{i=1}^{m} W_i E_i$$

where, WES-Comprehensive assessment of water environment safety index; Ei-The i-weight of the system security; Wi- the i-degree of a value system security; m-the number of subsist.

Security index level divided by a certain interval: Reference to a variety of classification methods, this study adopted a multi-level grading standards[5] and given the corresponding classification reviews (Table-3).

TABLE-3
SAFETY INDEX FATING FORM

Level	Safety index	Reviews
1	0.90-1.00	Security
2	0.70-0.89	Safer
3	0.50-0.69	Less secure
4	0.30-0.49	Unsafe
5	<0.30	Very insecure

Safety assessment of water environment of Hanjiang river in Wuhan: Taking 2008 as the current year, on behalf of the relevant indicators into the calculation of the numerical model, we got the safety indicators both in Hanjiang river in Wuhan and the nation. Further, we calculated the child and the general safety. the results shown in Table-4.

Table-4 shows the mainly indicators influence the safety of water environment in Wuhan section is: very insecure (per capita food, Engel coefficient of urban, percentage of river pollution); unsafe (GDP per capita, diameter than the sewage, water resources per capita); less secure (the number of people with high education, chemical fertilizer load, effective irrigation area /arable land, Urban green space per capita, Urban sewage treatment rate. The environmental protection investment -GDP percentage); safer (rural per capita net income, utilization of water resources, compliance rate of groundwater quality. The daily per capita water); security (urbanization, industrial wastewater treatment rate, rate of soil erosion).

It can be seen that the main problem of water environmental safety in Hanjiang Wuhan section is: on the one hand, per capita food production is not enough, the living standard of urban residents is not high and some rivers are serious polluted; on the other hand, with the large population base existing, although the total GDP has been improving, per capita GDP and unequal distribution problems in per capita water resources are still existing. At the same time, the Hanjiang river in Wuhan section still have great room for improvement in reducing the load of fertilizer, improving the effective irrigation area, increasing the per capita green area of the city and enhancing the amount of such investment in environmental protection.

RESULTS AND DISCUSSION

Table-4 shows that current year the main indicators to impact the national water safety are: very insecure (Engel coefficient of urban, effective irrigation area /arable land, Urban sewage treatment rate); unsafe (percentage of river pollution); less secure (GDP per capita, per capita food, urbanization, rural per capita net income, Urban green space per capita, rate of soil erosion. The environmental protection investment-GDP percentage, water resources per capita); safer (industrial wastewater treatment rate, utilization of water resources, compliance rate of groundwater quality. The daily per capita water); security (chemical fertilizer load).

Compared the results of Hanjiang river in Wuhan with the 2008 national data, it can be drawn to determine that the main indicators to impact the national water environment are Engel coefficient of urban, effective irrigation area/arable land, Urban sewage treatment rate and percentage of river pollution, *etc.*; some influence indicators are GDP per capita, per capita food, urbanization, rural per capita net income, Urban green space per capita, rate of soil erosion. The environmental protection investment -GDP percentage and water resources

TABLE-4
RESULTS OF EACH INDEX, SUBSYSTEMS AND INTEGRATED SAFETY

Subsystem	Indicators	X value (2008)		Safety					
				Indicator E_i		Subsystem E		General WES	
		HWs	N	HWs	N	HWs	N	HWs	N
Socio-economic system	GDP per capita	43891	22640	0.314	0.618	0.509	0.568	0.572	0.579
	Per capita food	142.5	398.1	0.116	0.597				
	Engel coefficient of urban	41.2 %	37.9 %	0.177	0.234				
	Urbanization	90.0 %	46.6 %	0.925	0.536				
	Rural per capita net income	6349	4761	0.797	0.690				
	The number of people with high education	350	175	0.694	0.585				
Ecological Environmental system	Chemical fertilizer load	0.390	0.261	0.598	0.901	0.757	0.623		
	Effective irrigation area /Arable land	76.7 %	48 %	0.529	0				
	Diameter than the sewage	0.130	0.016	0.480	0.655				
	Urban green space per capita	9.32	9.71	0.650	0.664				
	Industrial wastewater treatment rate	98.99 %	93 %	0.981	0.865				
	Urban sewage treatment rate	65 %	32.33 %	0.524	0				
	Rate of soil erosion	90 %	55 %	0.909	0.541				
	Environmental protection investment-GDP percentage	1.2 %	1.49 %	0.514	0.597				
Water environmental system	Water resources per capita	913	2071.1	0.384	0.675	0.490	0.558		
	Percentage of river pollution	70 %	37.6 %	0.145	0.342				
	Utilization of water resources	25.3 %	19.5 %	0.763	0.841				
	Compliance rate of groundwater quality	80 %	66.7 %	0.856	0.750				
	The daily per capita water	281	219	0.792	0.739				

(HWs-Hanjiang Wuhan section; N-National) per capita, *etc*. These safety factors are very different from the water environment safety of Hanjiang river in Wuhan.

Seeing from the perspective of various subsystems, the safety of Hanjiang river in Wuhan is slightly higher than the national average level, the socio-economic subsystem is slightly lower than the national average, but the water subsystem is significantly lower than the national average and it is a vulnerable system which can impact this region. Data show that the ecological conditions of Hanjiang river in Wuhan is slightly higher than the national average. It is because the gradual increase awareness of the ecological environment and investment by constructing environment-friendly and resource-saving society and the government has improved the ecological environment to some extent through continuous improvement; though the level of socio-economic development of Hanjiang river in Wuhan is relatively close to the national average, the security is still grim, which is significantly lower than the national average. Therefore, to solve environmental problems in the system is the key to improve the safety of the water environment of the region.

The safety of the water environment of Hanjiang river in Wuhan is 0.572 while the nation is 0.579, indicating that the both of their rapid development level in economy and society are at the cost of the safety of water. Water security has become an currently facing implication of Hanjiang river in Wuhan and the country's development.

Control measures: It can be seen from the indicators of water safety that Engel coefficient of urban, percentage of river pollution, GDP per capita, per capita food, water resources per capita, Urban sewage treatment rate and the environmental protection investment-GDP percentage are the factors to impact the safety of Hanjiang river in Wuhan. Therefore, we give the following recommendations: should strive to improve the level of family income of urban residents in the construction of water environment safety; improve the level of river pollution and in time management, time monitoring;Speeding up the construction of urban sewage treatment plants in the upper reaches of Hanjiang river; improve the urban sewage treatment rate; vigorously protect basic farmland, water conservancy construction, to ensure that food production in the region; make preparations for food reserves; promote a comprehensive water conservation to improve the utilization of water resources; continue to increase investment in environmental protection, improve environmental management; advocate to establish of emission rights trading system, *etc*; stick to construct the ecological environment in the region to provide the necessary protection.

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