Journal of Environmental Sciences Vol. 7, No. 4, pp. 430—434, 1995 ISSN 1001—0742

Study on urban water environmental support capacity

Guo Huaicheng, Ye Wenhu

Center of Environmental Sciences, Peking University, Beijing 100871, China

Abstract—A new concept of urban water environmental support capacity and its quantitative method are presented and applied to analyze water environmental support capacity in Benxi City, China. In this method, the size and relative size of water environmental support capacity E_j can show as follows:

$$|\tilde{E}_j| = \sqrt{\sum_{i=1}^{n}(\tilde{E}_{ij})^2} \quad \textit{and} \quad E_j = \sqrt{\frac{m^2}{n}\sum_{i=1}^{n}(\tilde{E}_{ij})^2}\text{ , respectively.}$$

Keywords: water environmental support capacity; urban water environment; development variables; support variables.

1 Introduction

Water environmental support capacity (WESC), a newly proposed concept, is a basic attribute of water environment with limited self - adjusting capacity. It means that certain water environmental condition and structure can bear a limited value on scale, intensity and speed under a prerequisite of being harmless to human live and development (Ye, 1991). WESC is different as the speed scale of economic development in a city. Therefore, it can be used as judging the size of support capacity for urban water environment. For this purpose, the indicators describing urban water environmental support capacity are discussed, and then a quantitative method is presented.

In a case study, the method is applied to support capacity analysis of water environment in a new zone for economic and technological development in Benxi City, China.

2 Quantitative method for urban water environmental support capacity

2.1 Selection of indicators

To select suitable indicators is a key link quantitatively describing water environmental support capacity. Urban water environment provides a necessary material base for urban social and economic development, as well as a receptor for urban sewage. The indicators of WESC, therefore, may be described by population and economy related to water resources, water pollution, investment for sewage treatment and cost of water supply and so on.

Adequate water resources and sewage loading will play an important role in urban social and economic development. Therefore, the conditions of water resources can be shown by extractable amount, available water supply, exploitative condition and investment. Water pollution is able to select discharge amounts of industrial wastewater and key pollutants, concentrations of pollutants in water bodies and investment of sewage treatment to reflect the support capacity of water environment on water pollution.

2.2 Quantitative description

First of all, two concepts of development variables and support variables are presented (Ye, 1992). Development variables, which are to reflect the intensity of social and economic development on water environment, can be shown as using these factors of population, output value, investment, water resources, amounts of sewage and pollutants related to social and economic development. A set consists of the factors, that is, set of development variables. The elements in the set are called development factors that can be quantitated, and then development variables can show a vector on n-dimensional space: $\vec{d}=(d_1, d_2, \ldots, d_n)$. Support variables are form of expression for water environmental system structure and functional condition on the support capacity of urban economic development. A set of support variables consists of the whole support variables, in which elements are called support variables. The support factors can be also quantitated and the support factors can show a vector on n-dimensional space: $\vec{s}=(s_1, s_2, \ldots, s_n)$.

WESC is a vector on space of n-dimensional development variables, of which each of component can be determined by the specific indicators related to development factors and support factors. As for a city, the directions of the vector may be different because the directions of urban economic development are different. In other words, the size of development factors and support factors may be changed with different strategy of urban economic development, so that the size of WESC is changed. Since the dimensions of components of WESC are different, they must be first dealt with normalization method, so that their size can be compared.

We hypothesize that m programs exist in a plan for urban economic development, thus there are m water environmental support capacities. The m WESC may as well show $Ej(j=1,2,\ldots, m)$, each of which is composed of n determined components of specific indicators:

$E_j = (E_{1j}, E_{2j}, \ldots, E_{nj})$.

After normalization:

$\widetilde{E}_j = (\widetilde{E}_{1j}, \widetilde{E}_{2j}, \ldots, \widetilde{E}_{nj})$.

Where, $\widetilde{E}_{ij} = \dfrac{E_{ij}}{\sum_{i=1}^{m} E_{ij}}$. $(i = 1,2,\ldots,n)$

Thus, the size of the j water environmental support capacity can be shown as using the module of normalized vector:

$$|\widetilde{E}_j| = \sqrt{\sum_{i=1}^{n} (\widetilde{E}_{ij})^2}$$

In order to stress the support effect of water environment on support factors in different programs of economic development, the relative size of the j water environmental support capacity can show as follows:

$$E_j = \sqrt{\frac{m^2}{n}\sum_{i=1}^{n}(\widetilde{E}_{ij})^2}$$

3 Application of support capacity to water environment in Benxi City

3.1 Study area

The study area, with proposal area of 47.2km^2, which is a new zone for economic and technological development in Benxi, is situated in the north of the urban district in Liaoning Province, China. In the area, the perennial average air temperature and precipitation are 7.8°C and 800mm, respectively. The total amount of yearly average water resources is 2.57×10^7m^3 including a groundwater resources of 2.39×10^7m^3, of which the maximum extractable amount is only 1.67×10^7m^3 per year.

The Beisha River runs through the area and its stem is about 15km within the area. The natural flow is very small in the upper reaches of the river. For example, the flow is only 0.003m^3/s at Gaochengzhai Section during normal flow period (September, 1992). Four discharge ditches, with a 1520kg BOD_5 load capacity, distributed on the river course and discharged 61384 tons of sewage per day into the Beisha River in 1992. Therefore, water quality in the river has been polluted by organic pollutants from industrial and domestic sewage.

According to the analysis on the economic development trend for the area, the determined leading industry is machining and medical industry, of which three programs of investment are designed. The analyzed results indicated that program II or III was the most possible one to be implemented. Therefore, these two programs are used as the basis of water environmental planning and their water environmental states are predicted. Programs II and III, will respectively lack 1.26×10^6 and 6.43×10^6 tons of water resources by the year 2000 and then 5.52×10^6 and 2.4×10^7 tons of water resources by the year 2010. Thus the diversion works from the outside of the area should be considered before the year 2000, otherwise lack of water resources will change into a key restricted factor for sustainable development of the area's economy.

Based on comprehensive analysis, two alternatives of water environmental plan including the short-term (2000) and long-term (2010) are made for the area accordingly (Guo, 1993). In alternative I, a 30000 ton of primary sewage treatment plant will be built with 40% BOD_5 removal efficiency by the year 2000, which will be extended into a 50000 ton of secondary sewage treatment plant with 85% BOD_5 removal efficiency by the year 2010. In alternative II, a 50000 ton of primary sewage treatment plant will be built with 40% BOD_5 removal efficiency by the year 2000, which will be extended into a 100000 ton of secondary sewage treatment plant by the year 2010; or it will be rebuilt a 50000 ton of secondary sewage treatment plant and then to build a same type and scale of treatment plant in other place again. The treated sewage from these plants will discharge into the Beisha River.

3.2 Selection of indicators

As mentioned above, seven specific indicators describing WESC are determined as follows: a ratio of total amount of available water resources (AWR) to urban water supply (UWS); output value of per unit consumption of water resources (OVWR); output value per sewage discharge

(OVSD); output value per unit BOD discharge (OVBOD); a ratio of BOD control goals (BOD-CG) to BOD concentration in water bodies (BODWB); investment for per unit sewage treatment (IST) and a ration of output value (OV) to total cost of diversion works or drawing water from wells (TCDW). According to above indicators, each component of WESC is calculated in the present situation and in the short - term and long - term of two alternatives (Table 1), and then is dealt with normalization method. Thus, the integrated indexes and relative values describing the size of WESC are gained(Table 2).

Table 1 Each component of indicators of WESC

Period j		Indicators i: $\frac{AER}{UWR}$	OVWR	OVSD	OVBOD	$\frac{BODCG}{BODWD}$	IST	$\frac{OV}{TCDW}$
Present situation	1992	2.47	48.5	60.6	27.8	0.705	0.200	171
Alternative I	2010	0.722	49.5	96.3	41.5	0.331	0.428	318
	2010	0.518	48.4	112	59.4	1.202	0.897	347
Alternative II	2000	0.571	49.2	95.8	41.5	0.286	0.447	260
	2010	0.290	46.1	108	53.4	0.897	0.740	177
Σ		4.57	242	473	224	3.42	2.71	1272

Table 2 Normalized components and integrated indexes of WESC

Alternatives j		Indicators i: $\frac{AWR}{UWR}$	OVWR	OVSD	OVBOD	$\frac{BODCG}{BODWC}$	IST	$\frac{OV}{TCDW}$	WESC 1	WESC 2
Present situation	1992	0.540	0.201	0.128	0.124	0.206	0.074	0.135	0.656	1.24
I	2000	0.158	0.204	0.204	0.186	0.097	0.158	0.250	0.489	0.924
	2010	0.113	0.200	0.237	0.266	0.352	0.331	0.273	0.698	1.319
II	2000	0.125	0.204	0.203	0.186	0.084	0.165	0.204	0.457	0.864
	2010	0.063	0.191	0.229	0.239	0.262	0.273	0.139	0.559	1.056

Notes: 1. intergrated values; 2. relative values

3.3 Analysis of the results

The data listed in Table 2 indicate that the integrated index(0.698) is maximum in the long - term in alternative I for the area; the integrated value (0.656) of the present situation is second. Because the area is in a starting stage of economic development, WESC of the present situation is relatively high and yet has a certainly bearing load for population and economic development. This integrated value in the long - term in alternative I is higher than that one in the present situation, which is also in accord with the actual conditions. Although the economic development in the area will cause lack of water resources and increase of sewage and BOD discharge, the increasing economic strength, drawing water from exotic stream and secondary treatment of sewage will undoubtedly improve water supply and water quality, so that the support capacity of water environment is increased.

We can yet compare the relative values E for WESC since the expected value of them is 1. To hypothesize the relative value of WESC is equal to one, then the intensity of human activities on water environment is 1 as well. Thus, the relative value E of WESC can be compared with the size of the intensity of human activities on water environmental effects, so that we can determine whether human activities on water environment is coordinated or not. In other words, as $E \geq 1$, in the alternative human activities on water environment is considered as being coordinative. In the present situation and in the long - term of alternatives I and II, the relative values of WESC are 1. 24, 1. 39 and 1. 056 respectively (Table 2), and indicate water environment and social - economic development in the area to be coordinative. In the short - term of alternatives Iand II, the relative values are 0. 924 and 0. 864 respectively, which indicate that the intensity of human activities are greater than WESC and it is difficult for water environment to maintain the sustainable development of the economy in the area.

4 Conclusions

A new concept and quantitative method of WESC have been presented and applied to analyze support capacity of urban water environment. WESC is defined as certain water environmental condition and structure to be able to bear a limited value on scale, intensity and speed under a prerequisite of no harm to human live and development, which will be changed with the speed and scale of human activities and economic development in a city.

In this method, two variables, that is, development variables and support variables are introduced. Development variables are used as reflecting the intensity of social and ecomonic development on water environment and can show a vector on n - dimensional space: $\vec{d} = (d_1, d_2, \ldots, d_n)$. Support variables are form of expression for water environmental structure and functional condition on support capacity of urban economic development and can show a vector on n - dimensional space: $\vec{s} = (s_1, s_2, \ldots, s_n)$. WESC is a vector on space of n - dimensional development variables, of which size may be changed with difference of development variables and support variables.

In a plan for urban economic development, if there are m alternatives, then m WESC exist also in it. M WESC may as well show $E_j (j=1,2,\ldots,m)$. The size and relative size for the j water environmental support capacity can show as follows:

$$|\tilde{E}_j| = \sqrt{\sum_{i=1}^{n} (\tilde{E}_{ij})^2} \quad \text{and} \quad E_j = \sqrt{\frac{m^2}{n} \sum_{i=1}^{n} (\tilde{E}_{ij})^2} .$$

This method is applied to support capacity analysis of water environment in Benxi New Zone for Economic and Technological Development, China. Seven specific indicators describing WESC are selected to calculate the size and relative size of the area's WESC. The results are considered as being in accord with actual conditions for the area.

References

Archibugi F, Nijkamp P., Economy and Ecology. Dordrec/Boston/London: Kluwer Academic Publishers. 1989:52

Editorial Bord of Environmental Sciences Dictionary. Environmental Sciences Encyclopedia. Beijing: Chinese Environmental Sciences Press. 1991:288

Guo Huaicheng, Xu Yunlin, Hong Zhiming. Water environmental planning for new zone of economic and technological development in China Advances in Environmental Sciences. 1994

Ye Wenhu, Mei Fengqiao, Guan Boren. Research of Environmental Sciences. 1992:5(supplement):108

Ye Wenhu. Environmental management and technology. Beijing: Chinese Environmental Sciences Press. 1994:26

(Received March 16, 1994)