Study on the ecological compensation standard for river basin based on a coupling model of TPC-WRV

Xin-jian Guan, Wen-kang Liu and Hui-liang Wang

ABSTRACT

The calculation of ecological compensation standard is the key to establishing ecological compensation mechanism. In the process of establishing the model, we follow the metastatic pattern of water resources’ ecological economic value. The model considered the discharge of pollutant between administrative area, pollutant absorbing capacity of river basin, ability of pollutant treatment and other factors, so as to closely combine ecological compensation standard with the total pollutants and water resource value (WRV). On this basis, total pollutant control model (TPC) and WRV model were constructed, the former model complied with properties of regional socio-economic, environmental resources and water environmental carrying capacity while the latter reflected the situation of resources, environment and socio-economic. And further, the ecological compensation standard coupling model of TPC-WRV was constructed by these two models, and the dilution water was introduced as a coupling pathway. Applying this coupling model to Xiao Honghe of China, the ecological compensation standard of four counties from 2008 to 2012 was calculated. The results show that the compensation value of Xiao Honghe basically presented increasing trend from upstream to downstream during 2008 to 2012. This study develops new ideas to comprehensively quantify the ecological compensation standard of river basin.

Key words | coupling model, ecological compensation standard, total pollutants control, water resource value

INTRODUCTION

Natural resources are important raw materials and limiting factors for economic and social development. In recent years, rapid natural resource depletion has become one of the major focal issues for governments and organizations worldwide (Chang et al. 2014). River basin is a complex system which takes water as the medium, various components conduct interaction of matter and energy, they share the value of ecosystem services in river basin. Although the same basin at the ecosystem are interrelated, in the process of management it was governed by multiple same level administrative areas, which leads to river basin environmental management relative to other resources management to have more variety and complexity, and easily appear to imbalance, asymmetrical cost-effectiveness and other issues in the development of the region. Therefore, establishing a reasonable and effective ecological compensation mechanism is an effective means of promoting balanced regional development, asymmetrical cost-effectiveness and other issues. Ecological compensation, as a new model of river basin management has considerable practical value.

For global scholars, the externality theory of economics was used more for the study of river basin ecological compensation standard. Namely, applying the ecosystem in Service Value Appraisal method (Loomis et al. 2000) to determine the upper limit of compensation, applying willingness-to-pay (Plantinga et al. 2001; Moran et al. 2007) to determine the lower limit of compensation, but the two methods have some defects. Then scholars study compensation standard quantitative problems starting with water...
environment, but more research is based on water quality objectives (Xie et al. 2013), namely the target control to compensate without considering river basin assimilative capacity, level of economic development and other factors.

The water resources of river basin through the process of water intake, drainage and consumption between upstream and downstream, as well as the process of natural precipitation, increase the concentration of pollutants in the river. The excessive emissions of pollutants that the region can bear can result in the loss of ecological value. With the increase of the amount of water or sewerage, socio-economic value of water shows a decreasing trend, while the loss of ecological value of water shows an increasing tendency. When the water pollution is more serious and the ecological environment is worse, the increase magnitude of the water economic value is not enough to offset the loss of ecological value, the ecological economic value of water resource will become lower (Mao & Fang 2005). The conversion rules are listed in Figure 1. In this case, the ecological economic value of water resources will gradually increase by imposing compensation on the polluters to compensate the victims, so as to inhibit the polluting behaviors of polluters and improve the governance enthusiasm of victims, the ecological economic value of water resources will gradually increase. With the increasing amount of compensation, environmental pressure is transferred to the economic and social development, and the economic and social development will be inhibited by it. So the economic value of water resources plummeted and a downward trend of water resources’ ecological economic value will appear. Therefore, in determining the ecological compensation standard of the river basin, the transfer rule of water resource ecological economic value should be followed. Finally, reasonably determine the reduction of pollutants according to the heterogeneity of the different region (Cai 2009; Wu & Wang 2014). For the pollutant emissions which exceed the affordability of the region, that is, the pollutant emissions required to reduce, which will result in the loss of water resource value (WRV) if discharged into the river basin. Through the WRV of dilution water (Cox 1974) which is desired when diluted to responsibility objective water quality, quantitative accounting of pollutant discharge excess water loss caused by the economic value of ecological discharged into the river basin ecosystems. Thereby, it was taken as ecological compensation standard between upstream and downstream in the river basin.

Figure 1 | Conversion rules of ecological economic value of water resources.

Xiao Honghe originates from Wugang City in Henan Province that lies in southern China Funiu Mountains. It flows through Wuyang County, Xiping County, Shangcai County, Pingyu County and Xincai County (see Figure 2). The watershed area of Xiao Honghe is 11,740 km², accounting for 95% of the total watershed area. In this paper, Zhumadian segment of Honghe River basin was mainly considered, it mainly flows through Xiping, Shangcai County, Pingyu County and Xincai County. The population of this river basin in 2012 is 4.476 million, which accounts for 50.2% of the population in Zhumadian City. The GDP of river basin increased from 34.3 billion yuan to 54.73 billion yuan in 2008–2012, the economic development of Zhumadian Xiao Honghe River basin is more rapid. The chemical oxygen demand (COD) and ammonia nitrogen pollution is particularly prominent, surface water, groundwater pollution is more serious and most of the river water quality exceeded V class water standards. The polluted surface water infiltrated into ground and polluted the groundwater resources, which brought a serious impact on the region’s ecology and water security of urban and rural residents. Therefore, it is urgent
to establish the calculation model of the ecological compensation standard of the basin, and provide the basis for the ecological protection of the basin.

METHODS

Based on the above analysis, we can conclude that ecological compensation standard coupled model of river basin was constructed which considered two factors’ contribution, include total pollutants control and WRV, namely ecological compensation standard TPC-WRV coupling model of river basin. The key is to build a total pollutant control (TPC) model and a WRV model of river basin.

Total pollutant control model

The construction of the total pollutant control model should first select a certain control index. The allocation indexes are determined from a set of control indexes that should account for the heterogeneity in different parts of the basin. Information entropy method (Wen et al. 2011) is then used to build the total pollutant control model. The analysis of influence factors for current global scholars mainly carried out from the following five aspects, including economic level and structure factors, production technology progress factors, population factors, pollutant treatment factors and water environment factors (Saeijs & Van Berkel 1995). By considering China’s specific national conditions, 80 experts were selected to conduct a questionnaire and, finally, six main indicators were determined to constitute the total pollutant control index system. The specific indexes are listed in Figure 5.

The construction of the total pollutant allocation model used information entropy method, and the following results were obtained with reference to the definition and construction process of information entropy method in the relevant literature. More details about TPC method can be found in reference (Guan et al. 2016).

The control reduction rate equation for each control object is:

\[ \eta_i = r \times \lambda_i \]  

where \( r \) is the reduction rate around China, i.e. the average reduction rate; \( \lambda_i \) is the ratio of the relative reduction...
rate of controlling objects to average relative reduction level.

The reduction amount of each allocating object is generated according to the reduction rate of each controlling object:

$$R_i = W_{i(0)} \times r_i$$

where $W_{i(0)}$ is the current emissions of pollutants in the i area.

**WRV model**

Water resource is one of the most important resources in natural resources which can provide a variety of production and means of subsistence for the people's material and economic system. On the contrary, there will be a certain effect on water resources system by the waste product. Thus, in both systems, energy and material conduct complex exchange and transition. With a certain ambiguity, it cannot be accurately determined, and these two systems form the value system of water resources. Since this system has the above features, the method of fuzzy mathematical model was used to study WRV model (Wei et al. 2006).

The natural resources value factors that constitute the water resources can be divided into three categories: natural factors, economic factors and social factors. In the natural resource value evaluation model of water resources, four factors were selected to involve in the evaluation, including water quality, water quantity, population and socio-economic, which covers natural and socio-economic factors. Different water qualities reflect different natural resources' values and, therefore, to a certain extent, the water quality reflects the value of water resources. The effect of water quantity on natural resources value of water is also very important and, therefore, water quantity is also an important factor that cannot be ignored. There is also inseparable necessarily linked between population and natural resources value of water resources. On the one hand, population increase allows the continuation of the deterioration of water environment, which influences the natural resources value of water. On the other hand, the increasing population makes the increasing water consumption, which aggravates water supply and demand. The water resources are closely related in natural resource value of water and economic value. The two factors: per capita GDP and million yuan GDP water consumption are select to represent the economic factors which influence the value of water resources in essence, and which contains water resources as factors of production element and life element to participate in the value creation.

The specific form of the model is as follows.

1. The determination of evaluation matrix of WRV

Assuming the domain $U$ to be an element set of WRV, $U = \{X_1, X_2, X_3, \ldots, X_n\}$, and the evaluation set $B$ is constituted by evaluation level of water resources, $B = \{\text{high, }$
higher, medium, lower, low). The comprehensive assessment of WRVs can be represented by the following formula:

\[ V = Q \odot R \]  \hspace{1cm} (3)

where \( Q \) is the weight allocation matrix of evaluation element which is \( X_1, X_2, X_3, \ldots, X_n \); \( \odot \) is the composite operation symbol of fuzzy matrix; \( V \) is the comprehensive evaluation matrix of single element which can represents the fuzzy relationship between the feature set \( U \) and the evaluation set \( B \), and which is built as a row vector based on each single element fuzzy evaluation result.

Using the excessive situation of single elements to determine the weight of each single element, the calculation formula is:

\[ a_i = \frac{c_i}{s_i} \]  \hspace{1cm} (4)

\[ s_i = \frac{1}{n} \sum_{j=1}^{n} s_{ij} \]  \hspace{1cm} (5)

where \( a_i \) is the weight of the \( i \)-th kind of evaluation factor in the single element while \( c_i \) is the measured values and \( s_i \) is the average value of standards at all level; \( s_{ij} \) is the \( j \)-th kind of standard of the \( i \)-th kind of evaluation factor in single element; \( n \) is the number of classification.

Normalizing the weight of \( i \)-th kind of evaluation elements in the single element:

\[ Q_i = \frac{a_i}{\sum_{i=1}^{n} a_i} \]  \hspace{1cm} (6)

In the above model, single elements evaluation matrix \( R \) is constituted based on each single element evaluation vector \( R_i \) which includes water quantity, water quality, population and socio-economic. It can be expressed as:

\[ R_i = Q_i \odot \mu_i \]  \hspace{1cm} (7)

where \( a_i \) is the weight of evaluation factors in the single elements; \( \mu_i \) is the membership function of each evaluation factor which is determined by their own membership function. Then, drop-half trapezoidal distribution is selected to establish unitary linear membership function.

The single element evaluation matrix and the corresponding weight allocation matrix are substituted into the comprehensive evaluation model of water resources, then the comprehensive evaluation matrix \( V \) can be obtained by it.

(2) Determination of water resources price

In order to convert dimensionless membership ‘vector result’ of fuzzy comprehensive evaluation of WRV into the corresponding water price ‘scalar’, it need to introduce the right price vector (García-Gallego et al. 2012). In this paper, the determination of water resources follows the following calculation model.

\[ WLJ = V \odot M \]  \hspace{1cm} (8)

where \( WLJ \) is the price of water resources; \( V \) is the comprehensive evaluation matrix of water resources; \( M \) is the vector of water resource price.

(i) Determination of water fee tolerance

The water fee tolerance (Nie & Miao 2003) is an index which can reflect the user’s affordability for water fee, and its expression is:

\[ WCI = \frac{CW}{AI} \]  \hspace{1cm} (9)

where \( WCI \) is water fee tolerance; \( CW \) is the expenditure on water; and \( AI \) is the actual income.

(ii) Determination of the price caps of water resources

The price cap of water resources is the water resources price when it reached the maximum bearing index of water fee, that is:

\[ PU = WCI_{\text{max}} \times \frac{AI}{QW} \times CP \]  \hspace{1cm} (10)

where \( PU \) is the price cap of water resources; \( WCI_{\text{max}} \) is the maximum bearing index of water fee; \( QW \) is water consumption; and \( CP \) is unit cost of water supply and normal profit.

(iii) Determination of the price vector
The price cap of water resources is \( PU \), so water resources price is between \([PU, 0]\). Adopting interval arithmetic, the corresponding water resources price vector is:

\[
M = [PU, P_1, P_2, P_3, 0]
\]  
(11)

where \( P_1 = \frac{3}{4}PU; P_2 = \frac{1}{2}PU; P_3 = \frac{1}{4}PU. \)

So, water resources price corresponding to the fuzzy comprehensive evaluation result of WRV can be obtained.

**Ecological compensation standard TPC-WRV coupling model of river basin**

TPC model and WRV model belong to two different model systems which each have the heterogeneity of matter and energy, but there is an inherent relationship between models through the above analysis. Therefore, to build eco-compensation standard TPC-WRV coupling model of a river basin, it just needed to determine the coupling channel between them. According to the ecological compensation mechanism (Mao & Zeng 2006), it will lead to the change of the value of the water resource when pollutants flow into the river basin which could cause watershed pollution. Accordingly, dilution water quantity is introduced as a coupling path between them. The WRV of this part of the water quantity that dilute the additional emission amount of pollutants in each areas to water quality concentration of responsibilities target claim is taken as the value of compensation between the upstream and downstream regions.

The construction of ecological compensation standard TPC-WRV coupling model of the river basin is based on conducting field research. Then, intend to calculate the required dilution water quantity that each water quality concentration returned to the responsibility target water quality from the perspective of dilution of pollutants, so as to determine ecological compensation standard. The construction process of ecological compensation standard TPC-WRV coupling model of river basin is as follows.

Assuming pollutant reductions set of all regions to be:

\[
R_i = \{a_1, a_2, a_3, \ldots, a_m\}, i \in (1, n)
\]  
(12)

Assuming pollutant index set to be:

\[
R_j = \{a_1, a_2, a_3, \ldots, a_m\}, j \in (1, m)
\]  
(13)

Thus, data matrix of pollutant reduction can be obtained, the matrix is \( n \times m \)-rank.

\[
R_{ij} = \begin{pmatrix} a_{11} & \cdots & a_{1m} \\ \vdots & \ddots & \vdots \\ a_{ni} & \cdots & a_{nm} \end{pmatrix}
\]  
(14)

where \( R_{ij} \) is the data matrix of pollutant reduction; \( a_{ij} \) is the reduction for pollutant \( j \) in area \( i \); \( n \) is number of reduction targets like provinces, cities, districts, \( i \in (1, n) \); \( m \) is the number of pollutants, \( j \in (1, m) \).

According to the law of conservation of mass, dilution water quantity of pollutant \( j \) can be obtained.

\[
y_i = I_i \frac{E_i}{I_i} - 1
\]  
(15)

Among it,

\[
I_i = \frac{R_i}{K_i}
\]  
(16)

where \( y_i \) is the dilution water quantity, unit: L; \( E_i \) is the water quality concentration of responsibility target, unit: mg/L; \( I_i \) is the sewage concentration, unit: mg/L; \( R_i \) is the pollutant reduction in area \( i \); \( K_i \) is the total water resources in area \( i \).

Furthermore, the dilution water quantity matrix distribution of different pollutants in various regions is:

\[
Y_{ij} = \begin{pmatrix} y_{11} & y_{12} & \cdots & y_{1m} \\ y_{21} & y_{22} & \cdots & y_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ y_{n1} & y_{n2} & \cdots & y_{nm} \end{pmatrix}
\]  
(17)

According to the calculation formula of dilution water, \( Y_{ij} \) reflects the degree of pollution of different pollutants in various areas. The higher the degree of pollution of the area, the greater amount of water is diluted, whereas the smaller amount of dilution water.
The calculation formula of ecological compensation standard of river basin in area $i$ is:

$$C_{ri} = WL_{ji} \cdot \sum_{j=1}^{m} Y_{j}$$  \hspace{1cm} (18)$$

where $C_{ri}$ is ecological compensation standard of river basin in area $i$, unit: t/yuan; $\sum_{j=1}^{m} Y_{j}$ is the total dilution water quantity of $j$ pollutants, unit: t; $WL_{ji}$ is the WRV in area $i$.

### RESULTS

#### Total pollutant control amount

According to the calculation of relevant total pollutant control model in the previous section, the reduction of COD of each allocation objects can be obtained. Provinces, cities, and regions need to make appropriate adjustments in line with the national reduction rate, to account for differences in their social and economic development, and reserves of natural resources. After comprehensive consideration of these factors, a value of 9.9% was determined as the COD reduction rate for Xiao Honghe River basin, while the value of ammonia nitrogen reduction rate is 12.6%, based on the pollutant reduction target during the ‘Twelfth Five-Year Plan’ period of Henan Province. The total control amounts are listed in Table 1. The source of the data in this paper is Zhumadian Statistical Yearbook provided by Henan Environmental Protection Agency in China.

The reduction of COD and ammonia nitrogen for each control object is quite different, Xiping County has the largest reductions. The amount of reduction in each region is related to the reduction rate and the emissions of the present situation in various regions. In some areas, the greater reduction is caused by the higher reduction rate and more emissions of the present situation, such as Xiping County which has the greater reduction, and this result is caused by these two factors. In other areas, the greater reduction is caused by one of these two factors, reduction rate or emissions of present situation, such as in Xincai County.

#### Calculation of WRV

According to WRV model constructed in the last section, this research calculates WRV of Xiao Honghe River basin, Xiping County, Shangcai County, Pingyu County and Xincai County from 2008 to 2012. The calculated results of WRV in these four counties are listed in Table 2.

As seen from Table 2, the WRV of Xiao Honghe River Basin in Zhumadian shows an increasing trend following with the time. And, from the point of view of space, the value is higher in upstream (Xiping County) and middle and lower reaches (Pingyu County), the value in midstream (Shangcai County) is moderate, while the value in downstream (Xincai County) is lower. The continuous economic development and increasing population in the Xiao Honghe River basin of Zhumadian from 2008 to 2012 are accompanied by the further deterioration of water quality and the decrease of water quantity. So, water resource is becoming more and more short and the WRV is becoming higher and higher.

#### Quantification of the ecological compensation standard in the river basin

According to the water functional categories, the water of class I and class II are source water quality which water

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**Table 1** | The reduction of COD and ammonia nitrogen based on information entropy method

<table>
<thead>
<tr>
<th>Pollution factors</th>
<th>Regions</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD</td>
<td>Xiping</td>
<td>0.075</td>
<td>0.071</td>
<td>0.066</td>
<td>0.068</td>
<td>0.067</td>
</tr>
<tr>
<td></td>
<td>Shangcai</td>
<td>0.034</td>
<td>0.026</td>
<td>0.023</td>
<td>0.028</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>Pingyu</td>
<td>0.043</td>
<td>0.037</td>
<td>0.031</td>
<td>0.029</td>
<td>0.037</td>
</tr>
<tr>
<td></td>
<td>Xincai</td>
<td>0.004</td>
<td>0.002</td>
<td>0.009</td>
<td>0.014</td>
<td>0.011</td>
</tr>
<tr>
<td>Ammonia nitrogen</td>
<td>Xiping</td>
<td>0.009</td>
<td>0.009</td>
<td>0.008</td>
<td>0.009</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>Shangcai</td>
<td>0.003</td>
<td>0.004</td>
<td>0.004</td>
<td>0.003</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>Pingyu</td>
<td>0.004</td>
<td>0.004</td>
<td>0.003</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>Xincai</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Unit: (R/ten thousand yuan).

**Table 2** | WRV of four counties in Xiao Honghe River basin from 2008 to 2012 (yuan/m³)

<table>
<thead>
<tr>
<th>Regions</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xiping</td>
<td>4.85</td>
<td>5.53</td>
<td>6.31</td>
<td>8.09</td>
<td>9.42</td>
</tr>
<tr>
<td>Shangcai</td>
<td>3.49</td>
<td>4.22</td>
<td>5.45</td>
<td>7.13</td>
<td>8.01</td>
</tr>
<tr>
<td>Pingyu</td>
<td>4.52</td>
<td>5.09</td>
<td>5.98</td>
<td>7.67</td>
<td>8.88</td>
</tr>
<tr>
<td>Xincai</td>
<td>2.62</td>
<td>3.45</td>
<td>4.64</td>
<td>5.78</td>
<td>6.69</td>
</tr>
</tbody>
</table>
quality are better and more close, so the water of class III was selected as $E_i$ to determine compensation standard. The COD and ammonia nitrogen dilution water quantity of each region were calculated according to the eco-compensation standard TPC-WRV coupling model of river basin constructed previously and were combined with the calculated pollutant reduction. The results are listed in Table 3.

After comprehensive calculated results, the ecological compensation standard of Xiao Honghe River basin in Zhumadian is listed in Table 4 and Figure 4.

**DISCUSSION**

As we can see the results of related dates in Table 4 and Figure 4, from the county perspective, ecological compensation value of Xiao Honghe River basin showed that Xiping is the highest, followed by Pingyu and Xincai with the lowest value, which related to the socio-economic development of each county and the rich degree of water resources.

Xiping County is located in the upstream of Xiao Honghe River basin in Zhumadian, which has the high level of economic development and is the most polluted. At the same time, the lower water quantity and greater density of the population have together resulted in its highest ecological compensation value. As a large agricultural county, the leather industry of Pingyu County is also relatively developed, leading to increased pollutant emissions of agricultural non-point source and population growth, water pollution is also more prominent, so its value is still high. These two factors common caused the Pingyu County ecological compensation value in the middle and upper level. Though Shangcai County is located in the middle and upper reaches, it is dominated by agriculture and the economy is less developed compared with Pingyu, which caused its compensation value in the middle and lower levels. Xincai County is located in the downstream area of Xiao Honghe River basin in Zhumadian, the water quality is more abundant, and the industrial sewage was conducted certain restrictions management, so the water quality of Xincai is relatively good and led to its minimum ecological compensation value.

<table>
<thead>
<tr>
<th>Year</th>
<th>Regions</th>
<th>COD reduction (10,000 ton)</th>
<th>Ammonia nitrogen reduction (10,000 ton)</th>
<th>Water resources quantity (10^8 m³)</th>
<th>COD dilution water (ton)</th>
<th>Ammonia nitrogen dilution water (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Xiping</td>
<td>0.075</td>
<td>0.009</td>
<td>12.27</td>
<td>304.93</td>
<td>699.61</td>
</tr>
<tr>
<td></td>
<td>Shangcai</td>
<td>0.034</td>
<td>0.003</td>
<td>16.77</td>
<td>101.76</td>
<td>185.90</td>
</tr>
<tr>
<td></td>
<td>Pingyu</td>
<td>0.043</td>
<td>0.004</td>
<td>14.31</td>
<td>147.79</td>
<td>303.76</td>
</tr>
<tr>
<td></td>
<td>Xincai</td>
<td>0.004</td>
<td>0.000</td>
<td>17.91</td>
<td>11.07</td>
<td>19.75</td>
</tr>
<tr>
<td>2009</td>
<td>Xiping</td>
<td>0.071</td>
<td>0.009</td>
<td>6.58</td>
<td>537.38</td>
<td>1289.99</td>
</tr>
<tr>
<td></td>
<td>Shangcai</td>
<td>0.026</td>
<td>0.004</td>
<td>9.00</td>
<td>146.15</td>
<td>454.05</td>
</tr>
<tr>
<td></td>
<td>Pingyu</td>
<td>0.037</td>
<td>0.004</td>
<td>7.68</td>
<td>237.16</td>
<td>497.03</td>
</tr>
<tr>
<td></td>
<td>Xincai</td>
<td>0.002</td>
<td>0.000</td>
<td>9.61</td>
<td>8.80</td>
<td>7.20</td>
</tr>
<tr>
<td>2010</td>
<td>Xiping</td>
<td>0.066</td>
<td>0.008</td>
<td>8.89</td>
<td>368.83</td>
<td>904.60</td>
</tr>
<tr>
<td></td>
<td>Shangcai</td>
<td>0.023</td>
<td>0.004</td>
<td>12.15</td>
<td>92.04</td>
<td>331.45</td>
</tr>
<tr>
<td></td>
<td>Pingyu</td>
<td>0.031</td>
<td>0.003</td>
<td>10.37</td>
<td>148.86</td>
<td>278.34</td>
</tr>
<tr>
<td></td>
<td>Xincai</td>
<td>0.009</td>
<td>0.000</td>
<td>12.97</td>
<td>33.33</td>
<td>9.58</td>
</tr>
<tr>
<td>2011</td>
<td>Xiping</td>
<td>0.068</td>
<td>0.009</td>
<td>4.15</td>
<td>813.20</td>
<td>2083.50</td>
</tr>
<tr>
<td></td>
<td>Shangcai</td>
<td>0.028</td>
<td>0.003</td>
<td>5.68</td>
<td>247.26</td>
<td>588.41</td>
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<tr>
<td></td>
<td>Pingyu</td>
<td>0.029</td>
<td>0.003</td>
<td>4.84</td>
<td>299.68</td>
<td>610.79</td>
</tr>
<tr>
<td></td>
<td>Xincai</td>
<td>0.014</td>
<td>0.001</td>
<td>6.06</td>
<td>113.56</td>
<td>125.96</td>
</tr>
<tr>
<td>2012</td>
<td>Xiping</td>
<td>0.067</td>
<td>0.008</td>
<td>4.44</td>
<td>756.09</td>
<td>1913.05</td>
</tr>
<tr>
<td></td>
<td>Shangcai</td>
<td>0.025</td>
<td>0.005</td>
<td>6.07</td>
<td>207.40</td>
<td>743.52</td>
</tr>
<tr>
<td></td>
<td>Pingyu</td>
<td>0.037</td>
<td>0.005</td>
<td>5.18</td>
<td>353.09</td>
<td>919.09</td>
</tr>
<tr>
<td></td>
<td>Xincai</td>
<td>0.011</td>
<td>0.000</td>
<td>6.48</td>
<td>83.81</td>
<td>14.10</td>
</tr>
</tbody>
</table>
From the point of year by year, the compensation value of Xiao Honghe basically presented increasing trend from upstream to downstream. The value is generally small in each county in 2010, which is because of the relatively abundant water resources quantity of the river basin in this year. On the one hand, the abundant water resources quantity alleviated the degree of pollution to a certain extent; on the other hand, it caused the lower value of water resources, and these two aspects both caused the decline in the value of ecological compensation. This shows that the pressure of ecological environment protection in Xiao Honghe River basin increased year by year, and the protection work of the river basin ecological environment has a long way to go.

In summary, it can be seen that the protection of water quality should be strengthened and sewage discharge should be strictly controlled in Xiao Honghe River basin, thereby improving sewage disposal standards and governance capabilities (Chen 2015). And, also, actively respond to a national call to vigorously develop green economy and accelerate the construction of ecological civilization.

**CONCLUSIONS**

Under the premise of analyzing ecological compensation mechanism of river basin, the relationship between ecological compensation standard and water resources’ economic value were discussed. Then, six major indexes were selected, and the total pollutant allocation model was constructed by using information entropy method. Through the comprehensive analysis of various factors that affect the value of water resources, the evaluation index system of WRV was established, and then used fuzzy mathematics method to construct ecological compensation amounts calculation model which considers water quality factors. On the basis of those two models, ecological compensation standard TPC-WRV coupling model was constructed through this coupling path of dilution water. Using this coupling model to conduct example analysis for Xiao Honghe River basin, the results showed that the ecological compensation value

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Ecological compensation value in Xiao Honghe River basin from 2008 to 2012 (Ten Thousand Yuan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>Pollution factors</td>
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<tr>
<td>2008</td>
<td>COD</td>
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<tr>
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<td>Ammonia nitrogen</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>2009</td>
<td>COD</td>
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<td>Ammonia nitrogen</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>2010</td>
<td>COD</td>
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<tr>
<td></td>
<td>Ammonia nitrogen</td>
</tr>
<tr>
<td></td>
<td>Total</td>
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<tr>
<td>2011</td>
<td>COD</td>
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<td>COD</td>
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<tr>
<td></td>
<td>Ammonia nitrogen</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
</tbody>
</table>
of Xiao Honghe River basin in Zhumadian basically presented a gradual decreasing trend from upstream to downstream while it presented a gradual increase trend in each year. It showed that the pressure of water resources protection of Xiao Honghe River basin in Zhumadian is still heavy, which provides a certain basis to the governance of water eco-environment in each counties.

In this paper, ecological compensation standard quantization of river basin was carried on a more in-depth study, but lack of research that how scientific and reasonable establishment on the ecological compensation mechanism. In addition, it is necessary to seek a more objective approach in the determination of the weight of the indicators and increase the validation of the study results. Therefore, in future studies, the researches on ecological compensation mechanism should be strengthened, include compensation mode, compensation categories and methods, capital raising, institution protection, and so on.

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