Preliminary Study on the Ecological Compensation of the Primary and Secondary Reserves in Drinking Water Source Area of the Shitoukoumen Reservoir

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Abstract The Shitoukoumen Reservoir is one of main drinking water source areas in Changchun City, and there is a contradiction between the protection and the economic development of water source areas. In this paper, the primary and secondary reserves in drinking water source area of the Shitoukoumen Reservoir are taken as research objects. Based on the theory of ecological compensation, the ecological compensation standard is accounted and determined from different perspectives, and the suggestion of the phased ecological compensation in water source areas is proposed.

Key words The Shitoukoumen Reservoir; Water source area; Ecological compensation

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By establishing calculation system of compensation standard, implementing the responsibilities of all compensation stakeholders, and promoting the protection and improvement of regional eco-environment, ecological compensation of water source area effectively protects its ecological environment when developing social economy of upstream areas, and coordinates the problem of "drinking good water" in downstream areas when solving the problem of "eating well" in upstream areas[1].

1 General situation of research zone

1.1 Geographical position The Shitoukoumen Reservoir is located in Jiutai City, Changchun area, central Jilin Province, and the dam site of the reservoir is about 500 m from southwest of Shitoukoumen Village, Xiyingcheng Town, Jiutai City. The reservoir is a large-scale control water conservancy project in the middle reaches of the Yinma River which is the second main tributary of the Songhua River. Catchment area in the upper reaches of dam site of the Shitoukoumen Reservoir is 4 944 km^2, and length of river in the upper reaches of the reservoir is 166.2 km, and average gradient of the basin is 0.7‰. Main rivers flowing into the reservoir are the Yinma River, the Shuangyang River and the Chalu River.

1.2 Division of water source reserve Drinking water source reserve of the Shitoukoumen Reservoir was delineated for the first time in October of 2002, and was adjusted twice in 2006 and 2012. At present, total area of drinking water source reserve is 4 944 km^2, containing all catchment areas of the Shitoukoumen Reservoir. Among them, areas of the primary, secondary and quasi reserves are 138.7, 202.8 and 4 602.5 km^2 respectively.

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1.3 Water supply situation The Shitoukoumen Reservoir is an important drinking water source area, servicing for 3 million population, and its water supply amount accounts for 80% of that in Changchun City. It is also an important irrigation water source in downstream Jiutai and Dehui, and provides water for Longjia International Airport, Jilin Urban Water Supply Co., Ltd. (the main water supply object is Changchun Corn Industrial Park and other industrial enterprises) and Huaneng Jiutai Power Plant.

1.4 Socio-economic situation Catchment basin of the Shitoukoumen Reservoir involves Lianhuashan Management Committee, Shuangyang District and Jiutai District of Changchun City, Yongji County and Panshi City of Jilin City, containing 27 towns, 400 villages and 840 000 population.

1.5 Current situation of ecological compensation for water source Shitoukoumen Reservoir Authority of Changchun City applied for national debt and raised investment for 101.4 million yuan, to carry out pollution control project of water source area in the Shitoukoumen Reservoir of Changchun City. Major projects contained wetland construction, relocating 1 329 population, setting boundary markers, boundary posts, signs and protective fences, relocation of industrial and mining enterprises, and treatment of drain outlet.

2 Construction of ecological compensation mechanism of the primary and secondary reserves in water source area of the Shitoukoumen Reservoir

2.1 Determination of compensation subject and object

2.1.1 Determination of compensation subject. According to the ecological compensation principle of "who benefits, who compensates", ecological compensation subjects of the primary and secondary reserves in water source area of the Shitoukoumen Reser-

voir are residents, businesses and governments in water use areas.

2.1.2 Determination of compensation object. Ecological compensation objects of the primary and secondary reserves in drinking water source area of the Shitoukoumen Reservoir contain Shitoukoumen Reservoir Authority, Yongji County Government and Panshi County Government of Jilin City, Lianhuashan Management Committee, Shuangyang District Government and Jiutai District Government of Changchun City, residents, village collectives and enterprises who have lost their interests due to water source protection within the water source reserve, as well as other individuals or units engaged in ecological protection of water source area.

2.2 Determination of ecological compensation standard

2.2.1 Determination of accounting method of ecological compensation standard. The cost of ecological protection starts from the perspective of ecological protectors, while the value of ecological service obtained by ecological beneficiaries starts from the perspective of ecological beneficiaries, and they have higher comparability. So, ecological compensation standard is accounted according to cost of ecological environment protection (from the perspective of ecological protectors, containing total cost and opportunity cost of upstream ecological protection construction and pollution control) and the value of ecological services obtained by ecological beneficiaries (from the perspective of ecological beneficiaries, containing downstream water use amount and value of water resources)[1-3].

2.2.2 Cost and opportunity cost of upstream ecological protection construction and pollution control.

2.2.2.1 Computational model. Input of the ecological protectors in the drinking water source areas to implement various ecological environment protection measures belongs to direct cost of ecological environment protection. To protect environment, governments and residents from drinking water source areas have limited economic development, which produces opportunity cost, and it belongs to indirect cost of ecological environment protection. So, the cost of ecological environment protection in upper reaches of water source reserve is composed of direct and indirect cost:

$$C_s = C_z + C_j \quad (1)$$

where C_s is total cost of ecological environment protection in upstream water source area; C_z is cost of upstream ecological protection construction and pollution control, namely direct cost; C_j is opportunity cost of upstream ecological environment protection, namely indirect cost.

(1) Direct cost of ecological environment protection in water source area. Direct cost mainly contains cost of point source and non-point source pollution control, cost of ecological restoration measures, cost of ecological protection project, cost of project of returning farmland to forest and reservoir, cost of relocation, and cost of water quality control.

$$C_z = D_d + D_m + D_s + D_f + D_t + D_b + D_k \quad (2)$$

where C_z is cost of upstream ecological protection construction and pollution control, namely direct cost; D_d is cost of point source pollution control; D_m is cost of non-point source pollution control; D_s is cost of ecological restoration measures; D_f is cost of ecological protection project; D_t is cost of project of returning farmland to forest and reservoir; D_b is cost of residents relocation in reserve; D_k is cost of water quality control.

(2) Indirect cost of ecological environment protection in water source areas. The loss of the development right in the water source reserve is mainly reflected in the development right of industry within the primary and secondary reserves: limiting the application of chemical fertilizers and pesticides, returning farmland to forest causing decrease of cultivated land area, restricting aquaculture, pollution industry and tourism development.

In this paper, below formula is used to calculate the loss of limited development right in water source reserve[4]:

$$C_j = (N_x - N_s) \times P_n + (M_x - M_s) \times P_m \quad (3)$$

where C_j is the loss of limited development right in water source reserve, $\times 10^4$ yuan; N_x is per capita income of farmers in downstream beneficiary area, yuan/person; N_s is per capita income of farmers in the upstream reserve, yuan/person; P_n is agricultural population in the upstream reserve; M_x is per capita income of urban residents in downstream beneficiary area, yuan/person; M_s is per capita income of urban residents in the upstream reserve, yuan/person; P_m is number of urban residents in the upstream reserve.

2.2.2.2 Calculation of direct cost of ecological environment protection(C_z) in water source areas. Preliminary accounting of direct cost of ecological environment protection in the primary and secondary reserves of the Shitoukoumen Reservoir is as below:

(1) Cost of point source pollution control: according to on-site inspection, the site left over by the existing sand ground in the primary reserve of water source area of the Shitoukoumen Reservoir needs to be cleaned, and the cost is about 4.2 million yuan.

(2) Cost of non-point source pollution control: garbage transfer station and garbage collection point are planned to be constructed in the secondary reserve, and the investment is about 0.902 million yuan[5].

(3) Cost of ecological restoration measures: dominant by construction of artificial wetland. Wetland projects of the Shitoukoumen Reservoir are mainly distributed in entry points of the Yinma River, the Shuangyang River and the Chalu River, and the end of small watershed in semi mountainous area on both sides of the reservoir. The constructed wetland is about 2 000 hm^2, and it is predicted that maintenance cost of artificial wetland is about 5 million yuan/a.

(4) Cost of ecological protection project: it is planned constructing fence in the primary reserve; it is planned constructing waste barrage in the entry points of the Shuangyang River, the Yinma River and the Chalu River, to intercept the living garbage of surrounding residents. Meanwhile, video monitoring equipment is installed, and 8 rivers flowing into reservoir in the primary and secondary reserves are controlled comprehensively. It is planned implementing protection project of reservoir bank. Total investment is about 89.88 million yuan[5].

(5) Cost of project of returning farmland to forest and reservoir: the investment of the project of returning farmland to forest and reservoir in the primary reserve is 471.09 million yuan[5].

(6) Cost of residents demolition in the reserve: compensation for overall demolition of existing houses in the primary reserve needs 0.58 billion yuan[5].

(7) Cost of water quality control in reservoir: environmental emergency investment is about 1 million yuan/a.

(8) Subtotal of direct cost: seen from above calculation, direct cost of ecological compensation in the primary and secondary reserves of drinking water source area of the Shitoukoumen Reservoir is about 1.146 072 billion yuan, and annual cost is about 6 million yuan/a.

2.2.2.3 Calculation of indirect cost of ecological environment protection (C_j) in water source area. According to the bulletin of national economic and social development in 2015 issued by relevant governments, the obtained data are shown in Table 1.

Table 1 Per capita income of upstream and downstream residents of water source area yuan/a

Region		Per capita income of urban residents	Per capita income of farmers
Downstream	Changchun City	29 483	12 159
Upstream	Yongji County	21 599	11 605
	Jiutai District	21 562	11 769
	Shuangyang District	22 700	11 586
	Lianhuashan Management Committee	22 131	11 677

Using above data, according to population in the primary and secondary reserves of water source area of the Shitoukoumen Reservoir, opportunity cost of ecological compensation in the primary and secondary reserves of water source area is calculated according to the formula (3). That is to say, indirect cost is 66.76 million yuan/a (Table 2).

Table 2 Opportunity cost of ecological compensation in the primary and secondary reserves of water source area $\times 10^4$ yuan/a

Region	Urban cost	Rural cost	Total
Yongji County	1 419	1 919	3 338
Jiutai District	1 098	5 395	1 637
Shuangyang District	–	1 165	1 165
Lianhuashan Management Committee	–	536	536
Total	2 517	4 159	6 676

2.2.2.4 Total cost of ecological environment protection in the upper reaches of water source reserve. Analysis from above, one-time ecological compensation cost in the primary and secondary reserves of drinking water source area of the Shitoukoumen Reservoir is 1.146 072 billion yuan, and annual compensation cost is 72.76 million yuan/a.

2.2.3 Compensation standard based on the value of water resources. The composition of ecological service of water resources ecological products includes water quality and water quantity, in which water quality corresponds with water environment protection fee in market transaction, while water quantity corresponds with charge for water resources in market transaction. Based on the market price of water resources products, the ecological compensation of the beneficiaries of ecological services to the water source area is obtained[6]:

$$P = Q \times (J + S) \tag{4}$$

where P is ecological compensation amount, $\times 10^4$ yuan/a; Q is annual water supply, $\times 10^4$ m^3; J is price of water resource fee, yuan/ m^3; S is price of environmental protection fee in water source area, yuan/m^3.

Charge for water resources of urban public water of Jilin Province taking surface water is 0.2 yuan/m^3, and charge for water resources of industrial, commercial and other water taking surface water is 0.35 yuan/m^3. In this paper, 1/5 of water resource fee is taken as calculation parameter of ecological compensation, and the price consistent with water resource fee is taken as price of environmental protection fee of water source area. According to water supply in water source area of the Shitoukoumen Reservoir in 2015, referring to the formula (4), the compensation of the beneficiaries of ecological services for water source areas based on the value of water resources is 10.189 million yuan/a.

2.2.4 Comparative analysis of different compensation standards. Based on statistical data of 2015, calculated by the cost of ecological environment protection in water source areas, ecological compensation standard in research zone is 72.76 million yuan/a. According to the value of water resources, calculated by the value of ecological service for ecological beneficiaries in water use areas, ecological compensation standard in research zone is 101.89 million yuan/a.

Seen from calculation results by two kinds of methods, ecological compensation standard differs by 29.13 million yuan/a, with larger difference. Major reasons are as below: compensation standard calculated by cost of ecological environment protection in water source area starts from the supply side of ecological service in water source areas, while compensation standard calculated by ecological service value of ecological beneficiaries in water source areas starts from the perspective of beneficiaries of ecological services in water source areas. Different angles cause the difference in calculated caliber. Ecological services of water source areas contain supply of water resources, purification of water quality, climate regulation, soil and water conservation, biodiversity and other values. Therefore, input from the supplier of ecological services in water source areas protects not only water body of water source areas but also each aspect of ecosystem in water source areas. Seen from benefits of ecological services in water source areas, the most important and intuitive ecological service they get from water source areas is drinking water. Therefore, the obtained compensation standards are different from different angles.

Since investment in ecological protection and construction, economic development situation, water supply and quality in water source areas are all dynamic, ecological compensation standard in water source areas is also changing. Therefore, ecological compensation standard in water source areas should be adjusted dynamically according to actual situation of each year, and accoun-

ted by year, to establish a long-term sustainable ecological compensation mechanism, thereby promoting sustainable development of economy and continuous improvement of drinking water quality in water source areas.

2.2.5 Suggestion of phased compensation. For status quo of social-economic development and residents' income in upper and lower reaches of the Shitoukoumen Reservoir, the opinion of establishing phased compensation standard is proposed, that is to say, ecological compensation in the primary and secondary reserves of the Shitoukoumen Reservoir is divided into two stages: initial compensation and mature compensation.

2.2.5.1 Initial compensation stage. Initial compensation indicates that it is conducted dominant by government in the form of industrial enterprises participation in initial implementation stage of ecological compensation. According to annual compensation standard proposed in "**2.2.2**", specific operations are as below:

(1) One off compensation (1.146 072 billion yuan): it is implemented to local environmental protection department or government according to project progress by Changchun City Government and Jiutai District Government.

(2) Annual compensation expense (72.76 million yuan/a): since the water resource fee and environmental protection fee of the water source area of the residential water users have not yet been collected by Changchun City, ecological compensation fee at initial compensation stage is commonly undertaken by government and industrial water users.

① Farmland in the primary reserve: according to the standard of Shitoukoumen Reservoir Authority renting farmlands to plant wetland plants, subsidy standard is 10 000 yuan/(a · hm^2) in paddy field and 0.8 yuan/(a · hm^2) in dry land, and it needs compensating 32.28 million yuan/a to the owner of cultivated land.

② Farmland in the secondary reserve: agricultural non-point source pollution in the Shitoukoumen Reservoir is declined by restricting the usage of pesticide and chemical fertilizer. The subsidy standard is 1/5 of rental standard in the primary reserve: 2 500 yuan/(a · hm^2) in paddy field and 2 000 yuan/(a · hm^2) in dry land, and it needs compensating 29.68 million yuan/a to the owner of cultivated land.

Total compensation for farmland in the primary and secondary reserves is 61.96 million yuan/a (Table 3).

Table 3 Compensation standard of farmland in the primary and secondary reserves

Type of farmland	Primary reserve			Secondary reserve			Total compensation amount $\times 10^4$ yuan
	Area//hm^2	Unit price $\times 10^4$ yuan	Compensation amount $\times 10^4$ yuan	Area//hm^2	Unit price $\times 10^4$ yuan	Compensation amount $\times 10^4$ yuan	
Paddy field	2 641.92	1	2 642	5 385.75	0.25	1 077	–
Dry land	732.93	0.8	586	11 816.91	0.20	1 891	–
Total	–	–	3 228	–	–	2 968	6 196

③ Other parts: after compensating farmland, remained ecological compensation amount of 10.8 million yuan/a could be used for ecological environment protection of water source areas.

2.2.5.2 Mature compensation stage. Mature compensation stage is after initial compensation. Upstream and downstream two-way compensation mechanism is increased under the situation that one-time compensation is basically over; socio-economic condition in the basin is better; water quality could basically reach standard requirements; the income of residents has been greatly increased, and public awareness of environmental protection has been strengthened.

(1) Compensation from upstream to downstream for non-point source pollution: taking county and district as the unit, water quality of section of main rivers flowing into the Shitoukoumen Reservoir is assessed. When water quality exceeds target value, upstream region will give compensation fund to downstream region. Shitoumenkou Reservoir Authority, Changchun City and Jilin City are responsible for determining specific position of section of rivers flowing into the Shitoukoumen Reservoir and target value of water quality assessment. Water quality of section is monitored by the third-party monitoring unit every month, which is entrusted by Shitoukoumen Reservoir Authority, and Shitoukoumen Reservoir Authority assesses water quality to determine compensation situation.

(2) Agricultural compensation: farmland compensation in the secondary reserve continues to be conducted. The compensation subject is water users, mainly containing residents, industrial enterprises and agricultural irrigators in Changchun City. Each water user pays corresponding ecological environment protection fees of water source area according to water consumption amount. Compensation standard refers to the calculation method in "**2.2.3**". According to current step water price scheme in Changchun City, 150 m^3 of annual water consumption is the first step. According to environmental protection fee of 0.2 yuan/m^3 for water source area paid by residents, most families spend 30 yuan/a of environmental protection fee of water sources, which could be sustained by most families in Changchun City. The object of compensation is the owner of cultivated land in the secondary reserve, and compensation standard is adjusted properly according to social and economic development.

(3) Other compensation: there will be a difference between the ecological compensation paid by water users and the farmland compensation. When ecological compensation paid by water users is more than farmland compensation, the difference is used for other ecological environment protection works of water source areas, and the insufficient part shall be undertaken by Changchun Municipal Government. When ecological compensation paid by water users is equal to farmland compensation, other ecological environment protection works of water source areas are undertaken by Changchun Municipal Government. When ecological compensation paid by water users is less than farmland compensation, the

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(FLT + PYR) are used to judge the aging degree and source of particulate matter. The ratio of IPY/(IPY + BGP) in $PM_{2.5}$ and PM_{10} was always greater than 0.5, which indicates that straw and coal-fired emissions played an important role in the contribution of particulate matter in Jiujiang City. The lower ratio of BeP/(BeP + BaP) implies an increase in fresh particulate matter emissions, and the higher ratio of BeP/(BeP + BaP) on December 7 implies the accumulation of local sources. During the period of heavy pollution, the higher ratio of FLT/(FLT + PYR) also implies the accumulation of particulate matter produced by biomass combustion in the atmosphere of Jiujiang City.

6 Conclusions

Based on the analysis of typical pollution events in Jiujiang City, the causes of accumulative pollution, local accumulation and transportation of local fine particulate matter are discussed. The results show that meteorological conditions were important factors for the formation of haze pollution in Jiujiang City, and the accumulation of pollutants under stationary weather or the transport of air masses carrying pollutants would lead to pollution; the analysis of backward trajectory shows that there were three main routes for long-distance transportation to Jiujiang City, particulate matter than could lead to heavy pollution in North China could be transported to Jiujiang City to cause impact; the impact of biomass combustion, dust discharge, and emissions of vehicle exhaust and other local sources on atmospheric pollution under adverse meteorological conditions can not be neglected; the natural U-shaped alpine topographic environment in Jiujiang City and the half valley environment of the Lushan Mountains are the causes of obvious diurnal variation of pollution concentration.

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insufficient part shall be undertaken by Changchun Municipal Government, and other ecological environment protection works of water source areas are undertaken by Changchun Municipal Government.

3 Conclusions

Experience at home and abroad shows that the establishment of ecological compensation system in water source areas could not only stabilize the economy around the water source areas but also promote effective protection and sustainable development in water source areas, and it is an important means of solving the contradiction between water source protection and economic development. In this paper, according to the principle of ecological compensation, subject and object of ecological compensation in the primary and secondary reserves of drinking water source area of the Shitoukoumen Reservoir are determined. By accounting, ecological compensation standard is 72.76 million yuan/a according to the cost of ecological environment protection by combining specific situation of reserve of water source area, while ecological compensation standard is 101.89 million yuan/a according to the value of ecological services obtained by ecological beneficiaries. After comparative analysis of two accounting results, the suggestion of staged compensation is proposed.

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