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The Flow of Elements and the Effects between the Industrial Economy and the Water Resource Environment in Riverside Cities

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Abstract

The transfer of elements between the industrial economy and the water resource environment in riverside cities consists of the flow of elements between the industrial economic system and the water resources system, the flow of elements between the industrial economic system and the water environment system, and the flow of elements between the water resources system and the water environment system. In this article, the connotation of the industrial economic system, water resources system and water environment system of the riverside cities would be explained. Then, this paper explores the path and law of factor circulation, and finally analyzes its specific performance.

Keywords

Riverside Cities; Industrial Economy; Water Resource Environment; Factor Flow.

1. Introduction

The flow of elements between the industrial economy and the water resource environment in riverside cities is that as a whole, the water resource environment provides the supplies of the water resources (generally referring to purified water resources) for the operations of the industrial economy through supplying water to industrial enterprises directly or the process of water supply through the waterworks. The purified water resources, together with other human resources, capital resources, technical resources and so forth, are produced through industrial economic operations(industrial production), producing industrial manufactured goods with industrial waste, for the water resource environment, this industrial waste is trade waste. After the trade waste is conducted by the sewage treatment plant and other departments, it is discharged back to the water resource environment, causing certain wastewater pollution to the water environment. After the trade waste has passed the self-purification cycle of the water resource environment, it turns into a purified water resource and provides the necessary guarantee for the smooth operation of the industrial economy. The elements flow chart between the industrial economy and the water resource environment in riverside cities is shown in Figure 1 below.

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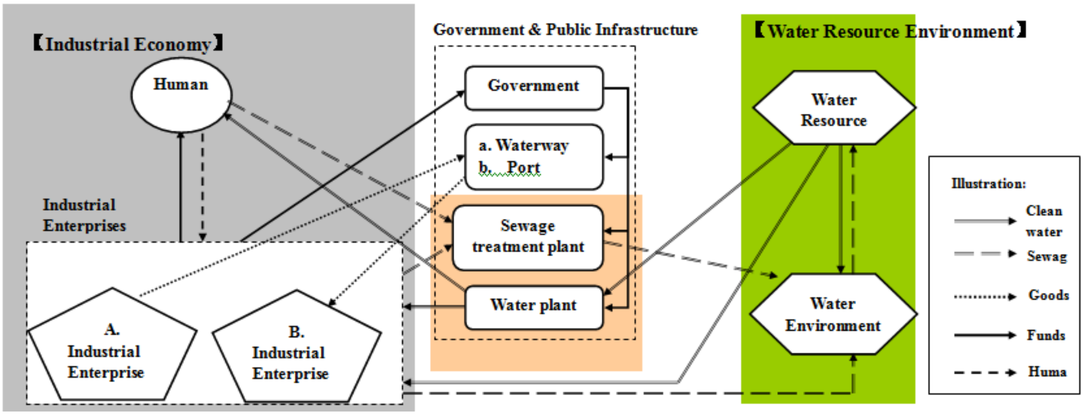

Figure 1. The elements flow chart between the industrial economy and the water resource environment in riverside cities

2. Methods & Results

2.1. Fundamental Principle

(1) Water resources will supply the industrial economy with water consumption, which is industrial water supply.

When the water supply satisfies the needs of industrial economic development, the two develop healthily; when the water supply quantity does not meet (generally less than) the industrial economic development demand, it will restrict the development of the industrial economy, which is manifested by the limitation of scarcity of water resources on the industrial economy.

(2) The development of the industrial economy requires demand for water resources, which is reflected in industrial water demand.

When the water demand is within the scope of water supply capacity, the two operate healthily; when the water demand exceeds the supply capacity of water resources, the quantities of water resources will be reduced, which is referred as water depletion.

2.2. Performance

(1) From a water resources perspective: the impact of water scarcity on industrial economy

The relationship between industrial economy and water resources is the relation between supply and demand of water resources in terms of water resources, specifically it can be measured by the scarcity of water resources to the industrial economy, namely the index of industrial water scarcity. Generally speaking, the scarcity of water resources refers to the finiteness of water resources relative to infinite economic production under certain technical conditions in a certain economic development statement. The scarcity of industrial water is relative to the infinite demand generated by industrial enterprises. Industrially available water resources are limited in quantity, yet the demand for industrial enterprises is growing, water resources supply cannot satisfy the needs of industrial enterprises, which is regard as being scarce.

The measurement of industrial consumption scarcity can be divided into two categories: physical metrics and economic metrics.

① Physical metrics: the physical measure of industrial water scarcity refers to measuring the degree of the industrial water scarcity by estimating the gross of existing water resources for industrial production and calculating the years in which this water resource is available based on current and future levels of use. It can be divided into static physical metrics and dynamic physical metrics for industrially available water resources. Static physical metrics adopts the ratio of current industrially available water to its annual utilization to indicate its scarcity over a certain period of time. The formula is as follows:

$$Y = S0 / R0 \tag{1}$$

In formula (1),Y is the index of static industrially available water stock, expressed as years;S0 is the current industrially available water;R0 is the current annual industrial water consumption.

In the previous formula,R0 is assumed to be constant, but in fact, the annual industrial water consumption is increasing over a period of time(on the basis of no major changes in the industrial model),which is not a constant. Assuming that the annual utilization of industrially available water resources increases at a rate of r, then in the t-th year, the industrial water consumption will be:

$$R_t = R_0 \times e^{rt} \tag{2}$$

In this formula, Rt is the industrial water consumption in the t-th year;R0 is the current annual industrial consumption. The total amount of industrial water available in the next T years will be:

$$R(T) = \int_0^T R(t)dt = \int_0^T R_0 \times e^{rt} dt = \frac{R_0}{r}(e^{rT} - 1) \tag{3}$$

In this formula, R(T) is the total amount of industrial water available in T years, Rt is the industrial water consumption in the t-th year; and R0 is the current annual industrial water consumption.

Consequently, the calculation formula for the fixed term in the total amount of industrial water available(regardless of improving water use efficiency due to technological progress factors) should be:

$$Y = \frac{S_0 r}{R_0(e^{rT} - 1)} \tag{4}$$

② Economic metrics: The scarcity of water resources available in industry can be measured from an economic perspective: industrial water prices, marginal use costs of industrial water and other indexes.

(2)From an industrial economic perspective: Seeking the optimal industrial water consumption

Industrial economic systems and water resources systems are reflected in the relationship between industrial (economic) output and industrial water use, that is, to seek the optimal industrial water consumption. The relationship between the two can be indicated in terms of the optimal industrial water model:

The basic assumption of the model:

① The other input factors of industrial production remain unchanged, only industrial capital and water resources vary, that is, fixed input in industrial production is capital(industrial capital),and variable inputs are water resources.

② There are N industrial enterprises (manufacturers) with the same conditions in a certain area. They produce the same industrial products and they are price takers in the market (that is to say that a single industrial company has no impact on the power of market prices)

③ The optimal water consumption of the whole industry (industrial industry) is different from the optimal water consumption of a single industrial enterprise. The disparity between the two constitutes is the optimal tax rate.

④ The amount of water resources available is a function of time and requires dynamic analysis.

Under the previous conditions, the production function of industrial enterprises is:

$$Q_i(t) = f[hw_i(t)] \tag{5}$$

In this formula, wi(t)-the amount of industrial water used by industrial enterprises named as i in the t-th year, t=1,2…,N. h-The water utilization efficiency coefficient of this enterprise,0<h<1.Therefore,hwi represents the valid industrial water consumption of the enterprise, and the remaining industrial water, that is,(1-h)wi is invalid loss.

The annual variation in the amount of industrial water resources available (industrial water available) is:

$$S(t) = R(t) - \sum_{i=1}^{N} hw_i(t) - aS(t) \tag{6}$$

In the formula, R(t)-annual recharge of industrially available water (the added water resources mainly due to natural factors, such as precipitation, the storage increments of water resources in water sources(rivers, lakes); a-annual loss rate of industrially available water(mainly natural factors such as evapotranspiration loss); S(t)-industrial water available in the t-th year.

Assuming that c(S) is the unit cost of industrial water,[c(S) is a decreasing function of the total amount of industrial water available, the more water resources used in industrial production, the lower the unit cost of industrial water], c'<0(monotone reduction),c''>0(convex function);then assuming that P(t) is the price of industrial products, from the perspective of the whole industry, the profit(gross) of all N industrial enterprises is:

$$\prod\nolimits_R(t) = \sum_{i=1}^{N} [P(t)Q(t) - c(S)w_i(t)] \tag{7}$$

In the meanwhile, the profit of a single industrial enterprise is:

$$\prod\nolimits_F(t) = [P(t)Q_i(t) - c(S)w_i(t)] \tag{8}$$

Optimize the discounted value of the net benefits of the entire industrial industry, then obtain:

$$\max_{w_i(t)} \int_0^{\infty} e^{-rt} \left\{ \sum_{i=1}^{N} [Pf(hw_i) - c(S)w_i] \right\} dt \tag{9}$$

Under the premise of the constraint(6),the optimal industrial water consumption of the whole industry can be obtained from the formula (9). The maximum condition of (9) is:

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$$P\partial f/\partial w_i(h\times w_i)-c(S)-\lambda\times h=0 \tag{10}$$

In the formula, λ is the shadow price of the industrially available water(the optimal target price, which is the most reasonable price reflecting the scarcity of water resources). Under the premise of the constraint(6)(the formula is equal to 0),the optimal industrial water consumption of the whole industry can be obtained by formula(10),which is:

$$w_i^*=w_i^*(P,S,\lambda,h) \tag{11}$$

In the following, the whole industrial optimal decision of the aforesaid industry is compared with a single industrial enterprise. Assuming that the industrially available water resources are self-contained, and individual industrial enterprises do not bear the economic responsibility for their water consumption; Assuming that each industrial enterprise is independently determined, and there is no cooperation between them (that is to say that it is unnecessary to consider the interests of other enterprises). Under the previous conditions, a single industrial enterprise maximizes its own profits through the use of water resources. Thus there are:

$$\max_{w_i} Pf(w_i)-c(S)w_i \tag{12}$$

The formula (12) indicates that unlike the best planners in the whole industrial industry, a single industrial enterprise does not consider the constraint(6) while making its own decisions, which means it does not consider the influences on its decision-making to the total amount of industrial water resources available. Therefore, for a single industrial enterprise, the formula(12) has a maximum condition.

$$Pf(w_i)-c(S)=0 \tag{13}$$

The formula(13) is the optimal solution for the water available of a single industrial enterprise when the total amount of water available in the whole industrial industry is at a certain steady state. By comparing the formula(13) with (10), the optimal tax rate (that is the industrial water tax rate, and the water resource tax rate for industrial water only) is determined as:

$$T(t)=h\lambda^*(t) \tag{14}$$

Among the optimal industrial water tax rates, the former part attempts to eliminate the externalities generated by water resources waste in industrial enterprises, that is, the rise in water prices caused by excessive water use of industrial enterprises.

3. Discussion

Known by the above that the industrial economic system includes various elements for industrial production, mainly containing human elements, industrial capital elements, technical elements, etc. The water resource environmental system includes water resources system and water environment system, it is the composite system composed of the two, consisting of water resource environmental elements, and the flow of elements between the industrial economic system and the water resource environmental system.

The industrial economic system carries out industrial production, which brings pressure to the water resource environment, mainly embodied in the discharge of industrial sewage, and the water resources system supplies the purified water resources for the industrial economic system, providing the necessary natural resource elements which is water resource element for the industrial production of the industrial economic system. The industrial economic system conducts industrial production activities together with the input of other important factors after obtaining the water resources necessary for production. The input resources mainly contain labor, industrial capital, production technology, various natural resources such as water resources, etc. The output resources mainly contain a sequence of industrial products, trade waste and other industrial wastes. This process is reflected in the discharge of trade waste from industrial economic systems to water environment systems.

On the other hand, the water resource environmental system will also furnish feedback on the industrial economic system. Among them, the feedback of the water resources system to the industrial economic system is manifested in the provision of water supply. If the water supply cannot meet the requirements of the industrial economic system for industrial production, in other words, it will impede industrial production; the feedback of the water environment system to the industrial economic system is reflected in the impact of water environment quality to industrial economy production, if the quality of the water environment is too poor, it will restrict the industrial system to proceed production operations. For instance, beverage enterprises produce beverage products in a certain place, but the polluted water environment cannot satisfy the production and life of the enterprises.

4. Conclusion

There is a complex coupling relationship between industrial economy and water resource environment in riverside cities, the development of industrial economy requires a mass of water resources(purified water resources),and the water resource environmental system supplies the purified water resources to the industrial economic system, after the specific industrial production behavior of the industrial economic system, then the industrial manufactured goods(the performance of economic attributes: industrial added value) and the co-product which is trade waste, and then the trade waste is discharged back to the water resource environmental system, when water supply, waste water discharge exceed the carrying capacity of water resources, the water resource environmental system will provide feedback to the industrial economic system. In this process, the press-state-response (PSR) mechanism, in other words, the development of the industrial economy puts pressure on the water resource environment, the carrying of the water resource environment supports the development of the industrial economy and has a feedback influence on it.

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