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Emission Characteristic Analysis of Urban Domestic Pollution Sources in China

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Abstract

Ever since China entered the period of rapid urbanization in the late eighties last century, the urban domestic pollution sources have become the major source of most urban water pollution. However, the current literature both at home and abroad rarely involves the analysis of pollution source emission characteristics. In this paper, the author chooses the consumption level and the disposable income of urban residents as the emission characteristic indicators of urban domestic pollution sources, building the statistical model of urban domestic pollution sources. Based on this, the author divided China into 5 regions and 25 categories, investigating the reasons of the urban life emission characteristic differences between these regions, providing decision support for more actively controlling the pollution and guiding the economical and social development.

Keywords: Urban domestic pollution sources, Emission characteristic, Pollution discharge coefficients, Environmental accounting system;

1. Introduction

Domestic pollution sources (GPS) investigation is a new active field concerning international environmental research following industrial pollution sources\[^1\]. Because of the presence of information asymmetry and the high uncertainty, the domestic pollution sources have characteristics such as dispersion, regional differences, difficulties to monitor and quantify, which make it very difficult to investigate and manage \[^2-4\]. The investigation on the emission of domestic pollution sources which are mainly caused by the family life of residents has been conducted ever since the eighties in the last century, but the existing studies are scattered, there were no systematic and regional studies, not to say the investigation of the socio-economic coupling emission characteristics \[^5-10\]. However, there is a close relationship between the municipal wastewater discharge and regional characteristics, socio-economic development levels and the internal factors of the domestic living standards \[^11\], but China’s existing environmental statistical sewage water is only based on the integrated water usage in the city, and is estimated according to the experiential coefficients. Obviously, this approach cannot objectively reflect the resulting changes in domestic pollution sources caused by urbanization and the economic and social development, as a result, the country fails to properly judge the environmental situation and formulate corresponding policies, plans, and can not

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implement macroeconomic regulations and take engineering measures timely. Thus, with the launch of our energy reduction work and the establishment of a livable city, our country needs to know the urban domestic pollution sources emission characteristics and laws with the changes in the socio-economic development and lifestyle, providing a scientific basis for the urban planning, environmental management and the building of a resource-saving and environment friendly society.

2. Data sources and methodology

2.1. Data sources

(1) The all-period measured data of 17 provinces, municipalities and autonomous regions;
(2) Statistics: 2001 ~ 2007 Statistical Yearbook of China, 2000 ~ 2007 Statistical Yearbook of the provinces, 2000 ~ 2006 Statistical Yearbook of China's regional economy, 2000 ~ 2007 Statistical Yearbook of Chinese cities, 2000 ~ 2006 Statistics Yearbook of Chinese environment;
(3) Relevant standards, technical specifications and other information: Design manual of water supply and drainage, "Urban water consumption standards" (GB/T 50331-2002).

2.2. Methodology

This study uses the national area sample survey measurement combined with statistical projections, i.e. taking the investigation of experimental data as the main method, supplemented by multivariate statistical analysis, based on GIS technology, using the multivariate statistical method to analyze the urban domestic pollution emission characteristics. The specific methods are: 1. The establishment of properties and spatial databases, including the collection and collation of statistical data, spatial data input, using GIS software to enable data visualization, etc.; 2. Based on multi-temporal social-economic-environmental statistics panel data using the typical correlation analysis to build the index evaluation system of the urban domestic pollution sources mission coefficient, and identify the division of urban domestic pollution sources mission characteristics according to this; 3. Based on 2007 census data and evaluation statistical data of the year, using multivariate statistical analysis to build the statistical model of urban domestic pollution sources in our country; 4. Using interpolation to analyze the characteristics of urban domestic pollution emissions.

3. Indicator system investigation of the urban domestic pollution emission characteristics

The building of the indicator system is the basic work of the investigation of the urban domestic pollution emission characteristics, we should not only consider the relationship between the social-economic level and the production and emission of domestic pollution sources, but also consider the availability of the indicator data. From the perspective of the theory of man-land relationship and in compliance with the regional, scientific, holistic, measurable and maneuverable standards, this paper sets and screens the indicator data, choosing the society-economy-pollution discharge indicators such as per capita GDP, per capita retail sales of social goods, disposable income of urban residents, consumption level of urban residents and disposable income of urban residents, per capita GDP and per capita ammonia emission coefficient, establishing Chinese social-economic-environmental panel data from 2001 to 2006 and the provincial social-economic-emission cross-section data in 2006. Based on this, we conduct the canonical correlation analysis. For the relationship between the indicators and the urban domestic pollution sources emission coefficients, see Chart 1 and Chart 2.

By analyzing Chart 1, we can find that COD and ammonia nitrogen are highly related to the population, consumption level of urban residents and disposable income of urban residents, which are respectively (0.88, 0.73, 0.81) and (0.83, 0.70, 0.75), the linear nature is significant, and the fit of the model is up to 0.97 and 0.94. According to Table 5.2-4, COD and the mission quantity of ammonia nitrogen are closely related to consumption level of urban residents and disposable income of urban residents, which are respectively (0.73, 0.64, 0.66) and (0.89, 0.97, 0.67), the linear nature is significant, the fit of the model is up to 0.94 and 0.93. So this paper takes the
consumption level of urban residents and disposable income of urban residents as the urban domestic pollution emission characteristic indicator, establishing the statistic model of urban domestic pollution emission.

Chart 1. Correlation coefficient statistical table of domestic pollution sources characteristics indicators in our country from 2001 to 2006

| Domestic pollution emission indicators | Social - Economic Indicators | population | per capita GDP | consumption level of urban residents | per capita retail sales of social goods | disposable income of urban residents | multiple correlation coefficients ($R^2$) |
|---------------------------------------|-----------------------------|------------|----------------|--------------------------------------|---------------------------------------|--------------------------------------|----------------------------------------|
| COD                                   |                             | 0.88       | 0.21           | 0.73                                 | 0.50                                  | 0.81                                 | 0.97                                   |
| Ammonia Nitrogen                      |                             | 0.83       | 0.61           | 0.70                                 | 0.15                                  | 0.75                                 | 0.94                                   |

Chart 2. Correlation coefficients statistical table of domestic pollution sources characteristics indicators in 2006

| Urban domestic pollutants | Social - Economic Indicators | population | per capita GDP | consumption level of urban residents | per capita retail sales of social goods | disposable income of urban residents | multiple correlation coefficients ($R^2$) |
|---------------------------|-----------------------------|------------|----------------|--------------------------------------|---------------------------------------|--------------------------------------|----------------------------------------|
| COD                       |                             | 0.73       | 0.59           | 0.64                                 | 0.36                                  | 0.66                                 | 0.94                                   |
| Ammonia Nitrogen          |                             | 0.89       | 0.38           | 0.79                                 | -0.20                                 | 0.67                                 | 0.93                                   |

4. Division of urban domestic pollution sources emission characteristics

Based on the national administrative division, with reference to "City domestic water consumption standards" (GB /T 50331-2002) water district, and fully considering geographic location, natural conditions, humanistic customs, diet and living habit and other factors, and combining the pollution emission characteristic reflected by the measured data, this paper divided china into five districts(see Fig.1.), following are the details:

The first district: Heilongjiang, Jilin, Liaoning, Inner Mongolia, Hebei, Beijing, Tianjin, Shanxi;
The second district: Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi, Hainan;
The third district: Henan, Hubei, Hunan, Jiangxi, Anhui;
The forth district: Chongqing, Sichuan, Guizhou, Yunnan;
The fifth district: Shaanxi, Xinjiang, Gansu, Ningxia, Qinghai, Tibet.

Figure 1. national domestic pollution sources emission characteristics zoning map
5. Urban domestic pollution sources emission characteristics model in China

Based on the measured pollution emission coefficients of provinces and cities in each district, the consumption level of urban residents and the sample data of the disposable income of urban residents, using the multiple linear regression method, this paper establishes the district pollutants multivariate linear model, for the details, see Chart 3.

Chart 3. Summery table of the district pollutants multivariate linear model

| District | Pollutants       | Multiple linear equation          | Correlation coefficients (R2) | F value |
|----------|------------------|----------------------------------|------------------------------|---------|
| first    | COD              | 65.92+97.19*X1-69.07*X2         | 0.93                         | 2.26    |
|          | BOD5             | 25.56+89.86*X1-62.98*X2         | 0.88                         | 37.67   |
|          | Ammonia nitrogen | 7.25+17.84*X1-12.65*X2          | 0.74                         | 1.87    |
|          | Total nitrogen   | 11.67+23.18*X1-17.53*X2         | 0.71                         | 1.87    |
|          | Animal and vegetable oils | 0.76+4.70*X1-2.62*X2 | 0.76 | 4.83 |
|          | Total phosphorus | -1.66+1.11*X1-0.07*X2+0.04*X3  | 0.96                         | 3.97    |
| second   | COD              | 47.82+3.25*X1+9.38*X2           | 0.86                         | 2.87    |
|          | BOD5             | 18.47+5.39*X1+1.830*X2          | 0.91                         | 4.89    |
|          | Ammonia nitrogen | 3.72-3.30*X1+5.23*X2            | 0.95                         | 10.48   |
|          | Total nitrogen   | 6.42-1.23*X1+4.06*X2            | 0.90                         | 4.37    |
|          | Animal and vegetable oils | 0.11+0.28*X1+0.60*X2 | 0.97 | 16.74 |
|          | Total phosphorus | 0.69+0.28*X1+0.03*X2            | 0.86                         | 2.87    |
| third    | COD              | 26.57-95.32*X1+102.16*X2        | 0.99                         | 10.97   |
|          | BOD5             | 18.19-44.58*X1+41.47*X2         | 0.97                         | 11.49   |
|          | Ammonia nitrogen | -2.36+31.62*X1-15.42*X2         | 0.96                         | 7.60    |
|          | Total nitrogen   | -3.33+45.36*X1-22.32*X2         | 0.96                         | 7.61    |
|          | Total phosphorus | -0.26+3.45*X1-1.67*X2           | 0.97                         | 7.61    |
|          | Animal and vegetable oils | -2.41+10.31*X1-3.98*X2 | 0.96 | 11.84 |
| forth    | COD              | 16.42+155.58*X1-69.24*X2        | 0.87                         | 1.70    |
|          | BOD5             | 42.98+170.15*X1-135.65*X2       | 0.89                         | 2.0     |
|          | Ammonia nitrogen | -1.79+14.23*X1+18.39*X2         | 0.98                         | 14.34   |
|          | Total nitrogen   | -10.87-47.62*X1+52.85*X2        | 0.91                         | 2.60    |
|          | Total phosphorus | -0.32-2.53*X1+3.05*X2           | 0.93                         | 3.47    |
|          | Animal and vegetable oils | 3.52+22.03*X1-17.41*X2 | 0.97 | 47.45 |
| fifth    | COD              | 22.24+92.76*X1-30.58*X2         | 0.94                         | 4.08    |
|          | BOD5             | 9.20+53.55*X1-23.38*X2          | 0.91                         | 2.43    |
|          | Ammonia nitrogen | 4.77+2.30*X1-0.24*X2            | 0.85                         | 1.41    |
|          | Total nitrogen   | 7.75+0.99*X1+0.45*X2            | 0.81                         | 1.02    |
|          | Total phosphorus | 1.50-0.48*X1-0.25*X2            | 0.93                         | 3.63    |
|          | Animal and vegetable oils | 1.15+0.74*X1-0.13*X2 | 0.93 | 2.51 |

Notes: in the equation, X1: consumption level of residents; X2: disposable income of residents

From Chart 3, in the 0.05 significance level assumptions, the regression model F of each district is greater than the corresponding plot F statistics; therefore the overall regression model in each district is significant, passing the F test.

6. Urban domestic pollution sources emission characteristics analysis in China

According to the above research, and using interpolation method, this paper calculates the urban domestic wastewater emission coefficient in national urban areas, counties (county-level cities), and towns. Based on per capita consumption level and the provincial emission coefficient scope, we divide the national urban domestic emission coefficient system into “5 districts and 25 categories”, for the details, see Chart 4 and Fig. 3.
**Figure 2. Urban domestic pollution emission characteristics of each district**

**Chart 4. Urban domestic pollution emission coefficient table of each district**

| Pollutants indicator                      | I         | II        | III        | IV         | V         |
|------------------------------------------|-----------|-----------|------------|------------|-----------|
| Domestic wastewater (L/d.person)         | 105~145   | 145~185   | 140~180    | 120~150    | 95~125    |
| Chemical oxygen demand (g/d. person)     | 60~77     | 58~79     | 59~81      | 53~82      | 53~76     |
| Biochemical oxygen demand for 5 days (g/d. person) | 22~32     | 26~33     | 27~36      | 21~34      | 19~31     |
| Ammonia nitrogen (g/d. person)           | 7.2~9.5   | 7.4~9.7   | 7.2~8.8    | 7.5~9.6    | 7.3~8.3   |
| Total nitrogen (g/d. person)             | 10.0~13.6 | 10.3~13.9 | 10.0~12.6  | 10.4~13.7  | 10.1~11.8 |
| Total phosphorus (g/d. person)           | 0.63~0.95 | 0.74~1.16 | 0.63~0.91  | 0.81~1.26  | 0.64~1.05 |
| Animal and vegetable oils (g/d. person)  | 1.16~2.21 | 0.95~2.00 | 0.84~2.15  | 1.05~2.21  | 1.47~1.89 |
| Domestic waste (Kg/d. person)            | 0.35~0.70 | 0.35~0.68 | 0.38~0.71  | 0.35~0.64  | 0.34~0.55 |
From Chart 4 we can see that:

(1) The urban domestic pollution sources COD sewage production coefficient of each district differs from one another by 11 ~ 29 g / person.d, of which the gaps between the towns in southwestern regions are the biggest; the domestic pollution sources BOD5 sewage production coefficient of each district differs from one another by 11 ~ 29 g / person.d, of which the gaps between the towns in southwestern and northwestern region are bigger. The sewage production distribution characteristics of COD and BOD5 are almost the same, of which the mid-southern and southwestern regions are the highest, followed by the coastal areas; the northwestern, northern, northeastern regions are the lowest. COD and BOD5 are mainly come from kitchen waste water, laundry waste water and stool, which are closely related to regional dietary habits, living habits, and natural conditions, for example, the dietary habits of mid-southern region plays the main role, in this place, there are various eating materials, with the characteristics of drizzle, colored and lubricious oil, thus the COD and BOD5 production coefficient is higher than other cities; while in the northwestern region, the living habits play the main role, because of the weather conditions and the lack of water, the washing times are less than other regions, so the COD and BOD5 production coefficient is lower than other cities.

(2) The urban domestic pollution sources ammonia nitrogen sewage production coefficient of each district differs from one another by 1~2.3 g / person.d, of which the gaps between the towns in northern regions are the biggest; the urban domestic pollution sources total nitrogen sewage production coefficient of each district differs from one another by 1.7~3.6 g / person.d, of which the gaps between the towns in northern and coastal regions are the biggest; the urban domestic pollution sources total phosphorus sewage production coefficient of each district differs from one another by 0.28~0.45 g / person.d, of which the gaps between the towns in southern region are the biggest. The distribution characteristics of ammonia nitrogen, total nitrogen and total phosphorus are almost the same, of which the coastal and southern regions are the highest, and the differences between the northeastern, northern, mid-southern and northwestern regions are not very obvious. The sewage production characteristics of ammonia nitrogen, total nitrogen and total phosphorus are closely related to regional dietary habits.

(3) The urban domestic pollution sources animal and vegetable oils sewage production coefficient of each district differs from one another by 0.42~1.31 g / person.d, of which the gaps between the towns in mid-southern region are the biggest. The distribution characteristics of animal and vegetable oils sewage production coefficient are closely related to the regional dietary habits, people in the western and northern regions mainly eat meat, pasta, especially large proportion of carnivore, while the food in the coastal regions is oil but not greasy and is very delicate, therefore the animal and vegetable oil sewage production coefficient of the western and northern regions are higher than the coastal cities.

7. Conclusion

1. This paper takes the consumption level and disposable income of urban residents as the urban domestic pollution sewage characteristics indicator, establishing the division of urban domestic pollution sources emission characteristics.

2. This paper establishes the multivariate statistical model of urban domestic pollution emission coefficients. Based on this, it establishes urban domestic pollution sources emission characteristics evaluation system of 5 regions and 25 categories, changing the current environmental statistical regulations of the simple north and south accounting system, further enhancing the scientificalness and practicability of the calculation.

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