Three industries and water consumption of Beijing

Wang Hong-rui

Institute of Environmental Sciences, Beijing Normal University, Beijing 100875, China

Wang Yan

Beijing Municipal Research Institute of Environmental Protection, Beijing 100037, China

Abstract—Beijing has been experiencing a severe shortage of water. At present serious wastes of water resources result from the unreasonable structure of water uses in various industries sectors. The current conditions of the municipal water use structure and its changes in the industrial sectors were analysed and discussed in terms of the indicators, such as direct water-use coefficient, complete water-use coefficient, water-use multiplier and water-reuse rate, by taking a year of 1990s as the base year. Some response strategies for water conservation have been studied and the corresponding recommendations were put forward. All of these have provided a basis for coordinating the relationship between aquatic environment and economic growth in this city, establishing a system for rational utilization of water resources, and promoting the implementation of a strategy for sustainable development.

Keywords: direct water-use coefficient; complete water-use coefficient; water-use multiplier; water reuse rate.

Beijing is serious short of water. The water resources which can be utilized in low flow year is only 4.05 billion m^3. The average volume owned by per capita in China is 400 m^3. Beijing stands at the end of line among 120 big cities in the world, and it is one of the 40 cities which is the shortest of water seriously over the country. The shortage of water resources has affected the production and people's daily life, and has become an important factor that may well hamper the future economic and social development.

1   The survey of water use

Table 1 is an annual summary of water use situation of Beijing in 1990s. Fresh water consumed by the secondary industry of the whole city is 839 million m^3 annually, 10.4% lower than that of 1980s, which was 936 million m^3. Fresh water consumed by the tertiary industry and residents is totally 561 million m^3, 27.5% higher than that of 1980, which was 440 million m^3. The percentage of fresh water use shows that fresh water consumed by the primary industry takes 61.5% if total fresh water consumed. Thus it's clear that agriculture is still a large water-use sector. Low water reuse rate (12.17%) shows there is a great water-saving potentiality in the primary industry. Fresh water consumed by resident was 112 million m^3, taking up 3.1% of the total water-use in a year of 1980s. Fresh water consumed by resident is 4.8% of total fresh water use in Beijing, 1.7% higher than that of 1980s. Table 2 shows the comparison of the fresh water

between the two periods.

Table 1   Water consumption of Beijing ($10^8 m^3$)

Type of consumption	Annual total	The primary industry	The secondary industry	The tertiary industry	Household use
Total water use	74.41	25.47	43.08	4.11	1.75
Fresh water	36.37	22.37	8.39	3.86	1.75
Tap water	5.23	-	1.42	2.42	1.39
Well water	22.82	17.17	3.85	1.44	0.36
River water	8.32	5.20	3.12	-	-
Reuse water	38.01	3.10	34.69	0.25	0
Reuse rate	51.12	12.17	80.52	6.08	0
Percentage of fresh water consumed, %	100	61.5	23.1	10.6	4.8

Notes: fresh water refers to tap-water, well water and river water

Table 2   Rates of fresh water consumed by the three industries in 1980s and 1990s(%)

Time	Total	The primary industry	The secondary industry	The tertiary industry	Resident use
1980s	100	61.6	26.1	9.2	3.1
1990s	100	61.5	23.1	10.6	4.8

Notes: primary industry: agricultural & mine; secondary industry: manufacture; tertiary industry: services *etc* .

Table 2 shows that the rate of fresh water consumed by the primary industry varies only a little, while the rate by the secondary industry dropped 3%, and that by the tertiary industry and resident use increased. It is mainly because water reuse rate of the secondary industry rose quickly.

2   Analysis of water-use coefficient of each sector

Direct water-use coefficient (DWC) is the direct consumption coefficient of each production sector, reflecting the direct requirement of water resources by a sector producing unit output value. In addition, each sector consumes water indirectly because raw and processed materials, fuels, motive power and mechanical equipment in the process of productions also consume water in the process of being produced. The sum of direct and indirect water consumption coefficient is complete water-use coefficient (CWC). It's an important index of water consumed by a sector and reflects the multiplex and indirect relation of various sectors.

2.1   Direct and complete influence of water used by each sector

Table 3 shows DWC and CWC of the total 32 sectors (The output value of oil and natural gas industry in Beijing is 0).

It can be seen in Table 3 that CWC of several sectors (such as public affairs & resident service, passenger transportation, administrative organization and education, hygienics & science research) are more than 1300. These are large water-use sectors, ranking among the top ten of the

total 32 sectors. Some other sectors (catering trade, cargo transportation & post telecommunication, trading and finance & insurance) with smaller CWC have great potentiality of

Table 3 DWC and CWC of each sector (t/10⁴ RMB Yuan)

Sector	DWC	Sector	CWC
1 Agriculture	3187.25	Agriculture	881.89
2 Electric power & steam & hot water supply	1339.14	Other industry	2544.25
3 Mining industry	324.33	Food processing industry	2253.03
4 Administrative organization	314.42	Public affairs & resident service	2106.66
5 Education hygienics & scientific research	238.55	Passengers transportation	1958.08
6 Non-metallic minerals mining industry	193.62	Sewing & leather processing	1885.09
7 Coal & gas product industry	180.20	Administrative organization	1763.57
8 Building materials & non-metallic mineral products	150.38	Electric power & steam & hot water supply	1745.78
9 Chemical industry	144.52	Education hygienics & scientific	1343.39
10 Metallurgical industry	139.85	Machinery maintenance	1317.16
11 Coal mining	126.12	Construction	1279.45
12 Paper & stationery manufacturing	103.61	Electric machinery & equipment manufacturing	1245.15
13 Public affairs & resident	94.67	Catering trade	1185.29
14 Textile industry	88.14	Metal products	1141.61
15 Cargo transportation & post & telecommunication	83.60	Instrument & meter manufacturing	1088.10
16 Food processing industry	82.17	Transportation manufacturing	1087.89
17 Machinery maintenance	61.63	Textile industry meal	1058.70
18 Instrument & meter manufacturing	59.43	Mechanical industry	1011.90
19 Trading	53.40	Coal & gas products industry	954.37
20 Metal products	50.05	Building material & non-metallic minerals products	911.53
21 Timber processing & furniture making	49.95	Cargo transportation & post & telecommunication	870.20
22 Petroleum processing	48.67	Chemical industry	804.44
23 Passenger transportation	46.72	Metallurgical industry	708.76
24 Mechanical industry	43.16	Timber processing & furniture making	669.20
25 Catering trade	42.64	Electron & communication equipment manufacturing	666.56
26 Other industry	36.10	Paper & stationery manufacturing	649.59
27 Electric machinery & equipment manufacturing	30.14	Non-metallic minerals mining industry	640.89
28 Transportation equipment manufacturing	26.03	Metal mining industry	600.08
29 Electron & communication equipment manufacturing	20.47	Trading	527.04
30 Sewing & leather processing	18.10	Coal mining	487.78
31 Construction	8.97	Petroleum processing	242.37
32 Finance & insurance	5.46	Finance & insurance	178.33

demand and development, and should be developed greatly. Especially trading and finance & insurance, whose CWC are 527 and 178, are water saving sectors adapting to economic construction and social development of the capital.

Some sectors (food processing, sewing & leather processing, electric power & steam & hot water supply, machinery maintenance, electric machinery & equipment manufacturing and metal products) of the secondary industry which have higher CWC are large-water-use industries. Some sectors (such as instrument & meter manufacturing, transportation industry, chemical industry, electron & metal product industry and paper & stationery manufacturing) whose CWC are lower than 1100 are suitable industries according to the situation of water resources of Beijing from the view of water saving. Agriculture, as the primary industry, not only its DWC but also CWC ranking the first among all industries, is the largest water-use sector.

2.2   Analysis of water-use multiplier

Water-use multiplier (WM), the ratio of CWC to DWC, is an important economic parameter. Large WM of a sector means, among the products of other sector directly or indirectly consumed by this sector, that there are series of products relying on water, and the economic relation of the relative sector is closer. Conversely, the relation is weaker. WM of each sector are shown in Table 4.

Table 4 shows water-use multipliers of construction and sewing & leather processing are quite big. Construction is closely relative with No. 21 (building material & non-metallic minerals products), No. 24 (chemical industry) and No. 26 (metallurgical industry) whose direct water-use coefficients are in the top ten (Table 3). CWC of construction is 1279.45 t/10^4 RMB Yuan highly ranking as eleventh, while its DWC is only 8.97 t/10^4 RMB Yuan, ranking as the 31st. The sewing and leather processing is closely related to No. 17 (textile industry), No. 24 (chemical industry) and No. 32 (agriculture). No. 17 and No. 24 a remedium to higher water-use sectors. For agriculture, both DWC and CWC are higher than those of any other sectors. So CWC of sewing and leather processing is as high as 1885.09, while its DWC is only 18.1. The water-use multiplier is 104.15, ranking as the secondary after construction.

CWC of above two sectors are most sensitive to the variation of DWC. In addition, water-use multipliers of other industries, such as passenger transportation, transportation equipment manufacturing and electric machinery & equipment manufacturing, are higher than 40. These sectors need indirect fresh water much more than direct fresh water.

Each sector uses water resources indirectly. Smaller water-use multiplier means less indirect water use. In the sectors of agriculture, electric power & steam & hot water supply and metallic minerals mining industry whose water-use multipliers are 1.22, 1.30 and 1.85, the direct water-use makes up a dominate proportion in complete water-use. For example, direct water-use takes 82% of complete water-use in agriculture, but 77% and 54% respectively in the other two sectors. This reflects that these sectors have weaker economic relation with other sectors.

Table 4   Water-use multiplier of 32 sectors

No.	Sector	Multiplier
1	Construction	142.64
2	Sewing & leather processing	104.15
3	Other industry	70.48
4	Passenger transportation	41.91
5	Transportation equipment manufacturing	41.79
6	Electric machinery & equipment manufacturing	41.31
7	Finance & insurance	32.66
8	Electron & communication equipment manufacturing	32.56
9	Catering trade	27.80
10	Food processing industry	27.42
11	Mechanical industry	23.45
12	Metal products	22.81
13	Public affairs & resident service	22.25
14	Machinery maintenance	21.37
15	Instrument & meter manufacturing	18.31
16	Timber processing & furniture manufacturing	13.40
17	Textile industry	12.01
18	Cargoes transportation & post & telecommunication	10.41
19	Trading	9.81
20	Paper & stationery manufacturing	6.27
21	Building material & non-metallic minerals products	6.06
22	Education hygienics & research	5.63
23	Administrative organization	5.61
24	Chemical industry	5.57
25	Coal & gas product industry	5.30
26	Metallurgical industry	5.07
27	Petroleum processing	4.98
28	Coal mining	3.87
29	Non-metallic minerals mining industry	3.31
30	Metallic minerals mining industry	1.85
31	Electric power & steam & hot water supply	1.30
32	Agriculture	1.22

2.3   Analysis of water reuse rate in each field

Water reuse rate (WRR) of a certain sector is the ratio of direct water use volume to total water use volume in a period. The higher water-reuse rate means fresh water less consumed. Water-reuse rates of each sector are shown in Table 5.

As shown in Table 5, the industrial sectors whose WRR is more than 80% are metallurgical industry, electric power & steam & hot water supply, chemical industry and coal & gas produce industry. Fresh water use of the above four sectors take 58.8% of the total fresh water use of the city. Total output value and net output value of the four sectors respectively amount to 2.01×10^{10}

RMB Yuan and 7.38×10^9 RMB Yuan, accounting for 26.84% and 33.64% of those of the whole city. Total output value and net output value of the other sectors are 73.16% and 66.36% of those of the whole city, but WRR of all the other sectors are less than 80%. This situation should be improved.

Compared with WRR of foreign countries, we could find out where we fall short and tap the potentialities to save water. Table 6 is the comparison of WRR of the main industrial sectors between South Africa and Beijing.

Table 5   Water-reuse rates of 32 sectors

No.	Sector	WRR
1	Metallurgical industry	89.93
2	Electric power & steam & hot water supply	86.06
3	Chemical industry	83.63
4	Coal & gas product industry	80.48
5	Textile industry	68.64
6	Timber processing & furniture manufacturing	63.52
7	Electron & communication equipment manufacturing	60.80
8	Building material & non-metallic minerals products	59.86
9	Mechanical industry	57.74
10	Metallic minerals mining industry	55.06
11	Electron machinery & equipment manufacturing	54.73
12	Paper & stationery manufacturing	53.55
13	Transportation equipment manufacturing	53.37
14	Instrument & meter manufacturing	50.54
15	Food processing industry	49.41
16	Machinery maintenance	42.09
17	Petroleum processing	33.97
18	Non-metallic minerals mining industry	23.06
19	Metal products	20.55
20	Coal mining	16.85
21	Other industry	13.22
22	Agriculture	12.17
23	Public affair & resident service	11.19
24	Sewing & leather processing	8.84
25	Administrative organization	8.43
26	Education, hygienics & research	6.27
27	Finance and insurance	0
28	Construction	0
29	Cargoes transportation & post & telecommunication	0
30	Trading	0
31	Catering trade	0
32	Passenger transportation	0

Situated in arid region, South Africa is short of water seriously. For the development of city and industry, they do well in economization of industrial water-use. The WRR of iron & steel industry heat & power plant, coal & oil refining and chemical industry are all over 90%. Though the classification of industrial sectors may differ a little between the two countries, some problems can be found.

As shown in Table 6, several industrial sectors in Beijing still have great potentialities of upgrading WRR. There is a big disparity (over than 60%) between WRR of coal mining & petroleum processing in Beijing and that of coal & oil refining in South Africa. This reveals that the water reuse level is very low and the waste of water is serious. If WRR of coal mining & petroleum processing is raised to 90% and the output value is on the level of 1990s, 1.44×10^7 t fresh water will be saved. Therefore, raising WRR is very important for water saving in this city.

Table 6   WRR of the main industrial sectors of Beijing and South Africa(%)

Beijing (1990s)		South Africa (1983)	
Metallurgical industry	89.93	Iron & steel industry	97.2
Electric power & steam & hot water supply	86.06	Heat & power plant	83.63
Chemical industry	83.63	Chemical industry	96.6
Coal mining, petroleum processing	29.92	Coal & oil refining	92.7

3   Conclusion and countermeasure

The water-use structure of industries and resident life has changed greatly comparing with 1984. Main reason is raised WRR of the secondary industry, while WRR of agriculture changed only a little. As a main water consumer, WRR of agriculture whose fresh water use is 61.5% of the whole city is only 12%. Agriculture has great potentiality on water saving. In order to deduce fresh water use of the primary industry, WRR of agriculture should be raised. Importing agriculture products is a good method for water saving. Meanwhile, WRR of the secondary should be continuously raised so that much fresh water can be provided for residents.

In the secondary industry, DWC of food processing industry ranks as the sixteenth of the whole sectors while CWC ranks as the third. It means that food processing industry has great indirect requirement of water use. Main reason is that agriculture, as raw materials providing for food processing industry, is a large water use sector. Therefore, we should import more agriculture products from other provinces to develop food processing industry in Beijing. This is tantamount to transferring water indirectly to Beijing so as to lighten the pressure of water consuming.

Instrument & meter manufacturing, transportation equipment manufacturing, textile industry, mechanical industry, chemical industry, electron & communication equipment manufacturing, metallurgical industry and coal gas product industry whose CWC are small should be greatly developed. What should be noticed is that the wastewater discharge and COD are quite high in the sectors of coal & gas product industry and chemical industry. Technological innovation should be strengthened to control pollution along with the development of the two sectors.

WRR of the teriary industry is low. Some sectors consume water largely, such as public affairs

& resident service, administrative organization, and education, hygienics & research. Attention should be paid to the water saving of these sectors. Economic, legal, administrative and technological measures should be taken to raise the percentage of water saving and reusing, and propaganda should be enhanced to strengthen public's awareness of water saving. Trading, catering trade and finance insurance, whose DWC and CWC are smaller, are high benefit and low water use sectors, and have great potentiality of water saving. They are the major sectors which should be developed in future.

References

Chen Mengxiong. Natural Resources, 1990, 6:29—35

Fang Pingxian. Environmental statistics handbook. Chengdu: Sichuan Science and Technology Press, 1985.111— 149

Ilkka Kananen. Operations Research, 1990, 38(2):221—228

National Environmental Protection Agency. Monitoring and analyzing methods of water and waste water . Beijing: Chinese Environmental Sciences Press, 1989. 354—357

Shang Shouzhong. Water resource and its exploitation and utilization. Beijing:Popular Science Press, 1993. 73—79

Zhong Xiefu, Chen Xikang. Input-output analysis. Beijing: Chinese Financial and Economic Press, 1987. 445—449