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Hydrological simulation in Tangnaihai and Lushi watersheds

Xieyao Ma[a], Yoshihiro Fukushima[b], Tetsuzo Yasunari[a,c],
Yoshinobu Sato[b], Masayuki Matsuoka[b], Xianfeng Wu[d] and Hongxing Zheng[e]

[a] Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology, 3173-25 Showamachi, Kanazawa-ku, Yokohama 236-0001, Japan
[b] Research Institute for Humanity and Nature, 335 Takashima-cho, Kamigyo-ku, Kyoto 602-0878, Japan
[c] Hydrospheric Atmospheric Research Center, Nagoya University, Nagoya 464-8601, Japan
[d] Beijing Normal University, Beijing 100875, China
[e] Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China

1. Introduction

Hydrological process of the Yellow River is very complex because it is affected by human activities very much. In order to understand the water circulation of the Yellow River basin and to examine some processes related to runoff formation change of the basin, a numerical model is necessary. In this issue, we will introduce a hydrological model system, in which some regional characteristics, like various land use and agricultural irrigation are considered, and report the result of the model application to the different scale watersheds of the basin, Tangnaihai and Lushi.

2. Model construct

A one-dimensional model (Figure 1) is set up based on Ma *et al*. (2000). The model is composed of three components: one-dimensional SVAT model, runoff formation model, and river routing model. The land use over the basin was lumped into five-group based on Matsuoka *et al.* (2005) dataset, namely, 1) Barren and urban, 2) Grass and shrub, 3) Forest, 4) Irrigated field and 5) Water. A brief summary of each component of the model is presented as follows:

SVAT model

The SVAT model is a simple biosphere model, in which the land surface includes a big-leaf and a soil layer. Using daily meteorological data, the model provides estimates of latent and sensible heat fluxes between the land surface and the atmosphere, and thermal regimes in the snow-cover and soil layer.

Parameters related to land use were determined according to the feature of vegetation. The irrigation period is designed from the climate and the kinds of farm product.

Runoff model

A conceptual model HYCY (Fukushima, 1988) is used to determine the formation of runoff for a regional scale watershed. There is a reservoir system representing each of the four runoff components, which are saturated land surface runoff, infiltration runoff from the topsoil zone, base runoff and direct runoff from the water surface.

River routing model

To estimate river flow from upper stream to downstream, a lineal model is used. The velocity of river flow is set as a constant.

The model was applied to the Tangnaihai watershed (120,000 km^2 in area, over 3,000 m in a.s.l.), a source area of the basin from 1980-2001, and Lushi watershed (4,600 km^2 in area, 900-2,000 m in a.s.l.), a source area of Luohe, a tributary river in midstream in the period 1980-2000 (see Figure 2). As model input, 117 meteorological station data was used.

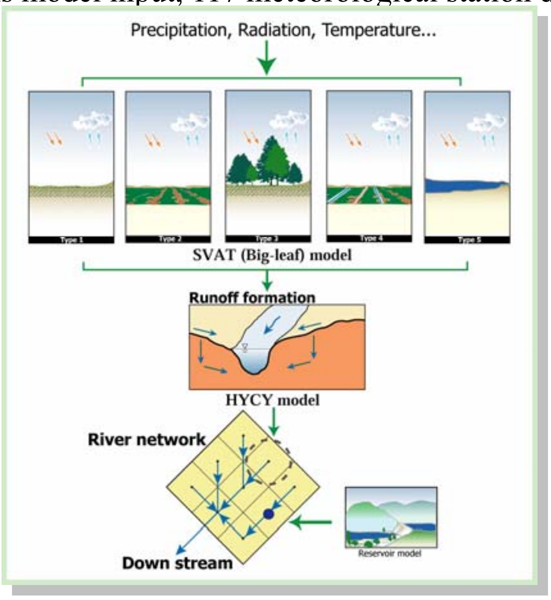

Figure 1 Hydrological model system.

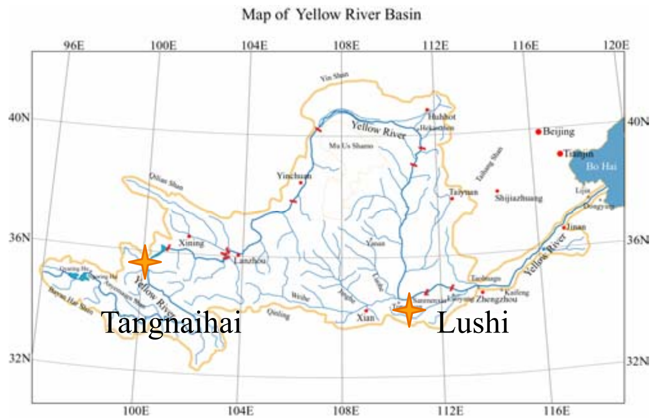

Figure 2 Location of two watersheds.

3. Results

Figure 3 shows the monthly hydrograph at Tangnaihai gauge. The simulated discharge is in agreement with observed one very well through 18-year. Annual runoff error between simulation and observation is shown in Figure 4. It is 1.8 mm in average and about 1% of the annual runoff average.

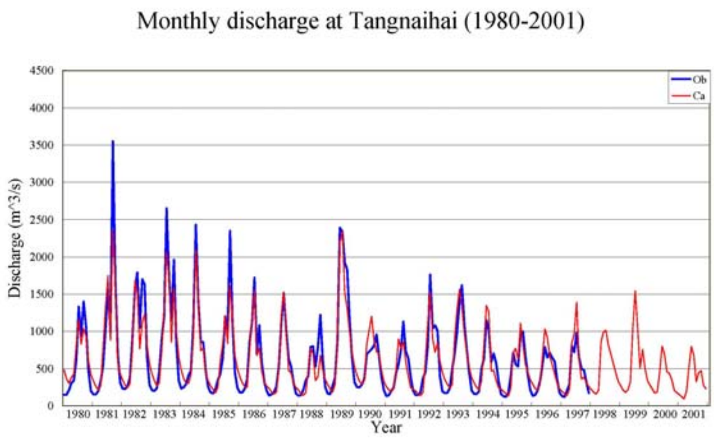

Figure 3 Monthly discharge at Tangnaihai gauge from 1980 to 2001.

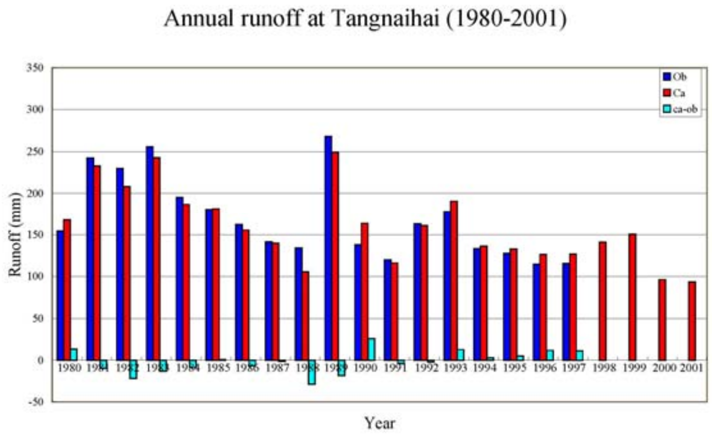

Figure 4 Annual runoff and its error between simulation and observation at Tangnaihai gauge from 1980 to 2001.

Monthly discharge and annual runoff at Lushi gauge are shown in Figure 5 and 6. The seasonal variation could be represented expect with extreme drought years, like 1986 and 1997. The error of annual runoff between simulation and observation is small, 3.4 mm in average and about 1.5 % of the annual runoff average.

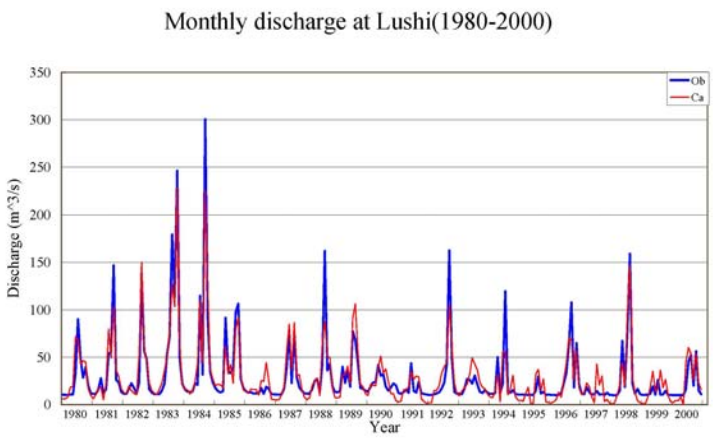

Figure 5 Monthly discharge at Lushi gauge from 1980 to 2000.

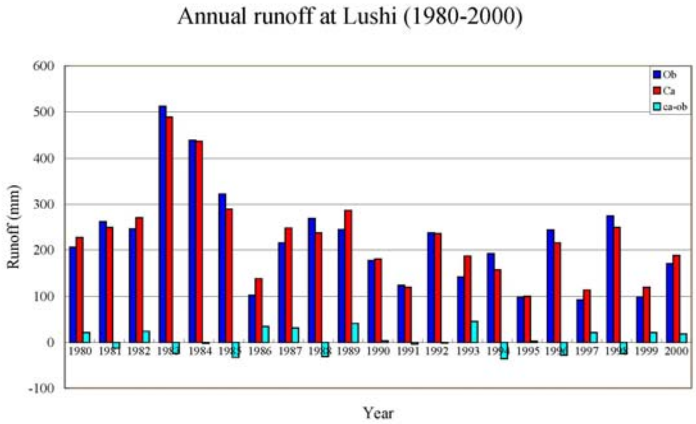

Figure 6 Annual runoff and its error between simulation and observation at Lushi gauge from 1980 to 2000.

4. Conclusions

A model system for the Yellow River study was constructed. The model system performance has been confirmed at Tangnaihai and Lushi watersheds of the Yellow River basin. Although the size and climate condition of two watersheds are very different, the seasonal variation of discharge and total annual runoff could be represented well. It is suggested to succeed in the estimation of each item concerning the water budget. In other words, the constructed model is very appropriate. In order to understand the water cycle change of the Yellow River, a hydrological simulation of the whole basin will be done using the model system in the future.

References

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Ma, X., Fukushima, Y., Hiyama, T., Hashimoto, T. and Ohata, T. (2000). A macro-scale hydrological analysis of the Lena River basin. *Hydrological Processes* **14**: 639-651.

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Water Resource Management in the Fen River Basin (II)

Hidefumi IMURA

Graduate School of Environmental Studies
Nagoya University

1. Introduction

This is a follow-up report of Imura (2005). The previous report overviewed water resource management in Taiyuan City. This report mainly focuses on the present situation of water usage for each sector of the urban area in the city.

2. Socio-economic characteristics and water resource in Taiyuan City

Taiyuan is the capital city of Shanxi province. The total population in Taiyuan City was about 3.3 million in 2003, of which 32% were agricultural population (Fig1). There has been almost no change in the size of agricultural population since middle of 1970s, where as the non-agricultural population size has doubled from 1976 to 2003. The GDP of Taiyuan City was about 50 billion yuan in 2003, with only 3.5% shared by primary industry, 51.7% by secondary industry and 44.8% by tertiary industry sectors (Fig 2). The GDP per capita in 2003 was 15,877yuan, which accounted for 1.7 times of national average, 2.1 times of average of Shanxi province and 63% of Beijing.

Fig 3 shows the amount of water consumption by sectors. Regarding agriculture and industrial sectors, there has been almost no change in the amount of water consumption since 1994, however, domestic usage has increased. Fig 4 shows the water resources for Taiyuan city. The surface water is only 10% of total water resources. Therefore, the city heavily depends upon the ground water.

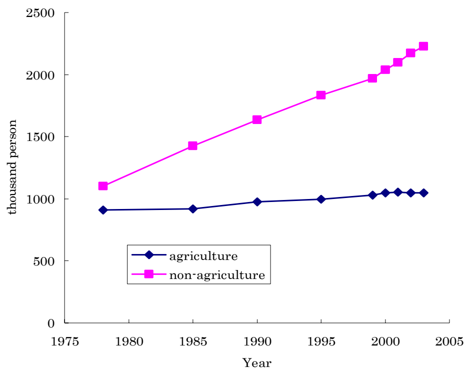

Fig. 1 Population of Taiyuan City

Source: Taiyuan City statistical yearbook

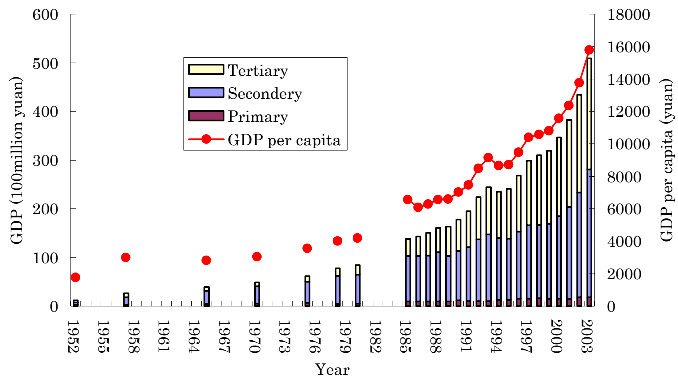

Fig. 2 GDP of Taiyuan City

Source: Taiyuan City statistical yearbook

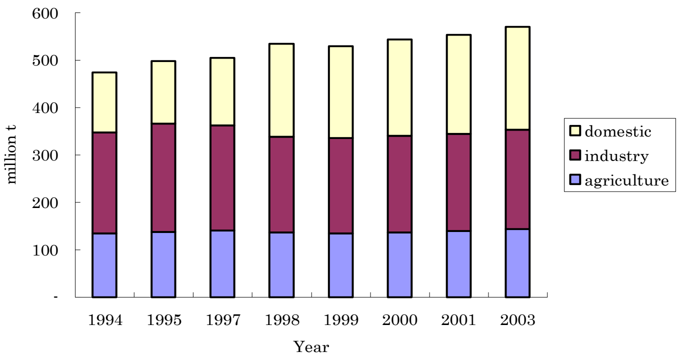

Fig. 3 Water consumption by sectors

Source: Shanxi provincial statistical yearbook

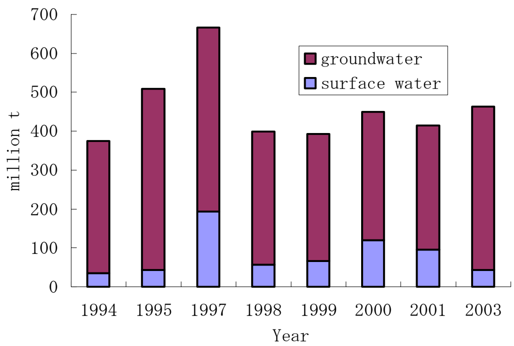

Fig. 4 Water resource in Taiyuan City

Source: Shanxi provincial statistical yearbook

3. Water management in Taiyuan City

Field studies were carried out two times (during February and September 2005) in order to clarify the water usage in an urban area of Taiyuan City in the Fen River basin. The main findings were as follows.

(1) Water saving regulation

In Taiyuan City, "Command and Control" (CAC) type regulation has been taken an important role for water management. In 1982, Shanxi provincial government enacted *Shanxi Water Management Ordinance*, which marked the beginning of the full scale water conservation activities in the province. Taiyuan City passed the *Water Saving Administrative Law* in 1985, followed by the *Taiyuan City Water Saving Ordinance* in 1997. This ordinance was amended recently in 2004 and the regulation is further tightened. It requires, all newly constructed or improved buildings must be installed with water saving equipments; and if water is used in excess of the allocated amount, a water-fee from 2 to 10 times higher than the usual rates will be charged. Furthermore, if there is a case of over use of water for over 3 months without any countermeasures, the municipal government can stop supplying water to the user.

(2) Effects of Wanjiazhai Water Diversion Project

As there is a shortage of surface water, Taiyuan city heavily depends on ground water. Since end of October 2003, the Wanjiazhai Water Diversion Project is being introduced to divert water from the mainstream of the Yellow River to the Fen River. Table 1 shows the changes of the source of tap water and water fee before and after the project. However, the effects of this project are mixed.

After introducing the project, there has been a reduction in the intake of groundwater from 0.5 million t/day to 0.29 million t/day in Taiyuan city. In addition to that, the city has closed 219 wells for the conservation of underground water. This policy resulted in the rising of the ground water level from 10m to 15m in some places during last two years.

On the other hand, the cost for diverting water from the mainstream of Yellow River is 2.28 yuan/t causing Taiyuan city to raise its water price. However, the raised water price is being ineffective to cover the additional cost and resulting in a deficit of 200 million to the water supply company. Taiyuan city is going to re-revise the water price by the end of 2005 but it is difficult to raise the fee drastically as water is an essential commodity.

Table 1 Comparing water source and water fee in Taiyuan city

		Before Nov 2003	After Nov 2003
Source of water	Ground water	0.5 million t/day	0.29 million t/day
	Yellow River	-	0.21 million t/day
Cost of water from Yellow River (yuan)		-	2.28 /t
Water fee (yuan)	Water resource fee	0.1 /t	0.5～0.6/t
	Domestic water	1.75/t	2.45/t
	Industrial water	2.7 /t	3.3/t

Source: Interview (Environmental Bureau of Taiyuan City on Sep 2005).

(3) Water conservation in industrial and service sector

Taiyuan city has been paying much attention to promote water conservation, such as recycling of water in order to control the increasing demand. The average recycling rate of industrial water in China was about 73% in 2003. But, Taiyuan City has kept the rate of water recycling over 90% since 1996 and achieved 95% in 2003 (Fig 4). Moreover, the fresh water consumption per unit of industrial output has been decreasing (Fig 5). It means that efficiency of water use in the production sector has been improved.

There is no statistical data on the present situation of water conservation for the service sector in Taiyuan City, though this sector also encourages water conservation. In case of industrial water, the charge is set at the total water cost not exceeding 2% of the total production cost. Therefore, the water price itself does not have strong effect on water conservation. However, in the case of service sector, the municipal government has set a relatively high price for water consuming service industry. For example, the water price for public bath is 15 yuan/t which is equivalent to about 4.5 times of industrial water (Table 2). According to the interview for a public bath company, total water cost is about 10% of the total cost. Therefore, the company promotes recycling of water in order to reduce the total cost of water.

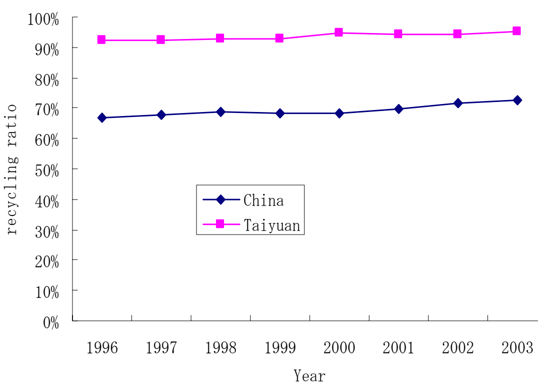

Fig. 4 Recycling ratio of industrial water

Source: China environmental statistical yearbook

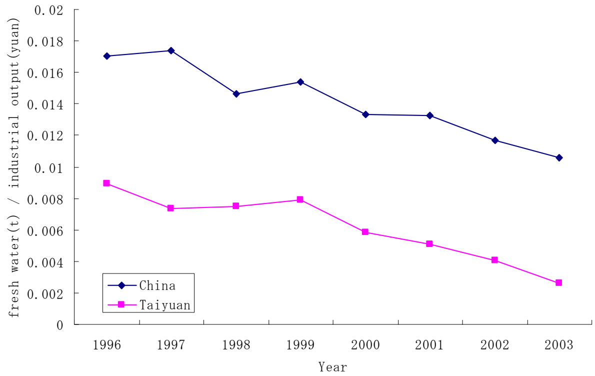

Fig. 5 Fresh water consumption per unit of industrial output

Source: China environmental statistical yearbook

Table2 Selected company's water use in Taiyuan City

Company		A	B	C	D	E	F
Industry		Food (vinegar)	Coal Mining	Cokes	Iron	Machinery (heavy-equipment manufacturer)	Service (public bath)
Type of company		xiangzhen company	state own	state own	state own	state own	Private
Industrial output (yuan)		180 million (2004)	432 million (2004)	900 million (2004)	29,000 million(2004)	0.18 million(2003) 0.28 million(2004) 0.40 million(2005)	-
Number of Employee		1,200	6,000	650	-	8,000	-
Annual production		0.1 million t	3.6 million t	0.9 million t	4.6 million t	-	-
Water consumption for production (upper:industrial water (new take), lower:recycled water)		78,000t/year (Ground water)	300t/day	3,000-4,000t/day 102,560t/day	80,000t/day (2004)	1.8 million t/year(2001) 1.3 million t/year(2005) 23.7 million t/year	8000t /month
Water use fee (yuan)		(only water resource fee)	0 (using spring water)	3.3/t	3.3/t	4.5/t	domestic water: 3.75/t water for bath: 15 /t restaurant: 4.5/t
Share of water cost for total cost		7%	-	0.85%		(negligible)	10%
Emission of waste water		-	700t/day	(only domestic water)	0.15 million t/day	0.4～0.5 million t /year	-
waste water treatment	volume	-	300t/day	1,440t/day	0.13～0.14 million t/day	0.9～1.0 million t /year	1,500～2,500t/month
	use	-	water sprinkling	cleaning of cokes	cooling water	cleaning	lavatory
	cost (yuan)	-	0.6/t	10/t	0.5/t	1.32/t	-
Water recycling ratio		-	-	over 95%	95%	92%	-

Source: Interview (September 2005).

(4) Water use in household sector

In order to investigate the present situation of water usage in the household sector, a questionnaire survey was conducted during September 2005 in Taiyuan city. Out of total 350 distributed copies 288 were collected. The collection ratio is 82.3%. The Main findings are as follows.

First of all, average household water consumption is about 5t/ month. This result is consistent with the interview responses from the Environmental Bureau of Taiyuan City. An average household water consumption per day per person is about 50ℓ and represents only 20% of Tokyo household water consumption (Fig 6). Secondly, with the water usage, almost all people take shower without using bathtub, and they take shower around three times a week (Fig7). Third, around 40% households reuse water after taking shower for flushing toilets (Fig8). It seems that the water saving regulation has an impact on the recycling of water for the households. With regard to peoples' attitude towards volume of water supply, 37% people answered "relatively unsatisfied" and 6% people answered "unsatisfied" (Fig9). These results imply that the household water consumption is limited by the availability of water supply.

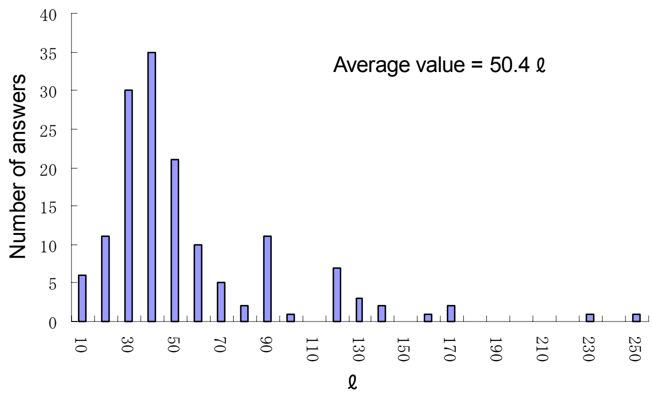

Fig.6 Daily per capita residential water use

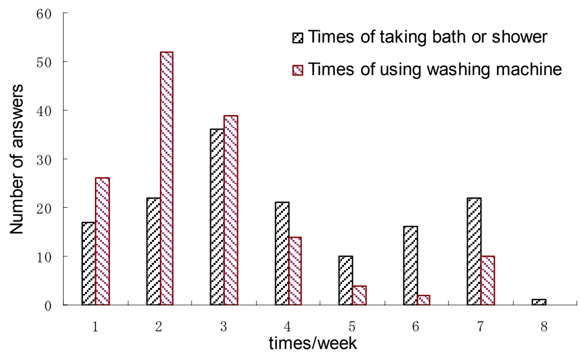

Fig.7 Times of taking bath/shower and using washing machine

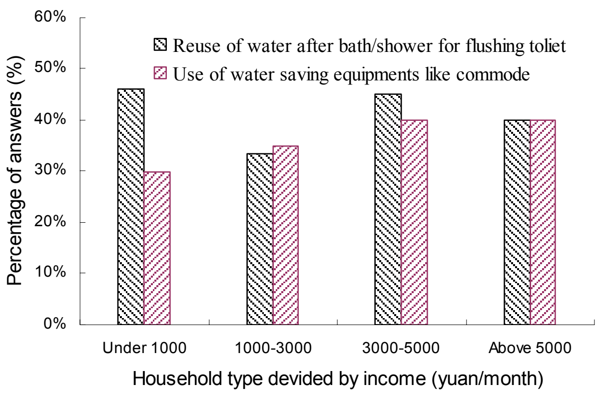

Fig. 8 Water saving and reuse

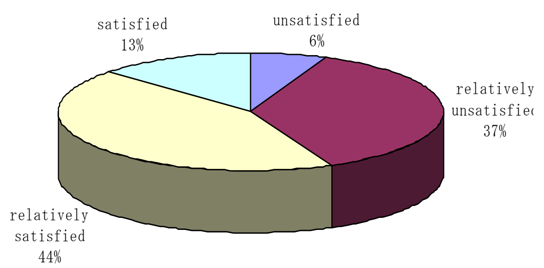

Fig. 9 Peoples attitude for volume of water supply

4. Conclusion

Taiyuan city has promoted severe CAC regulations in the background of the "absolute lack of water". As a result of this policy, industrial sector has achieved top level of recycling ratio of industrial water in China. The service and household sector is also encouraged to water saving activities.

However, it seems that there is room for improving water circulation in the social level as the disposal ratio of domestic water in Taiyuan city is about 60% only. It is also necessary to verify the validity of the water distribution between the sectors and between the regions.

It is prudent to clarify all social costs and benefits that pave the path for further study of an ideal means of water distribution.

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International research Activities (Global Water System Project)

Makoto Taniguchi and Yoshihiro Fukushima
Research Institute for Humanity and Nature, japan

One of international research activities related to Yellow River Studies is GWSP (Global Water System Project). The GWSP is a newly established joint project of DIVERSITAS, an international programme of biodiversity science, the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme (IHDP) and the World Climate Research Programme (WCRP). These four global change programmes form the Earth System Science Partnership (ESSP). Over the past few decades, environmental science has produced insights into the linkages, interconnections and interdependencies in the global water cycle. The various human and physical, biochemical, and biological facets of the cycle make up the global water system. This is especially true in Asian regions because of huge human impacts.

Japanese committee of GWSP was established in 2004 under the Science Council of Japan. There are 26 members and 3 advisers who are experts of IGBP, WCRP, DIVERSITAS and IHDP. The purposes of this Japanese committee of GWSP are to exchange the information of water related projects in Japan and to seek the possibility of financial supports for the joint studies.

Contrast between dry and humid condition/area is clear in Monsoon Asia, therefore the effect of climate change on the water cycle in regional scale is serious problem for the future water issues in Asia, such as shortage of water resources, water quality degradation, water hazard, and so on. Human impact on water cycle in Asia is another huge pressure for water issues because population increase and concentration occurs rapidly in Asian countries. There are many projects and organizations related to water issues in Asia, however, there is no network to integrate their knowledge. Therefore, Japanese committee of GWSP found that it is necessary to make a network of those research groups and projects in Asia.

The first GWSP-Asia meeting was held on August 29-31, 2005, in Kyoto, Japan. In this first meeting, we tried to make a network of water related studies and institutes in Asian countries, and to link the GWSP (Global Water System Project) to develop the understanding and knowledge on future potential human impacts and climate changes effect on water issues in Asia. We discussed new facts, new information, new methodologies, and new trends, related to water issues in Asian countries as well as water conflicts, policy making process, and capacity building in Asia. Hot spots studies were also discussed to demonstrate both impacts of climate change and human activities on water cycle in Asia.

Throughout the discussion at the fist GWSP-Asia meeting, we have reached to the following conclusions;

(1) We recognized the following hot spots study areas in Asia;
   (a) Effects of dam on water cycle, material cycle, and ecosystem in the basin,
   (b) Water and biogeochemical flows in the coastal zone with high population, and
   (c) Effects of land cover/use changes on physical and biogeochemical flows in the monsoon climate, and

(2) We need common data bases for the hotspot study areas mentioned above and water related issues in Asia, and networks of interdisciplinary water studies of WCRP, IGBP, DIVERSITAS and IHDP, should be made among the Asian research groups to link with GWSP groups, and

(3) Working groups on hotspot study area will lead to make first version of each database within a year, and a platform will be made soon to exchange information and establish database. RHIN will provide that platform.

The future activities of GWSP-Asia and GWSP-Japan will be announced at **GWSP-Asia home page**: http://www.chikyu.ac.jp/USE/GWSP/GWSPasia.htm

More information : Makoto Taniguchi
Research Institute for Humanity and Nature, Japan
makoto@chikyu.ac.jp


First GWSP-Asia Meeting at Kyoto, August 29-31, 2005

Yoshihiro Fukushima, Project Leader

Makoto Taniguchi, Secretary General

Research Institute of Humanity and Nature (RIHN), Inter-University Research Institute

Ministry of Education, Culture, Sports, Sciences, and Technology, Japan (MEXT)

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335 Takashima-cho, Kamigyo-ku, Kyoto 602-0878, Japan

Tel: +81-75-229-, Fax: +81-75-229-6150

E-mail: YRiS@chikyu.ac.jp, URL: http://www.chikyu.ac.jp/index_e.html