调水工程对汉江中下游水质影响的模型研究

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摘要：为了研究南水北调中线和引江济汉工程对汉江中下游水质的影响，应用 MIKE11 建立了一套完整的汉江水质模型系统，进行定量模拟和水环境评估。模型的范围从上游丹江口水库至下游湖北省武汉市。整套模型系统进行了水动力和水质的率定（2003 年），对 2003 年的水位、流量及各项水质指标进行再现，模拟值与 2003 年各监测断面的实测数据吻合较为理想。模拟结果显示：1）南水北调中线工程将会大大降低汉江的水量和减少流速（特别在枯季），从而会使汉江中下游水质恶化，提高水华事件发生的可能性；2）引江济汉工程仅会改善汉江下游河段的水质，对中游水质的改善不起作用，中游指的是襄樊市到引江济汉点的这段河道；3）政府规划的污水处理厂的建造和运行将会大大削减进入汉江的生活污染负荷，改善汉江的水质，特别当调水工程实施后，污水处理厂项目的实施是非常必要的。

关键词：水质模拟；MIKE11；污染负荷；调水工程；水华

Modelling of Water Diversion Projects' Influence on the Water Quality in the Middle and Downstream Han River

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ABSTRACT

In order to study the influence of South-North Water Diversion (Middle Route) and The Yangtze-Han Water Diversion projects on the water quality in the middle and downstream Han River, an integrated Han River water quality model system with MIKE 11 was established to make a quantitative simulation and water environmental assessment. The modelling covers the distance from the upstream Danjiangkou Reservior to the downstream Wuhan, Hubei province. The model system was calibrated (2003) in the Han River, including the hydrodynamic and water quality modelling, which can reproduce the water level, flow rate and water quality in 2003 satisfactorily at the monitoring stations. The simulated results show that: 1) the South-North Water Diversion Project will significantly reduce the flow rate and velocity in the Han River, especially in the dry season, which will deteriorate the water quality greatly and be able to pose the higher risk of algae bloom. 2) The Yangtze-Han Water Diversion Project can only improve the water quality for the lower reach of the Han River, but have no improvement for the middle reach, which is specified from Xiangfan City to the Yangtze water

diversion point. 3) Construction and operation of the government planned WWTPs will greatly reduce the domestic pollution load into the Han River and improve water quality significantly. It's very necessary to implement WWTP Projects when water diversion projects are carried out in the future.

KEYWORDS
Water quality modelling; MIKE 11; pollution load; water diversion project; algae bloom

INTRODUCTION

The study area of the Han River Basin is approximately half of the Hubei Province, covering eight regions: Shiyan, Xiangfan, Jingmen, Xiaogan, Xiantao, Qianjiang, Tianmen and Wuhan (Figure 1). The Han River is the largest and probably the most important tributary of the Yangtze River, which is China's major water resource. From its source in the Shaanxi Province, the Han River flows into the Yangtze River at Wuhan, Hubei Province with a distance about 1,567km.

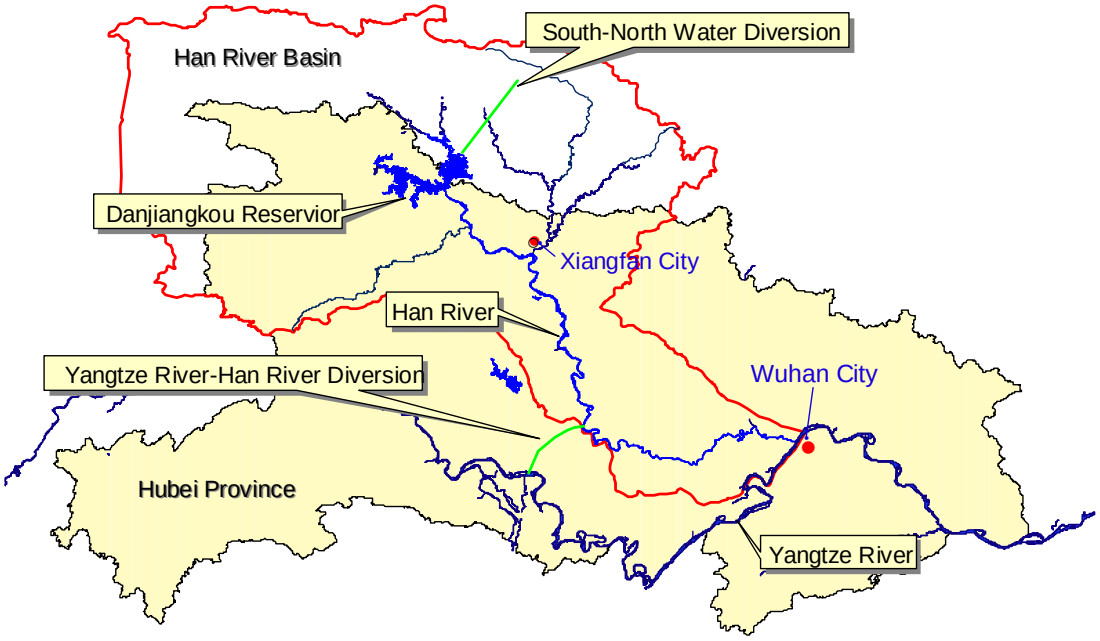

Figure 1 Han River Basin study area (red outline).

With the rapid urbanization, industrialization and enhancement of agricultural activity, increased pollution load into the river leads to a gradually deteriorating water quality in the Han River, which threatens to some extent the water resources used for drinking water supply. According the main water quality measurement at monitoring stations, most of river water belongs to Class II- III of environmental quality standards for surface water (GB3838-2002), and Class IV or V in few situations (**Han River Water Quality Official Reports**). The water quality in the tributaries is worse than the situation in the Han River, belonging to Class IV-V in the most tributaries, water quality in the Tangbai River is even worse than Class V which is the serious and vital contribution to the deterioration of water quality in the Han River around Xiangfan City.

This paper presents the water quality modelling study based on Hubei Han River

Environmental Project, which also illustrates the pollution load estimation, model calibration and scenario study, such as South-North water diversion, The Yangtze-Han Water Diversion project and government planned WWTP Projects. According to the simulation results, it is helpful to get some quantitative assessment and make some conclusions for client to make strategic planning or capacity building programme.

POLLUTION LOAD

The pollution situation is quite severe in the Hubei Province. Pollution loads for the Water Quality Modelling include the loads from point source (urban domestic, industrial and commercial) and non-point source (rural domestic, agricultural and livestock). In total, around 1,700,000 tons CODcr/year, 820,000 tons BOD_5/year, 680,000 tons Ammonia/year and 150,000 tons TP/year were generated within the Han River Basin in 2003, which are equivalent to pollution generated from 80-380 million people.

The pollution loads into the Han River have been estimated from the generated loads and Water Quality Modelling calibration results, most important pollutant parameters are CODCr, BOD_5, Ammonia, Nitrate and TP. The largest part of the generated non-point pollution load is removed before reaching the Han River, which is caused by a significant reduction from the runoff process. A possible reason for the low runoff coefficient (0.05) is believed to be caused by the detainment of tributary pollution by dams and gate operations, which prevents pollution load leaking into the main stream of the Han River. After considering the distance decay and runoff process, the pollution loads into the Han River are approximately 281,000 tons CODcr/year, 130,000 tons BOD_5/year, 40,500 TN/year and 6,500 TP/year, which is equivalent to pollution generated from 13-16 million people (Final Report, 2006).

For the scenario study next, the pollution loads conditions in 2010 have been projected according to the expected economic development, population growth and etc. The pollution loads into the Han River will increase about 20 percent for organic load and 30 percent for nutrients compared with the load condition in 2003.

1-D WATER QUALITY MODELLING

The Water Quality Modelling has been calibrated for the main stream of the Han River for the year 2003. The calibration has been performed over 12 months, covering the dry, normal and seasons coupling with the hydrological and hydrodynamic models. Water quality measurements from 21 monitoring stations were available for the calibration. Figure 2 presents the calibration results of BOD_5, CODcr, Ammonia and TP in the dry season, 2003. The concentrations are the average values in January, February, March and December.

From the results, it is clear that 1) the simulated concentrations show good agreement with the measurements in most monitoring sections; 2) The concentration profiles of pollution components increase significantly around Xiangfan City (chainage 112km) due to the point pollution from Xiangfan and the tributary pollution of the Tangbai River; 3) Water quality from Yanwan (chainage 473km) to the downstream of the Han River - Longwangmiao (chainage 614km) gradually deteriorates due to the main contribution from non-point pollution; 5) At the most downstream part of the Han River, the water quality deteriorates due to the intensive industry and population from the city of Wuhan.

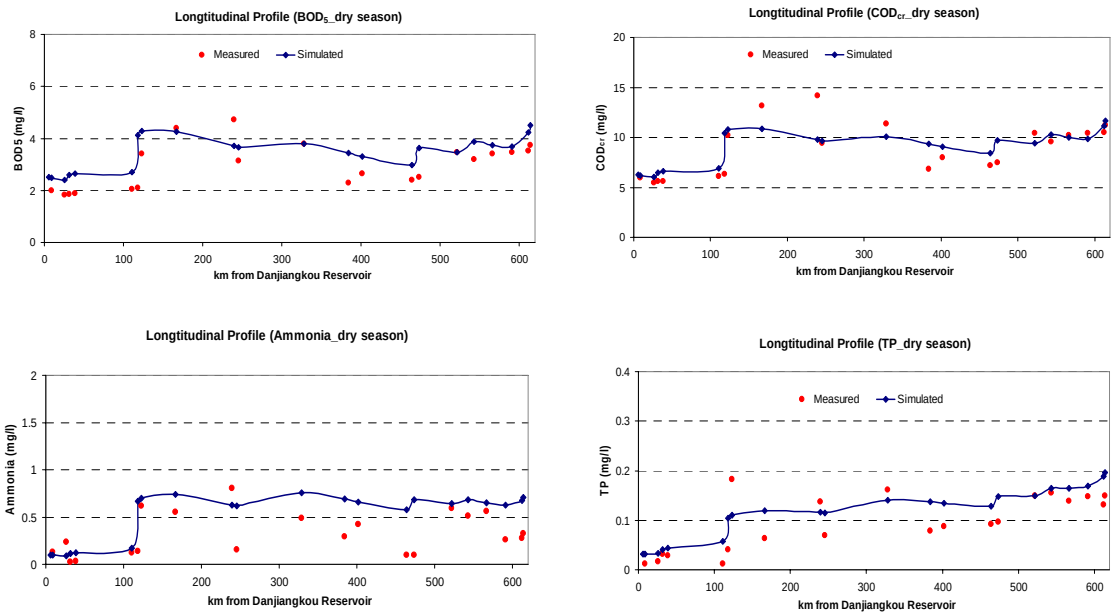

Figure 2 Comparison between measured and simulated values along the Han River in dry season, 2003.

SCENARIO STUDY

Here South-North Water Diversion, The Yangtze-Han Water Diversion and government planned WWTP projects are demonstrated. The concerned scenarios include:

- S100-Baseline 2003
- S200- Baseline 2010
- S201- Baseline 2010 + South-North Water Diversion **9,5** billion m^3/year
- S202- Baseline 2010 + South-North Water Diversion **13** billion m^3/year
- S203- S202 + Yangtze-Han River Diversion **500** m^3/s
- S204- S203+ domestic pollution reduction with all planned WWTPs projects

In 2010, there will be 9,5 billion m^3 of water transferred yearly from Danjiangkou Reservoir by the Middle Route of the South-North Water Diversion Project, which will lead to a significant reduced flow rate and worse water quality in the middle and lower reach of the Han River. In the future, the yearly transferred water volume will hit 13 billion m^3. Table 1 shows the estimated discharge changes at the upper boundary of the model after transferring water from Danjiangkou Reservoir to the north of China.

Table 1 Changes of flow rates at the upper boundary of the model after diverting water from Danjiangkou Reservoir to the north of China.

Period	Diversion of 9,5 billion m^3	Diversion of 13 billion m^3
	Reduction of average discharge (m^3/s)	Reduction of average discharge (m^3/s)
Entire year	256-330	352-453
Wet season	314-475	430-650
Dry season	197-243	270-333

With the aim to resolve the severe water quality pollution problem at the lower reach of the Han River, The Yangtze-Han Water Diversion Project will also be considered with about 500m^3/s water diverted from the Yangtze River to the Han River near Gaoshibei.

The scenario study for domestic pollution load focuses on the effect of implementing pollution reduction facilities according to the government planned WWTPs, with a total treatment capacity of 1,365,000 m^3/d in the Han River Basin. The estimated pollutant reductions are about 83,000 tons CODcr/year, 44,000 tons BOD_5/year, 6,800 tons Ammonia/year, 1,000 tons TP/year, respectively. Discharged wastewater after treatment can meet the standard of Class I-B, GB18918-2002 (Discharge standard of pollutants for municipal wastewater treatment plant), ie CODcr 60mg/l, BOD_5 20mg/l, Ammonia 8 mg/l and TP 1mg/l.

Table 2 show the simulated average of TN and TP concentrations in different scenarios from 15 February to 15 March.

1) According the simulated results, the middle and lower reaches of the Han River belong to eutrophic water body presently and the nutrient level will increase in the future. TP and TN concentrations will fall 0.1~0.4 mg/l and 1.1~6.2 mg/l, respectively. The ratio of TN and TP in the middle and lower reaches is 13:1~17:1, favouring the algae bloom.
2) Construction and operation of the government planned WWTPs will improve water quality significantly. However, the estimated nutrient level in the Han River will still be higher than the present condition even with the construction of WWTPs when 13billion water m^3/year is diverted from Dangjiangkou Reservior.
3) Through The Yangtze-Han Water Diversion project will increase the flow rate and velocity in the lower Han River, which will improve the water quality downstream but have no influence on the middle reach.

Table 2 Average concentrations of TN and TP along the Han River in different scenarios

Scenario	Upper Reach		Middle Reach		Lower Reach	
	TN (mg/l)	TP (mg/l)	TN (mg/l)	TP (mg/l)	TN (mg/l)	TP (mg/l)
S100	1.16	0.06	2.01	0.12	2.41	0.15
S200	1.19	0.06	2.24	0.13	2.87	0.18
S201	1.40	0.08	3.37	0.21	4.57	0.29
S202	1.63	0.10	4.48	0.28	6.21	0.39
S203	1.63	0.10	4.48	0.28	2.56	0.13
S204	1.44	0.08	3.80	0.21	2.30	0.11

Figure 3 show the simulated average BOD_5 concentrations in different scenarios in 2010.

1) With water diversion of 9,5 - 13 billion water m^3/year (S201 and S202), the water quality will fall in Class IV for BOD_5 in most sections. Particularly after Xiangfan City, the water quality will deteriorate because the flow rate here is significantly lower than downstream area. As a result, the BOD_5 concentration will increase from 2.6mg/l to 5.4 - 6.7 mg/l.
2) If the water diversion from the Yangtze River to the Han River (S203, 500m^3/s) will take place while the South-North Water Diversion occurs at its maximum (S202), this will improve the water quality in the middle and lower part of the Han River leading to a Class III status, but only for the last 200km of the Han River.
3) S204 considers the effect of change in hydraulic conditions and maximum domestic pollution load reduction. The water quality will be improved significantly at the sections from Xiangfan down to the junction of Yangtze River water diversion to the Han River compared with S203, but some sections will still be Class IV water with respect to BOD_5.

At the middle and lower reach of the Han River, the water quality will generally be quite improved, shifting to Class II/III for BOD_5.

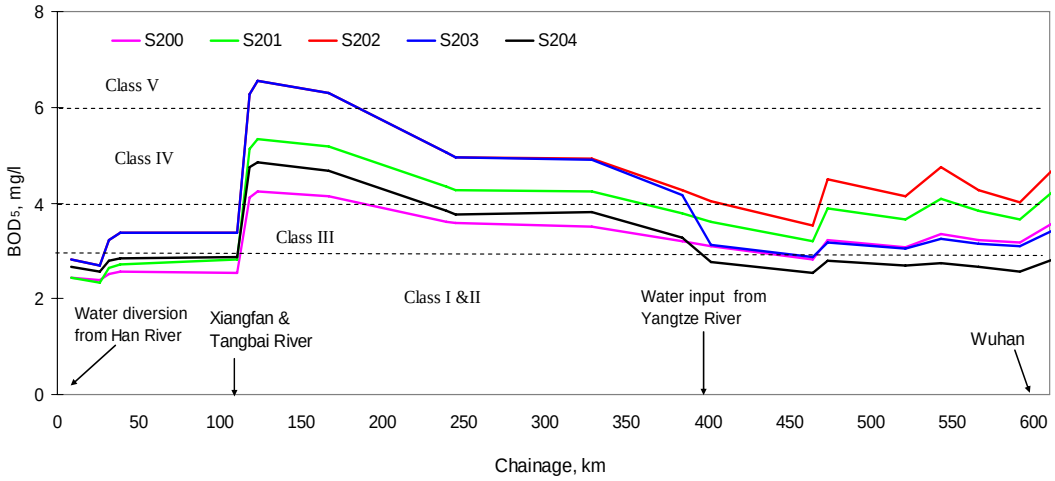

Figure 3 Average BOD_5 concentrations in the Han River in Scenarios S200, S201, S202, S203 and S204

CONCLUSIONS

1. From the investigation of pollution sources and water quality calibration, it is shown that domestic source is the dominant contributor to the organic pollution in the Han River; agricultural and domestic sources contribute the most nutrient pollution; the industrial pollution has been estimated to be lower compared with the other pollution sectors.
2. According the measurements and simulated results, the river water quality at the most sections falls in Class II- III in 2003, with a big jump around Xiangfan City due to the local pollution load contribution and the pollution from the Tangbai River, which is seriously polluted and the water quality is worse than Class V.
3. The modelling results of different scenarios clearly indicate that, until 2010 the Han River will be a Class IV river in some sections from Xiangfan City to the Yangtze River Diversion point even when the Yangtze-Han Water Diversion and WWTPs Projects will be implemented in the future.
4. The South-North Water Diversion Project will significantly reduce the flow and velocity in the Han River, especially in the downstream of the Han River, which will be able to pose the higher risk of algae bloom. The Yangtze-Han Water Diversion Project can only improve the condition in the lower reach of the Han River, but have no improvement for the middle reach.
5. Attentions should be paid to the risk of algae bloom in the middle reach of the Han River and a basin-wide pollution control program should be carried out in order to reduce the non-point nitrogen and phosphorus release, which is the dominant source of nutrients for the Han River.

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