People's Republic of China

FY2017 Ex-post Evaluation of Japanese ODA Loan Project

"Henan Province Nanyang City Comprehensive Environment Improvement Project"

External Evaluator: Kenji Momota, IC Net Limited

0. Summary

This project was implemented to reduce the discharge of water pollutants into the rivers in Nanyang City, Henan Province, and ease the air pollution burden, through the construction of wastewater treatment facilities and gas supply facilities that impose low environmental burdens, thereby contributing to the improvement of the living environment in the city.

The project is consistent with China's development policy and needs at the national and municipal levels from the appraisal to the present time. Although there have been changes in the operation of bio-gas production facilities as a result of an increase in natural gas supply under the national policy, the project as a whole is highly relevant. The efficiency is low because the project cost is a little higher than planned and the project period is far longer than planned. The constructed wastewater treatment facilities are operating smoothly and the effect of reducing the discharge of pollutants has manifested itself as expected. Although there is some concern that the bio-gas production facilities may have problems, gas has been supplied to Nanyang City almost as planned and the purpose of popularizing cleaner energy than coal has almost been achieved. Because the wastewater treatment ratio increased and the amount of wastewater discharged into the rivers decreased, the water quality of the main river, the White River (Baihe River), in the city is on improving trend. In addition, along with increase in the gas supply resulted in decrease in the consumption of coal and any other type of energy that imposes a high environmental burden, air pollution has been prevented from worsening. For these reasons, the effectiveness and impact of the project are high. With regard to the sustainability of this project, no significant problem is seen in the organizational and technical aspects. Although there is a slight concern over the financial condition of the gas production facilities, the gas supply is expected to increase in the future and it is likely that the financial condition will improve from both the mid- and long-term perspectives, and thus the influence seems limited. In light of the above, this project is evaluated to be satisfactory.

1. Project Description

Project location

Gas station in Nanyang City

1.1 Background

In China, while rapid economic growth was achieved, environmental pollution was accelerated from the 1980s because of its industrialization and increasing population. As a result, both the water and air environments continued to be far worse than the national standards. During the term of *the 10th Five-Year Plan (2001–2005)*, the Chinese government strived to protect the water environment through such measures as designating important protection areas and setting numerical reduction targets for the amounts of water pollutants. However, the government could not cope with the increasing discharge of industrial and domestic wastewater as a result of the rapid economic growth, and failed to reach the targets. On the other hand, air pollution became serious because of the substances produced through the burning of coal, the main primary energy source, such as sulfur oxides (SOx), total suspended particles (TSP), and nitrogen oxides (NOx) contained in automobile exhaust gases and dust. In addition, it was necessary to immediately restrain the emission of carbon dioxide (CO_2), etc., which causes global warming. To cope with this situation, China established *the 9th and the 10th Five-Year Plans (1996–2000 and 2001–2005 respectively)* to carry out measures against industrial pollution and develop urban infrastructures, such as city gas. However, China failed to fulfill the objective of reducing the emissions of main pollutants by 10% compared with 2000.

Nanyang City in Henan Province is located along the middle basin of the Yangzi, one of the seven major rivers in China. In the city, while the amount of wastewater increased as a result of the economic growth, the construction of wastewater treatment facilities was delayed. Without being treated, domestic and industrial wastewater was directly discharged into the middle basin of the Yangzi, which is important as a source of drinking water. As a result, the water quality[1]

[1] River water quality is classified into Grades I to V according to the Environmental Quality Standards for Surface Water (GB3838-2002). Grade-I water is mainly water at the source of a river in a national natural protection area. Grade-II water is used mainly for drinking and exists in a first-grade protection area, an area for rare kinds of fish,

of the Baihe River, which runs through the center of the city, sometimes reaches Grade below V, indicating a serious state of water pollution. In addition, energy demand was satisfied mainly by energy produced from coal, which has become the main source of air pollution. Therefore, improving the air environment was a urgent task.

1.2 Project Outline

The project aims to reduce the discharge of water pollutants into the rivers in the city and ease the air pollution burden, through the construction of wastewater treatment facilities and gas supply facilities which impose low environmental burdens, thereby contributing to the improvement of the living environment in Nanyang City, Henan Province.

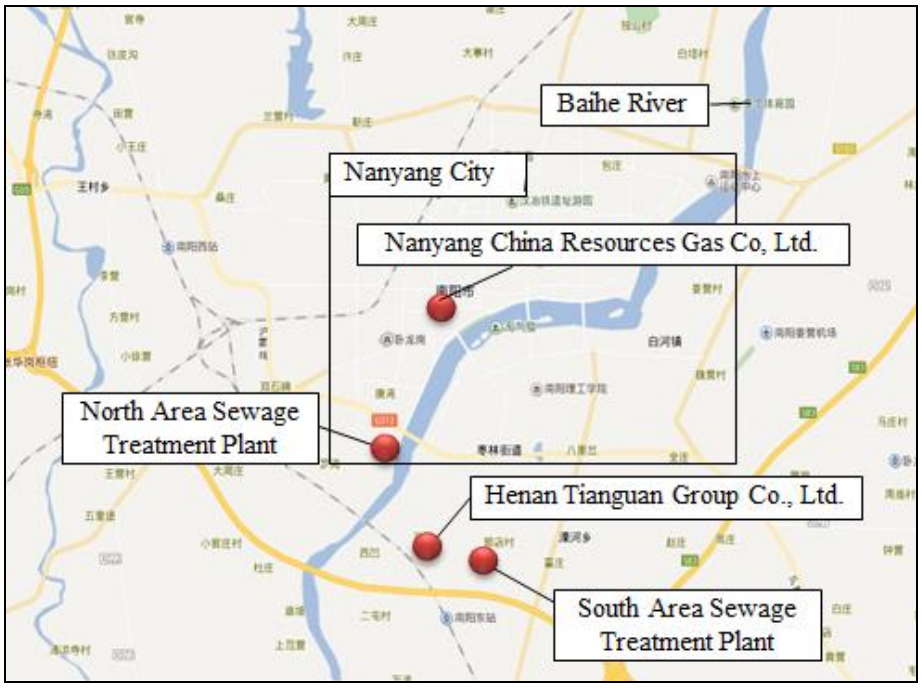
<ODA Loan Project>

Loan Approved Amount / Disbursed Amount	11,500 million yen / 10,114 million yen
Exchange of Notes Date / Loan Agreement Signing Date	December 2007 / December 2007
Terms and Conditions	Interest rate: 0.65% Repayment Period: 40 years (Grace period: 10 years) General Untied
Borrower / Executing Agency	Government of the People's Republic of China / Henan Provincial People's Government
Project Completion	April 2015
Main Contractors (Over 1 billion yen)	1. Beijing Zhonghui United Environmental Engineering Co., Ltd. (People's Republic of China): supply of materials and equipment 2. Henan Haorui General Engineering Co., Ltd. (People's Republic of China): supply and installation of plant equipment
Main Consultant (Over 100 million yen)	None
Related Studies (Feasibility Studies, etc.)	F/S (prepared by the Central and Southern China Municipal Engineering Design & Research Institute in May 2007)

or a place for fish or shrimp spawning. Grade-III water is used mainly for drinking and exists in a second-grade protection area, an area for protection of general fish, or a swimming area. Grade-IV water is used mainly as general industrial water and exists in a general industrial water area or a water area for entertainment where people cannot directly touch the water. Grade-V water is mainly used for agriculture and exists in an agricultural water area. It is also used for securing the general landscape.

Related Projects	[Japanese ODA loan] Henan Environmental Improvement Project (2002) [Asian Development Bank] Henan Wastewater Management and Water Supply Sector Project (2005)

The following map shows the central area of Nanyang City, the project site, and the Baihe River, which runs through the city.



Source: Prepared by the author based on Baidu Maps (URL: http://map.baidu.com/ (Accessed 4 June 2018))

2. Outline of the Evaluation Study

2.1 External Evaluator

Kenji Momota, IC Net Limited

2.2 Duration of the Evaluation Study

This ex-post evaluation study was conducted according to the following schedule.

Duration of the Study: August 2017–March 2019

Duration of the Field Survey: October 23–November 1, 2017; March 25–30, 2018

2.3 Constraints during the Evaluation Study

None in particular.

3. Results of the Evaluation (Overall Rating: B[2])

3.1 Relevance (Rating: ③[3])

3.1.1 Consistency with the Development Plan of China

(1) Consistency with the Development Plan at the Time of the Appraisal

Although the Chinese government began to carry out measures for improving the urban environment, such as the development of sewerage systems, measures against industrial pollution, and the establishment of urban gas systems according to *the 10th Five-Year Plan*, the objective was not attained. Thus, in *the 11th Five-Year Plan (2006–2010)* and in *the Notice on Printing of the Comprehensive Work Plan for Energy Saving and Emissions Reduction by the State Council (June 2007)*, the government included the objective of strengthening environmental improvement measures and reducing the total emissions of main pollutants by 10% compared with 2005. Moreover, the government restricted the construction of coal thermal power plants in urban areas and promoted the construction of thermal sources with lower air pollution burdens, such as centralized heat supply facilities and gas supply facilities.

In *the 11th Five-Year Plan for Economic and Social Development of Henan Province*, Henan Provincial People's Government expressed the objective of reducing the amount of main water pollutants and air pollutants by 10% by 2010 through promoting the construction of wastewater treatment facilities and promoting the use of alternative renewable energy sources in the existing energy systems. Responding to this, Nanyang Municipal People's Government established *the 11th Five-Year Plan for Economic and Social Development of Nanyang City* and *the 11th Five-Year Plan for Environmental Protection of Nanyang City*. These plans promoted improvement of the water and air environments through such measures as developing wastewater treatment facilities connected to the Baihe River, which was the most heavily polluted of all the rivers running through the city, substituting any coal-using facilities in the city with gas supply facilities, and strengthening environmental monitoring.

(2) Development Plan at the Time of the Ex-Post Evaluation

Regarding measures against water pollution, in *the 12th Five-Year Plan (2011–2015)*, the central government placed importance on the promotion of measures to prevent water pollution in important basins, the protection of river environments, and the strengthening of ecological control, aiming to reach the target of 85% for the wastewater treatment ratio in urban areas. In *the 13th Five Year Plan (2016–2020)*, this target was raised to 95% to make the numeric target stricter. *The 12th and 13th Five-Year Plan for Economic and Social Development of Henan Province*, the corresponding plans at the provincial/municipal level, aim to promote the construction of urban sewerage networks and construct wastewater treatment facilities in new

[2] A: Highly satisfactory, B: Satisfactory, C: Partially satisfactory, D: Unsatisfactory

[3] ③: High, ②: Fair, ①: Low

urban areas, intensive industrial zones, and population settlements for the efficiency of the treatment system. In addition, they encouraged those companies discharging polluted water and intensive industrial zones to strengthen their control of the total emissions of pollutants in a strict fashion and promoted the concentrated treatment of wastewater, urging the seriously polluting companies to construct facilities for the prior treatment of wastewater. Following these main plans of Henan Province, Nanyang City plans to construct wastewater treatment facilities in the central area and the prefecture-class administrative wards, make sludge from the wastewater treatment facilities harmless, remodel and expand its urban network of sewage pipes, and construct a network of pipes for dividing rainwater and wastewater.

In the atmosphere sector, the central government's *12th Five-Year Plan* expresses the objective of making the air quality level[4] Grade II or better in 80% in the urban areas of prefectural- or higher-level administrative areas. In addition, it is stated that the government encourages the diversification of clean energy, including biomass energy, as a measure for reducing air pollutants. *The 13th Five-Year Plan* also places importance on the reduction of air pollutants and sets forth the objective of increasing the city gas ratio with the objective of a 25% reduction in the number of days of heavy pollution in the urban areas of prefectural- or higher-level administrative areas. In addition, at the provincial/municipal level, the plan sets forth the objective of improving urban air pollution comprehensively and keeping the air quality level in province-class cities at Grade II or better for 292 or more days. Nanyang City's plan designates the Tianguan group, the agency who is implementing this project, as the core firm for promoting biomass energy and large-scale industrial bio-gas,[5] and promotes remodeling and expansion of gas pipes in the central urban area of Nanyang City.

As described above, priority is given to the improvement of water and air pollutants at the level of each development plan of Nanyang City and Henan Province as well as the national level, and thus highly consistent with this project, which aims to improve the river and atmospheric environments through the construction of both wastewater treatment facilities and gas supply facilities with low environmental burdens. The improvement of water and air pollutants continued to be given priority in the period between the appraisal and the ex-post evaluation. The central government has encouraged companies to keep their target volume of emissions reduction in a stricter fashion than before in the national development plan. Both Nanyang City and Henan Province have also maintained the attitude of placing importance on improvement since the appraisal. Therefore, the project is highly relevant to the development plan.

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[4] Air quality is divided into three grades according to *the Ambient Air Quality Standards (GB3095-2002)* (new standards came into force in 2016 and the number of grades was reduced to two). Grade I: nature protection areas, etc.; Grade II: residential areas, general industrial areas, farming areas and other areas designated under the urban plan; Grade III: specified industrial areas (integrated into Grade II in 2016)

[5] Main projects include the Tianguan group's production of 300,000 tons of ethanol a year, production of 240 million m^3 of bio-gas, and biomass electric generation of 1.01 billion kwh.

3.1.2 Consistency with the Development Needs of China

At the time of the appraisal, the population of Nanyang City was about 800,000. With the development of the economy, the volume of domestic and industrial wastewater was increasing, while the wastewater treatment ratio in the urban district was 52.2% because of a delay in the construction of wastewater treatment facilities. Unprocessed sewage flowed out into the rivers in the city, worsening the water quality of the Baihe River, the city's main river, down to Grade below V. In addition, although 86% of the demand for energy in the city was fulfilled by energy produced from coal, the facilities that were using coal had low energy efficiency and lacked adequate dust catching and desulfurizing systems. While these were the main causes of air pollution, the supply rate of gas, one of the alternative energies, was only 11.4%.

In the period between the appraisal and the ex-post evaluation, the population further increased by more than 70%, from about 800,000 at the time of the appraisal (in 2007) to about 1.4 million in 2015. Consequently, in Nanyang City, the number of cars, which cause air pollution increased and became tenfold the one at the time of the appraisal (from 212,000 in 2008 to 2,267,000 in 2015).[6] Allowing for further increases in population in the future, the development needs for wastewater treatment and gas supply remain high even at the time of the ex-post evaluation.

3.1.3 Consistency with Japan's ODA Policy

In *the Medium-Term Strategy for Overseas Economic Cooperation Operation* (2005 to the first half of 2008) of the Japan International Cooperation Agency (JICA), of all the priority sectors, such as support for poverty reduction, development of infrastructures for sustainable development, and support for measures to cope with global problems and peacebuilding, JICA clarified importance on the development of farming villages through the construction of sewerage systems in poverty areas, the promotion of sustainable growth through the development of highly needed economic and social infrastructures, such as waterworks, sewerage systems, and energy facilities, and measures against air and water pollution for the purpose of making the development compatible with the environment.

Moreover, in *the Country Assistance Strategy for China*, JICA has identified environmental problems resulting from rapid economic growth and places importance on environmental conservation mainly in inland areas.

[6] Source: Statistical Report on the Economic and Social Development in Nanyang City

3.1.4 Appropriateness of the Project Plan and Approach

(1) Changes in the Use of Bio-gas Production Facilities

The bio-gas business established under the project mainly consists of gas production facilities and gas supply facilities through pipelines. Although the produced bio-gas was planned to be used as the main source of supply of gas sent to the city through pipelines, it is now regarded as a supplementary source of supply of gas to the city and the amount of supply is only about 10% of the initially planned amount. This is due to the influence of changes in the national policy. The facts and backgrounds can be described specifically as follows:

1) Nanyang City requested the central government to supply natural gas under the West-East Gas Pipelines Project (WEPP), a China's national project.[7] When the project was planned initially, natural gas was planned to be supplied by using the WEPP. However, because Nanyang City was not able to obtain the supply of gas in the first term of the WEPP, which began in 2004, the project was planned by incorporating gas production facilities.
2) Although most of the produced gas was supplied to the city from the beginning of the project until 2012, it was decided in 2012 that Nanyang City could obtain a supply of natural gas in the second term of the WEPP. As a result, the main gas to be supplied was changed to natural gas. Bio-gas was changed to a supplementary energy source to natural gas. Because of this change, facilities for purifying gas were constructed for gas production, and bio-gas has continued to be supplied together with natural gas.
3) The amount of bio-gas sent through pipelines after purification accounts for only about 10% of the total amount of supplied gas. Types of produced gas have been diversified, including those used for other purposes.

Because of the background described above, the purpose of use of the produced bio-gas changed and the ratio of the amount of produced bio-gas to the total amount of supplied gas decreased. This change was inevitable because it was influenced by the low foreseeability of the national policy at that time. When the project was planned, while demand for gas was high, Nanyang City was not able to obtain the supply of gas in the first term of the WEPP. Because Nanyang City, a local city, could not predict when it could obtain the supply of natural gas, it seems appropriate that the city secured its own source for supplying gas under the project. In addition, the pipelines used for gas supply were designed so that they could be used for both bio-gas and natural gas, and from the outset measures were enacted on the assumption that bio-gas would be used together with natural gas. Therefore, the impact of changes in the policy was minimized. Moreover, because Nanyang City continues to expect an increase in gas supply

[7] Under the WEPP, natural gas is collected from the Tarim oil field in the Shinjang Uyghur Autonomous Region and is transported to major cities in the eastern coastal area through pipelines with a total length of about 4,000 km. In the first term, the whole section was completed in 2004.

and because the supply of only natural gas will make it difficult to secure the stable supply of gas, demand for bio-gas produced under the project is expected to increase in the future.

Therefore, the implementation of the project is highly relevant to the development plan and development needs of the Chinese People's Government, the Henan Provincial People's Government, and the Nanyang Municipal People's Government as well as Japan's ODA policy. In addition, although there has been a change in the project plan concerning the purpose of use of the produced bio-gas, it can be evaluated that the project as a whole, including this change, is highly relevant if consideration is given to the response to the high needs for gas supply at the time of the appraisal, the preliminary response to the prediction of conversion in the future, and the stable supply of gas through the diversification of supply sources.

3.2 Efficiency (Rating: ①)

3.2.1 Project Outputs

The following table shows the planned and actual outputs in this project, indicating that this project was carried out almost as planned:

Table 1: List of Outputs

	Plan	Actual
Wastewater treatment facilities	Total length of drain pipes: 224 km	Almost as planned[8]
	Wastewater treatment plants (expansion of 1 plant): 100,000 m^3/day (water recycling facilities: 30,000 m^3/day	Almost as planned The treatment method was changed.
	Wastewater treatment plants (construction of 1 plant): 100,000 m^3/day	As planned The treatment method was changed.
Gas supply facilities	Gas production facilities: bio-gas, 395,000 m^3/day	Almost as planned 4 IC reactors were changed to 10 UASB reactors.
	Gas pipe network: 250 km	As planned
	Gas vaporization facilities, gas pressure governor facilities	As planned

[8] Regarding the extent of treatment at the North-area Wastewater Treatment Plant, it was confirmed that the sewage pipe networks initially planned to be constructed were covered. Regarding the extent of treatment at the South-area Wastewater Treatment Plant, the local development plan was partially changed and the plan for sewage pipe networks also was changed. Sewage pipe networks have been established in the already developed areas. Because it was difficult to acquire statistical information about sewage pipe networks, it was difficult to measure the total length of the networks constructed by Japanese ODA loans accurately. However, based on consultations with local related agencies, it was judged that the initially planned networks were constructed almost as planned.

Training	Training program in Japan for the implementing agency's staff concerning sewerage service and gas supply service	Training in sewerage service was changed to training in China. Two staff members participated in gas supply service training program in Japan.

Source: The planned outputs are based on materials provided by JICA, while the actual outputs are based on the implementing agency's responses to questionnaires.

The background to main changes in the outputs is as follows:

(1) Wastewater treatment facilities

Although there was no change in the outputs concerning drain pipes, all the portions planned to be constructed using Japanese ODA loans were constructed using domestic funds, because the Nanyang City government planned to construct new roads in the initially planned sites and, at the same time, install drain pipes next to the roads.

As the process for treating sewage, the improved A_2O process has been adopted by both the North- and South-area Wastewater Treatment Plants. When the feasibility study was carried out for this project, the AO process was selected to fulfill the second-class standards among the national drainage standards,[9] but the Environmental Protection Bureau of Nanyang Municipal People's Government requested in November 2007 that this project should improve the drainage level to first-grade A. Thus, with the appraisal approval of the Provincial Development Reform Committee, the wastewater treatment process was changed to the improved A_2O activated sludge process, which is highly effective for removing nitrogen and phosphorus.

Although training could not be held in Japan because of stricter domestic procedures under cost-saving ordinance (December 2012), domestic technical training was held for the staff of the wastewater treatment center three times as a substitute.

[9] Regarding China's standards for drainage from wastewater treatment plants, *the Standards for Irrigation Water Quality (GB18918-2002)*, which were enacted by the State Environmental Protection Administration and the General Administration of Quality Supervision, Inspection and Quarantine, classifies drainage levels into first-grade A, first-grade B, second grade, and third grade in light of the condition, purpose of use, and other aspects of the area to which the sewage is discharged.

Aeration tank at the North-area Wastewater Treatment Plant
(The improved A_2O process was adopted)

Aeration tank at the South-area Wastewater Treatment Plant
(The improved A_2O process was adopted)

(2) Gas supply facilities

Regarding gas production, although it was initially planned that four IC reactors would be procured, in reality ten UASB reactors were procured. Because UASB reactors are more popular than IC reactors in China and can lower the cost, it was possible to increase the number of reactors.

Regarding the training program in Japan, one gas production staff member and one Japanese ODA loan office staff member participated in a 20-day training program in Japan concerning "Technologies for plant wastewater treatment and recycled water use" in October 2012.

Gas production facilities

Gas supply regulator station

3.2.2 Project Inputs

3.2.2.1 Project Cost

Although the total project cost was initially estimated to be 27,388 million yen (including a Japanese ODA loan of 11,500 million yen), in reality it was 29,701 million yen (including a Japanese ODA loan of 10,114 million yen), 108% of the estimate. The cost increased mainly

because of increases in the raw material cost and the personnel cost during the project period. In addition, the following points need special mention concerning the project cost:

- The wastewater treatment process was changed from the AO process to the A_2O process, which is more precise. Accordingly, the procured equipment and the suppliers were changed. As a result, the planned cost increased.
- Because of changes in the urban plan of Nanyang City, the installation of drain pipes, including the improvement of drainage canals and rivers, was carried out using domestic funds before the Japanese ODA loans were issued.
- Because the training program in Japan was substituted with domestic training, the cost decreased.

3.2.2.2 Project Period

Although the initially planned period was between December 2007 and January 2013 (61 months), the actual period was prolonged much longer, between December 2007 and May 2016 (101 months, 66% longer than planned). The period of each subproject was as follows:

Subproject	Plan (at the time of L/A signing) (2007)	Actual[10]	Compared with plan
1) Wastewater treatment facilities	Dec. 2007 to Jan. 2013 (61 months)	Dec. 2007 to May 2016 (101 months)	166%
2) Gas supply facilities (Gas production)	Dec. 2007 to Nov. 2011 (47 months)	Dec. 2007 to Apr. 2012 (52 months)	111%
2) Gas supply facilities (Gas supply)	Dec. 2007 to Dec. 2011 (48 months)	Dec. 2007 to Apr. 2016 (100 months)	208%

Sources: The plan dates are based on materials provided by JICA; the actual results are based on the project-implementing agency's responses to questionnaires.

Reasons for the delay in subprojects are as follows:

1) Wastewater treatment facilities

Regarding the wastewater treatment facilities, the design and the issuance of approval were delayed at the preparation stage, which influenced the processes thereafter. As a result, the trial run of the North-area Wastewater Treatment Plant began in September 2012. Moreover, construction of the network of main drainage pipes connected to the South-area Wastewater Treatment Plant was delayed because of a delay in the development of the entire area, which was a new industrial area, covered by the treatment. Because the treatment plant could not be operated until the network of drainage pipes had been completed, the start of construction of the

[10] At the time of planning, the time of completion was defined as the time of completion of the Henan Provincial People's Government's project inspection, which was planned to be carried out one year after the beginning of trial run. However, the actual inspection was greatly delayed because some subprojects were inspected, including equipment installed using domestic funds. Therefore, at the time of the evaluation, the time of completion was defined as the initially planned time of inspection – that is, one year after the beginning of trial run.

plant was delayed because of the delay in the construction of the network. Although there were no problems that might have caused a delay during the construction process, the duration of the subproject became 66% longer than initially planned mainly because of the reasons above.

2) Gas supply facilities

The establishment of gas production facilities smoothly progressed from the design stage to construction and was not delayed greatly.

The establishment of gas supply facilities was greatly delayed and took twice as much time as planned. This was because construction of part of the gas pipeline network was delayed for about two years. The gas supply itself already began in December 2012, when about 70% of the whole network had been completed. The establishment of the pipeline network was delayed mainly because approval for construction to begin could not be gained owing to the priority given to the construction of fields for the national athletic meet for farmers held in Nanyang City in 2012. In addition, in line with this project, part of the supply pipeline network was installed using the government funds. Within the framework of the whole plan, including the part installed using the funds, the part of the pipeline network covered by this project was completed in April 2015.[11]

3.2.3 Results of Calculations for Internal Rates of Return (Reference only)

(1) Financial Internal Rate of Return

At the time of the appraisal, the financial internal rate of return (FIRR) was calculated under the following conditions: the project life should be 30 years; the benefit should be the revenue from charges; and the cost should be the construction and maintenance costs. When FIRR was recalculated in the same way at the time of the ex-post evaluation[12], FIRR for the wastewater treatment facilities increased to 4.83% from 3.8% at the time of the appraisal. FIRRs for gas production and supply are 6.31%[13] and 6.24% respectively, slightly decreasing from 8.1% at the time of the appraisal. Regarding the factors for improvement of the wastewater treatment facilities, although a simple comparison is difficult because the calculation method is different

[11] The point in time when all planned values were achieved was regarded as being the time the trial run began, and the time of completion was estimated to be one year after (April 2016).

[12] When FIRR was recalculated, the revenue from charges as main benefit was multiplied by income unit price of each facility (e.g., income per m^3) and the actual amount (e.g., the amount of wastewater treatment, gas production and gas supply). In the cost, the construction cost was allocated by payment year as initial investment, and the maintenance cost was multiplied by the actual expenditure unit price and the actual amount. For example, the actual amount of treated wastewater was multiplied by the cost and revenue per m^3. Because the sewerage plants do not directly collect charges from the beneficiaries, it was assumed that the revenue and cost of treatment per unit was the total revenue and operational expenditure in the financial statements, divided by the annual amount of treatment.

[13] As a result of changes in the project scope, there are various operations, including not only those related to bio-gas but also purified bio-gas production and electricity generation added by domestic funds. When this was calculated, consideration was also given to the operation costs, production costs, and revenues of the bio-gas purification facilities and the electricity generation facilities.

from that at the time of the approval, as described below in the "Effectiveness and Impacts" section, it is fair to say that improvements in the quality of the wastewater flowing into the treatment plants resulted in a reduction in the treatment cost per unit and an improvement in the rate of return. The reasons for the declining rate of return at gas supply facilities seem to be complex ones such as a change in the structure of the production side and the supply side due to the change in the project scope, a decrease in the production amount of bio-gas described later, a slight decrease in the supply unit price according to the government policy. However, because both operations have achieved a certain rate of return, some financial stability has been secured for the management of operations. The Economic Internal Rate of Return (EIRR) was not calculated, because it was not long after the completion of this project and it was difficult to collect data on the beneficiary areas.

Based on what was described above, the project cost slightly exceeded and the project period significantly exceeded the plan. Therefore, efficiency of the project is low.

3.3 Effectiveness and Impacts (Rating: ③[14])

3.3.1 Effectiveness

3.3.1.1 Quantitative Effects (Operation and Effect Indicators)

The following is a specific analysis of the operation and effect indicators of each subproject.

(1) Wastewater Treatment Facilities

Name of indicator	Standard 2005	Target 2013	Actual performance 2015 Year of beginning	Actual performance 2016 Year of completion	Ratio to target Actual performance / target value
North-area Wastewater Treatment Plant Population of treatment (10,000 people)	52.2	55	100	-	182% (Year of beginning ratio)
North-area Wastewater Treatment Plant Wastewater treatment capacity (10,000 m^3/day)	10	20	18.9	18.9	95% (Year of completion ratio)
North-area Wastewater Treatment Plant Wastewater treatment volume (10,000 m^3/day)	10	20	20	20	100% (Year of completion ratio)
South-area Wastewater Treatment Plant Population of treatment (10,000 people)	0	24	28	30	125% (Year of completion ratio)

[14] Sub-rating for Effectiveness is to be put with considerations of Impacts.

South-area Wastewater Treatment Plant Wastewater treatment capacity (10,000 m^3/day)	0	10	10	10	100% (Year of completion ratio)
South-area Wastewater Treatment Plant Wastewater treatment volume (10,000 m^3/day)	0	10	4.65	7.07	71% (Year of completion ratio)
Wastewater treatment ratio (%)	34	67	-	-	

Sources: Materials provided by JICA, the project-implementing agency's responses to questionnaires

The total capacity of both treatment plants is 300,000 m^3/day. In 2016, the capacity reached 259,700 m^3/day of sewage, 87% of the designed treatment capacity. It is fair to say that this state of operation is satisfactory. On the other hand, because there is no extra room in the treatment capacity, polluted water was deposited in the sewage pipes, and the plants have been running at a high water level.[15] Although there is no serious effect at present, if this state continues, the generation of hydrogen sulfide or stinking gas may result in the corrosion of equipment, and the shortage of organic substances may result in the worsening quality of the treated water. Therefore, it may be necessary to take measures to maintain the stability of the wastewater treatment systems for extended periods of time. The population of treatment reached 162% of the target in 2015,[16] with both the treatment amount and the population of treatment almost achieving their targets. Because demand is estimated to increase further, the North-area Plant plans to expand its capacity by 100,000 m^3/day, using domestic funds.

The following table compares water quality at the time of the main pollutants' inflow and after treatment at each treatment plant.

[15] In Japan, a wastewater treatment plant is designed with an ample capacity calculated based on the maximum annual amount of sewerage. However, both plants were designed based on the daily average amount of inflow according to the ordinary design method in China. Because the treatment capacity is not large enough, pipe storage and high-water level operations, in which the plants usually store sewage in pipes and uniformly pump it up for 24 hours a day, have been continuously performed by storing sewage in the sewer. (for details, see the separate detailed analysis paper).

[16] The degree of achievement for the population of treatment is higher than the degree of achievement for the amount of treatment because the standards for wastewater discharge from plants have been applied more strictly than at the time of planning and local people's awareness of water conservation has increased, resulting in a considerable improvement in the quality of the water flowing into the treatment plants.

Name of indicator	Standard 2005	Target 2013	Actual performance 2015 Year of beginning	Actual performance 2016 Year of completion	1st-class level A
BOD concentration at North-area Wastewater Treatment Plant					
Entrance	280	-	125.3	93.1	-
(mg/L) Exit	-	30	5.3	5.3	10
COD concentration at North-area Wastewater Treatment Plant					
Entrance	500	-	218.9	172.4	-
(mg/L) Exit	-	100	27	26.6	50
SS concentration at North-area Wastewater Treatment Plant					
Entrance	280	-	19.86	21.94	-
(mg/L) Exit	-	30	0.93	0.87	10
BOD concentration at South-area Wastewater Treatment Plant					
Entrance	280	-	74	80	-
(mg/L) Exit	-	30	5.6	5.2	10
COD concentration at South-area Wastewater Treatment Plant					
Entrance	500	-	328.36	267.07	-
(mg/L) Exit	-	100	22.82	11.58	50
SS concentration at South-area Wastewater Treatment Plant					
Entrance	280	-	125	115	-
(mg/L) Exit	-	30	6	5	10
Removal COD (tons/year)	-	27,000	18,425	16,655	-
Removal BOD (tons/year)	-	-	9,439	7,988	-

Sources: Materials provided by JICA, the project-implementing agency's responses to questionnaires

Both wastewater treatment plants' average rate of reduction of the amount of pollutants has reached 93%. Since both plants began operating, they have achieved first-grade level A, the regulation level for treated water. Because the standards for wastewater discharge from factories are applied more strictly than at the time of the appraisal, the quality of sewage flowing into the treatment plants has improved and the quality of the treated water has greatly improved since the time of the planning. The treatment plants are monitoring data in real time, including the chemical oxygen demand (COD), and the suspended solids (SS) at the entrance and exits. Data are also sent to the Environmental Protection Bureau of Nanyang Municipal People's Government. Because strict measurement and control systems have been adopted, the reliability of the data is high.

The target rate of removal COD by this subproject was 68% in the beginning year. As described above, however, the concentration at the entrance has become much lower than the standard level. Accordingly, the amount of COD reduced by the treatment plants has decreased.

(2) Gas Supply Facilities

The gas supply facilities are evaluated in terms of the status of bio-gas production and the diffusion of gas supply to Nanyang City. The following are the main indicators:

Name of indicator	2005	2013	2014	2015	2016	Target
Gas supply						
Population of supply (10,000 people)	52.2	49.2	63.9	69.3	84.2	79
Amount of supply (10,000 m^3/day)	2.9	14.1	17.7	19.8	24.1	-
(Converted into bio-gas)*	-	28.1	35.4	39.6	48.1	42
Gas pipelines	-	12.7	9.4	17.2	21.2	-
(Converted into bio-gas)	-	25.4	18.9	34.4	42.3	-
Bio-gas equipment	-	1.4	8.3	2.6	2.9	-
(Converted into bio-gas)	-	2.7	16.6	5.3	5.8	42
Supply rate in whole city (%)	11.4	-	-	-	-	37.7
(Supply rate in urban area)**	16	41	45	46	52	33.5
Gas production						
Production capacity (10,000 m^3/day)	10	49.5	49.5	49.5	49.5	49.5
Amount of production (10,000 m^3/day)	-	33.6	39.8	38.7	16.9	49.5
Production of bio-gas	-	30.3	19.7	32.3	9.8	49.5
Conversion to purified bio-gas (Amount of terminal supply) ***	-	1.4	8.3	2.6	2.9	-
Amount of TSP reduction (tons/year)	-	7,800	-	-	-	
Amount of SO^2 reduction (tons/year)	-	25,200	-	-	-	

* Purified process (purified bio-gas) is necessary for supplying bio-gas as natural gas. Usually, the amount of unit production of finally produced purified bio-gas is equivalent to half of that of bio-gas.

** Because it was difficult to acquire information on population, the supply rate in the whole target area, the effectiveness indicator at the time of the appraisal, was replaced with the supply rate in the urban area.

*** Converted into purified bio-gas

At present, the population of gas supply in Nanyang City is about 840,000 and the amount of gas supply in the city is about 240,000 m^3 (480,000 m^3 if converted into bio-gas). The supply rate has reached 52%. These indicators are higher than initially planned. On the other hand, although the plants have kept their bio-gas production capacity at 495,000 m^3/day as planned, the actual production has remained at only around 34% of the initially planned production. This is mainly for the following two reasons:

- As described in "3.1.4 Appropriateness," because it was decided that natural gas would be introduced to Nanyang City through the national gas pipeline network, the main source for the gas supply is natural gas at present and bio-gas is used as a supplementary gas source.

- Since 2016, production has been adjusted, because international oil price fluctuations resulted in a decrease in the supply amount of raw materials for bio-gas (liquid waste discharged from factories).

Meanwhile, regarding the future status of utilization, the gas supply facilities is expected to be used more, because of the implementing agency following measures and changes in the business environment. To use the surplus production capacity effectively, the implementing agency used domestic funds to construct facilities for generating electricity using bio-gas in the gas supply facilities and began to operate them in May 2013. In 2017, the implementing agency began to sell electricity for the national power networks. In the future, in addition to using it as a supplementary supply source, the agency will attempt to use it effectively through these supply services.

In addition, the central government's priority measures for bio-fuels are expected to improve the business environment. In 2017, 15 government offices, including the National Development and Reform Commission, announced the plan to use bio-fuels for ethanol gasoline and expand the production of it, declaring the objective of entirely popularizing ethanol gasoline for automobiles by 2020. It is difficult for gas producers to secure a sufficient amount of factory-discharged liquid waste as a raw material for gas production because this depends on the volume of production by ethanol factories as suppliers. However, with the increase in demand for ethanol fuels owing to national policy, ethanol factories, the raw material suppliers, are expected to increase production.

Based on what was described above, the effectiveness of the whole project will be discussed. Regarding the wastewater treatment facilities, because almost all the indicators, such as population of treatment, the amount of treatment, and improvement of the quality of the discharged water, have been fulfilled, it is fair to say that this project has produced effects. Regarding the gas supply facilities, improvement in the gas supply within the city and an increase in the diffusion rate have almost been achieved. Given the increase in the population of supply also, it can be evaluated that the purpose of popularizing clean gas as a substitute for coal has almost been achieved. In addition, because the impacts described below demonstrate the tendency to improve air quality in Nanyang City, it can be evaluated that the purpose of this project has been favorably achieved. However, the gas production facilities constructed under this project have not produced even half of the initially planned amount of gas. Although the bio-gas production equipment has performed its function as a supplementary source in case of a shortage of natural gas as a supplementary energy source and has played an important role in establishing the system for a stable gas supply, issues remain concerning use of the outputs, which account for about 20% of the total project cost. However, the effectiveness of this project

can be expected to increase from both mid- and long-term perspectives because of the following: demand for ethanol fuels is likely to increase due to the national policy; demand for bio-gas can be expected to increase; and measures have been taken to diversify the purpose of use through development of the power generation business using gas.

In light of the above, the whole gas supply project is evaluated to have achieved the initial purpose.

3.3.2 Impacts

3.3.2.1 Intended Impacts

In the project, "Improvement of river water quality," "Improvement of air environment," and "Improvement of gas supply" are positioned as impacts.

(1) Improvement of River Water Quality

1) Monitoring data of observation points

The following data show changes in the water quality at major observation points on the Baihe River where treated sewage is discharged.

Name of indicator	2007	Target value	2013	2014	2015	2016
Water quality at the discharge destination (grade)	Below V	IV	V	IV	IV	IV
Water quality at the discharge destination (BOD: mg/L)	36.6–38.4	6	5.66	5.64	5.19	5.28
Water quality at the discharge destination (COD: mg/L)	139–146	30	25.2	26.6	22.9	24.7
Water quality at the discharge destination (NH_3-N: mg/L)	4.25–4.41	1.5	1.71	0.841	0.897	0.839

Source: Materials provided by the implementing agency
The water quality at the discharge destination is the water quality of the observation cross-section (Wa Dian) which is the same as that during the FS conducted in 2007.

Values of the water quality at the discharge destination have been declining across all indicators (water quality grade, the biochemical oxygen demand (BOD), COD, and ammonia nitrogen (NH_3-N)), compared with those at the time of the project planning (2007). This resulted in a significant improvement in the national standard water quality grade from category Below V to category IV. All sewage generated in the urban areas of Nanyang City is treated in the north plant and the south plant which were improved in this project. Improvements in the sewage treatment systems significantly improved the water pollution in the Baihe River. As for improvement of water quality at the discharge, it is necessary to consider the influence of stricter pollution control of factory wastewater since the revision of the Environment Protection Law in 2015. However, in 2014, all target values had already been achieved, and the impact of water quality improvement by the project is still considered to be high.

2) Results of interviews with beneficiaries

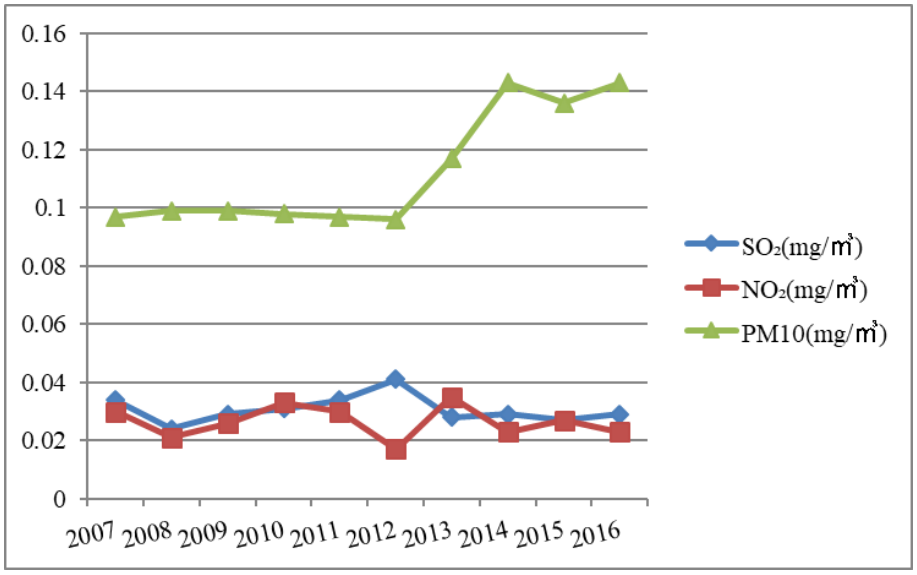
To understand what the beneficiaries think about "improvement of the river water quality," interviews were conducted with related enterprises and organizations to investigate changes in both the corporate activity environment and the river environment before the project implementation (2007), and at the time of the ex-post evaluation (2018). The results of these interviews are summarized below.

- Effects of benefits on businesses: According to a man who runs a transportation company which collects gravel from the bottoms of rivers and sells it as building material, the gravel collected from the bottom of the Baihe River could not be sold as a product when he established the company in 2006 as its color was black and its quality was poor. Therefore, he went outside the city to collect gravel. Because of the high costs needed for long-distance transportation, the company's profitability declined. However, since around 2012, the color of the gravel in the Baihe River has improved. By digging deep and collecting gravel that had a low impact from the sludge, he could meet the quality standards requested by his customers and collect gravel effectively. This improved the company's earnings.
- Effects of benefits on residents: According to a man who enjoys fishing and swimming in the river on a daily basis, he was accustomed to swimming only in the upper river basin because of the poor water quality, but now he can swim in the lower river basin as well. In addition, fish caught around the lower river basin had a muddy smell when cooked, but those caught recently do not have a muddy smell and are tasty. He realized the water quality has improved.

Although these results are based on interviews with a limited number of beneficiaries, what they realized indicates the improvement of the river water quality described above. It is fair to say that these results demonstrate the recent improvement in river water quality.

(2) Improvement of Air Environment

The table below shows changes in the annual average values of the contamination of air pollutants in Nanyang City.



With the progress of urban development, PM10[17] has been increasing. On the other hand, sulfur dioxide (SO_2) and nitrogen dioxide (NO_2), which are generated mainly owing to the combustion of fossil fuels, have been slightly declining. It seems that a decline in the use of coal-derived fuels is the main cause for this. As mentioned in "Relevance," Nanyang City's GDP and population have been continuously increasing, and the number of private vehicles has been dramatically increasing. However, SO_2 and NO_2, which increase in proportion to such increases, have been slightly declining. It is supposed that, of the city's entire energy consumption, fossil fuels have been consumed less or environmental measures have been taken to energy consumed.

The gas supply ratio in urban areas of Nanyang City increased from 16% before the appraisal to over 50% at the time of the project completion. Accordingly, it is fair to say that the spread of the gas supply has made a certain contribution to improving the air environment, with the decline in the consumption of coal and other inefficient energy sources.

(3) Improvement of Gas Supply

During the field survey, interviews were conducted with beneficiaries who were receiving the gas supply, such as crude processing-related enterprises and regional residents. The opinions from the enterprises include the following: "The introduction of natural gas has enabled us to achieve the national standard value of air pollutant emissions (imposed on each enterprise), which has been tightened in recent years, and contributed to our stable operation," and "The introduction of natural gas has increased the efficiency of our heating furnace." Among the opinions from the residents are "The change from propane gas to natural gas has improved the heating efficiency of our cooking utensils and the uniformity of the heating power," and "The change has reduced the cooking time."

[17] Of particulate matter floating in the air, matter with a particle diameter of 10 μm (0.01 mm) or less

Based on the opinions above, the results of the interviews show that the gas supply project has made a certain contribution to improving corporate activities and the living environment.

3.3.2.2 Other Positive and Negative Impacts

(1) Pollution Control Measures

In the project construction phase, the following measures were taken upon requests from the Environmental Protection Bureau and the Construction Administration Management Bureau of Nanyang Municipal People's Government:

- Dust control measures: Motor sprinklers were used to prevent soil dust.
- Noise control measures: Noise-reduction devices were used during the construction period. At sites where it was necessary to carry out construction work at night, noise-reduction measures were taken for the construction devices, and sound insulating walls were placed around the site. Night-time work was prohibited.
- Sewage pollution control measures: Discharged water generated during the construction period was collected in the sewage collection pond and delivered to the existing intake pump through the sewage pipe.

As a result of these measures, it was confirmed that the contamination in the surrounding environment was minimized and no delay or accident was caused by such contamination.

Concerning discharged water and sludge generated in the project implementation phase, the following measures have been taken:

1) Sewer plants

Until June 2017, all sludge generated had been reclaimed at waste treatment plants. After the sludge treatment center, developed by Nanyang City using its own funds, started operations in July 2017, all sludge generated at the sewage treatment plants has been treated with compost at the sludge treatment center after performing the dewatering process to reduces the moisture content to 80% or less.

2) Gas supply plants

Concerning discharged water generated during the production process of bio-gas, A_2O treatment, OD treatment, and final sedimentation are processed. The value of the treated water has been decreased to the regulatory value for discharged water or below, as specified by the Environmental Protection Bureau of Nanyang Municipal People's Government. The water is directly discharged into the Baihe River while part of the water is recycled as regenerated water.

Sludge dewatering process at the North-area Wastewater Treatment Plant

Drainage treatment in the gas production project

(2) Impacts on the Natural Environment

Problems not intended in the EIA report have not occurred, and as described above, since adequate contamination measures are taken at the time of the project construction and implementation, particular negative impacts on the natural environment have not been observed.

(3) Impacts on the Social Environment

An acquisition of 22 ha of land was planned at the time of the project planning, but a total of approximately 40 ha of land was actually acquired. The land acquired includes an area of land acquired for the next construction of a sewage treatment plant (land for purposes other than the project)[18]. As had been planned, there has been no resettlement. The land acquisition and compensation were made in accordance with land-related laws such as the "People's Republic of China Land Act," the "Implementation Regulations of the People's Republic of China Land Management Act," and the "Henan Province 'Land Management Act' Implementing Act," with specific compensation standards for each area.

In addition, complaints from residents have not occurred due to the implementation of the project.

(4) Others

With the Clean Development Mechanism (CDM) application in November 2011, the Certified Emission Reductions (CERs) transfer, of up to 5.95 million tons of CO_2, from the gas production project to a British enterprise (Allied Energy Capital UK Limited) was approved, and the project was identified as a clean energy project. It can be said that CO_2 reduction effect of the project was internationally recognized.

[18] The project site is adjacent to the planned site for the construction in the subsequent term in the same premises, and it is difficult to calculate the area of the project site precisely. However, the impact on the social environment is considered low because it was confirmed that the acquired land is an abandon area without residents.

As stated above, the project has almost achieved its objectives. Therefore, effectiveness and impacts of the project are high.

3.4 Sustainability (Rating: ③)

3.4.1 Institutional / Organizational Aspects of Operation and Maintenance

(1) Sewer Plants

As had been planned, the sewer plants have been managed by "Nanyang Sewage Purification Center," a state-owned enterprise. The center is an organization that focuses on treatment plants and sewage treatment, and does not collect sewage rates. Currently, the total number of its employees is 233 (including 22 administrative managers, 159 technical personnel, and 52 clerks). The percentage of technical personnel is around 68% of the total employees.

(2) Gas Supply Plants (Production/Supply)

The gas production project has been operated by a methane gas production company established as a subsidiary of "Henan Tianguan Enterprise Group Co., Ltd.," a state-owned enterprise. Currently, the total number of employees for the production project is 131 (including 106 production personnel and 25 non-production personnel). An alcohol plant which provides liquid waste, a raw material for bio-gas production, to the production project is also a subsidiary of Tianguan Enterprise Group. The plant has applied a system to supply all generated liquid waste.

The gas supply project had been operated by "Nanyang ZhengRan Fuel Gas Co., Ltd.", which had been a state-owned enterprise. Then in 2009, the company became a subsidiary of the China Resources Group[19] and was renamed as "Nanyang China Resources Gas Co, Ltd". The total number of its employees is 750 (Technical personnel: 35%). With improvements to operational efficiency, such as the use of unattended stations, the number of employees has been declining.

Concerning the method of collaboration between the production section and the supply section, they determine the supplied amount and the quality of bio-gas based on a contract, and through the procurement operation system, their procurement centers promptly communicate with each other by telephone.

3.4.2 Technical Aspects of Operation and Maintenance

As the operational technology for sewage treatment and gas supply had been established in China at the time of the appraisal, no major problems have been observed. An expert in the sewer service joined the field survey and evaluated both the capacity and the operating system from a technical perspective. This evaluation confirmed that the operation sections of all the

[19] A listed enterprise in Hong Kong in which state-owned funds account for over half of its issued shares

treatment plants had sufficient experience and skills, and had the appropriate technical capacity for project operation. In addition, each implementing agency has prepared manuals concerning operation and maintenance as well as inspection, and provides training on specialized and technical knowledge each year, intended for many employees. It is fair to say that there is no major problem with maintaining the technical level.

(1) Sewer Plants

- Technical personnel are mainly recruited from those people living in the region and those who graduated from a university in the region. The number of employees who leave their jobs is only around one or two a year mainly because of retirement. The retention rate is high.
- In a certain month every year, training on maintenance, facilities, and theory has been continuously provided intended for selected personnel according to their job type.
- As for matters related to electricity and facilities, technical examinations for electrical technicians, crane technicians, pressure vessel technicians, and machinists are held.
- According to the expert in sewer operations who joined the field survey, the levels of understanding of treatment flow, application of adopted technology, and response to trouble and problems were high. It was confirmed that their technical capacity for efficient operations was sufficient.

(2) Gas Supply Plants

- In the gas production project, technical training on sewage treatment, and gas production and purification was conducted 100 times in 2016. The project has introduced the position qualification system to have employees acquire a qualification during training after employment and be at their posts.
- In the gas supply project, technical, safety and operation management training on gas operation was conducted both internally and externally. In 2017, technical and safety training, such as training on the handling of hazardous materials and firefighting, was conducted approx. 30 times intended for selected personnel according to job type.
- According to the expert above who joined the field survey on the production and supply sections, the levels of understanding of treatment flow, and the handling and operation of facilities were carried out properly. It was confirmed that their technical capacity regarding effluent treatment in the gas production process was sufficient.

3.4.3 Financial Aspects of Operation and Maintenance

(1) Sewer Plants

Costs for the operation, maintenance, and management of sewage treatment plants are paid by the Financial Bureau of the city to the sewage treatment plants as sewage treatment costs. Each sewage treatment plant submits an invoice to the Financial Bureau each month based on the amount and the quality of water treated, and the Financial Bureau examines the invoice and reimburses the actual costs. The operation, maintenance, and management costs paid by the Financial Bureau are covered by the water and sewer rate income collected altogether by the water service company. The financial management is secured by municipal government finances. It is stipulated by law to cover any financial deficit of the plans.[20]

The sewer rates (income) collected by the water service company are 0.8 yuan/m^3 on average, which has not changed since the appraisal, and the current sewage treatment costs (expenditure) are 0.4-0.5 yuan/m^3. Thus, the profitability of the plants is secured.[21] As the government will not need to bear the financial burden for the time being, financial stability is also secured.

(2) Gas Supply Plants

1) Gas production project

Recent financial data for the gas production company are provided below. Major income sources of the project are gas selling rate, power generation-related rate,[22] and liquid waste rate. Gas selling rates are paid by the gas supply project and Tianguan Enterprise Group companies, power generation-related rates are paid by the State Grid Corporation of China,[23] steam selling rates are paid by Tianguan Enterprise Group companies, and liquid waste treatment rates are paid by the ethanol plant, which is a supply source of raw materials (industrial waste).

[20] In case of a deficit due to a shortage in sewage treatment costs, the deficit is ensured to be covered by Nanyang City under the policy of Article 33 of the State Council Order No. 641 "If sewage treatment costs collected for a special reason are insufficient to pay the costs of normally operating sewage treatment plants in the city, the local people's government will cover these costs."

[21] To enhance the sewer network and expand the treatment plants, a survey on increasing the sewer rates was conducted by the municipal government in August 2017. Sewer rates are scheduled to be increased in the near future.

[22] Power selling income and income by selling steam generated during power generation

[23] A state-owned enterprise that transmits electricity throughout the country

Unit: Thousand yuan	2012	2013	2014	2015	2016
Total Sales	116,154	136,295	179,502	194,386	80,925
Year on year rate		117.3%	131.7%	108.3%	41.6%
Operating income	28,237	50,904	49,656	25,463	-64,353
Operating income margin	24.3%	37.3%	27.7%	13.1%	-79.5%
Net income	23,232	43,415	46,102	24,618	-62,052
Capital adequacy ratio	19.3%	37.1%	38.2%	36.1%	31.0%
Flow ratio	18.6%	619.0%	193.7%	225.6%	191.3%

Source: Created by the evaluator based on materials provided by the implementing agency

Although sales of the company had been stable over the past several years, it did post a deficit in 2016. The cause of this deficit was a production adjustment due to a material shortage. The ethanol plant, which is also in the Tianguan Enterprise Group[24] and a supply source of raw materials, adjusted production in the wake of the international fluctuations in oil prices.

The gas production and supply sections have a year-round contract to adjust the amount of daily supply according to seasonal demands. It was confirmed during the field survey that discussions had been held towards increasing the supply amount of the bio-gas production section in the future, based on a shortage in natural gas supply and the future increase in gas demand through expansion of the supply network.

As for electric power selling, a long-term contract (three to five years) has been concluded based on the selling price determined by the National Development and Reform Commission. As there is no limitation on the purchase amount, all electricity produced has been purchased.

Regarding the shortage in raw materials, which is the main factor for the current deficit, the production of raw materials is expected be increased in the medium- to long-term, with the implementation of the national plan to promote the use of ethanol fuels as described in "Effectiveness." However, currently, no specific plan on such increase has been confirmed.

As stated above, the financial situation may improve in the future, in the medium- to long-term, as an increase in the production of raw materials is expected and the sales destinations of these raw materials after elimination of this shortage has been clarified. However, judging from the current financial situation, the financial sustainability of this subproject is fair.

2) Gas supply project

Recent financial data for the gas supply company are provided below.

[24] A plant designated by the government as one of the five fuel ethanol production plants nationwide

Unit: Thousand yuan	2013	2014	2015	2016
Total Sales	167,783	244,502	294,858	314,117
Year on year rate		145.7%	120.6%	106.5%
Operating income	12,765	25,293	34,494	38,391
Operating income margin	7.6%	10.3%	11.7%	12.2%
Net income	16,720	22,558	29,008	29,380
Capital adequacy ratio	28.3%	29.5%	27.3%	29.6%
Flow ratio	57.5%	77.8%	83.2%	97.8%

Source: Created by the evaluator based on materials provided by the implementing agency

Costs for the operation, maintenance, and management are covered by gas rate income. Currently, the company has been operating in the black. Standards for the gas rate collection are set by the national government at 1.8254 yuan/m^3 for residents and 2.72 yuan/m^3 for non-residents as of October 2017. Although these unit rates as a whole have been slightly declining under the national policy to promote natural gas supply, the amount of decline has been minimal,[25] and a significant revision of the rates has not been planned. As for the supply system, the supply network has been further expanded in line with the increase in future demand. It is expected that an increase in the supply amount caused by the network expansion will promote the efficiency of the system, and the supply cost per unit will decline in the future. Based on what is described above, no major concerns have been observed with regard to both income and expenditure, and the financial stability is relatively high.

3.4.4 Status of Operation and Maintenance

(1) Sewer Plants

The management status of the plants is good, and no failure has currently been observed. The operation status of the plants is monitored in the central control room around the clock. If an abnormal value is detected in the real-time online system, a three-level alarm is activated, and responsible personnel and technical personnel check the site and take actions according to the level and situation.

For the maintenance and management, regular inspections are conducted once a month for all equipment. Results of these inspections are saved in electronic or printed form.

Most of the main equipment used, such as pumps, blowers, and centrifugal dehydrators, is imported, but spare parts can be procured without any difficulty as there are many distributors in

[25] The rates as of October 2017 declined by approx. 0.4 yuan/m^3 from 2012 when the gas supply started.

China. Even in case of a major equipment upgrade, operations will not be affected as the upgrade is ensured by the manufacturer by making an appointment in advance.

Both treatment plants have introduced a monitoring system to measure data[26] on COD, NH_3-N and flow rate at the entrance/exit. The data measured are distributed online to the Environmental Protection Bureau of Nanyang Municipal People's Government in real time every two hours. The measurement equipment is strictly managed through monitoring by a third party delegated by the government.

Daily water quality results are displayed on the board at the entrance to the North-area Wastewater Treatment Plant.

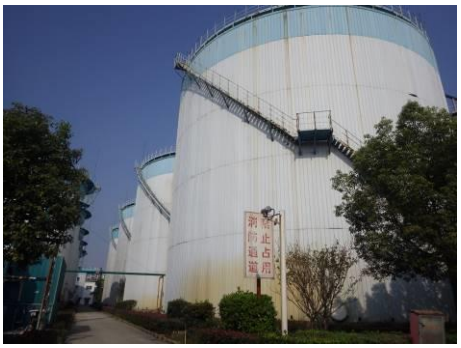
Imported blower at the South-area Wastewater Treatment Plant

(2) Gas Supply Plants

1) Gas production project

The plants have been maintained according to the maintenance and management plan, and no failure has currently been observed. During the first field survey, many parts with severe corrosion were found in the metal part of the gas tank external stairs. However, anticorrosion work was carried out by a professional in the winter of 2017, and it was confirmed during the second field survey that these parts had been restored to a good condition. Although a delay in the regular anticorrosion work was undesirable, the corrosion of the auxiliary equipment does not greatly affect the operation of the plants and does not cause any major concern. The treated water discharge destination of the production facilities has an online monitoring system installed by the Environmental Protection Bureau of Nanyang Municipal People's Government to constantly monitor the quality of the discharged water. As most of the equipment used, including the main equipment, is sourced domestically, there is no major problem with procurement of spare parts and repair of the equipment.

[26] COD and NH_3-N are measured using wavelength of ultraviolet rays



Fermentation tank of the gas production project section at the time of the first survey (October 2017)

Fermentation tank of the gas production project section at the time of the second survey (March 2018)

2) Gas supply project

The overall status of the operation, management, and supply is managed in the central control room. With respect to operation and management, a government-affiliated management bureau provides instructions and carries out investigations on a regular basis. In particular, it conducts inspections and provides instructions on sewage discharge indicators, safe production of hazardous chemical industrial products, quality monitoring and measurement of high-pressure hermetic containers, and checking pressure gauges intended for enterprises on a regular basis.

Inspections and parts exchange are also conducted on a regular basis according to the manual. For example, the gas gate station has a major inspection once a year or once every two years in addition to a daily inspection. Inspection items vary in accordance with the manual. In the daily inspection, corrosion and the sanitary condition of equipment, as well as values for gas leakage, pressure, temperature, and flow volume are checked and patrolled once an hour, and this inspection data is recorded once every two hours.

On the basis of the above, no major problems have been observed in the institutional and technical aspects of the project operation and maintenance system. Although the gas production project is currently in the red and there are still concerns over the stable securing of materials, it is fair to say that the impacts of these concerns are limited when considering the overall gas production project because the production project is just an auxiliary gas source in consideration of the overall subproject. Therefore, sustainability of the project effects is high.

4. Conclusion, Lessons Learned and Recommendations

4.1 Conclusion

This project was implemented to reduce the discharge of water pollutants into the rivers in Nanyang City, Henan Province, and ease the air pollution burden, through the construction of wastewater treatment facilities and gas supply facilities that impose low environmental burdens, thereby contributing to the improvement of the living environment in the city.

The project is consistent with China's development policy and needs at the national and municipal levels between the time of the appraisal and the present time. Although there have been changes in the operation of bio-gas production facilities as a result of an increase in natural gas supply under the national policy, the project as a whole is highly relevant. The efficiency is low because the project cost is a little higher than planned and the project period is far longer than planned. The constructed wastewater treatment facilities are operating smoothly and the effect of reducing the discharge of pollutants has manifested itself as expected. Although there is some concern that the bio-gas production facilities may have problems, gas has been supplied to Nanyang City almost as planned and the purpose of popularizing cleaner energy than coal has almost been achieved. Because the wastewater treatment ratio increased and the amount of wastewater discharged into the rivers decreased, the water quality of the main river, the Baihe River, in the city is on an improving trend. In addition, along with an increase in the gas supply resulted in a decrease in the consumption of coal and any other type of energy that imposes a high environmental burden, air pollution has been prevented from worsening. For these reasons, the effectiveness and impact of this project are high. With regard to the sustainability of this project, no significant problem is seen in the organizational and technical aspects. Although there is a slight concern over the financial condition of the gas production businesses, the gas supply is expected to increase in the future and it is highly likely that the financial condition will improve from both the mid- and long-term perspectives, and thus the influence seems limited. In light of the above, this project is evaluated to be satisfactory.

4.2 Recommendations

4.2.1 Recommendations to the Executing Agency

(1) Measures against Future Issues of Pipe Storage and High-Water Level Operations

Because of the insufficient treatment capacity of the sewage treatment plants improved in this subproject, pipe storage and high-water level operations have been continuously performed by storing sewage in the sewer. As this operation method may lead to deterioration of the plant equipment and the quality of treated water in the future, a combination of short- and long-term measures is necessary. Drug infusion is a possible urgent short-term measure. From a long-term perspective, improvements in operational technology need to be considered, such as introducing low-water level operations once a day to pump a fixed quantity of sewage so that it reaches the lower limit water level during hours when the influent quantity is relatively low. (For more details, refer to the detailed analysis paper separately created.)

(2) Measures to Improve the Durability of Auxiliary Equipment

During the first survey of the plant equipment in Nanyang City, peeling paint and rust were found in the inspection corridors and frames of the equipment at all plants. These were

addressed by the anticorrosion work carried out before the second survey, but the quality of used steel, the coating method, the processing method, or environmental factors are considered as the cause of the corrosion. To improve the durability of the plants in the future, it seems important to clarify the cause of this corrosion and prevent the deterioration of materials by taking appropriate measures according to the conditions. For example, carefully removing rust in the metal welded parts, antirust coating, anticorrosion coating, and light resistant coating are all worth considering.

4.2.2 Recommendations to JICA

The pipe storage and the corrosion of auxiliary equipment described above may be solved by examining the design specifications or the equipment selection method used at the time of procurement. To further improve the durability of the sewage treatment plants, it is desirable to consider the overall life-cycle costs during the planning and design phases. Specifically, it is recommended to standardize the "criteria and methods for selecting the methods at the time of planning," then use these criteria and methods for planning and designing a sewage pump station and sewage treatment plant, and continuously support the establishment of planning and design methods according to the actual situation in developing countries.

4.3 Lessons Learned

Reduction in project risks through flexible project design in consideration of the impacts of national policies and development plans

It was initially expected that the bio-gas produced in this project would function as a supply source of main gas for Nanyang City. However, as the current main gas source has been changed to the natural gas supplied in many areas in China, this project has been used as a supplemental supply source. Such a drastic change in the project environment may greatly affect the effective use of project outputs. This project designed the gas pipe network, which was concurrently improved, so that it enables transportation of a combination of bio-gas and natural gas, and took measures under the assumption that the project was implemented with the natural gas project since the beginning. Thus, impacts by the policy change could be minimized. As energy policy is greatly affected particularly by national policy or the market environment, it is desirable to develop a project plan that has flexibility in the design of project scope and change in the specifications, in consideration of mid- and long-term policy trends and market uncertainty.

Comparison of the Original and Actual Scope of the Project

Item	Plan	Actual
(1) Project Outputs		
1) Sewage pipe	224 km	Almost as planned
2) Sewage treatment plant (Expansion of 1 plant)	100,000 m^3/day (Recycled water plant: 30,000 m^3/day)	Almost as planned Changed the treatment method
3) Sewage treatment plant (Construction of 1 plant)	100,000 m^3/day	Almost as planned Changed the treatment method
4) Gas production facilities	Bio-gas: 395,000 m^3/day	Almost as planned Changed from four IC reactors to ten UASB reactors
5) Gas pipe network	250 km	As planned
6) Gas vaporization facilities and gas pressure adjustment facilities	Newly established	As planned
7) Training program	Training program in Japan on sewer and gas supply projects intended for employees of the implementing agency	Training program in Japan for sewer plants Two people from gas supply plants participated in the training program in Japan.
(2) Project Period	December 2007 to January 2013 (61 months)	December 2007 to May 2016 (101 months)
(3) Project cost Amount Paid in Foreign Currency Amount Paid in Local Currency Total ODA Loan Portion Exchange rate	 12,248 million yen 15,140 million yen (970 million yuan) 27,388 million yen 11,500 million yen 1 yuan = 15.6 yen (as of June 2007)	 10,114 million yen 19,587 million yen (1,299 million yuan) 29,701 million yen 10,114 million yen 1 yuan = 15.08 yen (average exchange rate between 2007 and 2016)
(4) Final Disbursement	April 2015	