LIVESTOCK WASTE MANAGEMENT IN EAST ASIA PROJECT

Guangdong, China

Semi-annual Progress Report

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I. Project Implementation Status

A. General Assessment

In the second half of 2007, the implementation of GEFLWM (Guangdong) project kept going on well. With the cooperation of the staff in PMO and the units related, substantive progress has been made in the component of demonstrated construction and environmental monitoring and evaluation.

So far, the first batch of the demonstrated construction sites, which are named Foling pig farm and Mashigang pig farm, have come to the last phrase. They are anticipated to be finished in two month. On the other hand, the investigations of the 2nd batch of the demonstrated construction sites have been finished, and the constructions of five pig farms selected from ten farms agreed by the Bank for 2nd year will begin soon.

In the past months, some progresses have also been made on the other components .Below come the details.

B. Implementation Progress by Component

Comp1. Livestock Waste Management Technology Demonstration

a) At present, the two pig farms of the first batch that named Foling Pig farm and Mashigang pig farm are being constructed. Now the power generators are being procured, and the program will be finished after the generators begin to work. The date is prospected to be finished at the end of 2008 January.

b) The investigations of the 2nd batch of the demonstrated construction sites have been finished and the name-list has been decided. By times of field visiting, PMO analyzed the feasibility of each candidate and finally selected 10 pig farms as the 2nd batch of the demonstrated construction sites, made decision for the preliminary technological design. Now the 10 farms all have been approved by World Bank.

The names of the 10 farms are, Taimei pig farm\ Luoxing pig farm\ Huangtian pig farm\ Xuhui pig farm\ Changning Dengdaming pig farm\ Changning Modong pig farm\

Longhu pig farm\ Shanglang pig farm \ Xikou ping farm and Xinfeng pig farm. The first five will be constructed no sooner than the first batch constructions are finished.

Comp2. Policy and Replication Strategy Development

a) The invite bidding and procurement task of making Replication Strategy and COP of the pig farms have been finished. The Institute of Environment and Sustainable Development in Agriculture CAAS got the contract. Two specific documents are being drafted.
b) The bidding and procurement of task of making the Spatial Planning and Nutrient Management plan have been done. The contract awarded to Dr. Liao Xindi ,a professor from the South China Agricultural University.
c) An international study tour is being arranged. The target countries are Australia and New Zealand. The objectives of the mission are: to learn about the policy framework of livestock production and waste management in the host countries,to exchange experiences of Agricultural Environment management, and to develop the project implementation skill. The Study group of 8 members from PMO and related government agencies will be led by Ms. Yu Jiane, Deputy Director-General of DOA. We will set off at the beginning of next year and stay abroad for 10 days. The expenses incurred will be borne by the provincial counterpart fund.
d) In November, held the meeting of DST with the specialist group of FAO.
e) In September, the web site of PMO was built. So far, there are three parts: Notes of Visiting, Invited Bidding and TORs, and mini PIP& Maps. Yet it hasn't been consummate, improvements will be made step by step. The address is http://www.gdhbny.org/webcmps/1000_136.html

Comp3. Project Management and Monitoring

a) The invite bidding and the procurement for the environmental monitoring unit have been finished. By the way of CQS, the contract was awarded to the Soil and Fertilizer Institute of Guangdong academy of Agricultural Science, the environmental monitoring now goes in order. The first report came out on Dec. 15th, 2007.
b) By the aim at accessing the impact by the project on the public health, we are planning to have sanitation monitoring and data collections. i) Detecting the sanitation situation of the pig farms.(Including the Ascarid, Hookworm and Intestinal microbe); ii) Detecting the sanitation situation of people around the pig farms; iii) Analyze the result of the detection, access the health risk of people. Now the invite bidding is being taken by the way of CQS.
c) Training and receptions.
    i. Brought Prof.HongLim Choi to field visit to the farms and had technological discussion.
    ii. Receipt the Vietnam study group in July.

iii. In December, receipt Mr. Kurt Roos, and pay field visit to Boluo County.
iv. In December, some PMO members flight to Bangkok and took part in the 3rd RCG meeting and Policy Workshop.
v. Meetings on project management were held by PMO, the Bureau of Environmental Protection, DOF, DOPH, the Bureau of Agriculture of Boluo county and the Township Executive Committee in project area from time to time, for ensuring the in time communications and to solve problems as soon as possible. Meanwhile, directors in management group paid special attentions to the implement and have had many field supervisions.

C. Implementation Progress by Procurement

a) Procurement of Works:
Now the constructions of manure treatment systems for Mashigang pig farm (contract No. W1) and Foling pig farm (contract No. W2) both come to the final process. And the constructions of the five farms in the 2nd group will be carried out soon.

b) Procurement of Goods:
The main procurements of this part are the Power generator, pipes and other equipments for Mashigang pig farm and Foling pig farm. They might begin to work in Jan. 2008. Each of them costs 40,000 USD.

c) Procurement of Consultant Services:
As mentioned above, the main work that we have done in this part are:
i. Draft out the Spatial Distribution Planning (for livestock production) and Nutrient Management Plan; to be as technical specialist
ii. Developing replication strategy
iii. Design of waste treatment technological process of the 2nd year's pig farms(five farms)
iv. Constitute the mini PIPs of the second period of Project farms (10 in total) With international/ national experts' experience, discussing and developing COP.
v. Invite professionals to develop the promotion website and maintain it.
vi. Made monitoring analysis report for the two farms in the 1st demo sites

d) Workshops, Trainings and Study Tours:
In the past months, we PMO have receipt some guests and professors, held some meetings and attended some workshop abroad. For example, brought Prof.HongLim Choi to field visit to the farms and had technological discussion, receipt the Vietnam study group in July, brought them to the farms and learnt/discussed the experiences from each other, in November, held the meeting of DST with the specialist group of FAO, from whom we learnt how to operate this work ,etc.

e) <u>Incremental Operating Costs</u>

After Surveyed the distribution of large-scale pig farms, pollution, waste management technologies, and so on, worked out proposed project farms' name list of the 2nd year for the Bank's review. Now the ten farms have been proved by World Bank and the constructions will be carried out soon.

D. Implementation Progress by Disbursement.

In the past months, PMO have signed many contracts related to the project, which totally cost about 1,754,000 USD. How ever, as most of the expenses are divided payments, we paid the money from the National Counterpart Fund first. When the constructions are finished, we will yield the account from World Bank. As far as December 2007, the disbursement has come to a number of,

GEF: 129694.03 RMB (17483.94 USD)

The expense of training in December 2007 and the environmental monitoring fee have drowned from the account, and others, such as the Reception fee of the GEFLWM Technical Assistance Mission and the Initial Payment for the consultative service have not been applied yet.

PHRD: 23895.5 RMB (3200.07 USD).

Include the procurement of a notebook PC and the expense of one PMO member's attending the procurement training in Beijing, and the fee of another computer has not been applied.

The National Counterpart Fund: about 1,220,000 RMB

E. Implementation Progress by Financing

GEF: having drown from the fund for twice, totally for 78007.03 RMB (10403.53 USD)

Include the expense of training in December 2007 and the environmental monitoring fee.

PHRD: having drown from the fund for twice, totally for 18595.5 RMB (2474.04 USD)

F. Implementation Progress of PHRD activities

Since July, we have disbursed some money from the PHRD fund for two matters:

a) Procured a notebook PC, which is used for PMO's daily working.
b) In October, One of the PMO members attended the Procurement Training in Tsinghua University.

II. Major Issues and Next Steps

So far, the project is implemented quite well, but there still some problems to be solved. One of the key barriers is the shortage of counterpart fund. As of today, the co-finacing part from the provincial EPB has not been in place, this constrained the technology demonstration scale of the project. We could not make the constructions of all the ten selected farms for second year until all the government funds would be available. Furthermore, we strongly request for raising the co-financing contribution from GEF Grant to the physical construction of livestock waste management facilities on demonstration farms from 25 percent to a higher percentage, perhaps 50 percent or more would be more reasonable. Only could we get more financing support from GEF Grant, we might suffer less pressure of seeking counterpart fund, also the implementation could be smoother. In short, the financial problem has come to the main obstacle for us.

Great progress have been made to project during the past six months, the constructions of the first two demo pig farms have been basically completed, after purchasing and installing the power generators, they could be put into operation. The policy documents including Spatial Distributing Plan, Nutrient Management Plan, Replication Strategy and COP also have been into drafted. During the next six months, we plan to:

1/ Try to finish the constructions of the second ten demo farms that have been approved by Work Bank. Considering of lacking of funds, meanwhile, to ensure the quality of construction, we pick up five farms from the second batch and begin to design and construct the wastewater treatment.

2/ Consultant experts are drafting Spatial Distributing Plan, Nutrient Management Plan, Replication Strategy and COP. In the coming six months, we plan to finish the draft of four documents. Then, we will submit them to WB and FAO. The consultant experts will revise the files according to WB and FAO's suggestion.

3/ Keep working on the healthy and environmental monitoring in the demonstrated sites. After the operation of the first two-demo treatment system, we will compare the before- and after- monitoring results.

4/ Prepare to survey and select the third bath of demo farms in project sites.

5/ Organize PMO members to attend the training about project management, procurement and so on.

6/ We have made some propagation for project on Guangdong Agricultural Department website, after watching the FAO's effort on website, we think we have lots of work to do and perfect it. In the next 6 months, we will do more propagation and extension.

III. Annexes

A. Implementation Progress

Table 1 The cost of the contracts

Component	Total	actual by end 2007	% of total
	US$ 000	US$ 000	
Livestock Waste Management Technology Demonstration	**4,510.0**	**65.31**	**1.45%**
Technology Demonstration	**4,200.0**	**61.11**	**1.46%**
Training and Extension	**310.0**	**4.20**	**1.36%**
Policy and Replication Strategy Development	**1,440.0**	**45.89**	**3.19%**
Policy Development and Testing	**839.0**	**45.89**	**5.47%**
Awareness raising	**601.0**		**0.00%**
Project Management and Monitoring	**1,550.4**	**64.20**	**4.14%**
Project Management	**500.0**		**0.00%**
Monitoring and Evaluation	**1,050.4**	**64.20**	**6.11%**
Total Cost	**7,500.3**	**175.40**	**2.34%**

Table 2 Draw out from the account

Component	Total	actual by end 2007	% of total
	US$ 000	US$ 000	
Technology Demonstration	**4,200.0**		**0.00%**
Training and Extension	**310.0**	**4.20**	**1.36%**
Policy and Replication Strategy Development	**1,440.0**	**0.00**	**0.00%**
Policy Development and Testing	**839.0**		**0.00%**
Awareness raising	**601.0**		**0.00%**
Project Management and Monitoring	**1,550.4**	**6.20**	**0.40%**
Project Management	**500.0**		**0.00%**
Monitoring and Evaluation	**1,050.4**	**6.20**	**0.59%**
Total Cost	**7,500.3**	**6.20**	**0.08%**

1RMB=1USD/7.3

B. Project Monitoring Indicators

Report number: TFS-SJ2007-001

Monitoring Report on Surface and Ground water Quality of Mashigang and Foling Pig Farms

(Monitoring Period: September, 2007 – December, 2007)

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December, 2007.

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1. Introduction

The first demonstration sites participating in Global Environmental Facility Livestock Waste Management in East Asia project locate in Yuanzhou Township of Boluo County in Huizhou city, which lies in 80 kilometers to the east of Guangzhou. This township is endowed with sub-tropical monsoon climate, and it's hot and rainy in summer, warm and dry in winter, with the annual average temperature of 21℃ and annual rainfall of 1700-2400 millimeters. The rural population of Yuanzhou Township is 51,000 in total. The annual amount of livestock is about 10,000 and hog production is 6,000. The local pig industry is mainly characterized as the model of "Pig Farm-Fish Pond" or "Pig Farm-Orchard", which is adopted by more than 100 pig farms with the annual production amount of over 100 hogs and half of them reach the amount of over 300 hogs. The majority of pig sewage went into the ponds around from these pig farms after simply feces picking-up, then gathered to the river through various channels, and ended up in Dongjiang River of the Pearl River, and finally entered the South China Sea.

The influences to the surrounding environment during the pig-raising process are obvious, which will not only produce wastewater and solid waste, but also emit offensive odors, which have great impact on the surrounding environment and human health. According to Chinese Environmental Management Requirements and Standards, both liquid and solid wastes produced during the pig-raising process should be under control and well-managed. In order to find out the situation of the overall condition of water environment around the pig farms and provide references to future environmental management, with the support of Global Environmental Facility Livestock Waste Management in East Asia project (GEF NO. TF056519-CHA) and the help of The Station of Rural Environmental Energy Sources of Guangdong Province, Soil and Fertilizer Institute of Guangdong Academy of Agricultural Sciences provides consultant service for the environmental monitoring of the first two demonstration sites.

Two pig farms were selected as demonstration sites: one is a large farm with 5,000 pigs in Mashigang village, owned by Mr. Zhai Riqiu, and the other was a medium farm with about 4,300 pigs in Foling village, owned by Mr. Huang Qingshui in Bolou County of Guangdong Province. For these two pig farms, they usually adopt the method of water-flushing to remove the manure. Therefore, except for water providing for drinking, water is also used to flush the dejections and clean the pig houses, which takes up a large portion and finally needs to be discharged and treated as wastewater. Generally speaking, the water consumption is 75-100L/ lactating sow, 45L/pregnant sow or boar, and 30L/hog. So, the wastewater discharged per day should be about 100 tons. After simply feces picking-up, the wastewater is with high organic matter and Pathogenic microorganisms.

According to the requirements, here we provide the reports on surface and ground water quality, basing on twice inspections before the operation of treatment system.

2. Monitoring Report on Surface Water Quality

2.1 Sampling Location

Ten surface water monitoring sites were suggested in MaShigang pig farm as follows: one at discharge hole of pig house, one at pig farm system boundary, each at seven large fish ponds and one at a small fish pond.

Four surface water monitoring sites were suggested in Foling pig farm as follows: one at discharge hole of pig house, one at the entrance of the river, one at fish pond and one at a small stream. Every sampling site was accurately positioned by GPS to identify sampling locations. The distribution of surface water monitoring locations of Mashigang pig farm was listed in Table 1-1 and Figure 1, and that of Foling pig farm was listed in Table 1-2 and Figure 2.

Table 1-1 Locations of surface water monitoring sites of Mashigang pig farm

Sample ID	Monitoring location and Sample names
#1	Pond 1 (E 114°00.155′N 23°10.696′)
#2	Pond 2 (E 114°00.201′N 23°10.708′)
#3	Pond 3 (E 114°00.201′N 23°10.750′)
#4	Pond 4 (E 114°00.085′N 23°10.788′)
# 5	Pond 5 (E 114°00.006′N 23°10.844′)
# 6	Pond 6 (E 114°00.058′N 23°10.781′)
#7	Pond 7 (E 114°59.995′N 23°10.826′)
#8	Discharge hole of pig house (E 114°00.192′N 23°10.760′)
#9	Small pond (E 114°00.193′N 23°10.699′)
#10	Pig farm system boundary (E 114°00.145′N 23°10.672′)

Table 1-2 Locations of surface water monitoring sites of Foling pig farm

Sample ID	Monitoring location and Sample names
#21	River
#22	Fish pond
#23	Canal for system drain
#24	Small stream

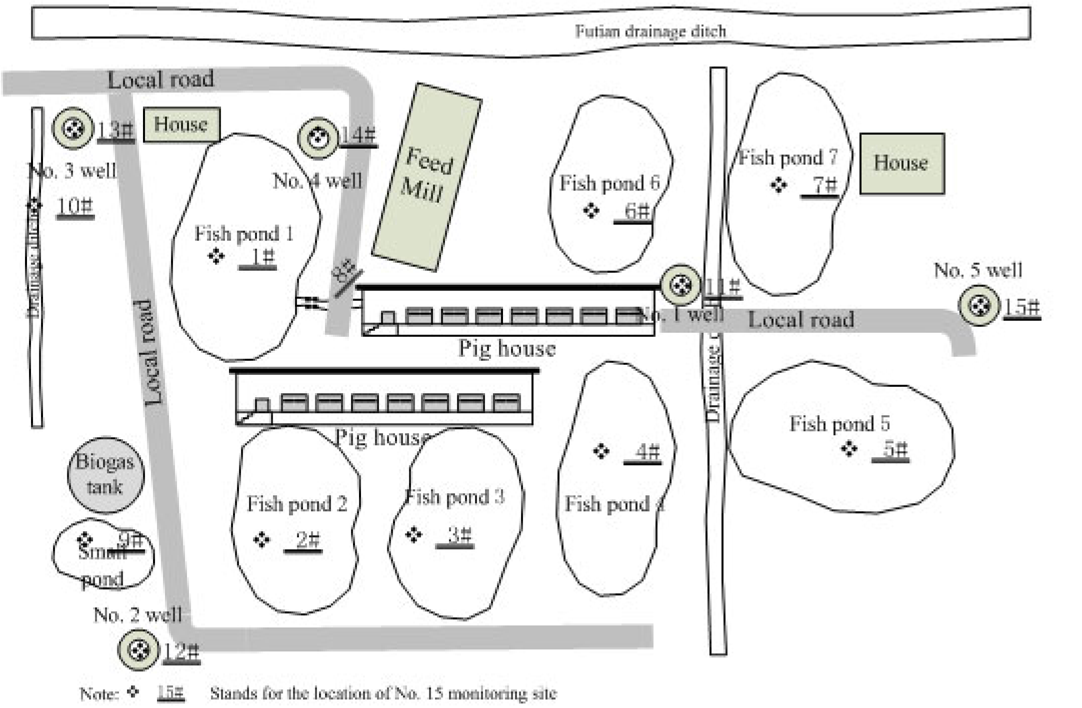

Figure 1 Sampling sites suggested for monitoring surface water of Mashigang pig farm

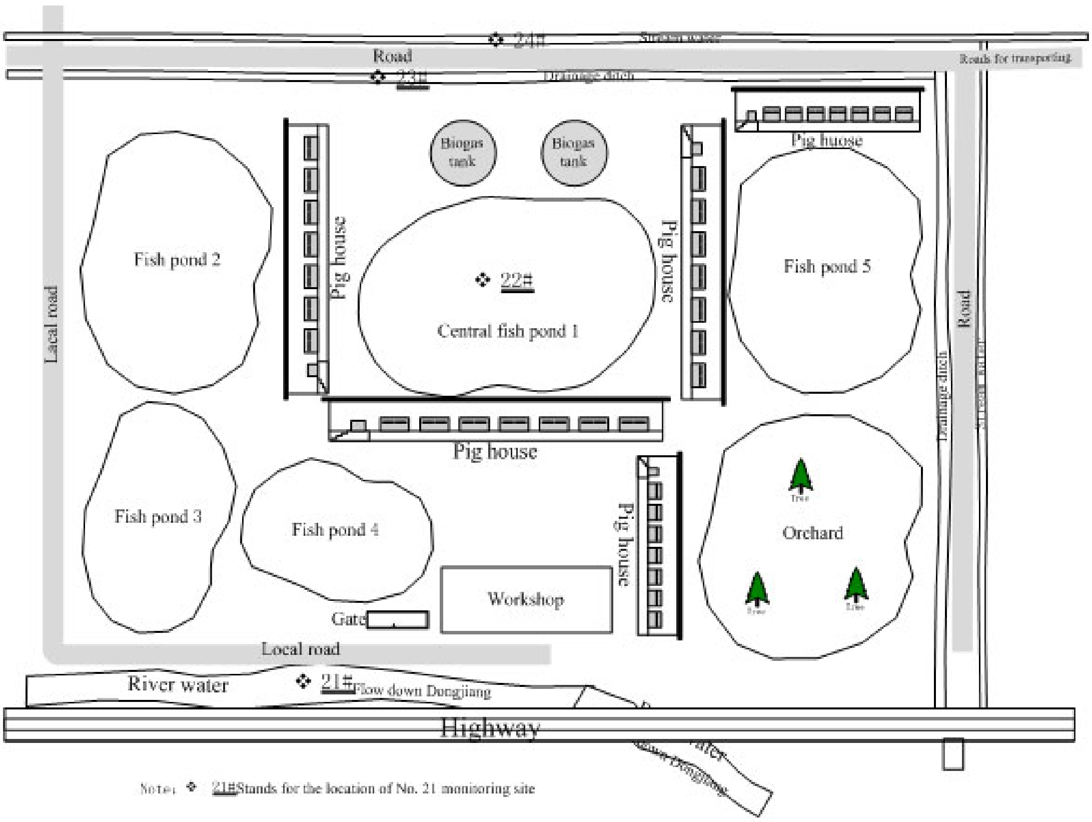

Figure 2 Sampling sites suggested for monitoring surface water of Fouling pig farm

2.2 Sample collection

The specific methods of sample collection were as follows: instantaneous water samples were respectively collected from discharge hole of pig house, pig farm system boundary, river and stream, and multiple mixed samples from ponds. Methods of water sample preservation and containers washing used in monitoring were listed in Table 1-3, which followed Surface Water and Sewage Monitoring Technical Specifications (HJ / T 91-2002) and Water and Wastewater Monitoring Methods (4th edition), and also referred to Water Sampling and Analysis Guidance for CAFO Monitoring. Surface water of Mashigang pig farm was monitored respectively on September 14th and October 16th 2007, and that of Foling pig farm was monitored on October 16th and December 13th 2007.

Table 1-3 Water Preservation and Containers Washing

Parameter	Sampling Container	Condition of Storage	Retention Period	Sample Size, ml	Container Washing
pH	Pyrex bulb		12h	250	I
CODCr	Pyrex bulb	acidification to pH ≤2 with H2SO4	2d	500	I
BOD5	dissolved oxygen bottle	0—4°C, away from light	12h	250	I
TP	Pyrex bulb	HCl, H2SO4, pH≤2	24h	250	II
TN	Pyrex bulb	H2SO4, pH≤2	7d	250	I
FCB	Pyrex bulb	adding sodium thiosulfate to remove remnants, 0—4°C, away from light	12h	250	I

Notes: I and II stand for washing methods, as follows:

I: wash with detergent, rinse three times with tap water and once with distilled water;

II: Wash with chromic acid mixture, rinse three times with tap water and once with distilled water.

Distilled water, deionized water cleaning steps can be omitted if sewage samples were to be collected.

2.3 Suggested Parameters and Analytical Methods for Monitoring

Analytical methods and apparatus of monitoring parameters suggested in Surface Water Environmental Quality Standard were listed in Table 1-4. Analytical methods adopted were from Surface Water environmental Quality Standards (GB 3838-2002), Water and Wastewater Monitoring Methods (4th edition) and Water Sampling and Analysis Guidance for CAFO Monitoring. Samples were analyzed quickly and accurately within the retention time suggested in the standards above to guarantee precision of the analysis.

Table 1-4 Method and apparatus for monitoring parameters from Surface Water Quality Standard

Parameters	Monitoring Methods	Apparatus	Lowest detection limit, mg/L
pH	Glass Electrode, GB 6920-89	420A pH Meter	—
CODCr	dichromated reflux method, GB 11914—89	Conventional glass apparatus	10
BOD5	dilution inoculation method, GB 7488—87	DO Meter, HI98186 Biochemical incubator	2
Total P	vanadomolybdophosphoric acid method, GB 11893—89	7200-Visible Spectrophotometer	0.01
Total N	Persulfate Digestion Method, GB 11894—89	pressure cooker UV2501-spectrophotometer	0.05
Fecal Coli form Bacteria	membrane filtration method, Monitoring Method of Water and wastewater (4th edition)	SW-CJ-1F-Super-clean worktable 250B-Biochemical incubator	—

All personnel involved in monitoring had work licenses. The highly trained lab-technicians were familiar with monitoring methods and technical specifications. Sample collectors, analytical reagents and standard solution were all well prepared before sampling. Samples preservation and preliminary treatment were strictly implemented as formulated. Analytical apparatus were adjusted to good working conditions before analysis, and internal standards and quality control samples were strictly used as suggested in technical standards of monitoring parameters during analysis. Other requirements were referred to Surface Water and Sewage Monitoring Technical Specifications (HJ / T 91-2002) and Water and Wastewater Monitoring Methods (4th edition), and the analytical procedures were recorded in detail. When analysis ended, results were summarized in time. All analytical results of surface water samples were summarized in Annex 1, and protocol was listed in Annex 2.

2.4 Evaluation of Samples of Surface Water

2.4.1 Evaluation Criteria for Surface Water Classification

Surface Water Environmental Quality Standards (GB 3838-2002) has been developed to help evaluate the quality of surface water. According to the National Standard, surface water falls into five levels:

Level I mainly suitable for source water and national natural reserve;

Level Ⅱ mainly suitable for central living drinking surface water source of first level protection zones, rare and precious aquatic biological habitat, fishes and shrimps spawning grounds, young juvenile fish feeding ground, etc;

Level Ⅲ mainly suitable for central living drinking surface water source of secondary level protection zones, fishes and shrimps wintering and returning grounds, fishery waters and swimming areas, etc;

Level Ⅳ mainly suitable for common industrial water districts and leisure water districts that contact human body non- directly;

Level Ⅴ mainly suitable for the agricultural water district, irrigations, and common landscapes, etc.
Surface Water Standard threshold parameters of five levels suggested in Surface Water Environmental Quality Standards are listed in Table 1-5

Table 1-5 Standard threshold of Surface Water parameters, mg/L

Parameters		Level Ⅰ	Level Ⅱ	Level Ⅲ	Level Ⅳ	Level Ⅴ
pH		6～9				
FCB/L	≤	200	2000	10000	20000	40000
T N (N), mg/L	≤	0.2	0.5	1.0	1.5	2.0
COD_{Cr}	≤	15	15	20	30	40
BOD_5	≤	3	3	4	6	10
T P (P), mg/L	≤	0.02	0.1	0.2	0.3	0.4

Note: data above is from GB 3838－2002.

Comprehensive Characteristic Model of Water Quality was used in evaluation because it shows good comparability between water quality evaluations of the same parameters and provides lots of information, and all numbers of different evaluation parameters can be reflected in the model noticeably. It is worth pointing out that the method can reflect the name of the worst parameter and the level of water quality which is helpful for working out plans for prevention and treatment.

In 1996, Shi Baozhong improved the Comprehensive Characteristic Model of water quality and the simplified formula is as follows:

$$\begin{aligned}&\mathrm{n}N_1^{\mathrm{n1}}(a_1,a_2\ldots)N_2^{\mathrm{n2}}(\mathrm{b}_1,\mathrm{b}_2\ldots)N_3^{\mathrm{n3}}(\mathrm{c}_1,\mathrm{c}_2\ldots)N_4^{\mathrm{n4}}(\mathrm{d}_1,\mathrm{d}_2\ldots)N_5^{\mathrm{n5}}(e_1,\mathrm{e}_2\ldots)\\&\times N_6^{\mathrm{n6}}(x_1,m_1;x_1,m_2\ldots)N_{\mathrm{y}}^{\mathrm{ky}}(f_1,h_1;f_1,h_2\ldots)\end{aligned} \quad (1)$$

$$\mathrm{n}N_1^{\mathrm{n1}}N_2^{\mathrm{n2}}N_3^{\mathrm{n3}}N_4^{\mathrm{n4}}N_5^{\mathrm{n5}}(e_1,\mathrm{e}_2\ldots)N_6^{\mathrm{n6}}(x_1,m_1;x_1,m_2\ldots)N_{\mathrm{y}}^{\mathrm{ky}}(f_1,h_1;f_1,h_2\ldots) \quad (2)$$

Meanings of letters in the formula are explained below:

n: Total number of different water quality parameters for evaluation;

n_1、n_2、n_3、n_4、n_5—— Number of water quality parameters from Level Ⅰ to Level Ⅴ ;

n_6—— Number of water quality parameters inferior to Level Ⅴ ;

k_y——Number of water quality parameters exceeding evaluation standards ;

N_1、N_2、N_3、N_4、N_5—— Respectively standing for waters from Level Ⅰ to Level Ⅴ

N_6——Waters inferior to Level Ⅴ, or called Level Ⅵ

N_y——Specified categories of waters in evaluation criteria, for example, Ⅲ will replace y for waters of Level Ⅲ;

a_1、a_2 …——water quality parameters for waters of Level I

b_1、b_2 …——water quality parameters for waters of Level Ⅱ

c_1、c_2 …——water quality parameters for waters of Level Ⅲ

d_1、d_2 …——water quality parameters for waters of LevelⅣ

e_1、e_2 …——water quality parameters for waters of Level Ⅴ

x_1、x_2 …——water quality parameters for waters inferior to Level Ⅴ

m_1、m_2 …——multiples of water quality parameters for waters inferior to Level Ⅴ

f_1、f_2 …——water quality parameters inferior to evaluation criteria

h_1、h_2 …——multiples of water quality parameters for waters inferior to evaluation criteria.

2.4.2 Evaluation of samples of Mashigang Pig Farm

The evaluation of surface water quality was based on samples collected twice from Mashigang pig farm, and the results were shown in Table 1-6 and 1-7.

Table 1-6 First Evaluation of Comprehensive Characteristic Model of Surface Water Quality Features of Mashigang pig farm

Sample ID	Monitoring Parameters	Observed Value, mg/L	Water Quality Level	Evaluation Criterion, Level Ⅲ	
				Standard Value	Times of Exceeding Standard
# 1	pH	8.55	Ⅰ	6～9	
	FCB/L	215000	Inferior to Level Ⅴ (4.38)	≤10000	20.5
	TN (N), mg/L	1.97	Ⅴ	≤1.0	0.97
	COD_{Cr}, mg/L	51.8	Inferior to Level Ⅴ (0.30)	≤20	1.59
	BOD_5, mg/L	4.9	Ⅳ	≤4	0.225
	TP (P), mg/L	1.07	Inferior to Level Ⅴ (1.68)	≤0.2	4.35

#2	pH	8.50	I	6～9	
	FCB/L	3750	III	≤10000	
	TN (N), mg/L	2.24	Inferior to Level V (0.12)	≤1.0	1.24
	COD_{Cr}, mg/L	42.6	Inferior to Level V (0.07)	≤20	1.13
	BOD_5, mg/L	5.5	IV	≤4	0.375
	TP (P), mg/L	0.48	Inferior to Level V (0.20)	≤0.2	1.4
#3	pH	8.95	I	6～9	
	FCB/L	887	II	≤10000	
	TN (N), mg/L	1.98	V	≤1.0	0.98
	COD_{Cr}, mg/L	37.1	V	≤20	0.855
	BOD_5, mg/L	5.6	IV	≤4	0.4
	TP (P), mg/L	0.53	Inferior to Level V (0.33)	≤0.2	1.65
# 4	pH	8.11	I	6～9	
	FCB/L	773	II	≤10000	
	TN (N), mg/L	1.39	IV	≤1.0	0.39
	COD_{Cr}, mg/L	39.0	V	≤20	0.95
	BOD_5, mg/L	2.2	I	≤4	
	TP (P), mg/L	0.27	IV	≤0.2	0.35
#5	pH	9.02	Inferior to Level V (0.01)	6～9	0.01
	FCB/L	235000	Inferior to Level V (4.88)	≤10000	22.5
	TN (N), mg/L	3.37	Inferior to Level V (0.69)	≤1.0	2.37
	COD_{Cr}, mg/L	57.4	Inferior to Level V (0.44)	≤20	1.87
	BOD_5, mg/L	9.4	V	≤4	1.35
	TP (P), mg/L	2.22	Inferior to Level V (4.55)	≤0.2	10.1

#6	pH	8.68	I	6～9	
	FCB/L	1367	II	≤10000	
	TN (N), mg/L	1.04	IV	≤1.0	0.04
	COD_{Cr}, mg/L	81.2	Inferior to Level V (1.03)	≤20	3.06
	BOD_5, mg/L	3.2	III	≤4	
	TP (P), mg/L	1.51	Inferior to Level V (2.78)	≤0.2	6.55
# 7	pH	9.19	Inferior to Level V (0.10)	6～9	0.10
	FCB/L	5900	III	≤10000	
	TN (N), mg/L	3.30	Inferior to Level V (0.65)	≤1.0	2.3
	COD_{Cr}, mg/L	73.9	Inferior to Level V (0.85)	≤20	2.70
	BOD_5, mg/L	8.5	V	≤4	1.13
	TP (P), mg/L	0.78	Inferior to Level V (0.95)	≤0.2	2.9
# 8	pH	7.20	I	6～9	
	FCB/L	313333333	Inferior to Level V (7832)	≤10000	31332.0
	TN (N), mg/L	42.3	Inferior to Level V (20.2)	≤1.0	41.3
	COD_{Cr}, mg/L	941.2	Inferior to Level V (22.5)	≤20	46.1
	BOD_5, mg/L	1216.4	Inferior to Level V (120.6)	≤4	303.1
	TP (P), mg/L	98.81	Inferior to Level V (246.0)	≤0.2	493.1
#9	pH	7.93	I	6～9	
	FCB/L	350000	Inferior to Level V (7.75)	≤10000	34.0
	TN (N), mg/L	16.97	Inferior to Level V (7.49)	≤1.0	16.0
	COD_{Cr}, mg/L	116.2	Inferior to Level V (1.91)	≤20	4.81
	BOD_5, mg/L	9.0	V	≤4	1.25
	T P (P), mg/L	0.74	Inferior to Level V (0.85)	≤0.2	2.7

# 10	pH	6.53	Ⅰ	6～9	
	FCB/L	660000000	Inferior to Level Ⅴ(16499)	≤10000	65999
	T N (N), mg/L	24.38	Inferior to Level Ⅴ(11.2)	≤1.0	23.4
	COD_{Cr}, mg/L	5371.2	Inferior to Level Ⅴ(133)	≤20	268
	BOD_5, mg/L	627.9	Inferior to Level Ⅴ(61.8)	≤4	156
	T P (P), mg/L	15.9	Inferior to Level Ⅴ(38.8)	≤0.2	78.5

Note: Numbers in brackets represent the times of exceeding-standard of surface water quality evaluation of Level Ⅴ

Evaluation expressions of the first monitoring on surface water in Mashigang pig farm were obtained from Table 1-6 as follows:

1: $6N_1^1N_4^1N_5^1N_6^3$ (FCB, 4.38; COD_{Cr}, 0.30; TP, 1.68)

N_{III}^5 (FCB, 20.5; TN, 0.97; COD_{Cr} , 1.59;BOD_5, 0.23; TP, 4.35)

2: $6N_1^1N_3^1N_4^1N_6^3$ (TN, 0.12; COD_{Cr} , 0.07; TP,0.20)

N_{III}^4 (TN, 1.24; COD_{Cr} , 1.13;BOD_5,0.375, TP,1.4)

#3: $6N_1^1N_2^1N_4^1N_5^2N_6^1$ (TP, 0.33)

N_{III}^4 (TN, 0.98; COD_{Cr} ,0.86; BOD_5,0.4; TP,1.65)

No. 4: $6N_1^2N_2^1N_4^2N_5^1N_{\text{III}}^3$ (TN, 0.39: COD_{Cr}, 0.95; TP, 0.35)

5: $6N_5^1N_6^5$ (pH, 0.01; FCB, 4.88; TN, 0.69;COD_{Cr} ,0.44; TP,4.55)

N_{III}^6 (pH,0.01; FCB,22.5; TN,2.37;COD_{Cr} ,1.87;BOD_5,1.35; TP,10.1)

6: $6N_1^1N_2^1N_3^1N_4^1N_6^2$ (COD_{Cr} ,1.03; TP,2.78)

N_{III}^3 (TN, 0.04;COD_{Cr} ,3.06; TP,6.55)

#7: $6N_3^1N_5^1N_6^4$ (pH, 0.10; TN, 0.65;COD_{Cr} ,0.85; TP,0.95)

N_{III}^5 (pH,0.10; TN,2.3;COD_{Cr} ,2.70;BOD_5,1.13, TP,2.9)

#8: : $6N_1^1N_6^5$ (FCB,7832; TN,20.2;COD_{Cr},22.5;BOD_5,120.6; P,246.0)

N_{III}^{5} (FCB,31322; TN,41.3;COD_{Cr},46.1;BOD_5,303.1; TP,493.1)

#9: $6N_1^1N_5^1N_6^4$ (FCB,7.75; TN,7.49;COD_{Cr} ,1.91; TP,0.85)

N_{III}^{5} (FCB,34.0; TN,16.0;COD_{Cr} ,4.81;BOD_5,1.25; TP,2.7)

#10: (FCB,16499;TN,11.2;COD_{Cr} ,133;BOD_5,61.8; TP,38.8)

N_{III}^{5} (FCB,65999;TN,23.4;COD_{Cr} ,268;BOD_5,156; TP,78.5)

The first evaluation of Comprehensive Characteristic Model of surface Water Quality of Mashigang pig farm indicated:

For #1 sample, pH was classed as Level Ⅰ, BOD_5 as Level Ⅳ, FCB, COD_{Cr} and TP were inferior to Level Ⅴ, and exceeded criteria of Level Ⅴ with 4.38、0.30 and 1.68 times respectively. So water service function in the monitoring site was classed as Level Ⅴ. Evaluated with Water Quality Standard as criteria, only pH of the sample met with the requirement of Level Ⅲ, the other five indexes were inferior to Level Ⅲ, with FCB exceeding 20.5 times, TN 0.97 times, COD_{Cr} 1.59 times, BOD_5 0.23 times and TP 4.35 times.

For #2 sample, pH was classed as Level Ⅰ, FCB as Level Ⅲ, BOD_5 as Level Ⅳ, TN, COD_{Cr} and TP as Level Ⅴ, and exceeded criteria of Level Ⅴ with 0.12, 0.07 and 0.20 times respectively. So water service function in the monitoring site was classed as Level Ⅴ. Evaluated with Water Quality Standard as criteria, only two indexes of the sample met with the requirement of Level Ⅲ, the other four indexes were above that Level, with TN exceeding 1.24 times, COD_{Cr} 1.13 times, BOD_5 0.38 times and TP 1.4 times.

For #3 sample, pH was classed as Level Ⅰ, FCB as Level Ⅱ, BOD_5 as Level Ⅳ, TN and COD_{Cr} as Level Ⅴ, TP exceeded criteria of Level Ⅴ with 0.33 times and was inferior to Level Ⅴ. So water service function in the monitoring site was classed as Level Ⅴ. Evaluated with Water Quality Standard as criteria, only two indexes of the sample met with the requirement of Level Ⅲ, the other four indexes were inferior to that Level, with TN exceeding 0.98 times, COD_{Cr} 0.86 times, BOD_5 0.40 times and TP 1.65 times.

For #4 sample, pH and BOD_5 were classed as Level Ⅰ, FCB as Level Ⅱ, TN and TP as Level Ⅳ and COD_{Cr} as Level Ⅴ. So water service function in the monitoring site was classed as Level Ⅴ. Evaluated with Water Quality Standard as criteria, three indexes of the sample met with the requirement of Level Ⅲ, the other three indexes were inferior to that Level, with TN exceeding 0.39 times, COD_{Cr} 0.95 times and TP 0.35 times.

For #5 sample, $BOD_5$was classed as Level Ⅴ, the other five indexes such as pH, FCB, TN, COD_{Cr} and TP were inferior to Level Ⅴ, exceeding the criteria of Level Ⅴ with 0.01、4.88、0.69、0.44 and 4.55 times respectively. So water service function in the monitoring site was inferior to Level Ⅴ. Evaluated with Water Quality Standard as criteria, all indexes monitored of the sample exceeded standard of Level Ⅲ, with pH exceeding 0.01 times, FBC 22.5 times, TN 2.37 times, COD_{Cr} 1.87 times, BOD_5 1.35 times and TP 10.1 times.

For #6 sample, pH was classed as Level Ⅴ, FCB was classed as Level Ⅱ, BOD_5 was classed as Level Ⅲ, TN was classed as Level Ⅳ, COD_{Cr} and TP were inferior to Level Ⅴ, exceeding the criteria of Level Ⅴwith 1.03 and 2.78 times respectively. So water service function in the monitoring site was inferior to Level Ⅴ. Assessed with Water Quality Standard as criteria, three indexes monitored of the sample exceeded standard of Level Ⅲ, with TN exceeding 0.04 times, COD_{Cr} 3.06 times, and TP 6.55 times.

For #7 sample, FCB was classed as Level Ⅲ, BOD_5 was classed as LevelⅤ, pH, TN, COD_{Cr} and TP were inferior to Level Ⅴ, exceeding the criteria of Level Ⅴwith 0.10, 0.65, 0.85 and 0.95 times respectively. So water service function in the monitoring site was inferior to Level Ⅴ. Assessed with Water Quality Standard as criteria, five indexes monitored of the sample exceeded standard of Level Ⅲ, with pH exceeding 0.10 times, TN 2.30 times, COD_{Cr} 2.70 times , BOD_5 with 1.13 times and TP 2.90 times.

For #8 sample, pH was classed as Level Ⅴ, the other five indexes such as FCB, TN, COD_{Cr}, BOD_5 and TP were inferior to Level Ⅴ, exceeding the criteria of Level Ⅴwith 7832, 20.2, 22.5,120.6 and 246.0 times. Water service function in the monitoring site was inferior to Level Ⅴ.Assessed with Water Quality Standard as criteria, all indexes monitored of the sample exceeded standard of Level Ⅲ, with FBC exceeding 31322 times, TN 41.3 times, COD_{Cr} 46.1 times, BOD_5 303.1 times and TP 493.1 times.

For #9 sample, pH was classed as Level Ⅰ, BOD_5 as Level Ⅴ, FCB, TN, COD_{Cr} and TP were inferior to Level Ⅴ. exceeding criteria of Level Ⅴwith 7.55, 7.75、7.49,1.91 and 0.85 times. So water service function in the monitoring site was inferior to Level Ⅴ. Assessed with Water Quality Standard as criteria, only pH of the sample met with the requirement of Level Ⅲ, the other five indexes were inferior to that Level, with FBC exceeding 30.4 times, TN 16.0 times, COD_{Cr} 4.81 times, BOD_5 1.25 times and TP 2.70 times.

For #10 sample, pH was classed as Level Ⅰ, the other five indexes such as FCB, TN, COD_{Cr}, BOD_5 and TP were inferior to Level Ⅴ, exceeding the criteria of Level Ⅴwith 16499, 11.2, 133, 61.8 and 38.8 times. So water service function in the monitoring site was inferior to Level Ⅴ. Assessed with Water Quality Standard as criteria, only pH of the sample met with the requirement of Level Ⅲ, the other indexes monitored of the sample exceeded standard of Level Ⅲ, with FBC exceeding 65999 times, TN 23.4 times, COD_{Cr} 268 times, BOD_5 156 times and TP 78.5 times.

Table 1-7 The second evaluation of Comprehensive Characteristic Model of surface Water Quality Features of Mashigang pig farm

Sample ID	Monitoring Parameters	Observed Value, mg/L	Water quality level	Evaluation criterion, Level Ⅲ	
				Standard Value	Standard Value
#1	pH	7.66	I	6～9	
	FCB/L	176000	Inferior to Level V (3.40)	≤10000	16.6
	T N (N), mg/L	5.19	Inferior to Level V (1.60)	≤1.0	4.19
	COD_{Cr}, mg/L	53.2	Inferior to Level V (0.33)	≤20	1.66
	BOD_5, mg/L	7.8	V	≤4	0.95
	T P (P), mg/L	0.62	Inferior to Level V (0.55)	≤0.2	2.1
# 2	pH	7.94	I	6～9	
	FCB/L	363333	Inferior to Level V (8.08)	≤10000	35.3
	T N (N), mg/L	5.15	Inferior to Level	≤1.0	4.15
	COD_{Cr}, mg/L	55.2	Inferior to Level	≤20	1.76
	BOD_5, mg/L	8.7	V	≤4	1.18
	T P (P), mg/L	0.31	V	≤0.2	0.55
# 3	pH	8.31	I	6～9	
	FCB/L	45000	Inferior to Level V (0.13)	≤10000	3.5
	T N (N), mg/L	3.13	Inferior to Level V (0.57)	≤1.0	2.13
	COD_{Cr}, mg/L	34.5	V	≤20	0.73
	BOD_5, mg/L	8.1	V	≤4	1.03
	T P (P), mg/L	0.18	III	≤0.2	

#4	pH	8.13	I	6～9	
	FCB/L	135000	Inferior to Level V (2.38)	≤10000	12.5
	T N (N), mg/L	2.43	Inferior to Level	≤1.0	1.43
	COD_{Cr}, mg/L	29.6	IV	≤20	0.48
	BOD_5, mg/L	5.2	IV	≤4	0.30
	T P (P), mg/L	0.57	Inferior to Level V (0.43)	≤0.2	1.85
#5	pH	8.09	I	6～9	
	FCB/L	493333	Inferior to Level V (11.3)	≤10000	48.3
	T N (N), mg/L	4.18	Inferior to Level V (1.09)	≤1.0	3.18
	COD_{Cr}, mg/L	38.0	V	≤20	0.90
	BOD_5, mg/L	5.9	IV	≤4	0.48
	T P (P), mg/L	1.91	Inferior to Level V (3.78)	≤0.2	8.55
#6	pH	8.50	I	6～9	
	FCB/L	1593	II	≤10000	
	T N (N), mg/L	1.29	IV	≤1.0	0.29
	COD_{Cr}, mg/L	47.3	Inferior to Level V (0.19)	≤20	1.37
	BOD_5, mg/L	2.8	I	≤4	
	T P (P), mg/L	0.23	IV	≤0.2	0.15
#7	pH	8.09	I	6～9	
	FCB/L	7700	III	≤10000	
	T N (N), mg/L	1.06	IV	≤1.0	0.06
	COD_{Cr}, mg/L	31.5	V	≤20	0.58
	BOD_5, mg/L	5.1	IV	≤4	0.28
	T P (P), mg/L	0.19	III	≤0.2	

# 8	pH	7.39	I	6～9	
	FCB/L	1195000000	Inferior to Level V (29874)	≤10000	119499
	T N (N), mg/L	176.3	Inferior to Level V (87.2)	≤1.0	175.3
	COD_{Cr}, mg/L	1990.1	Inferior to Level V (48.8)	≤20	98.5
	BOD_5, mg/L	586.6	Inferior to Level V (57.7)	≤4	145.7
	T P (P), mg/L	49.95	Inferior to Level V (123.9)	≤0.2	248.8
# 9	pH	7.74	I	6～9	
	FCB/L	65000	Inferior to Level V (0.63)	≤10000	5.5
	T N (N), mg/L	7.68	Inferior to Level V (2.84)	≤1.0	6.68
	COD_{Cr}, mg/L	37.4	V	≤20	0.87
	BOD_5, mg/L	2.7	I	≤4	
	T P (P), mg/L	0.17	III	≤0.2	
#10	pH	7.29	I	6～9	
	FCB/L	1800000000	Inferior to Level V (44999)	≤10000	179999
	T N (N), mg/L	250.6	Inferior to Level	≤1.0	249.6
	COD_{Cr}, mg/L	2266.0	Inferior to Level	≤20	112.3
	BOD_5, mg/L	1241.6	Inferior to Level V (123.2)	≤4	309.4
	T P (P), mg/L	57.68	Inferior to Level V (143.2)	≤0.2	287.4

Evaluation expressions of the second monitoring on surface water in Mashigang pig farm were obtained from Table 1-7 as follows:

#1: (FCB, 3.40; TN, 1.60;COD_{Cr}, 0.33;TP,0.55)

N_{III}^{5} (FCB, 16.6; TN, 4.19;COD_{Cr}, 1.66;BOD_5,0.95; TP,2.1)

#2: (FCB, 8.08; TN, 1.58;COD_{Cr} ,0.38)

N_{III}^{5} (FCB, 35.3; TN, 4.15;COD_{Cr} ,1.76;BOD_5,1.18; TP,0.55)

#3: (FCB, 0.13; TN, 0.54)

N_{III}^{4} (FCB, 3.5; TN, 2.13;COD_{Cr}, 0.73;BOD_5,1.03)

#4: (FCB, 2.38; TN, 0.22; TP, 0.43)

N_{III}^{5} (FCB, 12.5; TN, 1.43;COD_{Cr} ,0.48;BOD_5,0.30; TP,1.85)

#5: (FCB, 11.3; TP, 1.09; TP, 3.78)

N_{III}^{5} (FCB, 48.3; TN, 3.18;COD_{Cr} ,0.90;BOD_5,0.48; TP,8.55)

6: (COD_{Cr} ,0.19)

N_{III}^{3} (TN, 0.29;COD_{Cr} ,1.37;TP,0.15)

#7: $6N_1^1N_3^2N_4^2N_5^1N_{\text{III}}^3$ (TN,0.06;COD_{Cr} ,0.58;BOD_5,0.28)

#8: ： (FCB, 29874; TN, 87.2;COD_{Cr} ,48.8;BOD_5,57.7;TP,23.9)

N_{III}^{5} (FCB, 119499; TN, 175.3;COD_{Cr} ,98.5;BOD_5,145.7; TP,248.8)

9: (FCB, 0.63; TN, 2.84)

N_{III}^{3} (FCB, 5.5; TN, 6.68;COD_{Cr} ,0.87)

#10: (FCB, 44999; TN, 124.3;COD_{Cr} ,55.7;BOD_5,123.2; TP,143.2)

N_{III}^{5} (FCB, 179999; TN, 249.6;COD_{Cr} ,112.3;BOD_5,309.4; TP,287.4)

The second evaluation of Comprehensive Characteristic Model of surface Water Quality of Mashigang pig farm indicated:

For #1 sample, pH was classed as Level Ⅰ, BOD_5 as Level Ⅳ, FCB, COD_{Cr} and TP were inferior to Level Ⅴ, and exceeded criteria of Level Ⅴ with 3.40, 1.60 ,0.33 and 0.55 times respectively. So water service function in the monitoring site was inferior to Level Ⅴ. Evaluated with Water Quality Standard as criteria, only one index of the sample met with the requirement of Level Ⅲ, the other five indexes were above Level Ⅲ, with FCB exceeding 16.6 times, 4.19 0.97times, COD_{Cr}1.6 times, $BOD_5$0.95 times and TP 2.1 times.

For #2 sample, pH was classed as Level Ⅰ, BOD_5 and TP as Level Ⅴ, FCB , TN and COD_{Cr} were inferior to Level Ⅴ, which exceeded criteria of Level Ⅴ with 8.08, 1.58 and 0.38 times respectively. So water service function in the monitoring site was inferior to Level Ⅴ. Assessed with Water Quality Standard as criteria, only one index of the sample met with the requirement of Level Ⅲ, the other five indexes were above that Level, with FCB exceeding 35.3 times, TN 4.15 times, COD_{Cr} 1.76 times, BOD_5 1.18 times and TP 0.55 times.

For #3 sample, pH was classed as Level Ⅰ, TP as Level Ⅱ, BOD_5 as Level Ⅲ, COD_{Cr} and BOD_5 as Level Ⅴ, FCB and TN were inferior to Level Ⅴ, which exceeded criteria of Level Ⅴ with 0.13 and 0.57 times. So water service function in the monitoring site was inferior to Level Ⅴ. Assessed with Water Quality Standard as criteria, only two indexes of the sample met with the requirement of Level Ⅲ, the other four indexes were inferior to that Level, with FCB exceeding 3.5 times, TN 2.13 times, $COD_{C r}$ 0.73 times and BOD_5 1.03 times.

For #4 sample, pH was classed as Level Ⅰ, COD_{Cr} and BOD_5 as Level Ⅳ, FCB, TN and TP were inferior to Level Ⅴ, which exceeded criteria of Level Ⅴ with 2.38, 0.22 and 0.43 times respectively. So water service function in the monitoring site was inferior to Level Ⅴ. Assessed with Water Quality Standard as criteria, only one index of the sample met with the requirement of Level Ⅲ, the other five indexes were inferior to that Level, with FCB exceeding 12.5times, TN 1.43 times, COD_{Cr} 0.48 times, BOD_5 0.48 times and TP 1.85 times.

For #5 sample, pH was classed as Level Ⅰ, BOD_5 as Level Ⅳ, COD_{Cr} as Level Ⅴ, FCB, TN and TP were inferior to Level Ⅴ, exceeding the criteria of Level Ⅴ with 11.3, 1.09 and 3.78 times. So water service function in the monitoring site was inferior to Level Ⅴ. Assessed with Water Quality Standard as criteria, only one index of the sample met with the requirement of Level Ⅲ, the other five indexes monitored of the sample exceeded standard of Level Ⅲ, with FCB exceeding 48.3 times, TN 3.18 times, COD_{Cr} 0.90 times , BOD_5 0.48 times and TP 8.55 times.

For #6 sample, pH and BOD_5 were classed as Level Ⅰ, FCB as Level Ⅱ, TN and TP as Level Ⅳ, COD_{Cr} was inferior to Level Ⅴ, exceeding the criteria of Level Ⅴ with 0.19 times. So water service function in the monitoring site was inferior to Level Ⅴ. Assessed with Water Quality Standard as criteria, three indexes of the sample met with the requirement of Level Ⅲ, the other three indexes monitored of the sample exceeded standard of Level Ⅲ, with TN exceeding 0.29 times, COD_{Cr} 1.37 times, and TP 0.15 times.

For #7 sample, pH was classed as Level Ⅰ, FCB and TP as Level Ⅲ, TN and BOD_5 as LevelⅣ, COD_{Cr} as LevelⅤ. Water service function in the monitoring location was defined as Level Ⅴ. Assessed with Water Quality Standard as criteria, three indexes of the sample met with the requirement of Level Ⅲ, the other three indexes exceeded standard of Level Ⅲ, with TN exceeding 0.06 times, COD_{Cr} 0.58 times and BOD_5 with 0.28 times.

For #8 sample, pH was classed as Level Ⅰ, the other five indexes such as FCB, TN, COD_{Cr}, BOD_5 and TP were inferior to Level Ⅴ, exceeding the criteria of Level Ⅴ with 29874, 87.2, 48.8, 57.7 and 123.9 times. So water service function in the monitoring site was inferior to Level Ⅴ. Assessed with Water Quality Standard as criteria, only pH met with the requirement of Level Ⅲ, the other five indexes monitored of the sample exceeded standard of Level Ⅲ, with FCB exceeding 119499 times, TN 175.3 times, COD_{Cr} 98.5 times, BOD_5 145.7 times and TP 248.8 times.

For #9 sample, pH and BOD_5were classed as Level Ⅰ, TP as Level Ⅲ, COD_{Cr} as LevelⅤ, FCB and TN were inferior to Level Ⅴ, exceeding criteria of Level Ⅴ with 0.63 and 2.84 times. So water service function in the monitoring site was inferior to Level Ⅴ. Assessed with Water Quality Standard as criteria, three indexes of the sample met with the requirement of Level Ⅲ, the other three indexes were inferior to that Level, with FCB exceeding 5.5 times, TN 6.68 times and COD_{Cr} 0.87 times,

For #10 sample, pH was classed as Level Ⅰ, the other five indexes such as FCB, TN, COD_{Cr}, BOD_5 and TP were inferior to Level Ⅴ, exceeding the criteria of Level Ⅴ with 44999, 124.3, 55.7, 123.2 and 143.2 times. So water service function in the monitoring site was inferior to Level Ⅴ. Assessed with Water Quality Standard as criteria, only pH of the sample met with the requirement of Level Ⅲ, the other indexes monitored of the sample exceeded standard of Level Ⅲ, with FBC exceeding 179999 times, TN 249.6 times, COD_{Cr} 112.3 times, BOD_5 309.4 times and TP 287.4 times.

Monitoring results showed that surface water in Mashigang pig farm had been severely polluted, and the main pollutants are FCB, TN, TP, CODCr and BOD5. Water samples for monitoring belong to Level V or inferior to Level Ⅴ, and do not reach the standard of Environmental Quality Standard for Surface Water. Of the ten monitoring sites, nine were inferior to Level Ⅴ; the other one belongs to Level Ⅴ. Waste water from pig farm system was most severely polluted, followed by sludge from pig house and water in fish ponds.

Individual index distribution of water quality and exceeding standard situation of Mashigang pig farm were summarized in Table 1-9 and Table 1-10.

Results from Table 1-9and table 1-10 showed that the surface water in Mashigang pig farm was seriously polluted by pathogenic microorganisms TN and TP. Individual index exceeding Level Ⅲ accounted for more than 72% of the total indexes, and pH exceeded the standard with multiple of 0.01～0.1, FCB with the highest multiple of 179999 and its over standard rate is 65% averagely. TP and TN of all samples exceeded the standard of Level Ⅲ with the multiple of 0.04～249.6 and 0.15～493.1 and their over standard rates were 100% and 80% respectively. TN and TP are important nutritional factors of Water Eutrophication, and their pollution was very seriously. Generally speaking, when TP concentration was more than 0.02 mg / L, or inorganic nitrogen was over 0.3 mg / L, it could be considered eutrophication of water bodies. Surface water in Mashigang pig farm was in the state of eutrophication, and COD_{Cr} of all samples was over standard and BOD_5 of 80% samples was over standard. High concentration of COD_{Cr} and BOD_5 indicates much oxygen consumption organic matter in water, which will affect quality and output of aquatic products. In a word, surface water in the pig farms was severely polluted, and waste management should be strengthened to reduce sewage discharge and water environment load.

Table 1-9 Individual index distribution of water quality and exceeding standard situation of the first sampling of Mashigang pig farm

Parameter	Level Ⅰ	Level Ⅱ	Level Ⅲ	Level Ⅳ	Level Ⅴ	Inferior to Level Ⅴ	Times of Exceeding Standard
pH	8					2	0.01～0.10
FCB		3	2			5	20.5～65999
TN				2	2	6	0.04～41.3
COD_{Cr}					2	8	0.86～268
BOD_5	1		1	3	3	2	0.23～303.1
TP				1		9	0.35～493.1
Total	9	3	3	6	7	32	

Table 1-10 Individual index distribution of water quality and exceeding standard situation of the second sampling of Mashigang pig farm

Parameter	Level Ⅰ	Level Ⅱ	Level Ⅲ	Level Ⅳ	Level Ⅴ	Inferior to Level Ⅴ	Times of Exceeding Standard
pH	10						
FCB		1	1			8	3.5～179999
TN				2		8	0.06～249.6
COD_{Cr}				1	4	5	0.48～112.3
BOD_5	2			2	3	3	0.275～309.4
TP			3	1	1	5	0.15～287.4
Total	12	1	4	6	8	29	

2.4.3 Evaluation of samples of Foling Pig Farm

The evaluation of surface water quality was based on samples collected twice from Foling pig farm, and the results were shown in Table 1-11 and 1-12.

Table 1-11 The first evaluation of Comprehensive Characteristic Model of surface Water Quality Features of Foling pig farm

Sample ID	Monitoring Parameter	Monitoring Result, mg/L	Assessment Level	Assessment Standard of Level Ⅲ	
				Standard Value	Times of Exceeding Standard
#21	pH	7.61	Ⅰ	6～9	
	FCB/L	3233	Ⅲ	≤10000	
	T N (N), mg/L	2.06	Inferior to Level Ⅴ (0.03)	≤1.0	1.06
	COD_{Cr}, mg/L	8.8	Ⅰ	≤20	
	BOD_5, mg/L	4.3	Ⅳ	≤4	0.08
	T P (P), mg/L	0.27	Ⅳ	≤0.2	0.35
#22	pH	7.96	Ⅰ	6～9	
	FCB/L	3700000	Inferior to Level Ⅴ (91.5)	≤10000	369
	T N (N), mg/L	53.35	Inferior to Level Ⅴ (25.7)	≤1.0	52.4
	COD_{Cr}, mg/L	341.5	Inferior to Level Ⅴ (7.54)	≤20	16.1
	BOD_5, mg/L	54.4	Inferior to Level Ⅴ (4.44)	≤4	12.6
	T P (P), mg/L	21.98	Inferior to Level Ⅴ (54.0)	≤0.2	108.9
#23	pH	7.36	Ⅰ	6～9	
	FCB/L	6800000	Inferior to Level Ⅴ (169.0)	≤10000	679
	T N (N), mg/L	13.50	Inferior to Level Ⅴ (5.75)	≤1.0	12.5
	COD_{Cr}, mg/L	98.5	Inferior to Level Ⅴ (1.46)	≤20	3.93
	BOD_5, mg/L	39.3	Inferior to Level Ⅴ (2.93)	≤4	8.83
	T P (P), mg/L	15.21	Inferior to Level Ⅴ (37.0)	≤0.2	75.1
#24	pH	7.29	Ⅰ	6～9	
	FCB/L	5233333	Inferior to Level Ⅴ (129.8)	≤10000	522.3
	T N (N), mg/L	5.51	Inferior to Level Ⅴ (1.76)	≤1.0	4.51
	COD_{Cr}, mg/L	38.0	Ⅴ	≤20	0.90
	BOD_5, mg/L	15.8	Inferior to Level Ⅴ (0.58)	≤4	2.95
	T P (P), mg/L	1.91	Inferior to Level Ⅴ (3.78)	≤0.2	8.55

Evaluation expressions of the first monitoring on surface water in Foling pig farm were obtained from Table 1-11 as follows:

#21: $6N_1^2N_3^1N_5^2N_6^1$(TN,0.03）

N_{III}^3(TN,1.06;BOD_5,0.08;TP,0.35）

22: $6N_1^1N_6^5$ (FCB,91.5; TN,25.7;COD_{Cr},7.54;BOD_5,4.44; TP,54.0)

N_{III}^5 (FCB,369; TN,52.4;COD_{Cr},16.1;BOD_5,12.6; TP,108.9）

#23: $6N_1^1N_6^5$ (FCB,169.0; TN,5.75;COD_{Cr} ,1.46;BOD_5,2.93; TP,37.0)

N_{III}^5 (FCB,679; TN,12.5;COD_{Cr} ,3.93;BOD_5,8.83; TP,75.1)

#24 : $6N_1^1N_5^1N_6^4$ (FCB,129.8; TN,1.76; BOD_5,0.58;TP,3.78)

N_{III}^5 (FCB,552.3; TN,4.51;COD_{Cr} ,0.90;BOD_5,2.95; TP,8.55)

The first evaluation of Comprehensive Characteristic Model of surface Water Quality of Mashigang pig farm indicated:

For #21 sample, pH and COD_{Cr} were classed as Level Ⅰ, FCB as Level Ⅲ, BOD_5 and TP as Level Ⅳ, TN was inferior to Level Ⅴ, and exceeded criteria of Level Ⅴ with 0.03 times. So water service function in the monitoring site was inferior to Level Ⅴ. Evaluated with Water Quality Standard as criteria, three indexes of the sample met with the requirement of Level Ⅲ, the other three indexes were above Level Ⅲ, with TN exceeding 1.06 times, BOD_5 0.08 times and TP 0.35 times.

For #22 sample, pH was classed as Level Ⅰ, FCB, TN, COD_{Cr}, BOD_5 and TP were inferior to Level Ⅴ, and exceeded criteria of Level Ⅴ with 91.5, 25.7, 7.54, 4.44 and 54.0 times respectively. So water service function in the monitoring site was inferior to Level Ⅴ. Evaluated with Water Quality Standard as criteria, only pH met with the requirement of Level Ⅲ, the other five indexes were inferior to that Level, with FCB exceeding 369 times, TN 52.4 times, COD_{Cr} 16.1 times, BOD_5 12.6 times and TP 108.9 times.

For #23 sample, pH was classed as Level Ⅰ, FCB, TN, COD_{Cr} BOD_5, and TP were inferior to Level Ⅴ, which exceeded criteria of Level Ⅴ with 169, 5.75, 1.46, 2.93 and 37.0 times. So water service function in the monitoring site was inferior to Level Ⅴ. Evaluated with Water Quality Standard as criteria, only pH met with the requirement of Level Ⅲ, the other five indexes were inferior to that Level, with FCB exceeding 679 times, TN 12.5 times, COD_{Cr} 3.93 times, BOD_5 8.83 times and TP 75.1 times.

For #24 sample, pH was classed as Level Ⅰ, COD_{Cr} as Level Ⅴ, FCB, TN, BOD_5 and TP were inferior to Level Ⅴ, which exceeded criteria of Level Ⅴ with 129.8, 1.76, 0.58 and 3.78 times. So water service function in the monitoring site was inferior to Level Ⅴ. Evaluated with Water Quality Standard as criteria, only pH of the sample met with the requirement of Level Ⅲ, the other five indexes were inferior to that Level, with FCB exceeding 552.3 times, TN 4.51 times, COD_{Cr} 0.90 times, BOD_5 2.95 times and TP 8.55 times.

Table 1-12: The second evaluation of Comprehensive Characteristic Model of surface Water Quality Features of Foling pig farm

Sample ID	Monitoring Parameter	Monitoring Result, mg/L	Assessment Level	Assessment Standard of Level Ⅲ	
				Standard Value	Standard Value
#21	pH	7.27	Ⅰ	6～9	
	FCB/L	2567	Ⅲ	≤10000	
	T N (N), mg/L	7.7	Inferior to Level Ⅴ(2.85)	≤1.0	5.70
	COD_{Cr}, mg/L	31.1	Ⅴ	≤20	0.56
	BOD_5, mg/L	5.2	Ⅳ	≤4	0.30
	T P (P), mg/L	1.19	Inferior to Level Ⅴ(1.98)	≤0.2	4.95
#22	pH	7.83	Ⅰ	6～9	
	FCB/L	613333333	Inferior to Level Ⅴ(15332)	≤10000	61332
	T N (N), mg/L	35.8	Inferior to Level Ⅴ(16.9)	≤1.0	34.8
	COD_{Cr}, mg/L	751.4	Inferior to Level Ⅴ(17.8)	≤20	36.6
	BOD_5, mg/L	552.8	Inferior to Level Ⅴ(54.3)	≤4	137.2
	T P (P), mg/L	26.88	Inferior to Level Ⅴ(66.2)	≤0.2	133.4
#23	pH	7.07	Ⅰ	6～9	
	FCB/L	1266667	Inferior to Level Ⅴ(30.7)	≤10000	125.7
	T N (N), mg/L	6.51	Inferior to Level Ⅴ(2.26)	≤1.0	5.51
	COD_{Cr}, mg/L	76.9	Inferior to Level Ⅴ(0.92)	≤20	2.85
	BOD_5, mg/L	24.1	Inferior to Level Ⅴ(1.41)	≤4	5.03
	T P (P), mg/L	1.72	Inferior to Level Ⅴ(3.30)	≤0.2	7.60

#24	pH	7.61	Ⅰ	6～9	
	FCB/L	176666667	Inferior to Level Ⅴ(4416)	≤10000	17655
	T N (N), mg/L	38.42	Inferior to Level Ⅴ(18.2)	≤1.0	37.4
	COD_{Cr}, mg/L	300	Inferior to Level Ⅴ(6.50)	≤20	14.0
	BOD_5, mg/L	92.3	Inferior to Level Ⅴ(8.23)	≤4	22.1
	T P (P), mg/L	5.27	Inferior to Level Ⅴ(12.2)	≤0.2	25.4

Evaluation expressions of the second monitoring on surface water in Foling pig farm were obtained from Table 1-12 as follows:

#21: $6N_1^1N_3^1N_4^1N_5^1N_6^2$ (TN,2.85;TP,1.98)

N_{III}^4 (TN,5.70; COD_{Cr},0.56;BOD_5,0.30; TP,4.95)

#22: $6N_1^1N_6^5$ (FCB,15332; TN,16.9; COD_{Cr},17.8;BOD_5,54.3; TP,66.2)

N_{III}^5 (FCB,61332; TN,34.8; COD_{Cr},36.6;BOD_5,137.2; TP,133.4)

#23: $6N_1^1N_6^5$ (FCB,30.7; TN,2.26; COD_{Cr},0.92;BOD_5,1.41; TP,3.30)

N_{III}^5 (FCB, 125.7; TN,5.51; COD_{Cr},2.85;BOD_5,5.03; TP,7.60)

#24: $6N_1^1N_6^5$ (FCB,4416; TN,18.2; COD_{Cr},6.50;BOD_5,8.23; TP,12.2)

N_{III}^5 (FCB,17655; TN,37.4; COD_{Cr},14.0;BOD_5,22.1; TP,25.4)

The second evaluation of Comprehensive Characteristic Model of surface Water Quality of Mashigang pig

farm indicated:

For #21 sample, pH were classed as Level Ⅰ, FCB as Level Ⅲ, BOD_5 as Level Ⅳ, COD_{Cr} as Level Ⅴ, TN and TP were inferior to Level Ⅴ, and exceeded criteria of Level Ⅴ with 2.85 and 1.98 times respectively. So water service function in the monitoring site was inferior to Level Ⅴ. Evaluated with Water Quality Standard as criteria, two indexes of the sample met with the requirement of Level Ⅲ, the other four indexes were above Level Ⅲ, with TN exceeding 5.70 times, COD_{Cr} 0.56 times, BOD_5 0.30 times and TP 4.95 times.

For #22 sample, pH was classed as Level Ⅰ, FCB, TN, COD_{Cr}, BOD_5 and TP were inferior to Level Ⅴ, and exceeded criteria of Level Ⅴ with 15332, 16.9, 17.8, 54.3 and 66.2 times respectively. So water service function in the monitoring sire was inferior to Level Ⅴ. Assessed with Water Quality Standard as criteria, only pH met with the requirement of Level Ⅲ, the other five indexes were above that Level, with FCB exceeding 61332 times, TN 34.8 times, COD_{Cr} 36.6 times, BOD_5 137.2 times and TP 133.4 times.

For #23 sample, pH was classed as Level Ⅰ, FCB, TN, COD_{Cr} BOD_5, and TP were inferior to Level Ⅴ, which exceeded criteria of Level Ⅴ with 30.7, 2.26, 0.92, 1.41 and 3.30 times. So water service function in the monitoring site was inferior to Level Ⅴ. Evaluated with Water Quality Standard as criteria, only pH met with the requirement of Level Ⅲ, the other five indexes were inferior to that Level, with FCB exceeding 125.7 times, TN 5.51 times, COD_{Cr} 2.85 times, BOD_5 5.03 times and TP 7.60 times.

For #24 sample, pH was classed as Level Ⅰ, FCB, TN, COD_{Cr} BOD_5, and TP were inferior to Level Ⅴ, which exceeded criteria of Level Ⅴ with 4416, 18.2, 6.50, 8.23 and 12.2 times. So water service function in the monitoring site was inferior to Level Ⅴ. Evaluated with Water Quality Standard as criteria, only pH met with the requirement of Level Ⅲ, the other five indexes were inferior to that Level, with FCB exceeding 17655 times, TN 37.4 times, COD_{Cr} 14.0 times, BOD_5 22.1 times and TP 25.4 times.

Monitoring results showed that surface water in Foling pig farm had been severely polluted, and the main pollutants are FCB, TN, TP, CODCr and BOD5. The indexes above of monitoring water samples were all inferior to Level Ⅴ, and do not accord with Environmental Quality Standard for Surface Water. Waste water from fish pond was most seriously polluted, followed by sludge from pig farm system, water from small stream and river water.

Table 1-13: Individual index distribution of water quality and exceeding standard situation of the second sampling of Foling pig farm

Parameter	Level Ⅰ	Level Ⅱ	Level Ⅲ	Level Ⅳ	Level Ⅴ	Inferior to Level Ⅴ	Times of Exceeding Standard
pH	4						
FCB			1			3	369～679
TN						4	1.06～52.4
COD_{Cr}	1				1	2	0.90～16.1
BOD_5				1		3	0.08～12.6
TP				1		3	0.35～108.9
Total	5	0	1	2	1	15	

Table 1-14 Individual index distribution of water quality and exceeding standard situation of the second sampling of Foling pig farm

Parameter	Level Ⅰ	Level Ⅱ	Level Ⅲ	Level Ⅳ	Level Ⅴ	Inferior to Level Ⅴ	Times of Exceeding Standard
pH	4						
FCB			1			3	125.7～61332

TN						4	5.51～37.4
COD_{Cr}					1	3	0.56～36.6
BOD_5				1		3	0.30～137.2
TP						4	4.95～133.4
Total	4	0	1	1	1	17	

Results from Table 1-13 and table 1-14 showed that the surface water in Foling pig farm was severely polluted by pathogenic microorganisms, as well as large quantities of FCB. Individual index exceeding Level Ⅲ of the first and second monitoring accounted for 75% and 79% of the total indexes respectively. FCB of three samples exceeded Level Ⅲ with the highest multiple of 61332. TN and TP are important nutritional factors of Water Eutrophication, and all samples exceeded the standard of Level Ⅲ with the multiple of 1.06～52.4 and 0.35～133.4. Generally speaking, when TP concentration was more than 0.02 mg / L, or inorganic nitrogen was over 0.3 mg / L, it could be considered eutrophication of water bodies. Surface water in Foling pig farm was in the state of eutrophication. Superstandard multiple of CODCr was between 0.59 and 36.6 in the two bathes of samples, with 75% of the first sampling and 100% of the second. BOD5 of all samples exceeded Level Ⅲ, with the times of exceeding standard between 0.075 and 12.6. High concentration of COD and BOD5 indicates much oxygen consumption of organic matter in water, which will affect quality and output of aquatic products. In a word, surface water in the pig farms was seriously polluted, and waste management should be strengthened to reduce sewage discharge and water environment load.

2.5 Proposals on environmental management

Surface water quality of the two farms belong to Level V or the inferior Level V, and pollutants are basically organic waste and pathogenic microorganisms brought into by pig waste, which caused surrounding environment pollution. Thus the solutions to raise water quality were put forward as follows:

Firstly, minimize the pig farm waste. The discharge of pollutants quantity should be controlled to reduce the pressure on ecological environment and improve self-purification capacity of water environment. Now, new methods are developed for comprehensive management of excrement and urine waste in intensive pig industry, and minimization of pig farm waste was found to have the ability of eliminating pollutants before they are produced, which is called clean production. Concrete measures may be taken from the following aspects:

(1) Choose feed ingredients with high digestibility and small nutrient variability. Such feed can meet green production requirements of animal products, and could achieve rapid weight gain, less excretion and less pollution. Be careful to select low toxicity and high safety raw materials, which would improve absorption and utilization efficiency of feed. For example, fishmeal has high-quality protein, and will be almost

absorbed in the stomach, while low quality protein such as hydrolyzed feather meals will markedly increase nitrogen and ammonia excretion.

(2) Change feed formula in the diet and concept of ideal protein patterns for pigs. Keep feed nutrition structure in a reasonable ratio could not only meet the needs of animals but also increase feed digestion and utilization. Supply amino acid balanced diet would achieve low feed costs and reduce nitrogen pollution.

(3) Application of green feed additives. Adding appropriate enzyme will help animals absorb and digest the specific nutrients, and thereby reduce nutrients discharge and ammonia - nitrogen, phosphorus and eliminate odor pollution. 70% phosphorus in Cereal and oil-cake feed exists in the form of Phytate Phosphorus which can not be used by animals. In order to satisfy phosphorus demand of animals, inorganic calcium phosphate is usually added to the feed, and almost all Phytate Phosphorus was excreted. Using phytase in stead of inorganic phosphorus can make most phosphorus release from Phytate Phosphorus, and effectively reduced phosphorus excretion by 30%. Reduction in Phosphorus discharge, a key factor of water body eutrophication, would greatly reduce water and soil pollution. And at the same time, the utilization of protein will be improved.

(4) Improve Processing Technology for Feed. Feed grinding, mixing, pelleting and puffing will affect feed nutrient utilization.

Secondly, reduce the impact on the surrounding environment. It is necessary to enhance pig farm waste management and disposal technology. Specific measures are listed below:

(1) Separation of liquid and solid waste. Instead of flushing dung with water, it's better to use dry collection technology which meets the reduction standard. Flushing wastes lots of clean water, and greatly reduces the value of fertilizers from solid-liquid separation, with most soluble organic pollutants into water body, which will increase waste water management difficulty. The main procedure of dry collection is to improve fecal collection system design so that pig manures and sewage could be separated once produced. The dry dung can be collected mechanically or manually, and urine and rinsing water from the sewer outflow can be treated respectively. With this method, 80% of dry dung can be collected, and processed into organic fertilizer. The dry dung collection meets with the reduction standards and is appropriate to our national conditions.

(2) Composting technology. High-temperature fermentation of mature can avoid soil pollution and the spread of Parasitosis and zoonosis caused by micro-organisms and parasites in excessive untreated fresh waste. After a high-temperature fermentation and organic matter mineralization, humification and decontamination under microorganisms, the fresh wastes become harmless fertilizer. In the process of

organic matter decomposition, large amounts of bio-available nitrogen, phosphorus and potassium compounds were produced, and there are new syntheses of polymer organic humus, which is an important form of soil fertility substances.

(3) Use as raw material for Biogas Fermentation. Methane production is an effective way to manage pig manure and waste. Under anaerobic conditions, organic matters turn into carbon dioxide, thus large quantities of pig manure and will be treated and biogas residues can also be used as environmental friendly fertilizer or feed. Harmful pathogenic microorganisms in pig manure would be killed after high temperature fermentation, and the biogas residue containing a lot of organic matter can increase fertility and prevent land compaction. Deficiency of the procedure limits its generalization, such as high ammonia volatilization loss, onsite treatment, and high technique, huge susceptibleness to temperature or season and great investment.

(4) Biological recycling. Waste biological recycling aims at turning waste into treasure and ensure the safety production in piggery. Edible Fungi, housefly larvae and earthworms can be cultivated with waste of pig farms, and these cultures can be used as animal feed or for economic use.

(5) Improve economic benefits of the technology. At present, due to extremely complex process and more investment, end harnessing models of waste in intensive pig farms are difficult to operate. Enhancing the economic benefits is the only way to stimulate people’s motivation, guarantee long-term operation, and zero emission. Under the government's energetically supporting, Scientific Research Unit and livestock farm should united together to develop comprehensive utilization technology of Livestock and poultry pollution treatment technology, which includes waste fermentation, biogas and organic fertilizer production.

(6) Implementation of laws and regulations. Survey report of Development Research Center of State Council in 2004 pointed out that economic benefit and ecological benefit should be combined from the angle of the entire development of the livestock industry of China, and economic benefits consideration from intensive farms is not enough. Application of a high mechanization and automation in pig manure treatment technology requires large amounts of capital input; therefore, funds would be input to treat pig manure unless increasing economic efficiency of pig farms. But, if the government increases the investment and guide people to comprehensive utilization of animal waste and integration of specialized crop and livestock activities, implementation of regulations or standards relevant to livestock waste management and sustainable development of agriculture. At the same time, government should adjust the current rural policy, increase investment in the initial stage of Livestock and poultry industry in environment management, payment of environmental allowance instead of encouraging allowance, and strengthen environmental planning to achieve rational distribution and optimization of the industrial structure.

(7) Moreover, secondary pollution should be paid special attention to during the process of the utilization of the wastes. When used as fertilizer, feed or energy, the whole process including pig manure stacking, transportation, harmless disposal and residue utilization must be under strict control, otherwise it may cause failure.

Thirdly, widen the green coverage of pig farms, which can not only beautify the surrounding environment, but also effectively reduce the pollution and purify the air.

3. Monitoring Report on Groundwater Quality

3.1 Sampling location

Five groundwater monitoring sites were suggested in Foling pig farm. Every well was accurately positioned by GPS to identify sampling locations. The locations of surface water monitoring sites of Foling pig farm was listed in Table 2-1and Figure 1 in the report on surface water.

Table 2-1 Locations of groundwater monitoring sites of Foling pig farm

Sample ID	Monitoring Location and Sample Names
#11	Lagoon 1 （E114°00.039′N 23°10.810′）
#12	Lagoon 2（E114°00.214′N 23°10.724′）
#13	Lagoon 3（E114°00.216′N 23°10.614′）
#14	Lagoon 4（E114°00.103′N 23°10.710′）
#15	Lagoon 5（E114°59.990′N 23°10.882′）

3.2 Sample collection

Instantaneous water samples were respectively collected from every well, and methods of water sample collection and preservation and containers washing used in monitoring were listed in Table 2-2, which were originated from Groundwater Monitoring Technical Specifications (HJ / T164-2004) and Water and Wastewater Monitoring methods (4_{th} edition), and also referred to Water Sampling and Analysis Guidance for CAFO Monitoring.

Table 2-2 Water preservation and containers washing

Parameter	Sampling container	Condition of storage	Retention period	Sample size, ml	Container washing
pH	Pyrex bulb		12h	250	I
TN	Pyrex bulb	H_2SO_4， pH≤2	7d	250	I
FCB	Pyrex bulb	adding 0.2-0.5g/L sodium thiosulfate to remove remnants, 0—4°C， lucifuge	12h	250	I

Notes: I stands for washing method, wash with detergent, rinse three times with tap water and once with distilled water.

3.3 Suggested Parameters and Analytical Methods for Monitoring

Analytical methods and apparatus of some parameters suggested in Groundwater Environmental Quality Standard were listed in Table 2-3. Analytical method TP was adopted from GB 3838－2002, FCB from Groundwater Monitoring Technical Specifications (GB 3838-2002) and Water and Wastewater Monitoring Methods (4th edition) and Water Sampling and Analysis Guidance for CAFO Monitoring.

Table 2-3 Methods and apparatus for some parameters of Groundwater quality standard

Parameters	Methods for Monitoring	Apparatus	Lowest detection limit, mg/L
pH	Glass Electrode, GB 6920-89	420A pH Meter	—
Total N	Persulfate Digestion Method, GB 11894－89	Pressure cooker UV2501-spectrophotometer	0.05
FCB	Membrane filtration method, Monitoring Method of Water and wastewater (4th edition)	SW-CJ-1F-Super-clean worktable 250B-Biochemical incubator	—

All personnel involved in monitoring had work licenses. The highly trained lab-technicians were familiar with monitoring and technical specifications. Sample collectors, analytical reagents and standard solution were all well prepared before sampling. Samples preservation and preliminary treatment were strictly implemented as formulated. Analytical apparatus were adjusted to good working conditions before analysis, and internal standards and quality control samples were strictly used as suggested in technical standards of monitoring parameters during analysis. Other requirements were referred to Groundwater Monitoring Technical Specifications (HJ / T 164-2004) and Water and Wastewater Monitoring Methods (4_{th} edition), and the analytical procedures were recorded in detail. When analysis ended, results were summarized in time. All analytical results of surface water samples were summarized in Annex 1, and protocol was listed in Annex 2.

3.4 Evaluation of Samples of Ground Water

3.4.1 Evaluation Criteria for Groundwater Classification

Groundwater Quality Standards (/T14848－93) has been developed to help assess the quality of groundwater. According to the national standard, groundwater falls into five levels:

Level I mainly reflect low natural background content of chemical constituents in groundwater, suitable for all purposes;

Level Ⅱ mainly reflect natural background content of chemical constituents in groundwater, suitable for all purposes;
Level Ⅲ based on critical level of human health and mainly suitable for central living drinking water source, common industrial water source and agricultural water source.
Level Ⅳ based on water requirement of agriculture and industry and suitable for agriculture and part of industry, also suitable for drinking water after proper treatment.
Level V not suitable for drinking, other use can be selected for application aims.
Groundwater Standard threshold parameters of three Levels suggested in Groundwater Quality Standards were listed in Table 2-4

Table 2-4 Standard threshold of Groundwater parameters, mg/L

Parameters	Level Ⅰ	Level Ⅱ	LevelⅢ	Level Ⅳ	Level Ⅴ
pH	6.5～8.5			5.5～6.5 8.5～9.0	<5.5 >9.0
FCB/L	≤3.0	≤3.0	≤3.0	≤100	>100
TN (N), mg/L	≤2.0	≤5.0	≤20	≤30	>30

Note: data above is from GB /T 14848—93.

3.4.2 Evaluation of samples of Mashigang pig farm

Groundwater quality was evaluated on two settings of samples from Mashigang pig farm, and the evaluation results were shown in Table 2-5 and 2-6.

Table 2-5 First evaluation of Comprehensive Characteristic Model of groundwater Quality Features of Mashigang pig farm

Sample ID	Monitoring Parameter	Monitoring Result, mg/L	Assessment Level	Assessment Standard of Level Ⅲ	
				Standard Value	Standard Value
11	pH	8.02	Ⅰ	6.5～8.5	
	FCB/L	5900	Ⅴ	≤3.0	1966
	TN（N）, mg/L	4.63	Ⅱ	≤20	
12	pH	6.99	Ⅰ	6.5～8.5	
	FCB/L	111667	Ⅴ	≤3.0	37221
	TN（N）, mg/L	1.56	Ⅰ	≤20	

13	pH	6.77	I	6.5～8.5	
	FCB/L	1760	V	≤3.0	586
	TN（N），mg/L	1.20	I	≤20	
14	pH	7.50	I	6.5～8.5	
	FCB/L	23000	V	≤3.0	7666
	TN（N），mg/L	1.95	I	≤20	
15	pH	7.01	I	6.5～8.5	
	FCB/L	727	V	≤3.0	241
	TN（N），mg/L	0.54	I	≤20	

Evaluation expressions of the first monitoring on groundwater in Mashigang pig farm were obtained from Table 1-6 as follows:

No.11: $3N_1^1N_2^1N_5^1N_{\text{III}}^1$（FCB，1966）

No.12: $3N_1^2N_5^1N_{\text{III}}^1$（FCB，37221）

No.13: $3N_1^2N_5^1N_{\text{III}}^1$（FCB，586）

No.14: $3N_1^2N_5^1N_{\text{III}}^1$（FCB，7666）

No. 15: $3N_1^2N_5^1N_{\text{III}}^1$（FCB，241）

The first evaluation of Comprehensive Characteristic Model of Groundwater Quality of Mashigang pig farm indicated:

For #11 sample, pH was classed as Level Ⅰ, TN as Level Ⅱ, FCB as Level Ⅴ, and exceeded criteria of Level Ⅴ. evaluated with Water Quality Standard as criteria, the water sample was inferior to Level Ⅲ, and classed as Level Ⅴ.

For #13 sample,, pH and TN were classed as Level Ⅰ, FCB as Level Ⅴ, and exceeded criteria of Level Ⅲ, and its service function was inferior to Level V.

For #14 sample, pH and TN were classed as Level Ⅰ, FCB as Level Ⅴ, and exceeded criteria of Level Ⅲ, and its service function was inferior to Level Ⅴ.

For #15 sample, pH and TN were classed as Level Ⅰ, FCB as Level Ⅴ, and exceeded criteria of Level Ⅲ, and its service function was inferior to Level Ⅴ.

Table 2-6 The second evaluation of Comprehensive Characteristic Model of groundwater Quality Features of Mashigang pig farm

Sample ID	Monitoring Parameter	Monitoring Result, mg/L	Assessment Level	Assessment Standard of Level Ⅲ	
				Standard Value	Standard Value
11	pH	7.82	Ⅰ	6.5～8.5	
	FCB/L	4467	Ⅴ	≤3.0	1488
	TN（N）, mg/L	3.46	Ⅱ	≤20	
12	pH	7.61	Ⅰ	6.5～8.5	
	FCB/L	27333	Ⅴ	≤3.0	9110
	TN（N）, mg/L	1.65	Ⅰ	≤20	
13	pH	7.18	Ⅰ	6.5～8.5	
	FCB/L	1480	Ⅴ	≤3.0	492
	TN（N）, mg/L	1.97	Ⅰ	≤20	
14	pH	7.86	Ⅰ	6.5～8.5	
	FCB/L	8133	Ⅴ	≤3.0	2710
	TN（N）, mg/L	1.07	Ⅰ	≤20	
15	pH	7.59	Ⅰ	6.5～8.5	
	FCB/L	2733	Ⅴ	≤3.0	910
	TN（N）, mg/L	0.88	Ⅰ	≤20	

Evaluation expressions of the second monitoring on groundwater in Mashigang pig farm were obtained from Table 2-7 as follows:

No. 11: $3N_1^1N_2^1N_5^1N_{\text{III}}^1$ （FCB，1488）

No. 12: $3N_1^2N_5^1N_{\text{III}}^1$ （FCB，9110）

No. 13: $3N_1^2N_5^1N_{\text{III}}^1$ （FCB，492）

No. 14: $3N_1^2N_5^1N_{\text{III}}^1$ （FCB，2710）

No. 15: $3N_1^2N_5^1N_{\text{III}}^1$ （FCB，910）

The second evaluation of Comprehensive Characteristic Model of groundwater Quality of Mashigang pig farm indicated:

For #11 sample, pH and COD_{Cr} were classed as Level Ⅰ, TN as Level Ⅱ, FCB as Level Ⅴ, and exceeded criteria of Level Ⅴ. Evaluated with Water Quality Standard as criteria, the water sample was inferior to Level Ⅲ, and classed as Level Ⅴ.
For #12 sample, pH and TN were classed as Level Ⅰ, FCB as Level Ⅴ, and exceeded criteria of Level Ⅲ, and its service function was classed as Level Ⅴ.

For #13 sample, pH and TN were classed as Level Ⅰ, FCB as Level Ⅴ, and exceeded criteria of Level Ⅲ, and its service function was classed as Level Ⅴ.

For #14 sample, pH and TN were classed as Level Ⅰ, FCB as Level Ⅴ, and exceeded criteria of Level Ⅲ, and its service function was classed as Level Ⅴ.

For #15 sample, pH and TN were classed as Level Ⅰ, FCB as Level Ⅴ, and exceeded criteria of Level Ⅲ, and its service function was classed as Level Ⅴ.

Results from Table 2-5 and table 2-6 showed that five examples of groundwater of the two batches in Mashigang pig farm was classed as Level Ⅴ, and FCB was the main pollutant, which exceeded Level Ⅲ in the first and second monitoring with the multiple between 241 and 37221. So groundwater was seriously polluted by PCB. pH of all the five examples and TN of four examples were classed as Level Ⅰ, and only one example in the two monitoring sites was classed as Level Ⅱ evaluating with concentration TN. In short, effect of pathogen microorganism should be eliminated immediately.

3.5 Proposals on environmental management

Groundwater quality of the Mashigang farm belonged to Level V, and pollutant is basically PCB, which exceeded Level Ⅲ in the first and second monitoring with the multiple between 241 and 37221, while pH of all examples and TN of four examples were classed as Level Ⅰ and TN of only one example was classed as Level Ⅱ.As having been polluted by pathogen microorganisms, the groundwater belonged to Level Ⅴ, and was not suitable for drinking. Therefore it is necessary to control pathogenic microbes and organic matter and nitrogen into groundwater from various channels to reduce pollution of groundwater. Specific proposals on environmental management have been introduced for surface water management and innocuous management should be focused on reducing pathogenic bacteria pollution. Sterilization and disinfection should be paid attention if groundwater is used as drinking water.