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Report on the Development Status of Chinese Biogas Industry

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Abstract

On the basis of investigation and statistics, data (up to the end of 2009) have been gained on the discharge of industrial wastewater and residue, agricultural livestock excrement, municipal waste and sludge from sewage treatment plant of China, as well as the amount of biogas convertible resources.

The report has discussed the current development of the large and medium sized biogas projects of China, its main contents are as follows:

(1) The number of biogas projects, scale, annual biogas production, project investment and economic benefit.

(2) The major process technologies, equipments and auxiliary devices adopted by all kinds of biogas projects, the standards of the available technical equipments and the specific plans for the national standard of the key technical equipments.

(3) Problems in the design, construction, operation and management, project certification， special team construction and their solutions.

(4) Centralized mode of biogas projects and environmental protection.

(5) Utilization of biogas, fermented residue and liquid.

(6) Cases

In addition, the constraints for the industrialized development of the large and medium sized biogas projects of China have been analyzed and corresponding suggestions on the policy and technology have been put forward in the report.

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1.Preface

Since 1980s, when the fossil energy is getting exhausted and its price is getting higher and higher, the energy crisis has emerged quietly. At the same time, the high consumption of fossil energy has resulted in serious global environment problem.

Currently China is witnessing a rapid economic growth and sustainable development, the energy demand and environment pressure are increasing day by day. So how to easy the pressure, search for new energy and realize the win-win economic benefit have been a global concern.

In Beijing International Renewable Energy Conference of 2005, our country promised that the target of 15% non-fossil energy from the total energy consumption will be realized by 2020. The biogas development and utilization in China have had a history of several decades. The biogas industry has become a major part of the present renewable energy – biomass.

Since more than two decades of rapid development, riper experience has been obtained by the biogas industry of China. The biogas projects for industrial, agricultural and municipal wastes have achieved industrialized development in different degrees, it is of significance for dealing with the environment and easing energy pressure in the economic development.

In July, 2010, entrusted by Sino-Danish Renewable Energy Development Programme, the Environmental Protection Research Institute of Light Industry initiated the project - Research on the Industrialized Development of the Biogas Project of China. This report - Development Status of Chinese Biogas Industry is one of the reports which will be submitted according to the requirement of the programme. In this respect, the project team of the institute has consulted a lot of data and related literatures published by national and industrial departments. In addition the team has also investigated some large and medium sized biogas projects and interviewed some related industrial associations and experts, so as to understand the current status and existing problems in the development and construction of large and medium sized biogas projects and their operation and management.

The report gives a brief introduction to the current status of biogas industrialized development in China, analyzes the existing problems and puts forward some corresponding suggestions for policy, in terms of industrial waste treatment, large and medium sized biogas projects of livestock and poultry farms, landfill and municipal sewage treatment plant, including biogas resource, project construction, operation, technical equipment, biogas utilization, project mode and major obstacles for environmental development and the relative policy.

The biogas consists mainly of three components (see Table 1-1).

Table 1-1　Main Components of Biogas

Component		Content（%）
Main component	CH_4	50～70%
	CO_2	20～50%
Common component	H_2S NH_3 H_2	＜5
Trace component	VOC	＜1

Note：VOC refers to volatile organic compounds，including cycloalkane, aromatic hydrocarbon, halogen compounds etc.

The main combustible component of biogas is methane (CH_4)，the calorific value / m^3 biogas is about 21MJ（CH_4 60%）, equivalent to the calorific value of 1.45 m^3 gas or 0.69 m^3 natural gas. The main characteristic parameters of the biogas with different components are shown in Table 1-2.

Table 1-2 The main Characteristic Parameters of the Biogas with different Components

Parameter	CH_4 50% CO_2 50%	CH_4 60% CO_2 40%	CH_4 70% CO_2 30%
density（kg/m^3）	1.374	1.221	1.095
relative density	1.042	0.944	0.847
calorific value（kg/m^3）	17.937	21.542	25.111
theoretical air value (m^3/m^3）	4.76	5.71	6.67
theoretical flue gas（m^3/m^3）	6.763	7.914	9.067

2.Biogas Resources and Project Development

As the main part of current biomass, the large and medium sized biogas projects in China take mainly the industrial and agricultural wastewater, residue and domestic sewage, solid waste as their raw material. The statistics of the various industrial sectors are as follows:

Based on the analysis and estimation of the data published by the yearbooks of national statistics, related central department and various industries, the biogas resources of China (up to the end of 2009), the number of large and medium sized biogas projects and annual biogas production are summarized as follows:

(1) Resource of large and medium sized biogas projects

① Industrial effluent and residue	28.083 billion m^3
② Agricultural large and medium sized livestock and poultry farms	6.646 billion m^3
③ Municipal waste and sludge	10.084 billion m^3
Total	44.813 billion m^3

(2) The number of built large and medium sized biogas projects

① Industrial enterprises	ca.2,000
② Large and medium sized livestock and poultry farms	22,570
③ Municipal waste and sludge	ca. 627

(3) Annual biogas production

① Industrial enterprises	ca. 5 billion m^3
② Large and medium sized livestock and poultry farms	455 million m^3
③ Municipal waste and sludge	2 billion m^3
Total	7.455 billion m^3

(4) Proportion of annual biogas production for total resources 16.64%

2.1 Industrial Organic Wastewater Resource

In China, the annual discharge of organic wastewater and residue has reached 4.293 billion T and 945.58 million T respectively.

2.1.1. Organic wastewater discharge from light industry

It can be seen from the statistical data published by the major sectors of light industry that the annual discharges of organic wastewater and residue from more than 10 sectors of light industry (including alcohol, sugar, beer, rice wine, liquor, starch, monosodium glutamate, beverages, pulp & paper etc.) is 1.757 billion T and 43.2275 million T respectively by the end of 2009 (see Table 2-1) .

Table 2-1 Summery of the Biogas Resources Convertible from Organic Wastewater (Residue) of the Enterprises of Light Industry

Environmental Protection Research Institute of Light Industry July 2010										
	Industry	product output （year）		organic wastewater			orangic residue			note
				wastewater （10000T/a）	gas yield （m^3/kgCOD)	biogas (10000m^3/a）	residue (10000m^3/a）	gas yield （m^3/m^3residue)	biogas (10000m^3/a）	
1	alcohol	7.3174 mllion T	effluent	8000	320m^3/T alcohol	234156.8				
2	sugar	13.21 mllion T	effluent	9247	2.5-3m^3/m^3 effluent	27741				
			residue				1321	1	1321	
3	beer	42.3638 mllion T	effluent	84727.6		22029.2				
4	rice wine	1.0329 mllion T	effluent	1549.4	4.5-5m^3/m^3 effluent	7747				
5	liquor	7.063 mllion T	residue				2119	20	42380	
6	starch	18.5477 mllion T	effluent	37095.4	20m^3/m^3 effluent	741908				
	starch sugar	7.5 mllion T	residue				222.75	20	4455	
7	monosodium glutamate	2.2 mllion T	effluent	5500	0.45	137500	660	20	1320	
			residue							
8	citric acid	0.9 mllion T	effluent	1232.6	0.53	24652				
9	yeast	0.2 mllion T	effluent	2485.3	12m^3/m^3 effluent	29823.6				
10	enzyme preparation	0.7 mllion T	effluent	175	6m^3/m^3 effluent	1050				
11	semi-chemical pulp	4 mllion T	effluent	6000	20m^3/m^3 effluent	120000				
	chemical mechanical pul	3.5 mllion T	effluent	5250	0.43	52500				
	sulfite pulp	0.4 mllion T	effluent	600	40m^3/m^3 effluent	24000				
	cotton pulp	1.3 mllion T	effluent	1950	20m^3/m^3 effluent	39000				
	recycled pulp	27.39 mllion T								
12	wine	0.96 mllion T	effluent	499.2		12480				
13	lactic acid	100 thsousand T	effluent							
	Sorbitol 630000，xylose and xylitol 67500 T		effluent	2029.7	5m^3/m^3 effluent	10148.6				
14	Carbonated drinks	12.542 mllion T	effluent							
	fruit and vegetables juice	1447.6 T	effluent	0.676	1m^3/m^3 effluent	0.676				
15	Milk products	18.1056 mllion T								
	liquid milk	15.2522 mllion T	effluer	9322.1	1000m^3/TBOD	8048.6				
	Total			175663.976		1492785.476	4322.75		49476	
	（1） By the end of 2009, the organic wastewater (biogas convertible) discharged from the Enterprise of Light Industry is 1.757 billion/a, residue 43.2275 million T/a.									
	（2）The biogas convertible resources of the wastewater (residue) form the enterprises of light industry is 15.423 billion m3/a (56% water content).									

In accordance with the biogas output from the above wastewater and residue in the actual operation of the biogas project, the wastewater (residue) discharged from the above enterprises of light industry can be converted into 15.423 billion m^3 of biogas resources.

2.1.2 Organic wastewater discharge from non-light industry

The number of other major industries which discharge organic wastewater and residue is more than 10, such as Pharmacy, Slaughter, petrifaction, natural rubber, furfural etc. According to statistics, the annual discharges of organic wastewater and residue is 2.61 billion T and 902.3525 million T respectively.

In accordance with data from the actual operation of the biogas project, the wastewater (residue) discharged from the enterprises of the above other industries can be converted into 12.66 billion m^3 of biogas resources (56% methane content). See Table 2-2.

Table 2-2 Summery of the Biogas Resources Convertible from Organic Wastewater (Residue) of the Enterprises of Non-Light Industry

Environmental Protection Research Institute of Light Industry July 2010

	Industry	product output (year)		organic wastewater: wastewater (10000T/a)	organic wastewater: gas yield (m^3/kgCOD)	organic wastewater: biogas (10000m^3/a)	organic residue: residue (10000m^3/a)	organic residue: total Vs (10000T/a)	organic residue: gas yield (m^3/m^3residue)	organic residue: biogas (10000m^3/a)	note
1	medicine	201.22	effluent	84360	7.5-8.25m^3/m^3 effluent	695970					
2	Chinese drugs	200.8									
	honeyed pill,syrup	19.1475	effluent	7566.25		453.8					
	watered pill,tablet	40.95	residue				683.25		250	170812.5	
3	fibreboard	33.077 milliom m3	effluent	22227.7	93	145369.5					
			residue				89307	116 T	60m^3/T Vs	6965.9	
4	slaughter	7649.9	effluent	125458.4	350	114167.1					
5	flour	8695.2	effluent	869.5	1.45m^3/ m^3 effluent	1260.78					
6	vegetable oil	3280.1	effluent	328	500	2460					
7	soya sauce	503	residue				130	26 T	530m^3/T Vs	13780	
8	vinegar	250	residue				115	23 T	450m^3/T Vs	10350	
9	canned meats	12	effluent	12600	265	5670					
10	canned fruits	240	effluent								
11	Petrifaction	350		5250		52500					
	PTA	930	effluent	1365	350	42315					
12	furfural	30	effluent	900	200	3150					
13	natural rubber	61.9	effluent （whey	70	10m^3/m^3 effluent	700					
14	sisal+century plant*	4.5	fiber effluent	45	30m^3/m^3 effluent	1350					
	total			261039.9		1065366.18	90235.25			201908.4	

(1) By the end of 2009, the organic wastewater (biogas convertible) discharged from the enterprises of Non-light industry is 2.61 billion/a, residue 902.3525 million T/a, biogas 12.66 billion m^3.

（2）The biogas convertible resources of the wastewater (residue) form the enterprises of Non-light industry is 12.66 billion T /a (56% water content).

（3）*Unpublished formal data for estimation.

2.1.3 Biogas resources of industrial wastewater and residue

The organic wastewater and residue discharged from the industrial enterprises of China (which can be converted into biogas) are 4.367 billion T and 945.58 million T respectively. The biogas-convertible resource is 28.083 billion m^3（56% methane content）.

2.1.4 Status and analysis of the biogas project for industrial organic wastewater

According to the statistics of the major industrial associations, related provinces and cities, design and construction companies undertaking biogas project, designing institutes etc. and data from the national survey of the industrial pollution sources conducted in 2008, several statistical data (up to the end of 2009) which are close to the actual national industrial biogas projects have been estimated as follows:

(1) The number of built biogas projects	nearly 2,000
(2) Total volume of anaerobic equipment	5 million m^3 (averagely 2,500 m^3/each)
(3) Annual treatment of organic wastewater	over 500 million m^3
(4) Annual biogas output	5 billion m^3（8 billion KWH for power generation）, accounting for 17.86% of the total resource.

The projects are distributed in more than 20 provinces and cities, including the provinces of Shandong, Jiangsu, Henan, Anhui, Guangxi etc. Based on the statistics of alcohol and starch sectors which have the biggest biogas output, the provinces and autonomous regions with high number of biogas projects (biogas output) are in the following descending order: Shandong, Jiangsu, Henan, Anhui, Guangxi, Hebei, Sichuan, Guangdong, Zhejiang, Heilongjiang, Jilin, Inner Mongolia etc., accounting for about over 70% of the total.

Based on the analysis of application area, the wastewater treatment of alcohol, starch, beer, fermentation, food, bean product, slaughter, pharmacy and pulp & paper account for over 90% of the whole application area.

The fastest growing sectors for biogas project and biogas output are alcohol (increasing over 100 projects compared with 2002, with yearly biogas growth of 100 million m^3） and starch (increasing over 100 projects compared with 2004, with yearly biogas growth of 100 million m^3） . As for the fruit juice and fruit drink, Chinese medicine product, bean product and pulp & paper sectors, over 200 biogas projects are available .

Based on the estimation of various major industrial associations, the rough proportion of anaerobic technology applied in the industrial wastewater treatment (up to the end of June, 2010) can be seen in Table 2-3.

Table 2-3 Classification of Anaerobic Equipment Based on Industrial Sector

（2,000 projects ）

Industry	Number of project	Proportion（%）
alcohol	300	15
starch and starch sugar	200	10
paper making	200	10
beer and soft drink	400	20
rice wine, liquor and fermentation	150	7.5
pharmacy		10
slaughter, bean products, food fermentation		15
chemical engineering, PTA, textile etc.		3.5
others		9

2.2 Agricultural Biogas Resource and Biogas Industrialization

2.2.1 Total resource of livestock and poultry breeding

Agricultural biogas resources come mainly from the animal wastes of the intensive livestock and poultry farms, of them, pig, cattle and poultry are the main sources for waste discharge. According to the data from the Ministry of Agriculture, the animal industry of China has been maintaining a growth over 8% for recent years, therefore the animal wastes have been increased year by year.

According to China Statistics Yearbook 2010, the animal stock number can be seen in the following table (Table 2-4).

Table 2-4 Discharge of Livestock and Poultry Wastes (2009)

	stock （10 thousand）	manure/d （kg/each）	urine/d （kg/ each）	manure （10 thousand）	urine
Cattle	10726.5	15	25	58727.588	97879.313
Pig	64538.6	3	4	70669.767.	94226.356.
Chicken				19335.237	0
Total				148732.592	192105.7

Note: In China Statistics Yearbook there is no stock number for chicken, the above data is based on the 13% of chicken waste of the total livestock and poultry waste in each year. The above manure and urine/d are based on the empirical data.

Theoretically, 1 kg COD removal can produce 0.35 m^3 methane. However as the dry matter content and COD content of the different kinds of animals are different, so the amount of biogas from the anaerobic fermentation process is also different (see Table 2-5).

Table 2-5 Biogas Potential of Livestock and Poultry Wastes (%）

Species	Solid content	Gas output （m^3/t fresh manure）	CH_4
Cattle manure	18-20	40-50	≧60
Pig manure	20-25	55-65	≧60
Chicken manure	30-32	70-90	≧60

According to the above data，the total waste discharge of livestock and poultry breeding in China is about 1.48732592 billion T/a, if the anaerobic digestion is adopted by all the biogas projects, the biogas output will be 81.95 billion m^3/a.

2.2.2 Biogas resources from the wastes of industrial livestock and poultry breeding

When livestock and poultry breeding have reached the certain scale, it is advisable to adopt biogas project technology for the waste treatment.

The State Environmental Protection Administration and General Administration of Quality Supervision，Inspection and Quarantine of China issued Discharge Standard of Pollutants for Livestock and Poultry Breeding on December 28th, 2001, in which the application scope for the standard is defined and the livestock and poultry farms are classified based on their scale (see Table 2-6).

Table 2-6 Suitable Scale (Stock number) for Intensified Livestock and Poultry Farm

Scale	pig（over 25Kg /each ）	Chicken/ thousand		Cattle	
		egg layer	broiler	adult milk cow	beef cattle
I	≥3000	≥100	≥200	≥200	≥400
II	500≤Q<3000	15≤Q <100	30≤Q <200	100≤Q <200	200≤Q <400

According to the statistics of the Ministry of Agriculture, the scale definition for the large and medium sized breeding farms of milk cow, cattle beef, egg layer and broiler can be seen in Table 2-7.

Table 2-7 Definition for the Livestock and Poultry Farms of Large and Medium Sized Biogas Projects

Type	pig farm （fattened stock /a）	layer farm（stock） 10 thousand	broiler(Stock) 10 thousand	milk cow (fattened stock)	cattle beef (fattened stock)/
Medium	3000-10000	5-20	10-40	200-600	500-1200
Large	>10000	>20	>40	>600	>1200

According to the statistics from the Ministry of Agriculture in 2007 (see Table 2-8), the large and medium sized livestock and poultry resources account for 8.11% of the total in China. Based on the calculation, the total waste discharge of the large and medium sized livestock and poultry farms is 120.622 million T/a and the potential biogas output is 6.646 billion m^3.

2.2.3 Status for the large and medium sized biogas project of livestock and poultry farms

According to the statistics data from the Ministry of Agriculture, there are 56,534 large, medium and small sized biogas projects treating agricultural wastes in China in 2009, of them:

(1) Large sized biogas projects（tank capacity >500m^3）	3,717
(2) Medium sized biogas projects（50~500m^3）	18,853
(3) Small sized biogas projects（tank capacity<50m^3）	33,964
(4) Annual biogas output	764.9217 million m^3
Users	971.862 thousand
Installed capacity	33,203.2 Kilowatt
Annual power generation	102.8935 million KWH

If based on the output of 455.078 million m^3/a of the large and medium sized livestock and poultry farms in 2008 （data from CHINA ANIMAL INDUSTRY YEARBOOK 2009）, the amount of the presently developed biogas is only 6.85% of that of the resources. The total number of the large, medium and small sized biogas projects treating agricultural wastes in China is 22,570 (16.7 times higher for the number and nearly 10 times higher for the output than those in 2002).

The biogas projects of agricultural wastes are distributed in 31 provinces and cities of China (see Table 2-8).

Table 2-8 China Biogas Potential of Livestock and Poultry Wastes and Corresponding Regional Distribution in 2007

Region	Total number	Large and medium sized farms		Proportion of Large and medium sized farms（%）		Total number		Large and medium scale farms	
	pig stock (10 thousand）	farm number	pig stock (10 thousand）	farm number	breeding number	biogas potential/a（10 thousand m^3）	installed capacity (MW)	biogas potential/a（10 thousand m^3）	installed capacity (MW)
Country	79578	19743	6453	0.01	8.11	3135355	10471	254261	849
Beijing	418	491	184	0.79	44.15	16464	55	7268	24
Tianjin	585	266	107	0.34	18.28	23034	77	4210	14
Hebei	8490	1149	531	0.02	6.26	334503	1117	20933	70
Shanxi	1282	255	86	0.02	6.73	50517	169	3400	11
Inner Mongolia	4173	726	198	0.02	4.74	164422	549	7792	26
Liaoning	3134	958	245	0.03	7.82	123481	412	9653	32
Jilin	2673	904	174	0.03	6.51	105303	352	6850	23
Heilongjiang	3283	521	182	0.02	5.54	129353	432	7167	24
Shanghai	202	274	126	0.11	62.42	7972	27	4976	17
Jiangsu	2313	638	234	0.02	10.11	91148	304	9215	31
Zhejiang	1176	659	258	0.03	21.98	46326	155	10180	34
Anhui	2472	696	186	0.01	7.52	97404	325	7324	24

Table 2-8 China Biogas Potential of Livestock and Poultry Wastes and Corresponding Regional Distribution in 2007(Continued)

Fujian	1200	837	298	0.04	24.87	47283	158	11758	39
Jiangxi	1838	733	252	0.02	13.70	72433	242	9923	33
Shandong	6820	1506	505	0.03	7.41	268703	897	19900	66
Henan	7359	2898	841	0.03	11.43	289930	968	33146	111
Hubei	2572	984	342	0.01	13.29	101329	338	13472	45
Hunan	5114	900	265	0.01	5.18	201478	673	10431	35
Guangdong	2380	1791	582	0.04	24.45	93763	313	22928	77
Guangxi	2698	787	266	0.01	9.85	106320	355	10468	35
Hainan	359	152	62	0.01	17.40	14147	47	2462	8
Chongqing	1208	162	47	0.00	3.88	47609	159	1845	6
Sichuan	6156	488	146	0.00	2.37	242527	810	5760	19
Guizhou	1848	34	13	0.00	0.72	72794	243	523	2
Yunnab	2456	132	40	0.00	1.64	96759	323	1590	5
Tibet	322	0	0	0.00	0.00	12682	42	0	0
Shaanxi	1802	227	70	0.01	3.89	70995	237	2764	9
Gansu	1107	138	38	0.00	3.40	43630	146	1483	5
Qinghai	339	1	1	0.00	0.15	13372	45	20	0
Ningxia	578	91	46	0.01	7.91	22780	76	1802	6
Xinjiang	3221	345	127	0.02	3.95	126892	424	5018	17

The proportion of different wastes can be seen in Fig. 2-1 and 2-2.

It can be seen from the biogas potential proportion of different livestock and poultry wastes that the biogas production potentials of different animal wastes from the national breeding farms and large and medium sized scale livestock and poultry farms are : pig >milk cow>beef cattle >layer >broiler (see Fig. 2-1 and 2-2).

The main characteristics of this kind of project are:

(1) The average construction scale of the biogas project is 300 m^3/each，it is smaller than that of the industrial wastewater and municipal solid waste landfill.

(2) The biogas projects are mainly distributed in big sized provinces and big or medium-sized cities for livestock breeding, such as Shandong, Henan, Hebei, Sichuan, Hunan, inner Mongolia etc.

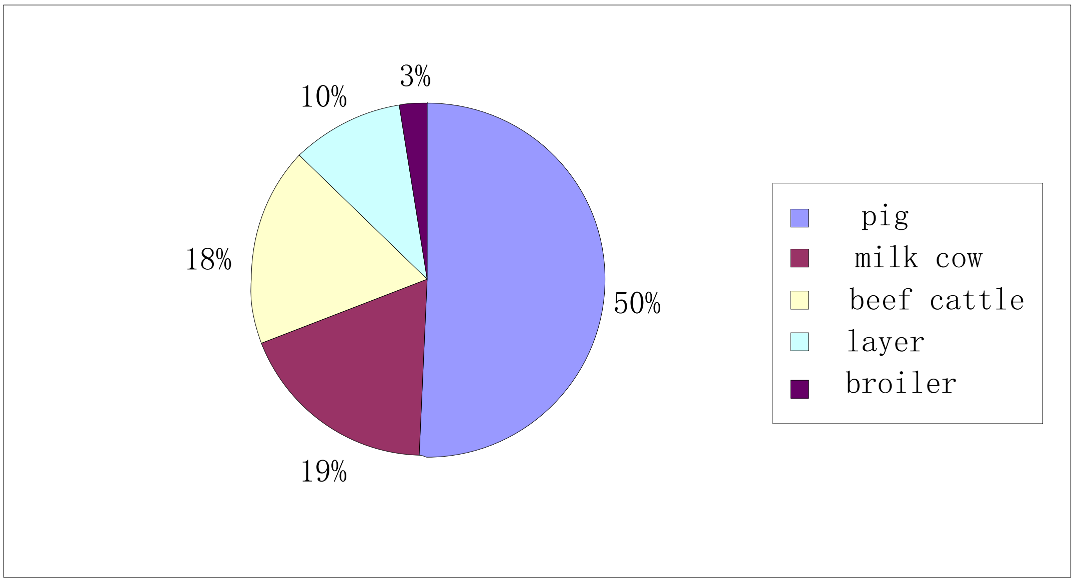


Fig. 2-1 Different Proportions of Biogas Production Potentials from Different Animal Wastes

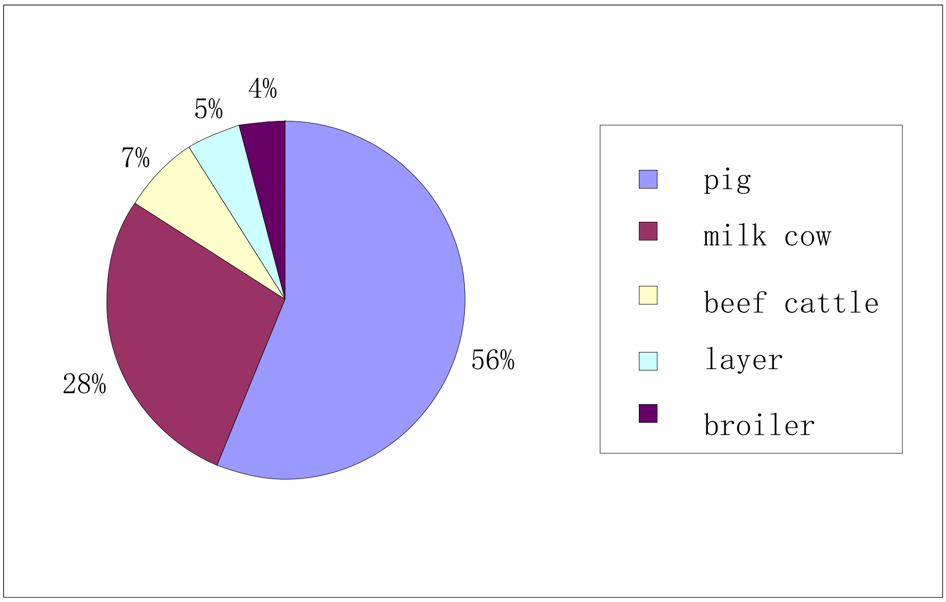


Fig. 2-2 Different Proportions of Biogas Production Potentials from Animal Wastes of different Kinds of Large and Medium Sized Scale Livestock and Poultry Farms

2.3 Biogas of Municipal Solid Wastes (Landfill Gas)

2.3.1 Resource

In the municipal solid waste area, the biogas relates mainly two aspects, one is the landfill biogas, the other is the anaerobic digestion of organic waste. Currently, the anaerobic digestion of organic waste in China is still at an initial stage, few of the projects are put into operation and biogas utilization is concentrated in the landfill gas utilization.

Landfill gas（LFG）is a combustible gas which is produced from the organics in the domestic waste decomposed by biogas fermentative microorganism. The main components of landfill gas are methane (CH_4）and CO_2, about 50～60% for methane content and 40～50% for CO_2 content, the rests are small content of H_2, N_2 , H_2S etc. The typical characteristics of the landfill gas are: temperature 43～49℃；relative density about 1.02～1.06；gross heat value 15630～19537 kJ/ m^3.

The methane content of landfill gas is generally over 50%. The explosion would occur when the methane concentration in the air is between 5％～15％. The flammability of the methane ($CH_4+O_2=CO_2+8813$ kJ/mol）determines its potential utilization value.

The negative effect of the landfill gas mainly embodies in the following aspects: enhancing greenhouse effect, equivalent to 21 times of CO_2; leading to offensive odor; toxic effect and health problem; the potential explosion; and vegetation growth problem etc.

Based on CHINA CITY STATISTICAL YEARBOOK 2010, by the end of 2009, the amount of domestic waste collection and transport in 654 cities of China is 157.3 million T (see Table 2-9). Based on the current biogas production of waste landfill in China, 100~150 m^3 of biogas (50% methane content) could be produced from 1 T of domestic waste. So the theoretical resource of biogas production from domestic waste of China is 15.7 billion m^3.

Table 2-9 Collection , Transport and Disposal of Consumption Wastes in Cities by Region (2009)

Region	Consumption Wastes Collected and Transported (10 000 tons)	Number of Factories for wastes Treatment (unit)				Treatment Capacity (ton/day)			
			Landfill	Piling	Burning		Landfill	Piling	Burning
Nation	15733.7	567	447	16	93	356130	273498	6979	71253
Beijing	656.1	19	16	2	1	13680	12280	800	600
Tianjin	188.4	7	5		2	7600	5800		1800
Liaoning	813.3	13	11	1	1	11695	10695	600	400
Heilongjiang	912.4	18	16		2	10048	9548		500
Shanghai	710.0	12	4	1	3	10345	5750	500	2575
Jiangsu	957.3	41	27		14	34570	20502		14068
Zhejiang	925.6	52	31		21	31173	15408		15765
Shandong	958.4	54	45	1	6	32810	24520	660	6700
Guangdong	1960.6	37	19		17	36087	22702		13035

Currently, there are mainly three kinds of methods for the calculation of the biogas from waste landfill, including statistical model, dynamic model and empirical model, of them the empirical estimation model of IPCC（Inter-government Panel on Climate Change）is relatively authoritative after the improvement year by year. Based on the IPCC 2006, it is estimated that the landfill gas from municipal waste sanitary landfill of China is 130.8 m^3/T, similar to the measured value of some landfill in China (see Table 2-10).

Table 2-10 Measured Biogas Production Value of Some Waste Landfills in China

Project Name	Gas yield（m^3/t）	Life time（a）	Average yield（m3/t*a）
Tianziling Hangzhou	140.46	23	6.11
Datianshan Guangzhou	127.98	18	7.17
Likeng Guangzhou	115.49	16	7.22
Xingfeng Guangzhou	121.74	18	6.75
Cuigu HK	111.12	17	6.54
Laogang Shanghai	137.34	22	6.24
Average	125.69	19	6.67

Here based on the biogas production of 100 m^3 /T of municipal waste landfill, then the theoretical value of biogas production from domestic waste of China in 2010 is 8.896 billion m^3.

2.3.2 The actual biogas production from domestic waste landfill

Based on the China City Statistical Yearbook 2010, by the end of 2009, there are totally 567 domestic waste treatment facilities, of them 447 landfills (accounting for 78.84% of the total), the treatment capacity is 273 thousand T /d and actual treatment is 88.96 million T /a.

Compared with the developed countries and regions, the domestic waste component of China has the characters of high content of degradable organic waste (such as food waste) and high content of water. So the biogas production during the waste landfill is faster, up to the gas production quickly and then followed up with a fast drop（see Table 2-11）.

Table 2-11 Comparison of Domestic Waste Components Between China and the Other Countries

Nation/ City	Organic（%）						Inorganic（%）			
	food	paper	plastic rubber	textile	bamboo	sub-total	metal	glass	marlstone tile	sub-total
China	49.3	6.7	10.7	2.1	2.8	71.6	1.0	3.0	24.4	28.4
US	23.1	39.3	13.3	4.0	5.5	85.2	7.8	5.4	1.5	14.8
EU	25.0	35.0	11.0	2.0	-	73.0	3.0	6.0	18.0	27.0

In addition, due to some factors including the equipment, technology and management of the landfill in China, the average collection rate of the actual landfill is about 20%. Based on the calculation, the annual biogas production of the domestic waste in China is roughly about 1.8 billion m^3（50% methane content）.

The following statistics can be drawn from the above calculation:

（1）National waste landfills 447

（2）Annual biogas production 1.8 billion m^3

（3）Biogas resource in 2010 8.896 billion m^3

（4）Proposition of annual biogas production in the total resources 20.23 %

2.3.3 The current status of domestic waste landfill

Compared with 2001, the domestic waste collection and transportation of China is increased by 16.8% in 2009. The annual growth is 2% on the average，the harmless treatment of domestic waste is increased from 58.2% in 2001 to 71.3% in 2009.

The construction of the domestic waste landfill in China has been promoted steadily, especially with the support of the national bond funds, a number of landfills with artificial seepage control system are built and put in to operation. The landfill is still a main process for the treatment of domestic waste in China and the number of landfills and their treatment capacity will maintain a growth momentum (see Fig. 2-3）.

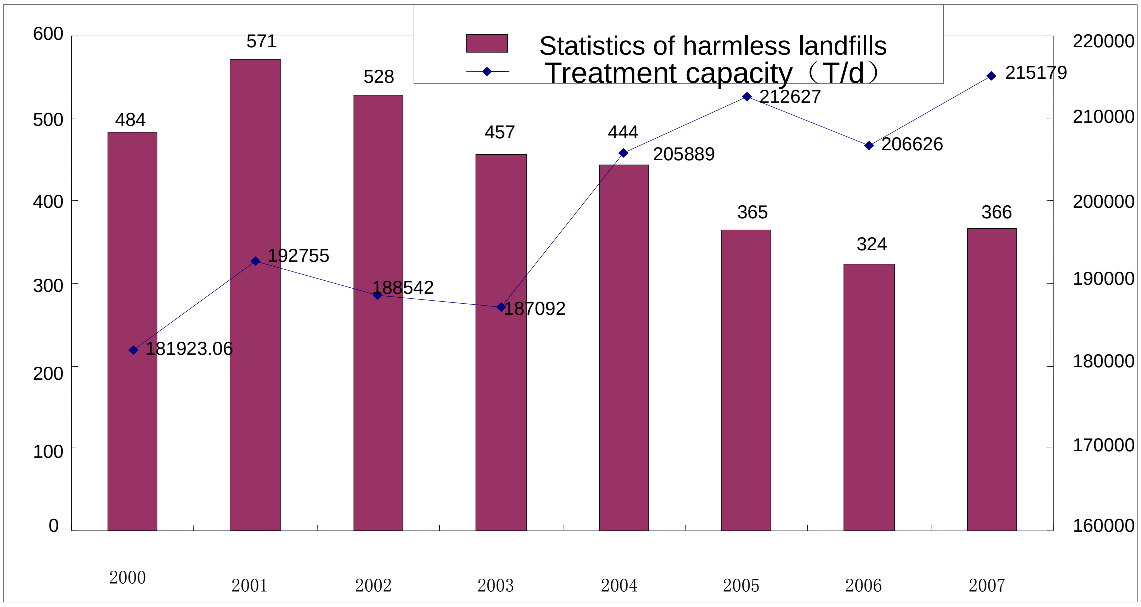


Fig. 2-3 The Number of Municipal Waste Landfills in China and Daily Treatment Capacity

At present, the construction level of landfill seepage control in China has reached the higher requirement standard of the developed countries (see Table 2-12)，For example, the basic requirement for the basement leachate control of the domestic sanitary landfill is up close to the Germany standard and higher than those of the European Union and USA.

Table 2-12 Comparison among the Basic Requirements for the Basement Leachate Control of the Domestic Sanitary Landfills

Basic requirement for artificial seepage control	Basic requirement of USA (40CFR 258)	Basic requirement of European Union (Landfill Directive 1999/31/EC)	Basic requirement of Germany （TASI，1993）	Engineering technology standard CJJ113—2007
Leachate support layer	$K>1\times10^{-4}$ m/s thickness 0.3 m	thickness 0.5m	thickness≧0.3 m $K\geqq1\times10^{-3}$ m/s	$K\geqq1\times10^{-3}$ m/s thickness 0.3 m
plastic film liner	no less than 0.75 mm plastic film, suggested thickness 1.5mm HDPE film	no requirement details，but the capacity should reach thickness 100 cm（$K\leqq1*10^{-9}$ m/s）	thickness≧2.5 mm HDPE film	thickness≧1.5 mm HDPE film
clay layer	$K\leqq1*10^{-9}$ m/s thickness 60cm	plastic film, clay layer thickness > 50 cm	$K\leqq5\times10^{-10}$ m/s thickness 3×25 cm	$K\leqq1\times10^{-9}$ m/s thickness 75 cm

The Ministry of Construction organized the functional check and harmless grade estimation of landfill in 2006. In accordance with the result, up to the end of 2005, the operational landfills are 372 across China and the treatment capacity is 194.7 thousand T/d, of them 190 are above the grade II and the treatment capacity is 127.5 thousand T/d, and most of them adopted HDPE film for Impermeable membrane for leakage prevention.

Between 2008-2009, the national second harmless grade estimation of domestic waste landfills involved 156 landfills in 23 provinces, autonomous regions and municipalities. After verification, totally 135 landfills met the evaluation standard, of them 48 were honored as Grade I, with total treatment capacity of 26,773 T/d；76 were honored as Grade II, with total treatment capacity of 32252 T/d；11 were honored as Grade III. In addition there are 20 county-level landfills and one of them had not yet been awarded the title according to the regulation, as its operation was less than one year. In accordance with the regulation of Harmless Evaluation Standard for Domestic Waste Landfills, the Grade I and II are defined as harmless treatment facilities for domestic waste treatment, there are all together 124, the total harmless treatment capacity is 59,025 T/d，the treatment capacity will be included in the total harmless treatment of the domestic waste of the city in the specific year.

2.3.4 Status of the collection and utilization of landfill gas

The remarkable progress has been achieved currently in the collection, treatment and utilization of landfill gas in China. The power generation plants of landfill gas in many cities of China, such as Hangzhou, Guangzhou, Nanjing, Xian, Wuhan, Beijing, Shenzhen, Fuzhou, Shijiazhuang, Chengdu etc. have been set up or put into operation.

In October, 1998, the first landfill power generation plant of China was set up in Hangzhou Tianziling Landfill and put into operation, with an investment of 3.5 million US$. The annual power generation capacity is nearly up to 16 million KWH and the production value is 7.9 million Yuan. By such means, CO_2 discharge can be decreased by 80-100 thousand T/a.

The first generator unit of Guangzhou Datianshan was put into operation during its first stage project on June 25th, 1999, with an investment of 2.8 million US$, installed capacity of 970 KWH and a sucking rate of 600 m^3/h. The implementation of the projects have laid a solid foundation for the development and utilization of landfill gas in China.

In July, 2002, Nanjing Shuige Landfill Gas Power Generation Plant was put into operation with the support of Global Environment Fund. The current power generation volume is 1250 kw, treatment capacity for methane gas is 400 m^3/h, and the annual power generation capacity is 8.7 million KWH. Based on the favorable electricity price of 0.50 Yuan/KWH provided by the Nanjing government, its income from power generation has reached about 400 thousand Yuan (RMB)/month.

In addition, the other two cities (Anshan and Ma An Shan) have also started their demonstration projects with the support of Global Environment Fund, with a total investment of 73 and 5.78 million Yuan (RMB) respectively. The project of Anshan is mainly at collecting landfill gas and using it for car fuel after purification, while the gas utilization of Ma Anshan project is divided into two parts: one is to set up centralized medical waste incineration station and make use of landfill gas to incinerate medical waste；the other part is to provide the nearby explosive factory boiler with fuel though gas pipeline.

Hereafter, the number of the project for utilization of landfill gas in China is increasing year by year. Base on the investigation, up to June of 2010, there are 30 projects of landfill gas utilization are put into operation in China, mainly for power generation , and the total installed capacity is close to 70 MW.

As for the utilization of the landfill gas, many parts of the country take an active part in applying for CDM project, By July 29th, 2010, 37 projects for landfill gas utilization have got the approval from the National Development and Reform Commission. At present, most of the larger sized landfill have signed agreement with some overseas companies for landfill gas utilization.

2.4 Statistics of Municipal Sewage Sludge Converted Biogas Resources and its Development Status

The municipal sewage sludge is a sediment produced during the sewage treatment, it contains a large amount of microbes, organic substances and rich nutrients such as N, P, K etc., so it is a valuable and available resource. Of the large sized modern sewage treatment plants, most of them adopt the sludge anaerobic digestion technology for pretreatment, so as to turn the volatile solids in the sludge into humus and at the same time to recover part of the resource (biogas). By this means, the sludge volume is greatly reduced by about 60%, at the same time the sludge characteristics are improved and the pathogenic micro-organisms are controlled as well. All these have laid a good foundation for the post-treatment. Therefore, the municipal sewage sludge can be calculated as one of the resources which are convertible into biogas.

2.4.1 Total amount of municipal sewage sludge

In accordance with the statistics from China Environment Yearbook of 2010, in the end of 2009, the municipal sewage discharge of China is 37.12129 billion m^3/a. Based on the sludge yield of 1.6 T DS / 10 thousand m^3 sewage, the dry sludge discharge is about 5.94 million T in 2009.

2.4.2 Amount of biogas resources

According to the current operation result of the sewage treatment plants (based on Beijing Gaobeidian Sewage Treatment Plant), when the entering sludge concentration is 94% and biogas output from 1 m^3 sludge is about 12 m^3， then the total biogas resource of domestic sludge is about 1.188 billion m^3, based on 5.94 million T of dry sludge converted into that with 94% water content.

2.4.3 The actual biogas output of domestic sludge anaerobic digestion

In accordance with the statistics from China Environment Yearbook of 2010, there are totally 1,692 municipal sewage treatment plants in China in 2008. Based on the current growth rate of 10%, there will be totally over 1,850 by the end of 2009. Based on the statistics of the National Seminar on New Technology and Equipment of Sludge Treatment and Utilization in Dec., 2010 (Shanghai), the sludge treatment plants of China which adopt sludge digestion technology account for about 10%, while the plants with sludge anaerobic treatment facility are all large and medium sized sewage treatment plants. Estimated on the figure, the biogas production from sludge in China is about 200 million m^3 in 2009. So the following statistics data is drawn as follows:

（1）Sludge projects of sewage treatment plant ca. 180

（2）Total biogas output/a 200 million m^3

（3）Proposition of annual biogas production in total resources 16.8%

2.4.4 Status of biogas production from domestic sludge

Along with the rapid development of our economy, the environment pollution is getting more and more serious. As one of the important parts of water environment treatment, the municipal sewage treatment has obtained a great attention from the government and all walks of life. The amount of municipal sewage and sludge treatment is increased more and more. Currently, the annual growth is over 10%. As the byproduct of municipal drainage system, the sludge has some disadvantages such as big volume, unstable, perishable and odorous, the secondary pollution will be occurred if it is not treated and disposed properly and it will bring about serious threat to the environment. However, limited by the development level of the municipal sewage treatment and degree of awareness, the sludge treatment and disposal have not yet been paid enough attention in China. The number of sewage treatment plant with sludge disposal only accounts for 25% of the total.

Of the main technologies for sludge treatment and disposal, sludge anaerobic digestion and compost for agricultural use account for 44.8%，landfill for 31% and the others for 10.5%. The common processes are anaerobic digestion (38.04%)，sludge compost (3.45%) and aerobic treatment (2.81%). At present, the sludge compost is under continuous research, incineration is too costly, while pyrolysis and chemical stabilization are seldom applied due to some technical, economic and energy reasons.

In conclusion, sludge anaerobic digestion for biogas recovery, while the sludge after anaerobic treatment for use as fertilizer or for landfill will be one of the main technologies for sludge treatment for quite a long time in China due to its fitness and it will maintain continuous development.

3. Industrialized Development Status of the Large and Medium Sized Biogas Projects

3.1 Technologies and Equipment of Biogas Projects

3.1.1 Major technical processes and equipment

（1）The biogas project for industrial organic wastes in China has development rapidly for the last decade, it is unique worldwide and has Chinese characteristics.

As stated above, 85% of the raw materials for the production of light industry and non-light industry are grain and agricultural by-products, containing high carbon, nitrogen, phosphorus and organics. The wastewater and residue from production also contain high organics. Therefore, these organic wastes can be utilized stably and effectively by the biogas project.

Based on the temperature of the wastewater and residue, the biogas project adopts mainly thermophillic digestion（52~56℃）and mesophillic digestion（35~38℃）。

The selection of the anaerobic reactors depends on the concentration of the wastewater, especially on that of the total solid. In general, CSTR is adopted when the total solid content is above 6% and the UASB and IC are adopted when the concentration of COD is below 10,000 mg/l and that of the total solid is below 3,000 mg/l.

There are also other reactors for application, such as EGSB, AF, UBF（Anaerobic complex reactor）.

According to the statistics, of the biogas projects for industrial organic wastes, UASB and CSTR（USR）account for 80% of the total. The estimation from the survey of 2000 built industrial biogas projects is shown in Table 3-1.

Table 3-1 Biogas Fermentation Process forIndustrial Organic Wastewater

	Kind of the Reactor	Number	Proportion（%）
1	UASB	1000	50
2	CSTR（USR）	500	25
3	IC	300	15
4	others	200	10
5		2000	100

As for the degradable（COD/BOD=2/1）thermophillic organic wastewater, CSTR is adopted and the maximum gas yield is up to 4.0~4.5 m^3/m^3·d, with a COD removal over 85% and a load rate of 8~10 kg COD/m^3.d. There are several mixing types for CSTR, hydraulic circulation, jet pump, mechanical and biogas mixers for example.

UASB is now used widely, especially in the biogas project with medium-low concentration wastewater. Generally, the load rate can reach over 10 kg COD/m^3.d, at mesophillic digestion.

EGSB process could achieve better effect when treating low concentration wastewater at low temperature.

Beijing Municipal Research Institute of Environmental Protection and Jinan Shifang Environmental Protection Co, Ltd undertook a national 10th five-year key project of Yishui Dadi Maize Developing Company Lid. In the company, the original EGSB（effective volume 275 m^3）was modified into suspended granular sludge bed reactor. According to the test result: when COD concentration of the influent is 2,000~3,000 mg/l，the reactor could operate stably at 30 kg COD/ m^3.d, with an average removal of 90%.

（2）Large and medium sized biogas projects of livestock and poultry farms

The agricultural biogas project in China deals mainly with livestock and poultry wastes and their washing water. However in recent years, there are some projects which use the mixed raw materials of crop straw and the animal wastes.

The Large and medium sized biogas projects of livestock and poultry farms mainly adopt vertical reactor, a small part adopt underground baffled reactor. Most small biogas projects are the simple enlargement of rural household biogas tank.

Nearly all the conventional and high-efficiency anaerobic digestion processes are applied in China, such as CSTR, Anaerobic Contact Reactor（AC）, UASB, Upflow Solids Reactor（USR）, IC etc.

Table 3-2 shows the proportion of the adopted reactors (an rough estimation from the survey) , of them CSTR and USR account for 65%.

Table 3-2 Technologies for the Large and Medium Sized Biogas Projects of Livestock and Poultry Farms

	Kind of the Reactor	Proportion （%）
1	CSTR	25
2	USR	40
3	baffled reactor	20
4	UASB	10
5	others	5
6		100

In order to save water resources and ease the load of follow-up standard treatment, currently most of the large and medium sized livestock and poultry farms adopt manual dry cleaning manure process. As the sewage from washing enters into digestion system to reduce the concentration of the fermentation material（TS 1%~3%）and the anaerobic digestion is generally conducted at normal temperature, so the gas yield is also very low（0.1~0.5 m^3/ m^3/.d）. Therefore, the running effect of the project is greatly influenced by the temperature. There is no obvious deference among the efficiencies of above processes in the project application. Generally, there is no agricultural biogas project in China which uses mechanical mixer, only a small part adopts back flow agitation, so the biogas yield / tank volume is relative low. Table 3-3 shows the general processes adopted by the large and medium sized biogas projects of livestock and poultry farms in China.

Table 3-3 Processes adopted by the large and medium sized biogas projects of livestock and poultry farms

Process type	Application type
TS content of feed（%）	＜2
Fermentation temperature	Normal
Fermentation process	Various digestions
Mixing type	With or without hydraulic mixer
Hydraulic retention time（d）	5～10
Volume load（VS/kg/m^3.d）	1.2～1.5
Gas yield（m^3/m^3.d）	0.1～0.5
Storage type	wet
Heating source	Coal or boiler hot water

Note: The TS content of feed means the average content of the biogas projects.

Along with the rapid development of large and medium sized biogas projects of livestock and poultry farms in recent years and import advanced technology and equipment from Germany, Denmark etc., the biogas power generation demonstration projects have been constructed though high efficiency biogas plant combined with heat, power and fertilizer production. For example, the demonstration project of Mengniu Australia International Dairy Farm (daily treatment capacity of 10,000 milk cow waste） and biogas power generation project of Beijing Deqingyuan Chicken Farm（daily power generation of 30,000 kwh）have been put into operation one after the other.

（3）Biogas project for municipal sewage sludge treatment

The surplus sludge from the municipal sewage treatment enters into anaerobic reactor after dewatering (94%~96% water content). As the sludge contains high suspended solid, CSTR is generally adopted for its treatment. There are two structures for CSTR, one is steel structure and the other is reinforced concrete structure. In addition, there is also an ovoid reactor imported from Germany. In general, mesophilic fermentation is adopted , with a hydraulic retention time of 20~30 days，so the single volume of the anaerobic reactor is normally above 1000 m^3 . The mixers within the reactor are biogas (compression) mixer, sleeve -type

(circulation) mixer or mechanical mixer etc.

Most of the tank group volume of large sludge treatment biogas project are more than 10,000 m^3.

（4）Introduction to several major anaerobic reactors

UASB — Up-Flow Anaerobic Sludge Bed, the key technology is the three-phase separator installed in the reactor, it prevents the loss of granular sludge cultured in the reactor and therefore greatly increases the anaerobic fermentation efficiency. The advantages of the reactor are non-stirring, simple operation, suitable for high or low COD concentration and small floor space, so it has won widely application. In recent 10 years, based on the introduction and digestion, the relative domestic research institutes and companies have made a further development on UASB. Currently, two major series of standardized designs are available (rectangular and round shaped UASB) and they are applied in the actual projects. Currently, the biggest UASB unit volume is up to over 4000 m^3 in China. In the past 10 years, owing to the domestic design and manufacture of the multi-layer modular three-phase separator made of steel or engineering plastic, the anaerobic fermentation rate has been improved further.

CSTR — Continuous Stirred-Tank Reactor (there is no mixing device in the system) , it is suitable for the high concentrated and high suspended wastewater and used mostly for alcohol slops and municipal sewage treatment. The most biggest tank group for alcohol slops was built and put into operation in Guiping Jinyuan Biological Chemistry Company of Guangxi Province in early 2008. The total volume of the tank group is over 60,000 m^3 and biggest unit volume of 8,000 m^3.

USR — Up-Flow Solid Reactor, it is an simple-structured digester and suitable for high suspended solid material. Its structure is shown in Fig. 3-1.

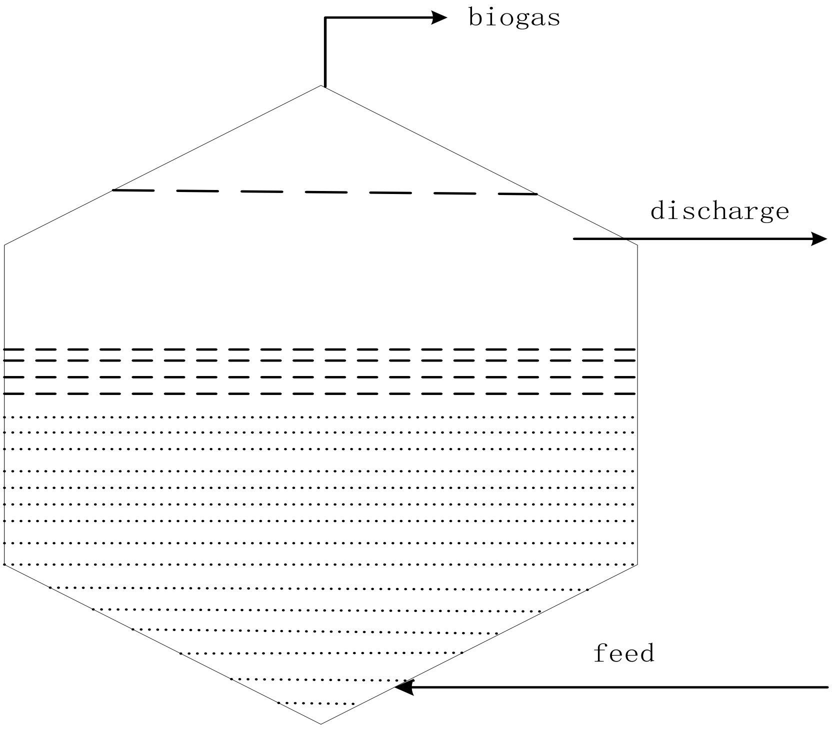


Fig. 3-1 Sketch Map of USR Reactor

Fig.3-1 Sketch Map of USR Reactor

The raw material enters into the digester from the bottom, there is no three-phase separator and mixing device installed in the reactor. The wastewater (residue) and biogas microbes are at the bottom, while the supernatant is released from the upper part.

Currently, USR is used mostly in the treatment of wastewater from agricultural livestock and poultry sector, accounts for about 40% in the large and medium sized biogas projects.

Due to no mixer, low reaction rate and high concentrated COD in the discharged biogas residue and waste liquor, USR is only suitable for field fertilization (ecological treatment) rather than the follow-up aerobic treatment for the emission standard.

By this way, SRT and MRT could be obtained, which are much higher than HRT, so that the dissociation rate and digestion efficiency for solid organics are enhanced remarkably.

IC — Inner Cycled Anaerobic Reactor

It is the world's most high-efficiency anaerobic reactor at present. The reactor combines the advantages of both UASB and fluidized bed reactor and it is a new type reactor which makes use of lifting biogas from the reactor to realize the inner circulation of fermented liquor. IC could be regarded as the overlap of two UASB reactors and it is particularly suitable for low suspended and low concentrated wastewater (such as the wastewater from beer, pulp & paper, starch sectors). Its volume load rate is about 3 times higher than that of the conventional UASB, so it saves a lot of land. However, the requirement is very strict for its manufacture, start-up and operation management.

Others :

EGSB — expanded granular sludge bed

AF — Anaerobic filter

UBF — Up-flow blanket filter

（5）Technical and economic comparison among several anaerobic treatment technologies

Table 3-4 summarizes the technical and economic characteristics of several anaerobic processes.

Table 3-4 Technical Characteristics of Several Fermentation Processes

	Type	Common digester	USR	CSTR	UASB	IC
1	organic load (Kg COD/m^3.d)	< 3.0	4.0-6.0	5.0-10.0	8.0-15.0	15-30
2	allowable organic suspended content for influent	up to 50g/l	up to 30-60g/l	up to 50g/l	generally <4g/l	<1.5 g/l
3	COD removal	lower	lower	medium	higher	higher
4	HRH (d)	15	8-15	4-10	1-10	0.5-4
5	power consumption	higher	low	higher	lower	low
6	production control	easier	easier	easier	difficult	difficult
7	investment	higher	medium	medium	lower	higher
8	occupied Land	larger	medium	medium	smaller	small
9	production experience	less	richer	richer	richer	less
10	Operation cost	low	low	low	low	medium

（6）Based on the above comparisons, the anaerobic technologies of domestic adoption have the following characteristics:

① Widely-used advanced anaerobic reactors

UASB is widely used all over the world, due to its high efficiency, low power consumption and small land space. In the past dozen of years, UASB has been developed very rapidly in China (especially in the up-to-standard wastewater treatment projects), accounting for over 50% of the biogas projects for industrial wastewater treatment (roughly 1,000).

IC is now the world’s most efficient anaerobic reactor, with strict technology and operation management. In the past decade, the number of newly built IC reactors in China has been greatly increased several-fold, about over 300 were put into operation (load rate >15 kg COD/m^3·d) in 2010 which is 10 times higher than that of 2002, accounting for about 15% of industrial biogas projects. This proportion is similar to that of the developed countries, which indicates that the technical level of China’s biogas project has been approached to the world’s advanced level.

② Extending area of anaerobic technology application

Fig. 3-2 shows the domestic anaerobic facilities based on industrial classification (totally 2000 for 2010).

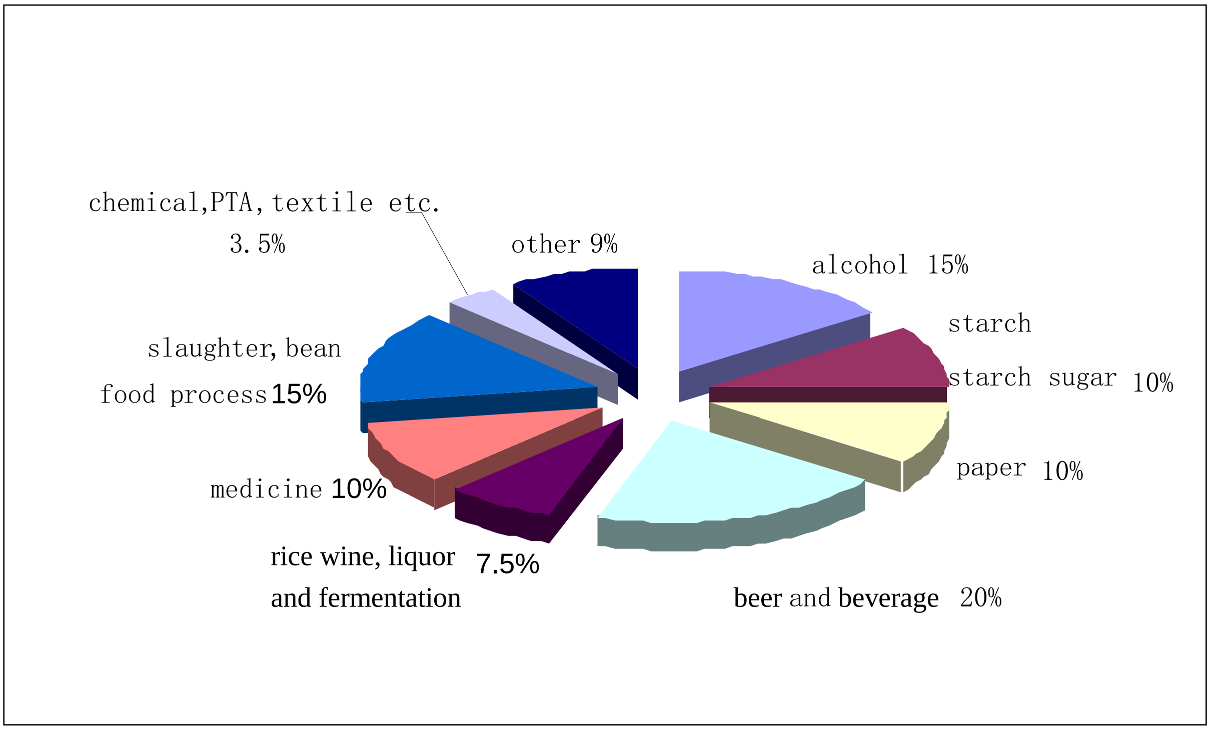


Fig. 3-2 Domestic Anaerobic Facilities Based on Industrial Classification

Fig. 3-3 is the result of an investigation made by the Environmental Protection Research Institute of Light Industry in 2002.

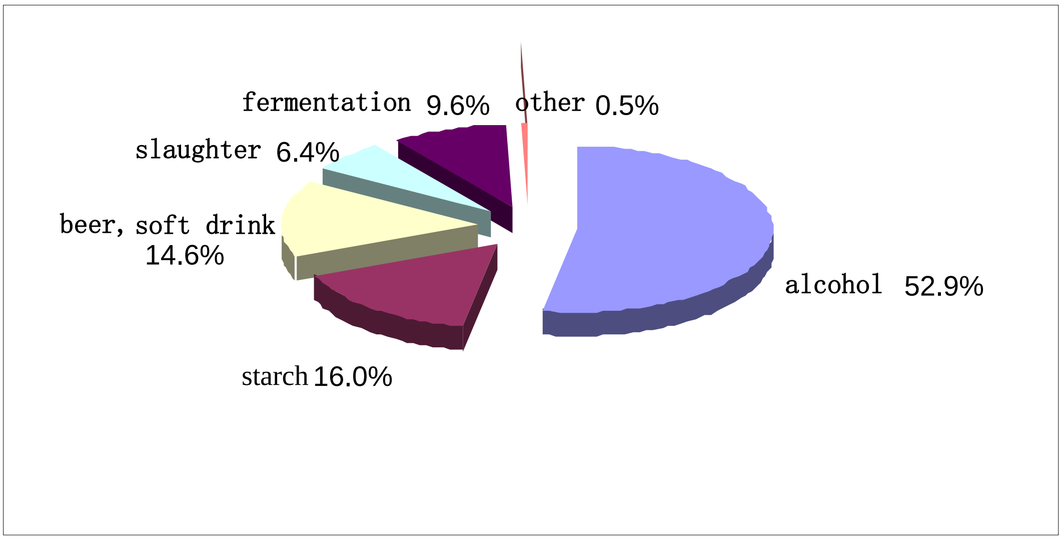


Fig. 3-3 Domestic Anaerobic Facilities Based on Industrial Classification（totally 219）

Fig. 3-4 shows the statistic data for anaerobic application of the two major companies （PAQUES and BIOTHANE）, which account for 63% of the international market (industrial wastewater). The investigation was made 10 years before.

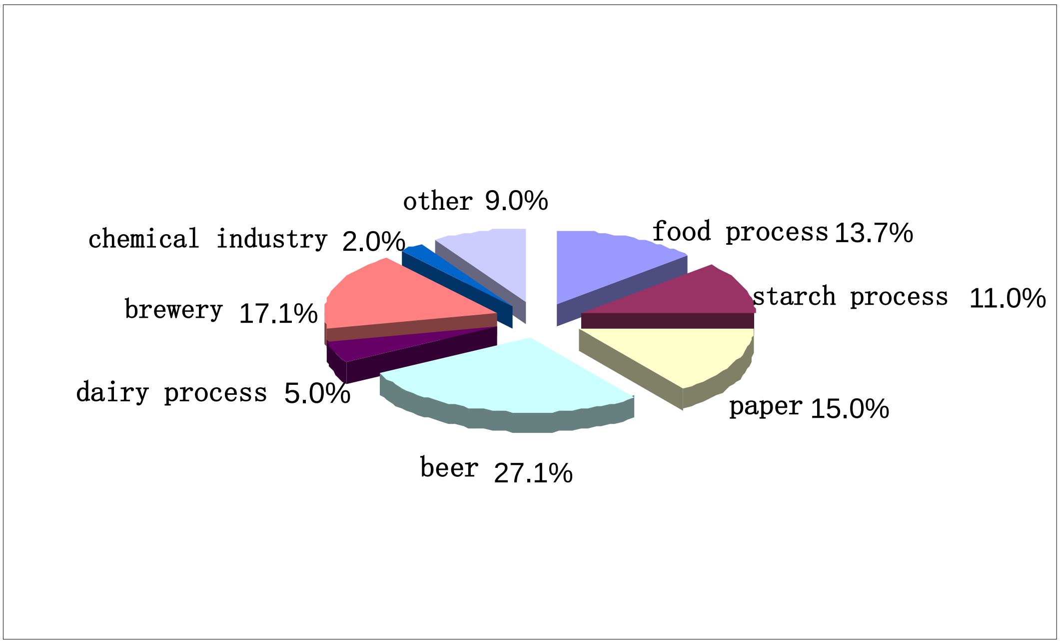


Fig. 3-4 Anaerobic Facilities of PAQUES and BIOTHANE based on the Statistics of the Type of Wastewater (totally 372)

In comparison among the above 3 figures (Fig. 3-2, Fig. 3-3 and Fig.3-4), it shows that the anaerobic technology is mainly applied in the process of agricultural by-products (such as alcohol, sugar, beer etc.) at the beginning, later when the technology is gradually getting mature, it is expanded to other treatment areas (such as wastewater from paper making, slaughter (low concentration) , municipality, as well as those from pharmacy (Chinese medicine) and chemistry which contain refractory organics.

With only 10- year period, the anaerobic technology has been successfully applied in more than 20 industrial sectors, it indicates that the anaerobic technology and its wide application area in China have been up to the international level.

3.1.2 Complete technology of biogas project

The research and development of complete biogas project equipment (including introduction and digestion) have been reached to higher standard. Now there are different types and specifications products sold in the market and widely used in all kinds of biogas projects.

(1) Solid-liquid separator

Horizontal spiral discharge centrifuge: The treatment capacity of various specifications of domestic horizontal spiral discharge centrifuge is up to 20~30 m^3/ h, after separation, the water content of the dry residue is 78%~82% and recovery rate of SS is 70~90%，up to the standard of international brand.

Plate and frame filter press: It is a kind of separating device which developed very rapidly in the last decade, with a great number of domestic manufacturers in China. In general, its SS removal from the wastewater is over 95% and water content of filtered residue is about 60%. Now there are various specifications of belt filter press and vertical filter press.

(2) Biogas desulphurization device

Dry desulphurization (also known as ferric oxide desulphurization) : Various forms of desulphurization agents for tower-type desulphurization device have been produced by Chinese enterprises, including ring, globular or strip Stripe forms etc.

Wet desulphurization: Absorbing H_2S by 2%~3% sodium carbonate solution.

Bio-desulphurization : Desulphurization by microorganism. The technology has been imported from Germany and other countries and applied in the large and medium sized biogas projects. The cost for desulphurization is only 30% of the conventional method.

(3) Biogas storage tank

Low-pressure wet or dry type gas storage tanks of different specifications have been designed in China, with the advantages of simple structure, easy construction and reliable operation. They have been widely used in the large and medium sized biogas projects in China.

Double-membrane dry-type gas storage tank is shown in Fig, 3-5 and 3-6.

Fig. 3-5 Outlook of Double- Membrane Dry -type Gas Storage Tank

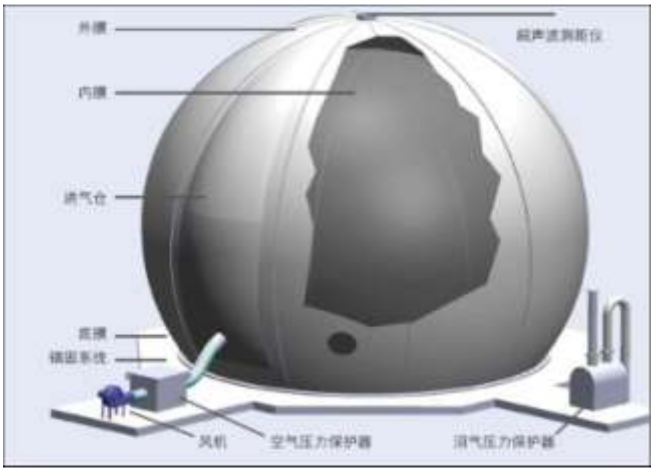


Fig. 3-6 Structure of Double- Membrane Dry-type Gas Storage Tank

This kind of gas storage tank is imported in the recent years. It is a high-level technology with the advantages of safety and reliability, anti-ultraviolet radiation and leak, and easy construction. It has been applied in the domestic large and medium sized biogas projects.

(4) Biogas power generator

Thanks to the research and development for more than a decade, the technology for biogas power generator it getting mature gradually. For example, the biogas power generators made by Jinan Diesel Green Energy Engine Co., Ltd. and Shengli Power Machinery Group Co., Ltd. have past the quality test. Their unit products are 500 kw and 700 kw respectively, with average power generation capacity of 1.6 kwh / m^3

biogas. The main technical indicators of the products have met the requirement indicated in the Technical Guidelines for the Project Construction of Biogas Power Generation issued by the State Development and Reform Commission. The power generation efficiency of the Generating set is no less than 33% and its heat (cold) supply is no less than 70% of the total heat (cold) load.

3.2 Biogas Project Design, Standard, Financing System and Economic Analysis

3.2.1 Project scale and economic benefit analysis

The biogas projects for industrial wastewater（residue）and municipal sewage sludge have formed certain scale, with an average thank volume of about 2,500 m^3 for each project. It is estimated that there are more than 50 large sized biogas projects with group tank volume of over 10,000 m^3.

The biggest tank group for alcohol slops was built and put into operation in Guiping Jinyuan Biological Chemistry Company of Guangxi, with a total volume of CSTR tank group over 60,000 m^3 and UASB tank group over 14,000 m^3, the biggest CSTR unit volume of 8,000 m^3 and daily biogas output of 120 thousand m^3.

The biogas project of Henan Tianguan Alcohol Group (a project in preparation) is planned to construct a group of CSTR tanks with a total volume of 160 thousand m^3 to treat alcohol slops (with Japanese loan). It is planned that the biogas is used for grid power generation and part of it is provided to the citizens of Nanyang.

The average tank volume of the large and medium sized biogas projects of livestock and poultry farms is 300 m^3. The large sized biogas projects with tank volume over 500 m^3 account only for 6.6% of the total, the medium sized biogas projects with tank volume between 50~500 m^3 account for 33.3% and the small sized ones account for 60.1%.

Due to the strict environmental requirement for the industrial enterprises, the initiative of the enterprises for biogas project is enhanced greatly, especially for the enterprises discharging high concentrated organic wastewater, as a good economic benefit can be gained from the biogas project and the payback time is generally less than 5 years (for alcohol and starch). The biogas yield varies with different concentration of the wastewater. The investment for three types of biogas projects is shown in Table 3-5.

Table 3-5 Investment for Industrial Biogas Projects (unit scale)

Type	Biogas output/ m^3 effluent	Investment for biogas project with 1 million m^3 /a （10 thousand Yuan）
I	>10m^3/m^3 effluent	200～300
II	5-10 m^3/m^3 effluent	600～800
III	<5 m^3/m^3 effluent	800～1000

A medium sized alcohol plant with an annual production of 50 thousand T of cassava can achieve a daily biogas production of 50 thousand m^3 and daily power generation of 80~100 thousand kwh，so the remarkable economic benefit makes it easier to get bank loan and financial fund.

It is understood that currently more than 20 projects for gasohol production are in the approval stage, with an annual alcohol production of 50-300 thousand T of alcohol. As this kind of biogas project has the best scale benefit, it is very attractive to the investors.

However, most of the biogas projects of livestock and poultry farm are relative small in scale and far from city and town, their biogas is mainly used for the production and living needs of themselves, only a small amount is used for power generation and centralized gas supply. In terms of biogas quantity, they roughly fall into II effluent of industrial biogas project （5~10 m^3 biogas / m^3 effluent ），so with poor economic benefit it is difficult for this kind of project to operate in a commercialized mode and get financial fund. Therefore it needs national sustained economic support.

Although there is little or even no economic benefit for most of the biogas projects, one of the important factors is that all the costs needed for the treatment of the organic wastewater have been included into the cost of biogas by the enterprises, so this is obviously not reasonable.

In addition, most of the products generated from biogas project (biogas and organic fertilizer) have not entered the market as actual products, i.e. the economic value of the products has not been realized yet. The biogas produced from the biogas project has not been effectively utilized and only a few projects could gain good benefit form grid power generation. Most organic fertilizer produced by the project has also not been applied effectively in the farmland and even worse, some of the fermented residue and liquid are discharged ignorantly, resulting in serious environmental pollution. For instance:

Case 2. Biogas Project of Tianmen Jiankang New Countryside Pig Farm of Hubei

The marketable fattened stock of the pig farm is 30,000 /a , with daily production of 50 T solid excrement and about 270 m^3 washing water. After the treatment of the biogas project, all the wastes are fully utilized (biogas for civil use, fermented residue and liquid for farmland fertilizer). Based on the market analysis, the annual production value of the farm is 4.522 million Yuan and the profit is 1.8917 million Yuan.

Case 5 Hangzhou Tianziling Domestic Waste Sanitary Landfill Biogas Power Generation Project

The landfill was built and put into operation in April, 1991, with daily municipal wastewater treatment over 2000 T. The biogas produced from the waste landfill is used for power generation. By this way, both economic and social benefits are gained highly, with an annual production value of 7.953 million Yuan and the payback time of 6-7 years.

In terms of economic benefit, it is suitable for the waste landfill with daily treatment over 500 T to set up a biogas power generation project.

Case 6. Biogas Project of Dalian Dongtai Xiajiahezi Sludge Treatment Plant

The biogas project is engaged in the treatment of sludge from Dalian City, purifying biogas into natural gas (（16500 m3/d）for civil use. Its economic, social and environmental benefits are gained obviously by turning humus soil (60,000/a) into compound fertilizer.

The above cases show that as long as the biogas and fertilizer products produced by the large and medium sized biogas projects are entered into market full utilized, a better economic benefit will be obtained surely.

3.2.2 The anaerobic equipment and its accessory device of the biogas project is in urgent need of standardized market and unified standard

As stated above, the biogas technologies have been mature at present in China and some of them have approached and even reached to the international advanced level. For biogas project, there have been already some departmental and local specifications and standards (from the design and construction to the operation and equipment manufacture), such as Technical Manual for Large and Medium sized Biogas Project, Construction and Acceptance Specification for Large and Medium sized Biogas Project etc. However, the authoritative national standard and specification have not been formed yet and there is no corresponding agency for technical test and supervision.

Currently, the large and medium sized biogas projects are subjected to different industrial departments, provinces and cities, without a unified administration. Due to lack of authoritative national technical standard and specification, the biogas projects in China are all designed by universities, companies and designing institutes themselves, while the constructions are organized by the owners. Therefore, the situation leads to the remarkably different technical levels of the large and medium sized biogas projects and the low rates of fermentation, gas yield and pollutant removal of the biogas equipment. It is even worse that a small number of projects have run into some losses, accidents and even failures because of unreasonable design and careless construction.

With the rapid development of Chinese biogas projects, up to now the number of the projects has been topped the world, and it is still growing nowadays. In order to promote the sustainable development of the biogas projects, a unified technical standard and specification should be made by the relative national department (as a leader) as soon as possible, so as to strengthen the project supervision and management.

3.2.3 Biogas project Construction and specialization development

Currently for the construction of large and medium sized biogas project, the owner looks for the construction team by itself, neglecting the qualification certificate for biogas project construction. Although in the last decade, a lot of specialized biogas construction companies have been set up one after the other in China, their scale is relative small. The number of competent companies is less than 20, while most of the companies have not yet formed the strong capability in design, development, construction and service.

Compared with other countries like Germany, currently there are about 400 companies in Germany which are engaged in the planning, design, construction and service for agricultural waste biogas project. Therefore, in order to enhance the overall technical level of the biogas project of China, it not only needs the reach and development of design and construction technology for anaerobic reactors and their auxiliary equipment, but also needs specialized, standardized and industrialized production. It should be done to encourage and support the development of specialized biogas company, so as to enhance the technical and constructive level for large and medium sized biogas projects, reduce project cost and increase the economic benefit.

3.3 Several Suitable Modes of the Biogas Projects and their Cases

According to the various qualities of the organic wastewater (waste) discharged from industrial and agricultural sectors, different on-site environmental conditions, different types and requirements for the treatment and utilization of the residue after anaerobic fermentation, the biogas projects can be divided into two major kinds, i.e. ecological type and environmental type. In the actual project design, the biogas project of the environmental type can be further divided into two kinds, i.e. utilization type and up-to-standard type. In recent years more and more biogas projects adopt mixed feedstock, this kind of project can be listed as mixed feedstock type.

There are huge differences in the above project modes in terms of economic, social and environmental benefits.

3.3.1 Ecological type biogas project

(Case 1. Biogas project of Deqingyuan Chicken Farm; Case 2. Biogas Project of Tianmen Jiankang New Countryside Pig Farm of Hubei)

For the ecological type biogas project, the fermented residue and liquid after biogas fermentation could be completely digested by the farm field, fish pond and orchard nearby, so it enables the biogas project to act as a bridge of the ecologically agricultural area. In general, the industrial wastewater biogas project could not be an ecological one, due to large amount of daily discharged wastewater and digested liquor, and lack of surrounding digestion condition.

In China, nearly 90% of the large and medium sized livestock and poultry waste biogas projects are ecological ones at present. Therefore, a rational allocation of breeding farms and plantation is needed, so that it can not only save the high cost for post-treatment, but also enhance the ecologically agricultural construction. Therefore this type of biogas project is an ideal process mode.

Its advantages: low investment and operational cost, due to simple post-treatment.

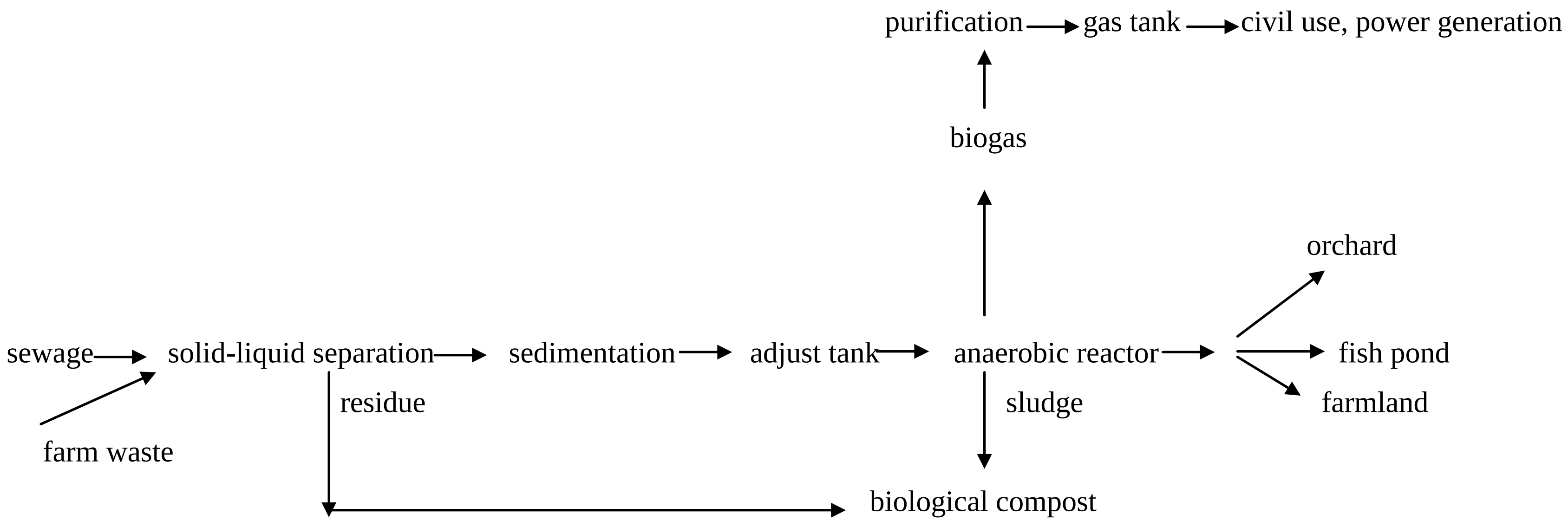


Fig. 3-7　Flow Chart of Ecological-Type Biogas Project

Table 3-6 Subsidiary Area and Investment of Ecological-type Biogas Project

Pig farm scale fattened stock /a	Waste treatment （T/d）	Anaerobic tank volume（m^3）	Subsidiary area for fermented residue and liquid digestion（Mu）	Biogas production （m^3/d）	Project investment (10,000 Yuan)
1,000	10	100	80 Mu field, fish pond and orchard	100	15
3,000	30	300	250 Mu field, fish pond and orchard	250	30
5,000	50	500	400 Mu field, fish pond and orchard	400	50

Note：The data of the subsidiary area is based on experience.

USR or CSTR can be used for this mode, with COD removal of 75~85% and gas yield of 0.6~1.0 m^3/ m^3/d. The advantages of the mode lie in the simple process, easy operation and management, low project investment and operation cost, short payback time and higher comprehensive benefit. However it needs a big environmental capacity and many occupied land resources for the subsidiary facility.

3.3.2 Environmental -type biogas project

Environmental-type biogas project is suitable for digested fermented residue and liquid which could not be digested by the surrounding environment. The biogas residue (anaerobic sludge) should be converted to commercial fertilizer, while the digested liquor should be treated up to the discharge standard.

The main target of the environmental-type biogas project is to meet the discharge standard, otherwise the project has to cease its production. For most of the enterprises, aerobic treatment should be followed to meet the emission standard, due to the great amount of discharge, full- continuous production the whole year and the discharge of the digested liquor (sludge) which can not be digested by the surrounding environment.

Concerning to the large and medium sized breeding farms, the first thing to do in the process is to minimize the sewage quantity, so as to meet the discharge standard, for example the dry cleaning of pig and cattle waste and artificial collection of solid organics. The solid organics is aerobically composted, while the wastewater gets into biogas tank for biogas fermentation.

（1）Utilization Type

(Case 3. Biogas project for dried cassava distillery’s wastewater treatment of Jiangsu Taican Xintai Alcohol Co. Ltd.)

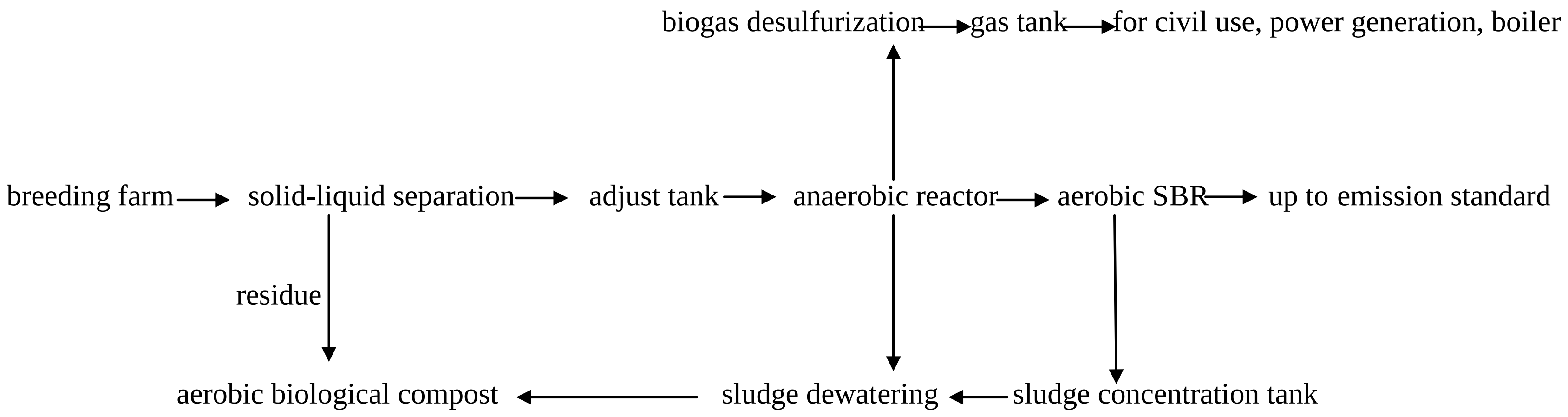


Fig. 3-8 Flow Chart of Up-to-Standard (Utilization) Biogas Project

The characteristics of this mode is：

① Good combination of biogas recovery and environmental treatment and wide application. For the industrial wastewater, this mode can recover a large amount of biogas energy and obtain organic fertilizer. As the organic waste can be fully utilized and a great amount of biogas energy can be recovered, a good economic benefit could be gained by this way. It is especially suitable for high concentrated organic wastewater due to its good biodegradability. Relatively speaking, the wastewater with a biogas production capacity of over 10 m^3/ m^3 is the most suitable one, such as wastewater form alcohol, starch and liquor sectors.

② High treatment efficiency, standardized project and high-level operation and management.

③ High removal of COD, BOD, NH_3-N and P and up-to standard discharge.

④ Fully utilized sources and developed organic fertilizer, without secondary pollution.

⑤ The disadvantages are: higher project investment and operation cost, strict operation and management. The biogas yield is relative low for livestock and poultry wastewater.

(2) Up-to-standard (environmental protection) biogas project

(Case 4. Biogas project for mechanical and de-inking pulp wastewater treatment of Fujian Nanping Paper Mill)

Through biogas fermentation process, this kind of biogas project can recover a certain amount of biogas and more important is that most (or part of) organics can be removed from wastewater by this process, so the following aerobic treatment and energy consumption could be reduced remarkably and this is favorable for meeting the discharge standard. Compared to the only aerobic method, it not only saves the investment and l floor space, but also a great amount of energy.

The wastewater treated by this mode of biogas project is generally lower in concentration (as stated in Table 2-3, the biogas output less than 10 m^3/ m^3) , mainly the industrial sectors of sugar, beer, rice wine, enzyme preparations, chemical – mechanical paper pulp, waste paper pulp etc.

The biogas project for municipal sewage sludge treatment can also fall into this kind of mode. The main purpose of this mode is to degrade and digest the surplus (aerobic) sludge from the sewage treatment plant and minimize the volume of sludge, so as to facilitate the follow-up sludge dewatering and other treatments (see Case 6. Dongtai Xiajiahezi Biogas Project of Sludge Treatment Plant, Dalian).

3.3.3 Mixed feedstock type

In recent years, more and more biogas projects are set up, which use mixed feedstock (livestock and poultry waste, stalk, kitchen refuse, sludge from domestic sewage and organic waste), this has become a new way for the biogas projects.

This kind of biogas project utilizes a large amount of industrial, agricultural or municipal organic wastes to produce biogas by anaerobic fermentation. It not only handles the environmental pollution, but at the same time also enhances the resource utilization of industrial and agricultural wastes for developing renewable energy, so as to meet the goal of energy conservation, pollution reduction and economic stainable development.

Cases:

(1) Anyang City of Henan Province imported the technology for Vehicle fuel biogas project from Denmark in 2007. The project uses local collected wastes from cattle, pig and human, wastes from slaughter and kitchen and sludge from domestic sewage treatment plant as its raw material in CSTR process, with thermophillic fermentation and 10% TS feeding concentration. The biogas is compressed into vehicle fuel after purification, while the biogas liquor and residue are used as organic fertilizer.

The project is supported by Danish governmental Partnership Facility Programme (PFP) and invested jointly by Danish Industrialization Fund for Developing Countries (IFU), NIRAS company of Denmark and Anyang Zhenyuan Group of Henan, with a total investment of 65 million Yuan. The contractors are Qingdao Tianren Environment Co., Ltd and NIRAS company of Denmark，the construction is lasted for 3 years. The annual production of vehicle fuel (95% of methane content) of the project is 4 million m^3. About 200 buses and 1,500 taxes were driven by the fuel in 2010 in Anyang City and the number of fuel driven buses will reach to 500 in 2011.

(2) Shenzhen City has decided to invest 150 million Yuan to set up biogas project with mixed materials (including wastes from kitchen, vegetable peel and residue, sludge from municipal sewage treatment plant) and with a daily treatment capacity of 600 T (1/3 each for the above raw materials). At present it has entered the design phase.

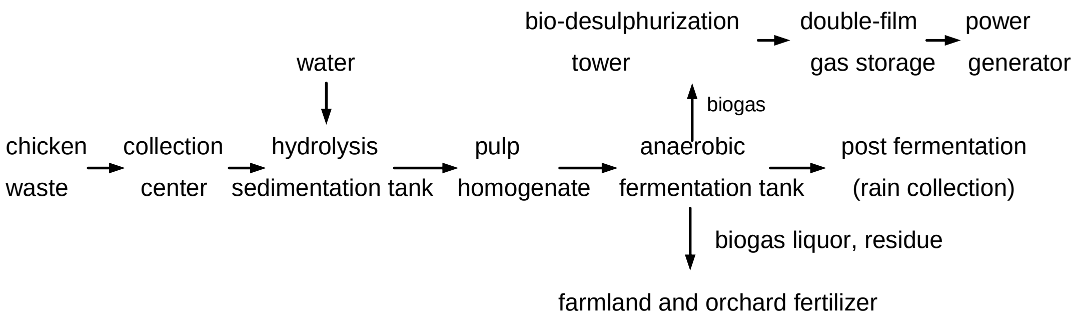
(3) Canshan County of Shandong Province is going to set up a biogas project with a daily treatment capacity of 300 T of vegetable waste and 175 T of stalk waste, with an investment of 67.64 million Yuan for phase I of the project. The total investment for the fixed assets of phase I and phase II is 89.41 million Yuan. Currently the project has past the first project demonstration.

After the completion of the project, the annual production capacity will be 18.315 million m^3 （60% CH_4 content）for biogas, 79 thousand T for residue-based fertilizer, 65 thousand T for liquor-based fertilizer and 222 thousand T CO_2 (equivalent) will be reduced accordingly.

Case 1. Biogas Project of Beijing Deqingyuan Chicken Farm

Deqingyuan Chicken Farm is located at the foot of Songshan Mountain in Yanqing County of Beijing, with a breeding stock of 2.1 million for layer and 900 thousand for chick. Currently it is the biggest (unit breeding stock) high-quality egg production base in Asia, with 3 million layer and chicken wastes of over 2.1 million T/d. The chicken waste biogas project was constructed in September of 2006 and put into gas production in October of 2007. The volume of its anaerobic fermentation tank is 12,000 m^3（4×3000 m^3）；The total installed capacity of power generating sets is 2 MW and the total investment is 62.79 million Yuan.

Flow Chart:



The anaerobic fermentation tank takes the form of CSTR, with inner mechanical mixer imported from Germany. Mesophillic fermentation (38℃) is adopted by the project, with a fermentation period of 22 days. The total solid contend of the influent is adjusted to about 8%. The volume of fermentation tank is 4,000 m^3. The double membrane dry gas-holder is imported from Europe, with a volume of 2,150 m^3.   The biological desulfurating tower imported from Germany is used for biogas desulphurization. After anaerobic treatment, the effluent COD is 2,000~3,000 mg/l and the methane content of the biogas is 63~65%.

There are altogether two biogas power generating sets (JMS320, purchased from Austria) , 1,063 KW for each. The daily power generation is 30 thousand kwh, with 37% power generation efficiency, 40% heat efficiency and 7% power consumption rate of power plant. The grid power price: 0.387+0.35=0.737 Yuan (0.35 is the government subsidy for grid power).

The project was completed in 2008 and the production value is 7.98 million Yuan, with annual production of 7 million m^3 for biogas and 1.400 KWH for power. In addition, a surplus heat equivalent to 4,500 T standard coal is produced and supplied to a village for heating.

The biogas project can digest 77 thousand T/a of organic waste and 150 thousand T/a of sewage in the ecological area and its equipment can produce 150 thousand T/a of liquor and 6,600 T/a of residue, which are used as organic fertilizer for about 10 thousand mu of fruit tree, vegetable and 20 thousand mu of corn plant nearby. At the same time, the fertilizer can also acts as a soil conditioner for the agricultural field, such as increasing the organic content of the soil. The breeding farm can accept 60 thousand T/a of corn produced by Yanqing area, by this way the local farmers can get a profit of 40 million Yuan from their corn (120 mu). Furthermore, the energy problems for the workers of the farm and nearby villages have been solved at the same time.

Case 2. Biogas Project of Tianmen Jiankang New Countryside Pig Farm of Hubei

（1）Introduction

The distributed energy station of Tianmen Jiankang New Countryside of Hubei is the cyclic economy concept followed by Jiankang (Group) Co., Ltd., it is a distributed energy project which is invested and constructed to control pollution and realize its bio-safety treatment and resource utilization. In accordance with the requirement of the national policies on environmental management and new energy, the project has not only recovered biomass energy, but also turned it into heat energy. Now it has become a model for the local new countryside construction.

With the integrated continuous-flow stirred two-stage fermentation (mesophilic fermentation) adopted by the project，its gas yield/unit is 15% higher，compared with the conventional fermentation process. The daily treatment capacity of pig manure is 20 T and daily biogas output is 1,200 m^3. Since operation, the project has met the gas demand of nearby 828 households and the plant area, while the fermented residue and liquid are turned into organic fertilizer for the farmland nearby.

Jiankang (Group) Co., Ltd. of Hubei is a key leading enterprise of national agricultural industrialization and a high-tech enterprise of Hubei. It owns the largest full-scale pig farm - Demonstration Pig Farm of National Livestock Engineering Research Center. The marketable fattened stock of the pig farm is 30,000 /a and the number of raising pigs is about 15,000/a. The dry manure-cleaning process is adopted by the pig farm, with a daily production of 50 T for solid manure and about 270 m^3 for washing water. In order to solve the problems of environmental pollution and resource waste, Jiankang (Group) Co., Ltd. of Hubei sticks to the principle of synchronous development of raising production and environmental protection in the construction of biogas energy and environment project. On the one hand, 20 T pig manure and 20 m^3 washing water are fermented in anaerobic fermentation tank （CSTR）and turned into biogas, residue and liquor. The biogas is used by 828 rural households of Health Village for cooking, the rest pig manure (ca. 30 T) is used for further processing and sold as organic fertilizer, while the unseparated residue and liquor are implemented directly to the surrounding farmland as fertilizer. On the other hand, the rest 250 m^3 washing water enters to the secondary fermentation tank after sedimentation and goes through anaerobic treatment in the state of complete mixture, then to be used as liquid fertilizer. This practice has solved the problems of rural energy and fertilizer usage fundamentally and achieved good integrated biological, environmental and social benefits. It also has set an example of integrated waste treatment mode of large-scale livestock breeding for other pig farms and major specialized raising farms around the area.

（2）Project construction

① CSTR reactor 1,000 $m^3 \times 1$ and auxiliary facilities, dry and flexible double-film gas storing bag 600 m^3；

② Secondary fermentation tank, 1,500 $m^3 \times 1$；

③ A biological organic fertilizer production line, with a production capacity of 10,000 T/a, the manually collected pig manure and the biogas residue from the biogas thank are fermented in a fermentation turning machine to product organic fertilizer.

④ Gas supply project and auxiliary equipment for 828 households.

The annual production of fermented residue and liquid of the project is about 116.8 thousand T and the project is also equipped with auxiliary facilities for biogas liquor utilization. The annual biogas production is 547.5 thousand m^3 and the biogas is provided to the village households, with an annual coal (standard coal) saving of about 550 T and fuel saving of about 400 thousand Yuan.

Table 3-7 Tianmen Jiankang New Countryside Biogas of Hubei

Pre-treatment unit	Sewage collection tank 350 m^3	1
Production unit	assembled anaerobic reactor 1,000 m^3	1
	Secondary fermentation tank 1,500 m^3	1
Storage unit	Flexible gas bag 600 m^3	1
Utilization unit	Biogas transmission and distribution system	828

（3）Project process and technical application

① Perspicacity and exemplariness of the project

Advanced process: The CSTR process adopted by the project is the most advanced process solely imported from Denmark by Tianren Company. The advantages of the process are wide application, inclusive materials, low unit energy consumption, high gas yield and good economic benefit.

Advanced automatic test system: SCADA automatic monitoring test system is installed so as to improve the operation management. The project is the first one among the large and medium sized projects in China, which adopt the automatic test system for operation monitoring and control.

The whole system is composted of three layers:

Bottom layer: Data collection layer, including various measuring instruments, contacts of controllers and protectors and signal of electrical apparatus.

Medium layer: Logic control layer. Through PLC, the data of the bottom layer is connected with the upper layer by logic calculation and control.

Upper layer: Data display and storage layer. Displaying the data transmitted by PLC on the computer screen through communication connection. It has the function of data storage.

Exemplariness of the project scale: The daily biogas demand of 1,000 households of the village or surrounding ones can be satisfied after the completion of the large sized integrated gas supply project of the Jiankang Village. The transportation pipe line of the project is as long as 14 km, it is the largest biogas project for village household.

② Technical Process

The excrement sewage from livestock and poultry farm has become one of the major pollution sources of rural non-point pollution. In order to effectively and scientifically deal with the sewage from the breeding farm and protect biological environment, the Test Pig Farm of National Livestock Engineering Center of Jiankang Village in Yuekou Town of Tianmen City sets up biogas project and deals with sewage from pig farm by advanced anaerobic digestion and biogas utilization technologies. Practice shows that this is a scientifically effective way. The collection of excrement sewage from pig farm follows the principle of reduce: one practice is to adopt " dry clean" , the dry waste is used for organic fertilizer, the rest excrement is washed with a small amount of water into the sewage collection sewer and goes though solid-liquid separation before entering into biogas tank; another practice is to separate rain water and sewage, all the sewage goes through the sewage collection sewer into biogas tank, while the waste liquor after solid – liquid separation is decomposed by anaerobic digestion, so that CODcr is fully degraded and reach the effect of harmless treatment. The biogas from the anaerobic digestion of pig farm sewage is a high quality clean energy. It can not only be used for the heat and gas supply of the households, but also for pig farm lightening, piglet house heating, farrowing house disinfection, mosquito and fly inducing and killing light, as well as farm worker's and local household's living energy (such as for cooking ,lightening, showering etc.). The fermented residue and liquid are high quality non-contaminated organic fertilizer and broad-spectrum biopesticide with high commercial value, all these are used as organic fertilizer for fruit, tea, vegetable, strawberry and corps. Therefore the breeding pollutants are turned into valuable products and all the resources are fully utilized, so that the zero-discharge is realized eventually. The process can be seen in Fig. 3-9.

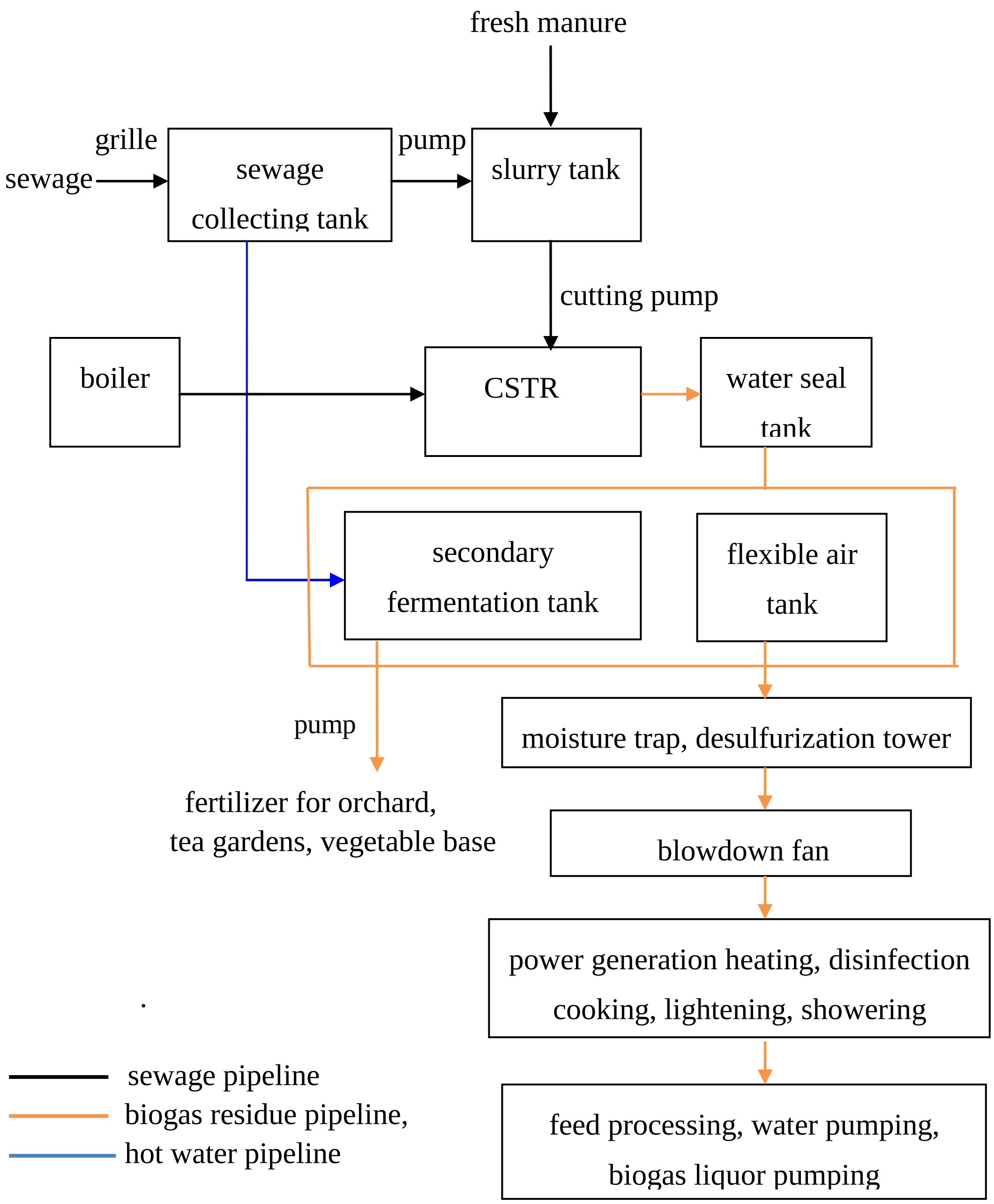


Fig. 3-9. Flow Chart of the Project

③ Technical application and innovation

By using anaerobic (UASB) and aerobic (SBR) biological process for excrement sewage treatment, the organic pollutants can be degraded considerably. The CODcr removal is up to 80-85% in the anaerobic stage and up to 80-90% in the aerobic stage.

The Continuous-flow Stirred Tank Reactor (CSTR) is adopted and the key parts are imported from EU. With mesophillic digestion (35-38℃, ca. 9% of TS), its removal is 70%～80%；As the pipeline gas supply is realized in the village, the gas supply pressure for the natural gas pipeline network is relieved, thus it is conducive to the realization of national implementation plan for distributed energy strategy.

The farrowing house disinfection is done by high temperature from biogas flame jet, resulting in good effect, low cost and without the environment pollution caused by the disinfectant.

The piglet house heating is realized by biogas warming lamp, so the living environment , survival and viability of the piglets are all improved, furthermore, the power consumption cost is reduced and safety factor of heating is increased.

Production process of organic fertilizer：dry-cleaned manure, manure from solid-liquid separation and biogas residue sludge are used as raw materials for composition, while the crushed stalk is used as supplementary material. They are mixed and added with biological bacteria, then goes though anaerobic fermentation screening, so the organic fertilizer is produced eventually.

(4) Investment benefit evaluation

The construction fund of the project is mainly from the Bank of Asia (1.6 million Yuan of loan), support from Hubei Science and Technology Bureau (1 million Yuan) and self-raised funds (6.352 million Yuan). The implemented construction of pollutant resource utilization type biological pig farm is a clean production technology. It has the advantages of environmental protection, higher economical benefit, sustainable biological agriculture development, increased agricultural efficiency and the improved farmer’s income. Is resource utilization benefits are as follows:

Economic benefit

The annual biogas production of the project is 547.5 thousand m^3, which can meet the living gas demand of 828 households in the village, the rest of the biogas can be used for boiler, biogas lamp and pig house disinfection lamp. The fermented residue and liquid are transported to the neighboring farm land for fertigation, or to the temporary fermented residue and liquid storage tanks nearby for farm land fertigation. They can not only meet the needs of enterprise itself, but also that of the villagers.

Social benefit

Now all the people in the Jiankang Village use biogas (clean energy) as their domestic gas, it has changed the backward situation of cooking by firewood which lasted for several thousands of years. This is a kitchen revolution, resulting in immeasurable social benefit.

Environmental benefit

Before the construction of the project, the sewage and excrement from the pig farm have caused a severe pollution to the environment: the surrounding soil, air and especially water have been contaminated seriously and people's health is also greatly affected. After is construction, the pollutants are used as raw materials and turned into energy through anaerobic fermentation, furthermore disinfection is done during the fermentation, so as to reduce pollution. The rest of fermented residue and liquid are used as fertilizer for the farm land fertigation. By this doing, the environmental pollution has been minimized and good environmental benefit has been realized.

Market analysis and expected effect: The annual organic fertilizer production is 10 thousand T, with a production value of 3 million Yuan/a; The annual biogas production is 547.5 thousand m^3，with a production value of 821.25 thousand Yuan/a; The annual biogas liquid fertilizer is 87 thousand T，with a production value of 700.8 thousand Yuan/a. So the total production value is 4.52205 million Yuan/a, with a profit of 1.8917 million Yuan/a.

Case 3. Biogas Project for Dried Cassava Distillery’s Wastewater Treatment of Jiangsu Taicang Xintai Alcohol Co. Ltd.

Jiangsu Taicang Xintai Alcohol Co. Ltd. is a specialized plant, which uses dried cassava as its raw material for alcohol production, with an annual alcohol production of 50 thousand T and a daily wastewater discharge of 1,600 T. The design capacity for the wastewater treatment project is 1,600 m^3/d.

The wastewater treatment project was listed as a demonstration project by former State Economic and Trade Commission in 1995, which adopts the two-stage anaerobic and aerobic process from the Environmental Protection Research Institute of Light Industry (the former Environmental Protection Research Institute of the Ministry of Light Industry). The anaerobic stage was completed and put into operation in 1999 and the aerobic stage was completed in 2002, with test and acceptance for up-to-standard operation. In August, 2008 the plant moved into Xiexinlu, Taicang port area (new plant) and biogas project was still designed by the Environmental Protection Research Institute of Light Industry. The new project was put into operation in the summer of 2009 and past a teat and acceptance in September of 2010.

(1) Treatment process

① The designed water quality

The distillery discharges 1,600 m^3 of dried cassava distillery’s wastewater /d (330 working days/y), with COD 55,000-60,000mg/l, BOD 24,000 mg/l, SS 22,700 mg/l and pH 4.2. The discharge standard after treatment is to meet the secondary grade standard of the National " Integrated Wastewater Discharge Standard " (GB8978—96), i.e. COD≤300mg/l，BOD≤100mg/l，SS≤150mg/l and pH 6-9. (Note: finally discharged to the urban pipeline network).

② Treatment process

The dried cassava distillery's wastewater belongs to the high concentrated organic wastewater (COD:BOD =2:1) with high temperature and high SS, it is of good biochemical property. By adopting anaerobic-aerobic treatment of the dried cassava distillery's wastewater, it can not only recover a lot of biogas energy, but also let the effluent to reach the emission standard. Therefore, it is the best treatment both on technology and economy.

Here the first-stage completely stirred thermophilic anaerobic fermentation, second-stage mesophillic UASB anaerobic fermentation and SBR aerobic treatment are adopted for the project.

The dried cassava distillery's wastewater from the alcohol distilling tower gets into the grid chamber after waste heat recovery, in which the grit coming together with the raw material is removed as much as possible. After that, it goes to the hydrolysis tank. Then the waste liquor is pumped into the first stage anaerobic fermentation reactor (CSTR) for thermophilic anaerobic fermentation (52-54℃) and pH 7. A large hydraulic inject pump and anaerobic sludge return system are equipped in the anaerobic fermentation reactor. The inject pump is used for completely stirring and can also be used for heating and breaking the floating residues. The biogas produced from the anaerobic fermentation (30 m^3/ m^3 of COD 55,000 mg/l effluent, equal to 30 kg of raw coal) goes through water-gas separation tank, water seal and enters into biogas storage tank and be then used as fuel for boiler.

CSTR is suitable for treating the dried cassava distillery alcohol wastewater with high concentration and high SS. After treatment, the removal is over 82% for COD, 90% for BOD and 80% for SS. As the treated wastewater by CSTR still has high content of SS, it then gets into high-level sedimentation tank for sludge and water separation, while the supernatant gets into the digested liquor tank. The thin sludge then goes though the centrifugal separator for dewatering and then be used as high quality organic fertilizer. The supernatant from the digested liquor tank is continuously pumped into the second stage UASB for anaerobic fermentation with mesophillic of 33-35℃. The digested liquor after anaerobic fermentation enters into air floatation system. The removal of the effluent is over 66% for both COD and SS.

The digested liquor after the above anaerobic fermentation and floatation treatment enters into equalization tank and at the same time the waste cooling water or the standard effluent is added, aerated at the bottom part and mixed. Here, the COD is controlled between 1,000-1,500 mg/l. After hat It is pumped into the SBR aerobic equipment to be treated. SBR is a sequence batch activated sludge aerobic treatment equipment. The wastewater undergoes the aerobic treatment in SBR, aerated, settled and discharged by decanter in turn and the effluent reaches the emission standard.

The anaerobic sludge discharged from the second stage UASB and air floatation system can be used as high quality organic fertilizer after dewatering, while the aerobic sludge from SBR returns to the hydrolysis tank and then enters into the first stage CSTR for treatment, thus the biogas output can be increased.

③ Flow chart

The flow chart is shown in Fig. 3-10

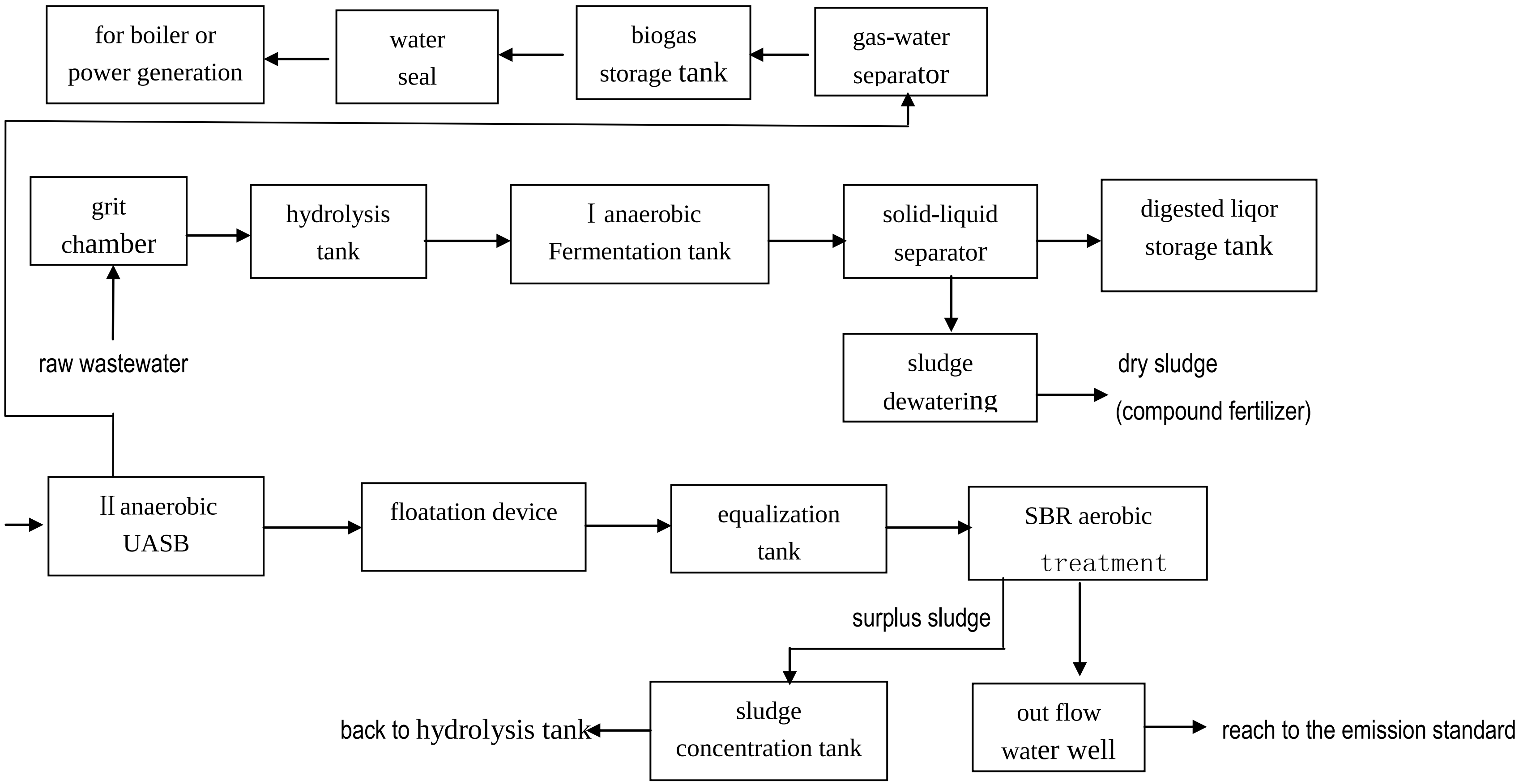


Fig. 3-10 Flow Chart for Alcohol Wastewater Treatment

④ Main design parameters

The main technical equipment includes: grit chamber, storage tank, first-stage anaerobic fermentation reactor, second-stage UASB anaerobic reactor, equalization tank, SBR tank, water-gas separator and gas storage tank.

First-stage anaerobic fermentation reactor : 6, made of steel, unit effective volume 3,300 m^3, fermentation time 7.5 days and volume load 8-10 kg COD/ m^3 · d.

Second-stage UASB anaerobic reactor: 2, reinforced concrete structure, unit effective volume 1,700 m^3, hydraulic retention time 1.3 days and volume load 3.3 kg COD/ m^3 · d.

SBR tank: 3, made of steel, unit effective volume 1,884 m^3, for alternative operation.

Biogas storage tank: wet-type, volume 1000 m^3, atmospheric pressure 350 mm water column.

(2) Graphic Design

Graphic design (omitted)

Elevation design (omitted)

(3) Operation

① Main technical and economic index

Compared to the conventional one-stage anaerobic and aerobic technology, this two-stage anaerobic and aerobic technology for alcohol wastewater treatment has saved 20% of project investment, 30% of energy and 50% of running cost. The main technical and economic index of the project is shown in the following table.

Table 3-8 The Main Technical and Economic Index of the Project

Item	Data
Amount of discharged wastewater	1,600 m^3/d
COD content of influent COD content of effluent	55,000-60,000 mg/l 150-280 mg/l
Ⅰ CSTR COD removal Ⅱ UASB COD removal Biogas output Dry sludge（high-quality fertilizer, 80% water content） Coal saving CO_2 discharge reduction /a	over 82% over 66% 60,000 m^3/d 19.8 million m^3/a 80-100 T/d 19.8 thousand T 464.4 thousand T

② Economic benefit

The energy conservation of the project is remarkable, with coal saving of 19.8 thousand T/a, CO_2 discharge reduction of 464.4 thousand T/a, the wastewater has met the discharge standard and environmental pollution has been controlled at the same time.

The total investment of the project is 30 million Yuan and the annual operation cost is 5 million Yuan. The annual benefit is:

Based on the calculation of raw coal caloric value of 650 Yuan/T, the annual recovery is 5.5 million Yuan.

Based on the calculation of natural gas caloric value of 1.301 Yuan/m^3, the annual recovery is 16 million Yuan (excluding the fertilizer benefit and pollution discharge exemption).

（4）Project Assessment

Experience and practice on distillery (dried cassava) wastewater treatment gained by the environmental Protection Research Institute of Light Industry for more than two decades are used for reference in the project. Here two-stage anaerobic treatment is applied for mutual complement. Series connection of first-stage and second-stage anaerobic treatment can obtain the best effect of anaerobic biological treatment and overcome the disadvantage of the only one-stage anaerobic treatment (hardly to meet the discharge standard).

A large hydraulic inject pump and anaerobic sludge return system are equipped in the CSTR anaerobic fermentation tank. It is suitable for high concentrated and high suspended alcohol wastewater. The equipment won the third prize of National Advanced Science and Technology in 1988.

For II UASB: The advanced design of a multiple double-layer three-phase separator is digested and imported from Germany in 2000.

For SBR: The equipment adopts imported silicon rubber membrane microporous aerated conduit from Germany.

The project has been listed in UN cases of large and medium sized enterprises. Official of the UNDP expressed that the practice of the alcohol plant has realized the win-win situation of environmental protection and economic development, it is of a general guidance significance to the medium and small sized enterprises in the whole world, especially for the ones in developing countries.

Case 4 Biogas project for mechanical and de-inking pulp wastewater treatment of Fujian Nanping Paper Mill

Fujian Nanping Paper Mill produces thermo mechanical pulp (TMP） and de-inking pulp (DIP), with daily discharge of 30,000 m^3 mixed pulp wastewater.

The paper mill adopts anaerobic and aerobic technology for the wastewater treatment and the total investment is 60 million Yuan. The advanced IC anaerobic treatment technology of PAQUES (Netherlands) is used as its wastewater pre-treatment technology for the anaerobic project, with an investment of about 30 million Yuan. The COD content of the mixed wastewater is relative low (1,500 mg/l -2,000 mg/l). After treatment by IC anaerobic reaction tower, COD and BOD removal can reach 60% and 80% respectively. Its daily biogas production is 27,000 m^3， with a daily benefit of 5,400 Yuan and annual benefit of 1.782 million Yuan. The treatment cost is 0.55 Yuan/T (including depreciation).

(1) Technical Process

For the pulping wastewater of TMP, CTMP, APMP, DIP etc., due to their high temperature， concentration of suspended matter and the content of COD (dissolvable and bio-degradable), it is better to adopt sedimentation, cooling and anaerobic methods for pre-treatment first, then adopt the conventional aerobic treatment method. The grille is used first to remove big particles, so as to prevent the damage of the wastewater lifting pump and the blocking of the pipe line; the sedimentation tank is used to remove the suspended matter and undissolvable COD; while the cooling tower is used to reduce the wastewater temperature and anaerobic treatment is used to degrade the dissolvable CODcr from over 1,500 – 2,000 mg/L to less than 1,000 mg/L. The final aerobic treatment is to enable the wastewater to reach the discharge standard.

(2) Characteristics of the process

Compared to BKP wastewater, TMP，CTMP，APMP and DIP wastewater contain less persistent macromolecule organics (lignin, cellulose etc.), its BOD/COD value is higher (generally above 0.35) and the concentration of dissolvable CODcr is above 1,500 – 2,000 mg/L, therefore the anaerobic pre-treatment technology is quite suitable for this kind of wastewater. If the project only depends on the conventional aerobic treatment, due to its high concentration of influent, the aerobic bacteria is rather difficult to adapt to it, so it will cause low pollutant removal and volume load. In order to meet the discharge standard, a large aeration tank must be set up， which occupies a large floor space, consumes high energy and more chemicals and produces more sludge. However if anaerobic method is adopted for pretreatment, especially IC anaerobic technology, many advantages can be brought about，such as low aerobic treatment load, small construction scale of aeration tank, less floor space and energy consumption, at the same time it can also reduce the dosage of regulators for neutralizing pH and nutrients of urea and phosphoric acid; The amount of sludge from aeration is greatly reduced and the treatment of sludge dewatering is reduced accordingly; As the biogas from the anaerobic process can be recovered and utilized as energy, the operation cost can be reduced further.

(3) Anaerobic reaction conditions

① Temperature It has an important effect on the activity and growth rate of the particle sludge. The most suitable temperature for the growth of methanogen is 30-40℃. The wastewater temperature of DIP, TMP, APMP and CTMP is mostly above 40℃，so cooling treatment is needed before the anaerobic treatment.

② pH value The most suitable pH for the growth of sensitive bacteria is 6.5-7.5，but the basic condition for methane production is that pH must be kept at 6.0-8.5. The wastewater from DIP is of Meta-alkalescence (pH above 9), while those from TMP、TCMP and APMP are neutral and meta-acidic (pH 5-7), so they should be neutralized based on the actual situation.

③ Nutrition The anaerobic bacteria can not grow without nutrients. If it is lack of nutrients, the activity of the bacteria will be reduced remarkably. The urea and phosphoric acid are added for the making up of NH_3-N and P. The necessary dosage of nutrients in the anaerobic process is based on the biodegradability（BOD/COD）, cell constituent, growth rate and pre- acidifying Degree.

(4) Operation of IC reaction tower

IC reaction tower is the main equipment for the anaerobic treatment, its running efficiency directly reflects the effect of the whole treatment system. The surplus particle sludge from other running anaerobic treatment systems is generally utilized during the start of the reaction tower. The amount of necessary particle sludge should account for over 50% of the tower volume. The sludge level is 1m below the lower part of the first-grade separator, so as to ensure enough particle sludge for inoculation, and at the same time to enhance the buffer capacity and prevent the shock of influent pH, high load and toxic substance. In the normal operation of IC reaction tower, the removal is over 80% for BOD_5 and 60% for CODcr, and the conversion rate from 1 kg COD to the total amount of biogas (including CO_2 and H_2S） is about 0.42 m^3.

In 2000, Fujian Nanping Paper Mill imported the IC anaerobic reaction tower from PAQUES (Netherland) successively for treating the mixed wastewater of TMP and DIP. Currently, the whole wastewater treatment system is in stable operation and its treatment effect is so good that the water quality of effluent is stable and can meet the discharge standard. At the same time, due to its advanced equipment and high level of automation, the operation cost is quite low (only 0.55 Yuan/T, including depreciation). Fujian Nanping Paper Mill is the first one in the paper industry of China to adopt IC anaerobic biological reaction technology for the treatment of pulping wastewater. In 2002, Yueyang Paper Co.,Ltd also imported the same technology for the treatment of APMP and DIP wastewater, it was put into operation in 2003. At present, nearly 200 paper mills (such as Shandong Shouguang) apply IC anaerobic technology to treat chemical-mechanical pulp and waste paper pulp wastewater.

Case 5 Hangzhou Tianziling Domestic Waste Sanitary Landfill Biogas Power Generation Project

Hangzhou Tianziling Domestic Waste Sanitary Landfill was built and put into operation in Apr., 1991, with a treatment capacity over 2,000 T/d. The landfill was elected as the Outstanding Project of National Environmental Protection by the

Ministry of Construction, the Excellent Model of Dubai International Dwelling Environment Improvement of 2000 by UN, the Demonstration Project of Key Implementation Technology in 2001 and Shichuanxiang Reward for Top Ten Pacesetter of Advance Groups for City Appearance and Environment Sanitation in 2002 by the Ministry of Construction respectively.

Tianziling Domestic Waste Sanitary Landfill is loaded in Qinglongwu mountain valley of Banshan Town (Shitang Village) in the northern suburbs of Hangzhou. It is an independent hydrologic geology unit. The area of the site is 48 ha. , with a landfill volume of 6 million m^3, total investment of 152 million Yuan and life time of 13 years.

The entire construction project is standardized and systematized: there are draining and gas-guiding systems in the side, such as gabion, flood drainage ditch and well; round the site, there are area flood intercepting trench and circular flood intercepting trench for surface water; In the front, there are double "curtain grouting" impermeable interception-pollutant dam, waste dam and leachate regulating tank (24.5 thousand m^3)；Internal sewage treatment plant, with a treatment capacity of 300 T /d (the leachate is discharged to the urban sewage pipe network after up-to-standard treatment); Environmental monitoring station, equipped with advanced devices for effective prevention and control of waste landfill operation area, management area, and surrounding atmosphere, surface water, underground water, sewage treatment influent and effluent, fly density, landfill height and the raw waste; In addition, there are three major internal roads of different elevations and functions, forming a handy internal transport network.

(1) Power generation from landfill gas

The power generation project of Hangzhou Tianziling Domestic Waste Sanitary Landfill is a first project for landfill gas utilization in China. The design scale of the project is 4～6 MW and the investment for the first phase project is 3 million US$. It is equipped with two internal combustion engines made by US, with an installed capacity of 970 kW for each. The average thickness of the landfill laystall is about 30 m and the amount of waste is about 3 million T. The gas components are CH_4 (50%～60%) and CO_2 (35%～40%) , while the gas flow is about 2,000 m^3/d.

The power plant of Tianziling landfill gas adopts international advanced process and equipment. In the gas collection system, there are over 30 gas wells, with a suction pipeline of nearly 2,000 m, When the gas goes through the general pipe into the power plant, it is dewatered in gas - water separator, then the separated condensate goes directly into the sewage treatment plant (1-2 T/week). The suction pressure of the general pipe is controlled at about - 4 kPa, after the gas goes though the processing module, it is pressed to 34 kPa. Later it enters into molecular sieve filter for further purification, then it is distributed to internal combustion engine set for power generation. Currently, the total landfill gas collection is about l,300 m^3 / h，the output pressure of the engine is 400 V and it is increased to 10 KV through transformer for grid power.

The whole process is automatically controlled by computer, from adjusting gas input flow, pressure, output flow to on-line tracking.

The flow chart for power generation from landfill gas is as follows:

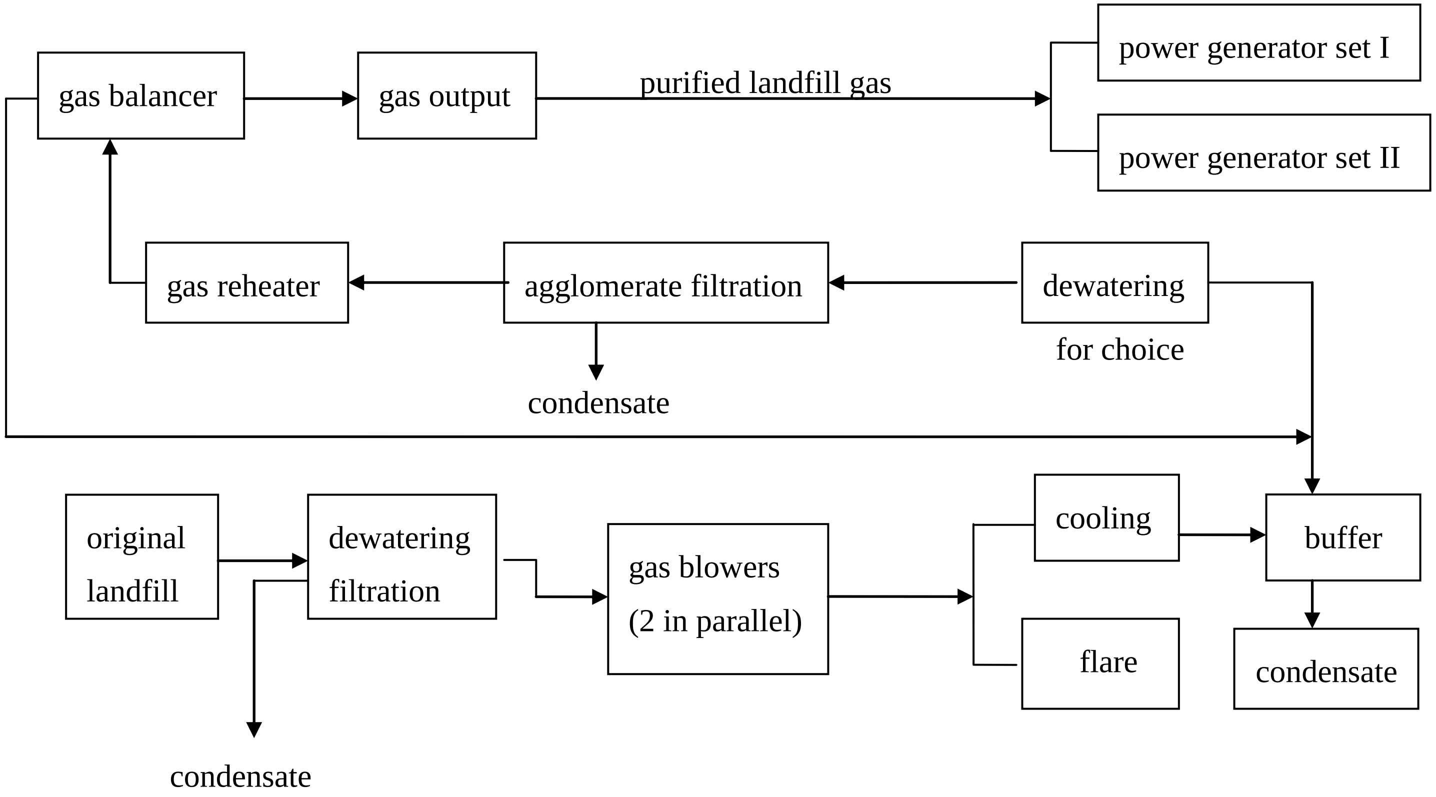


Fig. 3-11 Flow Chart of Gas Treatment System of Tianziling landfill

(2) Benefit Estimation of power generation from landfill gas

It has been nearly one year since the operation of power generation from the landfill gas. Now the system is operating normally and meets the design requirements after running-in period (from one-shift operation to three-shift operation). Its economic benefit is as follows:

In accordance with the electricity price checked and fixed by Hangzhou City, it is 0.68 Yuan/KWh for peak period of 14 hours (08:00～22:00) and 0.29 Yuan/KWh for valley period of 10 hours (22:00～08:00). In order to simplify the calculation, based on the average price of 0.52 Yuan/KWh (not including tax) and the related coefficient of 0.90 (actual power consumption)，then:

The annual power production: (2×971 kW/h×8760 h×0.9)/1000

= 15 294.96 MW

The annual production value: 15294.96 MW×1000×0.52Yuan/kW

= 7.953 million Yuan

(Note: The taxation is not included in the above calculation.)

（3） Leachate treatment of Tianziling landfill

The leachate flows into sewage storage tank through drainage system, the sewage surface can be oxidized through natural aeration, so that the organic concentration of the sewage is reduced to some extends and treatment load of the sewage treatment plant is lightened at the same time.

The biological oxidation treatment technology is adopted by the sewage treatment plant of the landfill for secondary bio-chemical treatment. Its design treatment capacity is 300 T/d，regarding BOD_5, CODcr, SS and pH as control targets for treatment. The treatment flow chart can be seen in Fig. 3-12 and its treatment effect in Table 3-9.

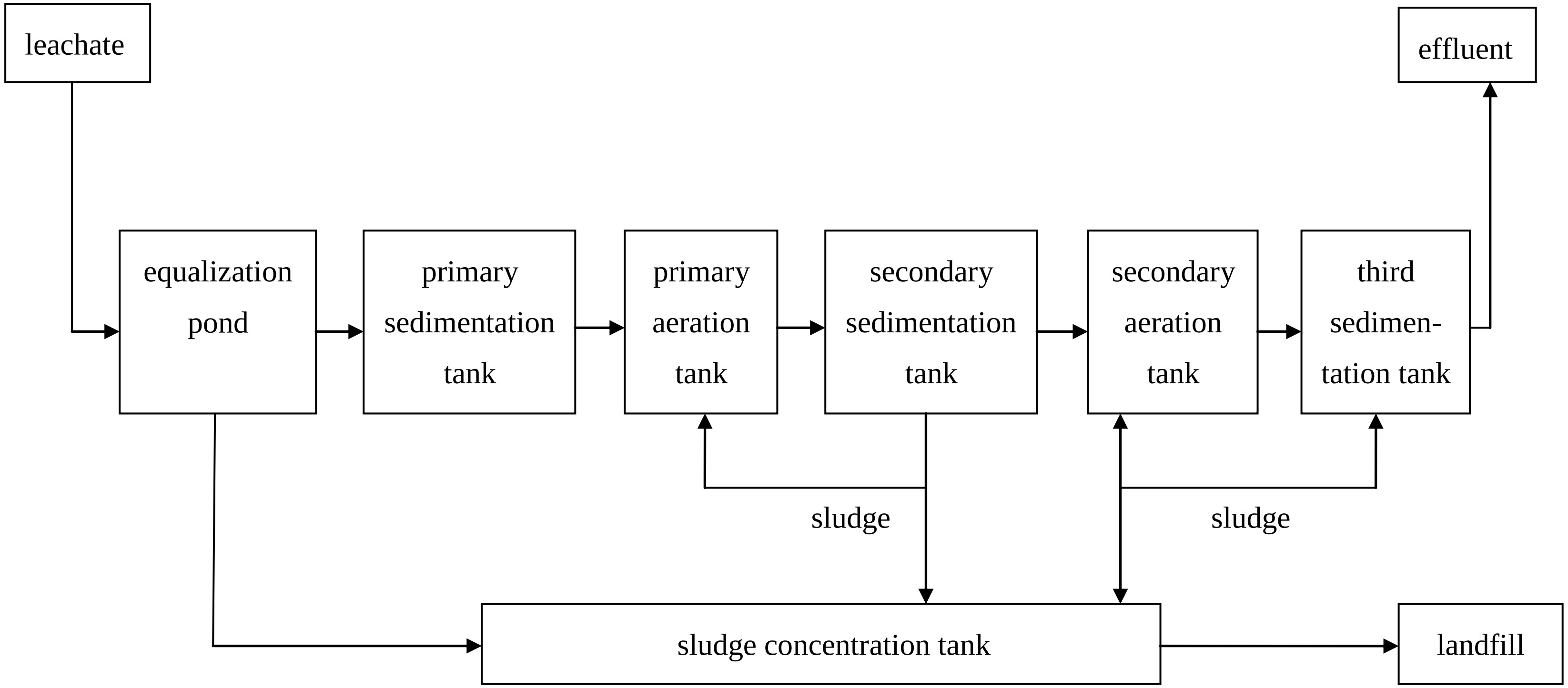


Fig. 3-12 Diagram for Leachate Treatment Process of Tianziling Landfill

Table 3-9 Treatment Effect of Landfill Leachate

Item	influent water quality	effluent water quality
BOD_5	3000 mg/L	≤50mg/L
CODcr	6000 mg/L	≤300mg/L
SS	6～7	6～9
pH		100mg/L

Case 6 Biogas Project of Dalian Dongtai Xiajiahezi Sludge Treatment Plant

(1) Background

The project of Dalian Dongtai Xiajiahezi Sludge Treatment Plant is aimed at solving the serious problem of water treatment and municipal sewage sludge treatment of Dalian City. The total investment of the project is 149.13 million Yuan, with an occupied land of 4. 11 ha. and a treatment capacity of 600 T/d (550 T/d for municipal sewage sludge and 50 T/d for food residue). The running cost of the project is 130-150 Yuan/T（80% water content）and daily power consumption is 15,000-18,000 KWh. Its treatment process is mainly used for municipal sewage sludge, at the same time, it is also used for the sludge from industrial sewage, food residue, kitchen waste, out-of-date food, manure residue as well as wastes and degradable organic wastes from slaughter and meat processing industries. The project can digest all the municipal sewage sludge from the sewage treatment plants in Dalian City.

The project is ranked the first in the list of 10 Recommended Cases for 2010 Sludge Treatment and Disposal of China.

(2) Analysis of integrated treatment mode

① Technical source

The integrated treatment process of municipal sewage sludge is adopted by the project, this technology is originated from LIPP Company of Germany. The company was set up in 1958 and distinguishes itself in the world in terms of wastewater purification, sewage treatment, organic waste treatment, resources recondition of bio-waste based raw materials and gas liquefaction. Currently, the company is mainly involved in the research on integration of advanced technology and equipment in environmental protection and wastewater treatment, so as to ensure the stability, noncorrosibility and long life cycle of its sludge treatment facility.

② Technical characteristics

LIPP tank technology uses entire metal structure and its lined composite steel plate is 316 L stainless steel with high noncorrosibility and long life cycle.

Practice has proved that the technology has the advantages of stable equipment process, high automation and treatment efficiency, low running cost and greatly reduced heat energy and electrical energy consumption.

By adopting the advanced anaerobic digestion technology, the integrated process can realize integrated treatment and reuse of all kinds of degradable organic wastes. Its general flow can be seen in Fig. 3-13. Two goals can be achieved by the system: (1) Pollution control and waste reuse of municipal sewage sludge; (2) Integrated treatment of municipal sewage and sludge.

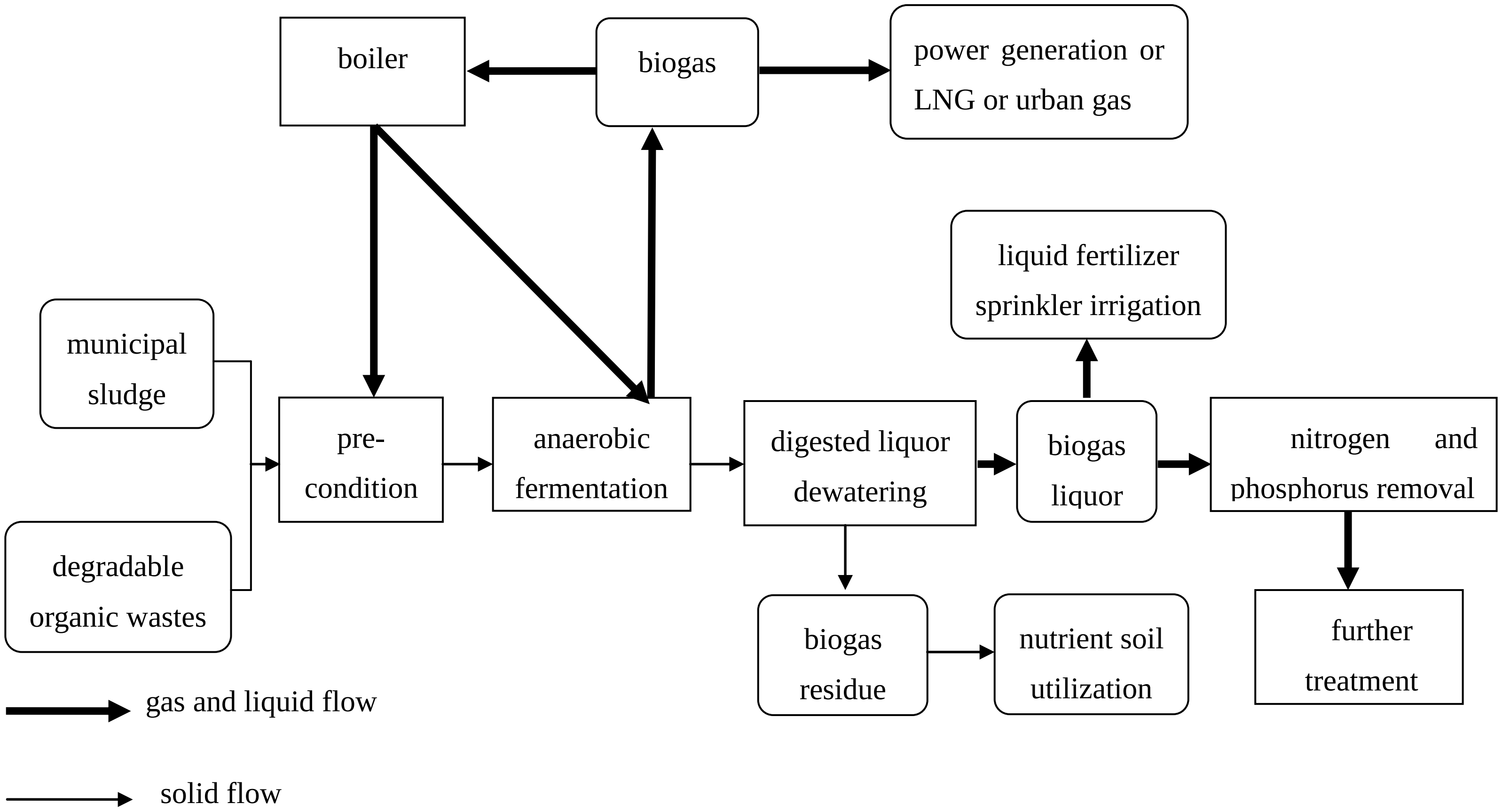


Fig. 3-13 Flow Chart of the Integrated Process

(3) Waste renew and reuse

The project itself fits in with the concept of environment protection, renewable energy use, energy conservation and emission reduction, degradable organic waste utilization, cyclic economy and sustainable development. The main types of waste renew and reuses are as follows:

① Biogas utilization

The main components of biogas are methane and CO_2 , it is a clean energy produced from anaerobic digestion of degradable organic wastes. The biogas production of different degradable organic wastes after anaerobic treatment can be seen in Table 3-10. Based on the treatment capacity of 600 T municipal sewage sludge /d, after purification treatment, 16,500 m^3 natural gas can be provided to 40,000 households or some industrial users, equals to a coke gas plant of 50,000 m^3 /d. The annual saving of high quality coke is over 3,750 T and the annual reduction is 7,000 m^3 for waste gas and 110,000 T for wastewater discharge.

Table 3-10 Statistics of Biogas Production from Degradable Organic Waste

No.	Degradable organic wastes	Organic content （dry matter）	Degradability	Biogas production （m^3/t）
1	Municipal sewage sludge	60%	55%	225
2	Residual Waste	85～90%	90%	870～930
3	Chicken manure	85～90%	90%	620～670
4	Duck manure	85～90%	90%	620～670
5	Pig manure	80%	70%	450
6	Cattle manure	80%	70%	450
7	COD	100%	100%	583
8	Fat	100%	100%	1500
9	Protein	100%	100%	700
10	Carbohydrates	100%	100%	600

In the meantime, as the most important gas resource in the resource recovery, the biogas production used to be unstable. After the technical development of the plant, both the sludge concentration effect and the degradable organic waste content of municipal sewage sludge have improved. In addition, the biogas production and resource efficiency have also greatly increased by means of co-digestion of kitchen waste, out-of-date food, manure residue as well as wastes and degradable organic wastes from slaughter and meat processing industries.

② Utilization of biogas residue

As the major solid product from municipal sewage sludge treatment, the biogas residue contains rich organic matters (such as humic acids and protein) and trace elements (including calcium, magnesium, zinc etc.). The main types of resource utilization are greening ecological nutritious soil or cover soil, organic or inorganic compound fertilizer directly used for farm land. It is expected from a forecast that 4,000 T/a of “guano” can be produced by the project. This kind of manure fertilizer is a slow-released phosphate fertilizer, it can increase soil nutrient and fertility preservation capability. 6,000 T of humic soil can be produced from the treated biogas residue and it can be used as nutrient soil for garden afforestation or landfill cover soil. The humic soil produced by the project has past test and accreditation for sludge soil and organic fertilizer of the Ministry of Agriculture, and is used by many enterprises as raw material of compound fertilizer. In addition, the feed-water needed for the project operation is totally provided by the reclaimed water. It is estimated that 18,300 T of fresh water can be saved and nearly 4,700 T/a of methane gas discharge can be reduced at the same time, equals to 100 thousand T of greenhouse gas (CO_2) emission reduction.

(3) Implementation effect

① Effective solution to the municipal sewage sludge

Along with the rapid economic development of Dalian City and continuous increased treatment quantity of municipal sewage sludge, the amount of municipal sewage sludge is also increased continuously. The existing sewage treatment capacity of the urban area in the center of Dalian City is 415 thousand m^3 /d and it will be up to 745 thousand m^3 /d by 2010. Based on the survey of the existing sewage treatment plants in the urban area in the center of Dalian City and the estimation of sludge production of the planned sewage projects, the existing municipal sewage sludge production is 330 T/d and it will reach 595 T/d by 2010. It can be seen from the estimation that the problem of municipal sewage sludge is getting more and more serious. If the conventional single or mixing landfill treatment is adopted, it will inevitably cause secondary environmental pollution and fail to meet the needs of municipal development and environmental protection of Dalian City. With the anaerobic fermentation and industrialized gas making technologies of Xiajiahezi Sludge Treatment Plant, the stabilization, reuse, recycle, reduce will be realized veritably. The biogas produced from the treatment process is recovered for clean fuel and the fermented residue can be used for garden greening or as humic soil for landfill coverage. The completion of this project can effectively ease the tension of municipal sewage sludge treatment of Dalian City and completely solve the problem of secondary pollution caused by municipal sewage sludge.

② Economic, social and environment benefits

Xiajiahezi Sludge Treatment Plant has effectively solved the difficult problem of municipal sewage sludge treatment and disposal of Dalian City and has met the needs of environmental protection; in the meanwhile, the industries for municipal sewage sludge treatment have gradually realized the well-defined power and responsibility and development towards the industrialization and marketization. The plant takes an active part in attracting enterprises and funds for the construction, operation and management of integrated sludge treatment projects. Xiajiahezi Sludge Treatment Plant is a BOT project and its construction period is 12 years. The municipal sewage sludge treatment will be undertaken by Dongtai Company to realize the integrated municipal sewage sludge treatment and disposal. Up to the Nov., 2009, the accumulated municipal sewage sludge treatment is 14 thousand T and the total production is 900 thousand m^3 for biogas and 3,000 T for humic soil. The good operation of the project shows the success of the integrated treatment mode. The solution to the municipal sewage sludge problem will certainly promote the development of water treatment industry. It has not only realized environmental protection and pollution control, but also realized economic, social and environment benefits at the same time.

3.4 Biogas Utilization

3.4.1 For boiler or civil use

As for the utilization of biogas as boiler fuel, the technology is mature at the present, it only needs to connect the biogas pipeline directly into the boiler, spray with a certain pressure and control its ventilation. As the industrial enterprises are all equipped with boiler, most of the industrial biogas is used by this way at present.

As for civil utilization, the biogas must be desulphurized and equipped with gas transportation pipeline network, generally it goes with the urban and rural construction. Henan Nanyang Distillery is the first one in China to adopt this method. From early 90's of the last century, the plant has supplied 20 thousand households in Nanyang City with 40 thousand m^3 biogas/d.

3.4.2 Biogas power generation

The biogas for power generation can get into the network, it is favorable for transportation. A long with the continuous growth of the biogas output, biogas power generation has become a new high-efficiency utilization technology. After more than a decade's effort, the biogas power generator researched and produced by China has narrowed the cap with the advanced international biogas generation set in terms of its performance and quality.

In China, currently there are 80, 200, 500, and 700 kw series biogas power generation sets for supply. The advanced international biogas generation set can turn 1 m^3 biogas （60% methane content）into over 2 KWh of power, while the domestic biogas power generator of China can turn 1 m^3 biogas into over 1.6 KWh of power. The power generating efficiency and the heat efficiency of the advanced international biogas generation set are 37% and 40% respectively, while those of the domestic biogas power generation set are 33% and 35% respectively. In general, the domestic biogas power generator has reached a standard in technology.

The industrial biogas project has a certain scale and high biogas output. At present, most of the enterprises use biogas as boiler fuel. If the grid biogas power generation can be supported by the governmental subsidy and achieve obvious benefit, it is likely that the enterprises will turn to this practice.

As the agricultural biogas project is relative small in size and far from the city, the grid biogas power generation is restricted by power generation scale, grid distance etc., so only a small number of the projects use biogas for power generation and centralized gas supply, while a great amount of gas is used for the production of the breeding farm or used as household fuel.

The technology for biogas power generation is only a start in China and the installed capacity is lower in general. In recent years, there is a rapid development in the biogas power generation projects of large and medium sized livestock and poultry farms and landfill sites.

According to the statistics of the related department, up to the end of 2009, nearly 450 biogas power generation stations of the large and medium sized livestock and poultry farms are in construction or ready to be built, with a total installed capacity of nearly 1,000 MW for biogas power generating sets.

For landfill biogas power generation project, totally 58 are in construction or ready to be built, accounting for 15.8% of the landfill sites. Up to the end of 2008, 25 biogas power generation projects are built and put into operation, with a total installed capacity of about 51.3 MW.

3.4.3 As natural gas after purification

The CH_4 content of the biogas is purified up to 97% (equivalent to the calorific value of natural gas) by water absorption and chemical absorption methods, so as to be used as natural gas. This technology is widely used in Europe, but it is only a start in China.

3.5 Environmental Protection

3.5.1 Up to standard aerobic treatment of digested liquor

In the last decade, the national law enforcement for environmental protection is strengthened increasingly, the anaerobic digested liquor produced from high concentrated organic wastewater could not reach the emission standard (or go to municipal sewage pipeline network) until it enters into the aeration tank for treatment after solid and liquid separation.

It is estimated that the digested liquor from 10% of the large and medium sized biogas projects of the livestock and poultry farms in China is discharged up to the emission standard after aerobic treatment.

Anaerobic equipment → Anaerobic digested liquor → solid and liquid separation

→ aerobic equipment → up to emission standard

The proven aerobic technologies of China include activated sludge, SBR（Sequencing Batch Reactor）, contact oxidation process, oxidation ditch, biological filter etc.

3.5.2 The utilization of fermented residue and liquid

The biogas residue can be used as organic fertilizer, soil conditioner etc., while the biogas liquor contains C, N, P， especially utilizable nitrogen. A research shows that 22.5 L pig manure equals to 1 kg of ammonium nitrate fertilizer (33% of N content).

Most of the large and medium sized biogas projects of livestock and poultry farms of China are ecological type biogas project, using fermented residue and liquid as fertilizer for the farmland. However, due to the decentralized land and dense population, a large number of biogas projects not only lack of enough storage facilities for the residue and liquor (for more than 3 months storage) , but also lack of transportation pipeline and equipment. All these have caused great difficulty to return the biogas wastes to the farmland, resulting in serious environmental pollution of the villages and towns in China. So how to deal with this kind of situation is a hot topic and key task in environmental pollution control of China in recent years.

3.5.3 Waste landfill and sludge biogas project

（1）The environmental problems caused by waste landfill is mainly in two aspects:

① gas leakage

The unstandardized construction of some waste landfills has caused low collection rate of biogas (less than 20%）, this has brought pollution to the environment, due to the gas release to the atmosphere.

② Landfill leachate

As the leachate has a high content of ammonia nitrogen (taking Beishenshu Sanitary Landfill as an example: ca. COD 8,000 mg/l，NH_3-N_2 500 mg/l), this kind of leachate is one of the effluents which are very difficult nowadays to be treated and discharged to the emission standard.

Some of the waster landfills adopt physico-chemical methods (including reverse osmosis) to treat the leachate, so as to reach the emission standard. However, this kind of treatment has the disadvantages of long process and high treatment cost. Some landfills adopt deep-lying equipment or incinerator for the treatment of high concentrated leachate, but the prerequisite for this kind of treatment is reasonable design and reliable construction of the equipment. However, a small number of the landfills have not yet had a complete solution to their leachate.

（2）Biogas project of municipal sludge

The volume of the municipal sludge is greatly reduced after biogas fermentation treatment and the digested sludge after dewatering can be used as fertilizer for farmland. As the daily digested sludge discharged from the large and medium sized sewage treatment is very high in quantity, in addition to the organic fertilizer, it can also used as soil conditioner, or for incineration, deep-lying treatment etc.

The digested sludge will bring about environmental pollution, if there is no measurement for post-treatment.

4. Obstacles in the Industrialized Development of Large and Medium Sized Biogas Projects

4.1 Biogas Project of Industrial Wastewater

Since the last decade, as the governments at various levels and industrial owners have paid a great attention to the environment protection and the environment treatment has been strengthened continuously, the industrial wastewater biogas project has witnessed a rapid development. The biogas production capacity of 2010 (already 5 billion m^3 at the end of 2009) has surpassed the requirement indicated in the Industrialized Development Programming Outlines for New Energy and Renewable Energy during 2000~2015, i.e. the annual biogas production capacity should reach 4 billion m^3 by 2015.

However there are still some rooms for development. The expert group of the project hold the view that the main limiting factors (as mentioned in the second part of the report) are: different levels of the biogas project technology and the even much different fermentation efficiencies. So the national subsidy policy for renewable energy grid power generation should be implemented, so as to further increase the economic benefits of the project.

4.2 Large and Medium Sized Biogas Projects of Livestock and Poultry Farms

In accordance with the estimation in the first part of the report, the annual biogas output for the biogas project of the large and medium sized livestock and poultry farms in 2009（455 million m^3）has been reached the target set in the National Renewable Energy Programme during 2000~2015.

However, the amount of the developed biogas only accounts for 6.85% of the resources, due to slower development pace. In addition, most of the large and medium sized livestock and poultry farms are built in the suburb, so the animal waste discharged from the farms could not be digested timely by the limited field nearby. The pollution caused by the great amount of the discharged wastes has brought about “public nuisance of livestock and poultry”, which has surpassed the environment tolerable limit. Now the treatment of livestock and poultry pollution and enhancement of the sustainable development of the livestock and poultry industry has become the hot topic of the whole society.

The main obstacles for the biogas project development is as follows:

（1）Lack of scale benefit

Currently, of the built large and medium sized (ecological type) biogas projects, there is almost no or only a little economic benefit. Up to now, only a few biogas projects operate according to the commercial mode, so this results in lack of the data for the best economical scale.

(2) High initial investment

In general, for the large and medium sized biogas projects with biogas output of 500~1,000 m^3/d, the total investment is 1~3 million Yuan. Compared to the poor equipped medium sized livestock and poultry farms, the investment of biogas project is likely higher than that of the farm itself. As the breeding farms generally are little profit ones, the owners can hardly bear the high initial investment for the biogas project.

(3) Chaos market and poor supervision

In recent years, facing the high national investment for the agricultural biogas project, the chief departments of many provinces, cities and counties are lake of related special knowledge and experience, so it is difficult for them to supervise and manage the whole project process including application, assessment, bidding, supervision, management and acceptance.

In order to compete in the biogas market, a great number of environmental companies have come into being. Some of them meet the local trend of “go after what is big and foreign” and some follow the concept of “ a single technology can be a key to global success”, both cause some problems, such as great regional differences in the project quality, fermentation efficiency and gas yield.

(4) Simplified biogas usage

Currently, the biogas from the project is mainly used as civil energy and gas source for the livestock and poultry breeding farms and surrounding residents. Therefore, the biogas from the large and medium sized biogas projects could not be digested completely, resulting in heavy energy waste and economic losses. The grid power generation is the most widely used technology internationally, but the domestic projects are restricted by some factors, such as project scale, the distance of the electric network and technical condition.

(5) Lack of technical and information services

At present, the large and medium sized biogas projects are lack of qualification certification for the design and construction and lack of market disseminating channels for technical information, so that most of the enterprises are lack of corresponding screening and identifying ability for the technologies.

The technicians and operators of the agricultural biogas projects are lake of series training encouraging guarantee and complete service system.

Suggested measures:

① Policy support

Providing subsidy to the enterprises which are not able to bear the pollution treatment and interest-free loan to the enterprises which use the livestock and poultry waste as their raw material. Gradually moving the national subsides for the biogas project construction on to the product (the amount of biogas usage) orientated subsides and encouraging the grid power generation.

② Organizing relative departments to set up industrial market information network for the biogas projects, so as to provide the enterprises with timely, accurate and complete market information service (both home and abroad).

③ Establishing technical standards and specifications, so as to strengthen the supervision and management for the biogas projects.

④ Encouraging the establishment and development of specialized service company. Building an high-efficiency and speedy service team for the large and medium sized biogas projects, so as to greatly enhance the operation efficiency of the projects.

4.3 Domestic Waste Biogas Project (Landfill)

The main obstacles for the industrialized development are as follows:

(1) The construction costs for the landfill is getting higher and higher

Along with the continuous expansion of the city to the surrounding area, it is more difficult for the site selection and the construction cost is high. For the small sized landfill (less than 200 T waste/ d, at about county level), it is not reasonable in economy. One of the technical problem is that the biogas from the landfill is hard to be utilized due to its small amount of gas output and difficult grid power generation.

(2) Low gas collection rate

The technical level for sorting and collecting domestic waste in China is relatively poor, water content is high and the technical equipment level of most landfills is low, so that the utilization rate of biogas from the landfill is generally less than 20%, while that of the developed countries can reach over 60%.

In the future period, the number of landfills in China will be still increased greatly along with the new countryside construction and strict environmental requirement.

Suggestions:

① Standardizing the landfill construction, improving the level of process equipment technology and solving the problem of construction fund.

② Strengthening the original domestic waste sorting and collection, so as to sort out the degradable organic waste as much as possible.

③ Enhancing the dissemination and promotion to enable the whole society pay more attention to the domestic waste treatment and environmental sanitation.

4.4 Municipal Sludge Treatment Biogas Project

In the Announcement of Municipal Sewage Treatment and Pollution Control Technology issued jointly by the Ministry of Construction, Ministry of Environmental Protection and Ministry of Science and Technology, it is indicated that it is suitable for the sludge from the secondary sewage treatment facility with treatment capacity above 10 thousand T/d to adopt anaerobic digestion process for sewage treatment and the produced biogas should be utilized. The statistics for the existing over 1,800 sewage treatment plants in China shows that there are at least 20% of the sewage plants with treatment capacity above 100 thousand T/d. For those with the scale between 40 and 100 thousand T/d and a short way from the domestic sewage treatment plant, their sludge should be collected for centralized treatment. According to the statistics of Tsinghua University, if the role of the anaerobic digestion of municipal sewage is fully played, then the amount of produced biogas can be compared with that of the agricultural wastes. However currently the running equipment for the sludge treatment in China only account for less than 15% of the total number of the sewage treatment plants (about 25% are being tested or fail to operation).

The main factors which effect the large-scale application of sludge anaerobic digestion are as follows:

（1）High investment

Most of the municipal sludge anaerobic fermentation adopt mesophillic fermentation, with a retention time of 25~30 days in the reactor added to the power generating system, the sludge digestion system accounts for up to 1/3~1/2 of the total investment of the sewage treatment plant.

(2) Relatively complex process for sewage anaerobic digestion and difficult operation. Generally the starting period is several months.

(3) If the sewage treatment scale is small, then the benefit from the biogas is not enough to cover the running cost. So the result is that even the small plants (daily treatment capacity less than 50 thousand T)have been built, the number of running ones could not reach 62.5%.

Suggested measures for rapid development:

① Enhancing the research and development of high-efficiency process for sludge anaerobic fermentation and shortening the fermentation time.

For example, adopting supersonic wave for pre-treatment to shorten the fermentation time to 8 days.

② Enhancing the research on the improvement of biogas yield. For example, adding ozone and soda for pre-treatment. Improving the economic benefit from the biogas utilization, such as grid power generation, producing natural gas etc.

4.5 Key Suggestions

In recent years, all kinds of biogas projects mentioned above have developed very rapidly, but still there are some different obstacles, of them the common and serious problems are great differences of technical levels and economic benefits among the biogas projects, disordered market and poor supervision.

Therefore, the report suggests that the following measures should be taken as recent priority:

(1) Establishing a national biogas information and test center under the National Energy Administration (The National Development and Reform Commission) to initiate the coordination and management of the large and medium sized biogas projects in China.

(2) Making up a series standard for the mostly used anaerobic reactors as a first step (for details, see Report 3 of the project).

① UASB - Up-Flow Anaerobic Sludge Bed

② CSTR - Continuous Stirred-Tank Reactor (USR)

Concerning UASB, a series design standard should be made up for three-phase separator (in module, modular, circular and rectangular forms), decanter, tank body etc.

As for CSTR, a series design standard should be made up for tank body structure, mixing system within the tank (mechanical, hydraulic and biogas mixing).

For USR, although it is mostly used in agricultural biogas projects, CSTR is imported in recent years and used more and more in the agricultural large and medium sized biogas projects, so its development and application will be enhanced further.

③ Corollary equipment

Concerning the corollary equipment, a series standardized design should be made up for biogas desulphurization device and biogas storage tank.

The series standards should be arranged and led by the State Energy Administration (a standard-rafting group including experts and managers is to be established) and they should be finally issued for implementation by the State Development and Reform Commission.

(3) Making up a technical guide for the construction of large and medium sized biogas projects.

Along with the deepening awareness for energy conservation, discharge reduction and environmental protection, many owners are ready to set up biogas projects (including the already built projects), however they are lack of the capability to screen and identify the biogas technologies, as the sewage quality and quantity are much different and each anaerobic reactor has its own applicable scope. Currently the domestic technologies for biogas project have not yet formed their own special technical service network, therefore the biogas market is lack of technical information channel. So the guide will play an important role in guaranteeing rapid development of biogas projects in the vast territory land of China.

(4) Making up a design standard for the large and medium sized biogas projects

The design standard mainly includes the design of process and gas supply, project quality and finance evaluation etc.

The standard should be divided into the following four parts:

Industrial wastewater biogas project, large and medium sized livestock and poultry farm biogas project, municipal sludge (sewage) biogas project and domestic waste biogas fermentation (landfill) treatment project.

This complete project design standard could be mad up in the next step, while other corollary standards and specifications could be made up for implementation one by one in the future.

If the above main standards and design specifications are completed, the design, construction, check and acceptance of the large and medium sized biogas projects and biogas equipment manufacture in the future will have a unified standard for them to follow, so that the market could be standardized step by step.

It is expected that the large and medium sized biogas projects of China will develop in a sustained, rapid and sound way.

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Attached Fig.A Biogas Project of Beijing Deqingyuan Chicken Farm

Attached Fig.B Biogas project for dried cassava distillery's wastewater treatment of Jiangsu Taican Xintai Alcohol Co. Ltd.

Tank group for anaerobic fermentation

SBR

Attached Fig.C Biogas project for Alcohol Wastewater Treatment of Guiping Jinyuan Biological Chemistry Company of Guangxi Province