Anaerobic wastewater treatment in (sub-)tropical regions

H. H. P. Fang and Y. Liu

Centre for Environmental Engineering Research, Department of Civil Engineering,
The University of Hong Kong, Pokfulam Road, Hong Kong

Over 1200 full-scale anaerobic wastewater treatment plants have been installed worldwide so far, over 40% of which are in the (sub-)tropical regions. Although the pace has picked up rapidly in the past 10 years, the market potential is still enormous. The application of anaerobic treatment process in (sub-)tropical regions has not just been limited to the traditional effluents of agro-industries, but has also been extended to the treatment of effluents from chemical industries, landfill leachate, municipal wastewater, etc.. In this paper, applications in China, India, Taiwan, Thailand, Philippines, Brazil and Mexico are discussed in detail. A few examples: China has installed over 5.7 millions of family-size anaerobic digestors producing biogas used for cooking and lighting by rural farming communities; Mexico has the largest UASB plant in the world (83,700 m^3) treating combined industrial and municipal wastewater; Nearly all the PTA (purified terephthalic acid) plants in Taiwan, the largest producer in the world, treat effluent anaerobically, including one having a total reactor volume of 15,000 m^3; An anaerobic municipal wastewater plant is in design in Brazil for one million inhabitants.

1. INTRODUCTION

Under anaerobic conditions, organic pollutants in wastewater are degraded by microbes, producing methane and carbon dioxide. The degradation process can be highly effective [1]. It produces only 5-10% of sludge as compared to the more conventional aerobic processes [2], and thus saves considerably cost associated with the sludge disposal. In addition, since it does not require aeration, anaerobic process also saves substantial amount of cost associated with aeration, including equipment, maintenance and energy consumption. Besides, the process converts organic matters into methane, a readily usable fuel. The aspects of energy saving/production and minimum maintenance make anaerobic process particularly attractive to the developing countries. Many rural communities in these countries cannot afford the capital and operational expenses for the aerobic treatment process, and some may not even have adequate supply of electricity to run the equipment at all. The process, which favors warm temperature, is especially attractive for the subtropical and tropic regions.

Traditionally, anaerobic process is used for the digestion of livestock wastes and sludge produced by the activated sludge plants. Since the late 1960's, a number of high-rate anaerobic reactors have been introduced for wastewater treatment. Among them, the most popular ones are anaerobic filter (AF) [3], and upflow anaerobic sludge blanket (UASB) [4].

The basic design principle of these reactors is to retain the sludge inside the reactor in order to increase the treatment efficiency. These reactors are highly effective for the degradation of fatty acids [5] and carbohydrates [6], and have been widely applied for the treatment of wastewater from food, brewery, and agricultural industries. More recently, they have also been found effective for the treatment of refractory pollutants, such as proteinaceous matters [7] and aromatic chemicals [8-10]. The application has thus been extended to the treatment of wastewater from chemical industry [11], and municipal wastewater as well [12,13].

This paper is to present an overview of present situation on the implementation of anaerobic technology in full-scale wastewater treatment. The worldwide applications is to be summarized, followed by the discussion of applications in the tropical and sub-tropical regions for industrial, municipal, and rural wastewater treatment. Applications in China, Taiwan, India, Thailand, Philippine, Brazil and Mexico are to be discussed in more details.

2. WORLDWIDE APPLICATIONS

Complete information of worldwide application of anaerobic wastewater treatment is difficult to keep track. Many plants were installed in the last 10 years, and the number is continued to increase each year. A 1990 survey [14] showed that the number of UASB plants alone at that time was 205, but the number had been escalated to 793 by 1998 [15]. In addition, many tropical and subtropical countries are either non-English speaking or under-developed. Relevant information of these countries is often unpublished, or only published in their native languages and thus unknown to the international communities. China has widely applied anaerobic technology for waste/wastewater treatment in rural areas for over two decades. Yet, reliable statistics and information on their experience are hard to find even in Chinese publications. Brazil is believed to have over 200 anaerobic sewage treatment plants built by local firms [16], but yet very little of this information is known elsewhere. On the other hand, getting information from international companies is also not easy. Two cases in point: BP-Amoco has developed a proprietary anaerobic process for the treatment of PTA (purified terephthalic acid) plant effluents; it has kept technology in-house without intention to publicize or commercialize it. As a result, only two of BP-Amoco plants were identified in a 1999 survey [11], while there are at least eight in existence. Furthermore, some companies are reluctant to reveal information, afraid of inviting competitions. In explaining the reason that its company does not publish its installation list, an executive of one leading company wrote to the authors that "..(one competitor).. to go and bother our customers frequently to ask them to change suppliers."

One of the most comprehensive survey in recent years was conducted by the Deutsche Geellschaft fur Technische Zusammenarbeit (GTZ) on behalf of the German Federal Ministry for Economic Cooperation. The resulting report in 1998 [15] showed that over 1229 full-scale plants had been identified worldwide. Japan leading the rest of the world with 162 anaerobic industrial wastewater treatment plants installed, followed by Germany (115), Netherlands (91), USA (83) and India (79). Judging by the "anaerobic reactor density", which was defined as number of plants per million inhabitants, The Netherlands with a value of 5.83 was clearly the leader. This density factor is strongly dependent on the degree of industrialization of individual countries. The values for Mexico and Brazil, the two leading countries in Latin America, were 0.46 and 0.40, respectively, as compared to 0.06 for India, the leading country

Table 1
Reactors, wastewater sources and leading companies in anaerobic treatment [15]

A: Reactor type

Reactor	Number
UASB	793
Anaerobic contactor	112
Anaerobic filter	104
Anaerobic pond	66
IC	50
EGSB	50
Hybrid	33
Fluidized bed	21
Total	1229

B: Wastewater source

Wastewater	Number
Food	336
Beer	207
Domestic	159
Distilleries	136
Pulp/paper	87
Sugar	76
Solid waste	71
Chemicals	71
Manure co-digestion	65
Beverage	58

C: Top ten companies

Company	Number
Paques	312
Biothane	250
Biotim	96
ADI	68
Purac AB	59
Degremont SA	56
Enviroasia	54
Kurita	39
Shinko	28
TBW GmbH	27

UASB: upflow anaerobic sludge blanket
IC: internal circulation
EGSB: expanded granular sludge bed

in Asia. These values clearly show that there is an enormous market potential for anaerobic technology in Latin America and in Asia.

The report also showed that UASB was the most common type of reactor design. With 793 plants, it accounted for 64.5% of the total number of reactors. Anaerobic contactor (112) and anaerobic filter (104) were the second and third most common types of reactors. These two reactors have been on the market for the treatment of agro-industrial wastewater since the early days; however, their growth is not expected to be substantial. Instead, several new reactors are expected to grow in popularity, including those of EGSB (expanded granular sludge bed), internal-circulation and fluidized-bed. Table 1A shows the details of various types of reactor installations. Table 1B summarizes the numbers installations for eight types of industrial effluents, plus solid wastes and co-digestion. Effluent from food industry, with 336 plants, was the most common, followed by brewery (207), sewage (159), distillery (136), pulp/paper (87), etc. Organic matters in the effluent of these industries are mostly easily-degradable carbohydrates. More recently, the technology has been extended to the treatment of effluent from chemical industries [11], including those containing concentrated organic acids, formaldehyde, phenol, aspartame, ethylene glycol, plastics, etc.

Table 1C lists the top ten leading companies in anaerobic wastewater treatment at the end of 1996. The top four companies at that time, i.e. Paques, Biothane, Biotim and ADI, installed a total of 726 plants, representing 57% of the total. A more recent survey conduct for the present study, indicated that the top four companies, i.e. Paques [17], Biothane [18], Enviroasia [19] and ADI [20], installed a total of 773 plants by 1999 treating 13,360 tons of COD daily. Out of these plants, 59 had daily capacity of treating over 50 tons of COD removing a total of 5,152 tons of COD each day.

3. APPLICATIONS IN (SUB-)TROPICAL REGIONS

A survey conducted for the present study in 1999 also showed that 338 of the 773 anaerobic wastewater treatment plants were installed in tropical and subtropical regions by the

four leading international companies. Table 2 shows that a total of 77 plants were installed in Brazil, followed by India (75), China (43), Mexico (22), Philippines (22), Taiwan (21), Thailand (14), etc. The COD removal capacities in these seven regions total 6,418 tons/day. Details of anaerobic wastewater treatment in these seven regions are discussed as follows:

3.1. China

More than 600 anaerobic reactors were built in China to treat wastewaters from poultry and cattle farms, breweries, sugar, and pharmaceutical production plants [21]. These anaerobic reactors had a total volume of 220,000 m^3 and produced biogas to 84,000 families for heating. Among them, the largest anaerobic treatment system, consisting of two 5,000 m^3 anaerobic reactors and a 10,000 m^3 biogas storage tank, was built in 1987 for the Nanyang Distillery in Henan province. It produces 40,000 m^3 of biogas daily for 20,000 households. In a suburban district of Shanghai, thirteen reactors with a total volume of 4,100 m^3 were installed for a large farming community treating animal manure, bean-processing wastewater, and slaughter wastewater [22]. The system produces 4,920 m^3/d of biogas for the consumption of 2,868 farm workers.

By 1995, there were 5.7 million underground anaerobic reactors in rural China treating agricultural and human wastes, animal manure and food residues [23]. Over 200,000 new installations have since been added annually [21]. In many remote rural areas without electricity supply, farmers installed these reactors to produce biogas for cooking and lighting. A reactor treating household wastes and animal manure can provide about 60% of energy needed by a farming family [24]. The total annual biogas production in rural China amounted to over 10^9 m^3 [25]. In Sichuan province alone, 2.2 million of such reactors producing 6.15×10^8 m^3 of biogas annually for 25 million people in rural areas [21,23].

Industrial pollution is extremely severe in China. Many financially struggling plants still discharge extremely high-strength effluents into the environment with limited treatment, including many of sugar, textile, food, pulp/paper plants. Only a small fraction of plants treat their high-strength wastewater using anaerobic process, many of which are from distillery,

Table 2
Anaerobic treatment plants in (sub-) tropical regions installed by four international companies

Country	Number	COD removal Ton-COD/d	Country	Number	COD removal Ton-COD/d
Brazil	77	1046.2	South Africa	3	41.0
India	75	3377.9	Argentina	2	30.9
China	43	366.5	Vietnam	2	17.0
Mexico	22	413.4	Hong Kong	1	12.4
Philippine	22	454.2	Guatemala	1	50.4
Taiwan	21	207.5	Malawi	1	1.1
Thailand	14	552.5	Kenya	1	100.8
Indonesia	10	31.8	Mauritius Island	1	0.8
Colombia	9	146.3	Nepal	1	49.0
Israel	9	67.8	Pakistan	1	756.0
Venezuela	9	264.1	Puerto Rico	1	1.5
Malaysia	8	142.2	Saudi Arabia	1	10.0
Chile	3	2.7	Singapore	1	12.5
			Total	338	7476.1

winery, pharmaceutical and chemical industries. Three of the top four international companies, Paques, Biothane and Enviroasia, entered the Chinese market in 1994; ADI remains absent as of today. By 1999, these three companies have installed a total of 43 anaerobic plants treating 366 tons of COD daily. Among the 43 plants, 17 are for beverage effluent, 18 for brewery, 3 each for food and potato, and 1 each for coffee and chemical. UASB is the most common type of reactor, representing 86% of all of these reactors. Anaerobic treatment plants in China are small. Twelve of these 43 plants have the daily COD removal capacity of less than 5 tons, and the largest one has the capacity of only 36.75 tons/d. A 1998 survey indicated that over 30 anaerobic plants had been installed by local companies in China treating industrial wastewater [26]. Seven of which use UASB type of reactors. Twelve of the 30 plants have reactors over 100 m^3 in volume, including five in the range of 1,000-3,600 m^3. Most of the plants treat high strength effluent with COD over 10,000 mg/l. Very few brewery effluents in China is treated anaerobically. It is often combined with bottle-washing and sanitary effluents, and the final effluent has less than 1,000 mg/l of COD [27].

Anaerobic treatment of domestic wastewater is mainly applied in the form of septic systems. All domestic wastewater is firstly discharged into small septic tanks near each housing complex. Solids are hydrolyzed and partially degraded in the septic tanks, and only the supernatant is discharged into municipal sewerage. Sludge built up in the tank is removed every 1-2 years. Biogas generated in the urban septic tanks are mostly vented. However, in the rural areas in southern China, biogas generated from these septic tanks are recovered for utilization. Zhang *et al.* [21] estimated that 35,700 biogas-recovering septic systems had been built by 1995 treating the domestic wastewater of 2 million population and supplying biogas as fuel for 22,000 households. A septic tank has a typical volume of 100-200 m^3 treating 30-70 m^3/d of domestic wastewater. Typical design parameters are 3 days of HRT, 0.2 kg-COD/m^3/d of loading, and 0.05 $m^3/m^3/d$ of biogas production rate [28].

3.2. India

In 1996, 3,674 tons of COD were removed daily by anaerobic processes in 79 industrial and 20 municipal wastewater treatment plants [15]. Such a COD removal capacity was far higher than any other countries in the world; for comparison, USA, the runner-up, only removed 2,019 tons of COD daily. Local companies designed and built most of municipal wastewater treatment plants in India, whereas international companies built the industrial wastewater treatment plants. Compared to those in other tropical/subtropical countries, anaerobic reactors in India are large and are used widely for the treatment of distillery effluent. The four leading companies, Paques, Biothane, Enviroasia and ADI, alone have installed a total of 75 anaerobic plants in India since 1986. Of these plants, 31 are over 5,000 m^3 in reactor volume, and 32 are in the range of 1,000-5,000 m^3; only 11 are smaller than 1000 m^3, accounting for only 1% of total COD capacity. All but one of these 75 plants are treating industrial wastewater, including 44 for distillery, 8 for chemical, 6 for pharmaceutical, 5 for paper, 3 each for brewery and starch, 2 for food and 1 each for dairy, textile and combined effluent. Forty plants treat distillery wastewater, accounting for 83% of the total COD removal capacity.

UASB is the most common type of reactor in India, totaling 47 in number and treating 53% of COD removal capacity. The second popular type of reactor is ADI's BVF®, a low-rate covered anaerobic pond system, accounting for 76% of total reactor volume and 44% of total COD removal capacity. Among the 23 BVF® reactors, 19 are treating distillery wastewater

with an average COD of 98,000 mg/l. These reactors are all huge. The average size of the 19 distillery-treating reactors is 22,140 m^3, producing 510,855 m^3 of biogas daily.

3.3. Philippines

At least 22 anaerobic industrial treatment plants have been installed since 1991, 21 by Enviroasia and 1 by Paques. Among them, 9 were for food industry, 5 for brewery, 3 each for distillery and starch, and 2 for beverage. Sixteen of them use UASB reactors, removing a total of 130 tons of COD daily (29% of the total). The other six plants use UAC reactors, removing 323 tons of COD daily (71% of the total). The sizes of these plants are over a wide range. Eleven of the 22 plants are less than 5 ton-COD/d in capacity, 4 are in the range of 5-10 ton-COD/d, 5 in the range of 10-50 ton-COD/d, and only two are over 50 ton-COD/d. The fractions of the total COD removed by individual groups are 8%, 5%, 25% and 62%.

3.4. Taiwan

The first anaerobic reactor treating industrial wastewater in Taiwan was built in 1984. By 1992, local companies installed 12 anaerobic plants with a total reactor volume of 15,500 m^3, 11 of which use UASB type [29]. All are treating industrial effluents, 7 for winery, 2 for chemical, and 1 each for citric, food processing, and yeast. Since 1992, anaerobic technology has also been applied to the treatment of wastewater from paper [30], dairy [31] and petrochemical industries [11].

International companies, including Paques, Enviroasia, ADI, BP-Amoco, Grontmij, and Proserpol, installed at least 24 anaerobic treatment plants in Taiwan, 23 during 1990-95 but only one thereafter in 1998. These installations treat effluents from a wide range of industrial effluents, including 7 for food, 6 for leachate, 5 for chemical, 2 for brewery, and 1 each for beverage, distillery and paper, plus one for an unspecified mixed effluent. The number of leachate treatment plants (6) is probably the highest in the world. Also, Taiwan, as the largest PTA producer in the world, has widely used anaerobic processes to treat this particular wastewater, including three 5,000 m^3 downflow anaerobic filters with circulation by BP-Amoco, one 7000 m^3 UASB reactor by Grontmij, and two hybrid reactor by ADI (5000 m^3 and 4000 m^3 each) [11]. UASB is the most common type of reactor, 21 in number and treating 68% of COD removal capacity. There are 13 plants having COD removal capacity of less than 5 ton-COD/d, representing 54% of total anaerobic plant number but 8% of total COD removal capacity. However, the three plants treating PTA wastewater account 52% of total COD removal capacity.

Anaerobic technology is also extensively used in Taiwan for the treatment of pig wastes. In Taiwan, the number of pigs increased from 2.9 million in 1970 to 10 million in 1990 [32], and to 12 million by 1999. Only half are for local consumption and the other 50% for export. All pig farms are equipped with wastewater treatment system. In 1994, pig farms in Taiwan produced annually 91,848,162 m^3 of wastewater with 936,851 ton-COD [33]. All of these effluents are treated by anaerobic processes.

3.5. Thailand

A total of 5,500 anaerobic reactors, mostly 4-6 m^3 in volume, had been built prior to 1988 as a result of a campaign to clean up the environment and to provide energy for many small farms [34]. However, only 40% of these reactors were still in operation by 1999; the other 60% had been shut down due to technical problem [34]. Newly installed anaerobic reactors are mainly for the treatment of pig farm effluent. The pig population in Thailand is 8.6 million,

producing 180,000 m^3 of effluent and 2,700 ton of COD daily. The Biogas Advisory Unit (BAU)/Chiang Mai University supported by the government under the National Energy Policy Office (NEPO) started in 1995 to build treatment system for wastes produced by pig farms. A typical system was composed of a low-rate anaerobic channel digester and a UASB reactor, plus an oxidation/stabilization pond used as post-treatment. By 1999, 17 of such systems with a total reactor volume of 42,000 m^3 had been built for farms of 210,000 pigs (2.44% of total pig population in Thailand). It produced 210,000 m^3 of biogas daily, generating 25,200 kw-h/day of electrical energy, and 42,000 kg/d of bio-fertilizer.

Three international companies, Biothane, Enviroasia and ADI, have built 14 anaerobic industrial wastewater treatment plants in Thailand by 1999. Most of them (11) were built during 1991-1996, and only two were built thereafter in 1999. All are treating agro-industrial wastewater, except one treating effluent from a synthetic fiber plant. One UAC/AC plant installed by Enviroasia alone has the capacity of removing 274,000 kg-COD/d from a distillery wastewater, equivalent to 49.5% of the total COD removal capacity. Among the other reactors, 12 are UASB and one is ADI's BVF® reactor.

There are 19 anaerobic industrial wastewater treatment plants built by local companies. Of which, 12 were the result of government-sponsored dissemination of UASB biogas works in the alcohol producing plants by 1996 [35]. Produced methane from these anaerobic reactors was not utilized. Anaerobic treatment of domestic wastewater is limited to septic tanks.

3.6. Brazil

Borzacconi, *et al.* estimated [36] that a total of 396 anaerobic reactors with 3.944×10^5 m^3 in volume, had been installed in Latin America by mid-1994. Among them, 1.823×10^5 m^3 (43%), was for the treatment of industrial wastewater, 97% of which was for the effluent of agro-industry. Of the 168 reactors treating industrial effluent, 138 were UASB representing 82% of the total reactor volume. The most common application was for the treatment of effluents from brewery (41), followed by dairy (24), distillery (15), slaughterhouse (15), beverage (12), yeast (10), coffee (8), etc.. Brazil, having 115 anaerobic plants with a total volume of 117,054 m^3, is the leading country in the Latin America.

The survey conducted for this study shows that Paques, Biothane and Enviroasia alone have built 76 industrial wastewater treatment plants, plus one for sewage treatment, in Brazil since 1984. Among all installations, 50 were for brewery, 5 each for beverage and yeast, 4 for food, 3 each for distillery and starch, 2 for cigarettes, and 1 each for chemical, dairy, paper and pharmaceutical. Brewery effluent alone accounts for 72% of the total COD removal capacity. Among the 76 plants, 59 are UASB reactors, 16 are IC reactors and 2 are EGSB reactors. Plants built by these international companies are often quite large; 38 plants are able to remove 10,000-50,000 kg-COD daily, representing 76% of the total capacity.

Campos [16] estimated that there are over 200 anaerobic municipal wastewater plants in Brazil. This is substantially higher than the 25 estimated in 1998 by Hulshoff Pol *et al.* [15]. The discrepancy is likely due to that most of these plants were designed and built by the local companies and thus unknown by the foreigners. Three plants in Belim, Para, alone are treating sewage from 130,000 inhabitants. Since Brazil has very positive experience in anaerobic municipal wastewater treatment, a number of large scale systems presently are in design [16]. These include a UASB plant in the state of Parawa for one million inhabitants, another UASB plant in Rio de Janeiro treating 4 m^3/s of flow, four systems in Sao Paulo State for 350,000, 140,000, 140,000, and 76,000 inhabitants, respectively.

3.7. Mexico

A survey by Monroy *et al.* [37] shows that in Mexico 85 anaerobic wastewater treatment plants have been installed since the technology was first applied in 1987. The total installed volume is 228,551 m^3 and are treating 216,295 m^3/d and 590 tons of COD daily. UASB reactors account for 74% of the installed volume and local companies have supplied 76% to the anaerobic market.

Mexico has 282 industrial wastewater treatment plants, treating only 12% of the total effluent nationwide. Of which, 43 are anaerobic wastewater treatment plants with a total reactor volume of 93,490 m^3 treating 76,644 m^3 of wastewater daily, accounting for only 0.53% of all industrial effluent. Eight more are under construction for 44,010 m^3 of additional volume, including a single 20,808 m^3 reactor treating PTA wastewater. Most of the wastewaters treated are those containing high levels of easily biodegradable substrates. Plant wastewaters from brewery, coffee, beverage, and yeast, respectively, represent 21%, 14%, 12%, and 5% by number, and 27%, 1%, 2%, and 53% by volume of the 43 plants in operation. Although the main polluting industries in Mexico are sugar, paper, chemical, petrochemical and oil refinery, only four plants among them use anaerobic treatment processes, three for paper and one for petrochemical (dimethylterephthalate).

UASB reactors are used in 58% of industrial anaerobic treatment plants, treating 91% of wastewater by volume. Two plants, using low-rate anaerobic ponds, have 52,500 m^3 of reactor volume but only treat 3,900 m^3 of wastewater daily, representing only 5.1% of total anaerobically treated volume. For the 43 plants, the reactor temperature ranges from 17 to 40°C, with an average of 28.6°C. About 53% of reactors are operated over 30°C, 35% at 20-30°C, and only 12% at 17-20°C. The wastewater COD varies from 700 mg/l to 23,000 mg/l, averaging 5,562 mg/l. HRT also varies widely from 5 to 336 hours, the average being 50 hours. Organic loading ranges from 0.45 to 15 kg-COD/m^3/d, averaging 6.09 kg-COD/m^3/d. All but three plants have COD removal efficiency over 70%, the average COD removal efficiency being 81%. Only 14.6% of anaerobic industrial wastewater treatment plants recover methane for uses, 43.9% flare the biogas and the rest simply vent the biogas into atmosphere. All anaerobic reactors built by international companies have biogas handling system; biogas is either flared or recovered for utilization.

A total of 33 anaerobic municipal wastewater plants were designed and built by local companies, plus one built by a Cuban company (CENIC). The majority of these plants (31) use the UASB design. The volume of these UASB reactors totals 90,697 m^3, representing for 99.7% of all anaerobic municipal treatment plants. One is the largest UASB reactor built in the world treating combined municipal and industrial wastewater; it alone has a volume of 83,700 m^3, and is expected to expand to 133,920 m^3 in the future. The reactor temperature ranges from 10 to 32°C; most reactors are operated around 20°C. The municipal wastewater COD ranges from 213 to 2400 mg/l, averaging 518 mg/l. The HRT ranges from 6 to 30 hours, with an average of 11.6hours. Organic loading ranges from 0.28 to 3.0 kg-COD/m^3/d, averaging 1.25 kg-COD/m^3/d. The COD removal efficiency ranges from 50% to 95%, averaging 65%. The effluent COD ranges from 26 to 480 mg/l, averaging 160 mg/l. Effluents of 25 plants (74%) have COD exceeding 100 mg/l of COD. Most of these plants have post-treatment system, either biological (aerobic lagoon, aerobic and anoxic reactors) or physical (secondary settler, sand filter, and activated carbon). Many effluents are chlorinated before final disposal. All plants vent biogas directly without even removing hydrogen sulfide.

4. CONCLUSION

Over 1200 full-scale anaerobic plants have been installed worldwide so far, over 40% of which are in the (sub-)tropical regions. Although the pace has picked up rapidly in the past 10 years, the market potential is still enormous. The application of anaerobic treatment process in (sub-)tropical regions has not just been limited to the traditional effluents of agro-industries, but has also been extended to the treatment of effluents from chemical industries, landfill leachate, municipal wastewater, etc.. International companies have played an important role in introducing the technology to the (sub-)tropical regions, but some local companies have shown the capacity to compete.

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