WHERE IS ANAEROBIC DIGESTION IN MEXICO? STATE OF THE TECHNOLOGY, LIMITATIONS AND POTENTIAL FOR ITS DEVELOPMENT.

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ABSTRACT

As a continuation of the inventory promoted by María Viñas, Matilde Soubes, Liliana Borzaconi and Lucía Muxi, organizers of the III Workshop on Anaerobic Digestion in 1994, by suggestion of Look Hulshoff Pol and with funds provided by TBW-Frankfurt in Germany, this updating of the situation of anaerobic digestion in Mexico (Noyola & Monroy 1994) is presented. New reactors have been recorded and the perspectives for the development of this biotechnology are analysed from the legal and financial point of view.

Due to the nascent wastewater treatment practice in the country there is a great opportunity to introduce anaerobic digestion as the core of the wastewater treatment because of its advantages as a sustainable and environmentally sound biotechnology. In order to be able to introduce it at the Latinamerican region it is necessary to identify its friends and foes. That is, to understand all those technical, economical and financial aspects which limit its development. According to the National Water Commission (CNA), in 1995 there was a potable water supply of 272 m^3/s through the city piping networks plus an undetermined amount via wells and other natural sources. Municipal and industrial wastewaters were produced at the rates of 232 and 168 m^3/s respectively. Today 20 % and 12% of these volumes are treated but with very low efficencies. For example, only 41 % of the municipal wastewater treatment plants work with efficiencies greater than 75% and very few reach the discharge conditions. There are about US$ 4,515x10^6 to invest in environmental projects which are managed by the development banks but there are other financing mechanisms through treasury incentives and penalties.

Within this situation, anaerobic digestion has grown but not at the necessary rate and the bigger investments keep being made on conventional aerobic and physicochemical technologies.

Presently there are in the country 65 anaerobic wastewater treatment plants (WWTP) treating a rate of 191,000 m^3/d with an installed volume of 181,000 m^3. UASB reactors make 70% of the installed volume and 70% of the anaerobic market has been covered by national companies. Proper integration of the anaerobic digestion processes for water and energy recycling has not been achieved and is badly needed to demonstrate economic and ecological sustainability.

Environmental Situation.

There is a great public concern in Mexico for the origin and fate of water and wastewaters. Due to this concern and to the recent environmental laws, there has been a great investment in water supply and wastewater collection and treatment (Table 1). Table 2 shows the growing rate in municipal WWTP and indicates a pace of 113 plants or 33 m³/s per year since 1988. Despite this relative high growth rate (compared to the economy growth), the gap between the treated 47 m³/s and the produced 232 m³/s of sewage is still very large giving place for advanced and not expensive technologies.

A closer analysis of the small fraction of treated wastewaters will show that out of the 946 municipal treatment plants, only 755 are operating (79%). From these, 41% (312 plants) operate with efficiencies greater than 75% and 199 plants (26%) with efficiencies lower than 50%. This is because the treatment works are of very different types as shown in figure 1. Average capacity of these plants is 42 l/s but range from 5000 l/s to 1 l/s. The largest number are stabilization ponds, most of them overloaded and thus working as primary treatment plants. The second largest number corresponds to activated sludge plants which together with oxidation ditches, aerated lagoons and trickling filters make, up to 40% of treatment plants. Very few of them have sludge treatment facilities which added to the high operating and investment costs make them a non-viable option in the long run.

TABLE 1 Drinking Water and Sewage Nets, Coverage and Growth Rate in 1996

	Flow rate (m^3/s)	Population covered %	Growth rate (%/yr)
Drinking water net.	272	86.2	4.34 (pop based)
Total MWW produced	232	-	
MWW in sewers	120	69	8.47 (pop based)
MWW Treatment	47	14.5	14 (plants based)

MWW = municipal wastewater, from CNA 1995,1996.

The background columns of figure 1 show the distribution of the plants which are not operating. It can be seen that, probably due to overloading conditions, most of the non working projects are stabilization ponds and primary treatment plants. Aerobic processes add up to 30 % of the non working plants due to maintenance of the aerators.

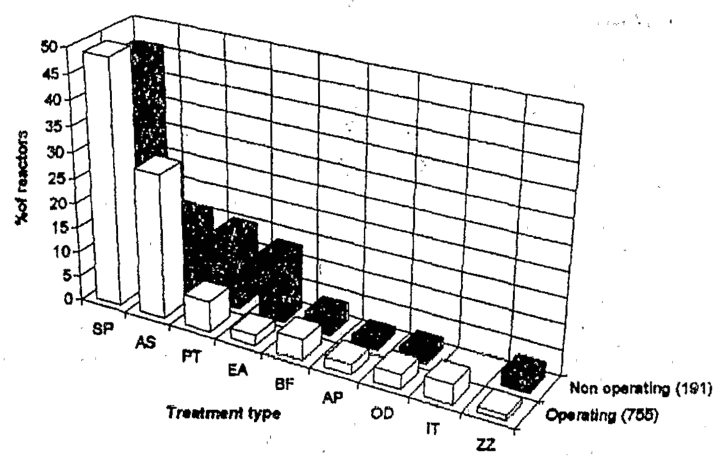
According to the CNA, by 1994, 168 m³/s of wastewater were produced by the industry, 12% of it being treated in 282 industrial wastewater treatment plants, 61 % being released to the environment and 27% discharged to the sewers. This volume is generated as 39% from the sugar cane industry, 21% from the chemical industry, 22% from the paper mill, petrochemical and the oil industries and 18% from other industries.

expensive technologies.

TABLE 2 Evolution of the Municipal Wastewater Treatment Plants.

Year	No. of plants	Treated vol. (m^3/s)	Expected removal (T BOD_5/d)
1988	233	14	302
1989	256	15.2	343
1990	310	19.3	418
1991	361	25.1	541
1992	577	29.1	627
1993	650	34.8	750
1994	825	38.4	830
1995	946	47.6	non det.

CNA, 1996; Sancho, 1992.



Legal, economic and financial aspects

In 1988 the mexican government issued the General Law for the Ecological Equilibrium and Environmental Protection which triggered an intense activity to match the discharge standards of the mexican industry with that of their partners in the NAFTA (North America Free Trade Agreement, TLC in Spanish). This activity is characterized by: a) the continuous inspection of industry with the consequent partial and total closures, b) penalizing on the amount of wastes discharged (CNA, 1993), c) an advertised availability of funds for any kind of depollution equipment, d) one hundred studies for the preparation of Ecological Standards (INE, 1993-1994) and programmes for training of human resources (Jiménez 1995). The Environmental Budget grew from US\$ 6.6 x 10^6 in 1989 to 78 x 10^6 in 1992 (Cerón 1993). Currently, according to the Secretary of Ecology (SEMARNAP) there will be an investment on environmental market of US\$ 4,515 x 10^6 from 1995 to 2000 (La Jornada 1996). These funds will come from the development banks and from national and foreign private investments.

To our knowledge the development banks (FORCCYTEC, FIDETEC, Nacional Financiera) do not provide agile, economic and fresh funds for most of the middle and large sized industries (Nacional Financiera, 1995; Nafin, 1995). The auto financing of most of the industry is being propelled by the charges on COD, SS and wastewater volume and the tariffs of tap water. Whenever there is an economic gradient, industry will invest at profit's expense rather than borrowing from banks.

The cities, with their larger treatment works, turn to contract the services of foreign or domestic private companies which invest under a Service Contract to build or operate new or existing works (BOT: build, operate and transfer) while the government keeps the responsability with the public. Contracts can agree a total privatization of the treatment works by the company or its recovery by the City after an agreed number of years. This system provides the Cities with the WWTP at no initial cost but these kind of contracts have been, so far, difficult to negociate because of the risks involved with the long range operation of the plants.

Historical Development of Anaerobic Digestion in Mexico

The use of anaerobic digestion (AD) as wastewater treatment started late in Mexico compared to the European countries or even North America. Figure 2 shows the rate of growth of AD in Mexico while tables 3 and 4 give some technical data of the digesters.

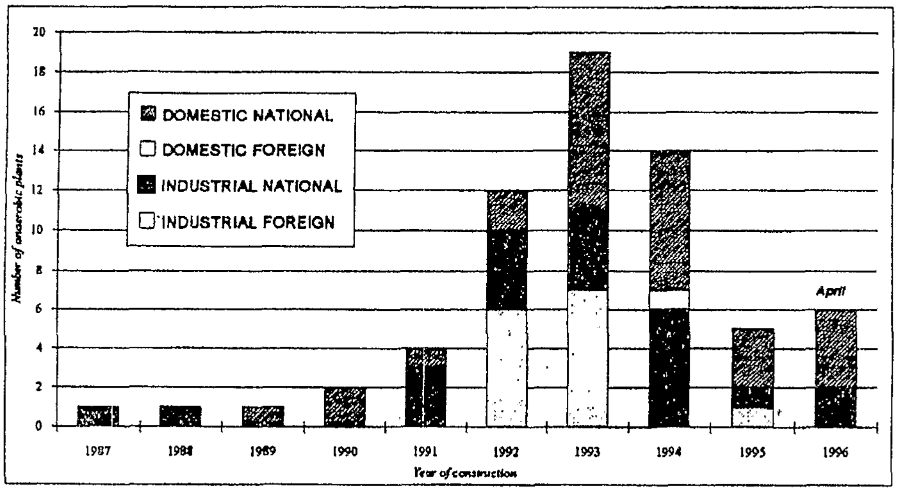


Figure 2. Number of anaerobic WWTP per type of wastewater and origin of technology.

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The first digester was actually constructed only in 1987. After it, the following development was rather slow since until 1991 the rate of digester construction stayed around one to four reactors per year. In fact, 1992 with 12 built reactors, marked a significant growth of 400%. During the two subsequent years, the rate of digester construction remained higher than 12 per year reaching a maximum of 19 in 1993 (Fig. 2). However, it was abruptly decreased in 1995 due to an economic crisis after the 100 % devaluation of the peso in december 1994. A slow recovery in 1996 was noticed despite the reduction of public and private funds available to solve environmental problems.

Present situation of AD

Nowadays, 65 full scale digesters (without considering the 71 very small reactors built by Tecnoadecuación -see table 4 plants 8 and 17), accumulating a total installed volume of 181,359 m^3 and treating 190,776 m^3 of wastewater per day (2,207 l/s) are in operation in Mexico (Fig. 3). This represents 0.55 % of the total wastewaters generated and 3.3 % of the treated wastewaters (2.9 % of the municipal, and 4.2 % of the industrial).

Type of wastewater treated

It should be noted that contrary to Europe and North America but similarly to Brazil, China, Colombia and India, anaerobic treatment has been applied in Mexico not only to industrial wastewaters but also to sewage. Indeed 44.6% of all the reactors (almost 50% of the digester volume) are treating this waste (Fig. 4). These reactors include even the biggest ever built in the world (83,700 m^3, 46% of the digesters' total volume) which is presently being commissioned and should be extended to 133,920 m^3 in 1997 (Tab. 4, reactor 7). Most of the digesters treating domestic effluents correspond however to very small reactors. Actually, 34.5% of them have a volume inferior to 40 m^3 and 69% a volume smaller than 100 m^3.

Most of the industrial effluents treated by AD in Mexico are classical of AD treatment in the world (malting, brewery, dairy and cheese, soft drinks, yeast, paper factory, food and fruit processing, pig slaughtery) with a predominance for the brewery sector -25% of the industrial digesters- (Fig. 5). Nevertheless, some effluents typical of local activities like wet coffee processing or dimethyl- terephthalate (DMT) production (there is only one other reactor in India) which are poorly treated in the world by AD are being treated here (Tab. 3, reactors 2, 6, 26, 34-36).

Figue 5 shows the distribution of anaerobic reactors per type of wastewater.

It is important to take notice of the absence of anaerobic reactors in the sugar cane industry and of

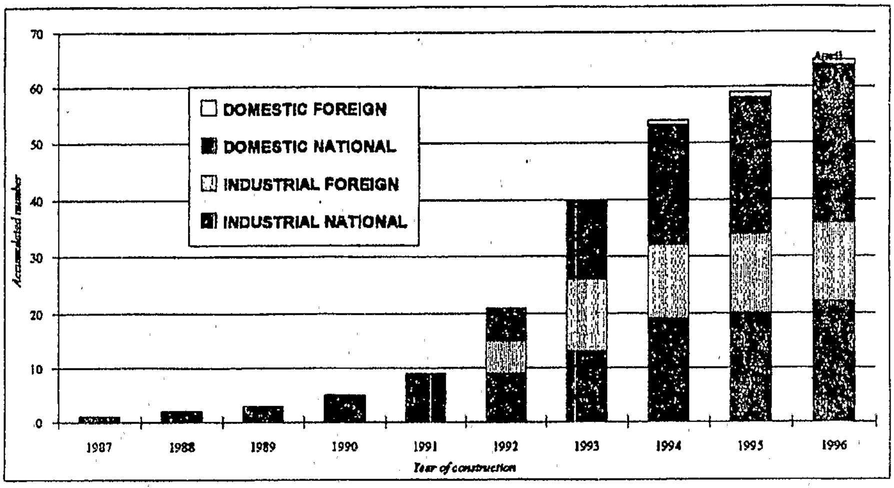

Figure 3 Accumulated Number of Anaerobic Treatment Plants in Mexico

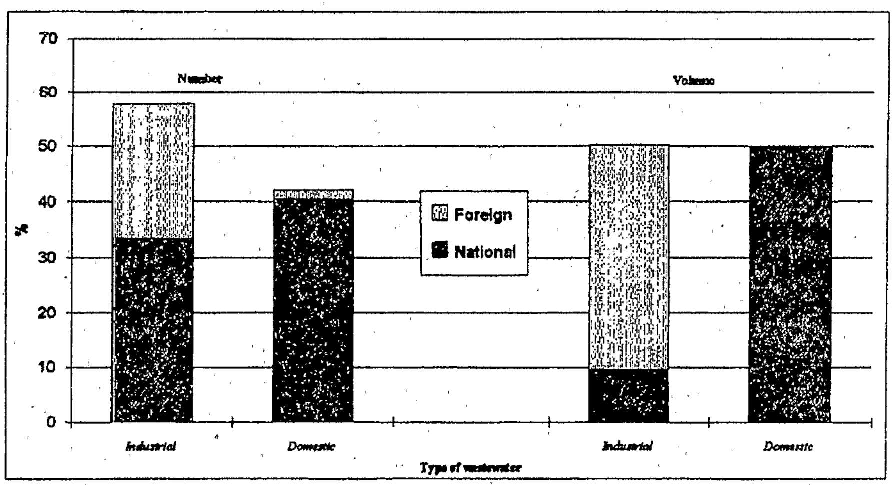

Figure 4. Distribution of reactor number and volume, type of water and origin of the technology.

their incipient presence in the chemical industry through the DMT. Research has been done with these two effluents (Durán de Bazúa *et al.* 1991; Ilangovan and Noyola, 1993; Macarie *et al.* 1992) to improve efficiencies by reducing inhibition and supplementing nutrients. Unfortunately the economic difficulties and lack of development program faced by the sugar cane industry will not allow it, to look into this field, in the near future.

As shown in figure 3, the first reactors built in Mexico were treating industrial wastewaters. Two years later (1989) however, the first UASB reactor treating sewage was built as a 50 m³ demonstration unit at the campus of the Universidad Autonoma Metropolitana (UAM) quickly followed in 1990 by 2 big units of 2200 m³ each, constructed by the government (Tab. 4, reactors 2 & 3).

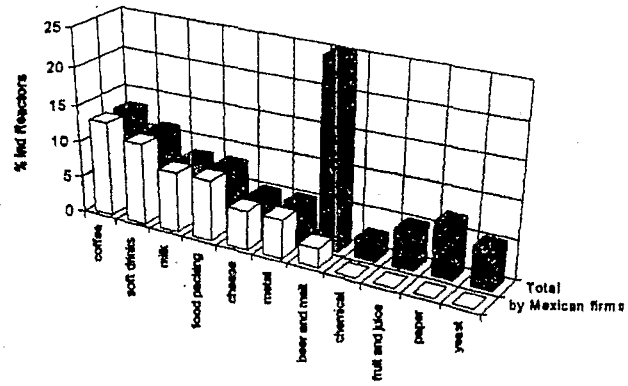

Figure 5. Distribution of anaerobic digesters in the mexican industry.

Source of technology.

Both local and foreign technologies have been applied in Mexico. Nevertheless, until 1991, only reactors based on local technology were built (Fig. 2). The existence of these nine units together with the promotion work done by the academic group formed by the Biotechnology Department of UAM, ORSTOM (French Scientific Research Institute for the Development in Cooperation) and the Engineering Institute of the Universidad Nacional Autonoma de Mexico (II-UNAM) as well as a particular economic situation (entrance of Mexico in the NAFTA, aperture to foreign investments, need of low cost treatment systems) opened the doors to the anaerobic market leaders, the Dutch Biothane and Paques, but also to the CanadianADI and the Cuban CENIC (Tab. 3 & 4).

The massive intervention of these companies (15 plants representing 23% in number and 40.6% in volume of all the plants built in the country, Fig. 4) was however restricted to the 1992-1993 period (the reactor built in 1996 by ADI corresponds only to an extension of a plant built in 1992) and has been drastically stopped (Fig. 2 and 3) by the mentioned economic crisis. This foreign intervention was also quite exclusively limited to the treatment of industrial effluents (Fig. 4) on a reduced type of wastewaters, mostly those from breweries, paper and yeast factories (fig. 5).

From all the local technologies applied, with 30 reactors totalizing 16,394 m^3, the one developed by the UAM-UNAM academic group and commercialized by IMASA, Energia y Ecologia, Forza, DescontaminAccion andTACSA has received the best acceptation. For some projects, IMASA and Energia y Ecologia have even competed successfully with the foreign multinational companies (i. e. plants number 3, 8 and 20 in table 3). The technologies developed by the Universidad de Yucatan (4 reactors treating industrial wastewater and totalizing 1728 m^3) and people from the SEMARNAP (6 reactors treating domestic wastewaters totalizing 88 261 m^3) are also emerging (Rodríguez and Altamirano, 1995). Contrary to what happened in Colombia and Brazil, the Mexican national companies have demonstrated the capacity for constructing large reactors and applying the technology to wastewaters not touched by the foreign companies (coffee processing, dairy and cheese, soft drinks and domestic effluents) (Borzacconi *et al.*, 1996; Borzacconi y López, 1994).

Type of Reactors Applied

Four types of reactors have been applied in the country: Upflow Anaerobic Filters, hybrid, low rate and UASB reactors (Tab. 5). The dominating technology corresponds however by far to UASB reactors considering both the number and volume of reactors (independently of the technology origin). This is probably the result of the construction simplicity and the low cost associated to the absence of packing material.

Except in one case (Tab. 4, plant number 19), all anaerobic filters and hybrid reactors have been built by local companies and treat industrial as well as domestic effluents. Contrary to what could be expected, only two low rate reactors, such as anaerobic lagoons have been constructed. More surprisingly, 92% of the volume of this type of

Table 5. Different types of reactors constructed in Mexico in april 1996 in relation to the type of wastewater treated and the origin of the technology.

Type of reactor	Upflow filter	Hybrid	Low rate *	UASB
% of total number of reactors	4.6	15.4	3	77
% of total volume	0.2	1.5	28.9**	69.4
% of the different reactors built by national companies	66.7	100	50	74
% of the number of reactors treating:				
industrial wastewaters	33.3	90	100	48
domestic wastewaters	66.7	10	-	52

* Includes ADI-BVF and lagoons, ** 27% of the 29% correspond to the plant built by ADI.

digesters correspond to one sole plant built by the foreign company ADI, (Tab. 3, plant 15). By itself, this plant corresponds to 27% of all the digester volume installed in Mexico. In fact, this plant plus the Rio Blanco one, (Tab. 4, plant 7) represent almost 73% of the total digester volume of the country.

Biogas Use

Despite the fact, that one important factor for the selection of anaerobic treatment is the possibility of energy recovery via combustion in boilers, this is done only in 6 plants in Mexico (Fig. 6). This is a world tendency caused by the extra investment required to achieve such recovery or, as in the case of domestic wastewater because of the low biogas production. More worrying is the fact that at least 44% of the plants installed in Mexico (Fig. 6) do not even flare the biogas produced and vent it directly to the atmosphere contributing to the greenhouse effect. Some of them however, perform at least iron filtration to eliminate hydrogen sulfide. It should be noticed that in all the plants commissioned by foreign companies, the biogas is recovered or flared and that the problem of venting is found exclusively with locally designed reactors independently of the type of wastewater.

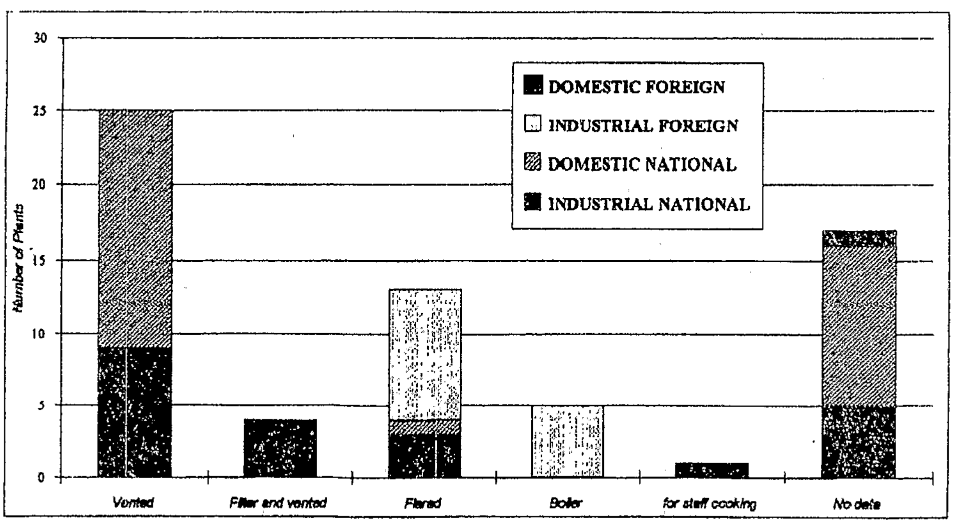

Figure 6. Uses of Biogas by type of wastewater and origin of the technology in April 1996.

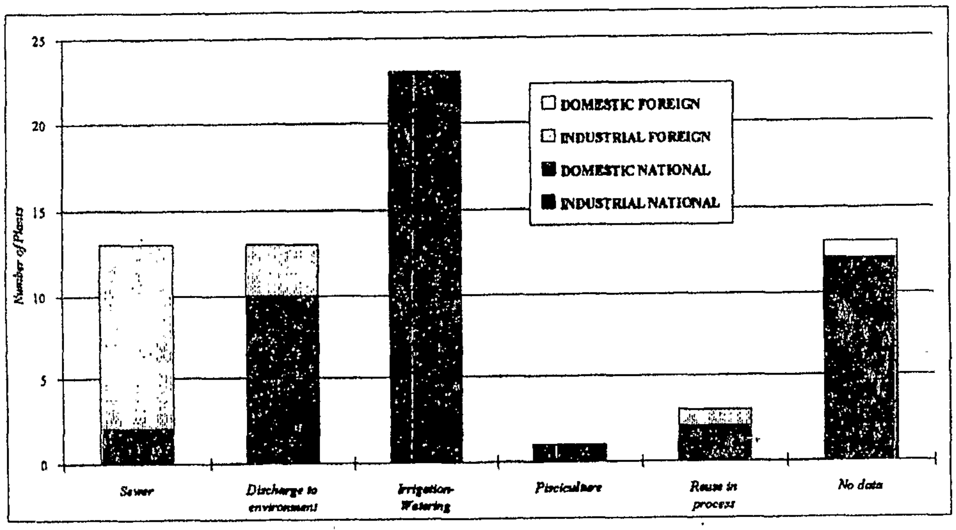

Figure 7. Uses of Treated Water by type of wastewater and origin of technology in April 1996.

Treated water use

While, the Mexican companies were not aware of the biogas fate, the limited resources of water in the country incited them to reuse it (Fig. 7). As a consequence in 23 plants (46% of the national plants), the water is used for the irrigation of crops or gardens and in one of them even for pisciculture. Other uses correspond to the recycle in toilets or cleaning operations (Tab. 4, plants 5 & 12) as well as in the production process (Tab. 3, plant 1). Contrary to the local companies, for 93% of the digesters built by the foreign companies no reuse has been projected for the treated water which is directly discharged into the environment or sewers.

Conclusions

Anaerobic digestion can be considered nowadays as a mature technology in Mexico. Despite its economical advantages it remains however in minority compared to other technologies. Local companies have shown the capacity to compete successfully with foreign companies. An effort should be made however to promote it as the core of a sustainable technology for wastewater treatment. As a first step, biogas utilization needs to be put to work. One interesting point is that compared to its North American neighbours, Mexico has shown a better acceptation of anaerobic digestion. Indeed, in less than 10 years Mexico has installed more than twice the number of digesters built in Canada (25 reactors, the first one in 1982) and 75% of the digesters operating in the United States (80 reactors, the first in 1977).

ACKNOWLEDGEMENTS

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Table 3: Anaerobic Digesters treating Industrial wastewater in Mexico

Reactor number	Year of construction/ actual state	Location	Design/ Constructor *	Reactor type **/ volume (m3)	Type of wastewater	Treated volume (m3/d)	COD (mg/l)	Pre-treatment	Operating temperature °C	Bv (kg COD/m3.d)	HRT (days)	COD Removal efficiency (%)	Post-treatment	Treated water use/discharge	Biogas production (m3/d) / use	Sludge treatment	Sludges use/ disposal
1	1987 in operation	Celaya,Guanajuato	IPN	108	greases (mechanical)	432	700	none	20	2.8	0.25	99.9	aerobic reactors	recycle to the factory process	Vented	none	-
2	1988 in operation	BOLA DE ORO Coatepec, Ver.	INIREB	AF 250	wet coffee processing	22.5	5000	Heating tank	35	0.45	11	97 (BOD)	Settler sand filter	to river	Vented	Sun drying	Fertilizer
3	1991 in operation	CENTRAL DE MALTA SA de CV Puebla	IMASA	UASB 2400	Malt	3800	1700	Screen, grit chamber, homogenization	30	2.69	0.63	77	Activated sludge, chlorination	to river	Flared	-	to Land
4	1991 in operation	PROTAPSA Guanajuato	IPN	UASB 4.5	Food	18	1000	none	38	4	0.25	80	Wet land subsurface flow system	Well injection	Vented	none	-
5	1991 in operation	MOULINEX Guanajuato	IPN	UASB 4.5	Industrial and domestic	18	700	Grease interceptor tank	38	2.8	0.25	97	Aerobic biofilter	Watering	Vented	none	-
6	1992 in operation	Tlapexcatl, Ver.	CIRAD (National)	hybrid 10	wet coffee processing	3-4	3000-6000	Primary settler, flotation	18-20	3	2.5-3.3	70	Aeration, sand filter	to river	7.7 for staff cooking	Sun drying	Fertilizer
7	1992 in operation	CORP BIMBO PLANTA BARCEL México-Toluca	ENERGIA y ECOLOGIA	UASB 300	Food	605	2119	DAF, grit chamber	26	4.27	0.5	85	Aerobic biodisc	-	Vented	-	-
8	1992 in operation	CUAUHTEMOC-MOCTEZUMA SA de CV Toluca Estado de Mexico	IMASA	UASB 4800	Brewery	9072	4056	Screen, primary settler, homogenization, tank	25-30	7.66	0.53	80	Activated sludge, chlorination	to river	6480 Flared	Sludge thickening, anaerobic digestion of activated sludge, filter press	Fertilizer
9	1992 in operation	CUAUHTEMOC-MOCTEZUMA SA de CV Tecate B.C.	PAQUES	UASB 2 x 700	Brewery	3100	5100	Screen, primary settler, acidification tank	30-32	11.3	0.45	85	Activated sludge, chlorination	to River	3000 Flared	Anaerobic digestion of activated sludge, band filter	Sold as inoculum
10	1992 in operation	CUAUHTEMOC-MOCTEZUMA SA de CV Guadalajara	PAQUES	UASB 2 x 925	Brewery	5600	4200	Screen, primary settler, acidification tank	30-32	12.71	0.33	85	Activated sludge, chlorination	to Sewer	5900 Flared	Anaerobic digestion of activated sludge, band filter	Sold as inoculum

* BIOTHANE is represented in Mexico by TECNOLOGIA INTERCONTINENTAL, the companies IMASA, ENERGIA y ECOLOGIA, TACSA, FORZA, GTSA and DESCONTAMINACCION comercialize the technology developed by UAM-UNAM

** AF: Anaerobic Filter; UASB: Upflow Anaerobic Sludge Blanket; ADI-BVF: Low-rate upflow sludge blanket process.

*** redesigned from existing facilities

Bv= Organic loading rate, HRT = Hydraulic Retention Time

**** Design data

Continuation
Table 3b: Anaerobic Digesters treating industrial wastewater in Mexico

Reactor number	Year of construction/ actual state	Location	Design/ Constructor *	Reactor type **/ volume (m3)	Type of wastewater	Treated volume (m3/d)	COD (mg/l)	Pre-treatment	Operating temperature °C	Bv (kg COD/m3.d)	HRT (days)	COD Removal efficiency (%)	Post-treatment	Treated water use/discharge	Biogas production (m3/d) / use	Sludge treatment	Sludges use/ disposal
11	1992 in operation	EL SAUZ Cortazar, Guanajuato	UAM-I ***/ User	Lagoon fed as UASB 4000	Cheese	500	4430	Grease interceptor tank	26	0.55	8	85	Aerobic and water hyacinth lagoons	Irrigation	Vented	no need	no need
12	1992 in operation	JUGOS DEL VALLE México, D.F.	PAQUES	UASB 380	Packing of fruits	1140	3700	Screen, acification tank	30	11 21	0.33	80	Aerobic biodisc, secondary settler chlorination	to Sewer	1800 Flared	none	sold as inoculum
13	1992 in operation	KIMBERLY CLARK Orizaba, Veracruz	PAQUES	UASB 1320	Paper factory	2200	9160	DAF, acidification tank	30-40	15.26	0 6	85	none	to Sewer	8500 Boiler	none	sold as inoculum
14	1992 in operation	UNIPAK Morelos	PAQUES	UASB 190	Paper factory	1000	3940	DAF, acification tank	35	20	0.19	70	Oxidation tank, filter press	to Sewer	1000 Flared	none	sold as inoculum
15	1992 in operation extention 1996 under start-up	Toluca Estado de Mexico	ADI	ADI-BVF 2 x 14250 ADI-BVF 20000	Yeast	3400	23000	Homogenization tank	35	1.6	14	62 (COD) 89 (BOD)	none	to Sewer	30000 Boiler	none	none
16	1993 in operation	LICONSA San Antonio de la Isla, Edo. de Mexico	TACSA	Hybrid 172	Dairy	345	1600	Homogenization tank, grease interceptor tank	18	3.2	0.5	78	Activated sludge	-	-	-	-
17	1993 in operation	LICONSA San Isidro, Morelos	FORZA	UASB 85	Dairy	260	2032	Neutralization, grit chamber	24	6.21	0.33	75	Activated sludge	Watering	138.6 Vented	none	landfill
18	1993 re-starp up	CAPERUCITA Querétaro	UAM-I***/ User	UASB 2 x 112	Cheese	172	3000	Grease and solid tramps, homogenization, tank, DAF	30	2.3	1.3	-	Sand filter, chlorination	Watering	Vented	none	none
19	1993 in operation	MODELO Ciudad Obregón	BIOTHANE	UASB 1700	Brewery	1800	7000	Screen Homogenization tank	32.4	7.45	0.94	85	Extended aeration activated sludge	< to Sewer	Boiler	Storage tank	Sold as inoculum
20	1993 in operation	CUAUHTEMOC-MOCTEZUMA SA de CV Navojoa, Sonora	IMASA	UASB 1816	Brewery	5356	2690	Screen, primary settler, homogenization tank	25-35	7.93	0.34	80	Activated sludge, chlorination	-	flared	Sludge thickening, aerobic digester of activated sludge, filter press	-

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*** redesigned from existing facilities

Bv= Organic loading rate, HRT = Hydraulic Retention Time

**** Design data

Continuation

Table 3c : Anaerobic Digesters treating industrial wastewater in Mexico

Reactor number	Year of construction/ actual state	Location	Design/ Constructor *	Reactor type **/ volume (m3)	Type of wastewater	Treated volume (m3/d)	COD (mg/l)	Pre-treatment	Operating temperature °C	Bv (kg COD/m3.d)	HRT (days)	COD Removal efficiency (%)	Post-treatment	Treated water use/discharge	Biogas production (m3/d) / use	Sludge treatment	Sludges use/ disposal
21	1993 in operation	CUAUHTEMOC-MOCTEZUMA SA de CV Monterrey	PAQUES	UASB 2850	Brewery	13825	3000	Screen, primary settler, homogenization tank, acidification	38	14.55	0.21	75	Activated sludge, chlorination	to Sewer	10600 flared	Sludge thickening, aerobic digester of activated sludge, band filter	Sold as inoculum
22	1993 in operation	CERVECERIA DEL TROPICO	BIOTHANE	UASB 3000	Brewery	3816	7000	Screen, homogenization tank	35	8.9	0.78	85	Activated sludge	to Sewer	boiler	Storage tank	sold as inoculum
23	1993 in operation	Cerveceria Zacatecas	BIOTHANE	UASB 5000	Brewery	5016	6849	Screen, homogenization tank	30	6.87	0.99	85	Extended aeration activated sludge	to Sewer	boiler	Storage tank	sold as inoculum
24	1993 in operation	EMPAQUES MODERNOS Guadalajara	PAQUES	UASB 715	Paper factory	2200	4500	DAF, acidification tank	30-40	13.84	0.32	70	Activated sludge	Reused and discharged to sewer	3000 flared	-	sold as inoculum
25	1993 in operation	IMEXA Puebla	BIOTHANE	UASB 500	Yeast	221	17000	Homogenization tank	32	7.52	2.26	75	none	to River	flared	Storage tank	sold as inoculum
26	1993 in operation	PETROCEL Tampico	BIOTHANE	UASB 2 x 2400	Chemistry (dimethyl-terephthalate)	2028	18500	Screen, homogenization tank	30.4	7.5	2.37	95	Extended aeration activated sludge	to Sea	flared	Storage tank	sold as inoculum
27	1994 in construction	RANCHO PORCINO SAN FRANCISCO Teran, Nuevo León	ENERGIA y ECOLOGIA	UASB 191	Pig slaughter	140	5828	Screen, grit chamber, primary settler, homogenization	20	4.28	1.36	70	-	-	-	-	-
28	1994 in operation	EMBOTELLADORA LA BUFA Zacatecas	Universidad de Yucatán/User	Hybrid 352	Gaseous beverage	259	7000	Neutralization, homogenization	30	5.15	1.35	80	none	-	Iron filtered and vented	Press filter	-

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** AF, Anaerobic Filter; UASB: Upflow Anaerobic Sludge Blanket; ADI-BVF Low-rate upflow sludge blanket process

*** redesigned from existing facilities

Bv= Organic loading rate, HRT = Hydraulic Retention Time

**** Design data

Continuation

Table 3d: Anaerobic Digesters treating Industrial wastewater in Mexico

Reactor number	Year of construction/ actual state	Location	Design/ Constructor *	Reactor type **/ volume (m3)	Type of wastewater	Treated volume (m3/d)	COD (mg/l)	Pre-treatment	Operating temperature °C	Bv (kg COD/m3.d)	HRT (days)	COD Removal efficiency (%)	Post-treatment	Treated water use/discharge	Biogas production (m3/d) / use	Sludge treatment	Sludges use/ disposal
29	1994 in operation	EMBOTELLADORA del CARIBE Cancún	Universidad de Yucatán /User	Hybrid 336	Gaseous beverage	432	5000	Neutralization, homogenization	30	6.43	0.78	80	Oxidation lagoons, sedimentation chlorination	Irrigation	Iron filtered and vented	Drying	-
30	1994 in operation	EMBOTELLADORA del SURESTE Mérida	Universidad de Yucatán /User	Hybrid 790	Gaseous beverage	691	5000	Neutralization, homogenization	30	4.37	1.14	80	Oxidation lagoons, sedimentation chlorination	Irrigation	Iron filtered and vented	Drying	-
31	1994 in operation	EMBOTELLADORA de CAMPECHE	Universidad de Yucatán /User	Hybrid 250	Gaseous beverage	346	5000	Neutralization, homogenization	30	6.91	0.72	80	Oxidation lagoons, sedimentation chlorination	Irrigation	Iron filtered and vented	Drying	-
32	1994 in construction	LICONSA Tlahuac	FORZA	UASB 945	Dairy	1210	3000	Grease interceptor tank, neutralization	20	3.85	0.78	70	Activated sludge, desinfection	Watering	889 vented	none	-
33	1995 start up at end of 1996	JUMEX/COSTEÑA Edo. de México	PAQUES	UASB 1450	Combination of fruit processing and pepper canning	4320	4030	Screen, homogenization tank, DAF, acidification	30	12	0.33	80	Activated sludge, chlorination	to Sewer	8000 flared	none	Sold as inoculum
34	1995 constructed	"Solidaridad Cafetera Sabaña" Huatusco, Veracruz	Marco Castillo	Hybrid 2 x 40	Wet coffee processing	-	3000-6000	Decantation tank, flotation	18-20	-	-	75	Oxidation lagoon, sand filter	to River	-	none	-
35	1996 constructed	"Prof. Manuel Sodas" Huatusco, Veracruz	Marco Castillo	Hybrid 2 x 225	Wet coffee processing	-	-	-	-	-	-	75****	Oxidation lagoon, sand filter	to River	225	-	-
36	1996 constructed	"Vicente Guerrero" Misantla, Veracruz	Marco Castillo	Hybrid 2 x 50	Wet coffee processing	-	-	-	-	-	-	75****	Oxidation lagoon, sand filter	to River	50	-	-

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** AF: Anaerobic Filter; UASB: Upflow Anaerobic Sludge Blanket; ADI-BVF: Low-rate upflow sludge blanket process.

*** redesigned from existing facilities

Bv= Organic loading rate, HRT = Hydraulic Retention Time

**** Design data

Table 4: Anaerobic Digesters treating domestic wastewater in Mexico

Reactor number	Year of construction/ actual state	Location	Design/ Constructor*	Reactor type **/ volume(m3)	Treated volume (m3/d)	COD (mg/L)	Pre-treatment	Operating temperature °C	Bv (kg COD/m3.d)	HRT (hours)	COD Removal efficiency (%)	Post-treatment	Treated water use/discharge	Biogas production (m3/d)/ use	Sludge treatment	Sludge use/ disposal
1	1989 in operation	UAM-I Mexico, city	Desconta-minaccion	UASB 50	56	365	Grit chamber, screen	32	0.4	21.5	70	none	to Sewer	Vented	none	none
2	1990 in operation	Topeyanco-Atlamajac Tlaxcala	SEDUE (National)	UASB 2200	2592	600	Screen, grit chamber	20	0.7	20.3	75-80 (BOD)	Aerobic and water hyacinth lagoons	-	Vented	Drying	-
3	1990	QUIROGA Michoacan	SEDUE (National)	UASB 2200	2592	600	Screen, grit chamber	20	0.7	20.3	75-80 (BOD)	-	-	-	Drying	-
4	1991 in operation	INGENIO PUGA Nayarit	-	UASB 75	86	800	Screen, grit chamber	23	0.9	20.8	60-85 (BOD)	-	-	-	Drying	-
5	1992 shut down	VITOCRISTA CUBIERTOS Estado de Mexico	FORZA	UASB (2) 4.25	17	458	Screen grit chamber	20	1.63	6	70	Desinfection with UV. Anoxic reactor	Reused in toilet	1.4 Vented	none	Landfill
6	1992 in operation	CENTRO CAMPESTRE ECOLOGICO ASTU-RANO, Morelos	ENERGIA y ECOLOGIA	UASB 21.6	87	500	Homogenization tank	20	2	6	75	Slow filter	Watering	-	-	-
7	1992-1994 under start-up	FIDEICOMISO ALTO RIO BLANCO Ixtaczoquitlan, Veracruz	SEDUE/Gutierrez de Velasco SA de CV (National)	UASB 5 x 16740	108000	2400**	Screen, grit chamber	22.5	3	18.6	80****	none	to River	54000 Flared	Incinoration project	Sold as inocula
8	1992-1996 in operation	Various places in Mexico	TECNOADECUACION	Hybrid***	0.3-3.8	81-213	Screen, grit chamber, grease interceptor tank	19	0.05- 0.28	18-38	32-88	-	Land infiltration	Vented	Digestion	to Soil
9	1993 in operation	ACATLIPA Morelos	FORZA	UASB 130	519	550	Screen, grit chamber	21	2.2	6	75	Filtration and desinfection	Irrigation	38.5 Vented	none	Landfill
10	1993 in operation	GRUPO BETA Centro Comercial	FORZA	UASB 14	47	500	none	28	1.7	7	75	Filtration and desinfection	to Sewer	3-17 Vented	none	Landfill
11	1993	Tlalpuente	FORZA	UASB (2) 2.17	9	500	none	20	2	6	70	Desinfection	Pisciculture	Vented	none	none
12	1993 in operation	CONJUNTO CORP TELEVISA SANTA FE México, city	ENERGIA Y ECOLOGIA	UASB 24.2	87	500	Grit chamber, Homogenization tank	20	1.8	6.6	70	Anoxic and aerobic submerged filter fast filter, chlorination	Irrigation and clearness	-	Sludge tank	-
13	1993 in operation	HUATECALCO Tlaltizapan, Morelos	ENERGIA Y ECOLOGIA	UASB 105	420	500	Screen, grit chamber	20	2	6	75	Slow filter, chlorination	-	-	-	-

* same abreviations as in table 1

** Domestic and industrial. For number 7 three more reactors of 16740 m3 are in project for 1997

*** Number 6 corresponds to 53 reactors < 5.4 m3 and number 17, to 7 < 35 m3

**** Design data

Bv = Organic loading rate, HRT = Hydraulic Retention Time

Continuation
Table 4b: Anaerobic Digesters treating domestic wastewater in Mexico

Reactor number	Year of construction/ actual state	Location	Design/ Constructor*	Reactor type **/ volume(m3)	Treated volume (m3/d)	COD (mg/L)	Pre-treatment	Operating temperature °C	Bv (kg COD/m3.d)	HRT (hours)	COD Removal efficiency (%)	Post-treatment	Treated water use/discharge	Biogas production (m3/d)/ use	Sludge treatment	Sludge use/ disposal
14	1993	Hotel LAS QUINTAS Morelos	ENERGIA Y ECOLOGIA	UASB 25	86	590	Grease interceptor tank screen, homogenization, trituration	20	2.04	7	70	Aerobic submerged filter, sedimentation, chlorination	Irrigation	-	-	-
15	1993 In operation	LA PAROTA Temixco, Morelos	ENERGIA Y ECOLOGIA	UASB 87	346	500	Screen, horizontal grit chamber, homogenization tank	20	2	6	75	Slow filter, chlorination	-	-	-	-
16	1993 In operation	TICUMAN Morelos	ENERGIA Y ECOLOGIA	UASB (modified Imhoff tank) 339	272	533	Grit chamber, homogenization tank	20	0.43	30	70	Slow filter	-	-	-	-
17	1993-1996 In operation	Various places in Mexico	TECNOADECUACION	Hybrid***	10-43	81-213	Screen, grease interceptor tank grit chamber	19	0.06-0.28	18-30	32-68	-	Land infiltration	Vented	Digestion	to Soil
18	1994 in operation	SEDENA Nayarit	National	AF 85	112	550	-	25	0.65	20.3	50	-	-	-	-	-
19	1994 In operation	CLUB DE TENIS Tepepan, Mexico city	CENIC (Cuba)	AF 24	27	-	-	20	-	21	-	Activated carbon and sand filter, chlorination	-	-	-	-
20	1994 In operation	Conjunto habitacional "San José Iturbide" Guanajuato	GTSA/ SABBIA SA de CV	UASB 100	200	500	Screen	20-25	1	12	70-80	Aerobic submerged filter, secondary settler, chlorination	Watering	23.25 Vented	none	to Cultivated land
21	1994 In operation	Conjunto habitacional "Fracc. Villas de Vista Hermosa" Toluca	GTSA	UASB 25	50	375	Screen	10-20	0.75	12	60-85	Secondary settler, chlorination	Watering	13 Vented	none	to Garden land
22	1994 In operation	NEPSA Mexico, city	GTSA	UASB 50	100	375**	Screen	20-25	0.75	12	80	Rapid sand filter	Watering	23 Vented	-	Landfill

* same abreviations as in table 1
** Domestic and industrial For number 7 three more reactors of 16740 m3 are in project for 1997
*** Number 8 corresponds to 53 reactors < 5 4 m3 and number 17, to 7 < 35 m3
**** Design data
Bv = Organic loading rate, HRT = Hydraulic Retention Time

Continuation
Table 4c: Anaerobic Digesters treating domestic wastewater in Mexico

Reactor number	Year of construction/ actual state	Location	Design/ Constructor*	Reactor type **/ volume(m3)	Treated volume (m3/d)	COD (mg/L)	Pre-treatment	Operating temperature °C	Bv (kg COD/m3.d)	HRT (hours)	COD Removal efficiency (%)	Post-treatment	Treated water use/discharge	Biogas production (m3/d)/ use	Sludge treatment	Sludge use/ disposal
23	1994 in operation	Unidad habitacional militar de Puerto Juarez Cancun	-	UASB 43.2	96	BOD mg/l 200	Screen, pump station, homogenization tank	20	0.4	12	80-85 (BOD)	Rapid sand filter chlorination	Watering	-	Drying	-
24	1994 in operation	Unidad habitacional militar de Champotón, Campeche	-	UASB 43.2	96	-	Screen, pump station, homogenization tank	20	0.4	12	-	Rapid sand filter, chlorination	Watering	-	Drying	-
25	1995 in operation	Ixtepec Oaxaca	ENERGIA y ECOLOGIA	UASB 37.3	112	280	Screen, grit chamber, grease interceptor tank, homogenization	20	0.8	8	50	Aerobic filter, second. settler, chlorination	Watering	2.8 Vented	-	Soil fertilizer
26	1995 in construction	El Sabino Chiapas	ENERGIA y ECOLOGIA	UASB 44.8	138	280	Screen, grit chamber, grease interceptor tank, homogenization	20	0.8	8	50	Aerobic filter, second. settler, chlorination	Watering	3.4 Vented	-	Soil fertilizer
27	1995 in operation	Esperanza Sonora	ENERGIA y ECOLOGIA	UASB 67.7	203	280	Screen, grit chamber, grease interceptor tank, homogenization	20	0.8	8	50	Aerobic filter, second. settler, chlorination	Watering	5 Vented	-	Soil fertilizer
28	1996 start up	Santa Gertrudis Chihuahua	ENERGIA y ECOLOGIA	UASB 16	47	280	Screen, grit chamber, grease interceptor tank, homogenization	18	0.8	8	25	Aerobic filter, second. settler, chlorination	Watering	0.6 Vented	-	Soil fertilizer
29	1996 in construction	San Luis Rio Colorado Sonora	ENERGIA y ECOLOGIA	UASB 48.4	145	280	Screen, grit chamber, grease interceptor tank, homogenization	15	0.8	8	35	Aerobic filter, second. settler, chlorination	Watering	2.86 Vented	-	Soil fertilizer
30	1996 in construction	Poblado de San Bartolo, Municipio de Acolman, Estado de Mexico	GTSA	UASB 270	600	450-675	Screen	18-20	1-1.5	10.8	90-95****	Aerobic submerged filter, secondary settler, chlorination	Watering	63**** vented	-	to cultivated land
31	1996 in operation	Cuauhtitlan, Ciudad Juarez	TECHOADECUACION	Hybrid 194.4	259	213	Screen, grit chamber, grease interceptor tank	19	0.28	18	87.65	-	Land infiltration	Vented	Digestion	to Soil

* same abreviations as in table 1
** Domestic and industrial. For number 7 three more reactors of 16740 m3 are in project for 1997
*** Number 8 corresponds to 53 reactors < 5.4 m3 and number 17, to 7 < 35 m3
**** Design data
Bv = Organic loading rate, HRT = Hydraulic Retention Time

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