Seminar on

ANAEROBIC WASTE TREATMENT AND SANITATION TECHNOLOGIES

Bangkok, Pattaya
1 - 3 September 1988

Organized by

Division of
ENVIRONMENTAL ENGINEERING

ASIAN INSTITUTE OF TECHNOLOGY

G.P.O. Box 2754
Bangkok 10501
THAILAND

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BACKGROUND

Seminars of the Division of Environmental Engineering of the Asian Institute of Technology offer professionals and all interested persons in the field of Environmental Engineering the possibility of exchange of thoughts and experience. The objective of this seminar is more the discussion of principle aspects of various technologies such as applicability, feasibility and viability than it is the communication of technical knowledge. Ample time will be provided for discussions and all participants are encouraged to communicate their personal experiences or views during the discussions following each presentation or through participation in panel discussions.

The seminar will focus on two topics of special relevance. Anaerobic waste treatment is a well established process in industrialized countries which offers considerable economic benefits through the recovery of biogas. However, its application in the Southeast Asian region is still marked by various difficulties. Successful applications and relevant problem cases will be compared and discussed at the seminar.

Various sanitation options have been presented in the past decades which are particularly adjusted to suit the financial and other constraints of developing countries. However, whereas technical details are well documented, much uncertainty still exists on environmental, financial, and administrative implications of those technologies when applied in large scale to an entire community. Such implications will be addressed primarily at the seminar.

The seminar is sponsored by the Government of the Federal Republic of Germany through Deutsche Gesellschaft fuer Technische Zusammenarbeit m.b.H.(GTZ).

PROGRAMME

Thursday, September 1, 1988 at AIT, Bangkok.

09:00 - 10:30	Opening Ceremony at the Env. Eng. Div. Welcome by the President of the Asian Institute of Technology
	Opening of the Ambient Laboratory by the Secretary General, Office of the National Education Commission of Thailand
	Opening of the Environmental Research Station by the Ambassador of the Federal Republic of Germany
10:30 - 11:00	Coffee Break at AIT Center Lobby
11:00 - 12:30	Overview of the anaerobic waste treatment process with examples from operating plants Prof. Dr. Carl Franz Seyfried, University of Hanover, Federal Republic of Germany.
	Applications of the anaerobic waste treatment process in Thailand Dr. Sumaeth Chavadej, Thailand Institute of Scientific and Technological Research.
12:30 - 14:00	Lunch at AIT Center
14:00 - 15:30	Experience with the up-flow anaerobic sludge blanket process applied to distillery wastes Dr. Suchint Phanapavudhikul, Water and Environment Consultant Corp. Ltd., Thailand.
	Technical and economic evaluation of biogas plant treating tapioca starch factory wastewater Dr. Morakot Tanticharoen, S.Lerttriluck, V. Loha and S. Bhumiratana King Mongkut's Institute of technology, Thailand.
15:30 - 16:00	Coffee Break at AIT Center Lobby
16:00 - 17:00	Panel discussion Moderator: Prof. Dr. Carl Franz Seyfried, University of Hanover, FRG.
17:30	Departure for Pattaya
20:00	Dinner at Merlin Pattaya Hotal

Friday, September 2, 1988 at Merlin Pattaya Hotel, Pattaya.

09:00 - 10:30	Comparison of alternative sanitation options applied to a medium sized town Dr. Hermann Orth, Asian Institute of Technology, Thailand.
	Feasibility study of sewerage and treatment systems for Chonburi regional city Dr. Smith Kampempool, Dr. Nara Khomnamool, Thailand Institute of Scientific and Technological Research, Bangkok.
10:30 - 11:00	Coffee Break at the Hotel
11:00 - 11:45	Bangkok Metropolitan wastewater problems Dr. Kasemsarn Suwanarat and Usa Charutawai, Bangkok Metropolitan Administration.
11:45 - 13:00	Lunch at the Hotel
13:00 - 14:30	Sewerage and sanitation master plan for Metro Manila Mr. Teofilo Asuncion, Metropolitan Water and Sewerage System, Manila.
	Financial and Economic Issues in the provision of Solid and Liquid Waste Disposal Mr. Michael Lindfield, Sinclair Knight and Partners.
14:30 - 15:00	Coffee Break at the Hotel
15:00 - 16:00	Panel discussion Moderator: Prof. Sacha Sethaputra, Khon Kaen University, Thailand.
19.00	Dinner at the Hotel
20:30 - 22:00	Informal discussion

Saturday, September 3, 1988

09:00	Departure for field trip to the city of Panatnikom and Distillery Treatment Plant in Chachoengsao.
18.00	Arrival in Bangkok

NO.	NAME	TITLE	ORGANIZATION	ADDRESS/TELEPHONE
	SPEAKERS & MODERATORS			
01	Prof. Dr. Carl F. Seyfried		University of Hanover/FRG	Welfengarten 1, Hanover, West Germany.
02	Dr. Sumaeth Chavadej	Chief Env. Lab	Thailand Institute of Scientific and Technological Research	Bang Khen, Bangkok 10900. Tel.5791121-30
03	Suchint Phanapavudhikul	Managing Dir.	Water & Environment Consultant Corp., Ltd.	321/27 Nang Linchi Rd., T.Chong Nonsi, A.Yannawa. Tel.2868010
04	Dr.Morakot Tanticharoen	Associate Prof.	King Mongkut's Institute of Technology	48 Suksawasd Rd. Rasburana , Bangkok 10140. Tel.4270162
05	Dr. Hermann M. Orth	Associate Prof.	Environmental Engineering Division-AIT	G.P.O. Box 2754, Bangkok 10501. Tel. 5290100-13 ext.2632
06	Prof. Dr. Smith Kampempool	Governor	Thailand Institute of Science and Technological Research	Bang Khen, Bangkok 10900. Tel.5791121-30
07	Dr. Nara Khomnamool	Director	Thailand Institute of Science and Technological Research	Bang Khen, Bangkok 10900. Tel.5791121-30
08	Dr. Kasemsan Suwarnarat	Director	Policy & Planning Division I- BMA	173 Thanon Ban Dinso, Bangkok 10200. Tel.2242978
09	Mr. Teofilo Asuncion		Metropolitan Waterworks & Sewerage System	Katipunan Rd., Balara, Quezon City, Philippines. Telex No.27947 MWSS PH
10	Mr. Michael Lindfield		Sinclair Knight and Partners	Unit 708, Nana Tai Mansion 225 Soi 4, Sukhumvit Rd., Bangkok.
11	Prof. Sacha Sethaputra		Khon Khaen University	c/o World Bank, 5th. Fl, Olympia Building, Rama IV Rd., Bangkok

PARTICIPANTS

01	Benyamin Karyadi		Directorate of Env.Sanitation, Dir.Gen of Human Settlement Ministry of Public Works	Raden Patah I/1. Jakarta 12110 Indonesia. Tel.7398054
02	Krisno Darusman	Sub-director	Directorate of Env.Sanitation, Dir.Gen of Human Settlement Ministry of Public Works	J.Raden Patah I/. Jakarta 12110 Indonesia. Tel.7398054
03	Dr. Paul Guo	Director	WHO - PEPAS Kualalumpur Malaysia	P.O.Box 12550 ,50782 Kualalumpur,Malaysia. Tel.9480311-2
04	Ponciano C.Somosot	Eng.Div.Mgr.	Fabcon Philippines,Inc	5th Flr.,Fedman Suites 199 Salcedo St. Legaspi Village Makati, Metro Manila. Tel.888321-25
05	B.G. Yeoh	Sr.Res. Officer	Standards & Industrial Research Institute	P.O.Box 35, 40700 Shah Alam, Selangor Darul Ehsan, Malaysia
06	Pornpimol Leiangsuthi-sakon	Scientist 7	Agricultural Chemistry Division, Department of Agriculture	Bangkhen , Bangkok 10900. Tel.5791994, 5790159
07	Jiraporn Luanprida	Scientist 6	Agricultural Chemistry Division, Department of Agriculture	Bangkhen , Bangkok 10900. Tel.5791994, 5790159
08	Petch Katanyukul	Scientist 7	Agricultural Chemistry Division, Department of Agriculture	Agricultural Chemistry Div. Dept.of Agriculture Bangkhen, Bangkok,10900. Tel. 5790159
09	Kanchana Iaosricharoensakul	Scientist 5	Agricultural Chemistry Division, Department of Agriculture	Agricultural Chemistry Div. Dept.of Agriculture Bangkhen, Bangkok,10900. Tel. 5790159
10	Kanya Thamnpornpun	Scientist 5	Agricultural Chemistry Division, Department of Agriculture	Agricultural Chemistry Div. Dept.of Agriculture Bangkhen, Bangkok,10900. Tel. 5894185

11	Somchai Soravanee	Scientist	Department of Drainage & Sewerage, BMA	605-625 Bunthudthong Rd. Pathoomwan,Bangkok 10500. Tel.2153511
12	Prapin Borisuthi	Policy & Planning Analyst	Department of Policy and Planning, BMA	Bangkok City Hall, Dinsor Rd. Bangkok 10200 Tel. 2242978, ext.5802
13	Apinan Jaruchaiyakul		Waste Water Treatment Plant Division Department of Drainage & Sewerage, BMA	605-625 Bunthudthong Rd. Pathoomwan,Bangkok 10500. Tel. 2153521
14	Paitoon Goolchai	Engineer	Department of Drainage & Sewerage, BMA	605-625 Bunthudthong Rd. Pathoomwan,Bangkok 10500. Tel. 2153521
15	Wullaya Wattanasiritanawong		Department of Public Cleaning, BMA	Technical Division 99 Mitmitee Rd. Huaykhwang ,Bangkok 10400. Tel. 2453376, 2453377
16	Samea Wayupharb		Department of Public Cleaning, BMA	Technical Division 99 Mitmitee Rd. Huaykhwang ,Bangkok 10400. Tel. 2453376-7
17	Narong Kemavuthanon	Director	Department of Public Cleaning, BMA	Technical Division 99 Mitmitee Rd. Huaykhwang ,Bangkok 10400. Tel.2461981, 2454849
18	Usa Charutawai	Policy & Planning Analyst	Department of Policy and Planning, BMA	Bangkok City Hall, Dinsor Rd. Bangkok 10200. Tel.2242978
19	Prasong Sri-aran	Operator	Boon Rawd Brewery Co.Ltd	977/32 Dusit, Bangkok 10300. Tel. 2411361-9 ext. 142
20	Phenwadee Thammarakkit	Microbiologist	Boon Rawd Brewery Co.Ltd	977/32 Dusit, Bangkok 10300. Tel.2411360-9 ext.164
21	Arunee Wajanavijai	Chemist	Boon Rawd Brewery Co.Ltd	977/32 Dusit, Bangkok 10300. Tel.2411361-9 ext.142
22	Sivawan Phoolphaandh	Microbiologist	Boon Rawd Brewery Co.Ltd	977/32 Dusit, Bangkok 10300. Tel.2411361-9 ext.142
23	Surapee Rojarayanont		Institute of Env. Research, Chulalongkorn Univ.	Phayathai Rd. Bangkok 10500. Tel. 2525939, 2514426-7

24	Thipphawan Rudeelert	Sanitary Eng.	EGAT	Nonthaburi , Bangkok. Tel.4363932
25	Porapote Kulsarapusit	Sanitary Eng.	EGAT	Nonthaburi , Bangkok. Tel. 4363932
26	Fuangfa Boonyarat	Sanitary Eng.	EGAT	Nonthaburi , Bangkok. Tel. 4363932
27	Tuarongsak Boonyanit	Env.Engineer	Industrial Works Department	112 Soi Mit A-Nan Nakhonchaisri Rd. Dusit, Bangkok 10300 Tel. 2461148-54 ext 232
28	Dr. Jurgen Orlich	Env.Scientist	Industrial Works Department, Ministry of Industry	Rama 6 Rd. Bangkok 10400. Tel.2461148-54 ext. 232
29	Boonsom Lewsriwilai	Env.Scientist	Industrial Works Department, Ministry of Industry	Rama 6 Rd. Phayatai Bangkok 10400. Tel. 2461148-54 ext. 232
30	Naris Grirasamee	Engineer	Industrial Works Department	Rama 6 Rd. Phayatai Bangkok 10400. Tel. 2461148-54 ext. 232
31	Nana Asawangkul	Engineer	Industrial Works Department	Rama 6 Rd. Phayatai Bangkok 10400. Tel. 2461148-54 ext. 232
32	Pinyo Thammasiri	Env.Engineer	Industrial Works Department, Ministry of Industry	53 Jaransanit-wong 96/2 Bang-Oar Bangkok-noi, Bangkok 10700. Tel.2459905
33	Angkana Nontabongkot	Sanitarian	International Rescue Comittee	216 Sukhumvit Soi 1, Bangkok 10110. Tel.2523946, 2526302
34	Vittaya Sumitmoh	Field Coordinator	International Rescue Comittee	216 Sukhumvit Soi 1, Bangkok 10110. Tel.2523946, 2526302
35	Pornpimon Pinprateep	Field Coordinator	International Rescue Comittee	216 Sukhumvit Soi 1, Bangkok 10110. Tel.2523946, 2526302
36	Nuanphan Na'Ranong	Lecturer	Division of Applied Biology, KMIT Ladkrabang	
37	Dusanee Thanaboripat	Lecturer	Division of Applied Biology, KMIT Ladkrabang	

38	Kittipong Ruangrak		Department of Agricultural Industry, King Mongkut Institute of Technology	King Mongkut Institute of Technology, Ladkrabang Campus Bangkok 10520. Tel. 3267342
39	Porchai Limphanudom		Department of Agricultural Industry, King Mongkut Institute of Technology	King Mongkut Institute of Technology, Ladkrabang Campus Bangkok 10520. Tel. 3267342
40	Kittichai Banjong	Lecturer	Faculty of Agricultural Technology (KMIT)	King Mongkut Institute of Technology Ladkrabang, Bangkok 10520 Tel. 3267342
41	Jirasak Jindarojana		Dept. of Environmental Engineering, Khon Kaen Univ.	Khon Kaen 40002. Tel.(043)241333 ext.1210
42	Chuchit Sakantarat	Technical Adviser	Metro Co.Ltd	180 - 4 Rajawongse Rd. Bangkok 10100. Tel. 2229154-60
43	Pisamai		National Energy Administration	
44	Prakit Tancharoen	Engineer 4	National Housing Authority	Klong chan Bangkapi Bangkok 10240. Tel.3775501 ext. 282
45	Prakorb Wilprakorbkul	Sanitarian	Chonburi Destrict Health Center	273/31 Sukhumvit Rd.93, phrakhanong, Bangkok 10250. Tel.3314779
46	Pariyada Chokewinyoo	Sanitarian 5	Sanitation Division Dept.of Health,Ministry of Public Health	Samsen Rd.,Bangkok 10200. Tel. 2819461
47	Vathinee Jitjaturunt	Sanitarian 4	Sanitation Division Dept.of Health,Ministry of Public Health	Samsen Rd.,Bangkok 10200. Tel. 2819461
48	Amphorn Bussarangsri	Sanitarian 4	Sanitation Division Dept.of Health,Ministry of Public Health	Samsen Rd.,Bangkok 10200. Tel. 2819461
49	Raweewan Soyraya		Env.Health Regional Center 3, Chonburi	12 Soi Sukapiban, Bangsai 5, Bangsai, Chonburi 20000. Tel. 038287058

50	Faruspong Soyraya		Env.Health Regional Center 2, Chonburi	12 Soi Sukapiban, Bangsai 5, Bangsai, Chonburi 20000. Tel. 038227053
51	Suvit Im-ngen		Env.Health Regional Center 2, Chonburi	Chonburi. Tel. 038282881
52	Chart Kasornkun	Head of Section	Env.Health Regional Center 2, Chonburi	Chonburi. Tel.038282581
53	Charoen Hanpanjakit	Sanitarian	Env.Health Regional Center 1, Dept. of Health	1046/10 Sukhumvit 101, Bangjak, phrakhanong, Bangkok 10260
54	Mana Chotikapanich	Dir.of Planning	Planning Division, Public Works Department	Phanfa Bridge, Thanon Lan Luang, Bangkok 10100. Tel. 2817878
55	Pranee Liatheamsila		Public Work Department	109 Trokchun Vorachuk Rd. Thepsilin, Prompra b ,Bangkok 10100. Tel. 2222565, 2224645, 4246846
56	Voranit Chayavivattanawong	Civil Eng.	Public Works Department	Public Works Department Phanfa Bridge, Bangkok.Tel.4249517-9
57	Wijarn Thunthithum	Sanitary Eng.	Public Works Department	Public Works Department Phanfa Bridge, Bangkok.Tel.4249517-9
58	Waewta Sommitr	Q.C.Chief	Siam Preserved Food Co.Ltd	148 Moo 6, T. Jedsamian, A. Phrotharam, Ratchaburi 70120. Tel.012111437
59	Chandran Nair	Project Manager	Siamtec International Ltd.	87 Sukhumvit Rd. Nailert Bldg.,Bangkok 10110. Tel.2512660, 2522
60	Taveewat Tachakumatornkit	Sanitary Eng.	Southeast Asia Technology Co.Ltd	123 Sukhumvit 57, Bangkok 10110. Tel. 3922711
61	Suthara Theinprapa	Engineer	Surathip Distillery	290 Surawong Rd. Bangkok 10500. Tel.2351350-9
62	Somchai Dararattana	Scientist	Surathip Distillery	415/33-35 Arunammarin Rd. Bangkok 10700. Tel.4242016-8
63	Unchalika Jongpornpraseod	Scientist	Surathip Distillery	415/33-35 Arunammarin Rd. Bangkok 10700
64	Supan Chaitrakoon	Scientist	Surathip Distillery	415/33-35 Arunammarin Rd. Bangkok 10700. Tel.4242016-8

65	Chusak Nutmakul		Surathip Distillery	
66	Dr.Sirinimit Boonyuen	Env.Scientist	Team Consulting Engineer Co.Ltd	51/301-305 Ladprao Rd. Soi 130 , Bangkapi, Bangkok 10240 Tel. 3773480, 3771770-1
67	Kanyarath Youthanasantimate	Chemist	Thai Wah Co.Ltd	Thai Wah Tower 21-22 Flr. 21 Sathorn Rd. Bangkok 10120. Tel.240
68	Dr. Sretsei Saittagaroon	Deputy Head, Tech.s.Dept.	Thai Wah Co.Ltd	21st. Fl. Thai Wah Tower, 21 South Sathorn Rd, Bangkok 10120. Tel. 2409340 - 59 ext.201
69	Indranil Chakrabarty			21, Sukhumvit Soi 10, Bangkok 10110. Tel.2516564
70	S.Vigneswaran	Associate Prof.	Env. Eng. Div. - AIT	G.P.O. Box 2754, Bangkok 10501, Tel. 5290100 -13 ext. 2635
71	Mrs. Samorn M.	Assiciate Prof.	"	" ext. 2626
72	Dr. Yamamoto	Visiting Faculty	"	" ext. 2633
73	Dr.Kriengsak Udomsinrot	Visiting Faculty	"	" ext. 2629
74	Sompol Boonthanon	Sr. Lab. Sup.	"	" ext. 2628
75	Loy Teck - Suan	Env. Scientist	ENSIC (A.I.T)	" ext. 2870
76	G. Mahinthakumar	Student(Sri Lanka)	Env. Eng. Div. - AIT	"
77	S. Suthakar	Student(Sri Lanka)	"	"
78	Samuel O. Rosales	Student(Philippines)	"	"
79	P. Raveendran	Student(Sri Lanka)	"	"
80	Dimanseto	Student(Indonesia)	"	"

81	Miss A. Uma devi	Student(Malaysia)	Env. Eng. Div. - AIT	G.P.O. Box 2754, Bangkok 10501, Tel. 5290100 -13
82	Bambang Setyadji Hamzah	Student(Indonesia)	"	"
83	Chan Tik Yuen	Student(Hong Kong)	"	"
84	Wong Yen Kiat	Research Associate	"	"
85	Mrs. Suwasa K.	Student(Thailand)	"	"

ORGANIZERS

01	Dr. Orth/Yerink	Associate Prof.	Env. Eng. Div. - AIT	G.P.O. Box 2754, Bangkok 10501, Tel. 5290100 -13	ext. 2632
02	Kammeier	Associate Prof.	Human Settlement Div.-AIT	"	ext. 2601
03	Lucia V. Sukhanenya	Sr. Res. Assoc.	Env. Eng. Div. - AIT	"	ext. 2630
04	V. Mohanathasan	Research Assoc.	Env. Eng. Div. - AIT	"	ext. 2630
05	R. Asadawut	Research Assist.	Env. Eng. Div. - AIT	"	ext. 2630
06	Kreeta Sroikeeree	Doctoral Student	Env. Eng. Div. - AIT	"	ext. 2639
07	Prapassorn Sthapitanonda	Secretary	Env. Eng. Div. - AIT	"	ext. 55

The number of participants

Speakers & moderators	11	persons
Participants	85	persons
Organizers	7	persons
Total	103	persons

OVERVIEW OF THE ANAEROBIC WASTE TREATMENT PROCESS WITH EXAMPLES FROM OPERATING PLANTS

Carl Franz Seyfried

University of Hanover, Federal Republic of Germany

Overview of the anaerobic waste treatment process with examples from operating plants

Prof. Dr.Ing. C.F. Seyfried,

Institut fuer Siedlungswaserwirtschaft und Abfalltechnik Hannover
University of Hannover / FRG

1. Introduction

The technique of anaerobic wastewater treatment is well known, but seldom used and not as intensively researched as the aerobic techniques. Anaerobic techniques have been applied mostly to the wastewater of yeast factories, wine press houses, sugar factories, strawboard factories, molasses distilleries, sauerkraut factories and so on. There is unfortunately a trend towards so-called "new" techniques - utilizing higher space loading, shorter detention times and higher yield of digester gas - , but, established on a bench scale, these often refuse to work during the daily routine of a full scale wastewater treatment plant. The chief reason for the failure is the use of "idealized substrates" and easily biodegradeble parts of waste water flow under ideal conditions during the preliminary tests which disregard occasional breakdowns of the production process, cleansing processes or similar incidents which sometimes change the chemical composition of the wastewater. A similar trend to higher space loading and smaller tank volumes for aerobic wastewater treatment was noticeable in the sixties, which was diagnosed as a fashionable craze and subsequently abandoned.

Semi-scale pilot plants (V = 2-10 m^3) should be used as a rule to receive reliable results of the preliminary tests. They should be installed on the spot and feeded with the existing wastewater "on line" and in same elative proportions to get a basis that is applicable to the dimension for planned large-scale plants. The optimilization of the microbiologically essential environmental factors is of great importance particularly in the anaerobic wastewater treatment process.

2. Microbiological Requirements

Unlike other microorganisms which oxidize organic contents of the wastewater to anorganic final products of low energy content simultaneously in one step, the anaerobic metabolism needs a couple of groups of microorganisms which contain facultative and strict anaerobic bacteria and reduce the organic contents step by step to a final product of higher energy content. The product of metabolism of the previous group of anaerobic bacteria is at the same time substrate for the next group of anaerobic bacteria. The anaerobic process works and produces the wanted methane only if the various steps of metabolism are working one after another with the same speed. The step with the lowest speed determines the total speed of the process of single-stage methane-formation (Mudrack, 1982; Sahm, 1981).
The reduction of organic contents of the wastewater to the products CH_4, CO_2, and H_2O, as well as some metabolites, works as described in the following scheme (Fig. 1) (Mudrack, 1982; Braun, 1982; Seyfried, 1982; Kroiss/Matsché, 1988).

a) Hydrolysis- and acidifying- phase

Polymolecular dissolved and undissolved substrates are changed to dissolved substrates by exoenzymes. The hydrolized products as well as the low molecular contents of the wastewater are acetified by mostly facultative bacteria depending on the enviromental conditions, resulting in simple organic acids (formic-, acetic-, propionic- and butyric acid and - at lower pH-values - lactic acid), alcohols and aldehyds as well as hydrogen and carbondioxide. The COD changes slightly during the hydrolysis and acidifier phase, yet the pH-level as drops a rule drastically. Furthermore smelly products of metabolism occur. (Fig. 1)

b) Acetogenic and methanogenic phase

Most of the metane bacteria are only able to use acetic acid, but sometimes also methanol and formic acid (perhaps even butyric acid ?) or hydrogen and carbondioxide. The methane bacteria are therefore only able to use a part of the products of the hydrolysis and acidifier phase directly. Those substrates which cannot be metabolised directly, are reduced by acetogenic bacteria in an intermediate stage to acetic acid, hydrogen and if necessary carbondioxide.This phase cannot proceed correctly if this symbiosis, which for energetic reasons is very confined is disturbed by high shearing stress (for example by high-speed centrifugal pumps).
Methane-forming bacteria are strictly anaerobic. They can be divided into two groups. The first group produces methane directly from acetic acid. These acetoclastic methane bacteria are very sensitive to changes of the enviromental conditions, especially to changes of the pH-value and the temperature. About two thirds of the methane is produced by this first group, as long as the composition of the wastewater is not too one-sided (Henze/Harremoes, 1983). The growth-rate is rather low, because the gain of energy is also relativly low. This first group of bacteria is often the "bottleneck" of the anaerobic process. They determine the efficiency and stability of the process.
The second group of methane-forming bacteria are characterized by a higher growth rate and a higher insensitivity to changes of a pH-value.

A special feature of the anaerobic bacteria is the developing of suspended, stable, about 1-2 mm large colonies (pellets, granulars) under certain conditions of stress. Medical research has observed similar colonies in coccus-infections.
Some criteria controlling the anaerobic process can be summarized as followed :

Rate of growth

The growth-rate is following the MONOD - function (Fig. 2) and depends thus on one limiting substrate. Only a very limited amount of energy is available to the anaerobic bacteria, in comparison with the aerobic bacteria. Therefore the growth-rate is small, the generation times are long and the yield of biomass is low. A general view is obtainable in Fig. 3. In this connection the individual metabolism depends mostly on the composition of the wastewater (Henze/Harremoes, 1983; Mosey, 1981; Mudrack, 1986). Therefore the data given by different authors vary considerably. Table 1 shows the data from Henze/Harremoes (1983).
The extreme differences in the growth-rates make it necessary to schedule a period of at least 5 - 8 months to test the anaerobic degration of industrial wastewater. There are some examples of anaerobic plants of faulty design because tests were too short in duration. Another consideration is the importance of retention of the developed biomass. Fixed bed reactors are approved in that respect.

Optimal temperature

- acidifying, facultative anaerobic organisms : T = 30.- 36 °C
- methanogenic, strict anaerobic organisms : T = 33 - 38 °C

Optimal pH-value

- acidifying phase : 3.5 - 6.5 depending on the main product of metabolisms
- methanogenic phase : 6.5 - 7.5

Please take note of the interaction between pH-value and hardness, sulphur compounds and ammonium compounds.

Sensitivity to oxygen

- facultative anaerobic bacteria do not suffer from short contact to oxygen.
- strict anaerobic bacteria (methanogetic bacteria) are sensitive to oxygen.
- mixed populations are not permanently damaged by short contact to oxygen

Sensitivity to shearing-stress

- acetogenic and methanogenic bacteria are living in a close symbiosis (interspecies hydrogen transfer)
- high turbulences and shearing-stresses destroy the symbiosis and deteriorate the settling properties of the anaerobic activated sludge as well as the metabolism of the reactor.

Toxic compounds / demand of nutrient salts

- relatively slow adaptation to inhibiting or toxic compounds (Kroiss, 1985/1986; Parkin/Speece, 1983; Henze/Harremoes, 1983)
- nutritient salts at least COD : N : P = 800 : 5 : 1

Trace elements

- The lack of trace elements (especially Co, Ni, Se) leads to an inhibition of the anaerobic process. Only sparse data are obtainable from the literature, which have not been measured under the same enviromental conditions. Table 2 lists some data, which have to be used with caution.

3. Parameters for dimension

3.1 The producer of wastewater

In biotechnological production methods, for example the production of beer, penicillin or peptide, the volume and quality of raw materials is specified exactly. The result is a well-regulated and stable process. In case of a malfunction, it is possible to stop production while making repairs; the spoilt product will not be sold. Things are quite different with biotechnological wastewater treatment processes. The "raw material" wastewater may change drastically in volume, degree of pollution and composition. A range of variation of 1:10 is totally normal in the case of municipal wastewater. As a rule in case of industrial wastewater, the smaller the factory and the range of product the larger the range of variation. In case of a malfunction in the wastewater treatment plant, it is not possible to switch off. Malfunctions at the production plant, which sometimes occur, result most of the time in higher degrees of pollution and have to be taken in account during the dimension. The basis of dimension is usually an overload of 100 percent. Therefore the following parameters are of main importance for dimension :

- exact evaluation of all properties of the wastewater including the cleansing process wastewater
- making a prognosis of the effects of a malfunction in the production plant
- analysing the effects of possible malfunctions in the wastewater treatment plant.

3.2 Organic sludge load as a parameter for dimension

Often you may read, that certain types of reactors or processing run at high space loading or short detention times. Nevertheless the obtainable spaceloading and/or the detention time depends on :

- the composition of the wastewater (carbohydrates, protein, fat, nutritient salts, trace elements, type and concentration of inhibiting or toxic compounds)
- a sufficient sludge age, which depends on the type of process used to keep the biomass in the system
- a stable process, insensitive to changes in volume and concentration of the wastewater as well to short-timed overloading.

Only if the process of biomass-retention in the reactor has been sufficiently calculated, so that the biomass maintains a high level, will the reactor reach high space loadings and short detention times. Analogous to the aerobic activated sludge process, the COD-load of the organic anaerobic sludge is the most important parameter. The results of a literature-research are recorded in Fig. 5.

4. Characterization of anaerobic reactors

4.1 General view

The anaerobic reactors have been operated since the 50´s similarly to sludge digestors mostly as wash-out reactors without accumulation of biomass. The inflow has usually been mixed in the recycleflow (loop reactor). Nevertheless in the thirties JUNG (1949) successfully tested in a semi-scale pilot plant, external sludge separation and sludge recirculation.The RUHR - river association used in 1958 for the first time the anaerobic activated sludge process for a yeast factory on a large scale (Sierp, 1959; Rohde, 1960). This process is now used in most of the anaerobic plants and billed as a one- or two stage process. From the biological point of view it is logical to use a two stage process instead of a one stage process. In this case the substrates are hydrolysed and acidified in the first stage, while the

second stage contains the acetogenic and methanogenic phases (Fig. 6). The methane reactor is always used together with a sludge separator and recirculation of the separated sludge. This method has not yet been successful in the acidifing stage,because the settling of the bacteria is insufficient. Since the accumulation of biomass is of highest importance to the stability, performance and therefore economic efficiency, reactors containing immobilized mocroorganisms on a fixed bed or a sludge blanket consisting of aggregations of microorganisms, called pellets or granulars (for example UASB process) have been gaining importance over the last ten years.
The ATV-comittee 7.5 (anaerobic processes) have classified the process engineering for anaerobic wastewater treatment processes as shown in Figure 7. The most common types of anaerobic reactors are characterized in table 3, the types of anaerobic process engineering in table 4.

4.2 Reactors with suspended growth

Wash-out reactors (Fig. 8a)

The content of biomass is determined by the ratio of the growth rate and the mean detention time, since no biomass is retained in wash-out reactors. The anaerobic process stops, if the mean detention time is lower than the generation time, resulting in a lack of biomass. The wash-out reactor is only useful if it is not possible to seperate biomass and solid substrate as for example in sludges.

Anaerobic activated sludge process (Fig. 6 and 8b)

The anaerobic activated sludge process (misnaemed the sludge contact process) has been already described (Fig. 6). The separation and recirculation of the biomass is of highest importance. The following processes are used for separation :

- Sedimentation (integrated or external)
- Floatation
- Centrifugalization.

Sludge blanket reaktor (Fig. 8c)

The sludge blanket process is often called UASB process (Upflow Anaerobic Sludge Blanket). The process is based on the forming of sludge pellets, which accumulate as a result of their good sedimentation qualities in the lower part of the reactor as a sludge blanket. The sludge blanket process is not universally applicable, since the pellets will not form in some kinds of wastewater or are disturbed by carbonate-precipitation.

4.3 Reactors with immobilized-biomass

The importance of the retention of biomass has been emphazised before. A reliable method is to provide fixed areas for growing bacteria. Lots of different materials are used for tests and practice. They can by classified as follows :

- coarse rock filling
- fine-granular mineral fillings, for example granitic chippings, lava pebbles, bloating clay, porous glass etc.
- fine quartz sand
- fillings of rings or similar materials made of plastic, raschigrings and so on
- packed plastic-elements, developed from trickling filter fillings (for example Bionet, Cloisonyle, Flocor and so on)

The types of reactors can be classified as follows :

Fixed-film reactors (Fig. 8d)
Reactor containing about 60 - 90 % fillings of orderly packed or dumped materials; sometimes with additional sludge recirculation. Sometimes the inflow is mixed into an additional slope, to get a more even supply of substrate, in sludge digestion a time-proven process.

Partial filled fixed-film reactor (Fig. 8e)

Combination of anaerobic activated sludge process and fixed film reactor; 20 - 40 % of the wetvolume are filled with orderly packed or dumped fixed film material. This material serves as a settling area and "filter" for the anaerobic biomass; mixing of the lower part accomplished by pumps or stirring devices; gasmixing can be utilized for flushing of the fixed film material. Recirculation of sludge is possible by separate, external settling tanks, parallel plate separators or floatation tanks.

Expanded bed reactors

Reactor filled with fine-grain material, which will be held "laminary" in suspension by an upflow. Expansion of bed by upflow about 10 -20 %. Up to the present only tested in pilot plants.

Fluidized bed reactor (Fig. 8f)

Reactor filled with inert material (for example quartz sand 0.6 mm), which will be held "turbulent" in suspension by the developing gas and the upflow of the fluid (fluidization), if necessary recirculation of settled anaerobic sludge and flushed-out inert material. High hydraulic recirculation rate by external pumps, to maintain fluidization (Heijnen, 1985).

Nearly all other, sometimes so called "new", anaerobic processes with inert material for immobilisation of the biomass can be reduced to these fundamental types of reactors. They are either combinations or slight modifications of well-known systems, which are ruled by the well-known anaerobic metabolism processes of hydrolysis, acidification, the acetogenic phase and the methanogenic phase.

5. Operating data in Germany (F.R.)

5.1 Wastewater treatment plant of the first German molasses distillery in Hannover with continuous fermentation and distillation

In 1986/87 a molasses distillery in Hannover switched production from the usual discontinous fermentation to continuous mode of operation. The molasses slop containing residual molasses is also continuously evaporated. It was not possible to make preliminary tests for the anaerobic treatment of that wastewater, because it was the first plant of that type in Germany. Only calculated data and some analytical data of a similar plant in the Netherlands were obtainable to predict the composition of the wastewater. It turned out that some of these data were in fact only partially correct. Since positive experiences with fixed film reactors has been gatherd in semi-scale tests (Seyfried/Saake, 1985, 1986), a anaerobic-aerobic plant for the pretreatment of the wastewater with following dimensions has been constructed (Fig. 9) :

Wastewater treatment plant

buffer tank	(V = 100 m^3, tR = 1.4 d)
acidifying reactor	(V = 140 m^3, tR = 2.0 d)
fixed film methane reactor	(V = 140 m^3, 2/3 fixed film material, tR = 2.0 d)
intermediate sedimentation	(A = 4.5 m^3, qA = 0.65 m/h)
cascade of activated sludge tanks	(Vges. = 60 m^3, tR = 0.86 d)
final sedimentation	(A = 4.5 m^3, qA = 0.65 m/h)
fixed film material	BIO-NET 150 (Norddeutsche Seekabelwerke, Nordenham) spez. A = 150 m^2/m^3

Wastewater (october to december 1987)

wastewater =	condensate of the vapors
volume	60 - 80 m^3/d
pH-value	3.2
COD	10,000 - 30,000 mg/l, mean 20,000 mg/l
BOD5	4,000 - 9,700 mg/l, mean 6,000 mg/l
TSS	0 mg/l (high concentrations, if slop comes into the vapor)

Operating data (october to december 1987)

methane reactor :	BR,COD	= 7.5 - 13 kg COD/(m^3xd)
	Ce,COD	= 2,200 - 7,000 mg/l
	COD	= 70 - 86 %
	Q gas	= 450 m3/d
activated sludge :	MLSS	= 3 - 5 g/l; SVI = 130 ml/g
	F/M	= 0.3 - 1.4 kg BOD5/(kg TSxd) mean 1.0 kg BOD5/(kg TSxd)
	Ce,COD	= 1,700 - 3,400 mg/l
	COD	= 30 - 65 %
	Ce,BOD5	= 400 - 900 mg/l
	BOD5	= 50 - 90%

The high variations of loading, as shown in Fig. 10, are a result of slop coming relativly often into the vapor, containing rarely biodegradeble molasses residues which emerge into the wastewater. The efficiency is still quite satisfactory, despite an overload of the metanereactor of more than 100 %. The evaluation of the results of the analysis showed that intermediate settling after the methane reactor was absolutely necessary.

TSS inflow intermediate settling 2.0 - 2.7 g/l
TSS outflow intermediate settling 0.1 - 0.16 g/l
Efficiency of anaerobic sludge retention 95%.

5.2 Wastewater treatment plant of a wheat-starch factory

Positive results from tests with fixed-film reactors, which have been previous reported (Seyfried/Saake, 1985, 1986; Saake 1986), resulted in the construction of a large scale plant, that has been working for two years now. The dimensions of the plant are shown in Fig. 11. The operating results of the plant are compared in Table 5 to those of the preliminary tests and the layout data respectivly. The data are shows that the operation results are slightly better than those of the preliminary tests; obviouly there were no "scaling-up" problems.
The markedly changing concentrations in the inflow are compared in Fig. 12 to the relatvely even concentrations in the outflow, showing the exceptional stability of a fixed-film reactor under a normal load.

5.3 Operating results of a potato-starch factory

Simultaneous to the construction of a newly founded potato-starch factory an anaerobic plant with fixed-film reactors system KWU has been constructed. Fig.13 shows the dimension of the different reactors. Following operating results have been the basis of dimension (without cleaning water):

wastewater flow	86 m^3/h	2,060 m^3/d
COD ø	17,000 mg/l	34,640 kg/d
BOD5 ø	11,500 mg/l	23,080 kg/d

The reactors (4 x 350 m^3) are filled with lava slag with a size of about 20/40 mm. The concentration in the outflow, after short preliminary test, were supposed to be :

COD ø	3,550 mg/l	6,900 kg/d
(guaranteed value)	4,600 mg/l	9,480 kg/d
BOD5 ø	1,200 mg/l	2,470 kg/d

The plant has been working since Autumn 1987. Only temporary results can be shown, since the starch factory is still in the breaking- in period. The influent data are in the estimated range, but are subjected to large changes. The fixed-film reactors are now very sensitive to fluctuations. Since the volume load is in the range of 20-30 kg COD/(m^3 x d), this is no surprise for a practician. The average effiency is about 50%; somewhat lower than the estimated 70-80%. The effluent data of the plant are shown in Fig. 14. The effluent of the anaerobic plant is flowing for further treatment to a municipal wastewater treatment plant. The industrial part takes only 50% of the wastewater flow, but 80% - 90% of the waste load.
The community had to treat the wastewater to an high level. Therefore the community was forced to build a large, sufficiently dimensioned, waste water treatment plant to degrade the "pretreated" wastewater of the factory.
Fig. 15 shows the dimension of the aerobic wastewater treatment plant. The municipal wastewater treatment plant was to date able to degrade the high loads of the anaerobic wastewater treatment plant.

5.4 <u>Wastewater treatment at the POMOSIN - factory</u>

This factory produces various types of pectin due to the applications required. Pectin has properties similar to those of polysaccharides and occurs naturally in the middle lamella between the cell walls of adjacent plant cells. It is used in the food industry as a thickener and as a jelly base (jam, etc.). At the very end of this production process the used water is to be treated before discharging to the Baltic Sea.

The wastewater resulting from pectin production contains approximately 100 mg/l pectin and approximately 150 mg/l alcohol; the bulk of the organic waste is comprised of natural compounds such as carbohydrates, protein, organic acids and lipids. Additionally the wastewater retains an high concentration of nitrate from the extraction process with nitric acid.

At the first step in water treatment a anaerobic stage was designed using a 3500 m^3 complete mixed reactor with a detention time of 6 days with a settling tank located behind for sludge return (Fig. 16). Table 6 give the wastewater parameters before and after the anaerobic stage. The distribution of COD values in the influent and effluent are shown in Fig. 17, indicating the wide fluctuation range (1000 to 8000 mg COD/l) with which the subsequent stage has to cope. The operation of this system had to face lots of problems, as the given data in Table 7 and also in Fig. 16 demonstrate. These problems occurred due to the high amounts of nitrate up to 2500 mg NO3-N/l in the influent, which caused periods of denitrification and sometimes ammonification. To solve these problems a three stage process was established based on the results of a research program.

On the basis of the experimental data the existing anaerobic treatment process was completed by erecting a predenitrification and an anaerobic aftertreatment. Biomass is recycled into the denitrification reactor from a seperator, where the sludge can be withdrawn from the bottom as well as from the top, since a significant portion of the sludge tends to float due to the degassing of nitrogen. The process is run at temperatures between 40 and 50 C with a detention time of about 6 hours. The NO3-N concentration decreases down to values between 5 and 30 mg/l even in cases where the influent concentration is up to 2800 mg/l. The figures given represent the average values during a seven month period. Influent concentrations differ quite

often from the given values according to the kind of pectin produced. The aerobic stage produces results which are exactly in the same range as were expected from the conducted labscale and semitechnical experiments. The results were gained from the same time of operation. Nitrification of the remaining ammonia is achieved, but there are still some problems to be solved since denitrification has not occured so far in the first unearates tank as it was planned.
The performance of the anaerobic stage became much better and more stable after denitrification could take place in a controlled way in the added high rate denitrification stage instead of in the anaerobic reactor itself.
Where nowadays the average value of the effluent COD lies at about 1500 mg/l, the 50 percent value was before, in times without that additional process, 2700 mg/l.
The results in operating this plant during 18 month are quite satisfactory, as shown in Table 7. These given values are the average values.
The denitrification of the nitrate prior to the anaerobic treatment leads to a better and more stable anaerobic process, so that very easy operation in the final aerobic treatment is possible.

6. Summary

After a general overview of the microbiological fundamentals and the requirements of the anaerobic bacteria, the importance of the "organic sludge load" as a good parameter for dimensioning anaerobic wastewater treatment plants in discussed. Out of that it is concluded, that the retention of the biomass in the reactor is of the highest importance, which can be accomplished be the use of fixed film reactors. The different fixed film materials and reactors will be described and the base conditions for evaluation developed. The advantages and also the

limitations of fixed film reactors will be shown by operating data of three large scale wastewater treatment plants. Out of that it is possible to realize, that the common rules of the anaerobic process applies also to so-called "new" techniques; it is impossible to bewitch bacteria.

REFERENCES

1. Beckereit, M.: Kosten der anaeroben Abwasserbehandlung.
Veröffentlichung des Institutes für Siedlungswasserwirtschaft und Abfalltechnik, Heft 71, Hannover 1988

2. Heinjen, J.J. et al. : Anwendung der anaeroben Wirbelschichttechnik in der biologischen Abwasserreinigung.
gwf-wasser(abwasser, 126, H. 2, S. 81-87 (1985)

3. Henze, M.; Harremoes, P.: Anaerobic Treatment of Wastewater in Fixed-Film Reactors - a Literature Review.
Wat. Sci. Techn., Vol. 15, 8/9, S. 1-101 (1983)

4. JUNG, H. : Schnellfaulung zur Behandlung stark verschmutzter Abwässer.
Vom Wasser, Bd. 17, S. 38 (1949)

5. KROISS, H. : Anaerobe Abwasserreinigung.
Wiener Mitteilungen, Wasser-Abwasser-Gewässer, Band 62 (1986)

6. KROISS, H.; Matsché, N. : Mikrobiologische und chemische Grundlagen der anaeroben Abwasserreinigung.
Wiener Mitteilungen Wasser-Abwasser-Gewässer, Band 73, Wien 1988

7. Kunst, S. (geb. Wernecke) : Untersuchungen zum anaeroben Abbau polymerer Kohlenhydrate zur Optimierung der Versäuerungsstufe bei anaeroben Abwasserreinigungsverfahren.
Veröffentlichungen des Institutes für Siedlungswasserwirtschaft der Universität Hannover, Heft 54, Eigenverlag Hannover, 1982

8. Lettinga, G. : Erfahrungen und neuere Einsatzmöglichkeiten mit der Up-flow-Technik
HIT 1985, Universität Hannover 1985

9. Mosey, F.E. : Anaerobic Biological Treatment of Food Industry Waste Waters.
Wat. Pollution Control, S. 273-289 (1981)

10. Mudrack, K. : Grundlagen mikrobiologischer Energieumwandlung.
Korrespondenz Abwasser 29, Heft 6, Seite 382-384 (1982)

11. Mudrack, K. : Biologische Grundlagen der aeroben und anaeroben Behandlung von Industrieabwasser.
Wiener Mitteilungen, Wasser-Abwasser-Gewässer, Band 65, A 1-13 (1986)

12. Parkin, G.G.; Speece, R.E. : Attached Versus Suspendet Growth Anaerobic Reactors: Response to Toxic Substances.
Wat. Sci. Techn., Vol. 15, 819, S. 261-289 (1983)

13. Rohde, H. : Organisatorische Fragen der Abwasserwirtschaft.
Kommunalwirtschaft 1960, Seite 341

14. Saake, M. : Abscheidung und Rückhalt der Biomasse beim anaeroben Belebungsverfahren und in Festbett-Reaktoren. Veröffentlichungen des Instituts für Siedlungswasserwirtschaft und Abfalltechnik der Universität Hannover, Heft 68 (1986)

15. Sahm, H. : Biologie der Methan-Bildung Chem.-Ing.-Techn. 53, Nr. 11, Seite 854-863 (1981)

16. Seyfried, C.F. : Vorbehandlung organisch belasteter Gewerbe- und Industrieabwässer. Berichte der Abwassertechnischen Vereinigung e.V. (ATV), St. Augustin 1982, Seite 271-291

17. Seyfried, C.F.; Saake, M. : Verfahrenstechnik der anaeroben Abwasserreinigung. Vortrag Nr. 2, 3. Hannoversche Industrieabwasser-Tagung, Oktober 1985, Institut für Siedlungswasserwirtschaft und Abfalltechnik, Universität Hannover

18. Seyfried, C.F. : Die biologische Behandlung schwieriger Industrieabwässer - Beispiele aus Forschung und Praxis. Korrespondenz Abwasser (32), Nr. 11/1985, Seite 932-939

19. Seyfried, C.F.; Saake, M. : Technik der anaeroben Behandlung von Industrieabwasser. Wiener Mitteilungen, Wasser-Abwasser-Gewässer, Band 65, C 1-74, 1986

20. Seyfried, C.F.: Der Festbettreaktor. Wiener Mitteilungen, Wasser-Abwasser-Gewässer, Band 73, Wien 1988

21. Sierp, F. : Gewerbliche und industrielle Abwässer. Springer Verlag, Berlin, Heidelberg, New York, 2. Auflage 1959 und 3. Auflage 1967

22. Wandrey, C.; Aivasidis, A.: Zur Reaktionstechnik der anaeroben Fermentation. Chem. Ing. Techn. 55 (1983), N . 7, Seite 516-524

APPENDIX

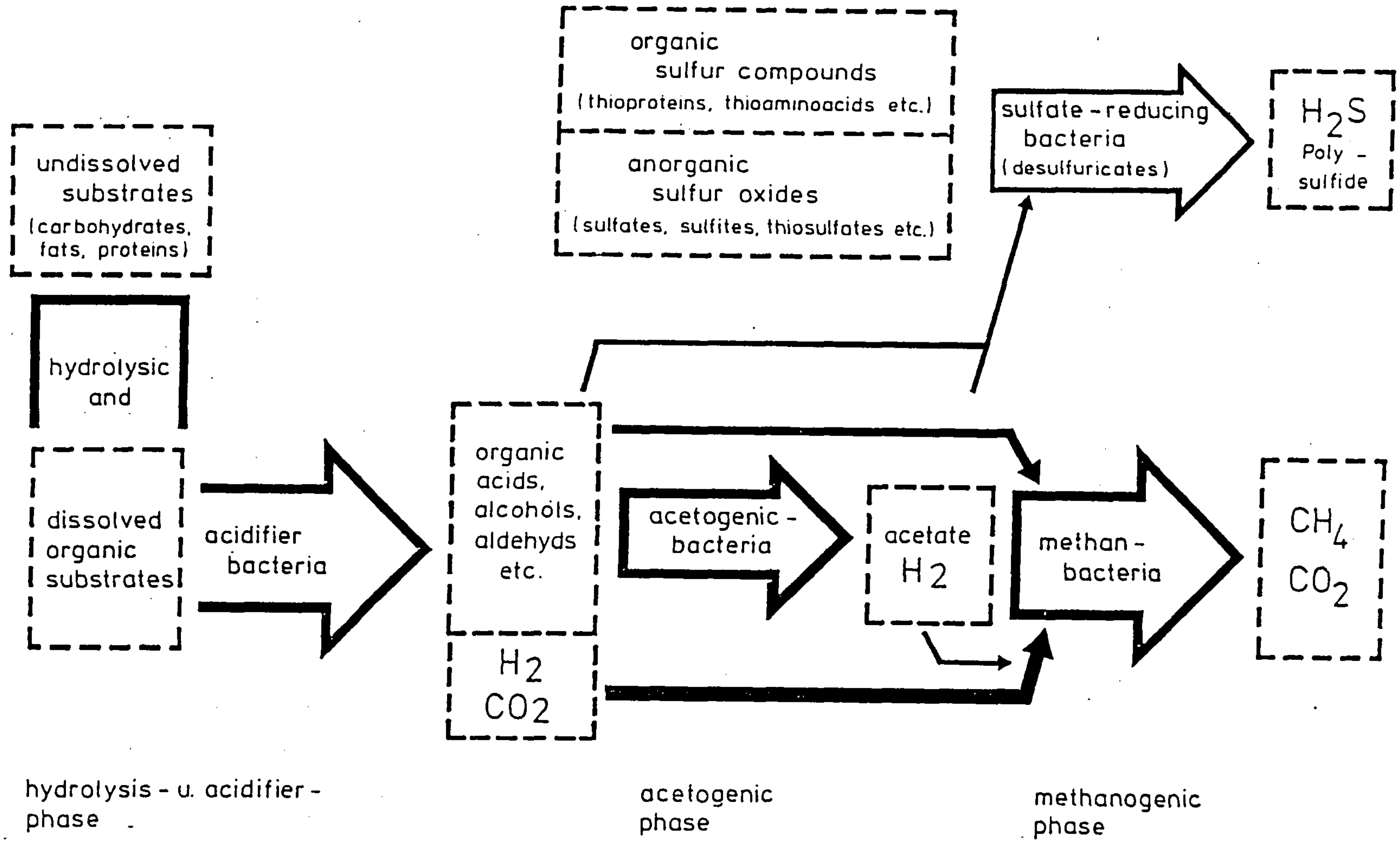
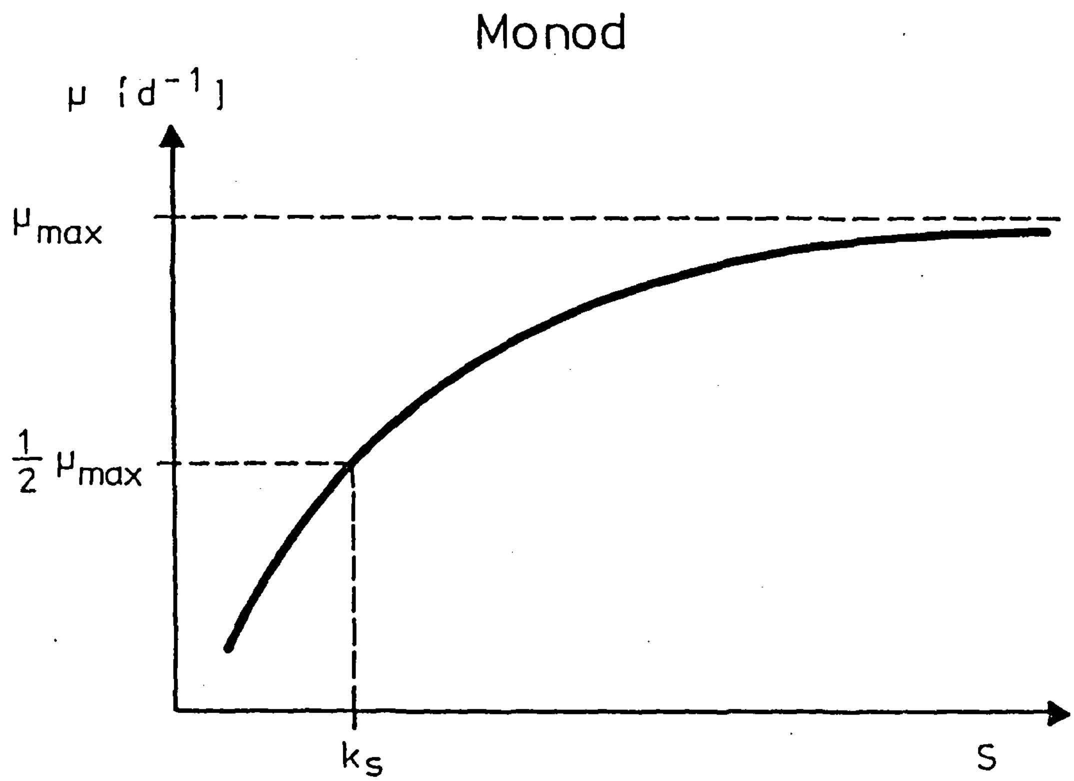


FIG. 1: ANAEROBIC DECOMPOSITION OF ORGANIC SUBSTANCE



$$\mu = \frac{S}{k_S + S} \cdot \mu_{max} \qquad [d^{-1}]$$

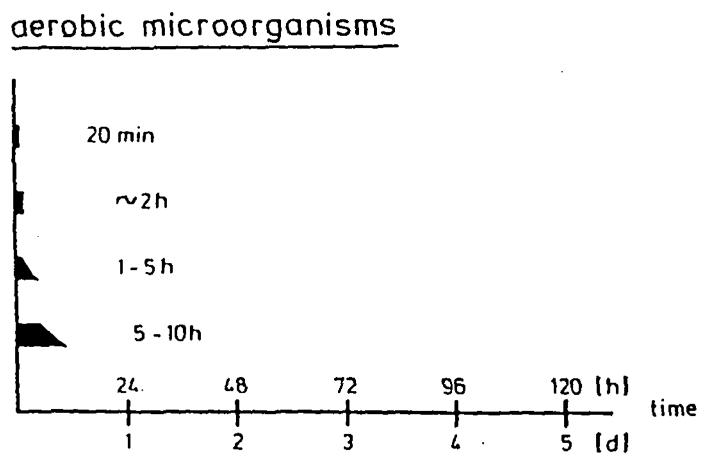
μ = growth rate

μ_{max} = maximum growth rate

S = substrate concentration

k_S = Monod - saturation constant

FIG. 2: RELATIONSHIP BETWEEN THE GROWTH RATE AND THE SUBSTRATE CONCENTRATION (MONOD)



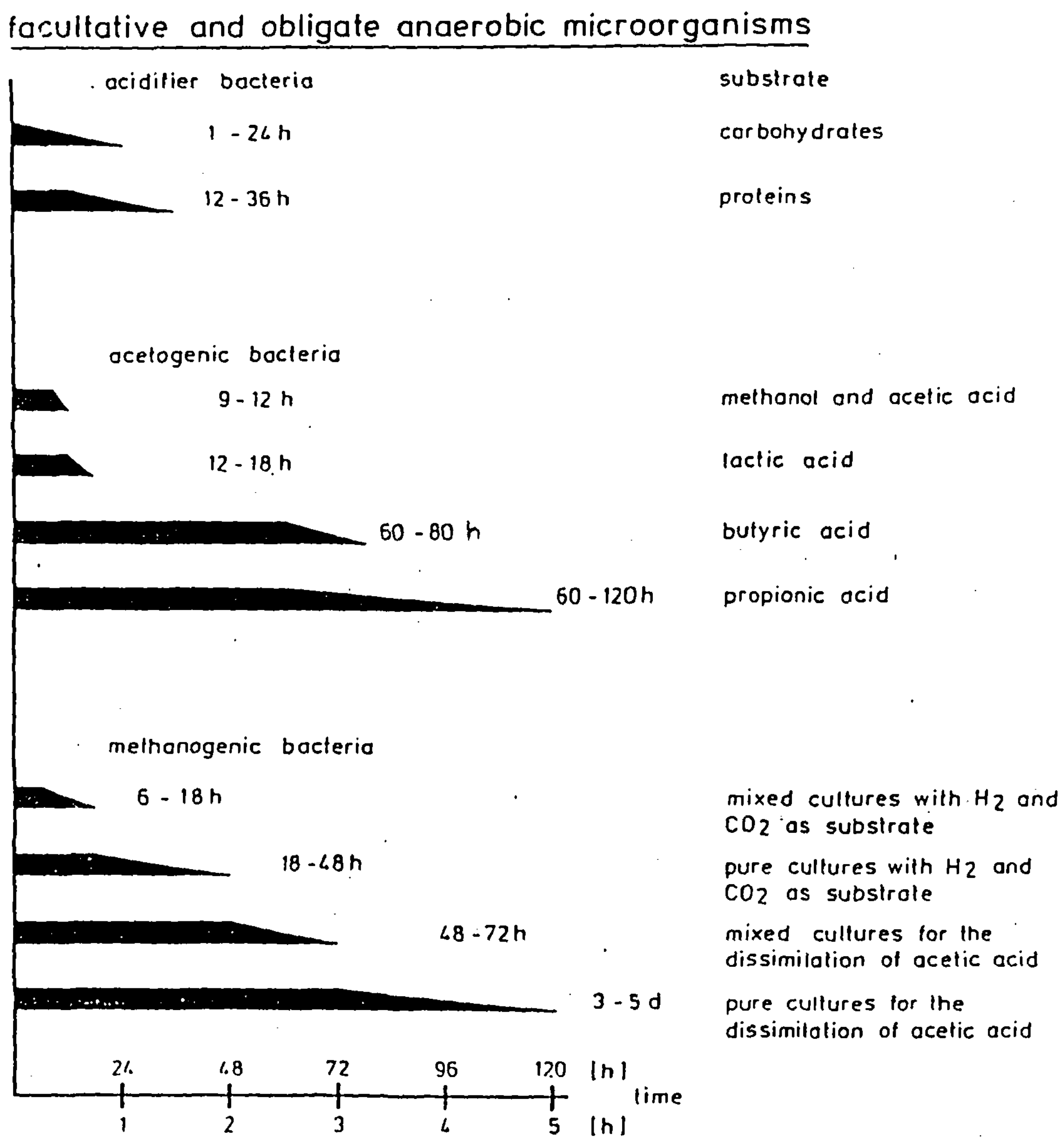


FIG. 3: COMPARISON OF GENERATION TIMES OF AEROBIC AND ANAEROBIC MICROORGANISMS (REFERENCE VALUES, WHICH ARE STRONGLY INFLUENCED FROM THE ENVIRONMENTAL CONDITIONS, DIVERSE AUTORS)

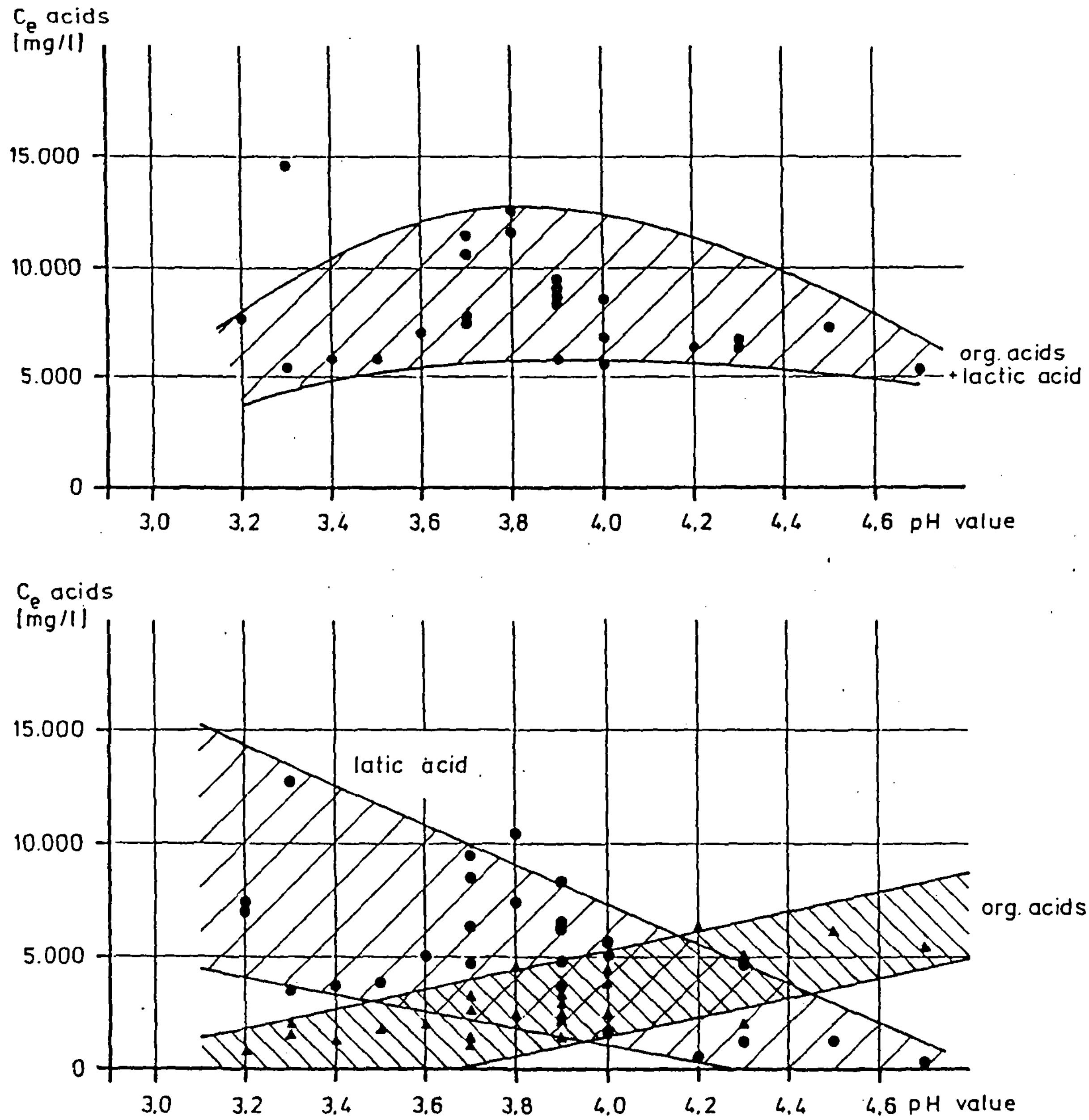


FIG. 4: ACID SPECTRUM IN THE ACID-DIGESTER-STEP (FIXED-FILM REACTOR) AT DIFFERENT PH VALUES (WHEAT STARCH WASTE WATER)

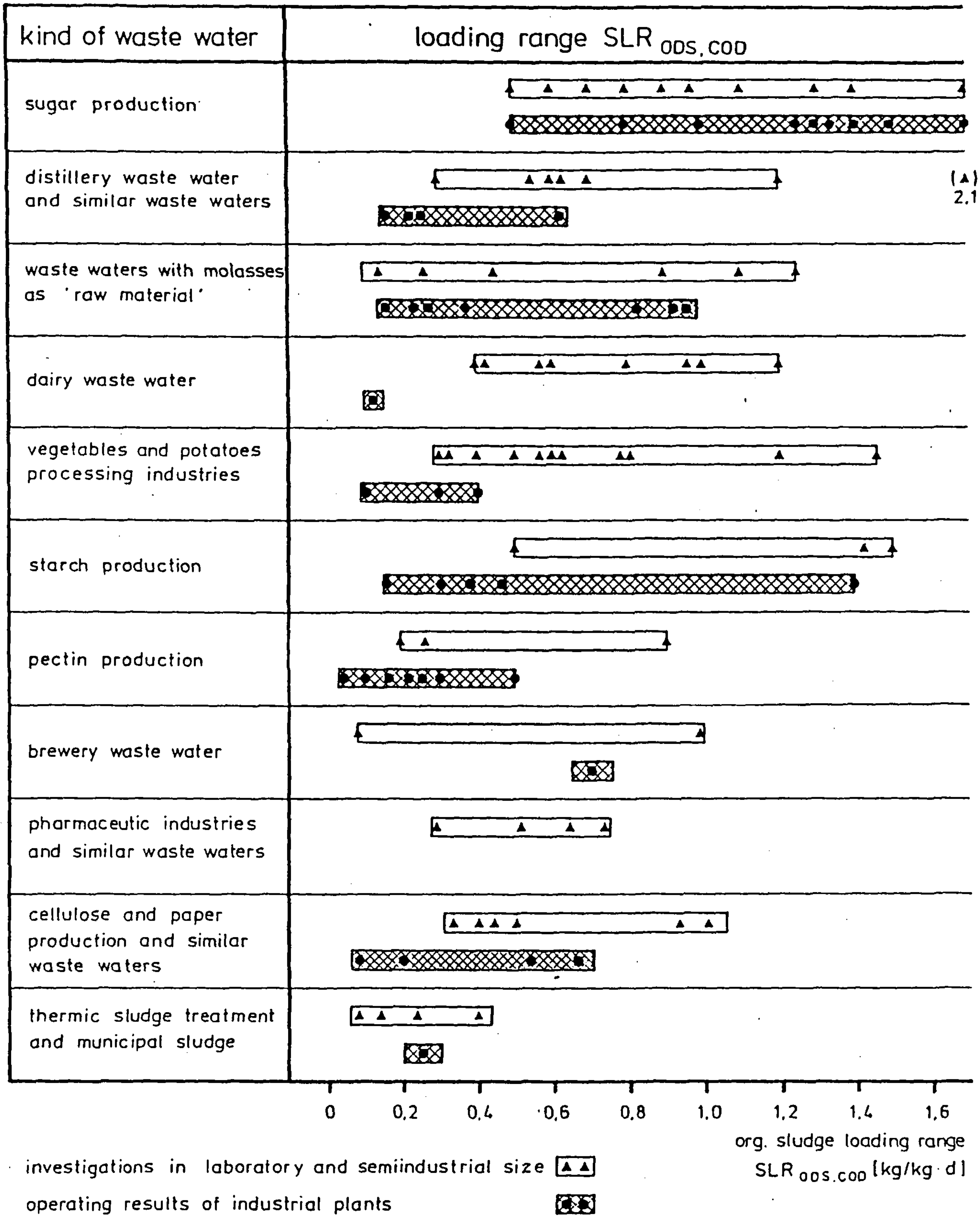


FIG. 5: COMPARISON OF BIBLIOGRAPHICAL REFERENCES OF ORGANIC SLUDGE LOADING RAHIOS IN SEMIINDUSTRIAL AND INDUSTRIAL ANAEROBIC PLANTS, DIFFERENTIATED BY THE KIND OF WASTE WATER (INCLUDING ONLY VALUES BY FULLY CLARIFICATION)

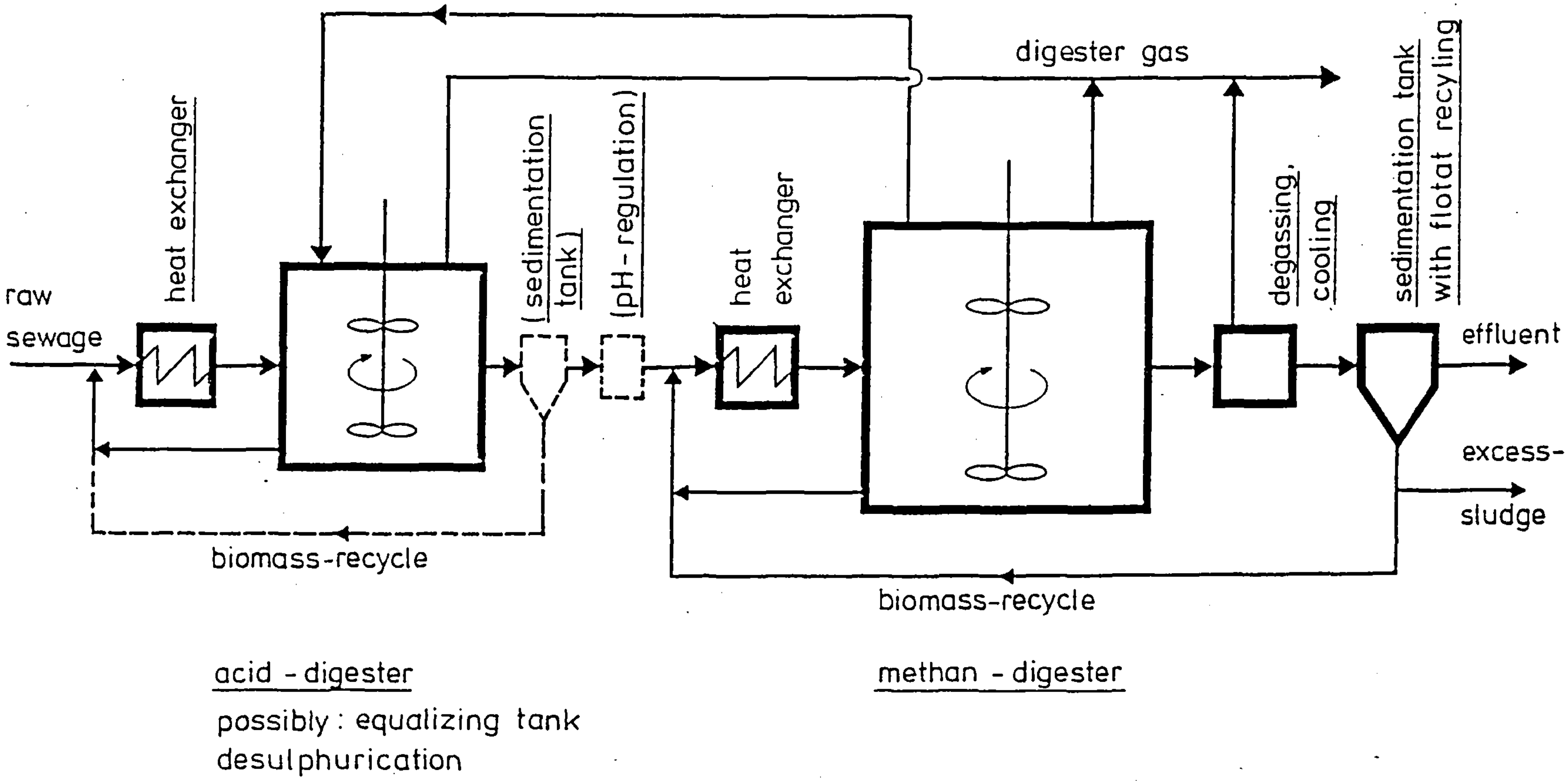


FIG. 6: PROCESS SCHEME OF THE TWO STEP ANAEROBIC ACTIVATED SLUDGE PROCESS

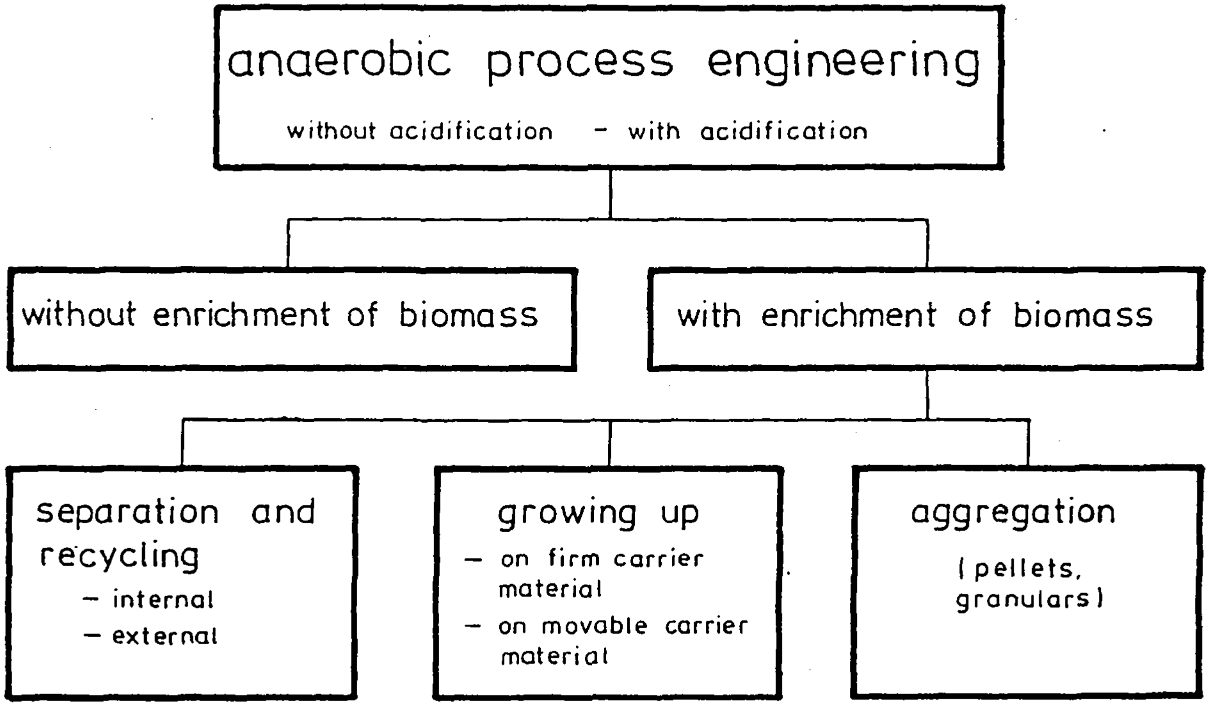


FIG. 7: DIVISION OF THE ANAEROBIC PROCESS ENGINEERING (ATV-FA 7.5)

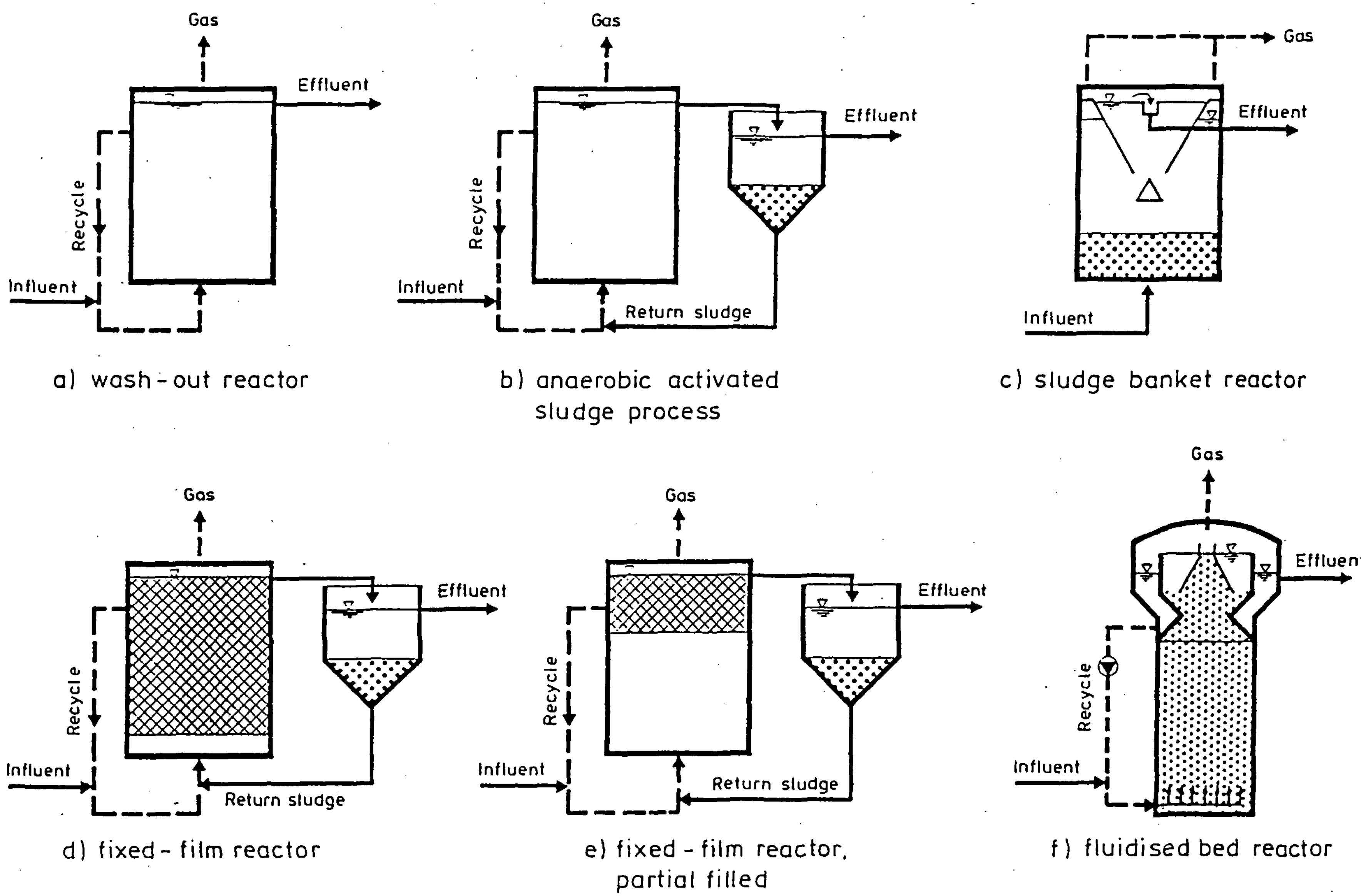


FIG. 8: PROCESS-DIAGRAM OF DIFFERENT TYPES OF REACTORS

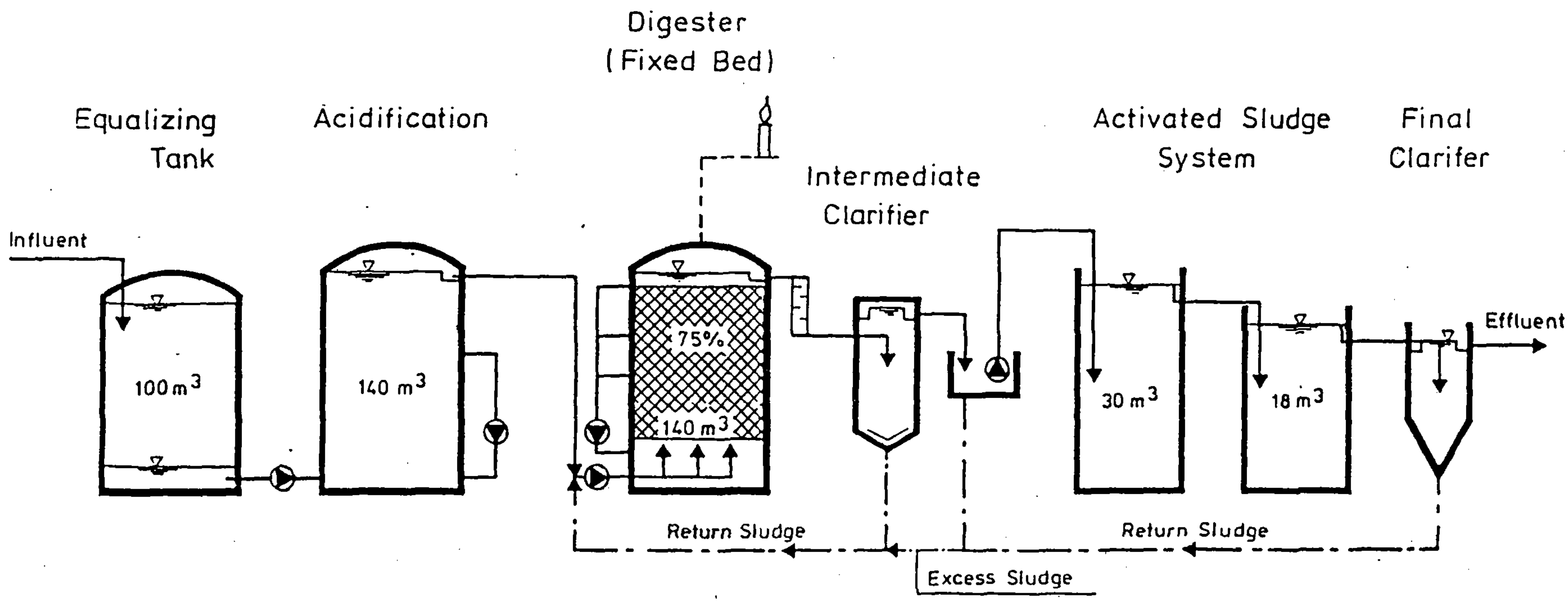


FIG. 9: PROCESS-SCHEME OF THE ANAEROBIC-AEROBIC SYSTEM OF A MOLASSES DISTILLERY

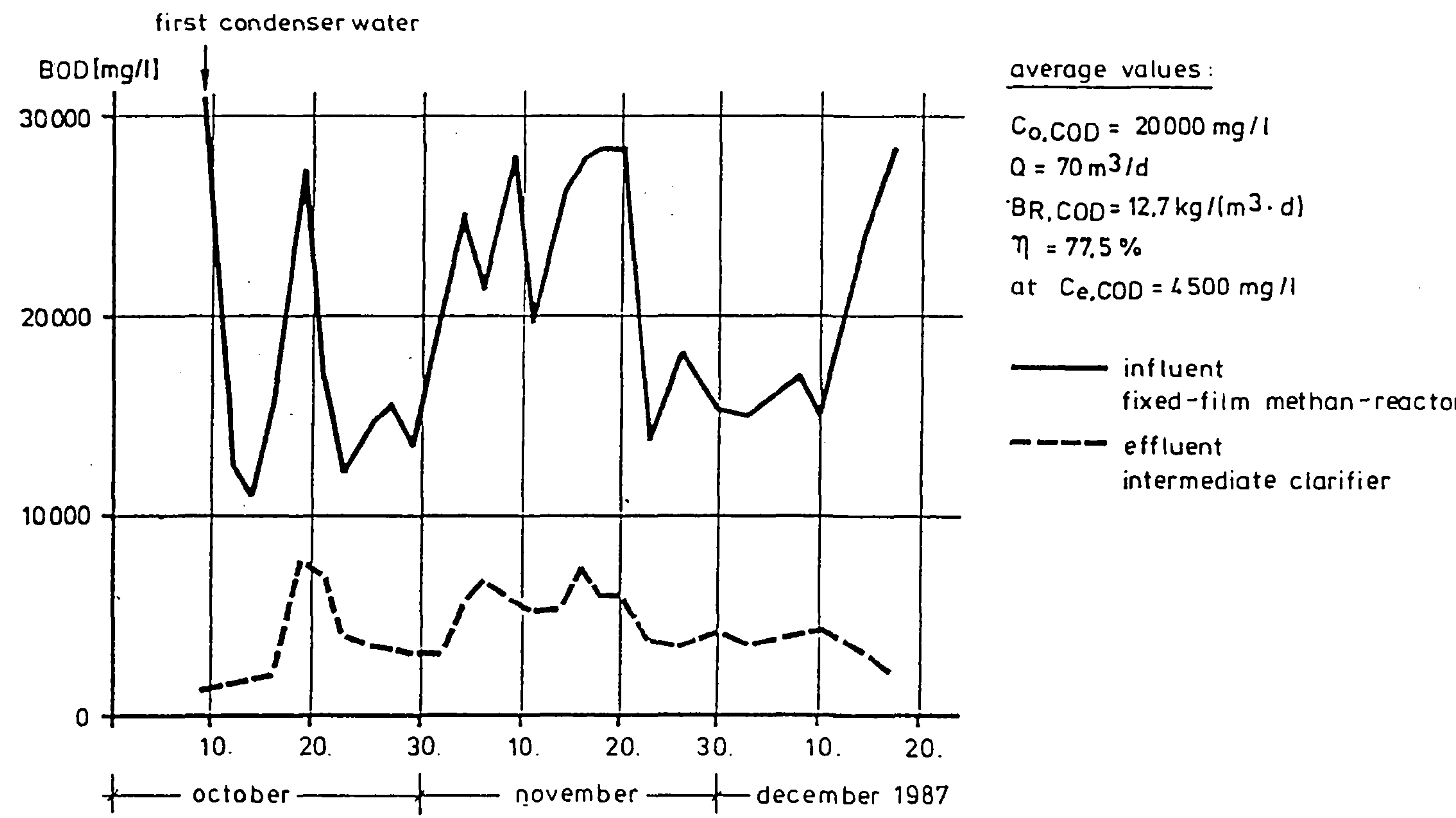


FIG. 10: OPERATING RESULTS OF THE FIXED FILM ANAEROBIC DIGESTER OF THE MOLASSES DISTILLERY

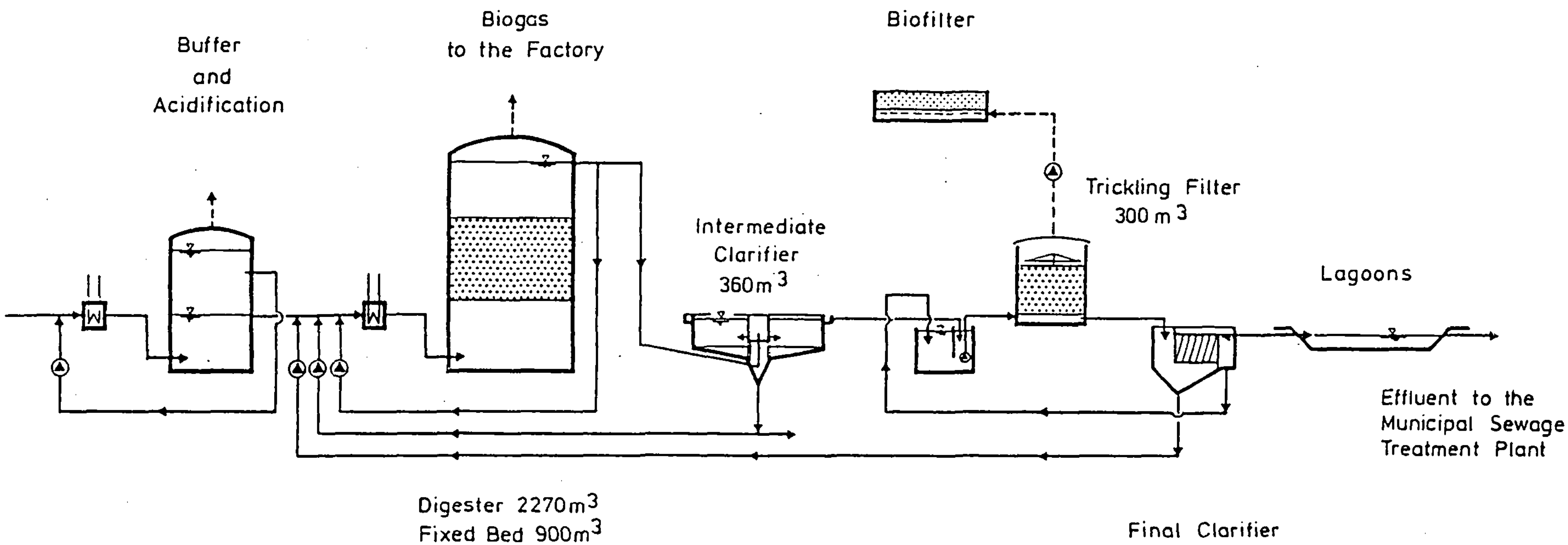


FIG. 11: PROCESS SCHEME OF THE ANAEROBIC-AEROBIC SYSTEM OF A WHEAT-STARCH FACTORY

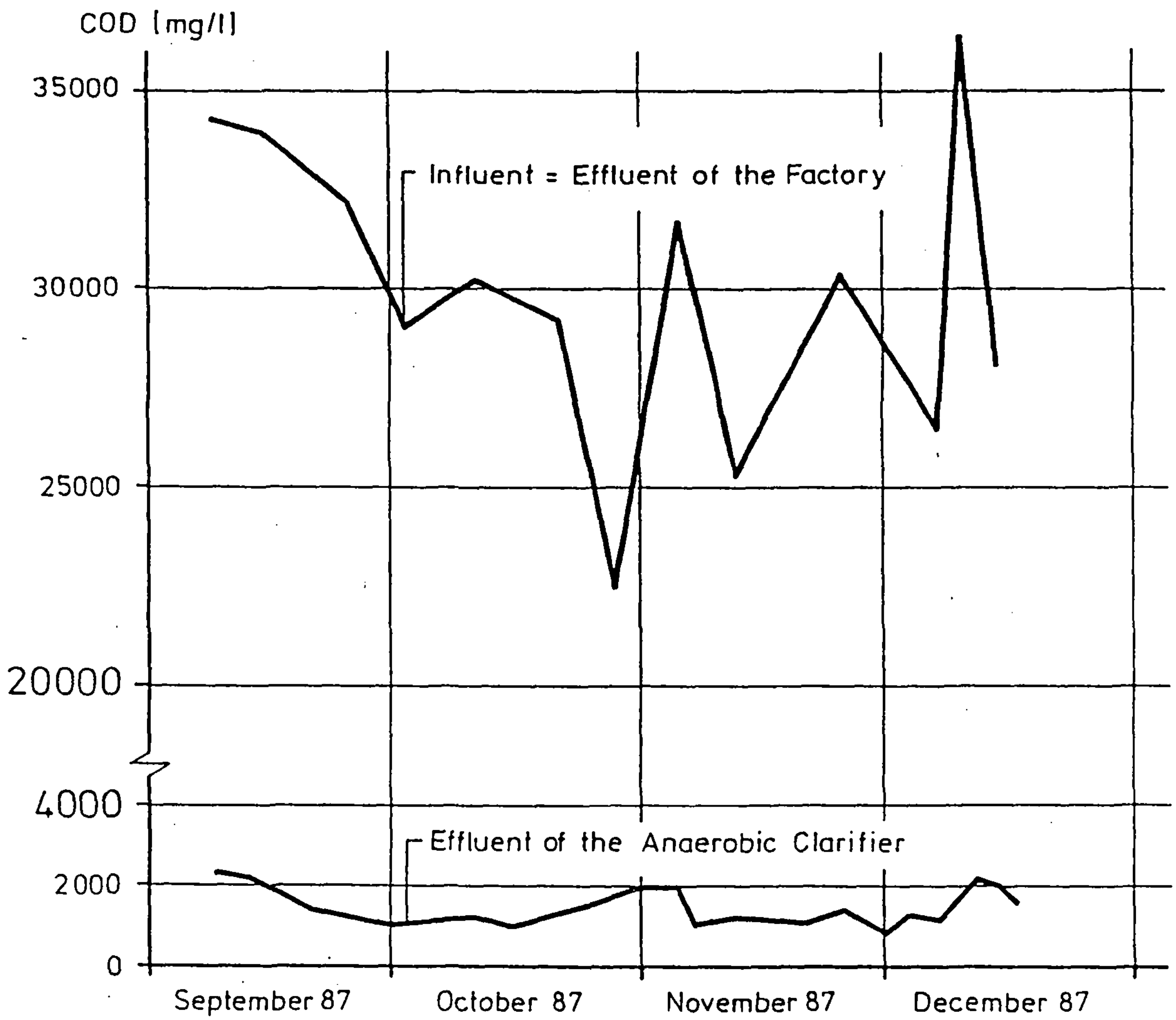


FIG. 12: OPERATING RESULTS OF THE ANAEROBIC PLANT OF THE WHEAT-STARCH FACTORY

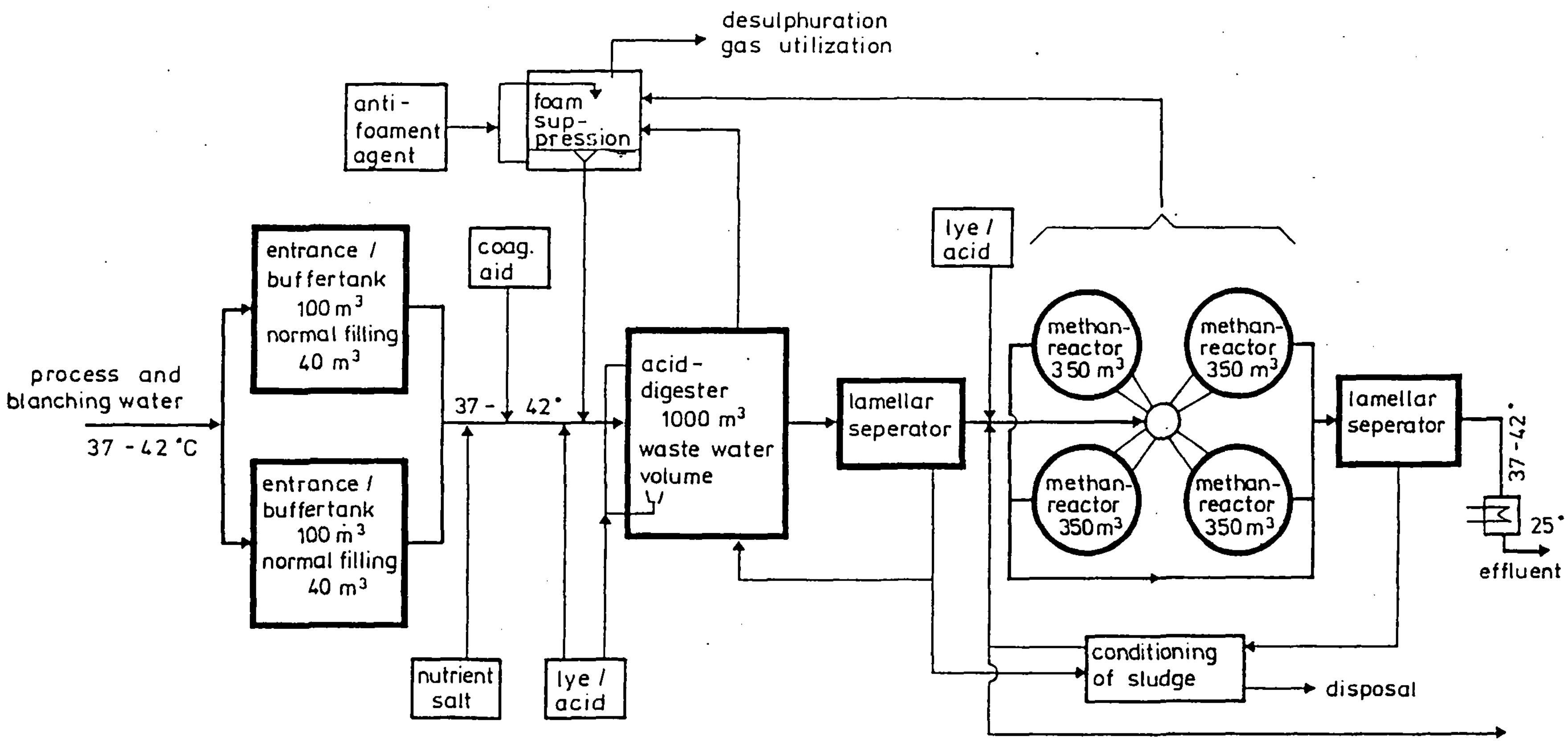


FIG. 13: PROCESS SCHEME OF AN ANAEROBIC PLANT OF A POTATO-STARCH FACTORY (KWU)

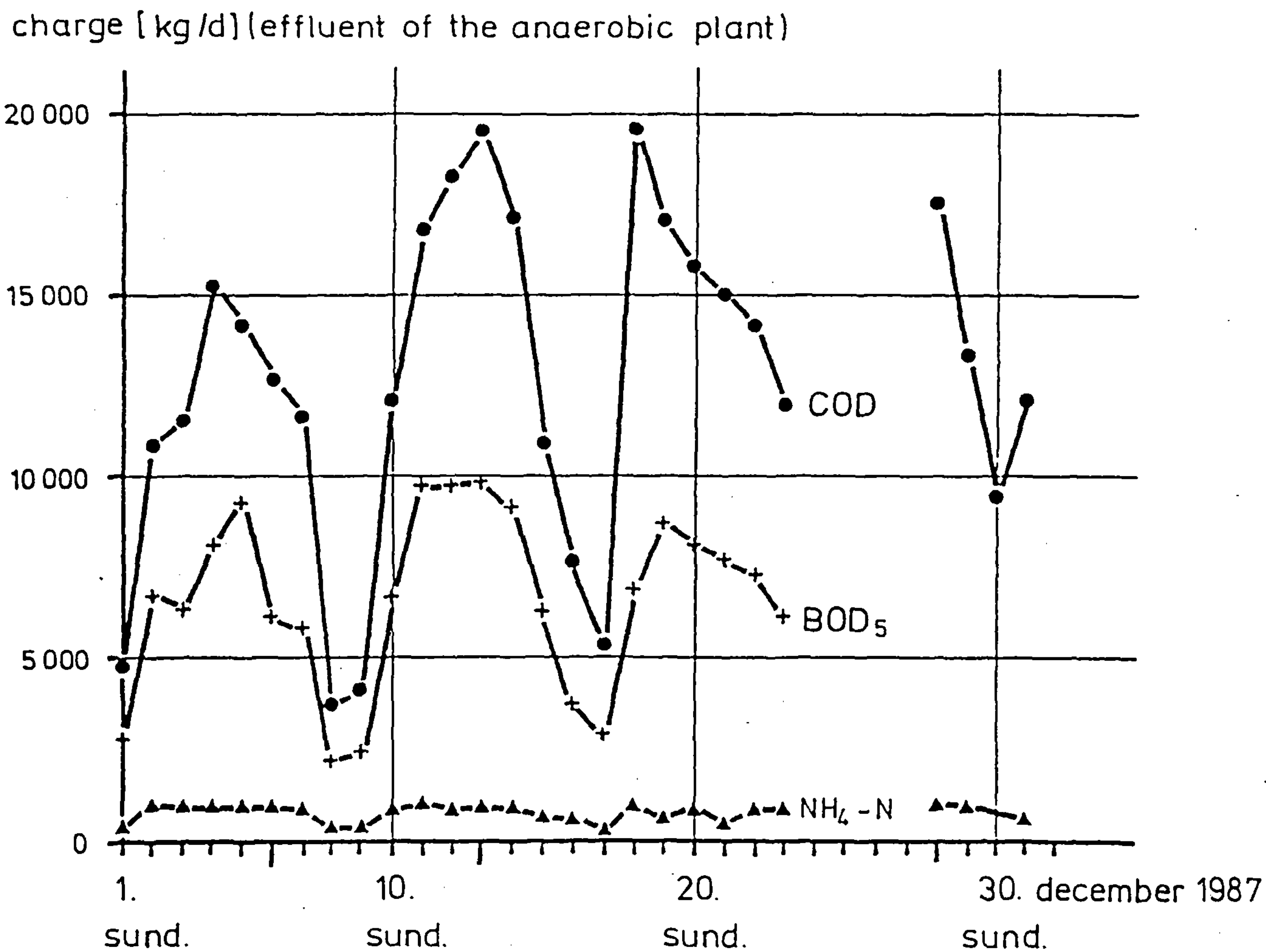


FIG. 14: UPERATING RESULTS (EFFLUENT CHARGE) OF THE ANAEROBIC PLANT OF AN POTATO-STARCH FACTORY (KWK)

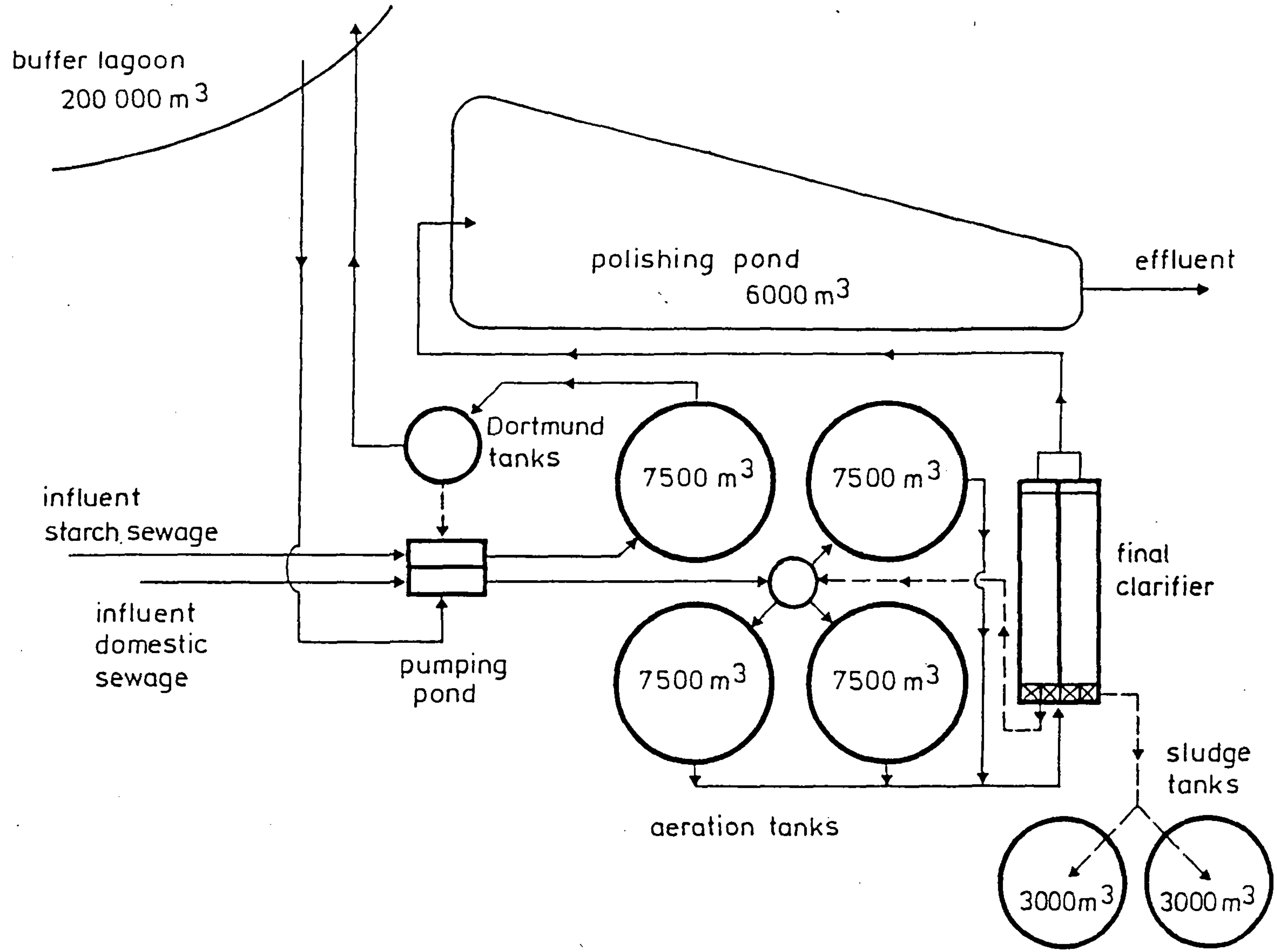


FIG. 15: WASTE WATER TREATMENT PLANT FOR THE COMBINED TREATMENT OF DOMESTIC SEWAGE AND ANAEROBIC PRETREATED SEWAGE FROM A POTATO STARCH FACTORY

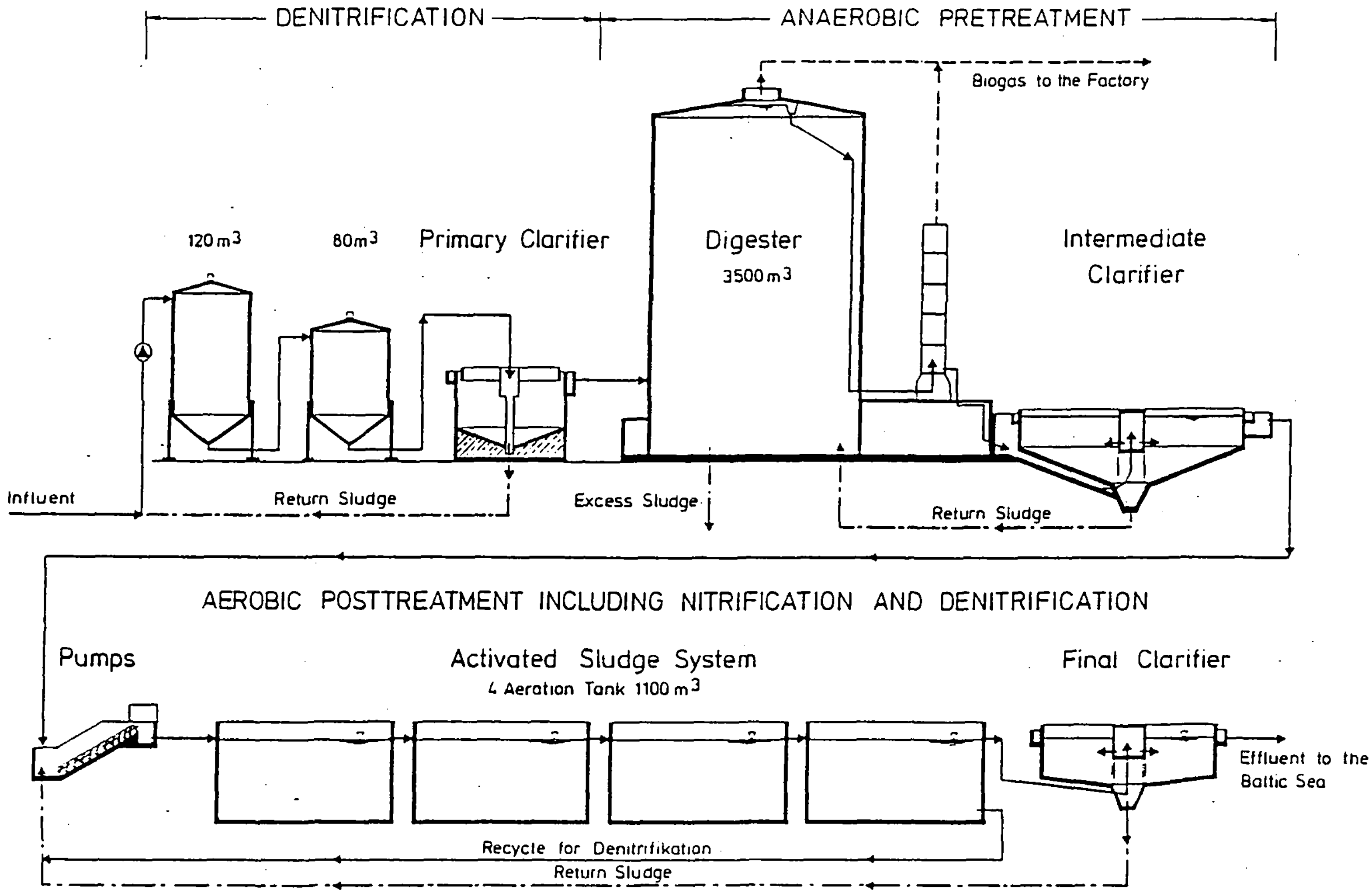


Fig. 16: Flow-diagram of the anaerobic-aerobic treatment plant of a pectin factory

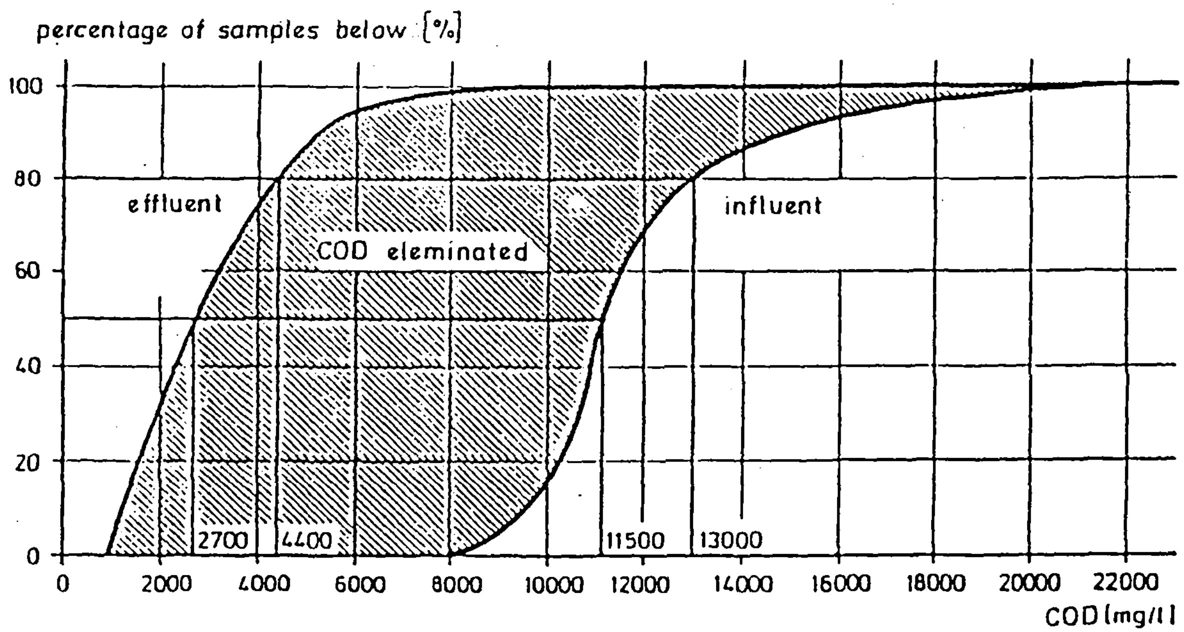


Fig. 17: Combined procentual curve of distribution frequencies for COD concentrations in pectin wastewater for influent and effluent of the anaerobic activated sludge tank (mixed samples)

	sign	dimension	acidic bacterias	methane bacterias
maximal growth rate	μ_{max}	1/d	2-7	0,1-0,4
generation time		d	0,15-0,5	2,5-10
biomass produce	Y_{max}	kg oDS/kg COD	0,12-0,30	0,02-0,15
Monod-saturation constant	K_s	mg COD/L	200-1000	50-200
maximale sludge loading rate (refer to the active dry solids)	$\eta^{B}{}_{aDS}$	kg COD/kg aDS·d	~12-13	~9-10

TAB. 1: GROWTH RATES AND OTHER CHARACTERISTIC VALUES OF ACIDIC AND METHANE BACTERIAS

tracer elements	dimension	nec. concentration/ bibliographical values
calcium	µg Ca/l	10 - 40
magnesium	µg Mg/l	10 - 20
iron	µg Fe/l	?
potassium	µg K/l	?
copper	µg Cu/l	?
cobalt	µg Co/l	3 - 60
zinc	µg Zn/l	?
nickel	µg Ni/l	6
selenium	µg Se/l	8
manganese	µg Mn/l	> 5
molybdenum	µg Mo/l	?
chromium	µg Cr/l	5

TAB. 2: NECESSARY TRACER ELEMENTS IN THE ANAEROBIC METABOLISM

reactor designation	method of intermixing	retention time behaviour of the fluid
completely stirred tank reactor (CSTR)	mechanical, hydraulic gas circulation	e-function approached
sludge blanket reactor f. e. UASB-reactor	hydraulic gas intermixing	e-function approached
fixed-film reactor	hydraulic upward and downward directed flow through	e-function approached
expanded bed reactor	hydraulic	e-funkction approached
fluidized bed reactor	hydraulic	e-function approached

*) expanded bed reactors and fluidized bed reactors can be combined under the genericterm "flow bed reactor"

TAB. 3: CHARACTERISATION OF ANAEROBIC REACTORS (ATV-FA 7.5)

process engineering	biomass concentration positions	biomass enrichment/ -separation	growing up of biomass
completely stirred tank (CSTR)	low differences	without	suspended growth
wash-out-reactor	low differences	without	suspended growth
anaerobic activated sludge process	minium of gradient desired	external separation and recycling	suspended growth
sludge blanket reactor	distinct concentration gradient	internal separation and recycling, aggregation, the separation of aggregated sludge is integrated too	suspended growth mainly "autoimmobilisation" aggregated sludge (pellets, granulars)
fixed film reactor	very differing	growing up on firm carrier material	suspended growth secondary in an ideal case, natural growth on different materials
expanded bed reactor and fluidized bed reactor	secondary	growing on versatile carrier material, separation and recycling internal or external	suspended growth secondary, mainly surface fixed growth

TAB. 4: DESCRIPTION OF ANAEROBIC PROCESS ENGINEERING (ATV-FA 7.5)

Anaerobic stage	Dim.	Pilot-Experiments	layout data min	layout data Ø	layout data max	Results Okt. 1987
Q	m^3/d	-	195	260	325	240
$C_{o,COD}$	g/l	-	45	45	45	37,5
$C_{o,BOD}$	g/l	-	30	30	30	23,3
$B_{d,COD}$	kg/d	-	8775	11700	14625	9000
$B_{d,BOD}$	kg/d	-	5850	7800	9750	5586
$B_{R,COD}$	$kg/m^3 \cdot d$	5- 7	3,9	5,2	6,4	4,0
$B_{R,BOD}$	$kg/m^3 \cdot d$	-	2,6	3,4	4,3	2,5
COD	%	95-88	90	85	80	97
BOD	%	96-90	95	90	85	98
$C_{e,COD}$	mg/l	-	4500	6750	9000	1000
$C_{e,BOD}$	mg/l	-	1500	3000	4500	480
Aerobic stage						
$B_{d,BOD}$	kg/d	-	293	780	1463	115
$B_{R,BOD}$	$kg/m^3 \cdot d$	2,5-4,0	1,0	2,6	4,9	0,4
$C_{e,COD}$	mg/l	1500-3000	-	-	-	900
$C_{e,BOD}$	mg/l	800-1500	-	-	-	235
$\eta_{tot.COD}$	%	-	-	-	-	98
$\eta_{tot,BOD}$	%	-	-	-	-	99

TAB. 5: COMPARISON OF PILOT EXPERIMENTS, LAYOUT DATA AND OPERATION RESULTS OF A WHEAT STARCH FACTORY

	influent	effluent after settling tank	
$c_{COD,mix.}$ (mg/l)	11.860	3.075	
BOD_5/COD ratio (-)	0,63	0,14 - 0,89	
$c_{organic\ acids}$ (mg/l) (CH_3COOH)	350	strong fluctuations	
settable solids (mg/l)	0-300	0.69	
filterable solids (g/l)	1,21	0,26	
coloration of the membrane filtrate (mg/l) (Hazen-coloration, 0,45 µm)	7.500	2.600	
$c_{org.N}$ (mg/l)	124	128	
c_{NH_4-N} (mg/l)	66	without ammoni-fication: 130	with ammoni-fication: 704
c_{NO_2-N} (mg/l)	n.n.	n.n.	
c_{NO_3-N} (mg/l)	1.077	0 - 10	
$c_{Phosphorus}$ (mg/l)	10,0	9,0	

Tab. 6: Arithmetic mean values for pectin wastewater before and after anaerobic treatment (January 1983 to June 1984)

	Volume	Area	Detention Time	COD	BOD	NH_4-N	NO_3-N
Influent : Flow 30 m³/h				13.500	-	30	1.000
Denitrification							
Reactor I	120 m³		4 h				
Reactor II	80 m³		3 h				
Separator	165 m³	64 m²	5,5 h	8.500	-	80	20
Anaerobic stage							
Reactor	3.500 m³		117 h				
Clarifier	480 m³	175 m²	16 h	1.500	350	230	1
Aerobic stage							
Denitrification	1.100 m³		37 h				
Aeratet Tanks	1.100 m³		37 h				
	1.100 m³		37 h				
	1.100 m³		37 h				
Clarifier	290 m³	95 m²	10 h	500	5	1	30-220
	9.000 m³		300 h = 12,5 d				

Tab. 7: Full scale process and operational results

APPLICATIONS OF THE ANAEROBIC WASTE TREATMENT PROCESS IN THAILAND

Sumaeth Chavadej*

&

UASB FOR DISTILLERY WASTEWATER TREATMENT

Supan Chattrakoon**, Chusuk Nutmakul**, Chaimanoo Boontheekul**, Sumaeth Chavadej* and Ob Nark-uam**

* Thailand Institute of Scientific and Technological Research, Bangkok

** Suratip Distillery Co. Ltd.

APPLICATIONS OF THE ANAEROBIC WASTE TREATMENT PROCESS IN THAILAND

Sumaeth Chavadej *

Introduction

In Thailand, water pollution is still one of the major problems. To sustain the environmental qualities especially water qualities, most of industries have been forced to have their own treatment plants. It has been known that anaerobic treatment can offer a lower treatment cost in comparison with aerobic processes. A combined anaerobic and aerobic process can offer even a better solution for wastewater treatment in terms of treatment cost.

For a strong organic wastewaters such as distillery wastewater, anaerobic treatment can also produce a valuable byproduct of the combustible biogas apart from a significant reduction of the treatment cost. Furthermore, anaerobic treatment has recently been used to treat diluted wastewaters successfully such as hospital and domestic wastes. The main purpose of this technical paper is to reveal and evaluate the present status of applications of anaerobic treatment in Thailand. The auther hopes that this technical paper will stimulate R&D in the field of anaerobic digestion and also result in an increase in practical uses of anaerobic treatment in the near future.

Anaerobic treatment for industrial wastewaters

In Thailand, the use of anaerobic treatment has been widely practiced for many years. It is commonly served as primary treatment in order to minimize the treatment cost. However, the effluent from the anaerobic unit still contains a high BOD value. Consequently, it is essential to have a secondary treatment to reduce the waste strength below the acceptable level before discharged into a public receiving water. Table 1 shows various types of industrial wastewaters to be firstly treated by anaerobic processes and then to be further treated by several methods. It is clearly stated that anaerobic treatment is commonly employed to handle the industrial wastewaters containing relatively high BOD values. As can be seen from Table 1, anaerobic ponds are in common for factories which locate far away from big cities especially Bangkok. This is clearly due to a low land cost. Septic tanks are generally applied in a small factory while an anaerobic pond system is commonly chosen for a factory having a large volume of wastewaters. In using the anaerobic pond system, it can be

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* Thailand Institute of Scientific and Technological Research 196 Phahonyothin Road, Bangkhen, Bangkok 10900, Thailand.

Table 1 Anaerobic treatment of industrial wastes in Thailand (1)

Type of Waste	Number	BOD mg/l	Flow m^3/d	Type of Anaerobic Treatment	Secondary Treatment
Distillery	17	35,000-40,000	20-1,500	AP, AC, UASB	C, AS, LD
Alcohol-producing	2	35,000	120	AP, AF	C
Sugar	35	200-3,800	200-2,000	AP	FP, Ir, E&I
Palm-oil	11	6,700-27,700	25-140	AP	AL, FP, Ir
Vegetable-oil	4	2,000-14,000	20-60	AP	FP, E&I
Natural rubber	68	240-5,800	20-200	AP, AF	FP, Ir, E&I
Textile	57	150-1,100	1-700	AP, ST	FP, E&I
SMG	1	100,000	120	AP	FP
Pickle & Sauce	25	270-9,050	1-50	AP, AF, ST	FP, E&I
Cannary	18	560-3,500	20-2,000	AP, AF, ST, UASB	FP, AS
Steamed fish	25	730-1,000	2-5	AF, AP	FP, E&I
Ice-cream	23	220-2,000	1-10	ST, AF, AP	FP
Frozen-Sea-Food	4	430-2,100	30-1,200	AP	FP, AS
Slaughterhouse & Frozen meat	4	450-900	3-1,500	AP, AF	FP
Meat-processing	9	350-4,600	0.5-30	ST, AF, AP	FP, E&I
Noodle	169	500-5,500	1-80	ST, AF, AP	FP, AL, OD, E&I

Table 1 (Continued)

Type of Waste	Number	BOD mg/l	Flow m^3/d	Type of Anaerobic Treatment	Secondary Treament
Transparent noodle	12	480-19,800	20-250	ST, AP, AF	FP, OD, E&I
Palp & Paper mill	3	400-10,000	2-80	ST, AP	FP
Parboiled rice	53	600-3,000	15-300	ST, AP	FP, AL, E&I
Lac	7	950-3,000		AP	FP, E&I
Tapioca starch	58	6,400-7,650	20-3,200	AP	FP, AS, E&I
Glucose syrup	8	370-10,000	2-80	AF, AP, ST	FP, E&I

AC = Anaerobic contact

AF = Anaerobic filter

AL = Aerated lagoon

AP = Anaerobic pond

AS = Activated sludge

C = Composting

E&I = Evaporation and infiltration

FP = Facultative pond

Ir = Irrigation

OD = Oxidation ditch

ST = Septic tank

UASB = Upflow anaerobic sludge blanket

claimed few advantages such as its simplicity in design and operation and low treatment cost. It is very interesting to point out that application of the high-rate anaerobic digestion has been increasing for the last 5 years. This is may be due to it's high efficiency and tangible benifit from methane recovery. Recently, anaerobic treatment has been applied to successfully treat diluted wastewaters such as domestic and hospital wastes. As mentioned before, the treated wastes from anaerobic units still contain very high BOD values and so secondary treatment is required. Facultative ponds have been widely practiced in rural areas while oxidation ditch, activated sludge and aerated lagoons are employed in cases of high land costs. Several factories such as tapioca-starch plants have no discharges since the treatment ponds are so large enough to completely evaporate the wastewaters. Surprisingly, direct discharges of the anaerobic effluents are commonly exercised among small factories.

Evaluation of existing anaerobic treatment

The anaerobic processes used in Thailand can be classified into two main groups namely open system and air-tight system. The open system can be anaerobic ponds and septic tanks which the biogas produced loses to the atmosphere. The treatment efficiency, of course, is extreamly low due to the inhibitory effect of atmospheric oxygen to the anaerobes. In addition, the microbial concentration in the system is very low. Consequently, a long hydraulic retention time (HRT) is required in order to achieve a high removal efficiency. Evaluation of anaerobic treatment of various industrial wastes using anaerobic ponds is given in Table 2. A series of several ponds is widely existed since a higher number of ponds can provide a better removal efficiency than a single pond according to the biokinetics concept. A high BOD removal up to 90% can be simply achieved provided that the anaerobic ponds are designed and operated under a very low loading and a long HRT. For examples, HRTs of the anaerobic ponds receiving pulp mill waste and distillery waste are 350 and 369 days, respectively.

For the air-tight system of anaerobic treatment is normally known as anaerobic digesters or anaerobic fermenters. The biogas generated can be easily recovered and directly used as fuel apart from it's high treatment efficiency in comparison with anaerobic ponds. Table 3 shows types of digesters used to treat different wastewaters in Thailand. For a large scale basis, there are 12 UASB units, 2 anaerobic contact units and 1 upflow anaerobic filter unit for distillery waste treatment. The UASB system is designed to operate as two-stage upflow anaerobic sludge blanket. The volumes of the acidogenic tank and the methanogenic tank are 450 and 3,000 m^3, respectively. The design loading and HRT are 15 kgCOD/m^3d and 7.7 days, respectively. Two of twelve UASB plants at Surat Thani and Chachoengsao are selected for first start-up studies. It has been recently reported that, for the Chachoengsao site, the start-up study of the UASB is achieved progressively. The present loading is about 4.5 kgCOD/m^3d which generates a high biogas production rate of about 3,200 m^3/d. The calculated gas yield is about 25 m^3/m^3 raw slop. The calculated benefit from biogas production to the factory is nearly

Table 2 Process performance of anaerobic ponds treating several types of industrial wastewaters

Type of Waste	Number of ponds	Waste Strength mg/l	Loading kg/m^3d	HRT d	Removal %	Basis	Note
Tapioca starch	1	7,650	0.67	15	60	COD	(2)
	2	1,200	0.25	18	68	BOD	
Pulp mill	4	3,900	0.0114	350	95.5	BOD	3
	4	13,000	0.037	350	91	COD	
Fibre board	1	2,650	0.126	21	79	BOD	first pond 4
	1	-	0.265	10	62	BOD	second pond
Sugar mill	7	1,200	0.0349	34.5	-	BOD	1
Distillery	20	36,000	0.0976	369	96	BOD	7, 8
	20	110,000	0.298	369	83	COD	
Frozen seafood	1	1,030	0.229	4.5	62	BOD	
Pineapple canning	2	6,000	0.216	25	92	BOD	
Slaughterhouse	2	1,000	0.313	3.2	79	BOD	13
Fruit canning	4	8,000	1.6	5	35	BOD	10

Table 3 Anaerobic digesters in use for various wastewaters in Thailand (11, 6, 7, 10, 9, 12)

Type of waste	Digester volume m^3	Type of digester	Loading kg/m^3d	HRT days	Removal %	Gas-Production m^3/d	Basis	Note
Distillery	9,000	Thermophilic A.C.	10(18)	10.8(6)	55	27,000	COD	Ayuttaya
Distillery	800	AC	2.5	40	60	600	COD	Thai Tum
Distillery	3,450	Two-stage UASB	4.5(15)	(7.7)	60	3,200	COD	Under start-up period
Sludge	1,000	Conventional AD	0.0188	389	-	-	SS	Hauy Kwang
Fruit canning	500	UASB	5	1	96	-	BOD	Anaerobic-Ponds as acid-stage
Noodle	16.2	AF	0.926	3.24	-	-	BOD	Sedimentation as pretreatment
Hospital	150	ST + AF	0.02	2.5 + 5	88	-	BOD	$<$ 200 beds

( ) Design criteria

HRT Hydraulic retention time

AD Anaerobic digestion

2×10^6 baht/year based upon the current loading. Undoubtedly, the other UASB plants will be operated successfully in the near future. The anaerobic system of Thai Tum distillery plant is the oldest digester in use. It consists of three identical digesters having a total volume of 800 m^3 It was designed to operate with sludge recycle under the thermophilic range. However, it is now operated under ambient temperature. Since, the production of this distillery plant is very low, the maximum COD loading to the system is about 2.5 kg/m^3d. Under this normal low loading, the anaerobic system works very well. The only anaerobic system which was designed to operate successfully under the thermophilic range is at Ayutthaya distillery plant. It is anaerobic contact process having total volume of 9,000 m^3 which is claimed to be one of the biggest anaerobic digesters in the country. The design loading was 18 $kgCOD/m^3d$ but the maximum loading is only 10 $kgCOD/m^3d$ at the present production capacity. The system is working effectively and the biogas production rate is 27,000 m^3/d which corresponds to a biogas yield of 30 m^3/m^3 slop. It is expected that the system will be able to withstand a high COD loading up to the design loading. Apart from a large scale of anaerobic digesters, a considerable number of anaerobic filters have been widely used to treat a small waste volume especially noodle wastes which is range from 1 to 20 m^3/d. It is not possible to evaluate the process performance of the anaerobic filters due to unavailability of technical data. It has been informed that a 500 m^3 UASB was designed to treat fruit canning waste. The waste is firstly passed through anaerobic ponds which are operated as the acidogenic stage. The effluent from the pond is fed into the UASB unit. It is said that a high BOD reduction up to 96% is achieved through the anaerobic process. There is only one sludge digester in this country. It was designed to digest the excess sludge from the activated sludge plant which receives the waste from Hauy Kwang Community having a population of 20,000. It has a working volume of 1,000 m^3 The heating unit has never been used because the temperature in the digester is closed to the mesophilic range throughout the year. Anaerobic filters have also been used to treat diluted waste waters such as domestic wastewater and hospital wastewater. It has been stated that its application to these diluted wastewaters is limited to a small scale since the construction cost becomes comparatively expensive for a large scale which is due to a high cost of packing media. Stones are commonly selected as packing media for a small-scale anaerobic filter because of their low cost.

Problematics of anaerobic treatment

In comparison to aerobic treatment, anaerobic digestion can provide several advantages such as it's low energy requirement, suitability for strong organic wastes and the valuable byproduct of combustible methane gas. However, anaerobic treatment has several drawbacks and limitation. The reaction rate of anaerobic digestion is relatively slow when compared with aerobic degradation rates. This results in a long HRT for an anaerobic pond system. The low efficiency of anaerobic digestion can by overcome by the use of high-rate-anaerobic processes (HRAP). The high-rate-anaerobic processes which are presently used in this country are anaerobic filters, anaerobic contact and upflow anaerobic sludge blanket (UASB).

It has been reported that most anaerobic ponds have a common problem of unpleasant odour from the ponds. The odour naturally comes from hydrogen sulphide and volatile fatty acids which derive from breakdown of organic substances under anaerobic condition. It is interesting to know that, to minimize odour problem during the start-up period, a slow increase of loading to the anaerobic ponds must be taken in conjunction with routine analysis of the wastewater in ponds to ensure no accumulation of volatile fatty acids in the ponds. It was reported that, for the case of distillery waste, a large quantity of lime was applied to the anaerobic ponds in order to minimize the odour problem and to eliminate the inhibitory effect of VFA to the methanogens. Since then, the anaerobic ponds have been operated without addition of lime. Accumulation of solids espectially in the first pond commonly occurs and can affect the removal efficiency. It maybe need to remove the solids every 4-5 years. It can be concluded that, for most of existing anaerobic ponds, the first ponds seem to be too small. This leads to possibility of VFA accumulation in the first ponds. It is suggested that a first pond should have a long HRT to ensure complete conversion of VFA into methane.

As be mentioned before, the use of anaerobic filters is limited for a small volume of wastes. It is reported that clogging is a major cause of failure. This is clearly due to the use of stone media which have a rather low porosity. This clogging problem is simply minimized by providing a large empty space at the filter's bed. A use of plastic media to replace stones is strongly recommended. The high cost of plastic media can partially offset by a reduction of foundation cost since the plastic media are much lighter than the stones.

The anaerobic contact digesters which are used at two distillery plants have two important problems. The first one is about temperature fluctuation. They were designed to operate at the thermophilic range. Without a temperature controlling unit, it is extreamely difficult to keep the temperature at around 55^{o}C. It is necessary to avoid any fluctuation of temperature in operating the digesters at the thermophilic zone since the thermophilic bacteria is very sensitive to a temperature change. Therefore, one of the distillery plant has to operate its digesters under ambient temperature. The second problem is a significant amount of anaerobic sludge to lose from the system even through a set of hydrocyclones was applied after the sedimentation chambers. The design HRT for the sedimentation chambers was about 10 hours which is considerably long enough. However, the overflow from the chambers still contain high SS values. This is clearly due to poor design of the sedimentation chambers.

As be mentioned earlier, the UASB process is considerably advance for Thailand. Few attempts of research works on UASB were carried out but only a single work done by the Suratip's group could achieve the perfect granulation. Currently, there are 12 UASB units for distillery waste and 1 unit for fruit canning waste. None of them has the granular sludge. Two of the twelve UASB units are now on starting-up. To achieve successful operation of UASB process, it is imperative to succeed granulation during the start-up period.

Concluding remarks

Anaerobic ponds have been widely used as primary treatment for various industrial wastewaters due to simplicity in design and operation and a low construction cost. The problems in using anaerobic ponds are large area requirement and nasty odour. To minimize the odour problem, a first pond should be large enough to eliminate the VFA accumulation. Research and development on Biogas recovery from anaerobic ponds should be carried out.

The uses of high-rate-anaerobic processes are very limited since few industrial wastewaters are economically feasible. It is essential to encourage more research on anaerobic digestion especially pilot scale UASB studies for both strong and diluted organic-wastewaters in order to gain more design data. It is strongly suggested that two-stage anaerobic treatment should be considered for improving any aerobic treatment plants. This will result in a significant reduction of aeration cost and it will allow the system handle a higher volume of wastewaters.

References

1) Ministry of Industry, Annual Reports on Chao Praya Sector, Mae Klong River and Southern Part Sector, Bang Prakong Eastern Sea Board and Northeast Sector and Tachin River Sector, B.E. 2529-2530

2) Bhumiratana, S.et al (1985), Report on Status of Treatment and Utilization of Tapioca-Starch Wastewaters in Thailand, NCGEB

3) Ratasuk, S.et al (1978), Report on Treatment of Wastewaters from Bang Pa-In Paper Mill, TISTR

4) Thailand Institute of Scientific and Technological Research (1978), Report on Treatment of Fibre-Board Wastewaters

5) Personal communication with Mr. Chaimanu Buteekul

6) Personal communication with Mr. Supun Chadtrakul

7) Personal communication with Mr. Chusuk Numakul

8) Personal communication with Miss Yajai Kajonworawattanakul

9) Personal communication with Dr. Surapol Saiphanich

10) Personal communication with Mr. Preecha Ploypatarapinyo

11) Personal communication with Engineering Division, Department of Health

12) Ploypatarapinyo, P. (1985), Report on Design of Wastewater Treatment Plant for Saraburi Slaughterhouse

UASB FOR DISTILLERY WASTEWATER TREATMENT

*Supan Chattrakoon, *Chusuk Nutmakul, *Chaimanoo Boontheekul,

*Ob Nark-uam and **Sumaeth Chavadej

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Introduction

There are twelve distillery plants which belong to the Excise Department. Two are located in the North, one in the South, four in North-East and five in the central part of Thailand. Suratip Company is given a permission to operate these plants. These plants were built to replace the old distillery plants. In the past, all distillery plants around the country did not have treatment plants. The wastewaters were simply discharged directly into rivers. This resulted in adverse impacts to the environment. By that time, how to handle and control distillery wastes was a hot issue. Therefore, in these 12 distillery plants, anaerobic digestion and composting were used to handle the waste. Upflow anaerobic sludge blanket (UASB) was selected for the design of the treatment plants since it was claimed several advantages over other anaerobic processes.

Characteristics of Distillery Wastewaters

There are two major wastewaters from the distillery plant. One is the wastewater from the bottling unit which contains a low organic content. Table 1 shows characteristics of the bottling wastewater.

*Suratip Distillery Co. Ltd.

**Thailand Institute of Scientific and Technological Research.

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Table 1 Characteristics of bottling Wastewater

Waste Volume	100 - 150	m^3/d
COD	50 - 250	mg/l
BOD	20 - 100	mg/l
pH	11	

The important wastewater is from the distillation columns which is commonly called slop. It contains considerably high contents of organics and minerals especially potassium. The characteristics of the slop is presented in Table 2. The slop volume is about 450 m^3/d. Since these two streams of the wastewaters are different in characteristics, they are segregated to treat by different methods.

Distillery waste treatment methods

Since the BOD value of the bottling wastewater is very low, aerated lagoon is used to treat the waste. The waste is firstly neutralized before discharged into the aerated lagoon. The aeration pond was designed to have a HRT of 5 - 7.5 days. The treated effluent can be discharged into a nearby receiving waterway.

The slop which is considerably a strong organic-waste is primarily treated by the UASB unit. The process gives a valuable by-product in form of biogas which is directly used in the boiler. The treated slop from the UASB unit is kept in the holding ponds which have a total capacity of about 100,000 m^3. This large volume of the ponds is to ensure to keep the waste throughout the year

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Table 2 Characteristics of distillery slop (average)

COD	100,000	mg/l
BOD	34,000	mg/l
Total Nitrogen	1,750	mg/l
Po_4^{-3} -P	150	mg/l
SO_4^{-2}	4,400	mg/l
Suspended Solids	<14,000	mg/l
Total Solids	100,000	mg/l
Total Volatile Solids	80,000	mg/l
pH	4.3	
Ca^{+2}	1,650	mg/l
K^{+}	5,500	mg/l
Na^{+}	120	mg/l
Volatile Fatty Acids (As Acetic Acid)	1,400	mg/l
Alkalinity	1,050	mg/l

The treated slop is further disposed of by composting technique. Composting is a technique to convert organic wastes into useful and desirable material through biodegradation process. During the biodegradation reaction, considerable amount of heat is generated which enhances the evaporation rate of the waste. Agricultural residues which have high absorption capacity should be used in this process. Bagasse is common in use and other agricultural residues such as coconut husk, rice straw, corn cob, sawdust are occasionally used. Selection of raw material depends upon price and availability. A special strain of bacteria named BIONIC is inocculated in the raws material mixed up with the waste. By using anaerobic treatment and composting, slop is completely disposed of.

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Design and Operation of UASB

Since BOD and COD values of slop are extremely high, biogas production from slop by anaerbic digestion is economically feasible. Upflow-Anaerobic-Sludge-Blanket (UASB) was selected for the twelve distillery plants. It is because the UASB process has several advantages over other anaerobic processes. It does not require a sedimentation tank and mixer. In addition, it can withstand a higher load and requires a shorter time for a second start-up in comparison with other processes. The twelve UASB plant were designed and constructed by Esmil International and Siam Technology, respectively. The design criteria is shown in Table 3. Figure 1 shows the Biothane reactor.

Table 3 Design Criteria of biothane System

slop volume	450	m^3/d
slop COD	100,000	mg/l
COD Loading	15	kg COD/m^3d
Two-stage System		
Acidification tank	450	m^3
Biothane Reactor	3,000	m^3
Biogas Yield	25-30	m^3/m^3 slop
Methane in Biogas	70	%

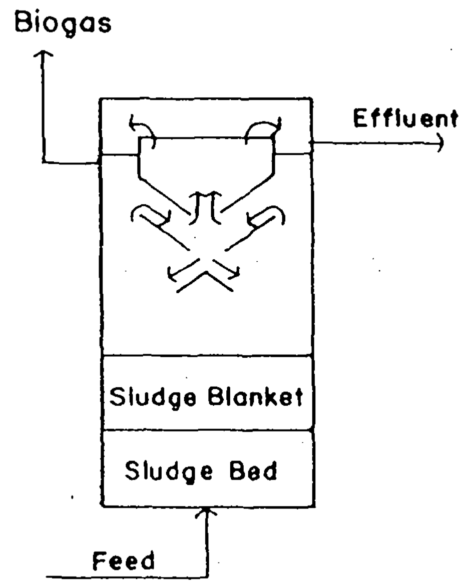

Figure 1 Diagram of UASB reactor

Flow diagram of UASB process (Biothane) is illustrated in Figure 2. It is expected that COD removal is 80-90% and total biogas production is about 13,000 m^3/d which is equivalent to 7,600 l/d of fuel oil. The energy from biogas is estimated to be about 50% of the total energy requirement. Energy saving is approximately about 3-4 million baht per year. This makes Biothane system is very promising.

Unfortunately, the start-up programme of these UASB units was interrupted and eventaully called off. Therefore, Suratip staff had to carry out the start-up programme by themselve. Two studies of UASB on both laboratory and pilot scales were conducted at Suratip in order to gain more experiences in operating UASB. Two sites of the distillery plants at Chachoengsoa and Burirum were selected for the start-up studies.

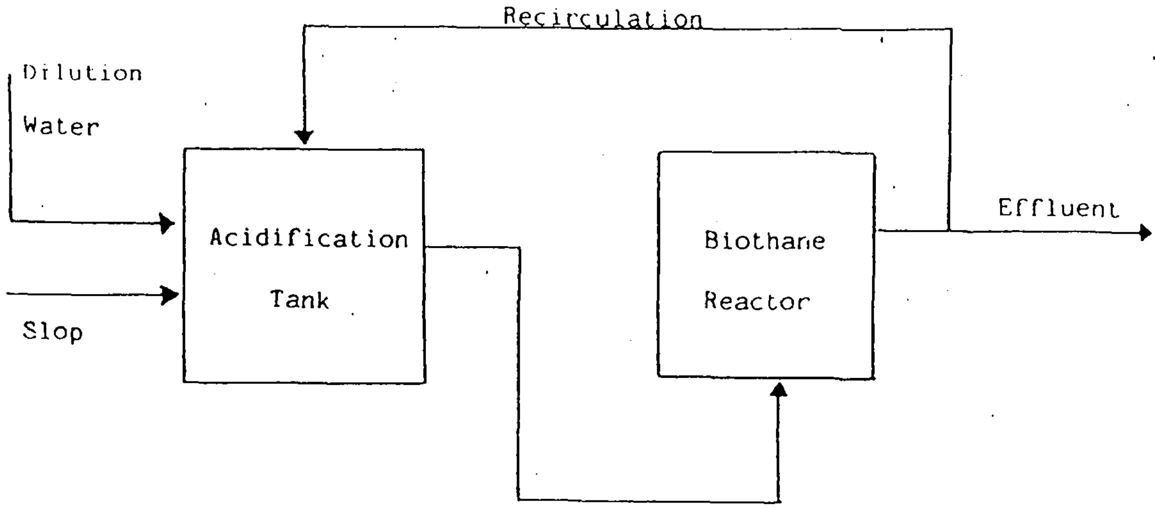

Figure 2. Biothane Process.

For the Chachoengsoa site, the start-up of the UASB unit was commenced in the mid of 1987. It took several months to repair the flow meters and the process control system. In addition, the process piping system was modified especially the feed distribution system inside the UASB reactor. The tank surface was also repainted for corrosion protection. Once the system had been passed a hydrostatic test, the UASB reactor was filled up with the anaerobic sludge taken from the nearby anaerobic pond. The system was firstly fed with the diluted slop at a low COD loading of 0.25 Kg COD/m^3d. This was to allow the sludge gradually adapt to the waste. An increase of COD loading was carefully taken with care. Routine analysis of feeds and effluents has been carried out in order to assess the process stabilities and efficiencies in terms of COD removal and gas production. Table 4 shows the present conditions in operating the UASB system.

Table 4 Current loading and process performance of UASB during start-up

COD loading	4.5	Kg/m^3d
Average feed COD	120,000	mg/l
Effluent COD	22,000	mg/l
Effluent VFA	200-300	mg/l as HOAc
Effluent pH	7.4	
COD Removal	82	%
Gas Production Rate	3,200	m^3/d
% CH_4	63	%
Gas Yield	25-30	m^3/m^3 slop

As been seen from table 4, the system works very well under the current loading. The biogas produced is directly used to generate steam. The factory claims that at the present COD loading of 4.5 Kg COD/m^3d, a reduction of fuel oil about 2,260 l/d is achieved by the direct use of the biogas. Therefore, 1 m^3 of biogas is equivalent to 0.7 l. of fuel oil. This saving is about 6,780 baht/day, or 2.47 million baht/year. However, the sludge in the UASB reactor is still in floculant forms since the system is operated under considerably low loadings. Hence, it is necessary to increase COD loading to proceed granulation. These granular sludge from the Chachoengsoa site will be used for start-ups of other UASB plants in the near future.

Summary

In Thailand, the first application of UASB was to treat distillery wastewater. The design loading and HRT were 15 Kg COD/m^3d and 6.67 days, respectively. The system consists of acidogenic tank and methanogenic reactor. The volumes of acidogenic tank and methanogenic reactor are 450 and 3,000 m^3, respectively. The system was designed to treat a waste volume of 450 m^3/d. A first start-up of the UASB plant at Chachoengsoa has been carried out progressively since the mid of 1987. At the present, the system is operated at a COD loading of 4.5 Kg/m^3d. Under this loading, the system works extremely well and a biogas production rate is about 3,200 l/d which is equivalent to 2,260 l/d of fuel oil. This results in saving 2.47 million baht/year of the fuel oil cost. The granular sludge obtained from the Chachoengsoa distillery plant will be used for start-ups of the other UASB plants.

EXPERIENCE WITH THE UPFLOW-ANAEROBIC SLUDGE BLANKET PROCESS APPLIED TO DISTILLERY WASTES

Dr. Suchint Phanapavudhikul

Water and Environment Consultant Corp., Ltd.
Bangkok, Thailand.

Experience with the Upflow-Anaerobic Sludge Blanket Process*
Applied to Distillery Wastes

Dr.Suchint Phanapavudhikul**
1 September 1988

Introduction

Effluents discharged from the food and beverage industry all tend to be heavily polluted and to contain high concentrations of biodegradable organic material. Anaerobic digestion is widely used for the stabilization of sewage sludges, can readily be adapted for the treatment of industrial wastes where it provides a compact and economical treatment process requiring no aeration, producing only minimal quantities of surplus sludge and generating a gaseous fuel of significant commercial value. Anaerobic Digestion is a bacterial fermentation by which organic matter is broken down in the absence of dissolved oxygen to produce a mixture of carbon dioxide and methane gases. The formation of methane is the key to the whole process because it is the method by which the chemical oxygen demand (COD) of the wastewater is reduced and also because the methane content of the fermentation gas provides it with a commercial value.

In Thailand, Surathip Group of Distillery Plants have provided 12 distillery plants with Biothane biogas system or UASB (Upflow-Anaerobic Sludge Blanket Process) for a sugar cane slop utilization, mainly for biogas production as fuel for use in the factory as well as to reduce the smell problem before the effluent is discharged to storage lagoons.

All the 12 plants were installed in 1984 but only two of the plants are working in Chachoeng Sao and Surat Thani in 1987-8. The third one at Burirum will be started in August 1988. The technical and economical problems of these biogas plants seem to reflect a bad reputation to the biogas technology in this country for all fields of application unless plant results can be published to confirm that the biogas system can produce some economic return in spite of its reputation.

* paper presented in "Seminar on Anaerobic Waste Treatment and Sanitation Technologies" organised by Asian Institute of Technology, 1-3 September 1988 at AIT and Phatthaya.

** Managing Director, Water & Environment Consultant Corp.,Ltd. (WEC)
321/27 Nang Linchi Road, T.Chong Nonsi, A.Yannawa, Bangkok 10120
Tel. 286-8010

Purpose of the Study

It is the purpose of the study to operate full scale UASB reactor at Suratthani using different feed rate of undiluted raw sugar cane slop from 60-300 m^3/day. Attempt will be made to justify the economic return from the recovery by product by producing maximum gas production.

Present Wastewater Treatment Process and Seed Sludge

The distillery wastewater treatment process for all 12 plants consists of biogas system (or anaerobic digestion AD), storage lagoon (SL), composting (C), and land application (LA). (see Fig. 1) The average wastewater (raw slop) flow rate is 300 m^3/day. Therefore the above treatment process represents zero discharge of the effluent to the receiving water. The storage capacity and the land requirement for different treatment processes are designed for the above flow rate and the dilution water in the wastewater during anaerobic digestion is not provided for initially.

During the initial plant start up in 1984 the slop or distillery waste was allowed to store in the SL and the pH was adjusted near neutral to reduce the smell problem and to utilize the SL to replace the AD when the AD could not be operated during that time. The hydraulic detention time of the Storage Lagoon (SL) is about 6 months when compared with 300 m^3/day of raw slop for present production rate. The effluent from SL can be used directly as organic liquid wastewater to make compost and to be dried on land by LA method in dry season.

The sludge accumulated at the SL bottom for three years can be utilized as seed sludge for the biogas system. The characteristics of the raw slop or spent-wash of sugar cane molasses and sludge seed are shown in Table 1.

Design Criteria

All 12 plants are designed to treat the slop of distillery producing white spirit from cane sugar molasses. Each has the same size and type in a two stage anaerobic digestion, an acid tank or acidification tank of 450 m^3 (9.15 m. Ø , H = 7.15 m.)* capacity and a UASB reactor of 3,000

Note : Ø = Diameter, H = Height

FIG. 1 RAW SLOP TREATMENT PROCESS AT SURATTHANI DISTILLERY

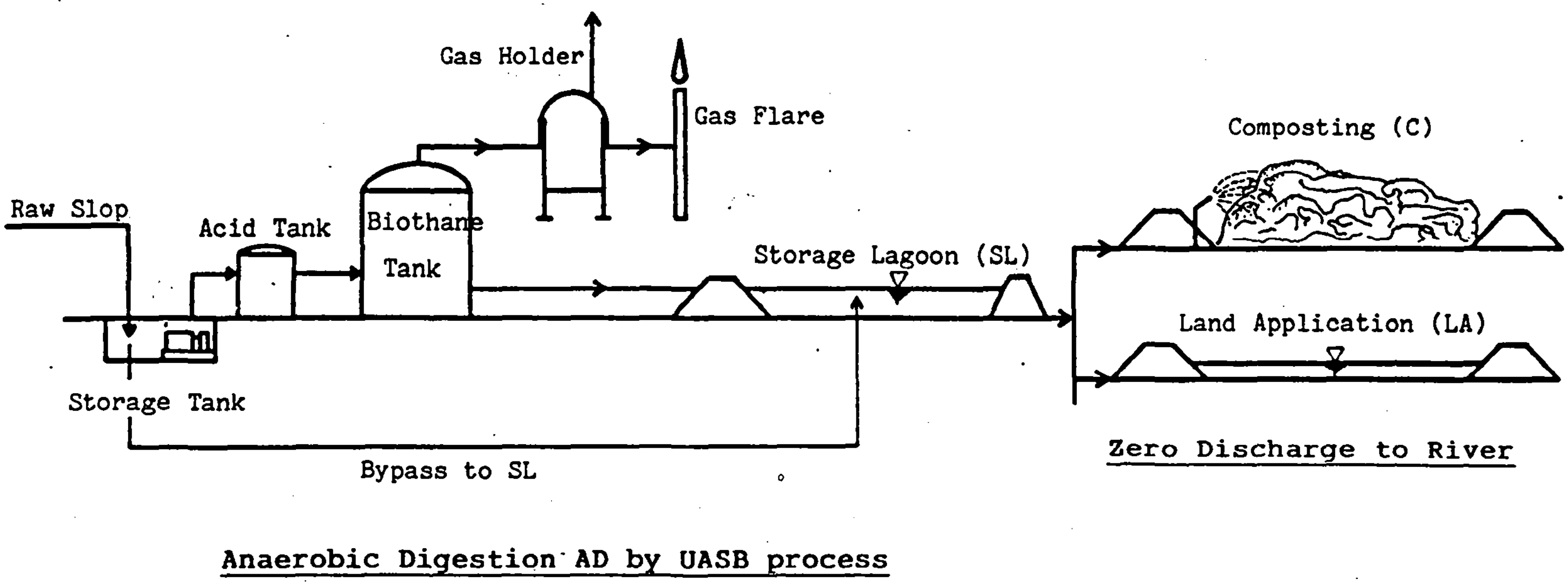

Table 1 Characteristics of Raw wastewater (slop or spent wash) and Seed Sludge

Characteristics	Raw Slop	Seed Sludge*	Remarks
COD, mg/l	100,000	28,700	* after 3 years digestion in Storage Lagoon.
BOD, mg/l	35,000	10,000	
Total N, mg/l	1,750	1,100	
PO_4^{-3}-P, mg/l	150	165	
SO_4^{-2}, mg/l	4,400	1,100	
SS, mg/l	< 14,000		
Settleable Solids, mg/l	< 250		
Total Solids, mg/l (TS)	100,000	35,565	
VS, % of TS	70	50	
pH	4.3	> 7.5	
Ca^{+2}, mg/l	1,650		
K^+, mg/l	5,500	1,500	
Na^+, mg/l	120		
Volatile acids, mg/l	11,700	4,500	
Alkalinity, mg/l	1,050	7,400	
Temperature, °C	35 - 37	30 - 34	
COD load max, kg/day	45,000	-	
BOD load max, kg/day	15,750	-	
Design flow rate, m^3/day	450	-	

m^3 (23 m. Ø, H = 7.15 m.)* capacity to digest 450 m^3/day of slop per day with a specific load of 15 kg.COD/m^3-day. Gas production was assumed to be 12,000 m^3 per day or 4 m^3/m^3 of neactor volume per day. The gas holder has a capacity of 300 m^3 (10.1 m. Ø, H = 5.1 m.) capacity.

Plant Start Up

Since the amount of sludge accumulated over 3 years in the SL (100,000 m^3 storage capacity)is estimated to be about 10,000 m^3 and can be perfectly used as seed sludge for plant start up. For Suratthani Distillery Plant, 100% of seed sludge or 3,000 m^3 was added to the acid tank and biothane reactor initially and the raw slop was then gradually added to these two tanks at 60 m^3/day in early July 1988. The slop distillation process is not a continuous one so the plant is closed down for cleaning purposes say 10 days each month therefore another storage lagoon is provided to collect the raw slop (1,000-7,000 m^3 capacity) to feed the biothane system during non-distilling period. (see Fig. 2)

Results of Operation

The operational parameters include slop waste flow rate, recycled rate, COD, pH, temperature,volatile fatty acid, alkalinity, total and volatile solids, gas production rate, gas analysis. The samples were collected from raw waste (slop), acid tank effluent, and biothane effluent. At times, samples were also collected from different depths say 0.5 m., 2.5 m. and 4.5 m. above the biothane tank to observe the pH and total solids for uniform mixing of each bed. The result of the study is shown in Figs. 3-12.

Wastewater flow rate

In July, the wastewater (slop) flow rate of 60-80 m^3/day was fed to the acid and biothane reactor and this is equivalent to a COD loading of 1.65 kg.COD/m^3-day. The recycle rate of sludge is 682 m^3/day. The excessive wastewater is bypassed to the storage lagoon.

COD removal efficiency

The average overall COD removal efficiency of raw slop and biothane effluent is 54.3%.

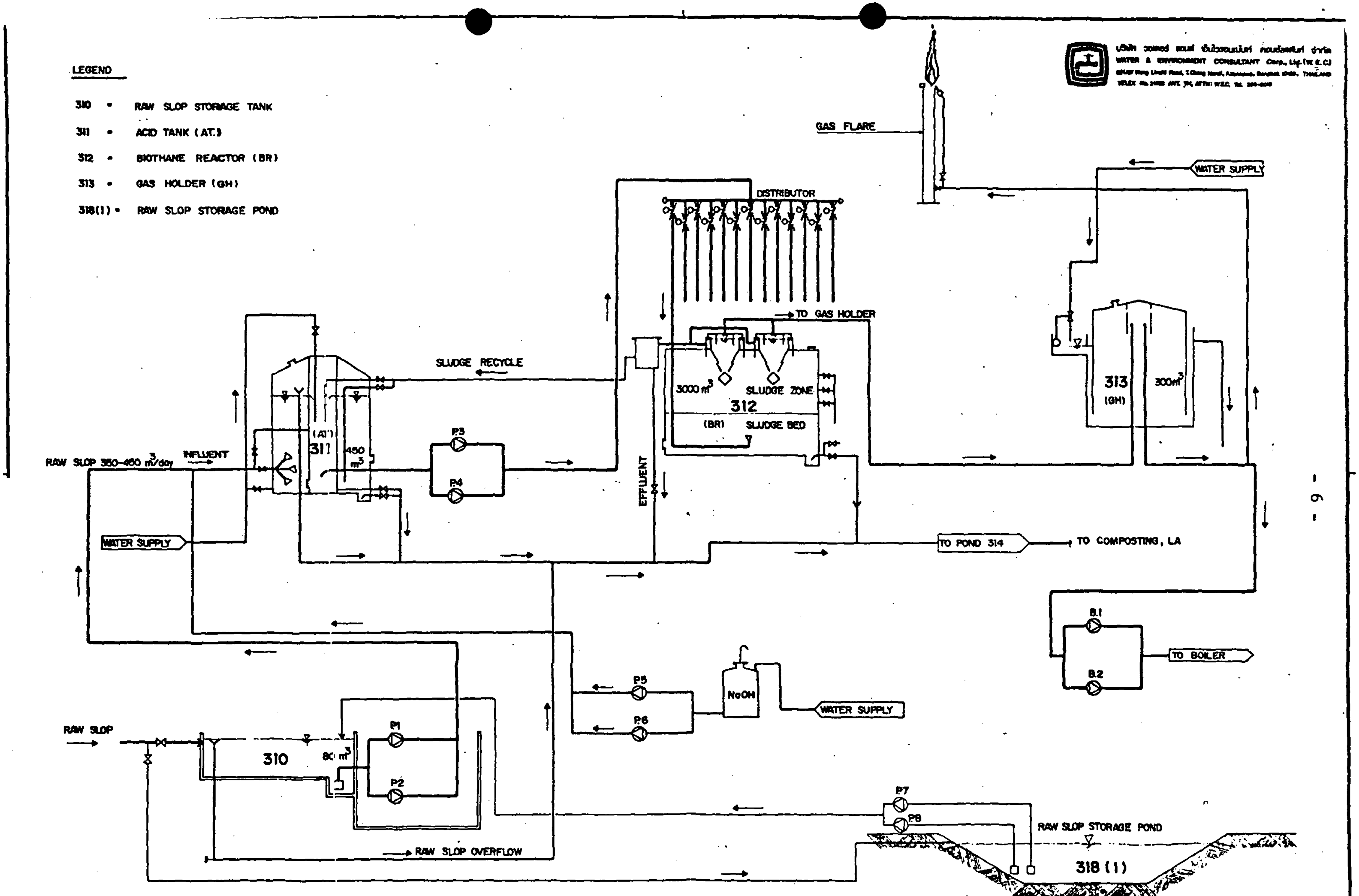

FIG. 2 SCHEMATIC DIAGRAM OF BIOGAG SYSTEM, SURATTHANI

Fig. 3 Raw Slop Flow Rate of Biogas System

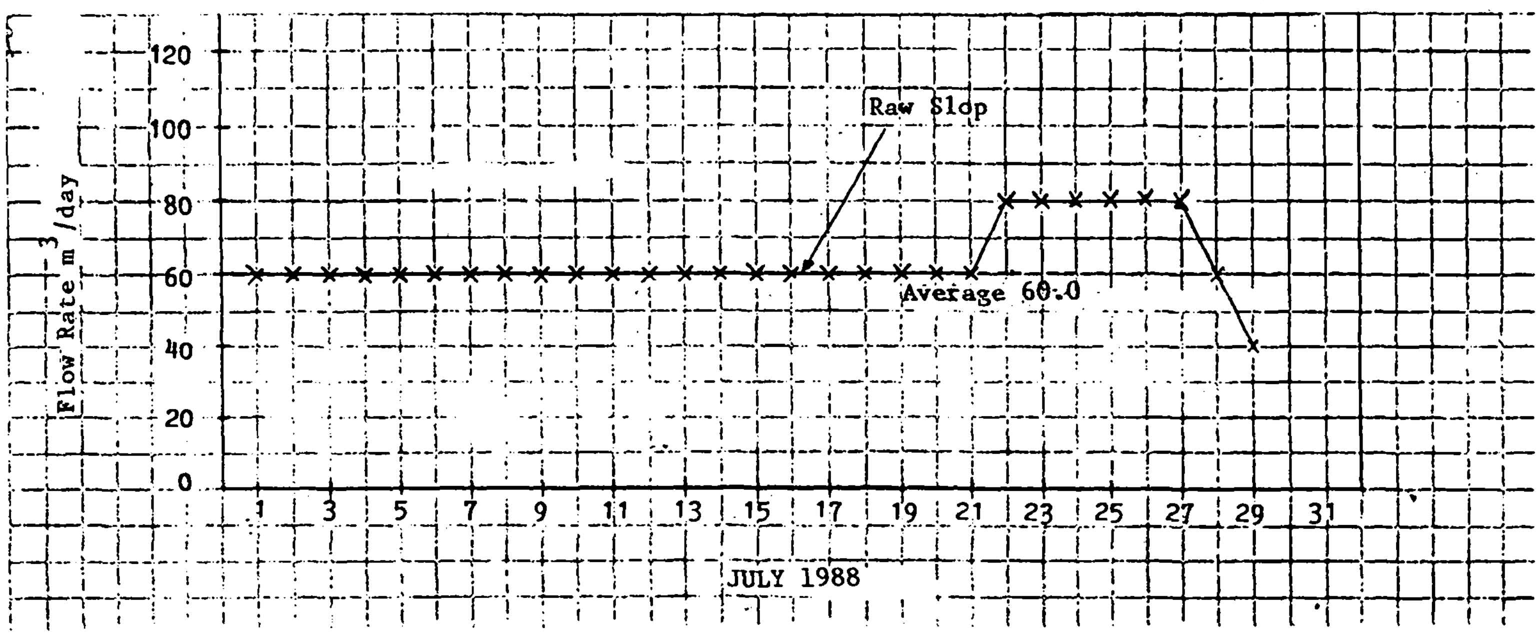

Fig. 4 COD Removal Efficiency of Acid Tank, Biothane Tank and Overall System

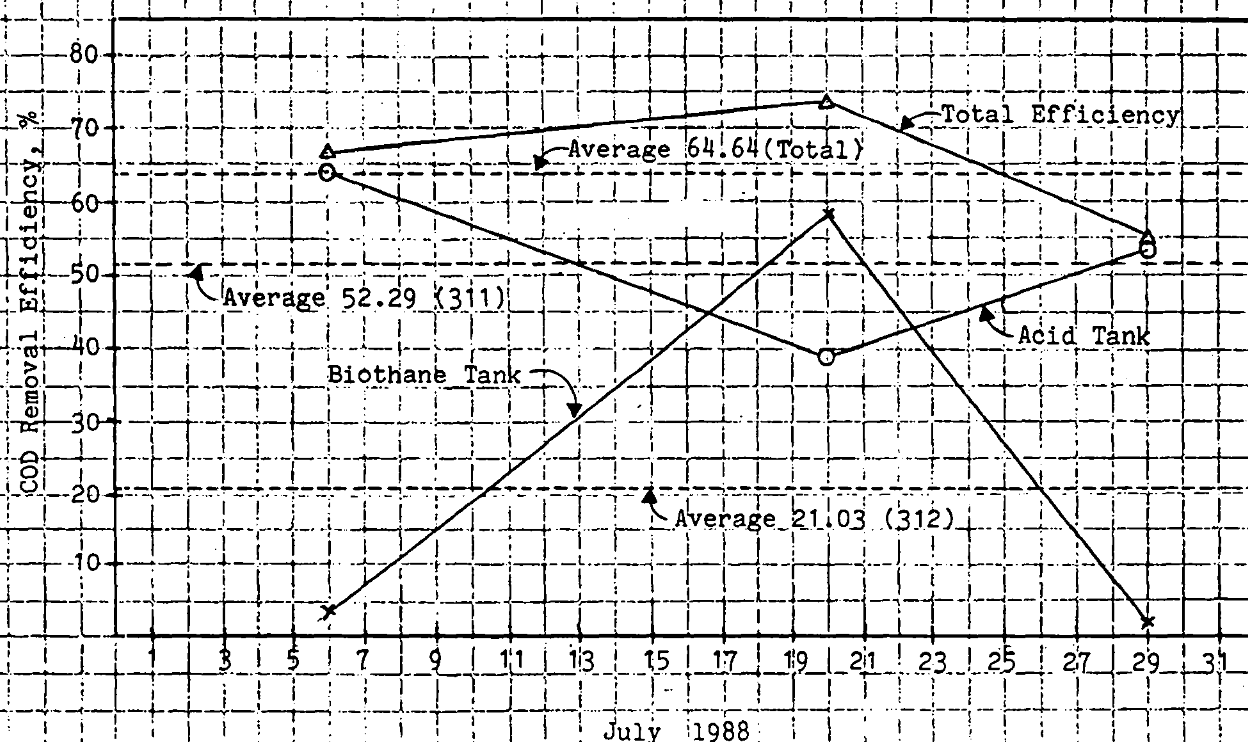

Fig. 5 pH Values of Raw Slop, Acid Tank and Sludge in Biothane Tank

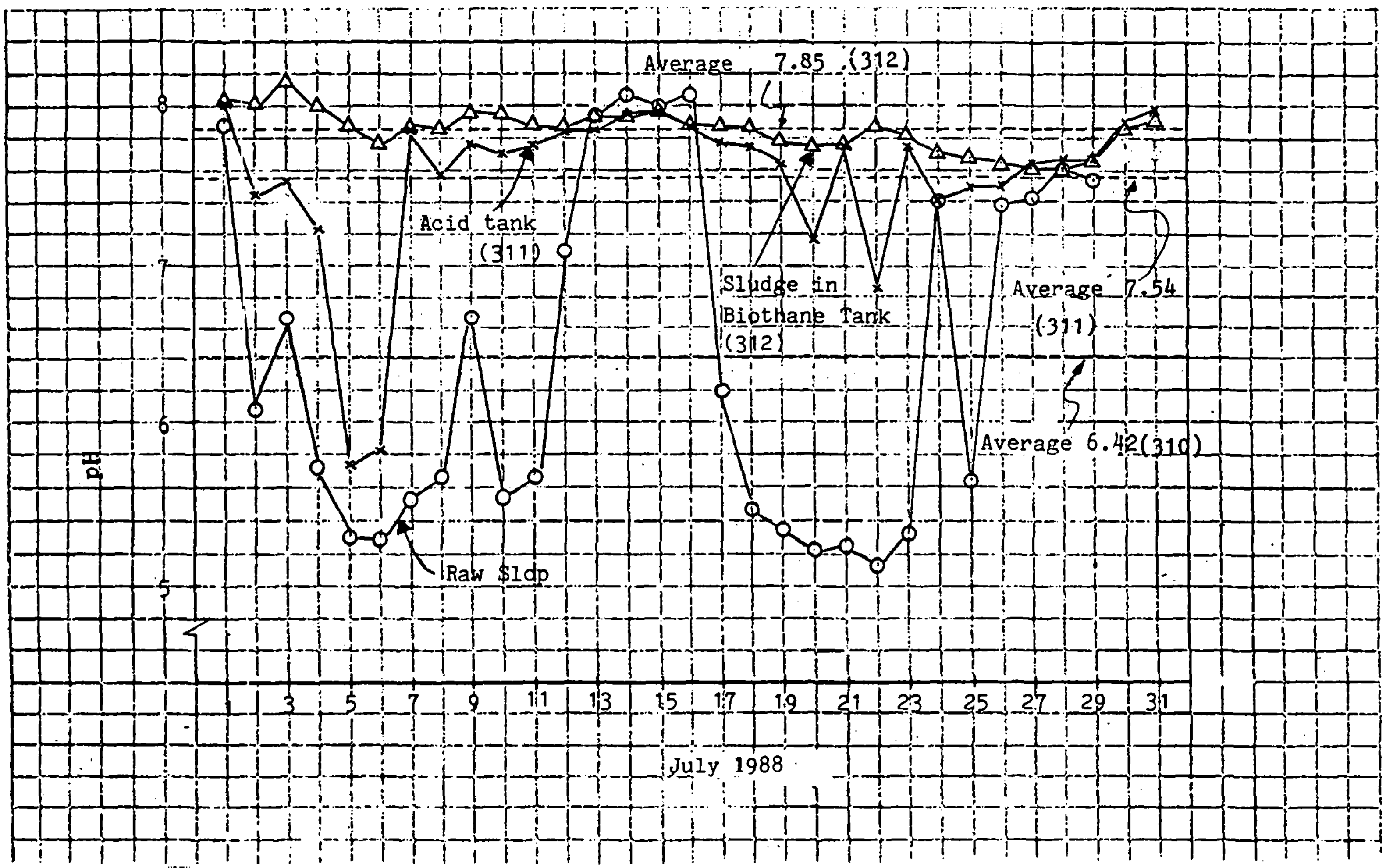

Fig. 6 Temperature of Raw Slop, Acid Tank and Sludge in Biothane Tank

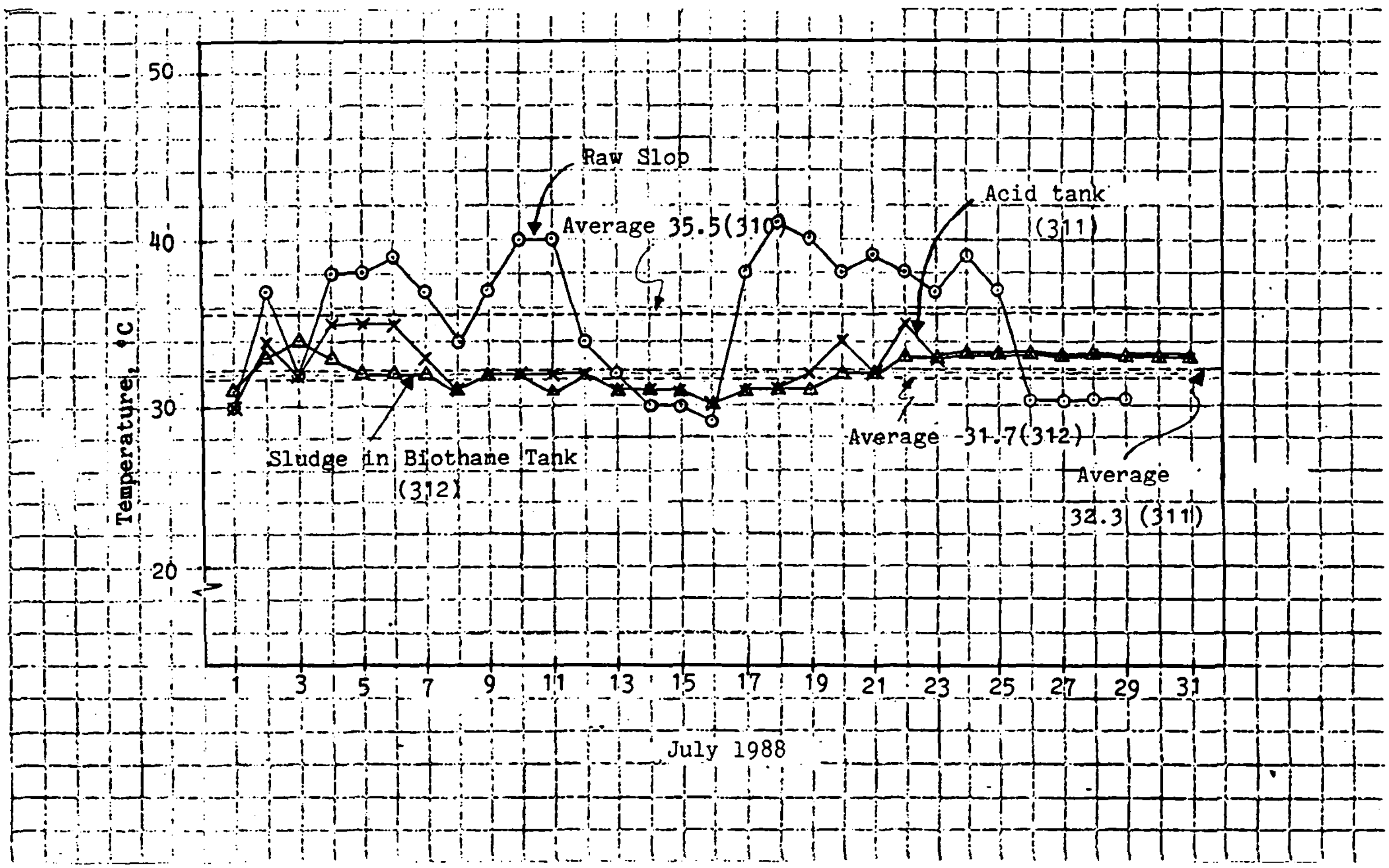

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Fig. 7 Volatile Fatty Acid (VFA) of Raw Slop, Acid Tank and Biothane Effluent

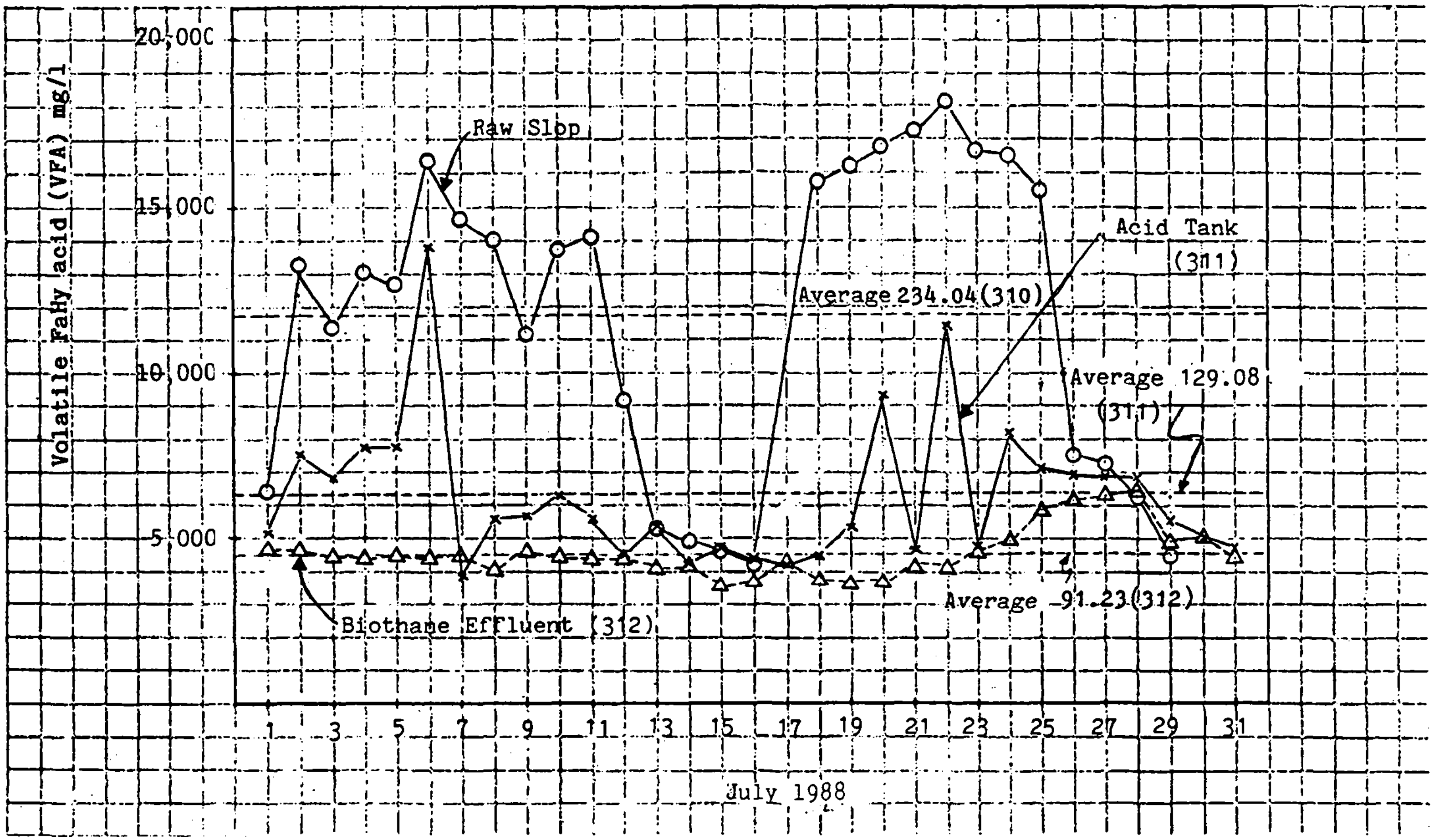


Fig. 8 Alkalinity (A) of Raw Slop , Acid Tank and Biothane Effluent

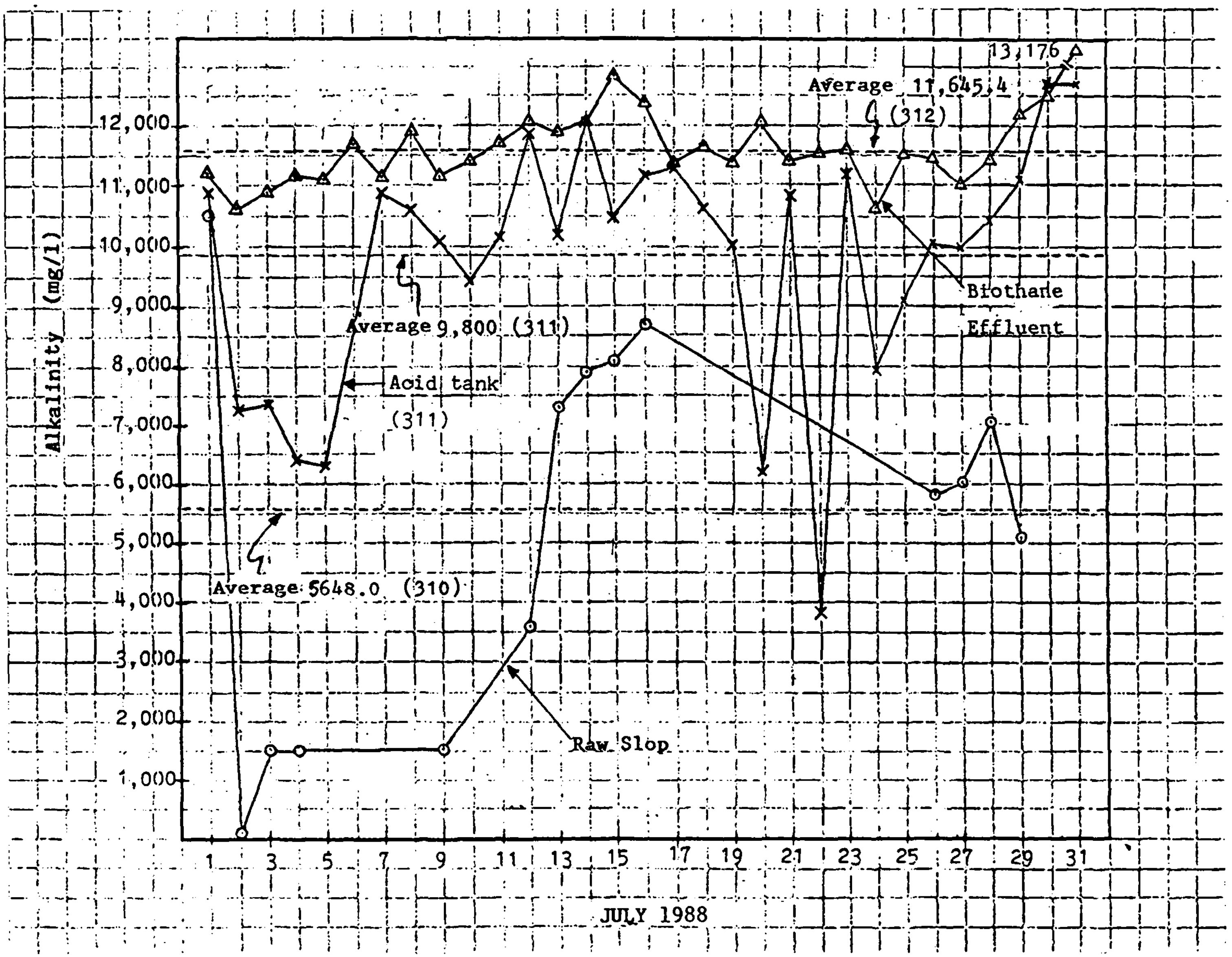


Fig. 9 Ratio VFA/A of Acid Tank and Biothane Effluent

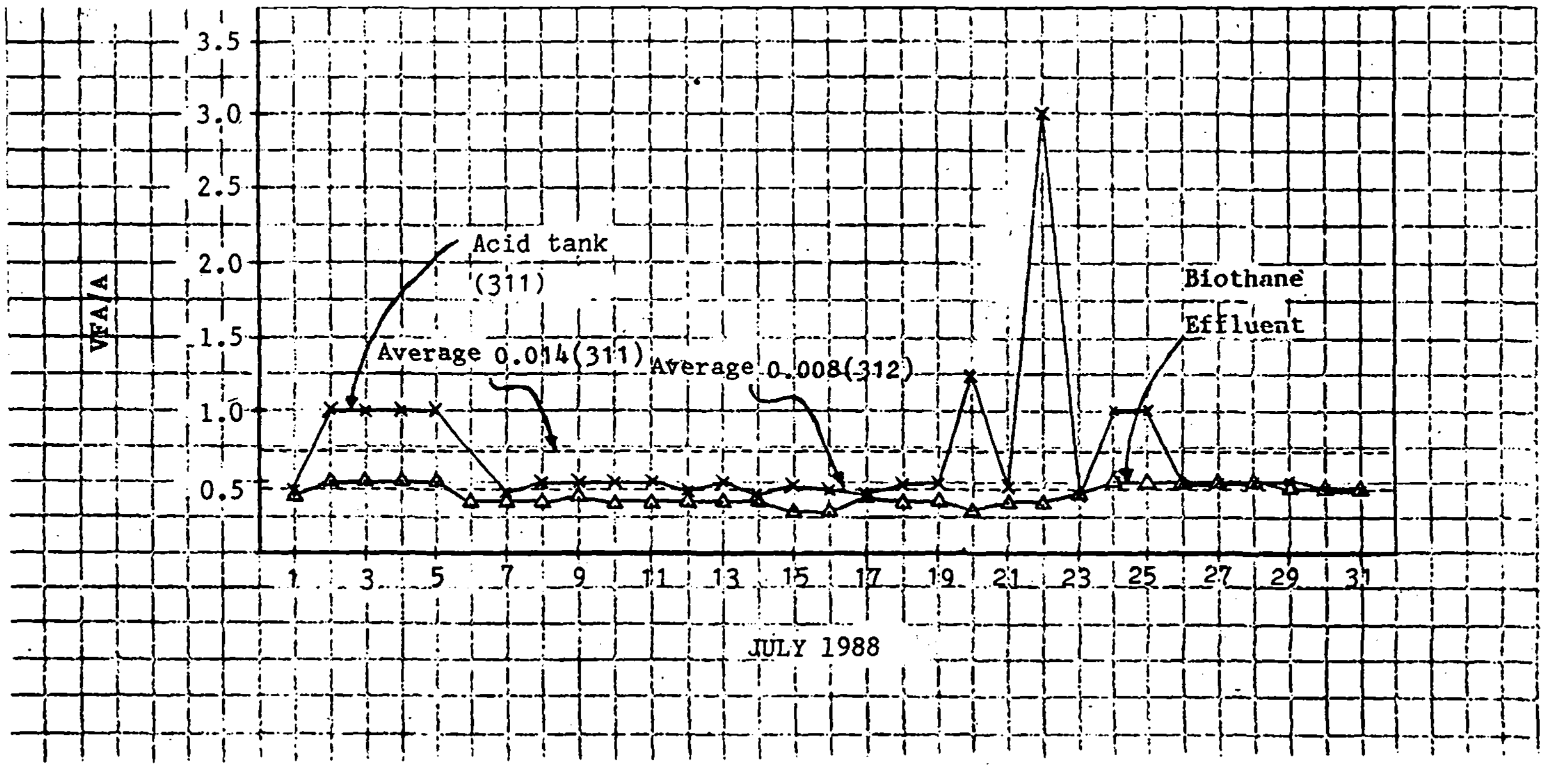


Fig. 10 Tatal Solids of Raw Slop and Biothane Effluent

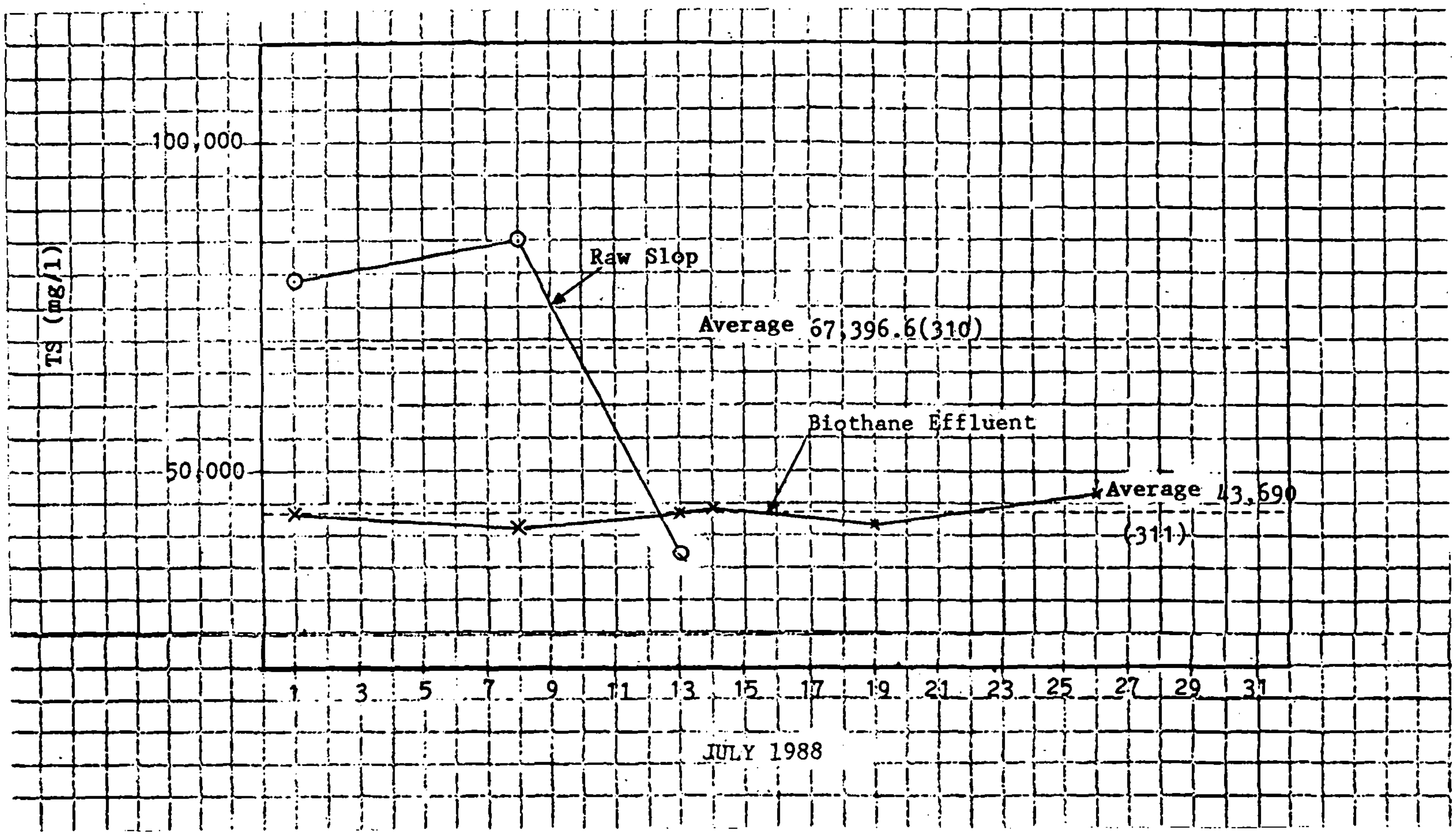


Fig. 11 Volatile Solids of Raw Slop and Biothane Effluent

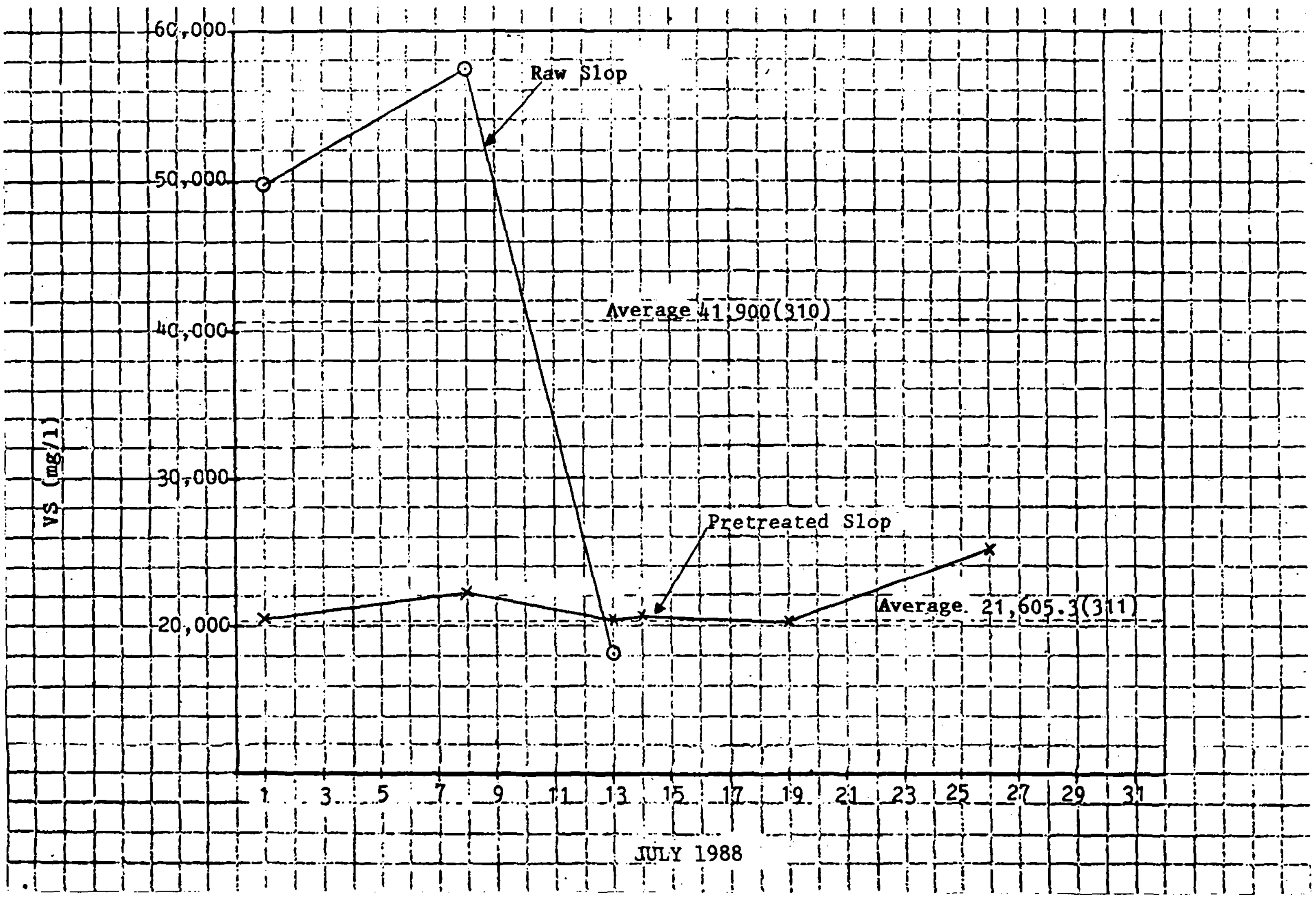
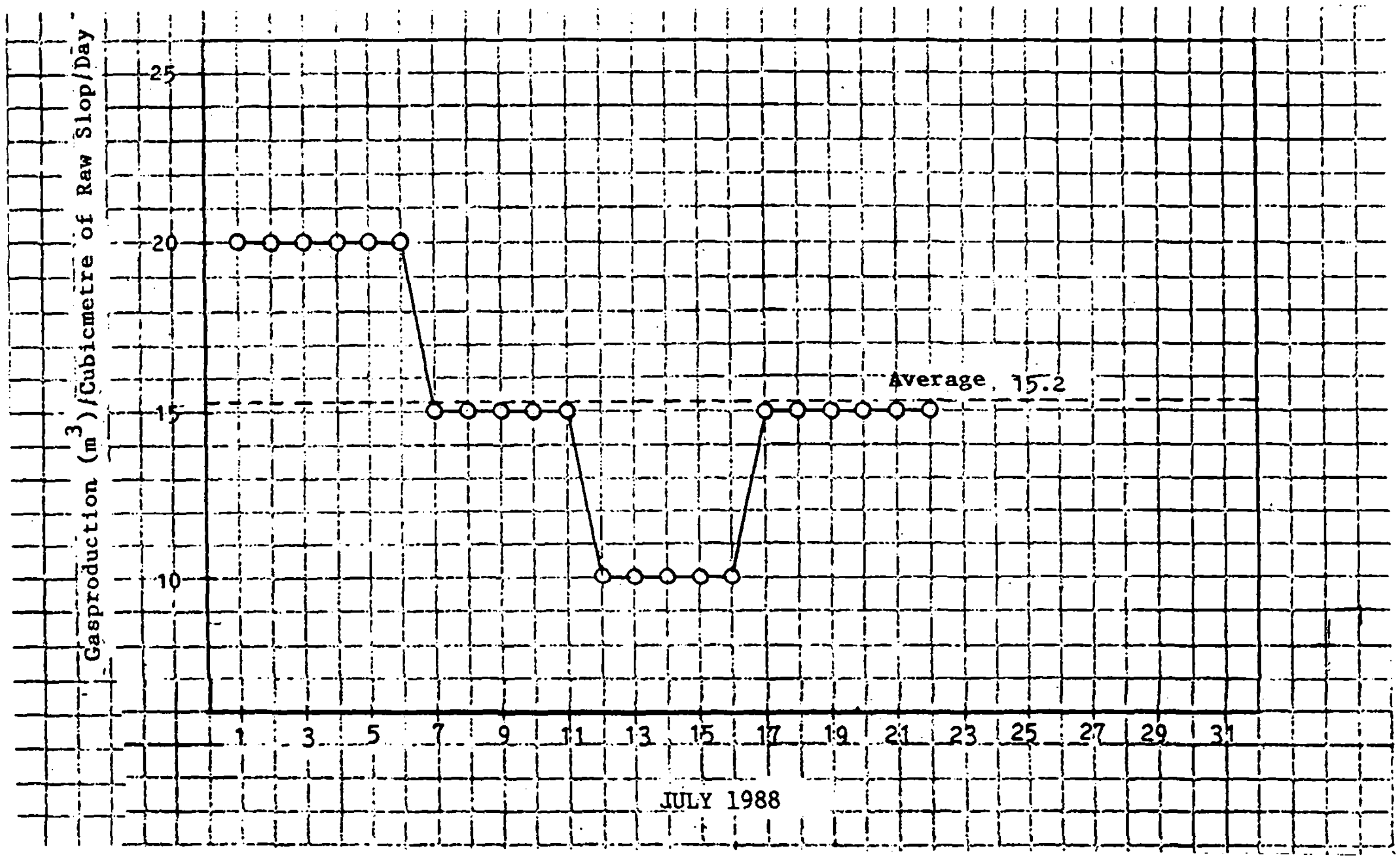


Fig. 12 Gas Production From Biogas System



pH

The pH of the raw slop ranges from 5.13-8.07. The high value represents the slop which has been retained in the storage pond 318(1) and some degradation of organic matter has already taken place because this pond has once been used as storage pond for digested sludge. The average pH is 6.42. Even though the raw slop has a low initial pH or acidic but no adjustment of pH is necessary because the biothane system has sufficient alkalinity present in the digested sludge.

The average pH in the acid and biothane reactor is within the favourable range 7.54-7.85.

Temperature

The temperature of the raw slop varies considerably from 29-41°C. If the slop comes directly from the distilling column and storage tank (310) the temperature tends to be relatively high between 35-41 °C but if it comes indirectly from storage pond 318(1) the temperature will be low between 29-30 °C. The temperature in the acid and biothane reactors is relatively constant between 30-35 °C and 30-34 °C respectively.

Volatile Fatty Acid (VFA)

VFA of the raw slop or influent is relatively high being between 10,000-18,000 mg/l if the slop comes directly from the distilling column but if it comes from 318(1) it will be low being below 5,000 mg/l due to its partial degradation in that pond.

Alkalinity

The raw slop has relatively low alkalinity between 1,500-4,000 mg/l but the average alkalinity in the acid and biothane tanks is relatively high being 9,800 and 11,645 mg/l respectively. The high alkalinity will serve as a buffering capacity for the acidic raw slop.

VFA/A

The average VFA/A ratio of the acid and biothane reactors is relatively low being 0.7 and 0.4 respectively. The max value of VFA/A if exceeds 0.5 may require pH adjustment in the raw slop.

Total and Volatile Solids (TS & VS)

The TS in the raw slop is 67,400 mg/l after digestion the TS of the effluent will be 43,690 mg/l or a reduction of 35%. The TS values at different depths (0.5 m, 2 m and 4.5 m. above the floor) in the biothane tank do not vary much. This value shows that good mixing occurs in the tank.

The VS has reduced from 41,900 mg/l to 21,600 mg/l after digestion and this represents a reduction of 48.4% efficiency.

Gas Production and Composition

The gas production is about 900-1,200 m^3/day for a slop feed rate of 60-80 m^3/day. This represents about 18:1 between the gas production per unit volume of slop. The gas production rate will drop by 1/2 if the slop from pond 318(1) is fed. The gas production is measured under pressure of 500 mm. of water and is not converted to standard pressure. This production rate is relatively low as compared to 25-30:1 as originally designed for.

In general the gas consists of about 71% CH_4 and 29% CO_2 and it is suitable to utilize gas flare to ignite and burn the gas. A gas specialist was asked on August 18 to adjust the gas flare when it was lit on the same date.

Conclusion

After 1 month of plant start up when the feed rate of undiluted raw slop is between 60-80 m^3/day the average gas production rate is between 15-20:1 and the COD removal efficiency is 54.3%. More result will be compiled and presented at a later stage.

TECHNICAL AND ECONOMIC EVALUATION OF BIOGAS PLANT TREATING TAPIOCA STARCH FACTORY WASTEWATER

Morakot Tanticharoen, S. Lerttriluck,
V. Loha and S. Bhumiratana

King Mongkut's Institute of Technology,
Bangkok

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TECHNICAL AND ECONOMIC EVALUATION OF BIOGAS PLANT* TREATING TAPIOCA STARCH FACTORY WASTEWATER

M. Tanticharoen, S. Lerttriluck, V. Loha and S. Bhumiratana
King Mongkut's Institute of Technology, Thonburi
48 Suksawasd Rd., Rasaburana, Bangkok 10140, Thailand.

ABSTRACT

Biogas technology was selected to treat and to utilize tapioca starch factory wastewater. After successful trial in the laboratory, 168 cubic metres of filterbed biogas plant was built at the factory to test for technical and economic evaluation before the full scale plant can be implemented. It was found that the effluent from conventional ditch (open pond) was a good source of seedling. It took 5 months to fill the reactor and the operation has been continued for the next 5 months. Though the operating time was still short, results were very promising. At the time factory closed due to rainy season, the reactor generated more than 200 cu.m. biogas from 6 cu.m. wastewater. The longer the operation, the system showed a sign of improvement in maintaining better buffering capacity and organic acid reduction.

Economic analysis of 1000-5000 cu.m. biogas reactors was done. These based on estimated cost of pilot plants and experimental data from laboratory reactors operated over 3 years period. A study of 70 ton starch factory/day indicated that internal rate of return and pay back period for 4000 cu.m. reactor were 45% and 3 years, respectively. The produced biogas was enough to supplement for fuel oil and electricity. Two 4000 cu.m. reactors were required to treat total amount of wastewater discharged from the factory. In this particular case, there was a need to sell the extra gas to get the total benefit from the biogas plant.

* Paper presented at Seminar on "Anaerobic Waste Treatment and Sanitation Technologies" Bangkok, Pattaya 1-3 September 1988.

I. INTRODUCTION

Tapioca, also known as cassava, is grown through out the tropical world and is one of the most important starchy root crops in the tropics. Among the Asian countries, Thailand is one of the largest producers of tapioca.

The main products of tapioca roots are pellets, chip and starch. Only the tapioca starch industry has a water pollution problem from its wet processing operation. As tapioca starch industry is one of the major export product with a promising future, a mean to alleviate its wastewater problem has to be developed.

A project entitles "Utilization and Treatment of Tapioca Starch Wastewater" has been started since 1984 to determine an appropriate technology for treatment of the tapioca starch wastewater in order to increase its value. Among various utilization techniques selected and tried on a laboratory scale, biogas production in an anerobic filter reactor was very promising (Tanticharoen et. al. 1987, 1988). To evaluate its technical and economic feasibility, a pilot scale biogas plant was built at Ban Pong Tapioca Starch Industrial Co., Ltd., Rajburi Province. This paper gives details on the design and construction of the plant, start up procedure and operational results. Economic studies is also presented.

II. MATERIALS AND METHODS

2.1 The pilot plant

The pilot plant composed of 168 cu.m. filtered biogas reactor and 36 cu.m. gas holder. The construction material for both tanks was steel. The inner wall of reactor was coated with epoxy. Fig. 1 shows a schematic diagram of the anaerobic filter reactor.

The reactor was an upflow type inwhich wastewater was fed from the bottom with the aid of distributors. Treated effluent left the reactor through an overflow system. There was a safety blower at the top of reactor which was set at 60 inches water pressure.

Nylon rings were used as the support media for the biofilm. The size was 9 cm diameter and 9 cm long. The specific surface area was approximately 94 sq.m/cu.m. Void fraction was 0.9. The volume of packing media and packing capacity of reactor were 8.2 and 82 cu.m., respectively. Fig. 2 is the picture of packing medias.

The gas holder was a floating type which can store the gas at maximum pressure of 30 inches water pressure by putting the weight on top. The diameter and height of the gas holder were 2.9 and 5.3 M, respectively. There was a pipe line from the gas holder to the burner where excess gas was automatically burned. The picture of the whole system is shown in Fig. 3.

2.2 Wastewater

Wastewater was a combined wastewater directly from the processing line. Table 1 gives wastewater composition during the operation of pilot scale anaerobic filter reactor.

2.3 Seedling of reactor and startup

Start up period began in August, 1987. To accelerate the process, seedling bacteria was taken from the laboratory and added to the pilot reactor. Startup involved stepwise increases in volumetric loading of combined wastewater. After first month, the reactor received 0.5 cu.m. of seedling and 0.7 cu.m. of combined wastewater. When available, more seed was added. In early October, the liquid volume was only 5.5 cu.m. Since a required volume was 116 cu.m., it may take indefinitely to fill the reactor by this method.

In conventional treatment, 10-12 open ponds are used to treat tapioca starch wastewater. Combined wastewater is discharged to the first pond which then overflow to the next one. The first pond has the highest COD concentration and dissolved oxygen is zero. During the peak of starch processing, wastewater is continuely discharged to the pond resulted in anaerobic digestion of starch waste particularly in the first pond and gas bubbles are seen on the surface.

From this point we decided to use the effluent from this conventional ditch as seedling. Every 3-4 days, influent was pumped from the pond into the reactor. If the pond had low organic concentration then the reactor was fed together the pond influent and combined wastewater. Table 2 is feeding program during October, 1987 inwhich influent from conventional pond was used to fill the reactor. At this stage the reactor contained 63 cu.m. of liquid.

The reactor was fed once a day with combined wastewater approximately 1 cu.m./day during November - December, 1987 until it was filled at 116 cu.m. liquid volume (Table 3). From this period the liquid volume was kept constant by an overflow. The volumetric loading rate was increased step by step. This report covered results from January, til May, 1988.

2.4 Sampling and Analysis

The chemical oxygen demand (COD) of influent and effluent samples, total volatile solid (TVS), total alkalinity (TAK), total volatile acid (TVA) and pH were determined twice a week in accordance with standard methods. Methane content of the gas was determined by the method described by Tanticharoen et. al. (1985). More samples were collected at 7 heights (1 metre from base and then every 0.5 metre) via the sampling ports of the reactor to determine the TVS, TVA and TAK concentration by the above method.

III. RESULTS AND DISCUSSION

3.1 Technical data

The following results are the summary from project which is still in progress. The factory processing line is started when it has enough cassava root thus reflected the availability of wastewater to feed the biogas plant. Not only the production method, the organic concentration of wastewater depends upon the starch content of the root and the amount of water used which can vary from day to day (Table 1). Thus feeding program usually based on fixed volume and not quite steady. Table 3 gives the results from November, 1987 to December, 1987 inwhich liquid volume was built up by feeding combined wastewater. By analysing organic concentration of the samples after feeding and before next feeding, it was found that COD reduction varied from 16 to 73% with the average of 47%. The average TVA and TVS reduction were 45 and 37% respectively. Liquid pH of the reactor was lower after wastewater was fed. However, it went back near neutral in couple days. The concentration of TAK rose to 1800 mg/l indicating an improvement on buffering capacity of the system.

When the reactor was filled up, it was then fed with combined wastewater, 4, 5 and 6 cu.m. once a day (Table 4, 5). The effluent was taken from the overflow and COD reduction of the system was calculated as belows:-

$$\% \text{ COD reduction} = \frac{\text{COD influent (wastewater) - COD effluent}}{\text{COD influent}} \times 100$$

Though we could not feed everyday but we had tried to do more regularly. We started measuring gas yield in March, 1988. The average gas yield was approximately 1.13 cu.m./cu.m. reactor or 0.54 cu.m./kg COD added during 1-7 April. The organic loading was 2.1 kg COD/cu.m. reactor-day-1 at 19.3 day HRT. Methane content was 58-60%. The average COD reduction was 86%. Eventhough, COD effluent was a little bit high, TVA concentration was in acceptable level. Comparing the TAK with the samples at early stage of operation, the stability of the system seemed to be better.

The pilot project is not completed yet. The factory has been closed due to rainy season and for maintenance. The starch processing will start in September and the pilot plant will be operated again. This will give an information how soon the reactor recovers from its resting period.

According to the laboratory results used for the design, the pilot reactor can receive up to 6 kg COD loading/cu.m. reactor-day-1 at 4 day HRT. The gas yield would be between 2-3 cu.m./cu.m. reactor-day-1. Though we do not get to this state yet but current result is encouraging. We believe to reach the target during the next operating season.

3.2 Economic analysis

Anaerobic filter reactor has been shown in our laboratory over 3 years study. (Tanticharoen et. al 1988) and on pilot plant to treat tapioca starch wastewater successfully at relatively high organic loading rate and short residence time. Because of high investment cost, it is necessary to do economic analysis to determine the investment conditions. In this work internal rate of return (IRR) and pay back period were analysed for reactor size ranged from 1000 to 5000 cu.m. Some of the criterias used in this analysis were:-

1. The cost of fuel oil (grade C) was 3 baht/litre

2. Quantity and quality of gas produced based on the laboratory studies. These were, HRT 4 day, COD reduction 90%, gas yield 12 cu.m./cu.m. wastewater or 3 cu.m./cu.m. reactor (COD 25,000 mg/litre) and methane content was 60% (1 cu.m. biogas equivalent to 0.52 litre fuel oil and 0.75 cu.m. biogas = 1 kilowatt-hr at 20-25% conversion efficiency).

3. Total capital cost covered construction cost for reactor and gas storage (including valves and piping), packing media, equipment and others (5% of the first three parts). The cost of pilot plant and major equipments were:-

	cost (Baht)
reactor, gas storage, piping and valves	600,000
packing media (nylon 9.1 cm x 9.1 cm in diameter and length)	270,000
equipments (flow meter, gas meter, temperature and pH recorder, etc.)	317,000
salvage value	50,000

The investment cost for biogas reactor and gas storage was estimated from 168 cu.m. biogas plant using the following equations

$$\text{investment cost} = 600,000 + (\text{reactor size})^{0.37}$$

Since the cost of packing material was high. In this analysis, the packing capacity was 30% of reactor volume.

4. Operating and maintenance costs per year (200 days)

chemical	100	Baht/cu.m. reactor
electricity	60	Baht/cu.m. reactor
salary (supervisor)	60,000	Baht
Labours (4)	96,000	Baht
others	15	Baht/cu.m. reactor

The program used here was Lotus (IBM). Table 6 summarises the capital cost for the reactors ranged from 1000-5000 cu.m. IRR and pay back period for these reactor sizes are shown in Table 7.

The factory has choice to select for the size of reactor. This depends upon its own purpose. The following paragraph gave an example of a 70 tons/day starch factory which discharges 2000 cu.m. wastewater/day. Fuel oil and electricity consumption are 2200 litres and 264 kilowatts/day, respectively. The factory has paid 380,000 bahts for electricity monthly. The operating day is 200 per year.

If the factory plans to use biogas as a supplementary for fuel oil, 2000 cu.m. reactor will be enough to produce 6000 cu.m. biogas equivalent to 3120 litres fuel oil. In this case, IRR and pay back period are 34% and 4 years, respectively.

When the factory would like to be an energy self - sufficient, it requires approximately 9000 cu.m.biogas to replace fuel oil and to generate electricity. The construction of 4000 cu.m. reactor is recommended.

For the above cases, part of wastewater is treated for energy production. Therefore, it may be necessary to treat 2000 cu.m. wastewater in 2x4000 cu.m. reactor. In this particular case, there is an extra of 12,000 cu.m. biogas. Since the calculation on IRR and pay back period based on the assumption of total utilization of biogas produced, there should be a mean to sell or to utilize the extra gas. Presently, the government does not allow the private sector to sell the electricity back to the grid. This is similar to palm oil factory in Malaysia where biogas from palm oil effluent has been sold to the near by factories.

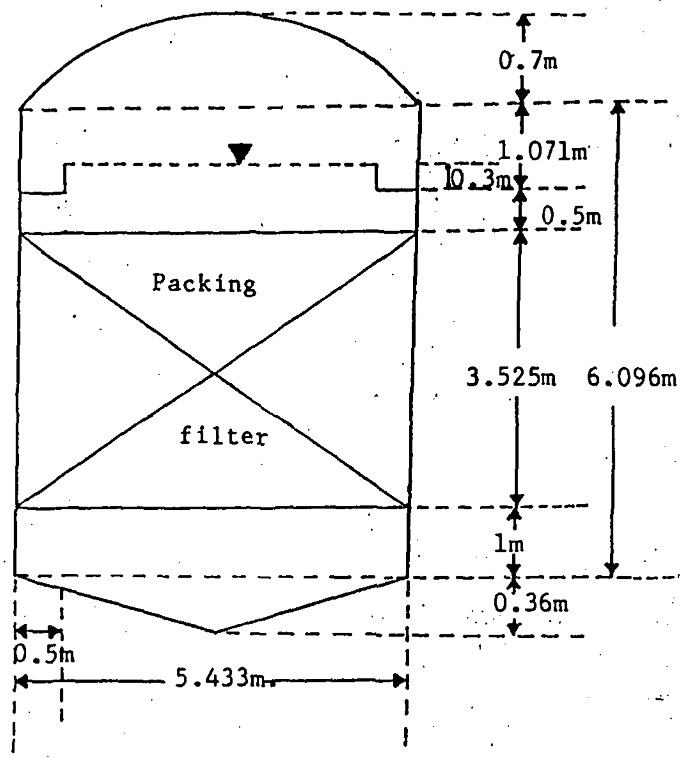

Fig 1. Schematic diagram of the pilot filter reactor.

Fig 2. Packing media used in the pilot filter reactor.

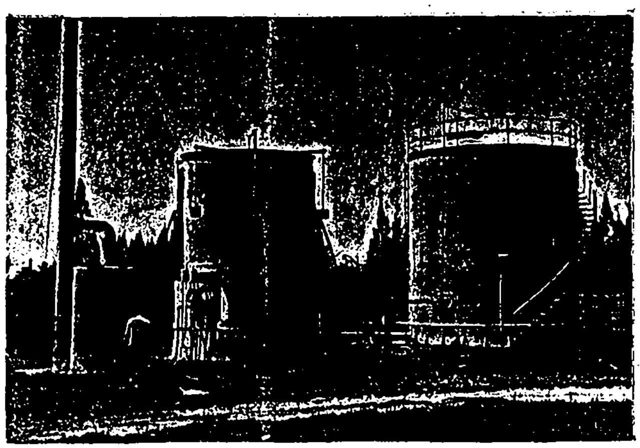

Fig 3. Pilot Biogas Plant at Bang Pong Tapioca Starch Industrial Co., Ltd, Rajburi Province.

Table 1 The characteristics of combined wastewater used to feed the pilot biogas plant.

Date of operation	COD mg/l	pH	Date of operation	COD mg/l	pH
3/11/87	20,000	-	5/1/88	50,700	5.8
5/11/87	15,000	-	8/1/88	45,000	4.7
10/11/87	57,000	4.9	12/1/88	47,000	4.8
13/11/87	47,600	5.1	15/1/88	83,000	6.0
17/11/87	15,000	5.4	16/1/88	11,500	4.7
20/11/87	15,000	5.3	19/1/88	47,500	4.7
24/11/87	38,000	5.0	26/1/88	21,300	5.4
27/11/87	48,800	5.1	29/1/88	41,500	4.7
1/12/87	15,000	4.9	2/2/88	35,000	5.4
4/12/87	13,000	5.6	5/2/88	11,600	5.4
11/12/87	37,800	5.4	9/2/88	35,200	6.9
15/12/87	38,600	5.8	11/2/88	36,000	6.0
18/12/87	38,450	5.9	12/2/88	32,500	5.0
22/12/87	38,000	6.0	13/2/88	52,900	5.1
26/12/87	19,700	6.0	14/2/88	70,600	6.1
10/3/88	32,000	5.2	6/4/88	65,600	5.9
12/3/88	32,000	5.1	7/4/88	65,500	5.8
14/3/88	85,600	4.7	11/4/88	24,300	6.1
21/3/88	62,200	5.2	19/4/88	32,000	5.6
22/3/88	27,100	5.2	23/4/88	25,800	6.3
1/4/88	62,800	5.4	24/4/88	24,400	6.0
2/4/88	65,900	5.3	29/4/88	26,300	4.7
3/4/88	39,200	5.6			
4/4/88	23,800	5.8			
5/4/88	56,800	5.4			

Table 2 Feeding program during October 1987 inwhich influent from conventional pond was used to fill the reactor

date	Liquid volume in the reactor and characteristics						Feed
	volume cu.m.	COD mg/l	TVS mg/l	TAK mg/l	TVA mg/l	pH	volume (cu.m.)
2-10-87	8.0	5000	-	1780	640	6.7	2.5 I
6-10-87	13.0	4300	-	1640	250	6.7	5 I
9-10-87	18.0	2060	-	1470	250	7.4	5 I
13-10-87	26.0	2330	2870	1070	290	7.6	8 I
16-10-87	32.0	2000	3260	1560	200	7.3	6 I
20-10-87	39.0	1800	1930	1350	210	7.6	7 I
24-10-87	41.0	1400	2040	1370	300	7.2	2 C.B
27-10-87	63.0	1860	2830	1450	240	7.2	20 I + 2 C.B

I = Influent from pond, C.B = combined wastewater

Table 3 Feeding schedule and characteristics of samples taken from sampling port at 1 Metre hight before and after feeding

Date Nov-Dec 87	feed volume l	liquid volume l	COD mg/l		TVS mg/l		TAK as CaCO3 mg/l		TVA as acetuc acid mg/l		pH	
			before	after	before	after	before	after	before	after	before	after
3/11	2	69	1600	2150	1960	2150	1400	1390	410	490	6.8	6.6
5/11	2	71	1800	2400	2000	2490	1170	1160	340	500	6.7	6.6
10/11	2	73	1400	1800	1230	2040	1580	1480	250	360	6.9	6.3
13/11	3	76	1000	3100	2090	2630	1420	1290	200	450	7.0	6.4
17/11	3	79	1100	1350	2100	2230	1500	1350	100	150	6.7	6.5
20/11	3	82	1000	2400	1540	2980	1320	1310	90	180	6.8	6.5
24/11	3	85	980	1800	490	1460	1580	1500	110	180	6.7	6.3
27/11	3	88	1000	4300	1100	3320	1610	1520	140	630	6.8	6.3
1/12	2	90	1150	2400	1730	2890	3200	2400	520	770	6.8	6.4
3/12	2	92	-	-	-	-	-	-	-	-	-	-
4/12	2	94	1300	2150	1690	1900	1060	990	200	420	6.9	6.5
7/12	1	95	-	-	-	-	-	-	-	-	-	-
11/12	4	99	1600	4100	1870	2190	1780	1720	110	310	6.9	6.7
15/12	4	103	1500	2200	990	1790	1760	1750	260	340	6.8	6.4
18/12	3	106	1400	4200	730	1050	1750	1720	310	570	6.9	6.5
22/12	3	109	1450	3700	1320	2820	1810	1700	240	460	6.9	6.5
26/12	4	113	2350	5900	-	-	-	-	-	-	7.0	6.8
27/12	4	117	-	-	-	-	-	-	-	-	-	-

Table 4 Experimental results from January 1988 to February 1988. The reactor was fed with 4 cu.m. combined wastewater once a time except on Jan. 31, Feb. 1, 2, 5 and 9 inwhich 6 cu.m. was fed each day.

Date from Jan 88 - Feb 88	organic loading kg COD/ cu.m.-day-1	COD* mg/l	TVS* mg/l	TAK as* CaCO3 mg/l	TVA as* acetic acid mg/l	pH*	% CH4
5/1	1.8	1670	2100	2050	290	7.0	-
8/1	1.6	2850	2180	1900	250	6.9	-
12/1	1.6	1600	2180	1990	390	6.9	-
15/1	2.0	1450	-	-	-	-	-
16/1	0.3	3500	-	-	-	-	-
19/1	1.6	1800	1790	1300	570	7.1	-
22/1	-	1500	3240	1500	290	6.7	-
26/1	0.5	1100	1730	2000	100	6.8	-
29/1	1.0	1700	3800	1300	410	6.7	-
31/1	-	-	-	-	-	-	-
1/2	-	-	-	-	-	-	-
2/2	1.25	8500	6030	1280	670	6.8	-
5/2	0.4	5300	4550	2300	650	6.8	60
9/2	1.25	4000	4060	2100	140	6.9	59
11/2	1.25	-	9120	1750	1350	6.8	56
12/2	1.1	3600	3570	2540	300	6.7	56
13/2	1.8	4700	3140	2560	600	6.8	59
14/2	2.5	5800	3140	2550	400	6.7	59

* Effluent sample

Table 5 Experimental results from March 1988 to April 1988. The reactor was fed with 5 and 6 cu.m. combined wastewater in March and April, respectively.

Date March-April 1988	organic loading kg COD/cu.m. reactor-day-1	COD* mg/l	TVS* mg/l	TAK as* CaCO3 mg/l	TVA as* acetic acid mg/l	pH*	gas cu.m./day	yield %CH4
10/3	1.0	5500	-	-	-	6.8	139	69
12/3	1.0	6800	-	-	-	6.8	115	69
14/3	2.7	5900	-	-	-	6.7	91	53
21/3	1.9	2500	-	2800	260	6.9	94	58
22/3	1.4	2400	-	2890	240	6.8	104	51
23/3	0.9	2250	-	2890	270	6.8	150	61
1/4	2.4	2400	-	2850	170	7.1	226	59
2/4	2.5	6400	4700	2810	200	6.8	243	60
3/4	1.5	7300	5400	2690	170	6.7	180	60
4/4	0.9	7150	5300	2670	160	6.8	140	-
5/4	2.1	6300	5000	2610	160	7.0	179	-
6/4	2.5	6800	6150	2420	125	7.4	188	58
7/4	2.5	6950	6500	2400	210	7.1	171	58
11/4	0.5	3700	3200	2540	120	7.0	170	58
19/4	1.2	6900	5300	2470	250	6.9	237	58
23/4	1.0	5000	5400	2760	210	6.8	124	58
24/4	0.9	6700	5250	2670	210	6.8	197	58
29/4	0.9	4400	5600	2850	180	6.8	109	60

* Effluent sample

Table 6 Summary of capital cost for 1000-5000 cu.m. reactors.

Capacity (cu.m.)	1000	2000	3000	4000	5000
Investment cost					
Subdivided cost estimate					
a. Digester, Gas holder, piping, Warehouse and Civil Work (K-baht)	1161	1500	1743	1939	2106
b. Packing media (30% packing) volume of total capacity (K-baht)	900	1800	2700	3600	4500
c. On-site equipments (K-baht)	440	537	557	584	614
d. Others (K-baht)	125	192	250	306	361
Total investment cost (K-baht)	2626	4029	5250	6429	7585

K-baht = baht x 10^3

1 US dollars = 26 Baht

Table 7 IRR and pay back period of various reactor size at 12.5% interest rate

Reactor size (cu.m.)	1000	2000	3000	4000	5000
Investment cost (K-baht)	2626	4029	5250	6429	7585
IRR (%)	21.88	33.46	40.26	44.75	47.97
Pay back period (Yrs)	6.65	3.91	3.14	2.78	2.57

REFERENCES

1. Standard Methods for the Examination of Water and Wastewater 1980. 15th Edition, APHA-AWWA-WPCF.

2. Tanticharoen, M., Bhumiratana, S., Utitham, T., and Supajunya, N. 1985. Biogas production from solid pineapple cannery. In Energy from Biomass 3rd EC Conference, Venice, Italy. Elsevier Applied Science Publishers. pp. 532-536.

3. Tanticharoen, M., Reungjitchawaly, M., Jetanachai, N., Loha, V., Bhumiratana, S., and Lettriluck, S. 1987. The Study on anaerobic digestion of tapioca starch wastewater factory. Proceedings of UNEP/TISTR/Bangkok MIRCEN Regional Workshop on Upgrading of Cassava/Cassava Wastes by Appropriate Biotechnologies. Thailand, November 24-26, 1987.

4. Tanticharoen, M., Reungjitchawaly, M., Loha, V., Bhumiratana, S., and Lerttriluck, S. 1988. Biogas production from tapioca starch wastewater factory. Poster paper for Fifth International Symposium on Anaerobic Digestion. Bologna, Italy. 22-26 May 1988.

COMPARISON OF ALTERNATIVE SANITATION OPTIONS APPLIED TO A MEDIUM SIZED TOWN

Hermann Orth

Asian Institute of Technology, Bangkok

A COMPARISON OF ALTERNATIVE SANITATION OPTIONS APPLIED TO A MEDIUM-SIZED TOWN

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1. OBJECTIVE AND BACKGROUND OF THE STUDY

Water borne sewerage with central waste water treatment has become in recent decades the primary sanitation technology in industrialized countries, mainly due to increased hygienic and environmental protection standards. The technology is, therfore, well documented in the international literature. Other technologies have been actively explored and publicized by international agencies, in particular the World Bank (e.g. Zajac et al., 1984; Kalbermatten et al., 1980; Rybczynski et al., 1978)). Their publications concentrate on technologies which are particularly suitable under the conditions of developing countries. Thus, the technical literature on sanitation technologies covers today a wide range of alternatives.

However, most publications still concentrate on technical aspects or on solutions at the level of individual households or smaller low-income communities. A broader coverage or at least more awareness is needed of the implications of alternative technologies when applied on a large scale. For example, the impact, particularly the hygienic and environmental impact, of a few on-site sanitation facilities in a rural community is completely different from the impact of 10,000 to 20,000 of such facilities when built in a medium-sized town and concentrated in a relatively small area.

It is with this background that a study (Orth et al., 1988) has been prepared at the Asian Institute of Technology with the objective of analyzing and demonstrating implications of alternative sanitation options, as applied to a typical medium-sized town in Thailand. More specifically, the objectives of the study were;

1. a comparative assessment of the technical feasibility of a set of alternative sanitation options;
2. a comparative economic evaluation of these sanitation options;
3. an assessment of the possibilities for cost recovery by means of user charges and revenue generation through recycling;
4. an assessment of institutional opportunities and constraints involved in implementing the alternative sanitation options.

Some of the results of the study will be presented in this report. They demonstrate the varying impact of alternative sanitation technologies and the need for a thorough investigation of a broad range of alternatives in any individual case. The interested reader may find a more complete summary of results in the conclusions of the study which are attached as an appendix to this report.

2. METHODOLOGY

A typical medium-sized town in Thailand was selected as model town for this study, although it was by no means the objective of the study to prepare a sanitation plan for this town. A specific town was selected for methodological reasons simply to ensure a realistic study scenario and to base the study on an internally consistent data set.

The first step in the analysis was the selection of sanitation systems to be included in the comparison. The present sanitation standard and present problems were the two main selection criteria. Most households in the model town have piped water supply and individual power-flush toilets. A reduction of this very high level of user convenience would without doubt not be acceptable for the population and a whole range of technically sound solutions must, therefore, be discarded. For example, communal toilet facilities or dry options would surely not be acceptable.

In contrast to the high user convenience, the waste water treatment and disposal system is rather unsatisfactory. Waste water is discharged into cesspools for infiltration into the subsoil. Sullage water is usually discharged directly into the drainage system or nearby canals. In addition to pollution from sullage water, many cesspools with inadequate infiltration capacity are equipped with a direct overflow into the drainage system. The results are unhygienic conditions in densely populated areas and highly polluted receiving waters.

Since the in-house facilities were considered as being satisfactory, the selection of technologies concentrated on collection, treatment, and disposal technologies. The technologies investigated are summarized in Table 1. At first four principal system options were established and technical alternatives were then investigated within the principal options. In the Maximum Sewerage Option, all areas will be served by a sewerage system with the exception of low density areas on the outskirts of the town. The Minimum Sewerage Option, by contrast, provides a sewerage system only for areas with a very high population density where infiltration of the discharged waste water into the subsoil seems technically infeasible.

Table 1: The sanitation technologies selected for comparison

Principal systems options	Technical alternatives
Maximum Sewerage Option	Sewers: alternative layouts
Minimum Sewerage Option	Septage treatment:
	- with and
Small Bore Sewerage Option	- without biogas recovery
Septic Tank Option	Sewage treatment:
	- Activated sludge process
	- Aerated lagoon system
	- Unaerated pond system
	- Fish culture

A small bore sewerage system is marked by an interceptor tank at each house which withholds coarse materials and reduces the quantity of the solids discharged into the sewer. Since only the liquid portion of the waste water is discharged into the sewer, construction standards for the sewer system can be simplified considerably resulting in remarkable cost savings. Since cesspools which can be converted into interceptor tanks exist in most houses in the model town, a small bore sewerage system is a particularly interesting option. The Small Bore Sewerage Option of this study covers the same service area as the Maximum Sewerage Option.

In the Septic Tank Option, the entire planning area is served by septic tanks. However, the septic tank option is not considered to be a actually feasible solution for the real condition of the model town. Due to the high groundwater level and the type of subsoil, it is impossible in high density areas to infiltrate all discharged waste water into the subsoil. The Septic Tank Option has merely been considered in order to show the impact of a solution completely based on on-site facilities as compared to a sewerage system.

Within these four principal system options, various technical alternatives were compared. Biogas recovery and fish culture represent two treatment technologies with waste recycling. Since many recycling methods are economically not viable on a small scale, it is interesting to evaluate the possiblity of waste recycling in the context of a medium-sized town. Similarly, the appropriate technical level of central waste water treatment is influenced by the scale of the operation. Accordingly, three central treatment systems were selected for comparison which represent three technical levels. The three levels are a natural system, a half-technical system and a technical system, represented by an unaerated pond system, an aerated lagoon system, and the activated sludge process respectively.

After defining the principal system options and technical alternatives, preliminary designs were prepared for the various facilities and the cost were then estimated from quantities and unit cost rates. The approach required designing the main sewer system four times. This was possible only by employing a design/ optimization program which after changing the respective design criteria or details in the layout of the network produces the alternative designs and system cost.

A somewhat different design approach was applied in the case of the lateral sewer system and of the activated sludge process. For costing the lateral sewer system, ten representative areas were selected which represented different land use categories. Unit cost per hectare of service area were then developed for these representative areas, based on road lengths, population densities, and estimated sewer diameters and depths. The cost of the total lateral sewerage system was then estimated by applying these area based unit cost rates to the entire service area. The representative areas cover about 39% of the total service area. No designs were prepared for the activated sludge process; instead cost equations were used. The cost equations were deduced (Loosereewanich, 1983) from an analysis of 44 operating activated sludge plants located in the greater Bangkok area. The cost estimates are based on the design flow rate and the organic loading expressed in terms of the Biochemical Oxygen Demand.

The quantities, dimensions, and cost as developed by the above methods were then the basis for the further comparison and an analysis of financial and institutional aspects.

3. OVERVIEW OF THE MODEL TOWN

Fig. 1 gives an overview of the planning area. The town is located on the sea and a large part of the town area is flat with elevations of about 2 m above M.S.L.. Some hills surround the town to the north and the east. 38,000 persons live in areas with a population density of 240 p/ha or more. A sewer system has been considered as essential in these areas (Minimum Sewerage Option). 17,000 persons live in the outskirts of the town in areas with a density below 90 p/ha. A sewer system would obviously not be viable in these areas. The remaining areas are provided with a sewer system in the Maximum Sewerage Option. About 89,000 persons are connected to the sewer system in this option.

The waste water discharge from domestic areas was taken as 120 l/c/d. This figure is based on previous reports (Kocks-TPEC, 1985; SEATEC, 1983). For commercial, institutional, and industrial sources, data were taken from the list of major customers of the Chonburi water supply system. The waste water discharge of 120 l/c/d results in areas with a population density above 250 p/ha in a waste water depth of more than 1,000 mm/a. Considering the type of subsoil, which is mainly sandy loam, it is easy to see that such waste water quantities cannot be infiltrated into the subsoil. Furthermore, the high density city center is located close to the sea where the groundwater table during the rainy season is only 1 to 1.5 m below the ground level.

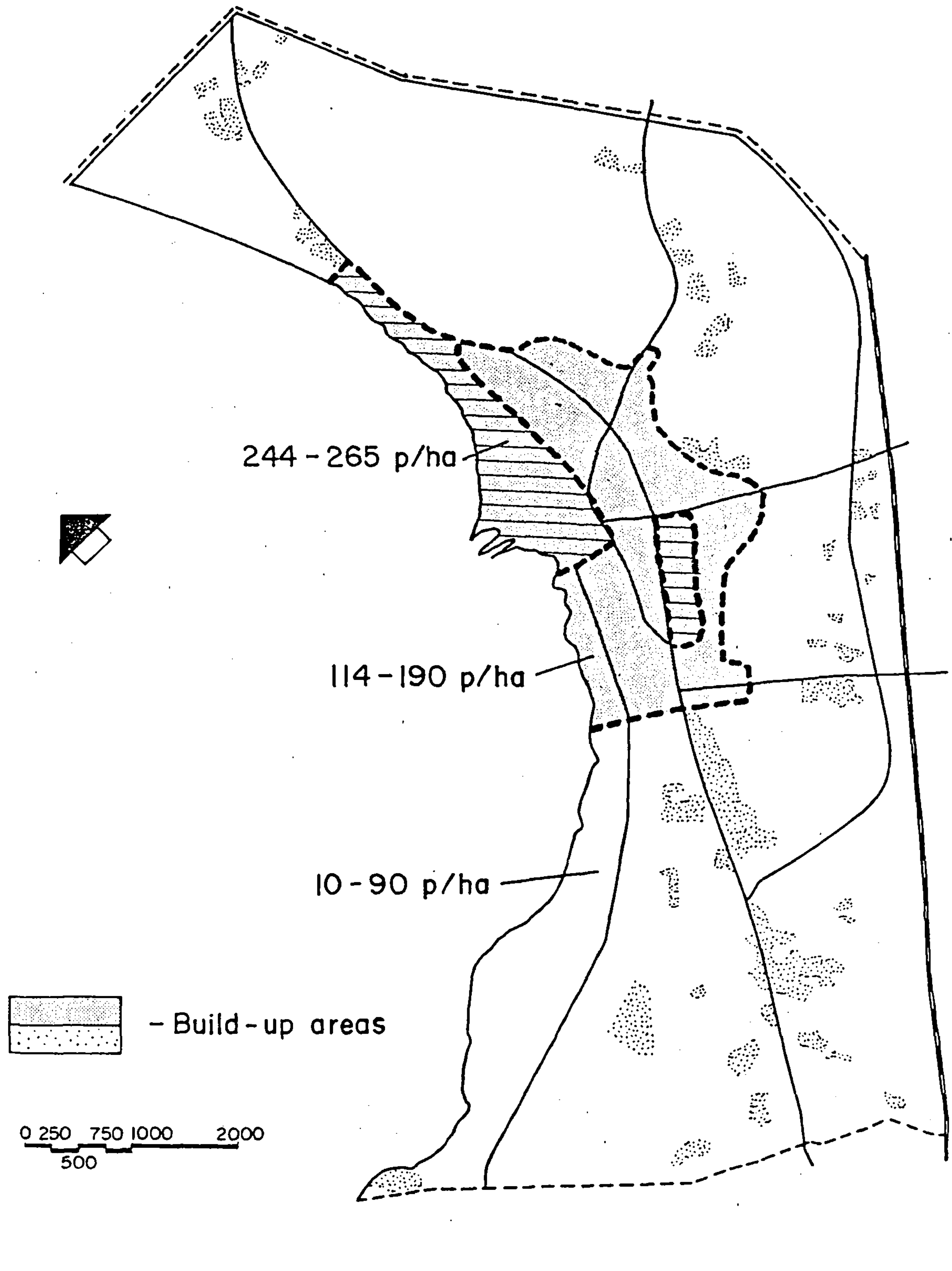


Fig. 1: Overview of the study area

4. RESULTS AND OBSERVATIONS

4.1 Comparison of the Technical Alternatives

The comparison of the technical alternatives within the four principal options gave a very uniform picture for all options and can, therefore, be discussed summarily. The comparison of the alternative main sewer layouts confirms the general experience that pumping stations should be avoided as far as possible. The alternative with the least number of pumping stations turned out to be the most economical one, even though the average sewer depth was somewhat greater in this case.

Two alternatives for septage treatment, namely with and without recovery of biogas, were considered. In the system with recovery of biogas, the digester is followed by a facultative pond for the treatment of supernatant. Sludge is dried on drying beds before delivery to agriculture. The septage treatment system without biogas recovery consists simply of an anaerobic pond followed by a facultative pond. The annual revenue from the biogas production amounted to only about 2% of the construction cost additionally needed for the implementation of the biogas system. This rough estimate is already sufficient to show that the recovery of biogas is not viable for this model case. Also fish culture combined with septage treatment turned out not to be profitable.

A somewhat different picture appeared in the case of fish culture combined with waste water treatment. This economic comparison is based on the assumption that the maturation ponds of the unaerated pond system can be used for growing fish and only additional cost and revenues incurred by fish culture are to be considered. The fish yield was estimated for the Maximum Sewerage Option, for example, to be as high as 48 t/a.

However, the revenue depends on whether the harvested fish can be sold as human food or as animal feed only. In coastal areas of Thailand, where fish is abundant, sewage fed fish can only be marketed as animal feed. In this case, an annual operating profit of 117,000 Baht is expected. Whether this amount justifies the additional administrative requirements may be a point of discussion. However, in other areas where fish is rather scarce, sewage fed fish may well be accepted as human food. In this case, an annual operating profit of almost 700,000 Baht is expected which would certainly make fish culture a viable alternative.

For central waste water treatment, the unaerated lagoon system turned out to be the most economical alternative in all three system options. As an example, the costs of the three alternatives for the Maximum Sewerage Option are shown in Fig. 2. The activated sludge system is the most expensive process with respect to construction as well as to operating costs. The construction costs

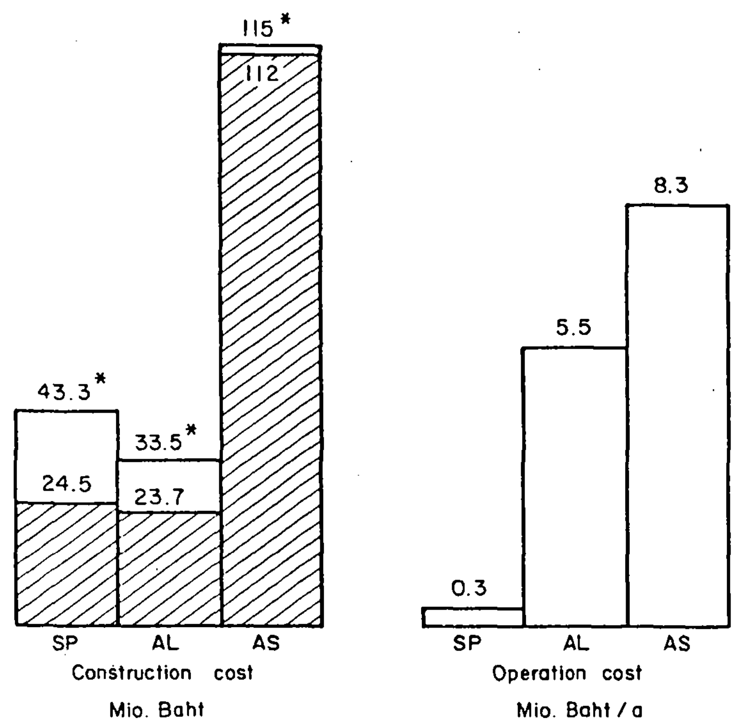


Fig. 2: Comparison of waste water treatment cost for the Maximum Sewerage Option (SP = Stabilization pond system; AL = Aerated lagoon system; AS = Activated sludge process; *) for increased land cost)

of the aerated lagoon system are lower than for the unaerated stabilization pond system. This difference became particularly pronounced after the land costs were doubled for the purpose of assessing the effect of possible future land cost developments. However, taking into account also the operating costs, the higher construction costs for the unaerated stabilization pond system would be compensated by lower operating costs in only about two years time.

At this point, a considerable difference between developing and industrialized countries becomes apparent; the treatment plant serves about 90,000 population equivalents. Pond systems of this size are usually not economical in industrialized countries compared to technical processes. In developing countries, however, they are economical in this size in many cases . This difference between developing and industrialized countries results from the resources used for the different technologies and the cost of these resources. The main resources or cost factors for unaerated ponds are land and labour. Both these resources are generally still cheaper in developing countries. In contrast, the costs for equipment and materials, often imported and transported over long distances, constitute a major part of the construction cost of the activated sludge process. Naturally, the related costs are not lower but rather higher than in industrialized countries. The operation cost of the aerated lagoon system and the activated sludge process result to a large extent from energy costs. Energy costs are in most developing countries comparable to those of industrialized countries.

In conclusion, pond systems are based mainly on resources which are still relatively inexpensive in developing countries, whereas technical systems are mainly based on resources which are on the same or even higher cost level than in industrialized countries. Considering additionally their operational advantages, pond systems should always be one of the first alternatives to be investigated wherever the required land can be procured.

4.2 Comparison of the Four Principal Options

Fig. 3 gives an overview of the investment and operation cost of the four principal options. The comparison between the Maximum/Minimum Sewerage Options and the Septic Tank Option confirms the general experience that on-site sanitation is less expensive than a conventional sewer system. Naturally, the Maximum Sewerage Option is also more expensive than the Minimum Sewerage Option where only a small part of the town is sewered. However, it should be recalled that the Septic Tank Option is a rather theoretical option, since the soil infiltration capacity would be exceeded

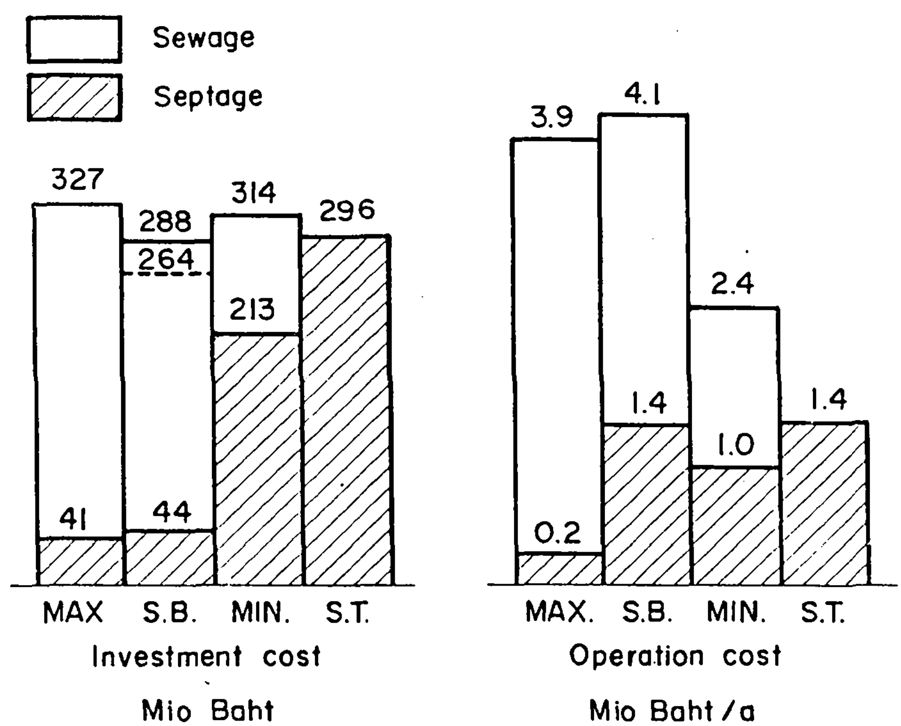


Fig. 3: Investment and operation cost of the four principal sanitation options. (Max = Maximum Sewerage Option; SB = Small Bore Sewerage Option; Min = Minimum Sewerage Option; ST = Septic tank Option).

in the high density areas of the city center. Thus, the most appropriate solution will be a system in which only those parts of the town are sewered where hygienic and environmental requirements demand it, and on-site facilities are provided in the remaining part. Such a flexible approach which allows for different systems in one town would also facilitate the gradual implementation of new sanitation systems.

The Small Bore Sewerage System offers actual economic advantages when compared to the conventional sewerage system. About 25% of the construction cost could be saved if the existing cesspools can be used as interceptor tanks for the Small Bore Sewer System. If new interceptor tanks are to be built, the savings would still amount to about 15%. The operation costs for the Small Bore Sewer Option are somewhat higher than for the conventional system, since a sewer system and a septic transport system have now to be operated in parallel. However, these additional operation costs if accumulated over the planning period are far smaller than the savings in construction costs.

4.3 Repercussions of the Standard of Construction

When collecting cost data for sewer systems, differences in a ratio of 1:5 were found for comparable sewers in different places. Investigating this situation revealed that the extremely low cost of some projects resulted from substandard construction work. For example, no seal rings were used and all pipe connections were rigid. The pipes were laid in wet trenches without proper dewatering or bedding. Such deficiencies will result in cracking of pipes and, due to the high groundwater table, the infiltration of large quantities of groundwater. A system built in this way will most likely lose much of its efficiency in a relatively short period of time.

Another observation is that manholes were a relatively expensive part of the sewerage options, amounting to about a quarter of the total construction cost of sewers. The high manhole cost resulted mainly from two factors: pre-fabricated manholes are not available, and the lack of modern cleaning and maintenance equipment and, thus, manual cleaning limit the manhole distances and increase the number of required manholes.

Sewer systems are apparently a technology which in our model town is not yet transferred or mastered in all its components. This may result in inefficient systems and unnecessarily high costs. In contrast, there is a long experience in the construction of cesspools and they are constructed in a very efficient way and at low cost. Thus, the local experience with a certain technology is certainly a factor to be taken into consideration when deciding on a sanitation technology. Otherwise, considerable losses are to be expected which, unfortunately, never appear in any cost estimate.

A small sample calculation may demonstrate the savings possible by improved construction methods. The following three assumptions were made: a) manhole cost can be reduced by 20% by the use of pre-fabricated manholes; b) manhole distances can be extended by half by replacing manual cleaning by modern cleaning and maintenance equipment; c) the sewer system is built simultaneously with the drainage system and the excavation and backfill cost can thus be reduced by about 30% and additional road surface repair is not required. With these three assumptions the cost for the conventional sewer system would be reduced in the present case by more than 20%.

4.4 Alternative Technologies and the Revenue System

Different technologies may imply a completely different structure of the revenue system. The cost of a sewerage system with central waste water treatment falls mainly on the public sector, the cost for on-site facilities on the private sector. This effect is clearly demonstrated in Fig. 4 with the capital funding as example. In the Maximum Sewerage Option, 70% of the capital funding is to be covered by the central government and the municipality.

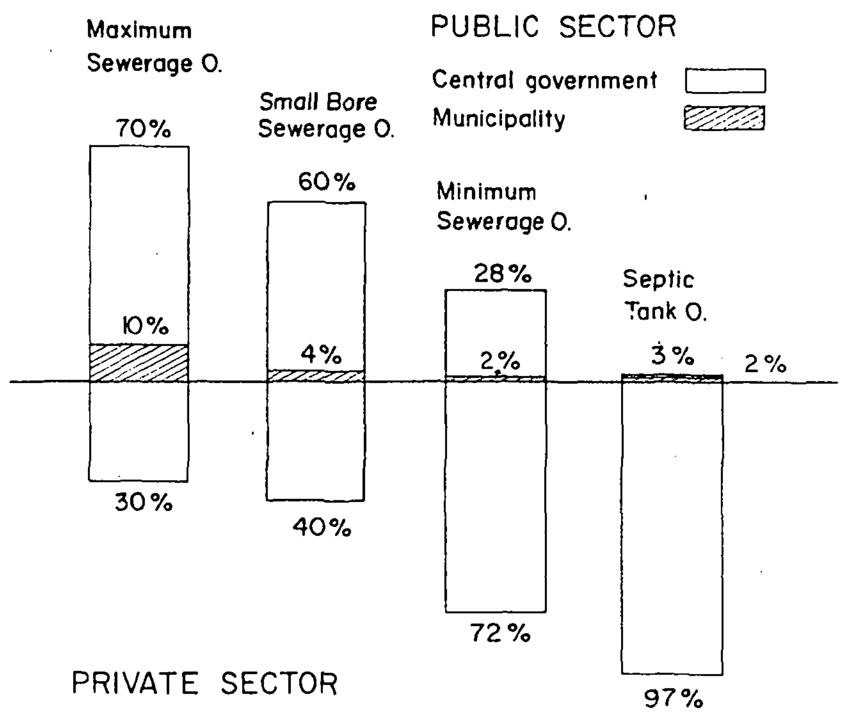


Fig. 4: Distribution of capital funding between the public and the private sector for the four principal sanitation options.

In the Septic Tank Option, the share of the public sector is only 3%. In parallel with revenues or funding, administration and management is also differently distributed between the public and the private sector. This effect may again have far reaching consequences. It is usually accepted that the private sector is more effective in providing a certain service if this service is asked for by the people and at the same time profitable. However, sanitation includes a strong component of environment protection and this may only be in the indirect interest of individuals. Supervision and maintaining environmental standards may be easier in systems operated by a public agency.

Another difference between a septic tank system and a sewerage system is related to the question of how to share the cost among individual users. The user of a septic tank system usually bears the cost which his system creates. In a sewer system, this very much depends on the charges system; the cost of a sewer system per person or per household is much higher in low density areas than in high density areas due to the long distances between individual houses. In the present study, the construction cost per household differed at a ratio of up to 1:10 depending on the population density. If the sewer charge is independent of the plot length along the road or of the plot area but an equal charge for all users, then the population in low density areas is necessarily subsidized by the population in high density areas.

4.5 Affordability of an Improved Sanitation System

Table 2 shows the required full cost recovery service charge for the four principal options together with the average expenditures of other utilities in the study area in 1987. The service charge for the sanitation systems is split up into the charge for households connected to a central system and households served by septic tanks. The sanitation service charge would thus increase the annual utility charges per household by about 22% in the case of septic tanks and by between 29% and 33% for households connected to one of the three sewerage options.

Table 2: Utility charges in the model town in 1987 in Baht/a

Present charges		Estimated sanitation charges	
Electricity	2130	Maximum Sewerage Option	1185
Water	1320	Minimum Sewerage Option	1103
Solid Waste	120	Small Bore Sewerage Option	1045
		Septic Tank Option	789

It may be expected that these charges would meet strong resistance, particularly since the user would not feel the benefit as immediately as he can feel it in the case of other utilities e.g. electricity. However, a clear difference is to be made at this point between affordability and willingness to pay. Although the initial rejection of any new charge is a very natural reaction, it may still be affordable for the majority of the population. The service charge for the Minimum Sewerage Option, for example, would constitute for about 60% of the households less than 2% of the income. For about 15% of the population this charge would constitute 4% or more of the income. The charge for septic tanks constitutes for about 75% of the population less than 2% of the income. These figures are based on income distribution data from 1981 and more recent data would certainly show an even more favorable situation.

5. CONCLUSIONS

Although a case study approach was employed in the investigation, some general conclusions may drawn from the results: first, a combination of a sewer system in high density areas and of on-site facilities in most parts of the planning area appeared as an appropriate balance between environmental requirements and cost. It can be concluded that for any specific town there is not a unique appropriate sanitation technology. A mix of different technologies adjusted to individual parts of the town is a more appropriate solution.

Sewerage systems require a considerably higher standard of construction than on-site facilities and additionally a central organisation for planning, operation and revenue collection. Any negligence with respect to construction standards will most likely result in malfunction and high cost.

Pond systems appeared as the most economical process for centralized waste water treatment also in this case of a medium-sized town with about 89,000 people connected to the system. Ponds should be one of the first alternatives to be investigated, whereever the required land can be found.

The investigations on biogas recovery and fish culture confirmed that the viability of recycling systems very much depends on the given situation. Although desirable in principle, recycling systems may increase treatment cost.

Finally, the considerable differences in cost, financing and administrative requirements of alternative sanitation technologies as they appeared in this study once more stress the need for a broad based and thorough comparison of alternative technologies in any individual planning case.

REFERENCES

(1) KALBERMATTEN J.M., JULIUS D.S., and GUNNERSON C.G. (1980), Appropriate Technology for Water Supply and Sanitation, A Sanitation Field Manual, The World Bank, Washington, D.C.

(2) KOCKS Consult - TPEC (1985), Chonburi Water Supply Project, Kocks Consult GmbH Consultung Engineers, Koblenz - THAI Professional Engineering Consultants Co., Ltd. Bangkok.

(3) LOOSEREEWANICH P. (1983), Cost Analysis of Wastewater Treatment in the Greater Bangkok Area. Master Thesis. Asian Institute of Technology, Bangkok.

(4) ORTH H., KAMMEIER H.D., POLPRASERT C., EDWARDS P., and RATANA-CHAREONSIRI C. (1988), Economic, Institutional and Technical Implications of Alternative Urban Sanitation and Recycling Options. A Case study of Chonburi, Thailand. Asian Institute of Technology, Bangkok.

(5) RYBCZYNSKI W., POLPRASERT C., and MCGARRY M. (1978), Low-Cost Technology Options for Sanitation, IDRC, Ottawa, Ont.

(6) SEATEC (1983), Report on Urban Sewerage and Excreta Disposal Planning for Chonburi, Thailand, SEATEC International Consultants, Bangkok.

(7) ZAJAC V., MERTODININGRAT S., SUSANTO H.S., and LUDWIG H. (1984), Urban Sanitation Planning Manual Based on the Jakarta Case Study, The World Bank, Washington, D.C.

Appendix

Conclusions from:

ORTH H., KAMMEIER H.D., POLPRASERT C., EDWARDS P., and RATANACHAREON-SIRI C. (1988), Economic, Institutional and Technical Implications of Alternative Urban Sanitation and Recycling Options. A Case study of Chonburi, Thailand. Asian Institute of Technology, Bangkok.

FEASIBILITY STUDY OF SEWERAGE AND TREATMENT SYSTEMS FOR RIGIONAL CITY

Smith Kampempool and Nara Khomnamool

Thailand Institute of Scientific and
Technological Research, Bangkok.

FEASIBILITY STUDY OF SEWERAGE AND TREATMENT SYSTEMS FOR CHONBURI REGIONAL CITY

Presented by

Smith Kampempool, Ph.D., Nara Khomnamool, Ph.D.

Thailand Institute of Scientific and Technological Research

1. INTRODUCTION

In the Eastern Seaboard Study of the National Economic and Social Development Board recommendation was made to improve and develop sewerage and sewage treatment facilities for the Chonburi Regional City, both for the existing built-up area and future development area. In order to be able to properly develop the sewerage and treatment systems the Public Works Department has authorized the Thailand Institute of Scientific and Technological Research (TISTR) to conduct a feasibility study for the sewerage and sewage treatment systems, subsequent to TISTR recent undertaking on the main drainage and flood control for the same project area, about 43.6 square kilometers of the proposed future Chonburi Municipality as shown in Figure 1. The main purpose is to plan and evaluate both engineering and economic feasibility of the project for use as guideline in further project implementation. The assignment commenced on 10 September 1985, and was scheduled for completion within 12 months.

Detailed description of the results of this study is presented in the project feasibility report, both in Thai and English, and is summarized for convenient reference in this summary report.

2. EXISTING PROBLEMS AND NEED OF SEWERAGE AND TREATMENT SYSTEMS FOR CHONBURI

At present the sewage disposal in Chonburi mostly relies on septic tank and leaching pit system. In some areas such system does not function properly, resulting in illegal draining of the leaching pits or even septic tanks overflows into public drain pipes. Such overflows and kitchen sullage and other solid waste draining into the public drains have created unhygienic conditions in the environment. Besides, houses on the mud flats in shallow water also discharge wastewaters and human waste directly into the sea, thus aggravate the deterioration of the marine water quality in Chonburi bay.

The present discharges of wastewater and pollutants into the sea far exceed the natural assimilative capability of the marine water in Chonburi bay. This has resulted in a rather serious deterioration of water quality.

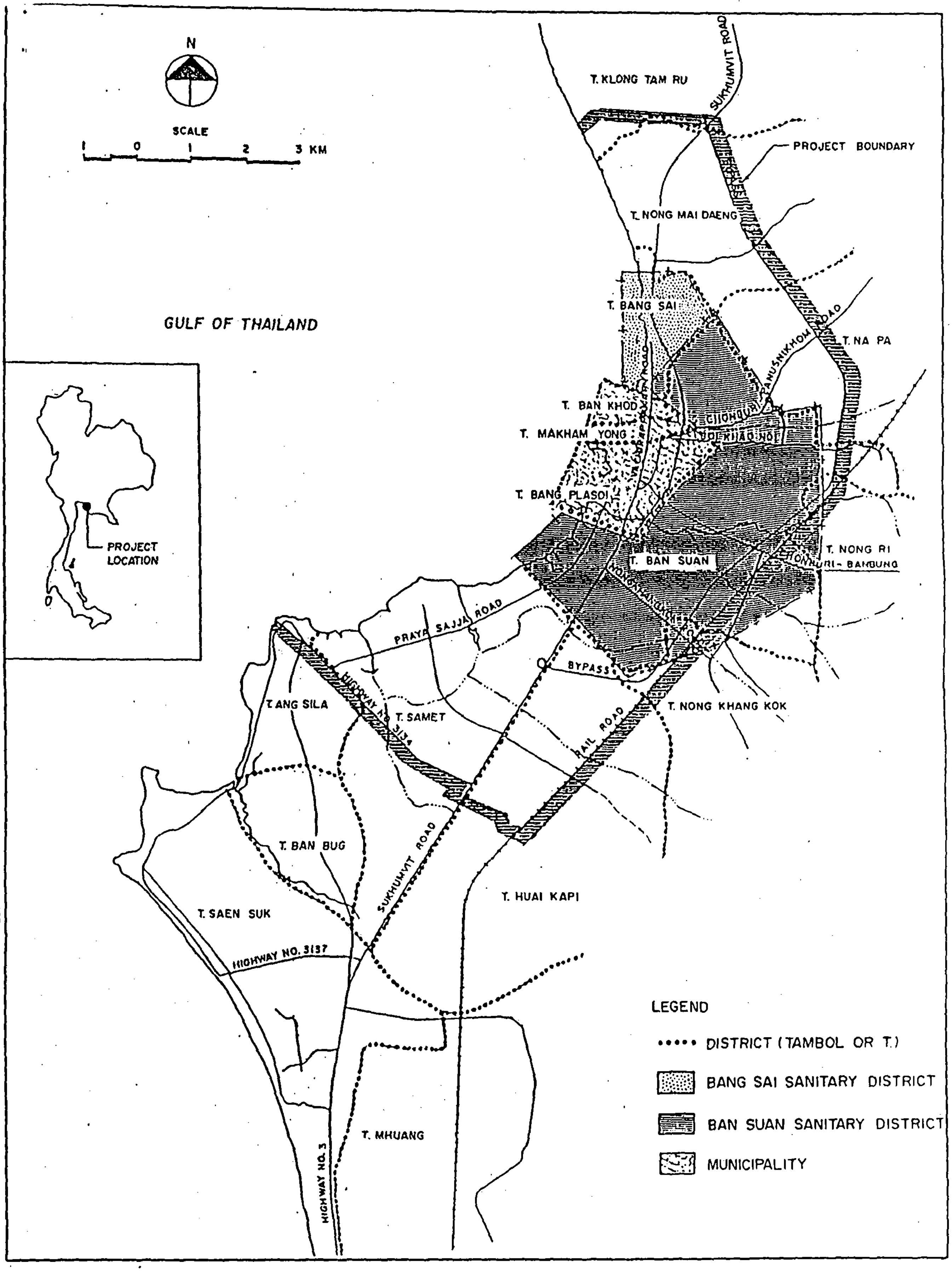


FIGURE 1
PROJECT AREA

The results of marine water quality survey in this project reveal that the sea water within a 3 000 meter distance from the shore has rather high contamination. The coliform bacteria concentrations found exceeded the limit of standards of water quality for shellfishing and aquaculture. The marine water contamination found deserves a concern, as there are many oyster and mussel farms in the bay. The bacteria accumulated in the shellfish can be harmful to the consumer of the shellfish and fisheries products from the bay.

Future trend for the marine water quality contamination is even worse if no proper waste management is carried out. A marine water quality modelling conducted in this study indicates a widespread contamination in the future as shown in Figure 2. The future concentration of coliform bacteria far exceeds all limits of standard of water quality for shellfishing and other purposes.

The marine water contamination in the Chonburi bay resulting from inadequate waste management is a pollution source hazardous to public health conditions, both for the local residents and the consumers of the fisheries products from the bay. Such health hazard has an increasing trend should no proper remedial measures be provided. Therefore the sewerage and sewage treatment systems in this project are urgently needed, so that proper area development as planned and gradually taking place can be obtained.

3. FEASIBILITY STUDY OF THE SEWERAGE AND TREATMENT SYSTEMS

In this project study,survey and data collection have been carried out, including:

(a) Data for estimating future wastewater quantity and quality

- present water use and future water supply project
- quality of water supply and wastewater
- infiltration into sewers and ratio of water use and wastewater

(b) Data for the sewerage system

- topographic and other maps
- engineering soils survey
- groundwater level
- drainage system

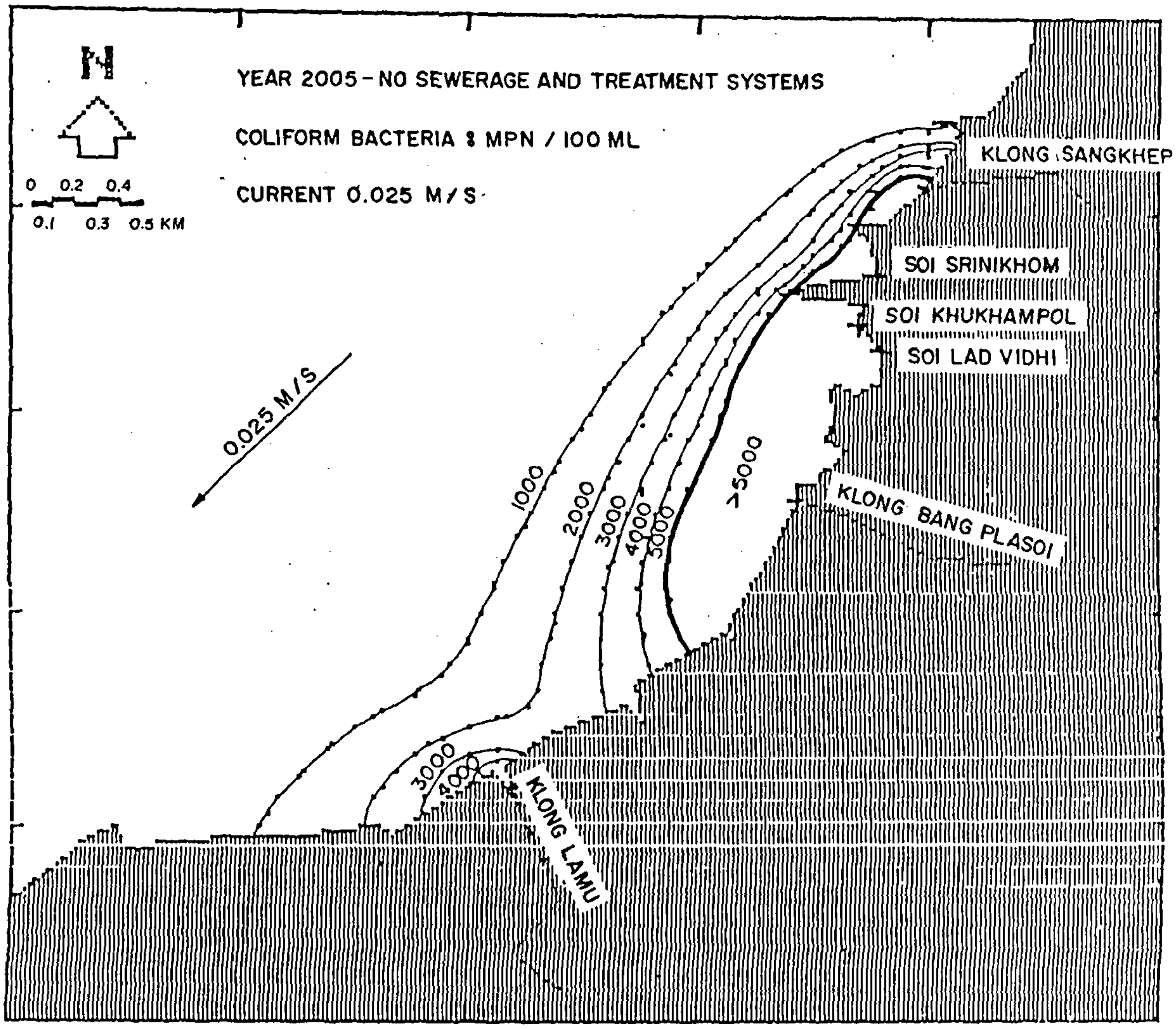


FIGURE 2

DISTRIBUTION OF COLIFORM BACTERIA IN CHONBURI BAY IN THE YEAR 2005
IF THE WASTEWATER MANAGEMENT REMAINS AS PRESENT

(c) Data for waste treatment plant

- plant sites
- conditions of receiving waters
- oceanographic data of Chonburi bay

(d) Data for cost estimation

- mechanical and electrical components
- civil work
- land cost
- operation and maintenance cost

These data were collected from both existing data and from additional surveys in this project study.

The wastewater quantity forecasted annually for 20 years, from the study year to the year 2005 has been used for sizing the project facilities. The wastewater in 2005 is estimated at 26 600 cubic meters per day, equivalent to about 200 litre per day per capita. The wastewater quality adopted for the project design includes: BOD of 150 milligrams per litre, suspended solids of 127.5 milligram per litre, and coliform bacteria of 2 million MPN per 100 ml. The effluent quality criteria adopted are BOD of not more than 20 milligrams per litre, suspended solids of not more than 30 milligrams per litre, and the coliform bacteria at the shellfish farms of not more than 70 MPN/100 ml.

Many alternatives are available as candidates for the sewerage and treatment systems, each with different advantages and drawbacks. In this study these alternatives have been preliminarily designed and cost estimated for comparison and alternative selection. The results are:

(a) Sewerage System

The most appropriate sewerage system includes a separate sewerage system for the service area outside the existing built-up area, and a combined sewerage system for the existing built-up area including a part of the Chonburi municipality. In the combined system area the sewages collected in public drains are intercepted by an intercepting sewer for conveying to a sewage treatment plant locating at the mouth of Klong Lamu.

(b) Sewage Treatment Plant

For the secondary sewage treatment system to be located near the mouth of Klong Lamu,the stabilization pond system is found to be most economical for this project, but it has a main disadvantage in requiring a large plant site of about 200 rai area. The secondary plant requiring smaller size of land found as the next lower priority is the Rotating Biological Contactor system (RBC).

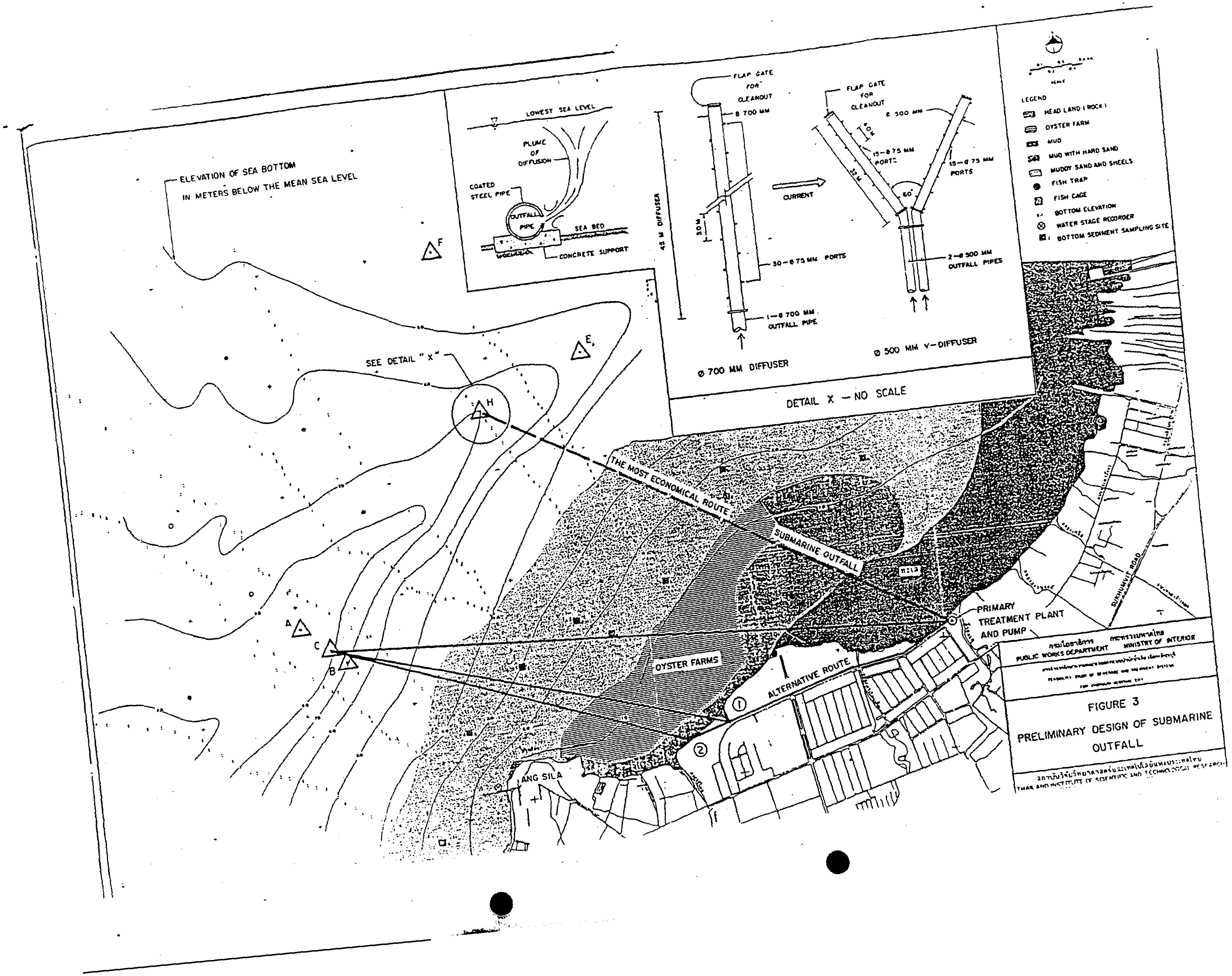
The submarine outfall system proposed in the preliminary planning in the Eastern Seaboard Study has been preliminarily designed as summarized in Figure 3. This system which discharges primarily treated sewage into the sea at about 4 690 meters from the seashore has been found to be significantly less economical than the stabilization pond and the RBC systems.

Therefore the stabilization pond system has been designed to a feasibility study level. Also the RBC system has been designed in parallel, to be timely used in the case that the land aquisition for the stabilization ponds is not feasible. The results of the final step of design and investigation in the feasibility study level are described in the following sections.

4. PROPOSED PROJECT COMPONENTS

The proposed project components are illustrated in Figure 4, consisting of a sewerage system and a sewage treatment plant. The trunk and main sewers include reinforced concrete and PVC pipelines with a total length of about 20 480 meters, and with the sizes from 0.2 to 1.0 m diameter. The intercepting sewer is a reinforced concrete pipeline of 0.80 m size and about 2 475 m length. In addition there are branch and lateral sewers serving about 12.5 square kilometer service area. In an area in the existing built-up area where the public drains continue to be used for conveying sewages to the intercepting sewer,the septic/leaching tank system is to be further used to minimize solid waste discharges into the public drains. The sewerage system is planned to adequately serve about 132 730 persons in 13.24 square kilometers in the project area. For the project area outside the service area,which is mainly agricultural and rural type area with scattered populated,the septic/leaching tank system is more economical, and should be used instead of connecting to the planned sewerage system.

Concerning the sewage treatment plant, the Rotating Biological Contactor system has been found to be most appropriate due to its smaller size of plant site of only about 22 rai . Its plant site is potentially available


ELEVATION OF SEA BOTTOM
IN METERS BELOW THE MEAN SEA LEVEL
LOWEST SEA LEVEL
PLUME OF DIFFUSION
COATED STEEL PIPE
OUTFALL PIPE
SEA BED
CONCRETE SUPPORT
FLAP GATE FOR CLEANOUT
Ø 700 MM
45 M DIFFUSER
3.0 M
30 – Ø 75 MM PORTS
1 – Ø 700 MM OUTFALL PIPE
Ø 700 MM DIFFUSER
CURRENT
Ø 500 MM
15 – Ø 75 MM PORTS
32 M
60°
2 – Ø 500 MM OUTFALL PIPES
Ø 500 MM V-DIFFUSER
DETAIL X — NO SCALE
LEGEND
HEAD LAND (ROCK)
OYSTER FARM
MUD
MUD WITH HARD SAND
MUDDY SAND AND SHELLS
FISH TRAP
FISH CAGE
BOTTOM ELEVATION
WATER STAGE RECORDER
BOTTOM SEDIMENT SAMPLING SITE
SEE DETAIL "X"
THE MOST ECONOMICAL ROUTE
SUBMARINE OUTFALL
PRIMARY TREATMENT PLANT AND PUMP
OYSTER FARMS
ALTERNATIVE ROUTE
ANG SILA
SUKHUMVIT ROAD
กรมโยธาธิการ กระทรวงมหาดไทย
PUBLIC WORKS DEPARTMENT MINISTRY OF INTERIOR
FIGURE 3
PRELIMINARY DESIGN OF SUBMARINE OUTFALL
THAILAND INSTITUTE OF SCIENTIFIC AND TECHNOLOGICAL RESEARCH

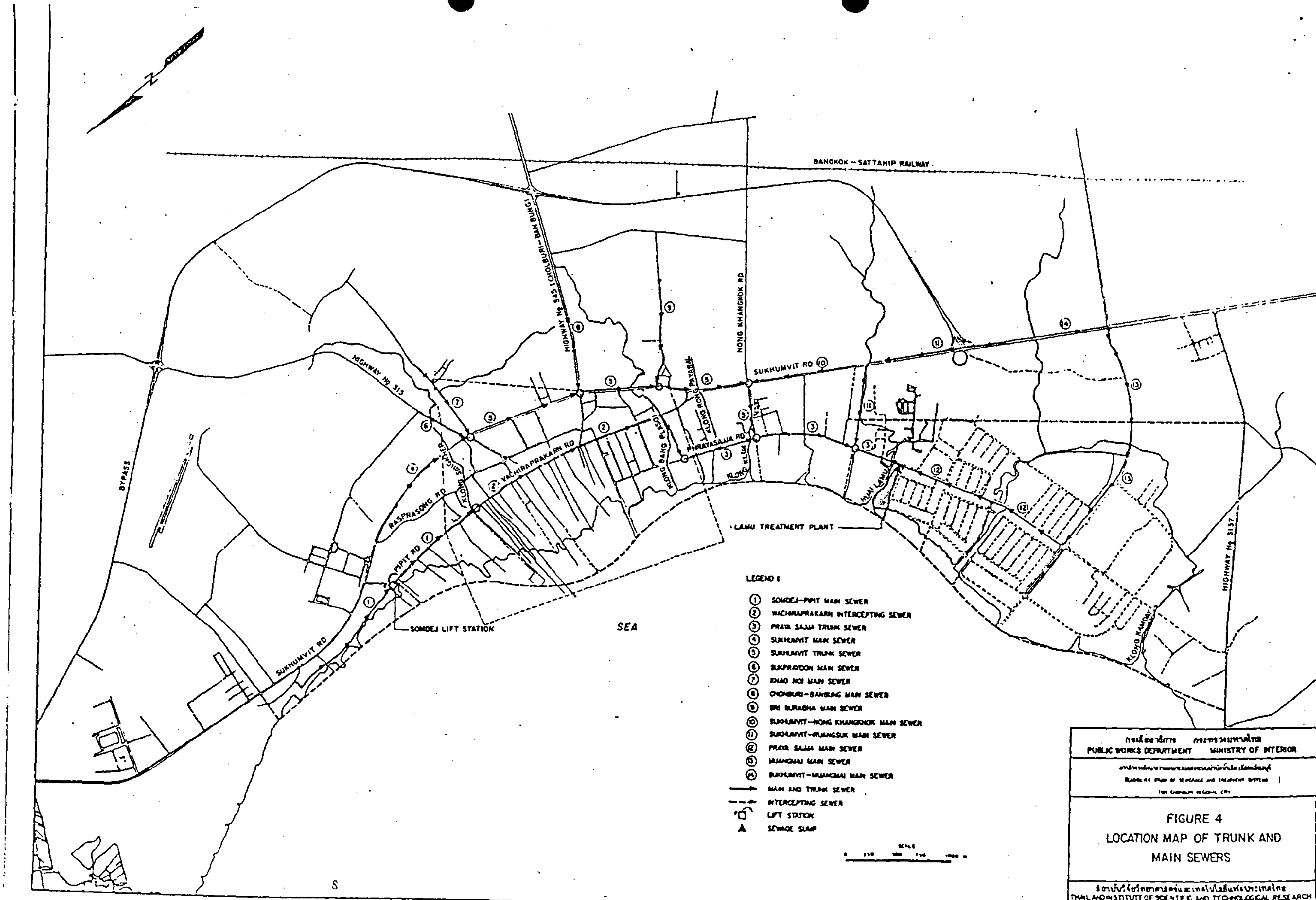


FIGURE 4
LOCATION MAP OF TRUNK AND MAIN SEWERS

at the mouth of Klong Lamu from the Chonburi Administrative Organization. The feasibility design of the RBC system is shown in Figures 5 and 6, together with the aerial view of the plant in Figure 7.

The treatment plant has been designed for the majority of project residents, from the present to the year 2005. The construction and replacement costs total about 450 million baht , consisting of about 381 million baht for the sewerage system and about 69 million baht for the sewage treatment plant (about 61 million baht excluding the land cost). The project construction is planned in phases, the first phase which will be adequate until the year 1994 costs about 201 million baht (about 63 million baht excluding the costs of land and branch and lateral sewers). The construction and replacement costs of the different phases of the various project components are summarized as follows:

Item	Phase I million baht	Phase II million baht	Total million baht
Trunk, main, and intercepting sewers	29.625	33.800	63.425
Branch and lateral sewers	130.690	186.700	317.300
RBC sewage treatment plant			
- Including land cost	41.044	28.216	69.260
- Excluding land cost	33.124	28.216	61.340
Grand total	201.359	248.716	450.075
Grand total, excluding costs of land and branch and lateral sewers	62.749	62.016	124.765

As concerns the operation and maintenance costs, if the sewage collected to the treatment plant annually is as estimated, the costs will be about 2.64 million baht in the first year of service, and increase to about 6.78 million baht in the year 2005.

The construction and replacement costs are equivalent to about 3 390 baht per person (about 940 baht per person excluding the costs of land and branch and lateral sewers). The operation and maintenance cost at full operating capacity is equivalent to about 4.26 baht per person per month, or about 0.71 baht per cubic meter.

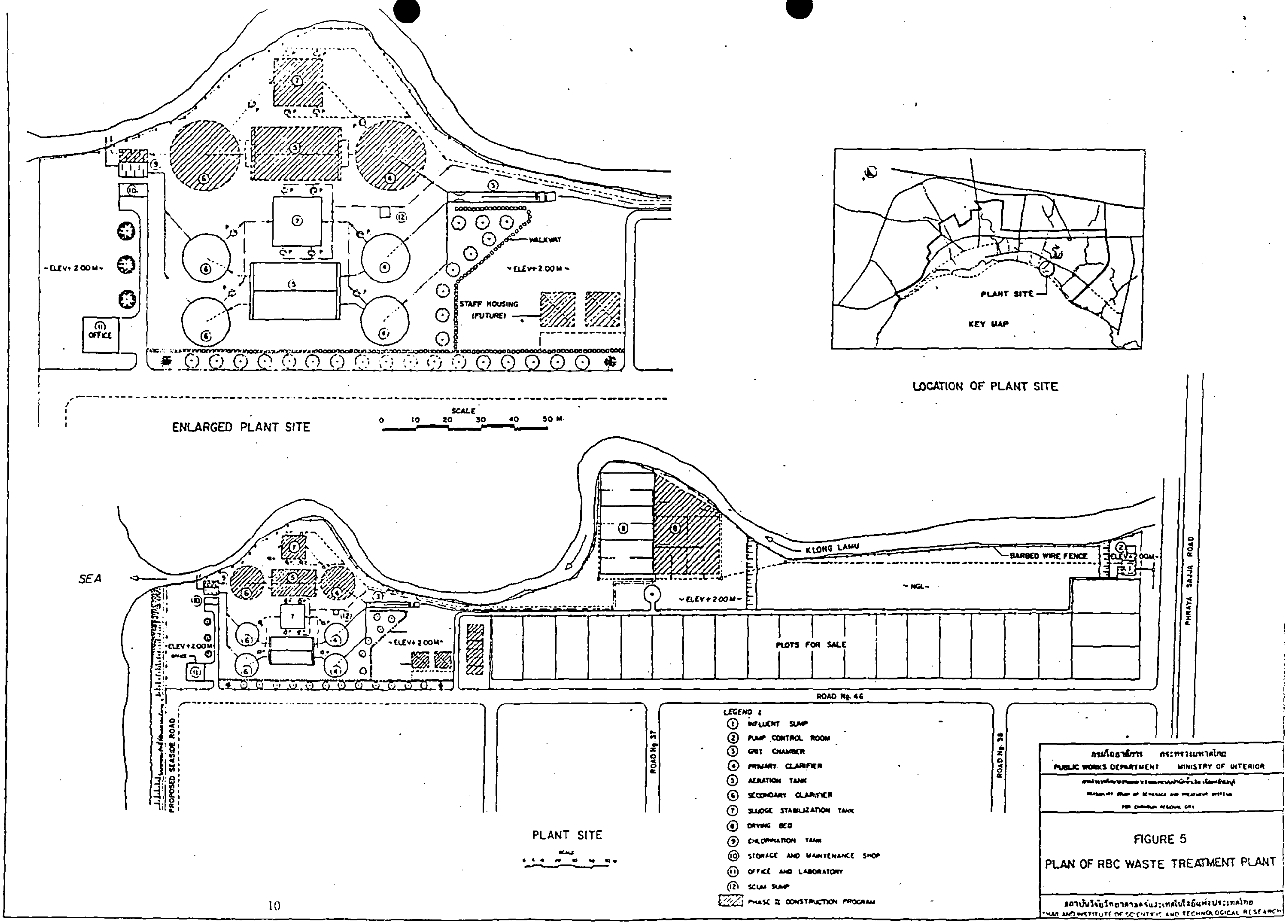
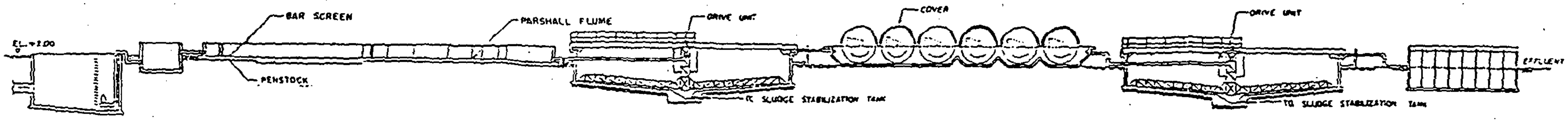
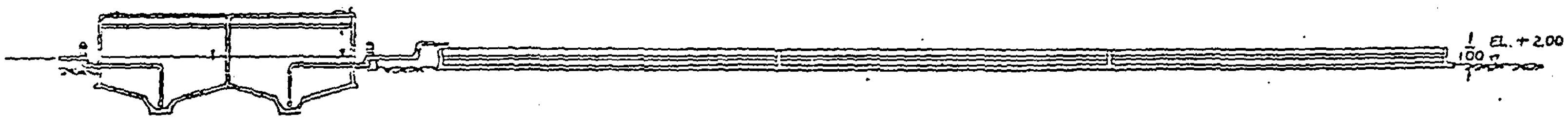


FIGURE 5

PLAN OF RBC WASTE TREATMENT PLANT



SUMP (9x9x5.50) | DISTRIBUTION BOX | GRIT CHAMBER | PRIMARY CLARIFIER (2-Ø16x4) | AERATION TANK (RBC) (2-15x26x2) | SECONDARY CLARIFIER (2-Ø16x3.5) | CHLORINATION TANK (2-4x10x4)



SLUDGE STABILIZATION TANK (2-15x15x5.5)

DRYING BED (6-20x34x1.0)

ALL DIMENSIONS ARE IN METER

กรมโยธาธิการ กระทรวงมหาดไทย
PUBLIC WORKS DEPARTMENT MINISTRY OF INTERIOR

FIGURE 6
TYPICAL SECTIONS OF RBC
WASTE TREATMENT PLANT

สถาบันวิจัยวิทยาศาสตร์และเทคโนโลยีแห่งประเทศไทย
THAILAND INSTITUTE OF SCIENTIFIC AND TECHNOLOGICAL RESEARCH

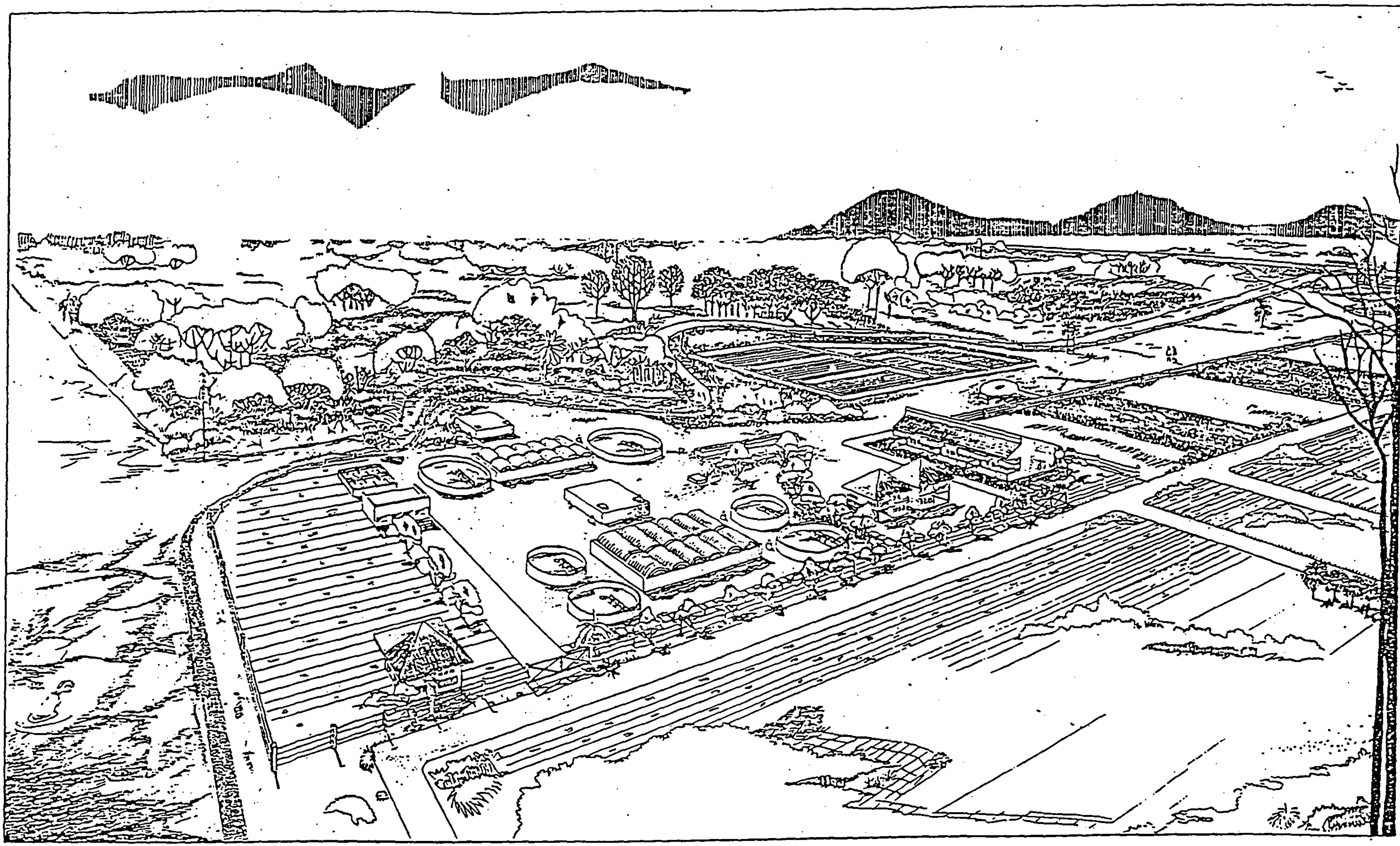


FIGURE 7

AERIAL VIEW OF RBC WASTE TREATMENT PLANT AT THE MOUTH OF KLONG LAMU

In order to urgently remedy the long lasting problems on waste management of the area, it is recommended that necessary steps be taken in order to have the project construction commenced in the fiscal year 1988. After a construction period of not more than 1 year the project should be ready for service.

5. PROJECT BENEFITS

Tangible benefits considered for project economic evaluation include: (a) increased income from fisheries; (b) saving of medical expenses due to waterborne diseases and more earnings for not being ill; and (c) reduction of construction cost with elimination of septic tanks/leaching pits. Tangible benefits not included in the project economic evaluation are promotion for marine fish fries production, and increased fishing fees. Intangible benefits are recreation promotion, enhancement of community environment, improvement of marine water quality in Chonburi bay, enhancement of quality of life on community public health, longer life expectancy, better living conditions, and the satisfaction of public services, etc.

Concerning the fisheries benefit, it is anticipated that without this project the existing income from fisheries in Chonburi bay will be diminished in 10 years due to the marine water contamination. However, with the project implementation and operation as planned the marine water quality will gradually improve. As a consequence, the fisheries income is expected to increase from a total of 40 million baht per year at present to about 80 million bahts per year in 10 years. Thus, the fisheries project benefit is assessed to increase from 8 million baht in 1989 to 80 million baht in 1998, and continues to maintain at this level to the end of the service life of the project.

With this project the medical expenses due to waterborne diseases are expected to gradually decrease, by about 1.0 million baht per year in the fiscal year 1989 to by about 1.63 million baht per year in the fiscal year 2005. Besides, the smaller number of cases of waterborne diseases will result in more income, which will otherwise not be possible due to the illness. The increased earnings for not being ill is assessed to increase from about 4.62 million baht per year in the fiscal year 1989, to about 6.48 million baht in the fiscal year 2005.

The reduction of construction cost due to the elimination of septic tanks and leaching pits is expected to be about 0.5 million baht in the fiscal year 1989. This figure is assessed to grow to about 1.93 million baht in the fiscal year 2005.

In total, the overall tangible project benefits considered in the project economic evaluation is assessed to increase from about 14.22 million baht per year in the year 1989 to about 90.40 million baht per year in 2005, as tabulated in comparison with the project expenses in Table 1.

6. ECONOMIC FEASIBILITY

Economic evaluation by comparing the project cost and benefit streams in Table 1 leads to the conclusion that this project is economically feasible, as indicated by a benefit cost ratio of 1.373 (at 12% annual discount rate) and a 20.78% internal rate of return. A sensitivity analysis with the results shown in Table 2 also indicates that variation of the project construction cost and benefits does not significantly affect the project feasibility, only with the exception of the large change in the fisheries benefit which is not likely to occur.

Therefore, it can be concluded that this project is economically feasible and worth an investment, i.e., the project direct benefits exceed the project expenditures. Moreover, the project will create other intangible benefits, such as the enhancement of quality of life in improving public health and improving life expectancy. Better environment to be provided by the project will also promote tourism in the area.

7. PROJECT FINANCE

Project financial analysis suggests that the project fund should be from government subsidy, local authority contribution, loan through the government, and service fee to be collected from the project direct beneficiaries. A total government subsidy of 281.714 million baht is planned to finance 60% of the construct cost and the operation and maintenance costs during the first 5 years of service. The local authority contribution of 72.554 million baht is allocated to finance the operation and maintenance and replacement costs from the sixth year of service to the end of the service life. The loan of 177.5 million baht is for financing 40% of the project construction cost. The service charge of 220.275 million baht is planned for the repayments of the loan and its interest. The service charge

TABLE 1

PROJECT COST AND BENEFIT STREAMS

Fiscal year B.E.	Benefit, million baht					Cost, million baht		
	Fisheries	Public health		Reduction of septic tank/ leaching pits cost	Total (1) + (2) + (3) + (4)	Construction	Operation and maintenance	Replacement
	Base case	Saving of medical expenses	Increase income for not being ill					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2531	0	0	0	0	-	89.339	-	-
2532	8	1.10	4.62	0.50	14.22	18.670	2.636	-
2533	16	1.12	4.73	0.63	22.48	18.670	2.792	-
2534	24	1.15	4.85	0.75	30.75	18.670	3.155	-
2535	32	1.18	4.97	0.82	38.97	18.670	3.317	-
2536	40	1.21	5.10	0.87	47.18	18.670	3.474	-
2537	48	1.24	5.22	1.00	55.46	41.285	3.636	2.486
2538	56	1.27	5.34	1.19	63.80	18.670	4.548	-
2539	64	1.31	5.49	1.32	72.12	51.836	4.712	-
2540	72	1.34	5.64	1.18	80.16	18.670	5.149	-
2541	80	1.38	5.79	1.19	88.36	18.670	5.315	-
2542	80	1.41	5.94	1.07	88.42	18.670	5.479	-
2543	80	1.45	6.09	1.25	88.79	18.670	5.645	3.115
2544	80	1.49	6.24	1.25	88.98	18.670	5.842	-
2545	80	1.52	6.39	1.38	89.29	18.670	6.216	0.634
2546	80	1.56	6.54	1.50	89.60	18.670	6.407	-
2547	80	1.59	6.69	1.50	89.78	18.670	6.587	-
2548	80	1.63	6.84	1.93	90.40		6.783	-

TABLE 1

TABLE 2

RESULTS OF SENSITIVITY ANALYSIS

Case	B/C	IRR, %
Base case	1.373	20.78
(A-1) Construction cost increases 20%	1.166	16.12
(A-2) Construction cost decreases 20%	1.669	26.98
(A-3) Considering salvage value	1.480	21.75
(B-1) Total benefit increases 20%	1.647	26.25
(B-2) Total benefit decreases 20%	1.098	14.55
(B-3) Normal fisheries benefits taken as 1.5 of the 1985 benefit	1.078	14.09
(B-4) Considering only shellfish benefit	0.519	-
(C-1) Construction cost and benefits increases 20% each	1.399	21.22
(C-2) Construction cost increases 20% while benefits decrease 20%	0.933	10.17
(C-3) Construction cost decrease 20% while benefits increase 20%	2.002	33.09
(C-4) Construction cost and benefits decrease 20% each	1.335	20.14

is suggested to be collected from two eligible target groups, i.e., the serviced residents in the project area, and the fishermen with activities in the Chonburi bay. The average service charge from the serviced residents varies from about 41 to 72 baht per month per household, depending on whether the contribution from the fishermen is obtained or not. These monthly service charges are only about 0.9 to 1.6% of the average income of the low income population in the project area.

8. PROJECT IMPLEMENTATION SCHEDULE

The long lasting problems concerning with sewerage and waste treatment have resulted in serious deterioration of the marine water quality in Chonburi bay. Therefore, the proposed project implementation schedule is prepared basing on a policy to urgently remedy the problem. This is proposed in two stages: project preparation and project construction. The objective is to have the first project service year in the fiscal year 1989, as shown in Figure 8. Both the waste treatment plant and the main sewerage system (trunk, main, and intercepting sewers) are scheduled for two stages construction, to suit the future sewage flow rates, as shown in Figures 8 and 9. The location of the sewers in each construction phase is also shown in Figure 10.

9. INITIAL ENVIRONMENTAL EXAMINATION

An initial environmental examination of the project indicates a definite overall positive environmental impact. Certain environmental parameters may suffer due to the project implementation, but such impacts will be of temporary nature and not serious. Moreover, feasible means for mitigating such adverse impacts have been described in the main report. As this initial environmental examination has been prepared in adequate details, it is judged that no further environmental impact statement (EIS) be necessary.

10. CONCLUSION

From the results of various study aspects summarized in this report it can be concluded that the proposed sewerage and treatment systems are engineeringly feasible. There is no tendency for any engineering problem in further project implementation. Moreover, this project is economically feasible as indicated by its benefit cost ratio of 1.37 and a rather high internal rate of return of 20.78%. In addition, the project will create other intangible benefits, such as the enhancement of environment giving rise to better quality of life, better community public health, longer life expectancy, and the improvement of marine water quality in Chonburi bay from

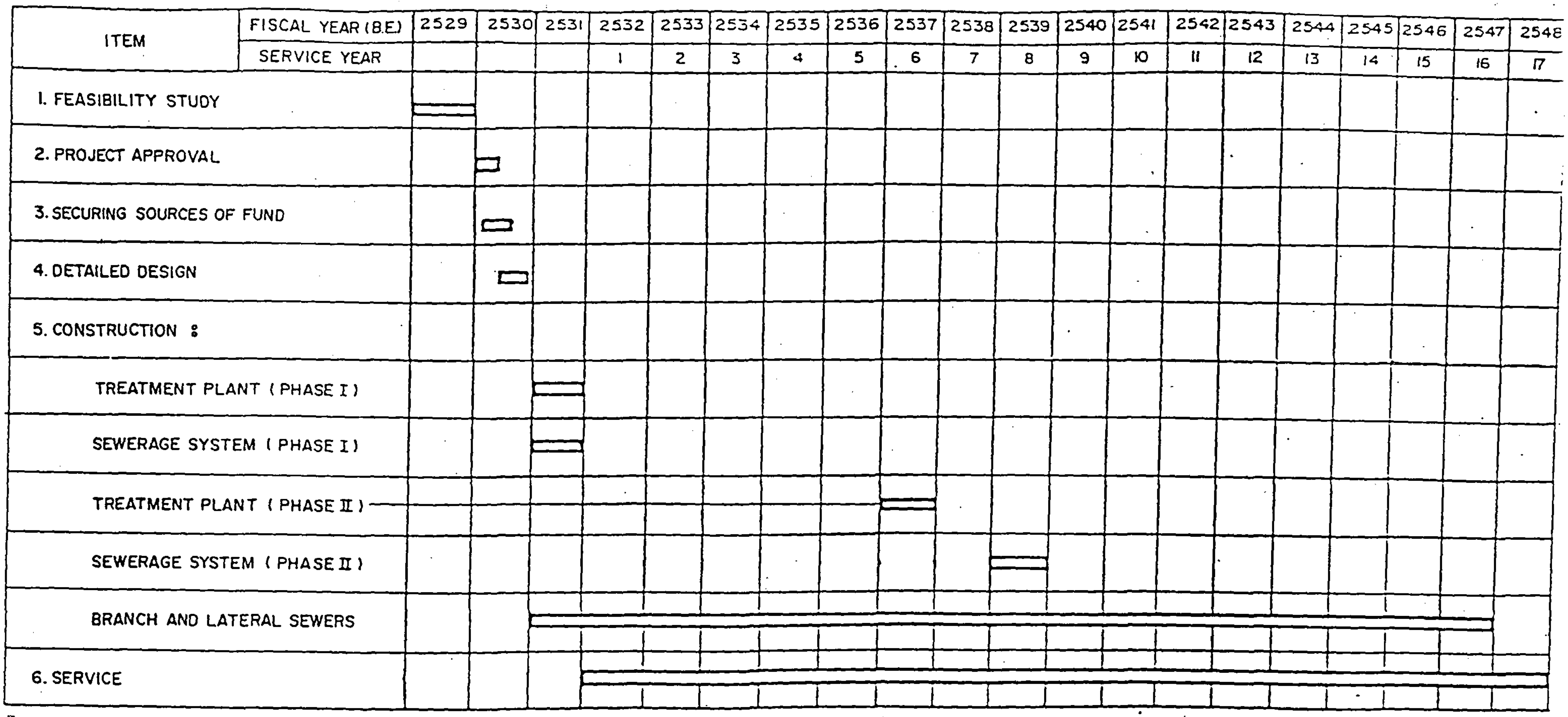


FIGURE 8

PROJECT IMPLEMENTATION SCHEDULE

FIGURE 8

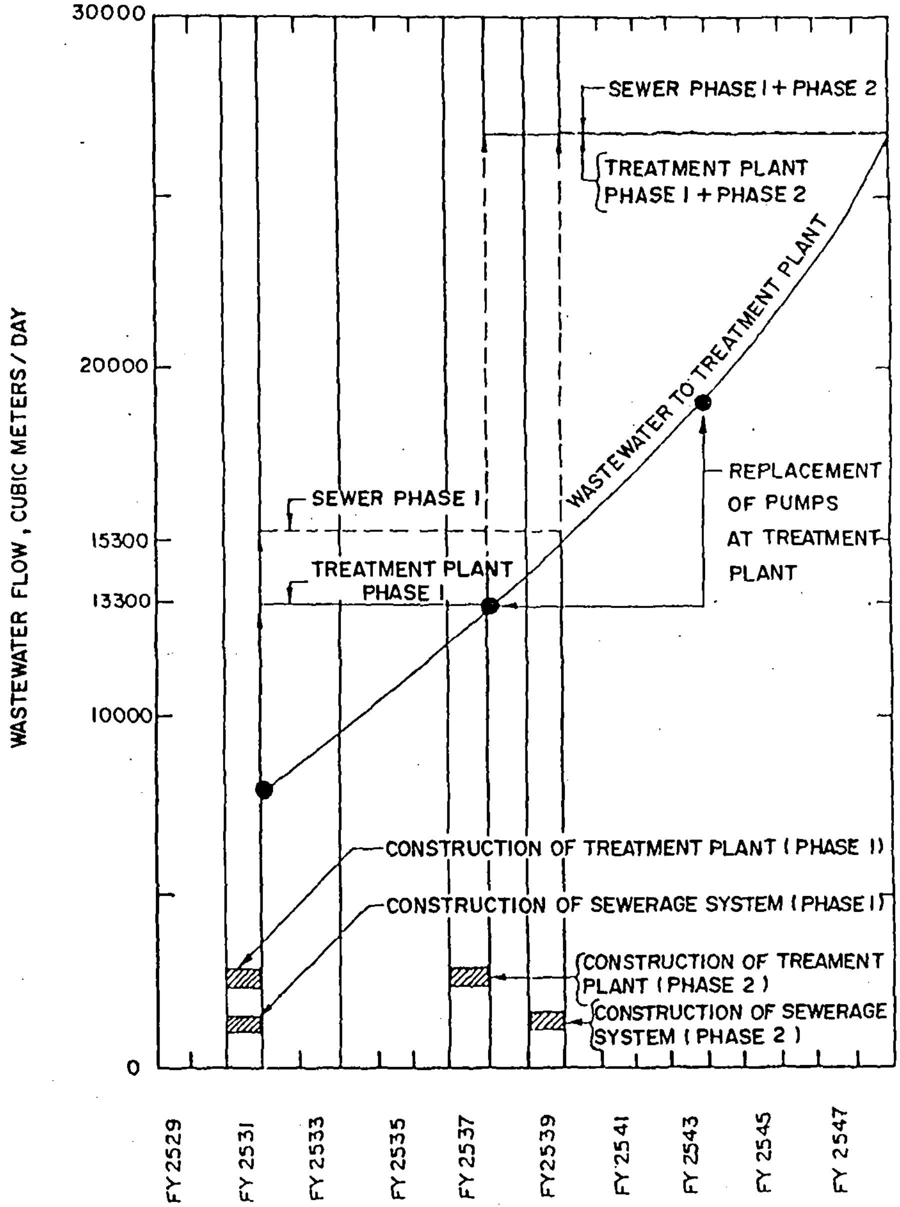


FIGURE 9

PHASING OF WASTE TREATMENT AND SEWERAGE SYSTEMS

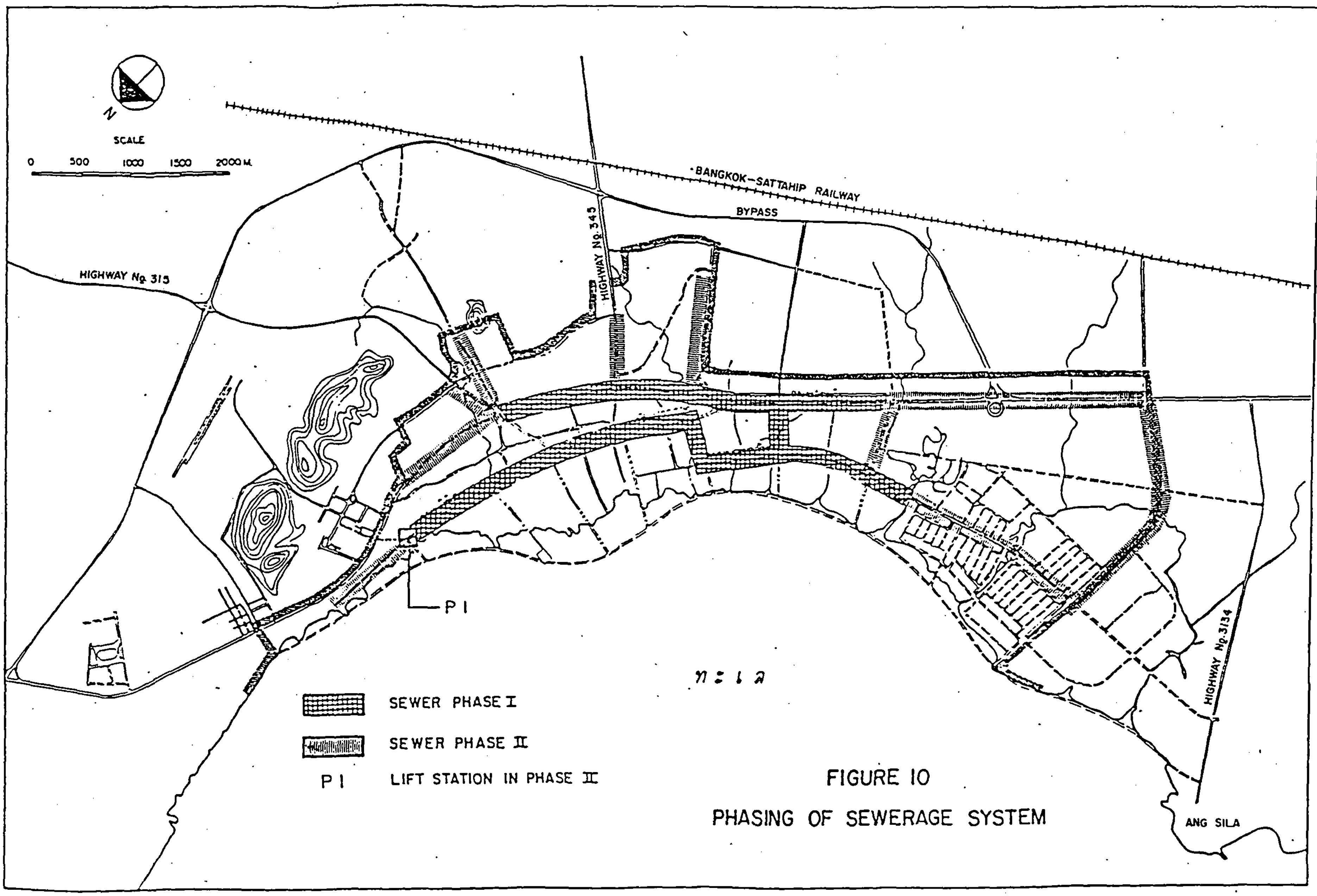


FIGURE 10

PHASING OF SEWERAGE SYSTEM

FIGURE 10

the severely contaminated condition at present until it becomes suitable for supporting beneficial fisheries activities. This will result in the promotion of marine fish fries production which will beneficially promote fisheries in the Gulf of Thailand.

As this project is feasible both engineeringly and economically, necessary measures should be further undertaken to have the project implemented and rendering the needed service as planned.

11. RECOMMENDATION

In order to achieve the goal of having the proposed project components implemented the following necessary tasks are recommended: (a) establishment of main responsible authority; (b) securing sources of fund; and (c) land acquisition.

11.1 Establishment of Main Responsible Authority

The Public Works Department is suggested to be the main responsible authority as it possesses experience and relevant technical staff, and familiarity with the problem. Full support and cooperation are also needed from the National Economic and Social Development Board, the Budget Bureau, the Office of the National Environment Board, the Ministry of Public Health, the Town and Country Planning Department, and the Office for Urban Development.

At the project preparation stage, functions of the responsible authority are

(1) To propose, follow up and coordinate for project approval;

(2) To plan, follow up and coordinate to seek for sources of loans including subsidy and contribution as planned ;

(3) To arrange for the detailed engineering design and the specification preparation ;

(4) To prepare plan and schedule for project construction including the organization of construction supervision and management ;

(5) To prepare and propose the guideline for project operation and management after the completion of project construction ; and

(6) To coordinate with all relevant local authorities for achieving cooperation at every step of project work including detailed engineering design, construction supervision and management, monitoring and maintenance, and fee collection.

At the stage of project construction,operation and maintenance, financial management and fee collection local authorities should be assigned to set up a responsible unit especially for this purpose, under the administration and direction of local authorities, possibly in the form of a governing board. The board is suggested to have representatives from the municipality, sanitary districts, and the Chonburi Administration Organization. The structure of the responsible unit should consist of

- General affairs and finance section
- Operation and system control section
- Wastewater laboratory, and
- Maintenance section

During the project execution from the construction stage onwards the main responsible authority will support the responsible unit on technical aspect and others as necessary by emphasizing on routine follow up. This is to ensure that the project is properly constructed, operated, and maintained as planned.

11.2 Securing Sources of Fund

The cost of this project is too large for local authorities to take all the burden. It is necessary for the government or Public Works Department to seek for loans to finance the project construction in addition to government subsidy. The loans may be obtained from overseas or domestic with low interest and reasonable conditions. Loan repayment will be from the service fee collection. This concept is considered to be more suitable than the case of fully subsidized by the government, and local authorities take partial burden only in administration and operation costs. With a share in capital investment in the project more sense of ownership should be realized by the local authorities, and the project should be more beneficially utilized.

11.3 Land Aquisition

Although the site of 22 rai for RBC treatment plant at the mouth of Klong Lamu has been agreed by relevant offices, especially Chonburi Administrative Organization which is the owner of this land, there exist certain procedures to legalize the use of the planned site as treatment plant.

The urgent activities in this respect are

(a) To officially contact local authority, i.e. Chonburi Administrative Organization to reserve the concerned land for the site of the treatment plant.

(b) To officially request Town and Country Planning Department for altering the planned type of land use at the RBC plant site to the type which can be utilized for sewage treatment plant.

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BANGKOK METROPOLITAN WASTEWATER PROBLEMS

Kasemsan Suwarnarat and Usa Charutawai

Bangkok Metropolitan Administration,
Bangkok

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Presented at The Seminar on Anaerobic Waste Treatment and Sanitation Technologies

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by Kasemsan Suwarnarat and Usa Charutawai
Policy and Planning Department,
Bangkok Metropolitan Administration,
Bangkok Thailand

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1. GENERAL VIEW

Thailand has its area of 513,115 km^2 and population of about 52 million persons (1985) surrounded by Cambodia, Laos, Burma, Malaysia, Andaman Sea and the Gulf of Thailand. Agriculture used to be the most important industry in this country and still constitue the economy of the country in general. However, the gross domestic product in manufacturing has exceeded that of agriculture in 1984 and the gap between the two sectors is getting wider.

Not only manufacturing but also the other sectors which belong to second and third industried are growing rapidly. It can be said that now Thailand is on its turning point from agriculture dominated country to an early stage of industrialization.

Bangkok, the capital city of Thailand is the centre of the development in the country. It has the characteristic of a primate city with a population of 5.5 million persons (1986) that is about 10% of the whole population of the country. The next largest provincial cities are Chiang Mai, Nakorn Ratchasima and Hat Yai with populations of only around 200,000 persons. It is obvious that Bangkok is by far the biggest city in Thailand. Therefore, the city has to face many problems relating to urbanization such as traffic congestion, slums, garbage etc. Water pollution is one of the problems. Fig-1 and Fig-2 show the spread of water pollution in the canals following the progress of urbanization.

The city administration realise that the most effective way to prevent water pollution is to implement a sewerage system and had prepared and maintain official master plan for the sewerage of the city since 1967. However, the plans have been only fractionally implemented due to the budgetary constraint.

The BMA tends to be slow in the implementation of sewerage when comparing with the other government agencies. Sewerage in the other area have been realised in many locations, for example:

There are several cities that are implementing or planning sewerage besides Bangkok. The first municipal scale sewerage

Fig 1 khlong water quality in 1969

investigated by Dr Kasemsan, BMA

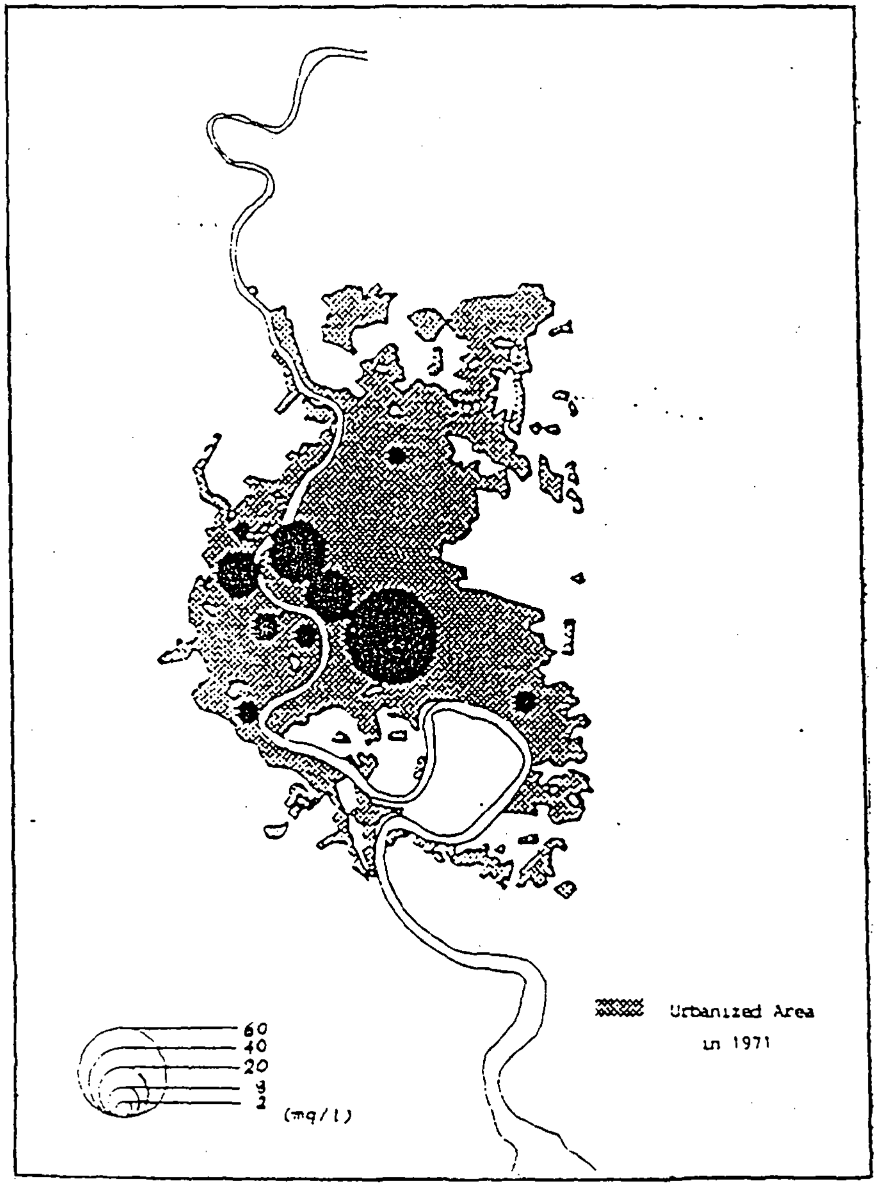
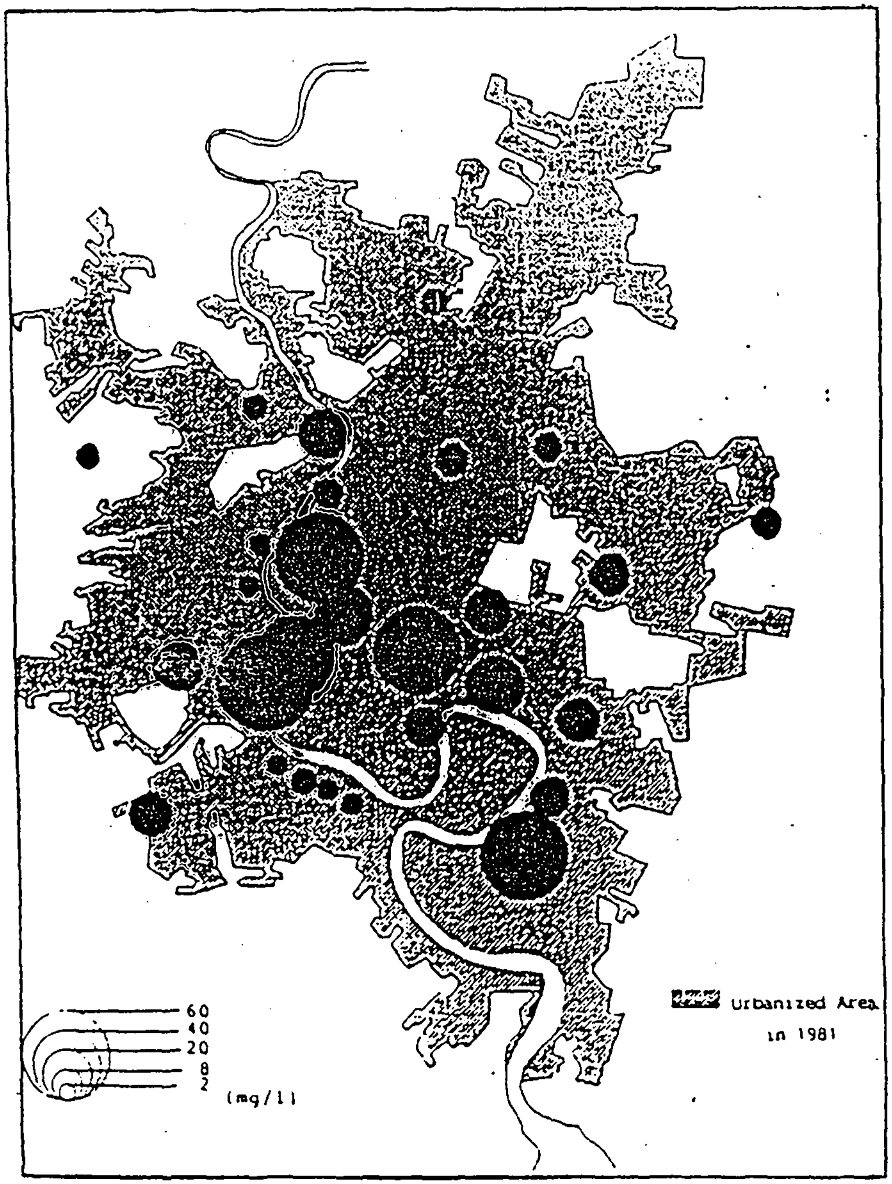


Fig 2 khlong water quality in 1982

investigated by MR HAYASHI, JICA



system was completed in Pattaya City in late 1985. The purpose of the construction was to keep the sea of Pattaya, the most famous tourists destination in Thailand in a condition which is favourable for the tourists. To prevent the water pollution in Pattaya, a waste water treatment system for 40,000 cu.m per day, employing bio-discs was constructed. The sewage of the city was collected by a main interceptor along the beach road and pumped back to the treatment plant which locates somewhat in-side the city. The origins of the wastewater discharges such as hotels, restaurant, etc. and even households will be required by the municipal law to pay for connection fee and also treatment fee. It was observed that beach water quality has markedly improved after the commissioning of the treatment plant's operation in 1985. The 26 million Baht was observed as a worthy investment and The Ministry of Interior is planning a second sewage work a Patong Beach in Phuket Island where an oxidation ditch system will be applied. Moreover, plans are already on the way for Khon-Khaen and Nakorn Ratchasima using lagoon method. The above mentioned projects tend to be in line of tourism promotion. However, Khon-Khaen and Nakorn Ratchasima are regional center cities.

In spite of the evidences showing strong supports of the government through the Department of Public Works, Ministry of Interior with the commission of the local governments on municipal sewerage, the ministry have not yet shown an active role to support the sewerage program of the Bangkok Metropolitan Administration.

The BMA has not been able to realise a major implementation of sewerage system within Bangkok, while the NHA has been somewhat more successful. The National Housing Authority (NHA) followed the Land Subdivision Law (The Revolution Party Announcement Number 286) to build 16 community sewage works serving about 100,000 people.

Judging from the existing sewage works, the reason to build can be noted as follow:

a. To promote tourism
b. To prevent water pollution
c. To abide to the law.

The implementation plan for the provincial cities being prepared by the Ministry of Interior indicates that the water pollution is spreading out not only within Bangkok but also in the other parts of Thailand.

2. WATER QUALITY STANDARDS.

Before one mentions about the water pollution problem, the first thing to be refered to should be the standard of water qualities which set the border line between being polluted and unpolluted. The National Environment Board of Thailand is the authority in this aspect. The standard issued drafted by Office of National Environment Board since January 1985 (Table 1,2) show the objectives of the water quality classifications which may serve as a reference for water pollution control activities both in the fresh water area and the coastal water area. Together with the effluent standard methods of water analyses were also prepared. However, the practical declaration of the water bodies which respective standards are to be applicable are still not publicly disclosed.

3. EFFLUENT STANDARDS

From a technical point of view, an effluent standard may reflect two objectives. One is the regulartory item to render the environmental quality require. Another is to ensure a proper treatment of the effluent to a level which is practically attainable.

There are three relavant sources of pollutants namely; industries, household and agriculture.

Effluent standard for factories has been issued since 1970 by the Department of Industrial Works, Ministry of Industry (Table-3). Literally, the standard is applied to all of the factories even the very small ones making it rather impractical from the technical point of view.

The DIW has inspectors who control discharges from factories. However, as the number of DIW's inspectors is very limitted (about 70) when comparing with the number of factories (about 80,000). It seems to be impossible for the inspectors to check all of the factories all over the country.

The ONEB will soon issue the Domestic effluent standard according to Table-4. This standard will be applicable to houses of any size but effective control can be expected only on big housing estate projects. However, the enactment of the standard seems to have some draw-backs in practice. For example, most of the effluent load derives from hundred of thousands of single houses, not from large housing estates which the standard is aiming at. If the single houses fail to build efficient on-site treatment units the effluent from single houses will still be discharged to canals passing through municipal drains, or even through the under-ground passages provided, legally, by the cess-pools. Therefore, the need for good municipal sewerage system to collect waste water from the single houses is still obvious and the implementation of a sewerage still remain relavant.

Table 1 Surface Water

Surface Water Quality Classification And Standards

Parameters	Units	Statistic	Standard Values for Class***				
			1	2	3	4	5
1. Temperature	°C	—	n	ń	ń	ń	—
2. pH value	—	—	n	5-9	5-9	5-9	—
3. Dissolved oxygen	mg/l	P20	n	6	4	2	—
4. BOD (5 days, 20°C)	mg/l	P80	n	1.5	2.0	4.0	—
5. Coliform Bacteria			n				
— Total coliform	MPN/100 ml	P80		5,000	20,000	—	—
— Fecal coliform	"	P80		1,000	4,000	—	—
6. NO_3 – N	mg/l	Max. allowance	n	←	5.0	→	—
7. NH_3 – N	"	"	n	:	0.5	:	—
8. Phenols	"	"	n	:	0.005	:	—
9. Cu	"	"	n	:	0.1	:	—
10. Ni	"	"	n	:	0.1	:	—
11. Mn	"	"	n	:	1.0	:	—
12. Zn	"	"	n	:	1.0	:	—
13. Cd	"	"	n	:	0.005* 0.05**	:	—
14. Cr (Hexavalent)	"	"	n	:	0.05	:	—
15. Pb	"	"	n	:	0.05	:	—
16. Hg (total)	"	"	n	:	0.002	:	—
17. As	"	"	n	:	0.01	:	—
18. CN	"	"	n	:	0.005	:	—
19. Radioactivity							
— Gross α	Becqurel/l	"	n	:	0.1	:	—
— Gross β	"	"	n	:	1.0	:	—
20. Pesticides (Total)	mg/l	"	n	:	0.05	:	—
— DDT	ug/l	"	n	:	1.0	:	—
— α BHC	"	"	n	:	0.02	:	—
— Dieldrin	"	"	n	:	0.1	:	—
— Aldrin	"	"	n	:	0.1	:	—
— Heptachlor & Heptachlor epoxide	"	"	n	:	0.2	:	—
— Endrin	"	"	n	←	none	→	—

Note: P = Percentile valve
n = naturally
ń = naturally but changing not more than 3°C
* = when water hardness not more than 100 mg/l as $CaCO_3$
** = when water hardness more than 100 mg/l as $CaCO_3$
*** = Water Classification

Table 1 (continued)

Classifications	Condition & Benificial usages
Class 1	Extra clean fresh surface water resources using for: (1) conservation, not necessary pass through water treatment processes require only ordinary process for pathogenic destruction (2) ecosystem conservation which basic living organisms can spread breeding naturally
Class 2	Very clean fresh surface water resources using for: (1) consumption which require the ordinary water treatment process before uses (2) aquatic organism conservation for living and assisting for fishery (3) fishery (4) recreation
Class 3	Medium clean fresh surface water resources using for (1) consumption but have to pass through an ordinary treatment process before uses (2) agriculture
Class 4	Fairly clean fresh surface water resources using for (1) consumption but require special water treatment process before uses. (2) industry (3) other activities
Class 5	The resources which are not classified in class 1-4 and using for (1) navigation

Table 2 Coastal Water

Coastal Water Quality Standards for Karon Bay, Phuket

Parameters	Units	Standard values of coastal water use for	
		Swimming	Coral Reef Conservation
1. Temperature	°C	23 - 33	23 - 33
2. pH	—	6.5 - 8.3	7.5 - 8.9
3. DO	mg/l	Not less than 4.0	Not less than 5.0
4. Salinity	ppt.	—	29 - 35
5. Transparency	m.of Secchi Depth.	Not less than 10	Not less than 15
6. S.S.	mg/l	Not more than 20	Not more than 10
7. Oil & Grease	mg/l	Non detectable	Non detectable
8. Coliform bacteria	MPN/100 ml	Not more than 1,000	—
Control Areas (500 m from lowest sea water line)		II. Karon bay	I. Lam Mai Ngang III. Ko Pu

Methods of Parameter Analysis

Parameters	Methods	References
1.	Thermometer	Standard Methods for the Examination of water and Wastewater by APHA-AWWA-WPCF
2.	pH meter	
3.	Azide modification	
4.	Chlorinity by hydrometric/Argento-metric/other equivalents	
5.	White Secchi Disc. (30 cm. diameter)	Oceanographic survey Hydrographic Department, Royal Thai Navy.
6.	Non-Filterable Residue through Glass Fibre Filter Discs	Methods for Chemical Analysis of Water and Wastes, EPA
7.	n-Hexane Extracts	Item 18 Method C JIS Method 0102 (Testing Method for Industrial Wastewater)
8.	Multiple tube fermentation technic	Standard Methods for the Examination of water and Wastewater by APHA-AWWA-WPCF

Source: (1) Notification of the Ministry of Science, Technology and Energy B.E. 2526, published in the Royal Government Gazette, Vol. 100, Part 201, dated December 27, B.E. 2526 (1983).

(2) Notification of the Office of the National Environment Board for reference Monitoring Station, dated April 29, B.E. 2528 (1985).

Table 3 Industrial Effluent Standards

Items	Units	Standard value	Remarks
BOD (5 day, at 20° C)	mg/l	20-60	Fishery canning Max. 100 Starch Ind. Centrifugal Max. 60 Sedimentation Max. 100 Noodle Ind. Max. 100 Tanning Ind. Max. 100 Pulp Ind. Max. 100 Frozen Food Ind. Max. 100
Suspended Solids	mg/l	Depend on dilution ratios of wastewater and receiving water	Ratio 1/8 to 1/150 Max. 30 1/151 to 1/300 Max. 60 1/301 to 1/500 Max. 150
Dissolved Solids	mg/l	Max. 2,000 or under office's consideration but not more than 5,000	not higher than receiving water dissolved solids 5,000 mg/l if salinity of receiving water is higher than 2,000 mg/l
pH	—	5-9	
Permaganate value	mg/l	Max. 60	
Sulfide as H_2S	,,	Max. 1.0	
Cyanide as HCN	,,	Max. 0.2	
Tar	,,	none	
Oil & Grease	,,	Max. 5.0	Refinery & Lubricant Oil Industry Max. 15.0
Formaldehyde	,,	Max. 1.0	
Phenol & Cresols	,,	Max. 1.0	
Free Chlorine	,,	Max. 1.0	
Insecticides	,,	none	
Radioactivity	Becqurel/l	none	
Heavy metals			
Zinc (Zn)	mg/l	Max. 5.0	Zinc Industry Max. 3.0
Chromium (Cr)	,,	Max. 0.5	Zinc Industry Max. 0.2
Arsenic (As)	,,	Max. 0.25	
Copper (Cu)	,,	Max. 1.0	

Table 3 (continued)

Items	Units	Standard value	Remarks
Mercury (Hg)	,,	Max. 0.005	Zinc Industry Max. 0.002
Cadmium (Cd)	,,	Max. 0.03	Zinc Industry Max. 0.1
Barium (Ba)	,,	Max. 1.0	
Selenium (Se)	,,	Max. 0.02	
Lead (Pb)	,,	Max. 0.2	
Nikel (Ni)	,,	Max. 0.2	Zinc Industry Max. 0.2
Manganese (Mn)	,,	Max. 5.0	
Silver (Ag)	,,	—	Zinc Industry Max. 0.02

Penalty: A licensee for operation a factory who dose not comply with this notification shall be punished by fine not exceeding ten thousand baht.

Source: (1) Notification of the Ministry of Industry No. 12, B.E. 2525 (1982) issued under the Factory Act B.E. 2521 (1978), published in the Royal Government Gazette, Vol. 99, Part 33, dated March 5, B.E. 2525 (1982).

(2) Notification of the Ministry of Industry No. 10, B.E. 2521 (1978) issued under the Factory Act B.E. 2521, published in the Royal Government Gazette, Vol. 95, Part 132, dated November 28, B.E. 2521 (1978).

Table 4 Domestic Effluent Guidelines (Drafted standards)

Parameters	Units	Domestic Effluent Standards for Community group-(persons)			
		A (<101)	B (101-500)	C (501-2500)	D (>2500)
1. BOD_5^{20}*	mg/dm^3	90	60	30	20
2. Solids					
2.1 SS	"	60	50	40	30
2.2 Settleable S.	"	0.5	0.5	0.5	0.5
2.3 TDS**	"	+500	+500	+500	+500
3. Sulfide	"	4.0	3.0	1.0	1.0
4. Free Residual Chlorine***	"	—	—	0.3	0.3
5. Nitrogen					
5.1 TKN	"	40	40	—	—
5.2 ORG-N	"	15	15	10	10
5.3 NH_3-N	"	25	25	—	—
5.4 NO_3-N	"	—	—	—	—
6. pH	—	5-9	5-9	5-9	5-9
7. Oil & Grease	mg/dm^3	20	20	20	20
8. Fecal Coliform	$MPN/100\ cm^3$	—	—	—	—
9. Phosphate	mg/dm^3	—	—	—	—

* Settled BOD (30 min)

** more than TDS of used water

*** Maximum allowance under epidermic condition only

4. SEWERAGE IN BANGKOK.

BMA has the duty to implement sewerage in the city as part of the city infrastructure which the administration is held responsible for by the law.

Three sewerage master plan studies have been conducted to prepare sewerage plan in Bangkok since 1967 but only a fraction of the plans has been implemented. Even currently there is yet another study under way to find out the practical solutions which might suit the unfavourable circumstances which obscure the need for water pollution control.

4.1 CDM MASTER PLAN

The first sewerage master plan was prepared in 1967 by an american engineering consulting firm employed by the Government of Thailand through the Ministry of Interior. The plan proposed only one very large treatment plant serving the whole city. The sewerage system which covered 360 sq.km. would cost about 3,900 million Baht without the treatment plant. The treatment plant was not considered essential at the early stage of implementation. It was suggested that a suitable method of treatment should be chosen after a pilot plant study at a construction site which was actually prepared for but the pilot treatment plant has never been constructed. The sewerage plan was laid out in conjunction with storm-water drainage and flood protection system which escalate the total investment plan to 11,300 million Baht (see Table-5). This large investment figure without detail break-down of cost items might have been the cause of difficulty to follow the plan which allow rather little flexibily of implementation.

Table - 5. CDM Master Plan
at 2510 (1967) price level

Item	Million Baht
Sewerage System	3,900
Storm-Water Drainage System	3,500
Flood Protection System	3,900
Total	11,300

Note: Sewerage System has no treatment plant

4.2 JICA MASTER PLAN

The second master plan was completed in 1982 with the help of the Japanese Government. This plan has 10 zones with 10 treatment plants to distribute the hydraulic load and the pollution load to various stretch of the river. The new plan also allow smaller main sewer pipes and a more feasible plan was proposed. The second master plan covered 370 sq.km. which is

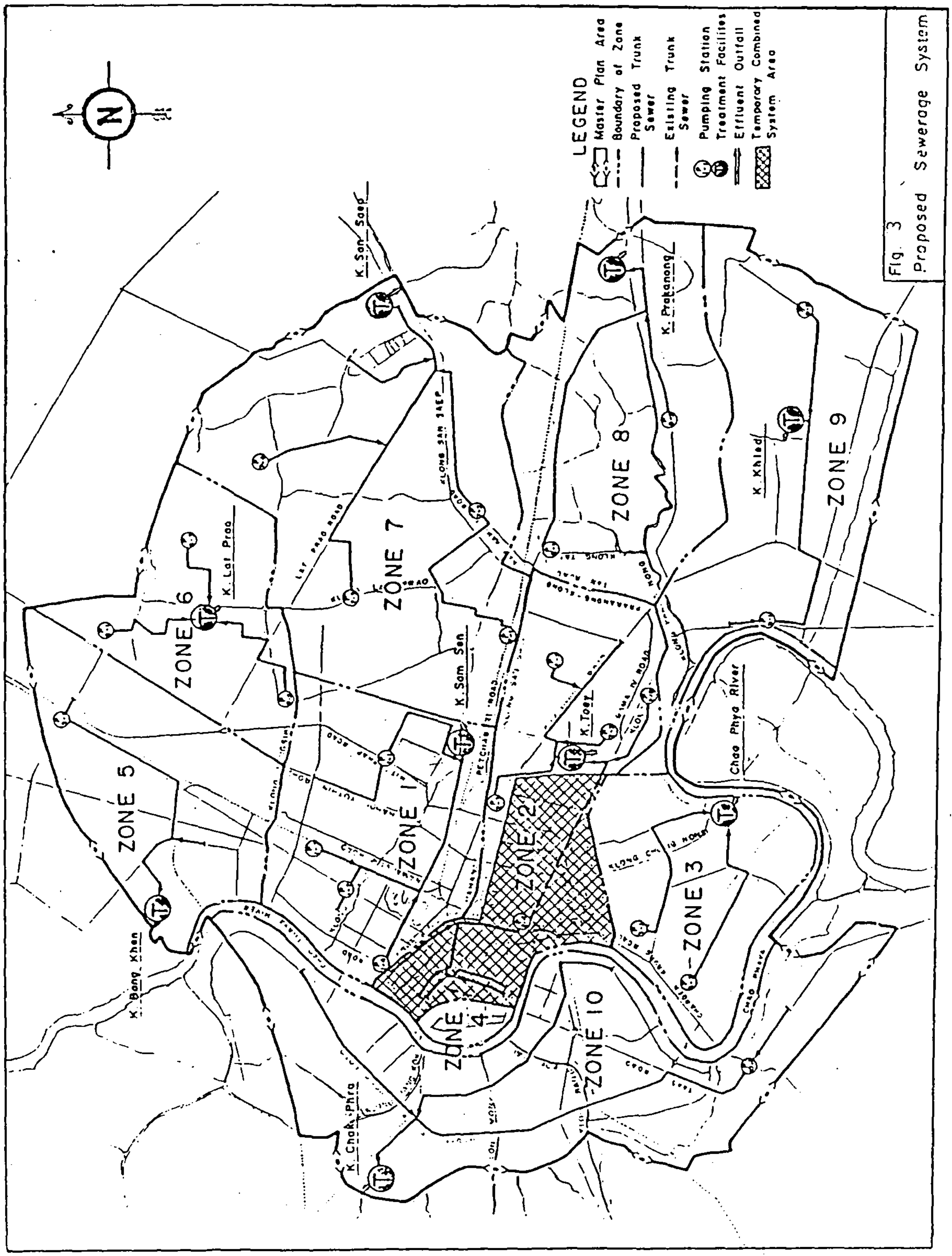


Fig. 3 Proposed Sewerage System

Table 6 Estimated Future Population and Wastewater Flow, 10 Sewerage Districts

	Sewerage District	Area (km^2)	Year: 2523 (1985) Population Served	Wastewater Flow, m^3/day Average	Peak	Year: 2543(2000) Population Served	Wastewater Flow, m^3/day Average	Peak
1.	Thonburi	61	235,000	36,200	90,600	432,000	103,000	224,000
2.	Construction-Government	12	170,000	26,200	72,500	295,000	70,000	173,000
3.	Sathorn-Rama IV	16	180,000	27,700	77,700	319,000	76,000	177,000
4.	Chan Road	24	190,000	29,200	82,000	349,000	83,000	181,500
5.	North West	43	250,000	38,500	95,000	460,000	109,500	242,000
6.	Sukhumvit	23	130,000	20,000	60,500	223,000	53,000	147,000
7.	North Central	48	230,000	35,400	88,000	416,000	99,000	225,000
8.	North East	50	130,000	20,000	60,500	235,000	56,000	155,500
9.	South East	67	195,000	30,000	83,700	346,000	82,500	180,000
10.	South	26	90,000	13,900	43,200	165,000	39,200	95,000
	Total Master Plan Area	370	1,800,000	277,100	554,000[1)]	3,240,000	771,200	1,382,000[1)]

1) Total peak flow is not the sum of the peak flow of each area.

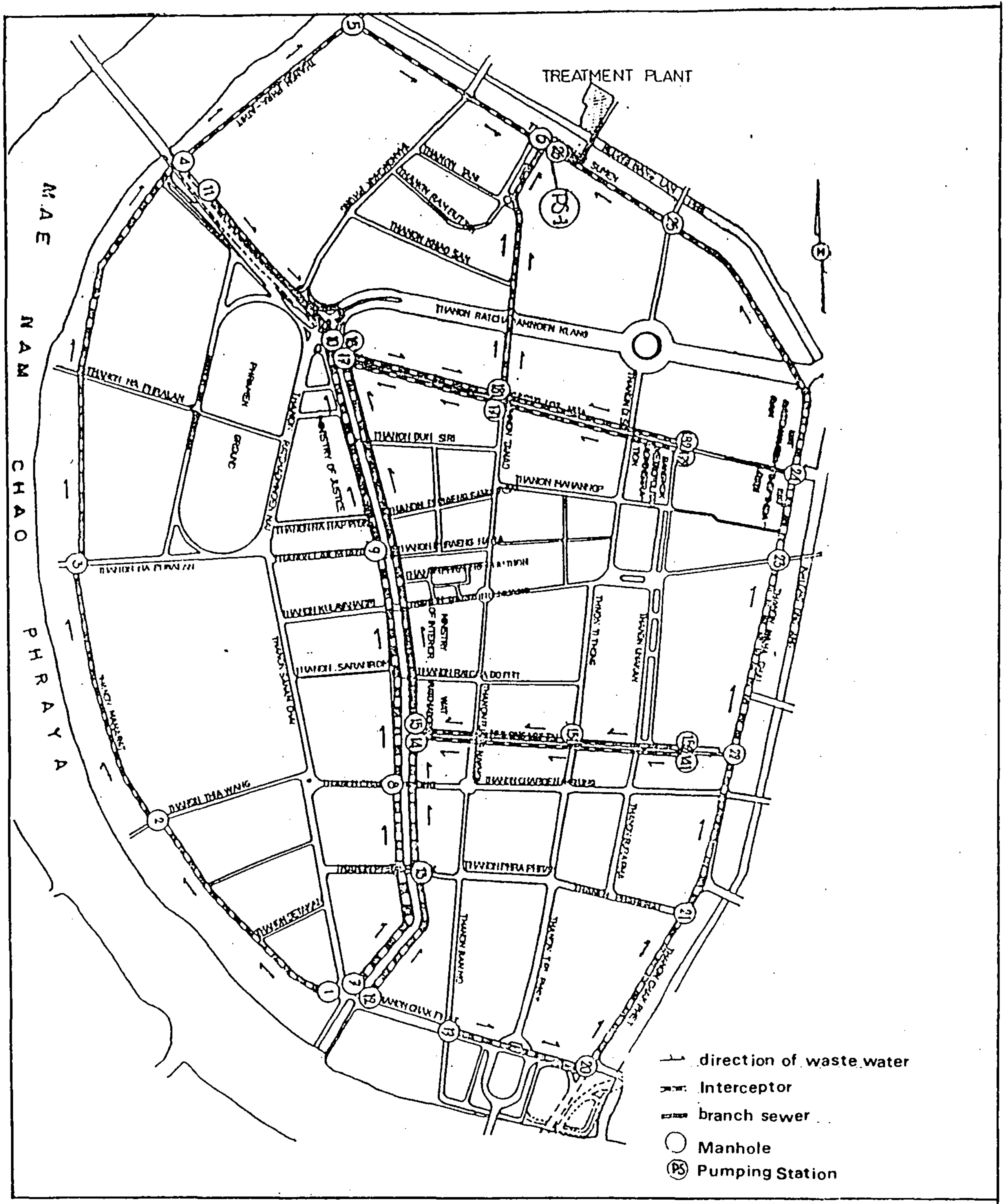
only slightly larger than the CDM plan. Inspite of the advantage of having shorter and smaller main sewers, the new master plan had a price tag of 36,671 million Baht. The huge price figure is due to the fact that the plan has included all the 10 sewage treatment plants, pumping station etc. and also 12,419 million Baht worth of house connections to serve a population of 5.6 million. A general information of the plan are show in Fig-3 and Table-6.

The treatment methods proposed for this plan are aerated lagoons (A.L.) for the suburban catchment areas and high rate or modified activated sludge systems (M.A.)for the urban catchments. The calculated per capita investment of the project was between 3,000-4,000 Baht. The JICA plan envisage that, the availability of construction site is most significant. If land is not available the plan cannot be realised. The high priority treatment plants had been located at vacant sites owned by government agencies such as the State Railway and the Thai Tobacco Monopoly in the hope that the government will see the importance of sewage works and allow the BMA to utilise those sites for such a purpose. However, the implementation has not yet been brought to the attention at a proper level of administration (i.e. the Ministries concerned or the Cabinet).

4.3 RATANAKOSIN PROJECT

Another implementation plan for sewerage at a smaller scale was conducted directly by the Department of Drainage and Sewerage of the BMA. This project is called "Ratanakosin Project" which includes not only sewerage but also canal improvement. The project was proposed because the target area is a historical center of Bangkok. Many government agencies and famous temples can be found in the project area. The major canals in this district are Klong Lord and Klong Padung krungkasem which function not only as borders of the city but also as water traffic street for transportation. Therefore, this area of the city deserves a special attention. The project was proposed to maintain the district and the canals as a kind of historical park with turist attractions and well reserved environment (see Fig.4). The estimated per capita investment of this project was only about 1,000 Baht which is much lower than the JICA master plan, however, due to the shortage of budget, all the projects mentioned above still far away from reality.

In order to over-come the budget problem, the BMA is trying to find ways and means to privatise this project by using the land value as an asset to attract a private investor. The BMA was assisted by an Engineering consultant SEATECH of Bangkok to draft a construction plan according to the prevailing building code which indicated that a 6 storey building can be built on to of the sewage work at the 6,400 sq.m construction site to yield 6,560 sq.m useful space plus 2,328 sq.m parking space (see Fig 5). The BMA is now in the stage of finding a number of investors who would put the building into a profitable business which would make the income high enough to cover the investment and the



Fig·4 Ratanakosin Project

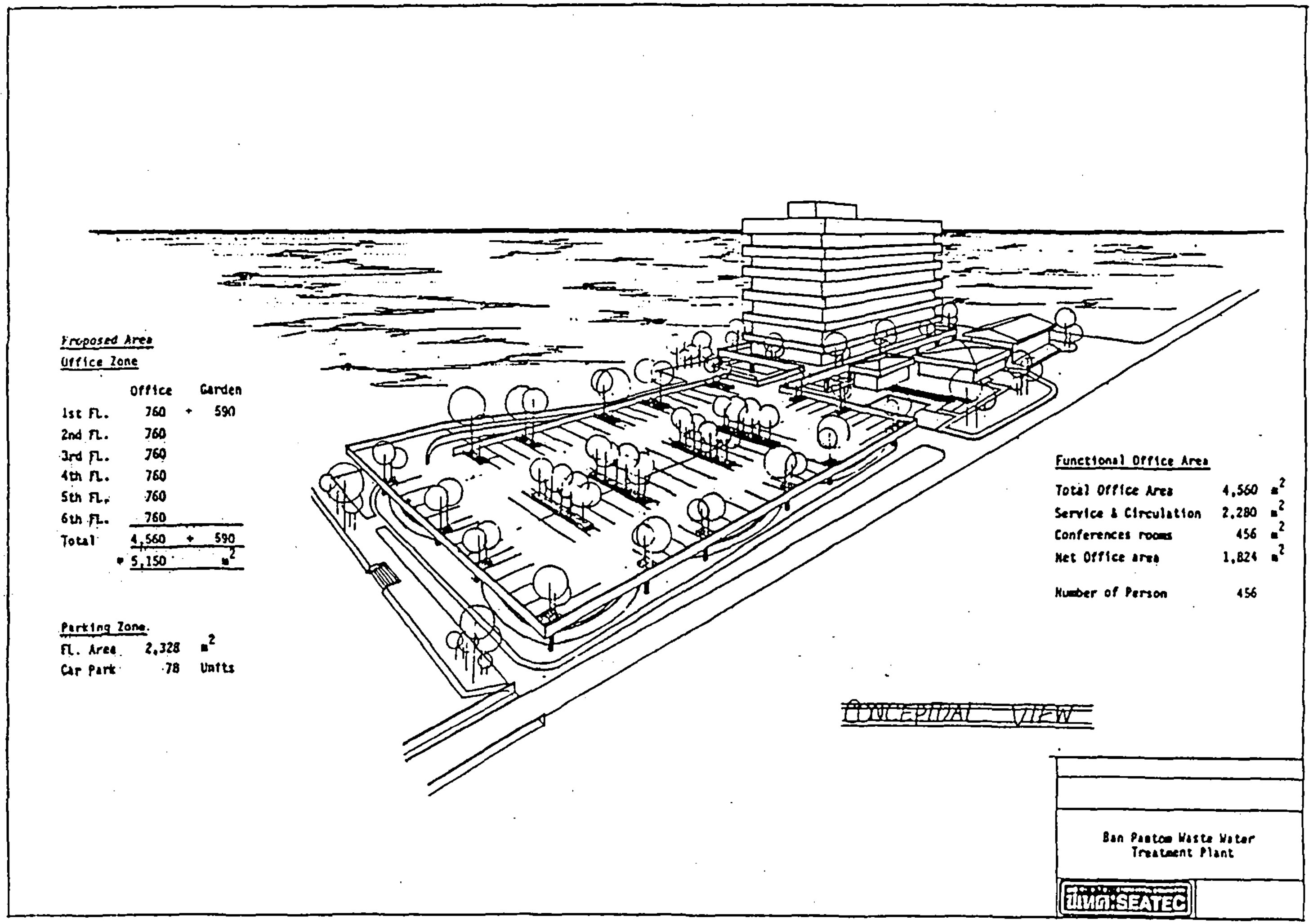


Fig. 5 Rattanakosin Sewage Work as proposed by SEATEC

sewerage operation cost.

4.4 KLONG PURIFICATION PROJECT

Recently a new study project has been brought in to action according to the request of the BMA to Government of Japan with the hope that there would still be some other approaches to stop the aggravation of the water pollution problems urgently. Klong Purification Project is the title of a new study which is to be completed in 1989. The Progress Report(1988) of the study suggested two approaches:

a. Introduction of fresh water from Chao Phraya River into the polluted canals to dilute the pollution.

b. Construction of simple treatment of polluted water using surface aerators(aerated lagoon).

The objective of this study is to find ways and means of utilising the retention ponds and pools of water in the right of way of the canal system which are to be built under the flood control schemes also to purify the polluted water during the dry seasons by simple technical means such as mechanical aeration as a short term implementation plan.

However, the urgent measure mentioned above will also be short-term in nature,because an aerated lagoon will be able to handle only one tenth or one twentieth of a full scale sewage work of the same volume while the energy consumption of the aerated lagoons are either the same or even more. The limitation of discharge capacity of the canals at various bottle necks (see Fig.6) also pose additional problems on the dilution approach.

4.5 MAKKASAN POND PROJECT

Makkasan pond was originally proposed in the JICA master plan to be the location for the sewage work zone 1 to treat about 0.3 million cu.m. sewage. Th pond is 2,380 m.in length 50-70 m. wide and 1.5 m. deep. The MBA has followed H.M.the King's advice to turn this pond into a natural purification pond utilising water weed such as Water hyacinth, Hollow Salad (Pak Bung) and Water Crest (Paka ched). This pond is receiving the over-flow from Klong Samsen and help buffering the rising level in that canal when there is a heavy rain-fall. According to the findings of the AIT (Orth,1987),a water hyacinth pond can handle up to 180 kg BOD/ha.d with 70% BOD removal efficiency. In such a condition the Makkasan pond can be used to disposed of the waste water from up to 150,000 people. The pond is now under constant supervision by the BMA.

4.6 TRANSFER OF NHA SEWAGE WORKS TO BMA

The National Housing Authority is unmistakably the most law-abiding land developer in Thailand. The NHA planned and built sewage treatment plants for every housing estate or land

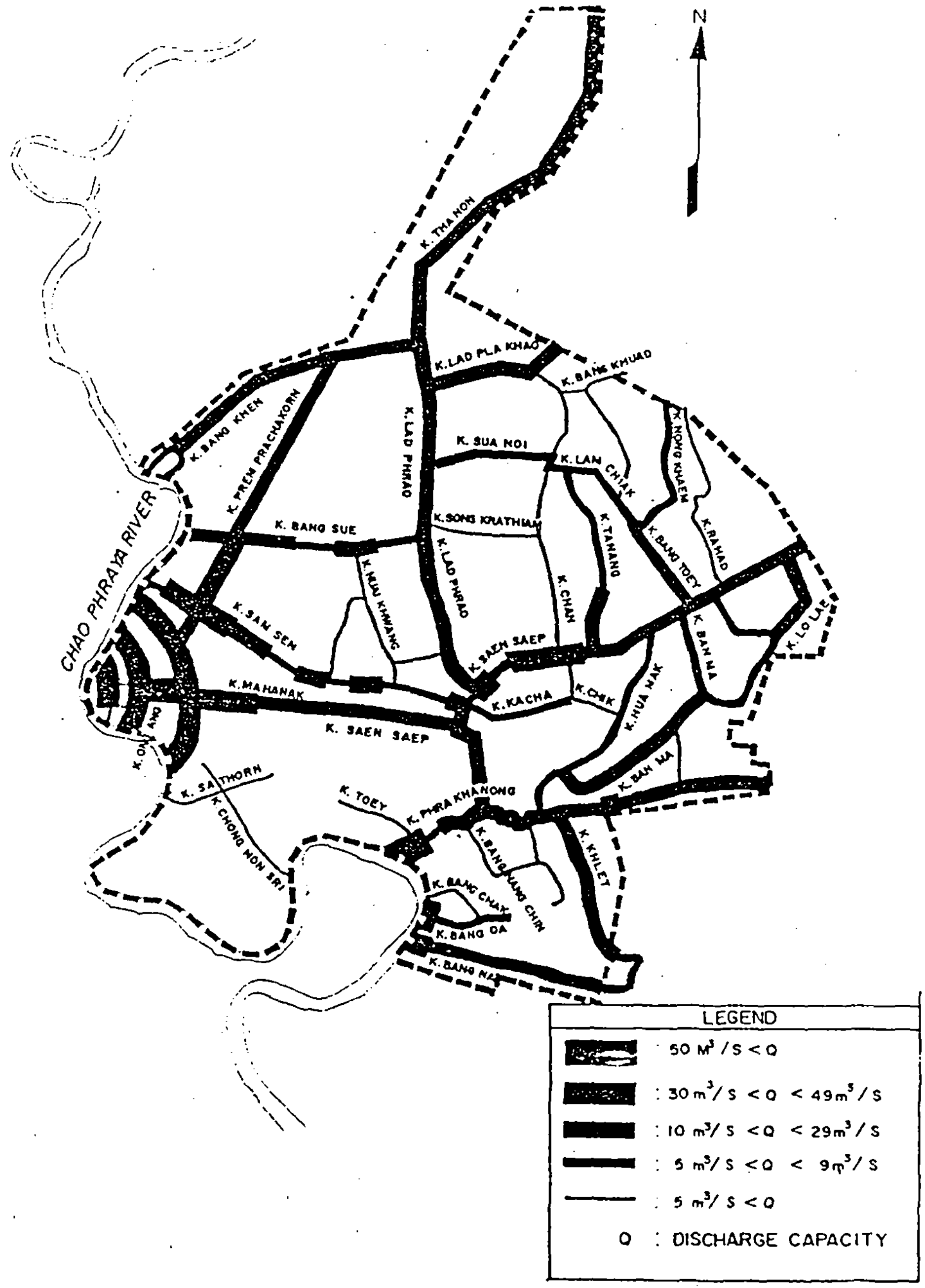


Fig. 6 CALCULATED MAXIMUM DISCHARGE CAPACITY OF MAJOR KLONGS

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

JICA 2532B.E. 1989A.D.

subdivision projects since the beginning of the agency.

The BMA realise that the pioneering work of the NHA on such a provision has been quite a burden to the Authority which had been established specifically to solve the housing problem not infrastructure problems which require continuing maintainance. The BMA, therefore, cooperates with the NHA to take over the maintainance of many infrastructures constructed by the NHA; such as roads, schools and also sewage works. It is planned that the BMA will take over the operation and maintenance of the following sewage works within BE 2531:

name	capacity cu.m/day	running cost Baht/year
Huay kwang	3,000	1,165,688
Klong chan	5,000	1,865,908
Bang na	1,350	413,813

Other works will also be gradually transfered. New sewage works of the NHA will be planned in cooperation. It is hope that future take-overs by the BMA will be immediately after the construction is complete.

5. SUMMARY

The Bangkok Metropolitan Administration realise the water pollution and the need for sewerage. The existing master plan indicates that the level of investment of this sector will be about 3,000-4,000 Baht per capita or about 20,000 million Baht which is beyond the financial capability of the administration. Therefore, the so called "standard implementation" will be applied only to some special areas.

The budget constraint compels the administration to use other less expensive alternatives such as canal flushing, natural purification and also the application of stringent building control regulations to cut the effluent load from concentration points such as market places, restuarants, hotels etc. which can utilise on-site treatment systems and donot need to build expensive under-ground sewers.

6. REFERENCES

Asian Engineering Consultants CORP./LTD. 1982 "Canals Improvement in Ratanakosin Area Project", Technical Report, Vol.2, Sanitary Engineering, 1982.

BMA 1987 "The Third Bangkok Metropolitan Development Plan (BE 2530-2534)", Policy and Planning Department, Bangkok Metropolitan Administration.

CDM 1967 "Master Plan, Sewerage, Drainage and Flood Protection Systems; Bangkok and Thonburi, Thailand" February 2511 BE, Camp Dresser and McKee, Boston, Massachusetts, USA.

JICA 1981 "Bangkok Sewerage System Project in Kingdom of Thailand" August 2524 BE, Japan International Cooperation Agency.

JICA 1988 "Purification of klong water in Bangkok", Progress Report, July 1988, Japan International Cooperation Agency.

NEB 1986 "Laws and Standards on Pollution Control in Thailand", Environmental Quality Standards Division, Office of the National Environment Board.

ORTH 1987 "Introduction Briefing upon the visit of Deputy Governor of BMA's visit to the Hyacinth Pond System at the AIT", Pratumthani, Thailand, by Dr.-Ing. H. Orth.

==August 24, 1988

SEWERAGE AND SANITATION MASTER PLAN FOR METRO MANILA

Teofilo Asuncion

Metropolitan Waterworks and Sewerage System
Republic of the Philippines

SEWERAGE AND SANITATION MASTER PLAN FOR METRO MANILA

The Metropolitan Manila area, over the past decade have become the center of culture and tourism and the symbol of high quality of life in the Philippines. In recent years, improvements have been made in nearly every aspect of life except sewage disposal.

The Metropolitan Waterworks and Sewerage System, the country's premier water supply and sewerage agency recognized the problem and in 1979 formulated a Master Plan for wastewater disposal and sanitation improvement within its service area. The Master Plan was directed to the immediate improvement of public health and quality of life of the people of Metropolitan Manila with emphasis to those belonging to the urban poor.

EXISTING FACILITIES BEFORE THE MASTER PLAN

The existing sewerage system in Metro Manila comprises of the Central Manila Sewerage System and other isolated independent systems.

The existing Central Manila Sewerage System covers an aggregate service area of 1,850 hectares. Most of the facilities were constructed before 1909 and originally intended to serve about 220,000 people with an overload capacity to serve 450,000 people. This system serves 530,000 people.

The system consisted of laterals and interceptors, ranging from 150 mm to 1500 mm in diameters with a total length of 240 kilometers, seven lift stations, a main pump station, and a sewer outfall to Manila Bay.

Although minor extensions and improvements were made on several occasions in the past, the construction of major expansion of the system has been neglected due to financial difficulties. The sewer pipes were very old and overloaded. Tremendous infiltration have been noted. Nearly all equipment including pumps, bar screens and switchgears were obsolete and in poor condition. The outfall to Manila Bay was 2 kilometers long, however the reclamation in the area caught up with it so that the discharge of sewage took place near the mouth of the Pasig River.

The other isolated sewerage systems in Metro Manila are in Quezon City and Makati. These are located mostly in housing subdivisions and commercial districts and serve about 350,000 people. The total length of interceptors, laterals and mains in these areas are about 140 kilometers.

Large portions of the remaining areas are served by septic tanks discharging to storm drains and drainage ditches that flow to creeks, esteros, rivers and finally to the Manila Bay.

MASTER PLAN

A Sewerage and Sanitation Master Plan for Metropolitan Manila was completed in 1979. The Master Plan consists of two major components which are:

1. A sewerage program that will provide an affordable scheme for the collection, treatment and disposal of sewage in the Metropolitan Manila area including improvements to the quality of water in Manila Bay and its tributary rivers.

2. A parallel sanitation program which is an interim action program considered to be cost effective method of achieving a quick and dramatic improvement in the sanitation, public health and quality of life of the people within the service area particularly in the densely populated low income areas.

In the preparation of the Master Plan, four options were considered: (1) No action; (2) Public Health program only; (3) Staged sewerage improvement with emphasis on sanitation for public health; and (4) Full conventional sanitary sewerage system.

Option No. 1, No action: In this option, the status of the wastewater and sanitation facilities will remain as is. Water quality will continue to deteriorate as Metro Manila grows. There will be increasingly serious public health problems in markets, public areas and residential areas as population increases and the water system is expanded.

Option 2, Public Health Program only: In this option, existing sanitary sewers would accept new connections until capacity is reached. No provision would be made for treatment, or disposal of wastewater. Sewage would be drained from densely populated areas utilizing new and existing storm drains. This program would provide improvements to public health, markets and public areas. It would plan the utilization of watercourses as sewers and ensure the continued deterioration of water quality as the population increases. The shell fishing industry will be endangered and the Manila shoreline will be eliminated from consideration as a bathing beach or recreational area. This option is an irreversible commitment to utilizing the rivers and esteros as combined sewers.

Option 3, Staged Improvement with Public Health Emphasis: This option provides staged construction of separate sanitary sewers in some areas while continuing the use of existing combined systems throughout their economic design life. Some expansion of combined sewers may occur initially. This plan recognizes and plans for delays in water quality improvements. Dry weather pollution control is possible in areas served by combined sewers and investments in infrastructures are minimized and provide for future conversions to a separate sewerage system. In this option particular attention is given to low cost systems for low income areas in order to serve the maximum number of persons at an acceptable level of service for a given investment. The population served is thereby maximized for any given level of investment.

Option 4, Full Collection, Treatment and Disposal: In this option, sanitary sewers would collect all sewage in Metro Manila and transport it to treatment and disposal facilities to meet public health and water quality objectives. Ultimately, this plan maximizes the quality of life in Metro Manila. Implementation of this program can proceed at a rate determined by the level of investment desirable when compared to other national investment needs. This objective is the most expensive one considered.

Each of the options was analyzed on its effect on quality of life and receiving waters, poverty pockets program, combined and separate sewerage systems, cost per capita, etc. The results of these analyses showed that Option 4 or full conventional sanitary sewerage system for the entire study area would have been the most ideal plan as this option meets government requirements on pollution control. However the cost of such a program of well over $2.2 Billion or approximately $200 per person is very prohibitive and non-affordable. Option 3, utilizing and expanding the existing combined sewers for a large portion of the study area with emphasis on public health, appears to be economical, affordable and a most practical solution. The Master Plan was, therefore, scaled down into a Year-2000 Objective Plan with implementation to be staged into manageable action programs.

In the development of the Master Plan, 21 alternative plans were originally evaluated using a computer model. The alternatives were developed based on technical and topographical considerations. Population and area served present worth analysis of construction and operating costs and cost per capita of each alternative was determined.

The number of alternatives was reduced to only 13 most promising alternatives which were then further evaluated and rated using the following factors:

1. Enviromental effectiveness
2. Quality of life and health benefits
3. Implementation capability and flexibility
4. Operational effectiveness
5. Investment impact.

The alternative selected which becomes the Sewerage Master Plan was the most practical solution and cost effective. It consists of rehabilitation of the existing central sewerage facilities, expansion of the collection systems to the north and south, disposal of the sewage through outfalls into Manila Bay and the provision of combined sewers in the surrounding areas of the Metropolitan Manila area. The Master Plan provides for the collection, treatment and disposal of sewage for approximately 51,700 hectares and a parallel, interim sanitation program to cover the remaining 141,000 hectares of the entire water supply service area.

Metro Manila Sewerage and Sanitation Project

The Year-2000 Objective Plan, as developed, was geared towards an orderly and progressively staged program of construction of facilities, but always in keeping with the Master Plan. As conceived, the Year-2000 plan would consist of a Sewerage component and a Sanitation component.

Sewerage Component

The sewerage component of Year-2000 plan maximizes the utilization of existing investment in combined systems, rebuilds and improves the existing Central Manila system, expands the sewer system to the north and south with disposal initially by outfall sewers to Manila Bay. The Plan will eliminate public contact with sewage, help abate pollution of beaches of the Bay, optimize investments by programmed treatment of sewage as will be indicated by continuous monitoring of Manila Bay and other receiving waters, control industrial discharge on a rational basis and reduce the rate of water quality deterioration in Metro Manila.

Sanitation Component

PROGRESS, which is the acronym for Program to Reduce and Eliminate Sewage from Streets, is the sanitation component of the Year-2000 plan. It is basically a minor drainage scheme devised to alleviate public health problems caused by presence of sewage in ponds and random open ditches adjacent to streets, houses or public area throughout Metro Manila. It is intended to provide immediate sanitation improvements in densely populated low income areas now suffering from acute sewage related public health problems.

The existing system of septic tanks and aqua privies with overflows to street drains, which is the predominating wastewater system in the large unsewered portions of Metro Manila, was studied in greater detail. It was found that the street drains often became clogged with solid waste and other debris, resulting in the overflow of the septic tank effluents onto streets with resulting public health and disease transmission hazards. Lack of properly designed drains and poor maintenance also was found to create public health problems.

Practically all known alternative low cost sanitation programs used in other parts of the world were evaluated in order to determine if a new approach might be more appropriate for the population densities and conditions of Metro Manila.

The conclusion reached is that the low cost sanitation schemes under trial in other parts of the world are not necessarily applicable to the Metro Manila situation. The sanitation program that was developed is considered to be the best system for a large portion of Metro Manila. It consists essentially to improvement and continued use of individual septic tanks and street drainage. It is estimated that the septic tanks themselves provide pollution reduction of 30 to 50 percent when the tanks are of sufficient size and properly maintained. Street drains are necessary in Metro Manila because of heavy rains during the monsoon season. Their use for transport of septic tank effluent, therefore, takes advantage of the natural drainage system required, and there is the added benefit of an effective cleansing action during the rainy season.

The recommended sanitation program also includes two major components: (a) A septic tank pumping program will be carried out in order to improve the functional capabilities of the existing septic tanks for pollution abatement; and (2) The street drainage system will be improved so that drains will no longer become filled with solid waste and street debris. Septic tank effluents will be carried away without the public health problems of sewage in the streets.

Metro Manila and its environs were surveyed and area-graded on a four point scale relative to health hazards. The four point scale are as follows:

Class 1 - No hazard area where likelihood of human contact with untreated sewage is almost nil.

Class 2 - Moderate hazard area where minor human contact with untreated sewage is possible.

Class 3 - Significant hazard area where minor human contact with human contact with untreated sewage exist.

Class 4 - Great hazard area where the public has difficulty in avoiding contact with raw sewage running over open ground surface.

A total of 812 hectares of Class 4 area and 2,563 hectares of Class 3 area has been identified in Metro Manila and three other MWSS service municipalities namely: San Mateo, Taytay, and Cainta. The Plan is all of the Class 3 and Class 4 areas scattered at random in Metro Manila will be upgraded to Class 2 status.

Construction Program

Three (3) construction programs which are independent of each other were developed. These are METROSS I, METROSS II and METROSS III. METROSS is an acronym for Metro Manila Sewerage and Sanitation Project.

METROSS I - First Stage

METROSS I would rehabilitate the existing Central Manila Sewerage System plans expansion in the north (Dagupan) and in the south (Pandacan), construct new main pump stations, extend the outfall to about 3.9 kilometers into Manila Bay, construct PROGRESS (minor drainage work), pilot public sanitation facilities, conduct septic tank maintenance program and conduct extensive monitoring program in cooperation with the National Pollution Control Commission in order to determine the nature, timing and sequence of construction of a proposed sewage treatment plant.

The cost of METROSS I is ₱1,200.0 Million. Foreign financing is by the World Bank in the amount of $36.5 Million and the Asian Development Bank in the amount of $42.8 Million. Peso counterpart amounts to ₱320.0 Million.

METROSS II - Second Stage

METROSS II would expand the sewerage system to the southern portion of Metro Manila, and provide direct sewer service to an area of about 3000 hectares and sewer mains capacity for an additional area of about 4000 hectares. The direct service area to be served is Guadalupe, Makati, part of Manila, Pasay, the reclaimed area, part of Parañaque. Capacity will be provided for sewage flows from Ft. Bonifacio, Nichols AB, and southeast Parañaque. The total population to be ultimately served by the Southern system is estimated to be 1.5 million persons in the year 2000.

This sewerage service expansion would greatly reduce wastewater discharges to the Parañaque and Pasig Rivers which originate from the areas to be served, and aims to improve public health conditions in these areas. This expansion will involve the design and construction of approximately 80 km of trunk sewers and interceptors in sizes up to 2.2 meter diameter, 400 km of sewer mains and laterals, several intermediate sewage lift stations, a terminal pumping facility with a peak capacity of 8.4 cu.m. per second (185 mgd), a new submarine sewer outfall of twin 1.8 meter diameter pipes 5 km long, minor drainage systems, and ancillary works.

The cost for METROSS II is estimated at ₱7,000 Million, including provision for escalation.

The minor drainage program would be completed under METROSS II and would benefit people in other unsewered areas of Metro Manila.

METROSS III - Third Stage

METROSS III would expand the sewerage system to the Northern portion of Metro Manila covering about 34000 hectares. This stage aims to reduce wastewater discharges to the Tullahan-Tenejeros River and north shore of the Pasig River. This stage will include trunk sewers, interceptors, laterals and sewer mains, intermediate sewage lift stations, a main sewage pump station, a submarine sewer outfall and ancillary works. METROSS III would be another major expansion of the sewerage system in Metro Manila and the improvement would benefit about 1.6 million people. The cost of this stage is estimated at ₱10,000 Million.

FINANCIAL AND ECONOMIC ISSUES IN THE PROVISION OF SOLID AND LIQUID WASTE DISPOSAL

Michael Lindfield

Sinclair Knight and Partners

FINANCIAL
AND ECONOMIC ISSUES IN THE PROVISION OF
SOLID AND LIQUID WASTE DISPOSAL

Michael Lindfield

With 30 minutes to speak, I will confine myself to making only the major points which I think are relevant to this topic.
I am breaking this talk into three main parts after an introductory look at the current situation and its consequences. These three areas are:

Financing Systems
Political/Administration Systems, and
Technical Issues

What is the current situation in Thailand with respect to sewerage and waste disposal?
The National Policy context has clear objectives. The Sixth National Economic and Social Development Plan (Urban and Specific Areas Development, Chapter 3, Section 3.6) aims to "lay down master plans including strategies and measures for urban environment conservation and pollution control, particularly with regard to water resources and liquid and solid waste" for each of the Regional Cities in Thailand.
The responsibility for implementing projects in these areas rests, however, with local government.

So what is the situation with local governments in Thailand?
Administering cities of between 40,000 and 200,000 people the Regional Cities Municipalities have severely limited budgets and a wide range of services they must already provide. Besides most roads, drains, bridges, and markets, primary schools, the fire brigade, and some health care services, the municipality must provide for solid waste collection and disposal. <u>All</u> of these facilities are underprovided in the context of rapid economic growth and the desire to increase the attractiveness of these cities as investment centres in order to slow the growth of the BMR.

Financially, the cities derive about 30% of their revenues from local tax sources, mainly from property tax. The remaining 70% comes either in the form of grants or from a share of taxes collected by the central government in the area. Average expenditure per person is approximately ฿ 1,000 per annum. Given that resources are very tight, and that no standards (enforceable or otherwise) of service provision and maintenance exist, there are several consequences

1) Maintenance expenditure is minimized
2) New capital works are designed to provide the most tangible benefit for the least cost. In this respect roads are better than solid waste because they immediately provide a benefit where as a new solid waste site provides no tangible benefit. Solid waste sites with no environmental safeguards are better than sites with such safeguards, because they are cheaper.

3) New areas of service provision eg. waste water treatment are <u>very</u> unpopular because, under the existing financial system, they take resources away from more visible and traditional areas.

You may argue that the above should not be the case, but I maintain that it is a logical response to the current financial and political system . If you wish to make changes in the output of the existing system you must know the mechanisms that operate within that system. It is these mechanisms we will address in the following sections. Firstly, however, I would like to set the current situation a little more by looking at some numbers.

Regional cities have accurate data on solid waste collection. Most systems cost about ฿ 100/person to operate in each year, although Chonburi at ฿ 180/person/year is expensive. Typical figures on cost recovery are ฿ 1.1 mill recovered on an expenditure of ฿ 13.9 mill (8%) for Hat Yai, and ฿ .3 mill recovered out of an operating expenditure of ฿ 7.8 mill (4%) for Chonburi. So if you suggest a ฿ 200 mill waste water treatment for Chonburi you are asking for an expenditure of four times the city's annual budget and a debt service burden of half the city's annual budget. This from a municipality which can collect only 4% of the cost of an established service. It is true that the fees are for cost recovery, fixed by the central government but these figures are indicative of expected performance unless significant institutional change occurs.

In the Sixth Plan, Municipalities are encouraged to become more 'self-reliant' in particular to "bear the investment burden of urban infrastructure development along(sic) the principles of financial capability, cost recovery and benefiting change". Just how far towards 'cost recovery' are we at present? I would like to use examples of solid waste collection in two of the Regional Cities and in the BMR.

With the above background, we can go into more detail on financial and other systems which the municipalities are stuck with and which have to be changed if new and better infrastructure projects are to be implemented. Such infrastructure as solid waste systems and waste water treatment have long-term benefits for the society as a whole. The problem is that these benefits are diffuse and are incurred often by the next generation, only as a result of significantly changing the behaviour of a specific group of people. The costs are borne by that specific group of people. One can argue that, for example, these people shouldn't have been dumping sewerage into the river in the first place. The reality is, they don't see it that way, the status quo is the standard. Doing better than that standard is fine provided someone else pays for it or there is a significant short term benefit to balance the cost. Only where, using the same example, the people down stream find their fish catch disappearing is it possible to develop a constituency for application of standards. But the problem of differing incidence of costs and benefits remains.

Financing Systems

Obtaining money for infrastructure, particularly less politically glamorous infrastructure, is the constant occupation of local government engineers. Sometimes these engineers do not understand the financial context in which they work. We will pass over the macro-economic problems of debt service ability, exchange rate policy and government fiscal deficits which can have a dramatic effect on the budgets and costings of these engineers and concentrate on the day-to-day business of who gets what money is available.

When addressing the issues of money availability we all too often think of money for capital works. Such works should, in fact, be thought of as an initial capital expense and a stream of operations and maintenance (O+M) expenditures over the life of the project
This is reflected in financial statements which separate out capital from O+M expenditures. Thailand's Regional Cities have a financial system which is capable of doing this on a Divisional basis, but which is not backed by records for individual infrastructure items or a regular O+M programme, although such a programme is being developed in four of the cities. Further, there are no standards of maintenance required or reporting as to performance against those standards. The tendency is thus for very little to be spent on maintenance. Infrastructure then tends to deteriorate to a point where it must be 'upgraded' (another capital expense).

Without such records and standards it is very difficult to estimate required levels of resources (money) for local government. The split of tax revenue between central and local government is therefore a matter for negotiation with the central government holding the upper hand. In fact, because of increasing demands and pressures on central budgets, the thrust of current policy is to devolve responsibility for funding to local governments. In Thailand, NESDB wishes to see the share of locally raised funds increase from 30 percent to 40 percent.

Services, like waste disposal and waste water treatment, can be paid for out of local general revenue, or from a specific fee levied on the user of the service or from a combination of both. Faults in the current systems make the shortfall in cost recovery very great as we have seen above. These faults are common to fee and general revenue and may be summarized as:

1) Lack of documentation
2) Lack of collection staff
3) Level of exemptions
4) Low levels of fee/tax assessment
5) Lack of policing power

Examining each of the above in turn:

1) Lack of documentation

Lack of adequate maps for property tax has been a problem in Thailand, but is being overcome by an extensive programme of tax mapping. This has brought some collection benefits. Similarly, for fee-based systems, records of house holders need to be kept up-to-date. A computer-based central record would be most efficient, but an effective system of notification of change of registration-address/owner operated between the municipality and the Department of Lands would be as effective. The problem with fee-based systems operated separately from the main property tax rolls is the increased cost of collection.

2) Lack of collection staff

Finance divisions often get the job of collecting all fees as well as main property taxes. These numerous fees take much time to calculate, to collect and to answer questions about. Unless this is done, or avoided by levying taxes in a different way, lack of collection will be a major problem,.

3) Level of exemptions

Property taxation in Thailand is shot through with exemptions which are both inefficient from the point of view of the municipality which must expend much effort in calculating them, and in equitable in that those who can afford to pay and who utilise urban services most, do not pay. From my observations, around 30 to 40% of central business district shophouses are exempt, although a similar brief survey in Khon Kaen concluded the percentage was just over [illegible]. Whatever the percentage it is very significant.

4) Low fee/tax assessment

Because there is no clear cut policy on cost recovery the definition of 'low' is rather arbitrary, but when land worth ฿ 32,000,000 per rai is valued at ฿ 1,000,000 for land tax purposes the only word one can use other than'incredible' is 'low'. The practice of Municipalities valuing land separately from the Department of Lands leads to these problems. Lands Dept land values should be used to calculate land tax, and rental under the House tax law should imputed from this land value, which, while often not fully reflecting market forces, is not in the realms of fantasy. The problem with such measures is that they would raise, under present legislation, so much revenue(see below). Similarly, lack of definition as to the expected recovery by fee revenue means a definition of 'low' is not easily achieved. Certainly fee income from solid wastes does not cover O+M costs, but it is at least closer to this than to covering both capital and O+M costs. A policy which stated that O+M costs must be recovered would show that the current, centrally fixed, charges are too low.

Centrally fixed fees are a problem in many ways . Changing them is often more difficult, as larger numbers of people are upset by such changes. A system based on automatic decentralised revisions of land value would be more easily adjusted. Furthur, such fees tend to be fixed so as to be appropriate for the whole country. This leads to problems of economic efficiency. For example, while average PWA tarriff is about ฿7 per cubic meter of water this figure covers the extra investment per person served required in small supply systems and in those systems requiring extensive reservoirs. While it may be the only politically feasible way to charge at present, this uniform tarriff does not give the correct price signals to water users. Development should be encouraged where it is cheapest to provide water.

5) Lack of policing power

Later on we will address 'carrots', now we will examine 'sticks'. It is necessary for effective collection to have several types of controls. Tax assessment must be appellable, but only after the assessment is paid. Courts should be able to award costs against appellants if the appeal is considered frivolous. Lack of payment should lead to a cut in services - all services if possible. None of these measures apply in Thailand.

Political and Administration Systems

The above financial systems can and will only be operated effectively by bureaucrats and politicians with a vested interest in doing so. Let us examine the local government political and administrative systems briefly.

The Mayor and Council are elected, they are usually local businessmen. The council has policy and detail control over municipal officers who belong to the Thai municipal service. These officers are permanent officers, and senior officers move throughout Thailand as they are promoted. The municipal service is controlled by the Local Government Affairs Division, in particular, and the Department of Local Administration of the Ministry of the Interior (MOI) in general. The MOI also controls the Provincial administrations headed by an appointed Governor (a full time public servant). The Municipal organization is divided into Divisions, the major ones being: Administration (Town Clerk's Office), Education, Public Health, and Engineering. We have discussed the service responsibilities of the municipalities above.

We can now discuss the major principles applying to municipal politics and administration. The first major principal is that politicians need a significant short term benefit to compensate for costs to their constituency. At worst, these politicians must be able to claim that the central government is forcing them to do something unpleasant, at best, the credit for something unequivocally good can be claimed by them. Usually the outcome will be a mixture - the costs being imposed on the community by a central government agency, while the benefits can be claimed by the local politicians.

The second major principle is that local government officers will do exactly what the politicians want unless it is expressly forbidden by law and/or it will affect their promotion prospects. As there is no performance monitoring of local government authorities or officers, there is no incentive or basis for officers to either

a) suggest more efficient methods of implementation or
b) resist inefficient or inequitable expenditures.

Looking at each of the major 'lacks' outlined above, we can see the context of these problems.

1) Lack of documentation

In principle, very little stands in the way of adequate documentation. Existing laws require this documentation, and only lack of resources can prevent its completion (and updating). It is also relatively easy to monitor completion of such documentation. The problem comes in the amount of documentation required. Excessive detail can prevent proper documentation. The test should be to ascertain the cost of documentation (and collection) and then to set this against the tax collected. Only the most efficient taxes should be used.

User fees can be difficult to calculate. Solid waste volumes and volume of waste water are difficult to monitor because of variations at each collection, in the case of solid waste, and the difficulty in metering waste water outflow. Thus, minimum fees are levied on each household, and only exceptional cases are charged special fees. The proxy for waste water output is usually water input, and so a sewerage levy is usually added to the water rate. Again, only exceptions should be documented. This type of charging is complicated for waste water if different agencies run the water supply and maintain waste water treatment systems. If this is the case, or if private ground water is a significant source of water, a rate based on property values is also reasonable.

2) Lack of collection staff

Again, very little should stand in the way of collection once the taxation law is in place. The test should be the cost of this collection (including documentation) versus the revenue gained. The best methods are those based on one mail billing for all services with collection staff following up only those who do not pay.

3) Level of exemptions

Levels of exemptions are politically sensitive. Having large numbers of exemptions from a tax makes few friends, removing exemptions is politically dangerous. Against this must be balanced the positive political effects of projects carried out with increased revenue. For the administrator, exemptions are a nuisance, requiring large numbers of staff to check, and offering extensive potential for corruption. However, they also provide excuses for lack of collection performance and are a hinderance to clear performance monitoring.

Inertia, then, preserves the present system and only significant and public benefits will enable the required changes to be implemented.

4) Low fee/tax assessment

Again, the political pressures against raising tax assessments or fees are considerable,as the old saying goes 'especially now when-the economy is doing so badly/ there has just been a rise in the (other) tax'. The issues involved are similar to 3) above, but administrators are less likely to be influenced one way or another provided re-assessment does not take an unreasonable amount of resources.

5) Lack of policing power

Politicians do not like to be in charge of administrations which throw people in jail or cut off water supplies to poor people (voters). However, where obvious problems of affordability occur exemptions can be made on a case-by-case basis. The problem is to ensure those who can afford to pay, do pay. Again benefits to the community must be emphasised.

Administratively, a balance must be struck between payment for policing versus additional resources required to fund collectors hounding people who know the local authority will ultimately do nothing. Again lack of performance standards prevents any incentive to change the existing situation.

<u>Technical Issues</u>

Leaving these financial implementation issues aside, we can now examine some significant technical issues which are important to solid and liquid waste disposal systems.

1) Economic assessment issues

These may strike both ways at the viability of such systems. Underestimating benefits of waste disposal systems can be a problem where benefits are unclear or uncertain. Preservation of fish catches in rivers and coastal waters counts as a benefit, as, without the project, this catch would have been significantly reduced by pollution. On the other hand, the disruption during the construction phase is often minimised. Traffic disruption costs in vehicle operating costs and time spent when large areas of narrow streets are dug up for waste water interceptors are often not fully accounted. This is unfortunate, because it could alert the proponents of the scheme to potential political problems which have to be balanced by benefits-preferably benefits to the same people experiencing the traffic jams.

2) Costing issues

Despite the above revenue enhancement/cost recovery measures, it is still very possible that a community in a developing country will not be able to afford a system which fully satisfies the required environmental standards of that country (not to mention developed country standards), and which leaves the local authority enough money to fulfill their responsibility for provision of other services. In this case there are three possible courses of action:

a) do nothing - which solves no problems but creates few waves, or
b) build a partial systems which goes come way to solving the problem and will be part of a more comprehensive system in the future, or
c) subsidise the local government to provide a system which satisfies all standards.

In the current economic context of most developing countries, alternative b), a partial system, is most desirable. The problem is that resistance from engineers and bureaucrats to anything less than a 'technically sound' solution can, and often does, force alternative a) the 'do nothing' course of action. Examples of such situations are not hard to find.

Using Chonburi for example, if the cost of significant parts of the waste water system could be reduced to, say, ฿ 50 mill. debt service could be reduced to a manage_able ฿ 2.5 mill per annuam with a 60% subsidy given through the Regional Cities Project. In such circumstances, especially where the works serve needed drainage functions, support will be forth_coming. The 60% subsidy is sufficient 'carrot' for the municipalities to accept the 'stick' of closer monitoring of cost recovery of operational costs.

Conclusion

In order to implement effective sanitation project, Governments must be prepared to clearly define the policies required of implementing authorities in money terms, they must then set performance indicators and monitor progress towards policy goals. They must be flexible in the technical means they use to attain these goals. In order to make these actions palitable and achievable they must be prepared to subsidise capital costs and to provide the required staff and incentives for efficient implementation and operation.