AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 52

1. SUBJECT CLASSIFICATION
A. PRIMARY: TEMPORARY
B. SECONDARY:

2. TITLE AND SUBTITLE
The study of microbial treatment of nightsoil

3. AUTHOR(S)
(101) Taiwan. Institute of Environmental Sanitation

4. DOCUMENT DATE: 1976
5. NUMBER OF PAGES: 32p.
6. ARC NUMBER:

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Okla.

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

(ENGINEERING--HYDRAULICS R&D)

Urban and industrial growth in developing countries has increased the demand for water and the related need for more information on water and sewage treatment. This project, conducted by the University of Oklahoma, focuses on that need by developing a global network of adaptive and innovative technologies based on economic, social, political and cultural factors. A series of detailed reports have been produced that are designed to assist planners in their selection of suitable water and wastewater treatment processes appropriate to the material and manpower resource capabilities of particular countries at particular times.

"Prediction Methodology for Suitable Water and Wastewater Processes," George W. Reid and Richard Discenza.
PN-AAB-491 English
PN-AAD-291 Spanish

"Prediction Methodology for Suitable Water and Wastewater Processes. Supplement I: Manual Computation Methods," George W. Reid and Richard Discenza.
PN-AAD-292

10. CONTROL NUMBER: PN-AAD-281
11. PRICE OF DOCUMENT:
12. DESCRIPTORS:
13. PROJECT NUMBER:
14. CONTRACT NUMBER: AID/CM/ta-C-73-13 Res.
15. TYPE OF DOCUMENT:

AID 590-1 (4-74)

"Prediction Methodology for Suitable Water and Wastewater Processes. Supplement II: Computer Program," George W. Reid and Richard Discenza.
PN-AAD-293

"Data Requirement," University of Oklahoma Bureau of Water and Environmental Resources Research.
PN-AAD-295

"A Mathematical Model for Predicting Water Demand, Wastewater Disposal and Cost of Water and Wastewater Treatment Systems in Developing Countries," George W. Reid and Michael I. Muiga.
PN-AAD-294

"Treatment Methods for Water Supplies in Rural Areas of Developing Countries," Ir. L. Huisman.
PN-AAD-284
PN-AAD-285

"Sewage Treatment in Developing Countries," L.W. Canter and J.F. Malina.
PN-AAD-286

"Contributions to a Mail Survey on Practical Solutions in Drinking Water Supply and Wastes Disposal for Developing Countries," International Reference Centre for Community Water Supplies, The Hague.
PN-AAD-287

"A Catalog of Water Supply and Waste Disposal Methods for Individual Units," George W. Reid.
PN-AAD-283

"Historic Implication for Developing Countries of Developed Countries' Water and Wastewater Technology," George W. Reid and Kay Coffey.
PN-AAD-288

"Evaluation of Lower Cost Methods of Water Treatment in Latin America," Odyer A. Sperandio and Jose Perez C.
PN-AAD-289

"Socio-Economic Conditions which Pertain to Cost of Construction and Operation of Water and Sewage Treatment Facilities and Quality of Water Consumption in Kenya," Erasto Muga.
PN-AAD-290

"A Water Sterilization Study in the Philippines," Reynaldo M. Lesaca.
PN-AAD-282

"The Study of Microbial Treatment of Nightsoil," Taiwan Institute of Environmental Sanitation.
PN-AAD-281

"Study of an Existing Water Treatment Plant on Simple Design and Operating System for Supplying Drinking Water to Rural Communities in the Lower Mekong Basin Countries," Thailand Ministry of Public Health, Department of Health, Rural Water Supply Division.
PN-AAD-280

THE STUDY OF MICROBIAL TREATMENT OF NIGHTSOIL
TAIWAN INSTITUTE OF ENVIRONMENTAL SANITATION

Under Contract With
The University of Oklahoma Project
on
Lower Cost Methods of Water and Waste
Treatment in Developing Countries
(USAID Contract Number: AID/CM-ta-C-73-13)

F I N A L R E P O R T

Prepared by

Taiwan Institute of Environmental
Sanitation PHA
Taipei, Taiwan

February 1976

THE STUDY OF MICROBIAL TREATMENT OF NIGHTSOIL
TAIWAN INSTITUTE OF ENVIRONMENTAL SANITATION

Introduction:

There are few sanitary sewerage systems in the cities or towns in Taiwan. Around 50% of nightsoil in the cities or towns is treated by septic tank then it is discharged into ditches and rivers. The remaining half of it is collected by the vacuum car. Because of the overload or unreasonable design of septic tanks, the effluent is the main source of water pollution. For controlling this situation, the government promulgated the standard of the septic tank and the quality of the effluent one year ago; therefore, the bad situation is expected to be improved.

Concerning the collected nightsoil, it is transferred to farmers to be used as a fertilizer or discharged into fish ponds to grow chlorella as food for fish. Later it is rarely used as a fertilizer or a feed because of the development of artificial fertilizer and feed. Therefore, the treatment of the large amount of nightsoil becomes a very serious problem.

For solving the above problem, Taiwan Provincial Institute of Environmental Sanitation has run studies on the treatment of nightsoil. First of all, the government constructs a 30 KL/Day nightsoil treatment plant at Chi-jen, Kaohsiung City, a 20 KL/Day at Pingtung and a 30 KL/Day at Feng-

shang, which use anaerobic digestion for nightsoil treatment and activated sludge method for its supernatant. Generally speaking, although the efficiency or effect of all the above plants can meet the design expectation, the remaining bulky sludge is still a big problem.

For solving the problem, an experiement by using the combined microbial method for nightsoil treatment is tried. This study is based on solving the above problem by using photosynthetic bacteria (P.S.B.) and chlorella to decompose the organic matter in nightsoil and to make it stable. The multiplied PSB and chlorella which contain high protein can be collected for animal feed.

1. The introduction of the microbes used at this study

1-1 Photosynthetic Bacteria (PSB):

PSB can be divided into three genus - green sulfuric bacteria Purple sulfuric bacteria (RSB) and purple non-sulfuric bacteria GSB and RSB can live only on CO_2 a carbon source under anaerobic and luminous conditions. Therefore, they are not fit to be used for wastewater treatment. Only purple non-sulfuric bacteria can be used for treating organic wastewater.

Purple non-sulfuric bacteria includes two species - Rhodopsendomonas and Rhodospirillun. According to its fundamental nutrients, purple non-sulfuric bacteria can be classified as the following table:

Fundamental nutrients	R P S Palustris	R P S Capsulatus	R P S Spheroides	R P S Gelatinosa	R P S Rubrum
Sodium thiosulfate	+	-	-	-	-
Sodium acetate	+	+	+	+	+
Sodium propiolic acid	+	++	-	-	-
Sodium lactate	+	+	+	+	+
Sodium citrate	-	-	-	+	-
Sodium tartrate	-	-	+	-	-
Asparagine	∓	+	∓	++	+
Sodium aspartic acid	∓	-	∓	+	+
Sodium glutamic acid	±	±	+	+	+
Ethanol	++	-	+	+	+
Glycerol	∓	-	+	-	
Mannitol	-	-	+	-	-
Mannose	-	-	+	+	
Sodium glutaric acid	++	∓	+	±	-
Sodium malate	+	+	+	+	+

Remarks:

The symbols ++ : it can grow very well

+ : it can grow

± : part of it can grow

∓ : most of it can not grow

- : none of it can grow

Purple non-sulfuric bacteria usually lives on paddies, ditches, canals, lakes, oceans, activated sludge, soil, etc. It will be discovered in large numbers where water is contaminated by organic matter (it has 10^2 - 10^6 in dried soil). This kind of bacteria can live on polluted organic sources such as low molecular fatty acids under anaerobic and luminous conditions or aerobic and dark conditions. Under anaerobic and luminous conditions it uses light-energy, sulfuret, hydrogen or organic matter to be a hydrogen donor to stabliize carbon dioxide for growing. For example, the organic matter such as low molecular fatty acids can be used as a carbon source. The chemical reaction is shown as follows:

organic matter bacteria

$$2H_2A + CO_2 \xrightarrow{\text{light}} 2A + CH_2O + H_2O$$

sodium butyrate

$$C_4H_7O_2Na + 2H_2O + CO_2 \xrightarrow{\text{light}} 5(Ch_2O) + NaHCO_3$$

If it is under aerobic and dark conditions the bacteria will oxidize and decompose the organic matter to obtain energy; therefore, it can still grow without light-energy.

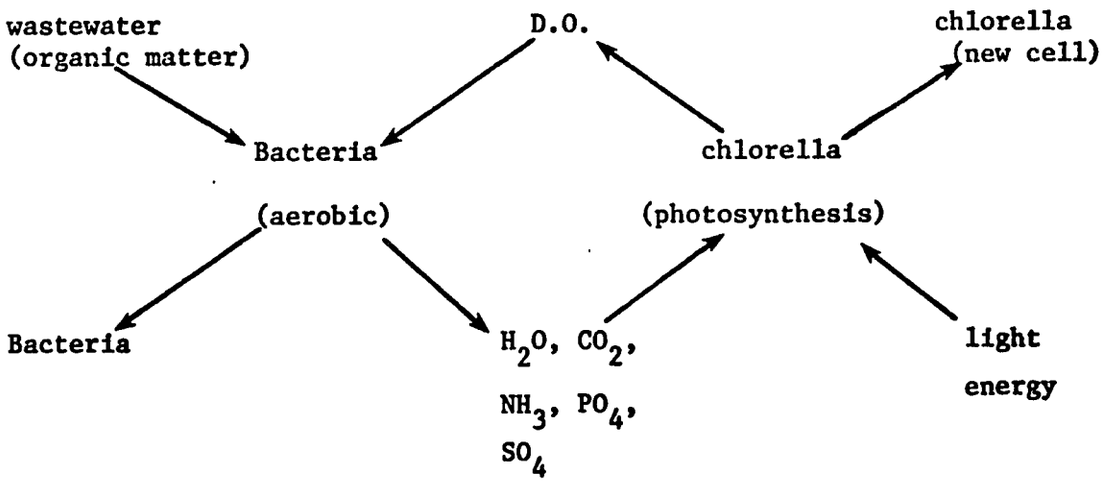
The special characteristics of PSB is shown in the following table:

genus	species	basic hydrogen donor	basic carbon source	growing factor	the ability to stabilize nitrogen	growing condition
green sulfuric bacteria	Chlorobium	H_2S, $H_2S_2O_3$	CO_2	-	-	anaerobic luminous
Chlorobactenaceae		except organic matter				
purple sulfuric	Chromatium	H_2S, $H_2S_2O_3$, H_2	CO_2	-	+	anaerobic luminous
bacteria		sometimes use	organic matter			
purple non-sulfuric bacteria	Rhodo-spirillum	H_2	CO_2	+	+	anaerabic-luminous
	Rhodo-pseudomonas	organic matter	especially organic matter			aerobic-dark
Athiorhodaceae						aerobic-luminous

From the above table, it is known that PSB can stabilize carbon dioxide and nitrogen (it is discovered that purple non-sulfuric bacteria have the ability of denitrification), and part of it can use organic matter as a carbon source. Consequently, it plays a very important role in the material recuclation of nature.

1-2 Chlorella

Chlorella used in this study is ball-shaped, single-cell, green chlorella. Its diameter is about 3 u to 10 u. Theoretically, aerobic bacteria uses oxygen of its own product or dissolved oxygen to oxidize organic matter. The waste products are CO_2, NH_3, PO_4 and SO_4. Then chlorella uses light-energy, CO_2 and trace metal to proceed photosynthesis to synthesize its own new cells and to release oxygen. The oxygen is an acceptor of hydrogen under oxidizing conditions. This interaction among organic matter, chlorella and PSB can oxidize the organic matter to become stabilized material in a very short time. This is what we called the mutualism of chlorella and aerobic bacteria. The following figure shows the metabolism of organic matter.



The following fundamental and chemical reaction formula represents mutualism of chlorella and Bacteria.

$$CO_2 + 2H_2O \xrightarrow[\text{Bacteria}]{\text{chlorella + light energy}} (CH_2O) + O_2 + H_2O$$

Stabilizing organic matter in sewage fundamentally bases on the aerobic decomposition. Aerobes uses oxygen as energy a source to do their metabolism as well as new cell synthesis.

2. The introduction of major facilities used for this study.

(1) Nightsoil storage tank: the storage tank is a R.C. structure of 1 M^3 capacity. A bar screen is installed at the inlet of the tank to remove the coarse matter in the nightsoil.

(2) Nightsoil pumpL A 3 Hp sludge pump is installed on storage tank to pump nightsoil from the tank to aerobic digestion tank.

(3) Two aerobic digestion tanks: Two existing anaerobic digestion tanks are used as aerobic digestion tanks by adding aerators inside. The tank is a R.C. structure. Its diameter, effective depth and volume are 2.5^m, 2.5^m and 12.25^{m^3} respectively. The supernatant is released at the mid-part of second tank.

(4) Blower: Using a 2Hp air compressor instead of blower for aeration.

(5) Air flow meter: Dry Type Flowmeter.

(6) PSB and chlorella culture tank: An existing high rate stabilization tank is used as a culture tank. It is a R.C. structure and its length, width and depth are 10m, 12m and 60^{cm} (the effective depth is adjustable) respectively. This tank is divided into four culture systems by four guiding flow baffles. The effective volume of each system is $18m^3$. At the end of each tank, there is a collection tank for storing the cultured liquid. This liquid will be transferred to centrifuge or another incubation system.

(7) Centrifuge (sharpless): (a) AS-6, 15,000 rpm open type centrifuge

is moved by a 2 Hp TEFC motor (220V 3 phases, 60 cycles). Its treatment capacity is 800-1,000 liters/hr for chlorella collection.

(b) A laboratory use centrifuge, 20,000 rpm x 4 tubes x 50 ml is for PSB collection.

3. The procedure of this study

Primarily batch tests are run to obtain some optimum data. Then these data or control parameters are used for running continuous operation of the pilot plant.

The optimum parameters obtained are explained as follows:

3-1 The pre-treatment of nightsoil

Aerobic and anaerobic digestion methods are used for the pretreatment of nightsoil to decompose high molecular organic matter such as protein, fat, cellulose, and starch to low molecular organic acid such as amino acid, fatty acids and ammonia. Between these two methods, anaerobic digestion is very good for the decomposition of organic matter in nightsoil. Although it does not need to have high operational technique to handle it, the duration of digestion is rather long and the demands of constituents of supernatant are difficult to control. Therefore, this method is not fit to be a pre-treatment for the incubation of PSB. And aerobic digestion used as pre-treatment of nightsoil has many benefits such as short duration of digestion, simple structure of treatment tank, cheap initial cost and low content of ss in supernatant (good for chlorella collection). The defects of this method are the large quantity of digested slu ,e and the bad odor in aeration.

Comparing to these two methods, the aerobic digestion method is adapted in this study for the pretreatment of nightsoil. The control parameters are as follows:

(1) BOD loading 1.9 Kg BOD/m^3 of digestion tank/day as BOD 2500 ppm of supernatant.

BOD loading 3.1 Kg BOD/m^3 of digestion tank/day as BOD 8000 ppm of supernatant.

(2) 80 m^3/day of air for removal of 1 Kg of BOD.

(3) Optimum duration of digestion is 4 days. When entered supernatant for culture is of BOD 8000 ppm.

3-2 The culture of PSB

PSB can be cultured under anaerobic and luminous conditions or aerobic and dark conditions. According to the result of the study for the culture of PSB, the optimum BOD range is between 4000 to 5000 ppm under anaerobic luminous conditions and between 7000 to 9000 ppm under aerobic dark conditions. The efficiency of purification of nightsoil under anaerobic conditions is worse than that under aerobic and dark conditions. Besides that, the technique of the culture of PSB under aerobic and dark conditions is difficult to control. Therefore, the method under aerobic and dark conditions is not suitable for the treatment of nightsoil.

The optimum control parameters under anaerobic and luminous conditions are as follows:

(1) The optimum BOD range of aerated nightsoil with seeding PSB is 2,000 - 3,000 mg/1.

(2) The best culture liquid for PSB: 30% nightsoil and 70% PSB liquid (it is a settled liquid which cultures PSB).

(3) The aeration facilities instead of a slow mixer is used for good mixing nightsoil and PSB.

(4) BOD loading of culture tank is 2 kg/m^3/day.

3-3 The culture of chlorella

The culture of chlorella with nightsoil should be based on the maximum production of chlorella and the best BOD removal of nightsoil.

The decision of the optimum effective depth of the culture tank and the duration has to be based on the above mentioned condition.

The optimum results are as follows:

(1) The optimum BOD of culture liquid is 400-420 mg/l.

(2) The optimum depth of tank is 30.^{cm}

(3) The duration is 3 days.

4. The result of this study

4-1 The physical and chemical states of raw nightsoil

pH 7 - 9

BOD 8,000 - 15,000 mg/l

COD 18,000 - 30,000 mg/l

Total solids 22,000 - 32,000 mg/l

Chloride 5,500 - 6,500 mg/l

NH_3 - N 3,000 - 4,000 mg/l

Phosphorous pentoxide P_2O_5 1,000 - 2,000 mg/l

Potassium oxide 2,000 - 3,000 mg/l

Total count 10^8 - 10^{10}/ml

MPN 10^7 -10^9/ml

Ascaris ova density 40 - 100/ml

Viable percentage of ascaris 60 - 90%

4-2 The result of aerobic digestion treatment

(1) Unit operation

Duration (day)	pH	BOD ppm	BOD removal (%)	Total solids (ppm)
0	7.8	12,500	-	31,200
1	8.6	11,500	8	29,010
2	8.6	10,050	15.6	25,720
3	8.6	9,000	28	20,400
4	8.7	8,000	36	18,320
5	8.8	7,000	44	15,780
6	8.9	6,020	51.8	14,240
7	8.9	5,000	60	14,010
8	8.9	4,200	66.4	13,950
9	8.9	4,000	68	13,780
10	8.9	3,500	72	13,570
11	9.0	3,000	76	12,280
12	9.0	2,700	78.4	11,350
13	9.1	2,400	80.8	10,298
14	9.1	2,100	83.2	8,610

Explanation: 1. Entered raw nightsoil 12.25 m^3/ounce

Total BOD 12,500 x 12.25 x 10^{-3} = 153.13 kg

Aeration 7 m^3/min.

Check: 153.13 Kg BOD x 85.2% removal = 127.4 Kg

Total air quantity per day = 7m^3/min.x 60 x 24 = 10080 m^3/day.

The demand of air quantity for 1 Kg BOD removal =

$$10080\ m^3/day = 127.4\ kg/day$$

$$79.1\ m^3/Kg\ BOD = 80\ m^3/Kg\ BOD$$

(2) Continuous operation

The quantity of nightsoil: 1.75 KL/day

The aeration quantity: 60 m^3/hr

The tested result:

Duration (day)	Entered nightsoil		supernatant of first digestion tank		supernatant of second digestion tank		Remarks
	pH	BOD (mg/1)	pH	BOD (mg/1)	pH	BOD(mg/1	
0	7.7	12,400					
1	7.8	12,600					
2	7.75	12,550					
3	7.6	12,400					
4	7.7	12,500					
5	7.4	11,900					
6	7.8	12,800					
7	7.6	12,000	8.1	5,620			
8	7.8	12,400	8.25	5,480			
9	7.7	12,600	8.25	4,930			
10	7.8	12,700	8.30	4,850			
11	7.85	12,800	8.30	4,840			
12	7.7	12,500	8.30	4,820			
13	7.4	11,900	8.25	4,800			
14	7.4	10,950	8.35	4,810			
15	7.6	12,450	8.20	4,790	8.9	2,230	
16	7.8	13,200	8.20	4,870	8.8	2,160	
17	7.8	12,800	8.20	4,800	8.8	2,120	
Average	7.67	12,413	8.24	4,964	8.83	2,170	

Check: The BOD removal at first digestion tank:

(12413 - 4964)/12413 x 100 = 59.9%

The total BOD removal:

(12413 - 2170)/12413 x 100 = 82.4%

BOD loading of aerobic digestion tanks:

$12413 \times 1.75 \times 10^{-3}/24.5 = 0.9\ kg/m^3/D$

The loading at first tank:

$12413 \times 1.75 \times 10^{-3}/12.25 = 1.76\ kg/m^3/day$

The quantity of BOD removal:

$(12413) - 2170) \times 1.75 \times 10^{-3} = 17.92\ kg/day$

Air quantity used $60\ m^3/hr \times 24 = 1440\ m^3/day$

Air quantity demand per kg BOD

$1440/17.92 = 80.3\ m^3/day = 80\ m^3/day$

4-3 The PSB culture experiment:

(1) Unit operation

A: PSB culture with nightsoil under anaerobic and luminous condition.

item / duration / result / various combination	Volatile acid mg/l						B C D mg/l						
	0	1	2	3	4	5	0	1	2	3	4	5	B O D removal %
Blank (100% raw nightsoil)	5430	5460	5610	5760	5790	6000	11740	11150	11125	11015	8650	8600	Natural removal 26.7%
I (30% raw nightsoil 70% P S B)	1620	1470	1260	1140	960	780	4862	4700	4100	3650	2950	2620	Actual removal 46.1-26.7 =19.4%
II (50% raw nightsoil 50% P S B)	1800	1610	1410	1050	850	680	5542	4950	4525	4125	3900	3240	Actual removal 41.5-26.7 =14.8%
III (70% raw nightsoil 30% P S B)	1980	1540	1330	1020	800	650	7140	7010	6230	5417	5000	4670	Actual removal 33.3-26.7 =6.6%

B. The PSB culture with 4-days aerobic digestion liquid under anaerobic and luminous condition.

item / duration / result / various combination	Volatile acid mg/l						B O D mg/l						
	0	1	2	3	4	5	0	1	2	3	4	5	B O D removal %
Blank 100% digestion liquid	2010	2120	2200	2250	2430	2480	8020	7960	7800	7780	7690	7200	natural removal 10.6%
I 30% digestion liquid 70% P S B	680	650	720	570	410	320	2440	2010	1790	1040	812	790	Actual removal 67.6-10.6 =57%

II 50% digestion liquid 50% P S B	1340	1120	970	700	650	460	[illegible]	3020	3040	2520	2310	2040	Actual removal 49.7-10.6 =39.1%
III 70% digestion liquid 30% P S B	1560	1320	990	450	[illegible]	820	5820	5740	5430	5014	4570	3850	Actual removal 33.8-10.6 =23.2%

C. The PSB culture with 7-day aerobic digestion liquid under anaerobic and luminous condition.

item / duration / result / various combination	Volatile acid mg/l						B O D mg/l						Remarks
	0	1	2	3	4	5	0	1	2	3	4	5	B O D removal %
Blank 100% digestion liquid	1080	1760	2100	1980	2100	1920	5140	5006	4760	4012	3790	3640	Natural removal 29.10%
I 30% digestion liquid 70% P S B	[illegible]	450	420	410	410	400	1610	1280	980	850	830	770	Actual removal 52.1-29.1 =23%
II 50% digestion liquid 50% P S B	790	760	730	680	620	570	[illegible]	1960	1400	1326	1240	1010	Actual removal 59.1-29.1 =30%
III 70% digestion liquid 30% P S B	1500	1320	1200	720	600	640	3260	3100	2880	1820	1470	1340	Actual removal 58.8-29.1 =29.7%

From the above A.B.C. tables, first of all, it is very clear that the high molecular organic matter is difficult to be decomposed by PSB. Therefore, the effect of B O D removal is not good in (A) case. Secondly, in (C) case, the BOD content of the 7-day digestion liquid is much more diluted, its range is about 5,000 ppm. If the liquid is mixed with PSB, the BOD range is only 1,600 to 3,200 ppm. From the result, it is shown that the digestion effect becomes slow after the third day. Generally speaking, case (B) is the best one. The four days BOD loading of aerobic digestion tank is $12,413 \times 1.75 \times 10^{-3}/1.75 \times 4 = 4.1$ kg/m^3/day.

(2) Continuous operation

a. The volume of digestion tank $10^{m(l)} \times 3^{m(w)} \times 0.6^{m(h)} = 18^{m3}$.

b. Entered aerobic digestion liquid $\doteq 4.5^{m3}$/day

kind / item / result / duration (day)	Inflow (aerobic digestion liquid)			Effluent (after 4-day culture)			Remarks
	pH	Volatile acid	B O D	pH	Volatile acid	B O D	
0	8.7	2020	8025				
1	8.75	2010	8010				
2	8.60	2240	8946				
3	8.72	2005	8020				
4	8.70	2030	8100				
5	8.75	2040	8890	8.80	320	780	
6	8.60	2280	9000	8.90	310	790	
7	8.72	2060	8870	9.00	305	770	
8	8.70	2040	8210	8.80	350	800	
9	8.85	1990	7980	8.90	340	790	
10	8.70	2000	8100	9.00	330	780	
Average	8.70	2003	8368	8.90	331	780	

Check: (1) BOD removal 2023-780/2023x100 = 61.3%

Actual BOD removal 61.3-10.6=50.7%

(2) BOD loading of culture tank

$8368 \times 4.5 \times 10^{-3} = 37.66$ kg/day

37.66 kg/18^{m3}/day = 2.09 kg/m^3/day = 2 kg/m^3/day

Elplanation: (1) For thorough contact between digestion liquid and PSB, the air blowing pipes are installed on the bottom of the culture tank and the blower homogeniously blows the air at $0.1^{m3}/m^3$/hr into the tank for good mixture.

(2) Owing to lack of collection facilities, PSB can not be separated from the liquid. For the continuous operational use, the effluent is settled for 30 minutes. Then the supernatant is diluted for the use of chlorella culture.

(3) At the beginning of the operation, 12^{m3} of adjusted PSB, liquid is put into the tank, then digestion nightsoil liquid is thrown 4.5^{m3} every day. And the analysis of some control parametes is run for understanding the treatment effect from the fifth day.

4-4 The chlorella culture experiment:

This experiment is based on the optimum control parameters to run in both summer and winter seasons. The digest liquid after culturing PSB is diluted to two times for the continuous operation to culture chlorella. The result is as follows:

season	summer season		Winter season	
result item	Inflow	Effluent	Inflow	Effluent
BOD_5 mg/l	398	27	410	28.5
BOD removal%	93.1		93.4	
COD mg/l	1280	268	1190	270
DO mg/l	4.3 (am 8:00)	25.4 (pm 2:00)	6.0 (am 10:00)	18 (pm 2:00)
pH	8.1 (am 8:00)	8.7 (pm 2:00)	8.12 (am8:00)	8.7 (pm 2:00)
Total nitrogen mg/l	283	112	210	105
PO_4 mg/l	48	22.2	43	20

Explanation: (1) The effective depth of the culture tank is 30^{cm}, the area 23.9^{m2} and the volume 7.17^{m3}.

(2) The entered liquid is 2380 liter/day and the duration is 3 days.

(3) The BOD loading of culture tank:

398 mg/lx23.8 kl x 10^{-3}= 0.9472 kg/day

0.9472/7.17 = 0.132 kg/m^3/day

4-5 The collection of PSB and chlorella.

(1) PSB collection

The 4-day PSB cultured liquid is sampled for PSB collection with a laboratory centrifuge. The continuous operation was run for three months and the collection test is run every day. The PSB obtained is 0.4 gram/l of culture liquid on dry basis. That means one ton nightsoil can culture PSB and obtain the quantity of PSB as follows:

100 kg x 0.99=990kg digestion liquid (1% of solids and sludge removed)

$$0.4 \times \frac{1,000}{990} \times 1,000 = 404 \text{ g} = 0.404 \text{ kg (dry basis)}$$

(2) Chlorella collection

The chlorella cultured liquid flows into storage tank, then it is pumped to the centrifuge (15,000 rpm, sharpless) for chlorella collection. The obtained chlorella is 420 g/m^3 of cultured liquid on dry basis.

But under continuous operation conditions, the result will be as follows:

1^{m3} chlorella cultured liquid=0.5^{m3} PSB cultured liquid

0.5^{m3} PSB cultured effluent=0.5/0.99=0.505^{m3} raw nightsoil.

Therefore, one ton nightsoil can culture and obtain chlorella 420/0.505=831 g = 0.831kg on dry basis.

5. Conclusion

The nightsoil treatment with PSB and chlorella can save more than 20 days on duration time, comparing to that by anaerobic digestion with its digested supernatant treated by activated sludge or trickling filter method, and more than 10 days comparing to aerobic digestion method. Especially, this treatment method can produce the byproduct-PSB and chlorella as animal feed and very little sludge and few pollution problem. Generally speaking, it is suitable for the use in Taiwan Province.

In the aspect of flowing sheet, first of all, the nightsoil is settled, then pumped into aerobic digestion tank for 4-day aerobic digestion. Then the digested liquid is centrifuged to remove coarse material and sludge. Finally, the treated liquid is very good to be used for 4-day PSB culture and 3-day chlorella culture.

For making this treatment method widely accepted, the operation condition should be easy and the initial and maintenance costs, economic. Therefore, the depth of PSB and chlorella culture tanks is a keypoint. The problem of how to increase the depth of the tanks to save the land area and still have good PSB and chlorella collection is expected to be further studied.

APPENDIX

The plan for microbial nightsoil treatment plant

Taiwan Institute of Environmental Sanitation

1. The outline of the treatment plant

(1) Design capacity: 20 kl/D

(2) The constituent of raw nightsoil: BOD : 12,500 mg/l

Total solids: 3:2

(3) Treatment procedure: The nightsoil is pre-treated to remove grit, then it is treated by aerobic digestion for 4 days. After that, the settled material is removed by decanter, and the digested liquid is used to culture PSB for 4 days. After the collection of PSB, the liquid is diluted to two times to culture chlorella for 3 days. This liquid is centrifuged to collect chlorella, then it is chlorinated and discharged. Those collected PSB and chlorella can be dried to be used as feed material.

(4) Design basis:

A. The capacity of nightsoil storage tank:

$20m^3$/day

B. Aerobic digestion tank:

BOD loading 3.1 kg/m^3/day

Air: 80 m^3/D for removing 1 kg-BOD

BOD content of effluent: 8,000 mg/l

Duration: 4 days

C. PSB culture tank:

BOD loading 2 $kg/m^3/D$

Effective depth: 60 cm

Duration: 4 days

D. Chlorella culture tank:

BOD loading: 0.132 $kg/m^3/D$

Effective depth: 30 cm

Duration: 33 days

E. Discharged effluent: BOD 20-30 mg/l

2. Loading Computation

2-1 Grit chamber

(1) nightsoil loading: 20 kl/D

(2) duration: 4 hr.

(3) Demand capacity: $20 \times \frac{x}{24} = 3.3\ m^3$

2-2 Aerobic digestion tank

(1) nightsoil loading: 20 kl/D

(2) BOD loading: $12{,}500 \times 20 \times 10^3 = 250$ kg/D

(3) Tank capacity: $250/3.1 = 80.6\ m^3$

(4) Air quantity demand: BOD removed: $(12{,}500-8{,}000) \times 20 \times 10^3$

$= 90$ kg

Air: $90 \times 80 = 720\ m^3/D = 30\ m^3/hr = 0.5\ m^3/min$

(5) Digested sludge and various residue: $20 \times 1\% = 0.2\ m^3 = 20011/D$

2-3 Storage tank

storage nightsoil $= 20\ m^3/D$

2-4 PSB culture tank

(1) Entered digestion liquid 20 x 99%=19.8 kl/D

(2) BOD loading 8,000 x 19.8 x 10^3 = 158.4 kg/D

(3) Tank capacity 158.4/2=79.2m (26.4 m^2)$_3$

(4) mixing air quantity 79.2 x 0.1=7.92 m^3/hr = 0.132 m^3 min

2-5 PSB liquid storage tank

(1) Entered digestion liquid 19.8 kl/D

(2) Duration: 4 hr.

(3) Tank capacity 19.8 $\frac{x}{24}$ = 3.3 m^3

2-6 Dilution tank

(1) contact time: 5 minutes

(2) Tank capacity: 19.8 x $\frac{5}{60}$ = 1.65 m^3

2-7 Chlorella culture tank

(1) Entered digestion liquid and dilution water: 19.8 kl x 2

= 39.6 kl/D

(2) BOD loading: 400 x 39.6 x 10^{-3} = 15.84 kg/D

(3) Tank capacity: 15.84/0.132 = 120 m^3 (400 m^2)

2-8 Chlorella liquid storage tank

(1) Entered chlorella liquid 39.6 kl/D

(2) Duration: 4 hr.

(3) Tank capacity: 39.6 x $\frac{4}{24}$ = 6.6 m^3

2-9 Chlorination

(1) Discharged effluent: 39.6 m^3/D = 1.65 m^3/hr

(2) Chlorine quantity: Chlorine dosage 15 mg/l

$1.65 \times 15 \times 10^{-3} = 0.02475 = 0.025$ kg/hr

(3) Tank capacity: $39.6 \times 15/60/24 = 0.4125\ m^3$

2-10 Mechanical facilities

(1) The nightsoil quantity pumped from grit chamber to storage tank is 20 kl/D, and the pumping duration is 2 hours. Therefore, the pumped quantity is 10 m^3/hr (0.17 m^3/min)

(2) Decanter for removing sludge and various residue

Nightsoil quantity: 20 kl/D

Operation time: 3 hours

Treatment quantity: 6.7m^3/hr.

(3) Blower

BOD removal $(12,000-8,000) \times 20 \times 10^3 = 80$ kg/D

Air quantity $80 \times 80 = 6,400\ m^3/D = 266\ m^3/hr = 4.4\ m^3/min$

(4) Aerobic digestion liquid pumped into PSB culture tank is 19.8 kl/D that is 0.014m^3/min = 14 l/min

(5) PSB culture liquid pumped to centrifuge is 19.8 kl/D

= 0.014 m^3/min

(6) PSB centrifuge: treatment quantity 825 l/hr

(7) PSB oven: the computation for getting centrifuged thick liquid quantity:

The water content dried PSB is 10%

Bulkdensity 65.5g/100 ml

PSB cultured and collected from 20 kl/D of nightsoil is

20,000 l x 0.4 g/l = 8,000g

the volume will be 8,000 x 100/65.5 = 12,213 ml

Then the centrifuged PSB liquid (70% water content)

is $12213 = v \times \frac{(1 - 0.7)}{(1 - 0.1}$

$v = 12213/0.33 = 37{,}000\ l = 37\ m^3$

The drying thickness of a layer is 10 cm then area demand

is $37/0.1 = 370\ m^2$

The drying duration for one layer is 50 minutes under 60°C

and 10 minutes for extra, then the total duration is one hour.

Taking 8 hours/D as the operation time, then the area demand

is $370/8 = 46.25\ m^2$

(8) Dilution water well and pump:

water demand: 19.8 kl/D:19.8/24/60= 0.14 m^3/min

use 1½" p x 1.5 kw pump

(9) Chlorella liquid pump to centrifuge

19.8 kl/D x 2 = 39.6 kl/D = 0.28 m^3/min

(10) Centrifuge for collecting chlorella 39.6 m^3/D=1.65 m^3/hr

= 1,650 l/hr

(11) Chlorella oven

drying quantity 39.6 m^3/D=1.65 m^3/hr=1,650 l/hr

The centrifuged thick liquid:

dried chlorella 10% water content

bulkdensity 65.7 r/100ml

chlorella cultured and collected from 20 kl/D of nightsoil

is 20,000 l x 2 x 0.42 g/l = 16,000 g

its volume is 16,000 x 100/65.7 = 24,353 l

then the volume of centrifuged chlorella liquid (70% water content) is $24353 = v \times \frac{(1-0.3)}{(1-0.1)}$

If drying thickness of a layer is 10 cm then area demand is $73.8/0.10 = 738\ m^2$

Operation time uses 8 hr/D then the necessary drying area will be $738/8 = 93\ m^2$

(12) PSB and chlorella collection

If water content is 10%, PSB quantity is 8 kg and chlorella 16 kg. use only one crusher for both PSB and chlorella. 4 hours for PSB and 4 hours for chlorella. Then the treatment capacity of the crusher will be 16 kg/4 = 4 kg/hr.

3. The shapes and dimensions of various tanks

3-1 Grit chamber

shape: rectangle, the slope of the bottom 15% R.C. structure

Dimension: length 5^m x width 1^m x height 1^m (effective height 0.7^m)

= $3.5m^3$ (the volume for storing grit not included)

3-2 Aerobic digestion tank

Shape: square, covered R.C. structure with vent hole (waste gas will be removed from vent hole through odor removing tower)

Dimension: length 4.2^m x width 4.2^m x height 5.3^m (effective height 5^m) = 88.2 m^3

3-3 Storage tank:

Shape: rectangle, the slope of the bottom 15% R.C. structure

Dimension: length 5^m x width 2^m x height 2.3^m (effective height 2^m) = 20 m^3 (the slope part not included)

3-4 PSB culture tank

Shape: Open square, R.C. structure with 4 guiding baffles

Dimension: length 5.2^m x width 5.2^m

x height 0.9^m (effective height 0.6^m)=$27m^3$

3-5 PSB liquid storage tank:

Shape: square, R.C. structure with steel cover

Dimension: length 1^m x width 1^m x height 3.6^m (effective height 3.3^m) = 3.3 m^3

3-6 Chlorella culture tank

Shape: Open square, R.C. structure with 4 guiding baffles

Dimension: lenght 20^m x width 20^m x height 0.6^m (effective height 0.3^m) = 120^{m3}

3-7 Chlorella liquid storage tank:

Shape: rectangle, R.C structure with steel cover

Dimension: length 2^m x width 1^m x height 3.6^m (effective height 3.3^m) = 6.6^{m3}

3-8 Chlorination tank

Shape: ditch shape, R.C structure

Dimension: length 2^m x width 2^m x height 0.42^m (effective height 0.12^m) = 0.48^{m^3}

4. Mechanical facilities:

(1) Nightsoil inlet: its diameter is 20 CL, it is casted with FC 20 cast iron and water sealed.

(2) Nightsoil pump (p_1): use two pumps (one spare)-50¢ 0.75kw 935 rpm 0.06 m^3/min lifting height 3.5^m.

(3) Nightsoil pump (p_2): use two pumps (one spare)-50¢ 0.75kw 935 rpm, 0.06 m^3/min lifting height, 3.5^m

(4) Blower: usetwo rotary blowers (one spare) - 5.5kw, 4.5 m^3/min

(5) decanter: use two units (one spare) - its 40L, the treatment capacity 7 m^3/hr.

(6) diaphram pump: use one pump - 15 1/min, 0.75 kw

(7) nightsoil pump (p_3): use two pumps (one spare) - 50¢ 0.75kw, 935 rpm, 0.014 m^3/min. lifting height 3.5^m

(8) PSB centrifuge: use two sharples units (one spare) - 3.75kw, 20,000 rpm, 1,000 1/hr.

(9) PSB oven: use one box-type oven -eight layers, $6m^2$ for one layer, 10 kw drying fan x 2

(10) dilution water pump: use one pump - 1½ x 1:5kw

(11) nightsoil pump: (p4): use two pumps (one spare) - 80¢

1.5 kw x 1,720 rpm, 0.3 m^3/min.

(12) Chlorella centrifuge: use three sharples (one spare)

15,000 rpm, 2 hp, 1,000 l/hr.

(13) Chlorella oven: use two box-type ovens - 8 layers, 6 m^2/

layer, 10 kw/drying fan x 2

(14) Crusher: use one Hammer Mill - type - 5 kg/hr. 2.25 kw

(15) Chlorinator: use one chlorinator - 0.4 kw, 0.025 kg/hr.

Item	Specification	Quantity	Budget ($N.T.dollar)	Remarks
A. Civil engineering				
Grit chamber	3.5 m^3 R.C. structure	1	14,000	
Aerobic digestion tank	88.2 m^3 R.C. structure	-	352,800	
Storage tank	20 m^3 R.C structure	-	80,000	
PSB culture tank	27 m^3 R.C structure	-	108,000	
PSB storage tank	33 m^3 R.C structure	-	13,200	
Chlorella culture tank	120 m^3 R.C structure	-	480,000	
Chlorella storage tank	6.6 m^3 R.C structure	-	26,400	
Chlorination tank	0.48 m^3 R.C structure	-	2,000	
Management room	400 m^2	-	800,000	
Total			1,876,400	
B. Mechanical facilities				
Inlet	F.C	2	20,000	
Nightsoil pump (P1)	0.75 kw x 2	2	60,000	
(P2)	0.75 kw x 2	2	60,000	
Blower	5.5 kw x 2	2	200,000	
Decanter	22 kw x 2	2	3,000,000	alternative drum screen 1 NT.600,000
Diaphram pump	0.75 kw	1	40,000	
Nightsoil pump (P3)	0.75 kw x 2	2	40,000	
PSB centrifuge	3.75 kw x 2	2	200,000	
PSB oven	10 kw	1	150,000	
Dilution pump	1.5 kw	1	10,000	

Nightsoil pump (p4)	1.5kw x 2	2	40,000	
Chlorella centrifuge	1.5kw x 3	2	240,000	
Chlorella oven	10 kw x 2	2	300,000	
Crusher	2.25kw x	1	60,000	
Chlorinator	0.4kw	1	22,000	
Total	87.4kw		4,442,000	
C. Others water supply and electric facilities		1	120,000	
Wall & Road		1	80,000	
Total			200,000	if use drum screen the grand total will be 4,118,400
Grand total			NT. 6,518,400	

6. Maintenance Cost

(1) Cost for electricity: 87.4kw x 5hr(average) x 0.8 N.T.dollar/kw/hr x 365 day=127,604 N.T./year

(2) Cost for repair: 6,518,400 x 1% = 65,184 N.T.dollar/year

(3) Chemicals : A. Chlorine 0.025kg/m x 24 x 365=219kg/year
219 kg/year x 200 N.T./kg =43800N.T.dollar/year

B. Others 87,412 N.T.dollar/year

(4) Personnel expenses: Operator 1 person 4,500N.T./month x 12 month = 54,000N.T.dollar/year

Technician " "

Technical labor 2 x 4,000 x 12 =96,000 "

Labor 2 3,000 x 12 =72,000

Total 276,000 N.T.dollar/year

Grand total:
127,604+65,184+43,800+87,412+276,000
=600,000 N.T. dollar/year