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Wastestreams and Integrated Resource Recovery Systems in Developing Countries Step 2: Application of the State of the Art to Tacloban City, Philippines

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Meta Systems Inc
10 Holworthy Street
Cambridge, Massachusetts 02138

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This report was prepared by Mr. Devinder Sood, Consultant, Fairfax, Virginia and Dr. Peter Rogers, Principal of Meta Systems Inc.

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1. Summary of Tacloban City, Philippines, Field Studies (August-September 1982)

1.1 Introduction to Tacloban

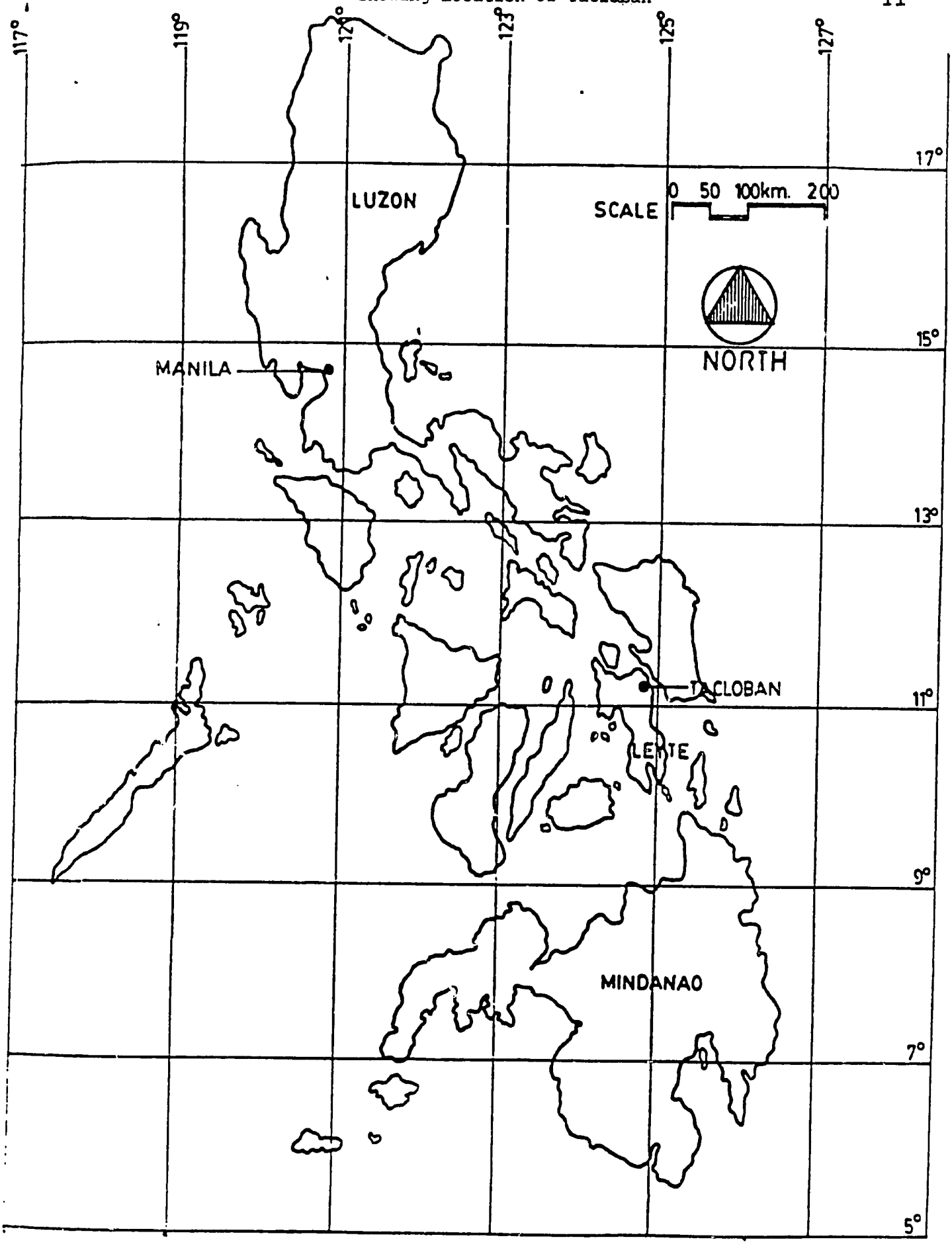
The Office of Urban Development, Bureau of Science and Technology, US Agency for International Development (USAID) under the project, "Managing Energy and Resource Efficient Cities" (MEREC), addressed the problem of increasing the efficiency of small and intermediate size cities in consumption of scarce and costly resources. In order to test various strategies to meet the goals of the project, the Philippines, and in it, the city of Tacloban, was chosen as a pre-test site for the global project.

The objective of the MEREC pre-test is to develop (for Tacloban City) a strategy designed to increase the city's efficiency of consumption of important scarce resources. The objective is based on the assumption that the future pattern and nature of development of small- and intermediate-sized cities, such as Tacloban, can be influenced while they are still in the relatively early stages of development and modernization.

During 1981, Meta Systems Inc, of Cambridge, Massachusetts, contracted with USAID's Office of Urban Development to examine integrated resource recovery systems for waste management in small- and medium-sized cities. For a variety of reasons, the original town chosen was not available. Tacloban was suggested by USAID even though the MEREC project was already well under way at that time. For the purposes of the Meta Systems study, Tacloban was a good location to test some of the ideas about the technical and economic feasibility of integrated resource recovery systems. While reading this chapter it should be remembered, however, that the goals of the MEREC study and the Meta Systems study do not exactly coincide.

The city of Tacloban is located on the island of Leyte, in Eastern Visayas, one of the thirteen administrative and planning regions in the the Philippines. Tacloban City is situated about 360 miles southwest of Manila. Figure 23 shows the location of Tacloban.

Figure 1-1. Map of the Republic of the Philippines
Showing Location of Tacloban



The city is composed of 138 political units, known as barangays, 21 of which are located outside the city proper. Tacloban City has a total land area of 10,855 hectares or about 108 square kilometers. The city proper covers an area of about 1,770 hectares or approximately 16.32 percent of the total, while the remaining major portion is mostly rural or agricultural land.

The city has a population of 108,433 and as a city, it registered the nation's highest growth rate of 5.6 percent over the past five years. The household population is steadily increasing at an average of about 4.1 percent per annum for the last ten years.

Tacloban City is the primary trade center of the region. The National Economic and Development Authority (NEDA), estimated that the city recorded a share of 55.9 percent of the total trade among the five major ports in the region. In 1983, the Philippines Port Authority is planning a multi-million expansion of the Tacloban port* to decrease congestion, improve efficiency and accommodate future growth. In terms of income, the National Economic and Development Authority (NEDA) reports that for 1975 the average annual income per household and per capita are P8,908** and P1,457, respectively, an increase of about 86 percent over the 1971 figures for income from all sources.

1.2 Current Waste Management Practices in Tacloban

Currently, solid waste is collected in three open dump trucks and covers residences, commercial establishments and institutions such as hospitals and schools. The area covered by the system contains a total population of 70,000 and is divided into three collection areas, with two designated as residential and one classified as commercial. Due to the lack of a sewer system, the liquid wastes are usually disposed of via the storm/drainage system. The effluents from septic tanks and domestic sewage are allowed to flow into the storm or drainage pipes, provided it passes through a leaching chamber then to a catch basin before entering

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* Citation.

* The exchange rate during August 1982 was P8.43 = US$1.0.

the drainage pipes. Of the estimated 12,040 houses in the city, about 80 percent, or 10,000, have a sanitary toilet, while the remaining 20 percent depend upon unsanitary disposal, including disposal into the sea, rivers and streams. Some human waste is deposited in the waste piles found along the sides of the street.

The average quantity of solid waste based on total number of dump trucks entering the site during the present study, has been estimated at 22,000 cum. per year. Of the total solid waste disposed, it was observed that about 50 percent is residential, 32 percent commercial, 8 percent street sweepings, 5 percent agricultural and 5 percent other.

Scavenging for materials, such as bottles, cans, cardboard, etc., is commonly practiced at the dumpsite. Scavengers also retrieve materials from storage containers along the street and from the collection vehicles. A small network of material buyers and sellers exists, especially for unbroken bottles. The two dumps in Tacloban in general receive the highly putrescible municipal solid waste in addition to a variety of other wastes such as those originating at hospitals and institutions.

A number of problems associated with the present system of handling solid and liquid waste exist. The vehicles in the motor pool are on the order of eight to ten years old and subject to frequent breakdowns. Table 1-1 gives a brief description of the dump trucks. Frequent breakdowns are primarily caused by old equipment, poor maintenance, overloading, and intensive use. Table 1-2 shows the costs of each garbage crew and Table 1-3 shows the total cost to the city of both collection and disposal of the solid wastes.

1.3 Description of Areas Served by Garbage Collection:

A. Residential Areas:

Primary solid waste in both these areas consists of garden and food wastes about 60 percent mostly consisting of tree branches, trimmings, banana trunks, leaves, some vegetable waste and the remaining 40 percent

Table 1-1.

Description of the Tacloban City Dump Trucks

Sr. No.	Truck Number	Year Acquired	Remarks/History
1.	Dump truck No. SCF 559 (ISUZU), Diesel, Current cost (1982) p.300,000. capacity 10 cm.	1975	When procured, it was a reconditioned truck. Subject to minor breakdowns.
2.	Dumpt truck No. SBK 229 (ISUZU), Partially modified to increase volume. Capacity 10 cum.	1970	Acquired as new by the City Engineers Office for hauling sand, gravel and construction material; transferred to General Services for garbage hauling in 1981. Frequent breakdowns, (average: 5 days'mo. out of service).
3.	Dump truck No. SCF 558 Chevrolet. Capacity 6.2 cum. Actual 4.9 cum. (waterfilled capacity).	1974	Acquired by General Services as a new dump truck in 1974 for garbage hauling, frequent breakdowns since 1981; also original body changed. Average breakdown 6 days/mo.
4.	Dump truck No. SBK 225 Chevrolet, capacity 4.55 cum. usual load 5 cum. Current (1982) cost of such truck (gasoline powered) p.175,000.	1982	Borrowed in 1982 from General Services Office to serve V&G subdivision. Acquired as a new dump truck; used only 3 times a week; not many breakdowns. It is a temporary arrangement.

Table 1-2.

Costs of a City Garbage Crew

Each crew for each collection route consists of the following:

		Basic Salary	Living Allowance (16%)
1.	One laborer foreman/driver/leader	P7,500	P1,200.00
2.	Seven laborers	P6,000	-
	Others (Support staff)		
3.	One automotive mechanic	8,000	1,280
4.	24 garbage collectors*	6,000	960
5.	20 street sweepers	6,000	960

*21 are paid monthly and 3 are casual (temporary).

Notes: a) one crew for residential area consists of 1 laborer/foreman and 7 laborers

b) For U&G Subdivision, a new and developing residential colony the crew is smaller, and isntead of laborer/foreman/driver the title as classified by the city general serves is only driver, and carries a lesser salary, 6,500 + 16% cost of living allowance.

c) For city outskirts (also residential), 1 laborer, 1 laborer/foreman, and 5 laborers only.

Total Strength

a)	Laborer/foreman	=	4
b)	Driver for V&G	=	1
c)	Mechanic	=	1
d)	Laborers/Garbage Collectors	=	24
e)	Street sweepers	=	20
	Total		50

Table 1-3.

Expenditure Breakdown City Garbage Collection
and Disposal Service
(in Pesos)

		1980	1981
1)	Personnel		
i.	Salaries and Wages	228,051	282,990
ii.	Life Insurance Premiums	9,718	14,440
iii.	State Insurance (1% of (i))	2,280	2,829
iv.	Medicare Premium	1,348	4,410
v.	Cost of Living, P100/person/mo.	58,800	58,800
	Subtotal	300,197	363,469
B)	Operating Expenditures		
i.	Supplies, Materials, Fuel, Oil, etc.	108,000	214,800
88.	Uniform, Raincoat, Boots, etc.	6,900	5,750
888.	Repair of Equipment	23,000	32,000
	Subtotal	137,900	252,500
	Grand Total (A) + (B) =	438,097	616,019
	Total Fee collected	43,831	52,132
	Deficity	394,266	563,887

Deficit is shouldered by the city under its welfare obligations to the public.

includes cans, paper, discarded roofing material, etc. During peak periods, April, May and June, when residents prepare for the June 30 Fiesta ceremony and the opening of schools, solid waste generated contains heavy amounts of nipa shingles (made of palm and coconut leaves) and other construction debris.

1. Commercial area with houses: shown in Figure 1-2, contains 21 barangays.

2. Almost all residential except few commercial establishments, shown in Figure 1-3. Total number of barangays served is 31.

3. Outskirts (shown in Figure 1-4). Daily collection of solid waste generated is similar to the above, except a higher percentage of garden waste, especially from the Philippine Homesite Housing Coproration (PHHC), a government agency. The total number of barangays served is 43.

4. V&R Subdivision. There are two planned subdivisions, each of which has developed to some extent. Both of these subdivisions manage their solid waste independent of the city (compost, etc.). The number of barangays in this area is 6. V&G has six phases which are similar to subdivisions.

5. Imelda Village Subdivision. It is near the V&G Subdivision, located in the southwest part of the city and is expected to contain approxiamtely 200 middle income group houses. They all have septic tanks and also have their own drainage which goes into a creek with no outlet. No garbage is collected by the city from this subdivision and the common garbage disposal practice is burning in open pits.

6. Algo Homes Division--near airport. The subdivision is planned for 50 units but currently there are only 20 units built. It is located in the southeast region of the city near the airport. All houses have individual septic tanks but no drainage. No garbage collection takes place and it is burned in open pits.

Figure 1-2. Map of Tacloban City (proper) Showing Garbage Collection Route and Time Schedule of Group II.

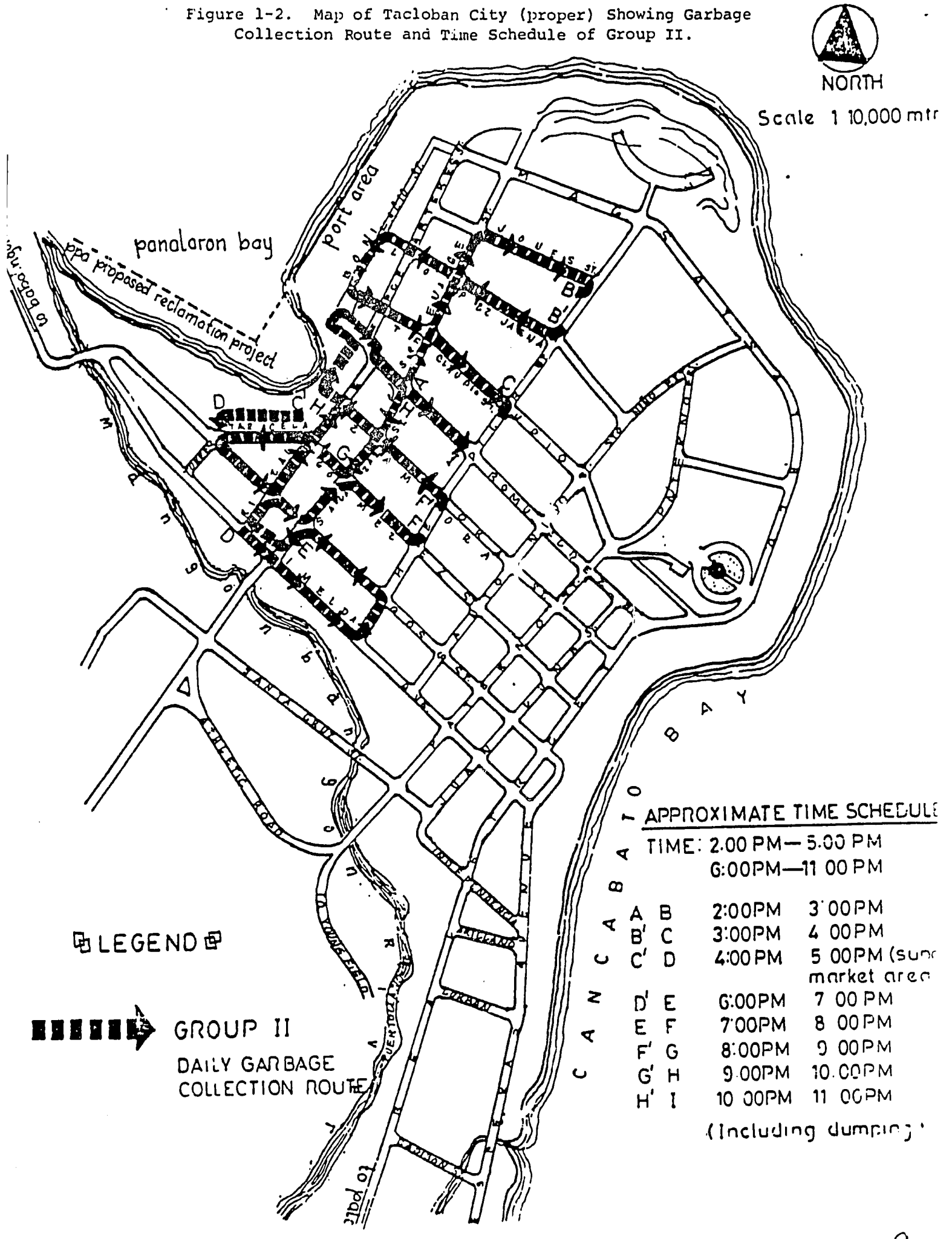

Figure 1-3. Map of Tacloban City (proper) Showing Garbage Collection Route and Time Schedule of Group I

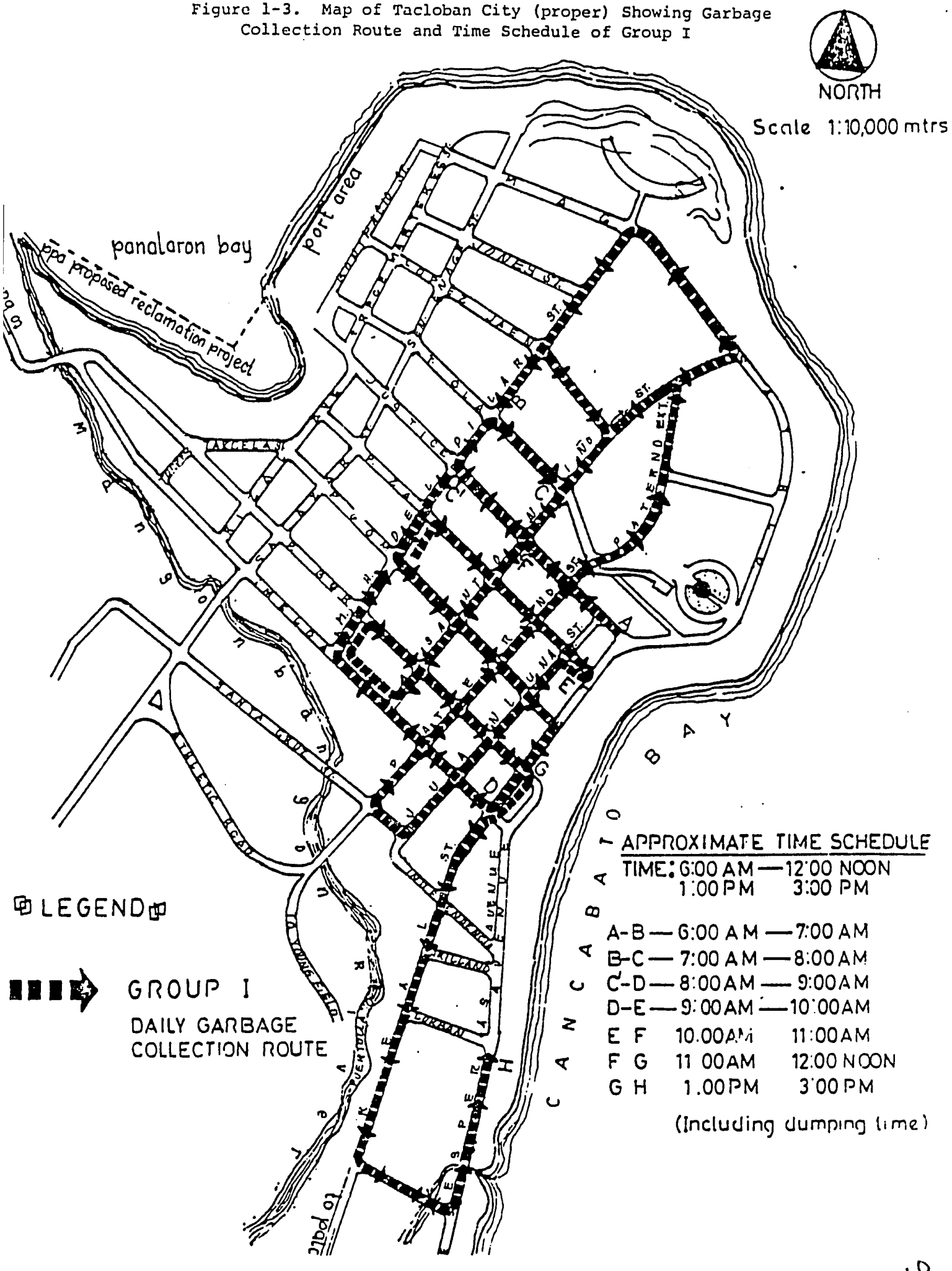

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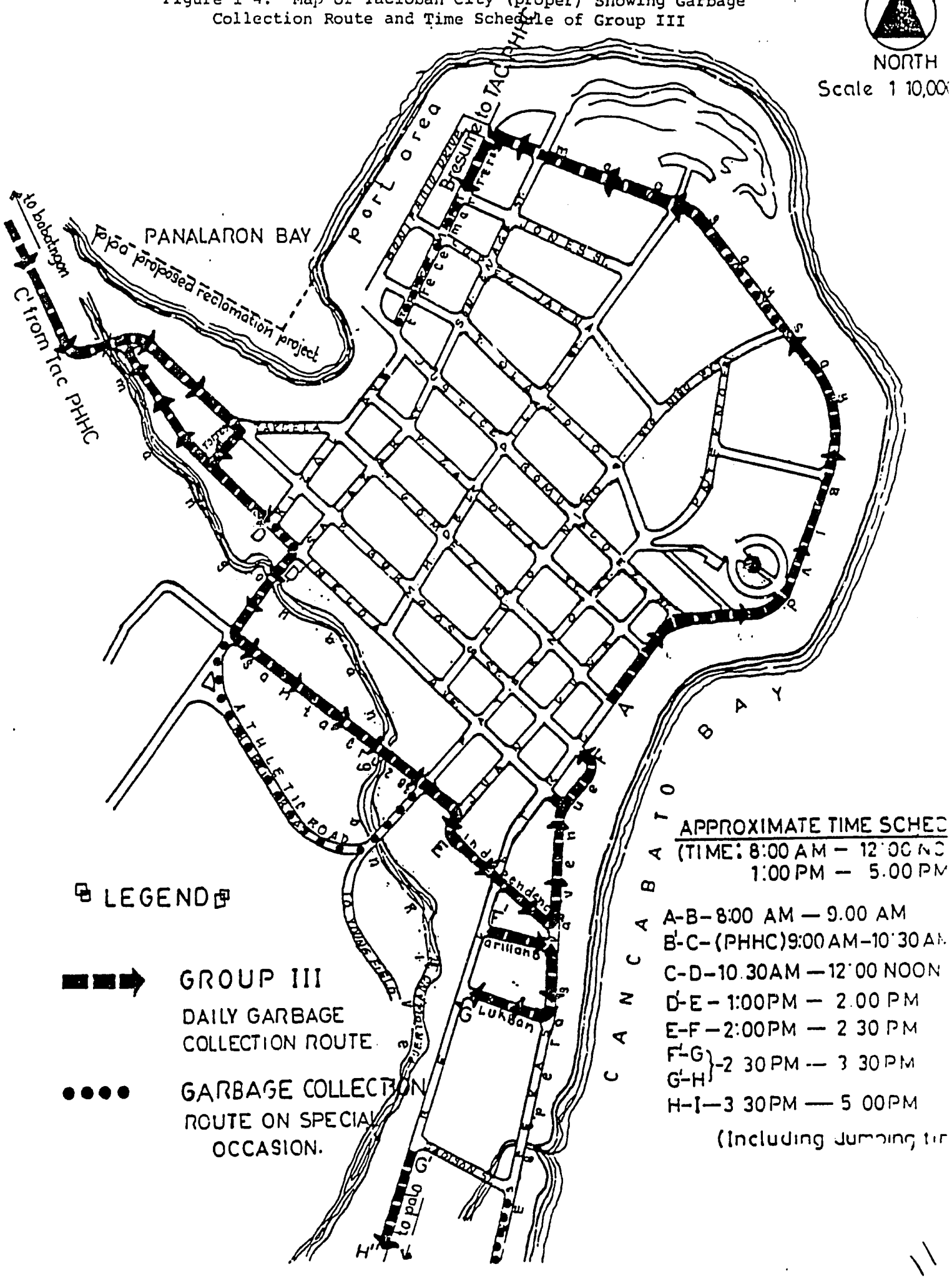
Figure 1-4. Map of Tacloban City (proper) Showing Garbage Collection Route and Time Schedule of Group III



7. Other subdivision are essentially upper income residences in other much smaller subdivisions, mainly near the Algo Subdivision. There are 150-200 houses, with no garbage collection, and most residents bury the garbage in an open pit, however, they do not have septic tanks for liquid waste disposal.

B. Commercial Areas:

Major establishments in Tacloban City's commercial area include:

- Bakeries
- Grocery stores
- Hardware stores
- Elementary schools
- Tailors
- Lumber yards
- Dormitories
- Electric supply stores
- Restaurants & hotels
- Carenderia (small eating places)
- Beauty parlors
- Barber shops
- Movie theaters
- Lodging houses
- Offices (few)
- Sari-sari (Mom & Pop) stores

The waste in the commercial area is different in composition from that of the residential areas. Burned rice husks are used as a source of heat by many commercial establishments in Tacloban. This generates large quantities of ashes particularly at restaurants and bakeries. Each large restaurant generated approximately 10-15 sacks/day (one sack's average weight is 18 kg) during the period of this study. The total number of such restaurants is estimated at about thirty. Other major types of waste include tin cans, cartons, vegetable waste, wood wrappings, leftover food, steel wrappings from electric and hardware stores.

Tacloban City's commercial area is primarily centered around Imelda Avenue, Del Pilar, T. Claudion, Enage Street, Lopex Jaena, Bonifacio Street and the supermarket (see Figure 1-2). It includes two public markets, warehouses, (Pepsi Cola, for example) and the Grand Hotel. The following are the key parts of the commercial area in Tacloban:

1. The Tacloban Super Market is housed in a large building on Tarcela Street. The building is owned by the city government. Approximately 4-5 cu.m./day of the solid waste (90 percent) mostly vegetable and banana peelings, entrails, discarded sea shells, coconut sheels and other, is collected while an almost equal amount goes uncollected. The collected solid waste is dumped into Panalaron Bay for reclamation of a part of the bay for development purposes.

2. The Tacloban Shopping Center is government-owned and is housed in a one-block building, bounded by Zamora Street, Rizal Avenue, Romuldez and Salazar Street. During normal times, approximatey 1 cu.m./day of garbage is collected, while during peak times (April-June) the quantity is generally 2-3 cum.m./day. Peak-time garbage includes mango and banana leaves used for protecting the mangoes. On the second floor, there are about 150 rooms that are mostly occupied by the offices. These have a private janitorial service that collects the garbage and places it along the roadside where the city dump truck picks it up. Most of the refuse is paper waste, cartons and some plastic bags. Renters pay garbage charges to the city through their business permits and licenses.

3. The San Fernando Public Market (Coastal Line Development) is located in a residential area and is supposed to be torn down to make place for shore protection. A coastal tree-lined boulevard is planned to be constructed in about two years. It generates approximately one-fourth cu.m./day of garbage, most of which consists of plastic bags, paper, banana leaves (used for display and wrapping of fish), vegetable waste and a few cans. The shopping center consists of about 25-30 stalls that are generally smaller than shops.

1.4 Meta Systems' Solid and Liquid Waste Survey

One of the major problems in developing countries is the lack of data on the composition of the wastestreams for liquid and solid wastes. Since the wastestreams had not been measured in Tacloban, a small comprehensive survey (see Appendix for the survey proticol) and sampling of waste producing units was conducted in Tacloban to establish the following:

1. kind (quality and quantity) of waste generated; residential versus commercial versus institutional; relationship to income levels, if any;

2. disposal practices and their relationship, if any, to waste characteristics and income levels;

3. difficulties encountered in collecting the wastes;

4. recycling--awareness, needs and attitudes; relationship with income levels, if any;

5. sources, characteristics of liquid waste;

6. disposal practices, problems and awareness of environmental impacts.

Survey Technique

The City of Tacloban was divided into 18 subdivisions to cover residential, commercial and institutional (schools, hospitals, etc.) areas. Each subdivision on the average has about 200 houses (not households) and out of this, 50 houses were selected at random.

A broad questionnaire was prepared to cover the above objectives, and six experienced survey aids from the City Planning Office were assigned the job of interviewing the respondents over a period of five days. Each survey aid was assigned a particular area for observations and interviewing various respondents. These included housemaids (generally on weekdays) and household heads on weekends.

In order to estimate the quantity of wastes generated, various dump trucks were weighed over a period of five days. Care was taken to ensure that the degree of compaction and depth of fill were taken into consideration in the evaluation. The following precautions were taken in the measurements:

1. The loaded dump truck was unloaded on clean ground and three laborers manually (using shovels, etc.) mixed the contents of the truck and then spread it as uniformly as was practical. From ten different spots selected randomly, almost equal amounts of sample were picked up totaling to a weight of 100 kg (on a weighing machine). This was repeated for commercial, residential, city outskirts, and V & G Subdivision garbage over a period of five consecutive days. The 100 kg samples were sorted manually into various fractions, weighed and percentage calculated. This was carried out under the supervision of the project consultant, city engineer, a trained technician, and four laborers.

2. V & G Subdivision and city outskirts, though both mostly residential areas (90 percent V & G, 80 percent city outskirts), are shown separately for reasons of the use of data in other elements of this study, though the percentages can be shown under residential. The very high percentage of yard waste in V & G Subdivision is due to houses with much larger backyards, trees, etc. as compared to those near the city.

3. Quantity. Each dump truck entering the site was weighed over a period of five consecutive days. The number of trips and the origin of garbage was noted. The average daily weights are shown in Table 50.

1.5 General Findings of Solid Waste Survey (August 1982)

1. Residential areas contribute more than 60 percent by weight; commercial areas, 30 percent; street sweepings, 3 percent; agricultural wastes, 3 percent; and the remaining 4 percent is a mixture. The exact percentage composition is shown in Table 1-5.

2. Based upon discussions with the city engineer and General Services Department, it appears that the quantity and quality of wastes varies according to the season and can increase by as much as 30-50 percent during fiesta and school opening season (April-June months). People often engage in renovating their houses during this season. These renovations particularly increase the percentage of nipa* shingles by as much as 100-200 percent. This requires borrowing and temporarily hiring additional manpower.

3. Demolition debris generated is generally disposed of by the building contractors and those engaged in renovating activities (e.g., household heads) and usually in low-lying areas in and around the city or in the surrounding bays. Some of this waste is also left on the streets where it may get picked up by the city garbage collection service.

4. Wastes disposed of at the dump site are collected from 102 of the city's 147 barangays** and the V and G Subdivision (a new residential colony). The collection of wastes in some residential areas in the remaining barangays is irregular or even nonexistent. It is assumed that wastes collected from a

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*Nipa is a plant--a palm tree--whose leaves can be fabricated into shingles.

**Barangays are small subdivisions in a city. These are generally headed by an elected barangay chairman. Their size can vary significantly.

Table 1-4. Average Daily Weights of Garbage*
(by Location of Origin--Tacloban City)

Origin of Garbage	Average of 5 Days' Collection
Commercial	6883 kg/day
Residential	6777 kg/day
City Outskirts	4615 kg/day
V & G Subdivision **	2900 kg/day

*Data collected during the survey August 3-9, 1982, with assistance of City Planning Office.

**V & G Data (Based on 2 Days' Collection Only).

Table 1-5. Percentage Composition of Solid Wastes
(average of five consecutive days)

	Type of Waste	Residential	Commercial	V&G Subdivision	City Outskirts	Remarks
1.	Yard waste	32.2	29.7 *	52.0	27.7	
2.	Vegetable waste	35.1	22.9	32.4	38.7	
3.	Paper	5.5	11.5	5.5	6.2	
4.	Plastic containers and bags	3.5	5.5	1.8	2.4	
5.	Glass	2.8	4.8	0.5	5.0	Mostly broken bottles and a few others
6.	Corrugated cardboard	3.6	4.8	3.6	3.3	
7.	Leather	1.5	1.6	-	1.4	
8.	Textiles	1.3	3.7	0.4	3.3	
9.	Demolition Debris:					
	Nipa shingles	0.8	0.8	-	0.8	Made of coconut leaves
	Bamboo and wood	2.0	3.8	3.4	1.6	
	GI sheets	0.9	0.6	-	1.2	
10.	Others:					
	Rice husks and ashes	4.5	2.7	-	4.07	
	Rubber	1.2	0.2	0.2	-	
	Tin cans	2.7	2.8	0.8	3.6	
	Dust and stones	0.2	2.6	-	0.81	
	Seashell wastes	.06	0.35	-	-	
	Coconut husks	1.1	-	-	-	
	Scrap iron	0.06	0.31	-	-	

* Due to high concentration of residences around the commercial market.

residential area were generated there (unlike the commercial wastes that could have come from outside the area).

5. Certain inaccuracies in classification of the waste sources are apparent. These discrepancies can occur in situations such as when commercial wastes generated in areas deemed to be predominantly residential were counted as residential wastes; conversely, residential wastes disposed of in containers placed at the markets, or in predominantly commercial areas, get counted as market or commercial wastes. These inaccuracies are considered acceptable, since to correct them would entail major changes in the collection system.

6. Per capita waste generation rates (quantity) could not be classified according to the income level, socio-economic, or separated by barangays because collection vehicles often cover more than one barangay. A collection route often serves both upper and lower income families.

7. Well-packed refuse was found to have a bulk density of 358 kg/cum.; or approximately one-third ton/cum. Based on this bulk density, the total quantity of waste disposed per day amounted to 20,000 kg/day, or equal to 56 cu.m./day.

8. If only the people who utilize the public collection service are considered, the per capita generation of residential and commercial wastes comes to 0.28 kg/day.

9. At present, there are three hospitals in the city that contribute only little to the solid waste generated in the city. The problem of the hospital wastes, however, stems from their characteristics rather than from their quantity. The city collection service used to collect hospital wastes only from St. Paul's Hospital as the other two hospitals were disposing their wastes themselves. However, at St. Pauls' Hospital, this service was discontinued after repeated requests to the hospital administrators to pack the highly infectious wastes generated at

the hospital in plastic bags or similar containers, so as to avoid direct contact with wound cleaning materials, bandages often soaked with blood and pus, operated human body portions, syringes, serum bottles, etc., went unheeded. Currently the hospital is dumping all its waste in a ditch on its grounds, which could cause serious environmental and public hazards--especially for the hopital staff, its patients, and visitors. During the survey, the matter was again brought to the attention at the highest level of concerned authorities at the hospital, including a threat to enforce very strictly the existing city ordinances and codes.

Some schools and universities generally dispose of their wastes by open or pit burning and/or composting. Their waste generally consists of office scraps, cartons, sawdust (due to current construction activity), broken bottles and plates, used examination booklets, school papers, etc. There is a great deal of scavenging that occurs before any burning takes place. However, such disposal practices cause fumes that may be subject to inhalation by students and nearby residents--posing a potential health hazard. Moreover, the operation is labor intensive and problems of ash removal and its disposal remain. Due to timing and frequency of grabage collection, these institutions are unable to use the city collection services. A change in the city garbage collection schedule would, in view of shortage and frequent breakdowns of dump trucks, be detrimental to other areas.

10. Scavenging.

Scavengers for the purposes of the survey were classified into four groups.

1) "Itinerant Scavengers" travel from house to house and buy material that has been segregated by the householder.

2) "Street Scavengers" are those who retrieve materials from storage containers; they generally sell to scrap dealers in the city.

3) "Collection Crew" also does scavenging and segregates recoverable items from refuse while it is being collected.

4) "Dump site Scavengers" recover materials at the dump sites and pick through the piles with small picks.

From the survey, the following general conclusions regarding scavenging can be drawn:

1) Citywide, almost 72 percent of the people (in 90 percent of the cases the respondent was a housewife) said that if the city starts buying such items as cans and bottles, they would separate them in the households; 8 percent said they would not, while 20 percent had no response. At present it was estimated that no more than 7 percent separate trash themselves.

2) Itinerant scavengers mostly work on the residential streets and at commercial sources. The total number scavenging from the stockpiles or heaps in the city is 100 and approximately 30 scavenge at the dump site. According to the city scrap dealers, their numbers vary significantly and can generally be linked with the market prices of the recoverables these scavengers sell.

3) The exact number and type of scavengers currently operating could not be determined due to time constraints and extreme fluctuations in degree of scavenging. It was mentioned by a Chinese scrap dealer that the current price of crushed tin cans delivered in Cebu (200 miles south) is 60 centavos per kg; hence, there is absolutely no incentive at such a low price. In general in Tacloban, the following factors seem to determine the scavenging activities and/or operation of the system.

   - the proximity to materials markets;
   - the market value of recyclables;
   - the contract provision (if any) between the city and the buyer;
   - the disposal costs if the material is not reclaimed;
   - the design and the cost of the system; and
   - the public participation rate (and frequency).

4) Cans and bottles are used as "flower pots" or as containers for household materials. Leftover food is used as animal food while paper serves as fuel for cooking, as wrapping material or is made into, generally after some pretreatment for softening, toilet paper. About 55 percent of the respondents indicated that they regularly recycle some of these materials (Table 52).

5) About 20 percent save approximately P.7-8 weekly by recycling/reuse. However, about 25 percent indicated that they have no time for salvaging and just leave it to the maid or the city scavengers. The remaining do scavenging on an off-and-on basis, depending upon the availability of salvage.

11. Garbage Storage. Institutions (schools, universities) store their garbage in such items as 200-liter drums, 200-liter half drums, 15-16 liter cans, small plastic grocery bags, abaca (jute) sacks, 1 or 2 concrete communal storage containers located in their vicinity and hand carried, plastic pails or wooden boxes. In some instances, wastes are merely piled adjacent to containers for collection. A major percentage of these waste containers are recycled items.

12. Among the areas served by city garbage collection, according to the survey 65 percent rated the system as good, 18 percent said it was not good, but not very bad, while the remaining 10 percent were not sure. The reasons for dissatisfaction were:

- inadequacy of facilities and manpower as reflected in collection efficiency;
- irregular collection;
- garbage collectors often collect only the garbage they want to collect, and leave the rest; and
- several areas are not being serviced and garbage is stored on site or dumped in the bay.

Table 1-6. Waste Material Reused and Recycled
(each respondent gave more than one answer)

Material	Number (Percentage) of Respondents, N=100	
Cans (used as flower pots, containers, dippers, or sold	45	(45%)
Bottles (used as containers or sold)	38	(38%)
Food leftovers (used as animal food)	28	(28%)
Paper (used as fuel, as wrapping paper, or for toilet purposes)	26	(26%)
Plastics (used as containers)	10	(10%)
Plant debris (used as fertilizer)	7	(7%)
Old shoes, slippers, etc. (used as fuel, sold, or donated)	3	(3%)

The majority of the respondents realize the need to dispose of the garbage properly, e.g., 90 percent agreed that plastic bags would be a good idea; however, they were unwilling to buy these on their own.

13. In general, commercial establishments generate more garbage per capita than Tacloban households.

14. In the vegetable and fish market 85 percent of the vendors do not provide any containers for their wastes. The fish cleaning wastes, exposed (rotted) meat, fruit and vegetable residues are discarded on the floor or behind the stall causing unsanitary, unaesthetic, environmental and public health risks. When questioned each vendor claimed that the wastes belong to the other.

15. It was determined that moisture content on air dried samples approximated 55 percent by weight, which makes the refuse suitable for biodegradation and composting but unsuitable for incineration. This is 3 to 4 times higher than the moisture content of an industrialized city in the Western Hemisphere.

16. Particle size could not be determined for lack of facilities (sieves, etc.). However, it appears to be small.

1.6 General Findings of Liquid Waste Survey

1. In the city proper no more than 60-65 percent of the households have septic tanks. Other means of disposal include water sealed toilets, pit privies, direct disposal into the sea, rivers, and streams as well as a few households depositing all of their sanitary wastes on the side streets.

2. Only about 70-80 percent have any kind of sanitary toilets while the rest depend upon unsanitary disposal practices of all kinds.

3. During the survey 95 percent agreed (when explained) with the need for a sewage treatment plant for the city. The rest had no answer or did not care. Among the 95 percent, 25 percent thought the city should pay the entire bill for construction, maintenance, etc., while the rest agreed to share to some extent the cost of operation if it is reasonable and they can afford it. The number of respondents with no answer was insignificant. This showed that the people were aware of the existing situation and need for improvements.

4. The practice of unsanitary waste disposal is more common among shanty dwellers, poor residents, and those living near the Bay.

5. The city storm drainage system also serves as the city sewage system especially for those people with septic tanks. The effluents are dumped into the drainage system. It consists of 10,840 lineal meters of different sizes of reinforced concrete culvert pipes.

6. Efforts were made to determine the chemical and physical properties of the sewage and various effluents at the outfall. However, the existing facilities at the only possible place--the Divine World University are not adequate and would have resulted in unreliable analysis. The idea was subsequently dropped.

7. Only one portion of the city has a centralized sewage collection system with no treatment plant. The effluents are disposed of into the Bay. However, residents near the outlet complain of the odor problems and the waste being deposited in their area. Residents along the mountain side of the city complain of the old drainage system being constantly clogged with mud and earth, thus flooding their area during heavy rainfall. The city engineers' office lacks funds for rectifying the situation.

1.7 Possible Trends in Tacloban Solid Waste Generation

Tacloban solid waste generation will increase as it has in other places. Major facts that will influence this increase are given below:

1. A seven to ten percent yearly increase in the amount of waste to be collected resulting from increases in population and per capita waste generation, possible banning of open burning, and stricter enforcement of local laws. As the economic standards of a population improve, the quantity and amounts of waste generated also increases.

2. The number of residences receiving collection service, particularly in the city outskirts and some of the newer subdivisions, such as Imelda Village, that seem to be always increasing in Tacloban.

3. Expanded level of service, such as increased frequency of collection which is currently limited by lack of equipment. An example of this would be the requirement that the hospital change from optional to mandatory proper disposal (and hence collection by the city).

4. Increase in collection of separate materials for resource recovery and biogas feedstocks, such as organic matter, cans, newspapers, bottles, etc., requiring sorting and perhaps hauling to the Resource Recovery Center, thereby resulting in the higher manpower and transportation costs.

Chapter 2

Options for Solid Waste Disposal and Resource Recovery Currently Under Consideration in Tacloban

Based on the recommendations of an earlier study called the "MEREC Study", the city at present is considering three options; the fourth option is being suggested by Meta Systems:

1. Resource recovery and reuse project;
2. Use of push carts for collection and transport (of garbage);
3. Compost plants; and
4. Upgrading the current open dumps to sanitary fills suggested by Meta Systems.

2.1 Option No. 1: Resource Recovery and Reuse Project

i. To make resource recovery from city wastes more efficient and profitable;

ii. Improve cleanliness and sanitation; and

iii. Discourage improper scavenging.

Resource recovery refers to the collection and use of solid wastes, generally residential and commercial wastes for the production of energy and materials. Resource recovery can be carried out at central or dispersed processing facilities. In general, the most cost effective and efficient way to reintroduce usable materials into productive use is through segration at the point of origin. It seldom makes sense to mix these diverse materials together in a garbage stream, only to be forced to invest still more energy later in their desegregation. Hence, the keyword is "Source Separation".

Resource recovery primarily has two objectives--the need for environmentally sound disposal of solid wastes, including the need to reduce dependence on land disposal and the need for alternate energy sources and increased energy conservation. In Tacloban most resource recovery is for recycling and reuse and has been generally on a small scale. Commercial resource recovery has fluctuated and has been wildly buffeted due to the dramatic price changes that have often occurred in the buying price of these recovered materials. For example, the current price of crushed cans delivered in Cebu city (about 200 miles away) is 43 centavos (approximately

5 cents) per kg. making it a losing proposition for dealers involved in collection and delivery of recycled materials. Often the resource recovery has fallen to zero, and in a few instances, the recovered materials have been deposited back in the solid waste stream for lack of any markets.

It appears that in considering resource recovery, the following key questions must be addressed:

- Is sufficient refuse available to support a resource recovery project and can the refuse be committed in the long term to a project?
- Do realistic long term markets for energy and material products exist?
- Are sites and technologies available which are environmentally sound and politically acceptable?
- Do local laws permit procurement options and necessary contractual agreements?
- How does resource recovery compare to the non-recovery disposal options?

If the various key issues are not discussed in a timely and proper manner, a planned project can result in a failure, wasted effort, time and money. In situations like Tacloban, primarily due to the quantity recoverables and lack of incentives, the recycling centers cannot function without government subsidies. Thus, government ownership or underwriting of recycling efforts is required. This may dampen the source of entrepreneurial spirit, so pervasive in the recycling field. Other options are government price supports or guaranteed government markets for recycled goods, thus stabilizing the prices of recovered goods.

While some combination of taxes, incentives and subsidies should provide a context within which a materials conserving ethic would evolve, a major program of public education will doubtlessly also be necessary. Such participation cannot be legislated and broad public participation is required.

Different countries have different incentives for resource recovery. For instance, in the United Kingdom and France, it is done for a greater self reliance on local raw materials. The Swedish government aims at reducing tree cutting as forestry is the main-stay of their economy and, hence, they emphasize paper recycling. Americans spend over $4 billion a year collecting and disposing municipal solid wastes. It is believed that

this volume can be significantly reduced by active source separation and recycling programs using the system of credit given to residents for the monthly amounts saved prevalent in a few communities. Today, only about six percent of U.S. municipal solid waste is recovered in any form.* In the U.S., for a sustainable resource recovery, three basic components are considered essential:

- o Waste reduction, with emphasis on smaller, simpler, more easily repaired, more durable products;
- o Waste separation requiring consumers to segregate useful constituents of wastes instead of mixing them together;
- o Waste recovery generally through high technology, centralized facility to desegregate mixed wastes into useful components.

Several materials and variety of different energy products can be recovered from municipal solid wastes and sold to produce revenue. The recoverable forms of energy include solid, liquid and gaseous fuels as well as steam and electricity. The materials that are considered to be primary recovery candidates, particularly in the U.S., are paper, ferrous metals, glass and aluminum. The recovery technologies used depend not only upon the basic components of a recovery system but also the specific manner in which these components are designed and operated. While recycling can save large amounts of energy in most cases (see Table 2-1), the recovery technology depends primarily on the markets for the recovered products.

In Tacloban, due to the nature and quantities of solid waste and the markets for recoverables, source separation seems to be an efficient way of resource recovery especially for bottles and cans. To that end, the city has an active/dormant resource recovery center which is active or dormant depending upon the prices of recovered materials. A source separation program can be successful depending upon:

- o the extent of public participation;
- o programs that can be easily followed and participated. This can lead to people changing their behavior and attitude

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*U.S. EPA, Fourth Report to Congress on Solid Wastes, 1977.

towards source separation. Average family needs to spend sixteen minutes/week to be involved in a source program; and

- Proper incentives.

It is hard to believe that even rather modest changes in prices, coupled with a reasonable effort at public education, could not bring about at least some reasonable level of participation.

Current Practices for Resource Recovery

The city has a resource recovery center set up in 1980 and run by the solid waste section of the Department of City General Services. It was set up two years ago, and has on the average ten scavengers. The seed money was supplied from the Philippines Ministry of Human Settlement, with the primary objectives of elevating the life of city scavengers, while strengthening the recovery and reuse. At present, this fund stands at only P2000 ($237), as no additional funding was provided after the initial capital of approximately P50,000. The city centre is housed in a temporary shelter behind the city fire department and covers a fenced area of less than 1/8 of an acre.

Currently there are 3 regular scavengers, each of whom is advanced P 50/day to buy cans, bottles (including broken glass), plastics and corrugated cardboard from households. These recovered materials are then bought by the city at a slightly higher than market price, and the daily difference (averages P 20/day) contributes to the income of the scavenger. The city in turn, sells these materials to the scrap dealers who, according to a preagreement, pay a slightly higher price than they would pay to a scavenger in the open market. This is generally one centavo/kg more than, or the same price, as the prevailing prices.

There are at present 7-10 (both large and small and mostly Chinese) scrap and recovered material dealers in Tacloban. A few of them specialize and deal only in such items as thick and thin scrap iron and discarded aluminum wires.

All the recovered material, except the ones that can be reused locally, are sent for reprocessing to Cebu city about 200 miles away. This includes cans, cartons, broken glass, animal bones for feed (crushed)

Table 2-1. Energy Used in Processing Virgin and Recycled Materials

Material	Energy Needed to Process (Btu per Pound)		Amount of Energy Saved by Recycling (Percent)
	Virgin Ore	Recycled Material	
Steel	8,300	7,500 (40% scrap)	10
		4,400 (100% -do-)	47
Alumimum	134,700	500	96
Aluminum Ingot	108,000	2,200-3,400	97
Copper	25,900	1,400-2,900	88-95
Glass Containers	7,800	7,200	8
Plastics (polyethylene)	49,500	1,350	97
Newsprint	11,400	8,000	25

Source: Adapted from Hill Christopher and Charles Overby. "Improving Energy Productivity Through Recovery and Reuse of Wastes", in John Sawhill, ed. Improving the Energy Productivity of the American Economy, (New York, Prentice Hall, 1979).

and fertilizer. A small portion of the unbroken bottles goes to the two local wineries. Since almost everything has to be transported to Cebu where prices fluctuate very dramatically, scavenging and resale of the recovered material is often subjected to extreme fluctuations in price and activity. This poses a planning problem for the City Recovery Center. Buyers enter only when the market is good.

The following are the types of scavengers who, at present, operate in Tacloban city. The estimated number of these are shown in Table 2-2.

a) Itinerant Scavengers: These scavengers travel from house to house and buy materials that have been segregated by the householders. They also purchase industrial and commercial wastes such as used wire and small pieces of machinery whenever available in reasonably good condition so they have no difficulty selling it either to a user or to a middle man. A few of the local dealers are known to give cash advances to the scavengers to enable them to buy the material for resale to them.

b) Street Scavengers: These scavengers retrieve material from storage containers and in process spread the garbage around the deposited area. This practice exposes the public to additional health and environmental risks and makes the collection more difficult. These scavengers generally tend to collect items of lower value and do not buy items from the residents. The number of street scavengers fluctuates very widely and averages approximately 25 a day including those operating 1/2 to 1 hour a day. Most operate at the commercial market center.

c) Collection Crew: Scavengers frequently look for recoverable items, especially unbroken (prefer Coke/Pepsi bottles, as their current sale price is P 2/each) bottles and reusable items. The recovered items are generally sold to "Dump Site Scavengers".

d) Dump Site Scavengers: These scavengers recover materials from the refuse deposited at the dump sites. Often these scavengers live in shanties near the dump site where the entire family seems to scavenge. Cans are manually crushed with a hammer and piled up. If the quantity is enough, one of the local scrap dealers does the buying and the pick up from the site or else scavengers sell the collected materials, especially bottles, cans, pairs of shoes, corrugated cardboard etc., to the dealers

Table 2-2.

Estimated Number and Type of Scavengers

Type of Scavengers	Number
Itinerant	30-40
Street	50-60
Collection Crew*	1-2
Dump Site	30-40

*Look only for valuable items

Table 2-3. Monthly Purchases of Junk and Scrap by Waste Buyers*

Item	Purchases/Month	Current Buying Price (Pesos)
1. Carton (corrugated brown boxes)	80 tons	0.10/kg
2. Broken Glass	170 tons	0.10/kg
3. Scrap Iron	200 tons	0.30/kg
4. Aluminum	6 tons	6.00/kg
5. Copper and Bronze	8 tons	7.00/kg
6. Tin Cans	150 tons	0.10/kg
7. Plastic	60 tons	0.60/kg
8. Shell	800 tons	0.50/kg

Note: The above items purchased come, not only from the city of Tacloban (approximately 60%), but also from several other nearby municipalities, e.g., Palo, Bebatngon, Tanaun, etc.

*Nine (2 are large and 7 are small)

in the town. At both the dump sites, as many as 30-40 scavengers have been seen depending upon the prices available in the market. When interviewed, dump site scavengers claimed that they, and their families, have developed immunity to diseases. Their poor health showed otherwise.

The City Resource Center is currently staffed with one laborer/ manager, who is paid P 18/day, the minimum salary in Tacloban. The practice of advancing P 50/day by the city to its scavengers for buying recoverable and reusable materials often gets misused by these people for non-scavenging purposes including meeting personal needs. This has resulted in city minimizing such activities to the detriment of the Resource Center's objectives. This personal use of money can, however, be prevented by bonding the scavenger.

Reconditioning and reuse of such things as automobile parts from wrecked cars is not considered as it is very infrequent and is not a normal activity of the type of scavengers mentioned above.

As stated earlier, segregation at the source, and separate collection would facilitate recovery, but there is little evidence that most urban residents in Tacloban can be persuaded under present conditions to separate paper, glass, cans, metals, etc. in their trash.

It is interesting to note that among the recovered materials, paper, corrugated cardboard are the only major items that are derived from a renewable resource.

The local scrap dealers generally tend to underestimate the amounts of materials they buy and sell, as they do not want people estimating their income and fear information being passed on to the Bureau of Internal Revenue (Taxes). Dealers were unwilling to show any written records. This makes estimating the quantity recovered, their marketability and hence, planning of a resource recovery program in Tacloban, difficult. Some estimates that were made by personal visits, including observation of the daily material brought in, from discussions with scavengers, and the meager records kept by the scrap dealers are shown in Tables 2-3 and 2-4.

Table 2-4. Number of Empty Bottles Purchased by Waste Buyers

Item	Purchases/Month	Current Buying Price (in Pesos)
1. Tuyo or maloinca*	42,000 pcs	0.20 ea.
2. Tanduay bottles*	204,000	0.20 ea.
3. Tuyo (big) (Fish liquid)	11,200	0.30/ea.
4. Catsup	305,200	0.20/ea.
5. Shicktong wine*	150,000	0.30/ea.
6. Soft drink (Pepsi, Coke, etc.)	250,000	1.50/ea.

*All locally manufactured wines

Number of scavengers:

Street scavengers	50 to 60
Dumping area scavengers	30 to 40
Scavengers who go around and buy from households	30 to 40 (Itinerant)

All items priced above are sold at 15-20% profit.

Improving the Performance of the Resource Recovery System in Tacloban

Lack of public participation and awareness, lack of funds, extreme fluctuation in prices of recovered materials and the distance of the materials market are among the factors, rather than poor planning, lack of interest or need on the part of the city, that have been responsible for the poor performance of the city's Resource Recovery Center. Though there is nothing like average refuse, the percentage of recoverable materials in the city's solid waste approximates 10-15 percent/day. It primarily includes cans, bottles, broken glass, corrugated cardboard and boxes. In a successful resource recovery program, a major incentive for municipal adoption is that the city is paid for materials they would otherwise pay to get rid of. Whether or not the system pays for itself depends upon a number of factors, including:

- the proximity to the materials market;
- the market value of recyclables;
- the contract provision between the municipality and the buyer;
- the disposal costs, if the material is not reclaimed;
- the design and cost of collection system; and
- the public participation rate.

In Tacloban, transportation costs of recovered materials for reprocessing in Cebu, about 200 miles away, and the wide price fluctuations in their prices are the only two major barriers in the smooth functioning of the Resource Recovery Center. Practically, for lack of facililties, nothing is reprocessed in the city. This has discouraged the city from acquiring any specialized systems such as special racks or compartments, either bought of devised, for recyclables in dump trucks which can collect recyclables and trash at the same time or even incorporate a separate small truck collection system (estimated cost of truck P 7,500). Collecting recyclables at the same time as other trash can save on personnel and equipment costs. It is recognized that these options will involve added costs to the city's solid waste collection, that will not, under Tacloban conditions, be offset by the sale of collected materials, but nevertheless, will generate several quantifiable as well as nonquantifiable benefits.

The following is a suggested approach.

1. Systematize Scavenging. Scavengers should be encouraged to buy directly from the source and the city should provide them with appropriate tools and equipment.

2. Provide a support price and guaranteed purchase of materials from these scavengers.

3. Work with the local scrap dealers to set up a system of shipping bulk volumes to Cebu or Manila, so as to lower the high transportation costs. Explore the need and possibility of subsidizing these costs especially when prices offered are very low. Scrap processors seem to have good working relationships with scrap users, are trusted for quality control, can market to numerous alternate buyers and can inventory materials (given proper assurances to help match supply and demand).

4. Expand garbage collection program. Close or change to sanitary landfill, the present dump site to stop all scavenging at the dump site.

5. Anti-Scavenging Ordinance to prevent few people from reaping, particularly when the prices are good, the profits of a community wide service. Such ordinances will clarify the city's ownership of materials placed at curbside both in the residential and commercial areas for pickup. Additionally, it will prevent indiscriminate searching and strewing of city's garbage and minimize environmental and public health risks.

6. Consider ordinances that require city's residents to separate recoverables from their trash.

7. Sign contracts with potential buyers and assist them by defining markets.

8. Publicize the program, after measuring public awareness.

   - Involve Barangay chairmen and various interest groups;
   - Explain "nuts and bolts" of the program including a) how often recyclables are collected, b) is the program mandatory or voluntary, c) will the city make or lose money from the program, d) bundling and typing of newspapers and what to do about rainy days, e) monetary, environmental, public health, legal implications of not following a proposed system.

2.2 Option No. 2: Use of Push Carts for Collection and Transport

The costs of fuel and equipment used for garbage collection can be reduced through the use of manually operated push carts. The practicality of using push carts for the collection and transport of residential refuse

has been verified in other cities, at least one of which (Angeles City) is in Philippines. It must be recognized that like any other technology, acceptance and utilization of push carts by the public and workers may require some initial persuasion as well as demonstration.

Push carts are basically metal drop boxes mounted on trailers and their usage involves very low fuel, capital and maintenance costs. These generally have two wheels and the drop box has a volume of approximately 2 cu.m. (800 kg.).

The use of push carts should be limited to an area from where they can be readily pushed to the disposal site for, if they are placed too far from the disposal site, they may require towing.

Proposed Location of Push Carts in Tacloban

One possible site is V & G Subdivision, that can use five push carts, each with 2 laborers. Size suggested is 1 cu. m. push carts. This subdivision is excellent for demonstration purposes. Moreover, this time, only temporary garbage collection service is available (3-4 times a week). This new V & G residential subdivision has approximately 1000 houses with a population of about 6000 people.

2.3 Option No. 3: Composting for Tacloban Solid Wastes

A major constituent of solid waste in Tacloban is vegetable matter--mainly from garden yard and kitchen waste (average daily about 65 percent by weight). Urban areas generate domestic and shop waste on a large scale, approximately 0.28 kg/person/day. The city as a whole generates 56 m^3/day with approximately 65 percent on the average, putrescible vegetable matter. Composting is a method of solid waste management, whereby the organic component of the solid waste stream is biologically decomposed under controlled conditions to a state in which it can be handled, stored and/or applied to the land without adversely affecting the environment.*

The purpose of controlling the process differs in composting from biological decomposition in nature to include the following attributes:

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*Golueke, Clarence G., 1980. "Biological Reclamation of Solid Wastes, page 2, Rodale Press, Emmaus, PA).

- To make it esthetically acceptable;
- To minimize the production of offensive odors;
- To avoid the propagation of insects or odors;
- To destroy pathogenic organisms present in the original wastes;
- To destroy weed seeds;
- To retain the maximum nutrient content N, P, and K;
- To minimize the time required to complete the process;
- To minimize the land area required for the process.

Three bases of classificaiton in composting that are comsidered to have a practical significant are:

1. Aerobic vs. anaerobic;
2. Mesophilic vs. thermophilic; and
3. Mechanized vs. non-mechanized systems.

Modern composting processes are generally aerobic, offering advantages including:

- Lack of objectionable odors, so long as aerobic conditions are maintained;
- High temperatures attained during the process are generally lethal to plant and animal pathogens and parasites as well as weed seeds; and
- Aerobic composting is more rapid (2-4 weeks) than anaerobic. However, careful designs and operating procedures can accelerate the anaerobic process considerably.

The major disadvantages include:

- Maintenance of aerobic conditions requires greater handling as well as spatial requirements compared to anaerobic composting.

- Aerobic process involves some loss of nitrogen, due to high temperature and eventual alkaline conditions reached.

The Process of Composting

Composting is a biological process and only organic ;materials of biological origan be composted. Thus plastics if present, undergo virtually no change during composting. The size and composition of the microbial population determines the rate and extent of compost activity. However, a definite upper limit exists. Thus, even with all the optimum environmental factors, the rate of bacterial activity is limited by the genetic makeup of the bacterial population. Also, the more diverse the

material, the more diverse should be the population. Many types of organisms assist the process: bacteria predominate at all stages, fungi often appear at the first week; and actinomycetes assist during the final stages.

The process begins at ambient temperatures by the activity of mesophilic bacteria which oxidize carbon to carbon dioxide, thus liberating large amounts of heat. Usually the temperature of wastes reaches 45°C within two days, and thus, represents the limit of temperature tolerance of the mesophilic organisms. At this point, the process is taken over by the thermophilic phase which lasts about two weeks, takes place in the temperature range of 55°-70°C; and any increase beyond 70°C temporarily slows the thermophilic activity. The presence of actinomycetes in a composting mass can be readily detected visually and olfactorily. Under favorable conditions the composting material begins to acquire a faintly earthy odor after five or six days have elapsed, and this odor, which becomes more pronounced as time progresses, is caused by actinomycetes. Fungi at the same time grow intermingled with the actinomycetes. More types of fungi have been identified in the compost process than has been the case with bacteria and actinomycetes.

It can be safely said that urban solid wastes, of the kind generated in Tacloban (high organic matter), already contain at the time of collection all the organisms required for every phase of aerobic composting. Innoculants, whether of selected bacteria or nutrients, are totally unnecessary; numerous studies have revealed no difference in either the speed of composting or the quality of the product as between innoculated and untreated wastes.

Environmental Factors Affecting Composting

1 Substrate. Substrate is extrinsic to the microbial population and as such exercises an influence on the extent and rate of microbial activity. Particle size and moisture content are important. Particle size determines the surface area per unit of mass exposed to bacterial attack.

Moisture content is a critical factor in aerobic composting. The following are the main requirements:

- The rate of composting declines below 40% moisture content.

- Below 20% decomposition ceases.
- Above 55% water begins to fill the interstices between the particles of wastes reducing the intersticial oxygen and causing anaerobic conditions as the compost becomes more compact thereby reducing the amount of air present. Thus, although theoretically 100% moisture content may be acceptable, practicality demands oxygen availability.

Moisture content can be easily determined for the substrate. An aliquot of the new material is weighed and then dried at 100°C for a period of 6-8 hours. The dried material is weighed. The loss in weight over the original weight times 100 equals the percent moisture. A crude indication of the adequacy of moisture content is a glistening appearance of the composting material. Excess moisture is indicated by the presence of drainage. Drainage may occur before a foul odor becomes noticeable. On the other hand, a dry, dusty appearance indicates insufficient moisture. These indicators are qualitative in nature and should be backed by quantitative analysis. A drop in temperature is another indication of inadequate moisture, provided other factors are suitable.

In mechanical digesters, water can be added at any time. In windrow composting, it is better to add water during turning as the windrows tend to shed water when sprinkled on them.

Table 2-5 shows typical ranges of the maximum permissible moisture content of wastes. Tacloban wastes fall within the optimum range of initial moisture content and are unlikely to require the addition of moisture during the first few days. During the thermophilic stage (50° - 60°) however, the high temperature causes rapid loss of water and this must be replaced from time to time, until the final fall in temperature. At this point, it was desirable to allow the moisture content to decline to 25% in order to minimize the weight of material to be transported to the farm, or wherever the compost is to be disposed of.

2 <u>Carbon-Nitrogen Ratio</u>. The C-N ratio is an important aspect of nutritional balance and must be an important criterion for assessing the suitability of a given waste for composting. Living organisms require available carbon as a source of energy and need nitrogen to synthesize protoplasm. However, if the excess of carbon over nitrogen is too great,

biological activity diminishes, requiring an excessively longer time for composting. A C:N ratio of 25 or 30 parts of carbon to one part of nitrogen is optimum for most types of wastes since living organisms utilize about 30 parts of carbon for each part of nitrogen. A low nitrogen content requires that the micro-organisms metabolizing during the decomposition process recycle this nitrogen through many generations, gradually building up the percentage of nitrogen, as carbonaceous materials decompose through aerobic decomposition to carbon dioxide and water. This process of regeneration is very slow and, hence, composting (digestion) time is greatly increased. In windrow composting* with a C:N ratio of 20, a digestion time of 9 to 12 days is required; 10-16 days if the C:N ratio is 30 to 50 and 21 days if the C:N ratio is 78.

Composting will generally not take place in an environment in which the C:N ratio is greater than 80. Phosphorous is the other nutrient essential to composting. The carbon-to-phosphorous ratio of 100:1 is proper for microbial growth** and digestion. Solid waste streams, particularly of the kind in Tacloban, usually contain a sufficient amount of phosphorous for microbial growth. The Tacloban wastes, however, is below optimum C:N ratio. This is because the main source of nitrogen is the vegetable/ putrescible matter, which has a C:N ratio of about 24:1. Paper is the main source of carbonaceous material. Thus, higher the ratio of paper to vegetable/ putrescible matter, the higher the C:N ratio. C:N ratio of several substrates is given in Table 2-6. For composting purposes it seems Tacloban wastes could be improved by the addition of carbonaceous materials.

3 Temperature. In composting during the initial stages of decomposition by mesophilic flora, optimum temperature range of 26-35°C, predominates and is responsible for most of the metabolic activity that occurs. This increased microbial activity elevates the temperature of the compost with subsequent replacement of mesophilic by thermophilic fauna, which metabolizes optimally at a temperature of 55°C. This change in

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*California, University of, "Reclamation of Municipal Refuse by Composting," Technical Bulletin No. 9, Series 37, Sanitary Engineering Project, Berkeley, University of California, June 1953, p. 89.

**Hagesty D. J; et al. Solid Waste Management, page 10, Van Nostrand Reinhold, New York 1973.

Table 2-5

Maximum Permissible Moisture Content*

Type of Waste	Moisture Content (% of total weight)
Theoretical	100
Straw**	75 - 85
Wood (sawdust, small chips)	75 - 90
Rice hulls	75 - 85
"Wet" wastes (vegetable trimmings, law, clippings, garbage, etc.)	50 - 55
Municipal refuse	55 - 65
Manures (without bedding)	55 - 65

*Source: Golueka, C. G., 1980. op cit, pg. 39.

**Serves as the "absorbent" and principal source of carbonaceous material. Needs sufficient nitrogenous wastes, such as manures, grass clippings and sewage sludge added to bring C:N ratio down to the proper level.

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temperature is greatly controlled by the amount of oxygen available; that is, the amount of aeration provided. Due to this phenomenon the temperature of the composting mass is normally an indication of the amount of biochemical activity taking place. A drop in temperature means that the material needs to be aerated or moistened or that the decomposition is almost completed. However, unless special measures are taken, a composting mass of any appreciable volume will assume higher temperatures.

4 pH. Hydrogen ion concentration or the pH varies during the composting process and is a good indicator of the extent of decomposition, within the composting mass. The initial pH of solid wastes is between 5.0 and 7.0 for refuse, which is about 3 days old. In the first 2-3 days of composting, pH drops to 5.0 or less, and then begins to rise to 8.5 for the remainder of the aerobic process. If the digestion is allowed to become anaerobic, the pH will drop to about 4.5*.

5 Aeration. Oxygen demand in composting is greatest at the beginning, declines as the process nears completion. However, an increase in moisture content imposes a need for more aeraton. Various attempts to quantify oxygen requirements have provided such diverse results as to suggest that there is a wide range of oxygen need depending upon such factors as the detailed composition of the waste, and the average particle size. A rule of thumb is that any onset of anaerobic conditions is immediately signalled by the offensive odors. Appropriate remedial action is easy (e.g., turning the mass) and can be immediately taken.

Composting by Windrows

Composting has been practiced for centuries and the most common method was placing animal and vegetable matter in piles and allowing the decomposition to proceed.

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*Gainesville Municipal Waste Conversion Authority, Inc. "Gainesville Compost Plant; An Interim Report," U.S. Department of Health Education and Welfare, Cincinnati, 1969, p. 345.

In contrast to a properly run compost system, an open compost heap can be best described by the following:

- Based on original supply of interstitial air, the temperature in an open dump rises (mesophilic) and the insects hatch their eggs.
- Thermophilic stage occurs for a short period and internal heat causes insect larvae to migrate to the cooler layers.
- Anaerobic bacteria take over as soon as the interstitial air is exhausted and the temperature of the heap declines to ambient.
- The larvae in the outer layer hatch into insects and begin to lay more eggs in the exposed wastes. Meanwhile rodents enter the heap in search of food and nesting conditions.
- A large heap will apparently have odor at all times, while a small heap will give off an odor when disturbed. In the anaerobic center of the heap, decomposition is very slow and may cease in the outer layer because of dehydration.
- After several months, a form of compost may be produced. This, however, is actually a mixture, adulterated with uncompostable broken glass, plastics, metals, stones and coarse fibrous materials, some of which may be large enough to interfere with cultivation, if applied to the land; while others will be dangerous to animals. The outer layers are likely to contain viable weed seeds while most of the pathogenic microorganisms may have survived.

Attempts to systematize and improve the composting process began in the 1920's when Sir Albert Howard* developed the Indore Process in India, and Beccari later patented his process in Italy.

The Indore process involves the degradation of leaves, garbage and animal manures for 6 months in pits. This process was later modified to include turning the compost during degradation to encourage aerobic digestion to occur. The Beccari process was quite similar to Indore except that it utilized concrete cells as digestion chambers.

Howard's Indore Process was essentially based on building piles of vegetable material and animal manure and wood ashes, which were heaped and turned after 16, 30, and 60 days with intermittent watering. The finished

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*Howard, A. "The Manufacture of Humus by Indore Process", Journal of Royal Society of Arts, Volume 84, November 22, 1935, pp. 26-59.

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Table 2-6

Approximate Nitrogen Content and Carbon:Nitrogen (C:N) Ratios of Various Wastes (Dry Weight Basis)

Material	Nitrogen (%)	C:N Ratio
Night Soil	5.5 - 6.5	6 - 10
Urine	1.5 - 1.8	0.8
Blood	1.0 - 1.6	3.0
Cow Manure	1.7	18
Poultry Manure	6.3	15
Sheep Manure	3.8	-
Pig Manure	3.8	-
Horse Manure	2.3	25
Raw Sewage Sludge	4 - 7	11
Digested Sewage Sludge	2 - 4	-
Activated Sludge	5	6
Grass Clippings	3 - 6	12 - 15
Non-legume vegetable waste	2.5 - 4	11 - 12
Mixed grass	2-4	19
Potato tops	1.5	25
Straw, wheat	0.3 - 0.5	128 - 150
Straw, oats	1.1	48
Sawdust	0.1	200 - 500

Source: Golueka, Clarence G., 1980. Biological Reclamation of Solid Wastes, pg. 27, Rodale Press, Emmaus, Pa.

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compost was moved to fields after 90 days where it showed very favorable results on agricultural crops.

With the growing interest in composting of municipal refuse for urban areas, currently the system has been fully mechanized. Various devices for material handling, grinding of refuse and its aeration have been developed. Among them is the Dano process developed in Denmark besides numerous other proprietary processes.

The Indore Method

The refuse in this process is packed loosely in heaps and if night soil is also used, a trench in the refuse is filled with well-stirred crude night soil. The top of the trench is then covered over loosely with refuse drawn from the side of the heap. The quantity of night soil filling the heap is generally kept between 1/5 to 1/6 of the volume of heap. The site selected for making compost by this method should be well drained, and free from flooding. The site should be leveled and drained with shallow earth drains.

Except for daily moistening with water in dry weather, the heap is left undisturbed for a week. At the end of the week, the outer portion is turned so that it becomes the inner portion and the rubbish inside the heap forms the outer portion. At this stage, an additional and up to 1/10 of the heap volume of night soil can be added and covered with composted refuse. At the end of the third or fourth week, the heap is again turned, but no more night soil is added. Daily watering is discontinued and the heaps are left to age for 30 days. In the event of heavy rains, a loose covering of grass or coconut fronds can be laid over the heaps. Two months after commencement of composting, the heap will have reduced to almost 30% of its original size. The compost is ready for use.*

In the Indore Method, the temperatures reached in the first week average 65°C (152°F) and are sustained for over 20 days. Fly maggots may be seen on the surface of the heap during the first week, but disappear after the first turning of the heap, however, by the end of the third week, the compost is free from intestinal worm eggs. (Scharff, op cit)

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*Scharff, J.W. 1940. "Composting. The Safe Conversion of Village Refuse and Night Soil into Valuable Manure". J. of Malayan Branch. British Medical Association. 4:126-135.

It has also been established that heat produced during composting effectively destroys many known human pathogens.

Windrow Layout and Management in Composting

Windrow composting is one of the most important and widely used techniques. The following are the key points.

1. The windrowing stage is the most important part of every composting system except for "Digester Composters" described elsewhere. The area occupied by the windrows should be paved, drained, and provided with a water supply. The other main cost element is that of turning the windrows to aerate them. This, however, depends upon manual or mechanical turning.

2. Excessive windrow height will decrease interstitial volume and hence aeration. Optimum windrow height is 1.6 - 2.0 meters.

   a) At lower heights, temperatures achieved are less;

   b) At greater heights, anaerobic pockets are more likely and manual trimming is difficult.

3. Width is critical. Normally it is 3.0 to 4.0 meters, however, for small operations, it can vary from 1.5 to 2.0 meters.

4. Length of the windrow, is usually equal to one day's production. Length, however, has no bearing on the biological process.

5. The following are the main components of plant design for windrowing:

   a) Transfer of waste to windrows;

   b) Aeration of windrows; and

   c) Layout of windrows

Basic Requirements for Controlled Windrow Composting

1. Form the wastes into windrows of manageable size.

2. Reform the windrows after 3-7 days, for aeration.

3. Turn over the material so that the outer material is in the center and vice versa. Temperatures in the center are much higher.

4. Replace lost moisture by sprinkling the wastes with water during the turning process.

5. Continue this procedure for 20-25 days until a steady fall in temperature indicates the end of the process.

6. If the moisture content gets to be too much, for example, due to rain, increase the frequence of turning.

7. After the process is complete, separate mechanically (if mechanical operation) or manually, non-compostables such as plastics, large pieces of wood, tins, etc.

It should be noted that whatever the level of mechanization and sophistication, almost all current composting systems rely on windrowing for all or part of the decomposition process. The following are the four common types.

1. Windrowing of untreated wastes and separating the non-compostables (non-biodegradables);

2. Windrowing of size reduced wastes and separation of non-compostables; this is the most common type of plant is use today. Size reduction is normally done by hammermill, however, before this any salvage and ferrous metals are removed. Hammermill not only reduces the waste, but also increases the surface area which speeds up the degradation process.

3. Windrowing of size reduced, separated wastes which have been partially decomposed in an enclosed vessel.

   Here, instead of a hammermill, a very large rotating drum is employed (several hundred ton capacity) where wastes are retained for 7-8 days. Rotation reduces the size of the material due to attrition as they rub against each other. Wastes become homogenous and air is supplied. The gaseous products are withdrawn and passed through a filter to minimize odors. Thermophilic temperatures kill most of the pathogenic organisms before wastes are delivered to windrows.

4. Total, or almost total, decomposition of pretreated wastes within a digester; here separation and size reduction treatments are carried out before hand. Digester vessels could be a multi silo with multiple floors where aperature in the floors allow the wastes to descend through the silo over a retention period of about a week during which they are supplied with forced aeration and the required moisture level. However, due to prohibitively expensive nature of this plant and the lack of compost market in Tacloban, it is unlikely to be economical.

<u>Disadvantages of Windrow Method</u>

1. Operation being in the open, is affected by local climate.

2. Odors are difficult to control and contain.

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3. Often excessive retention time, 20-25/day depending upon climate, refuse characteristics, etc., excessive in relation to mechanical composting.

4. Excessive land requirements.

5. C:N ratio and windrow composting:

C:N Ratio	Time in days
20:1	9-12
30:1	10-16
78:1	21-25
80	Composting may not occur

Pilot Compost Plant for Tacloban Waste

For composting to be a successful operation, besides availability of assumed feedstocks there must be a potential market or an economic return for the end product. However, it appears from discussion with city officials, including the Agriculture Office, that this may not be the case for Tacloban. In view of this, it was agreed that a pilot compost plant be established to obtain data and to study the suitability of the operation, not only for solid waste disposal, but also to evaluate its suitability as a cover material for the proposed Tacloban sanitary landfill. Moreover, the possibility of marketing and/or using compost for agricultural and/or landfilling for low lying areas can also be evaluated.

Key Considerations

The following are the relevant elements for such a pilot plant.

- Tacloban's solid waste with its high organic matter and moisture content is considered suitable for composting;
- According to the Agriculture Office, based upon an initial survey among the very few area farmers, it appears that at present, there is not any significant market or interest in using compost by farmers existing within a radius of 25 km. This is considered the economical region for transporting compost for sale. Thus, in absence of any steady agriculture market for compost, a pilot plant is suggested;
- One possibility for using compost in Tacloban is to use it along the national highways, parks, etc. and as a filling material for the Sanitary Landfill; and

- Two basic requirements, therefore, appear to play a critical role in composting Tacloban solid wastes:
  - Land for composting
  - Land for disposal
- In the U.S. Composting has failed for the following five main reasons:

  1. No steady market for the end-product
  2. Compared to other methods, initial investment and operating costs are generally high.
  3. Without excessive expense, a high quality end product cannot be derived.
  4. The separation of non-compostables requires a secondary method of disposal and increases the costs of disposal.
  5. Costs per ton of composting exceeds those of landfilling by approximately 400-500 percent.

- Large size operations such as those prevailent in the U.S. generally are mechanical in nature. Essentially such oprations have the following basic components.

  - Scales;
  - Tipping area and receiving bin;
  - Various systems for conveyors for refuse transportation within the plant;
  - Sorting equipment for salvage and bulk items removal -- for example, magnetic extraction;
  - Grinders and shredders, e.g. for size reduction. This will include using such devices as hammermills, rasps, short term drums, shears and cutters. An alternative to a hammermill or rasp is to tumble the wastes in a revolving drum for between 1-2 hours;
  - Finishing equipment, e.g. final grinding, screening, pelletizing, bagging, etc.; and
  - Adequate storage for compensation of equipment failure. For domestic refuse, generally accepted unit weight is 0.175 tons/yard^3.

- In view of the <u>absence of market for compost in Tacloban</u>, and lack of previous experience, the pilot compost plant envisioned for Tacloban can achieve the following, while keeping the initial investments low:

  1. Familiarization of personnel with basic operations of composting, considered necessary for larger operation.
  2. Impart training to the mid-level technical staff and technicians.
  3. Evaluate key parameters under Tacloban conditions. (e.g., optimum windrowing period using daily temperature records).
  4. Quantity and quality of compost produced.

5. Developing and encouraging local especially agricultural markets, e.g. by greenhouse and field experimentations agricultural crops and compost under local conditions.

A Manual Windrow Pilot Compost Plant for Tacloban

A manual windrow compost plant is especially suitable for producing compost for a landfill site, as well as for evaluating various operational parameters for a larger sized operation later. The following are various steps required to establish such a plant.

1. Approximately 9 m^3 of refuse is delivered directly to one of the 20 windrow spaces on unpaved, but level and well-drained, land.

2. Each windrow is 3m long x 2m wide x 1.5m high with a total volume of about 9 m^3.

3. Each windrow would be turned on the 6th and 11th days, the outside to the center, to destroy pathogenic organisms and provide aeration. On the 16th day, the windrow is broken down and passed through a manually operated rotary screen of about 25mm square mesh to remove the oversize noncompostable materials. The screened compost would be stored for about 30 days in a maturing heap, about 2.5 meters wide, 1.5 meters high, and up to 18 meters long for stabilization of the compost before use.

4. Area Required:

   a) For 20 windrows = 20 x 3 x 2 m
      = 120 m^2

   b) Area between each windrow at 0.5 m = 30 m^2

   c) Total = 150 m^2

   d) Central roadway for delivery of wastes = 25 x 5 m = 125 m^2

   e) Maturing (storage) area = 50 m^2

   f) Entrance area 15 m x 4 m = 60 m^2

   Total: 385 (or approx. 400)m^2

5. Personnel:

   a) One windrow to be stacked daily from new wastes = 9 m^3

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b) Turning of 2 windrows; (volume declines during decomposition) 15 m^3

c) One windrow to be broken down and screened = 6 m^3

Total: 30 m^3

Usually one man can turn wastes up to 5 tonnes or approximately 15 m^3 per day and, therefore, two men are needed; also, two men would be required for screening and piling in the storage area.

Laborers required = 4 men

6. Rotary Screen:

Rotary screen is used for separating large, generally non-compostable material. The screen is a simple, inclined, perforated drum, and is hand-operated through a gear drive. It should be mounted at a reasonable height so that the operations can be performed by conveniently by a person standing on a small stool or platform. The screened material can be discharged at the ground level. The costs of such a pilot compost plant are given in Table 10

For the calculations in Table 2-7, it is assumed that suitable land (1/2 - 1 ha.) for windrow composting is already available. No transportation of wastes to composting sites have been shown since several suitable sites less than 2 km from the centroid of garbage generation and 4 km away from residential areas are available. No additional delivery costs beyond the present refuse collection and delivery costs are foreseen.

Composting by the Chinese Method: City Garbage and Night Soil

While windrow composting is primarily suitable for solid and agricultural wastes, the Chinese method has been popular for composting city garbage and night soil. This method, described below, has several socio-cultural constraints limiting its applicability in Tacloban. It is described as follows:

The Method*

- The Chinese method of composting city garbage (70-80% compostable matter by weight), free from non-compostable materials, such as glass and ferrous metals, is mixed with 20-30% night soil (by weight).

*FAO SOILS Bulletin, No. 40, 1977.

- The mixed material is piled in a heap about 4m wide at the base and 2m wide at the top, and 1-5m high and about 4m long. In between after heaping about 30 cm high, sets of bamboo poles are held horizontally on the heap at every 1.5-2m, each set connected to at the center with a bamboo pole placed vertically. On completion, the heap is sealed with a 2-3 cms thick coat of 40% soil and 60% cinders mixed with water. The day after heaping, bamboo poles are withdrawn, leaving airways for ventilation.

- Temperature of the heap rises to over 50-55°C within 1-2 days. This temperature is maintained for more than 10 days, effectively destroying pathogenic organisms and putrefying organic matter as well. The compost is ready in 3-4 months.

In summer, bamboo poles need not be used. With proper moisture content and loose stacking, a temperature of about 55°C is developed.

The following technique is used if Chinese composting is practiced on a large scale. City refuse and night soil are placed in heaps 1m high, 1m wide, and any convenient length. The garbage and night soil are placed in alternate layers in the ratio of 3:1 by volume or in equal weights. This type of composting requires less work and space and maintains temperatures above 50°C.

Plastering of heaps with mud maintains moisture and temperature, avoids nutrient losses, prevents emergence of maggots from the pile to complete their life cycle and keeps out breeding flies.

Issues in Tacloban for Utilization of Chinese Methods

The method as practiced in China requires a systematized collection of night soil and the availability of commune latrines. Except for one public latrine located on a septic tank in nearby Palo city (10 miles) there are no public latrines in and around other communities of Tacloban. Due to cultural problems and attitudes it is doubtful if such a system would work in Tacloban.

In China the transport of raw refuse to the countryside involves considerable distance and is a serious public health hazard. The public health is directly related to 1) the source and the nature of the wastes; 2) the manner in which they are composted, and 3) the use of the product. Generally the public health aspects of composting are positive, however, it

Table 2-7

Cost of the Pilot Windrowed Compost Plant for Tacloban

(The plant capacity is based on 3 tons of waste/day producing 1 1/2 tons/day compost)

a) Capital costs (Pesos)

i)	Hand operated screen	2,000
ii)	Fencing and gates, 5 strands, 300-meter long fence, including posts and erection labor	3,000
iii)	Roadway (graveled) for wastes delivery, 125 m^2.	5,000
	- P40/m^2 requires no elevation, but only gravel & sand, includes labor cost (30% of 40.00)	
iv)	Covered 50 m^2 (Nipa shingles) storage area (shed)	2,500
	- Labor is 35% of the cost of materials; Nipa shingles cost 75 centavos each.	
		12,500

b) Annual Operating Costs (Pesos)

i)	Tools & equipment (shovels, rakes, sprinkling cans, etc.)	1,000
	- (includes a well for water, @200)	
ii)	Boots and gloves, raincoat	500
iii)	Disinfectant	200
iv)	4 Laborers at compost site (includes fringe benefits)	43,800
	and supervision and administration	6,000
v)	2 laborers at the dump site for sorting and shredding garbage for compost (sorting is manual & dump site & compost site different)	21,900

c) Quantity produced per year @ 1 1/2 tons/day: 468 tons
Cost of production: 73,000 + 2,035*

75,035
P160/ton

*10 year life discounted at 10%

could become a constraint if the hazards of handling night soil are ignored or improperly managed.

It is extremely doubtful that the technique of night soil composting as practiced in China today can have use and application in Tacloban. However, other systems of night soil composting, such as compost toilets described later, may have better acceptance in Tacloban.

Economics of Composting in Tacloban

A compost operation need not be a money making activity to be judged as a success. There are two arguments that stand out to justify this statement. One is the cost of otherwise disposing of the solid waste in a satisfactory manner, since composting can easily stabilize wastes and has no adverse environmental impact. Thus, a major consideration in composting refuse is whether or not composting is to be an integral part of an overall resource recovery operation or whether it is to be the only resource recovery system. The second important credit is that as a fertilizer; it can provide plant nutrients in addition to soil building humus.

Absence of a market for compost can adversely impact its economics and hence, its relative suitability when compared to other methods of solid waste disposal such as Sanitary Landfilling. The use of compost as a Sanitary Landfill cover material or for land reclamation, generally a public activity, is taken at no charge or a very minimum charge. For example, in Table 2-7 we showed that compost cost P 160/ton (at 50% moisture content) to produce. Assuming that it is 5 percent nitrogen (a favorable dry weight assumption) the cost of the nitrogen fertilizer is 160/0.0375 or P 4,266 per ton. The current cost of urea in Tacloban is P 5,652 per ton of nitrogen (46% of urea). This implies that even on nutrient content alone, ignoring its soil building aspects, compost may be economically competitive with chemical fertilizer at current prices.

At present, however, according to the local Agricultural Office, the compost usage potential market in Tacloban is almost non-existent. Development of a market would require an increase in those agricultural activities that provide the greatest cost returns and convincing the agricultural community about the potential benefits of using compost, primarily through public education and field demonstrations. This will

require budget approvals, demonstration of benefits of compost in farmer's fields, and pre-supposes that the initial inertia and bias have been overcome. Local Barangay chairmen may have to be involved to test the products at no cost on their own land or farms.

With the potential lack of any market for compost and the initial high investments required of a compost plant for disposal of Tacloban solid and liquid wastes, composting does not appear to be a recommended option. One possibility, could be setting up of a small compost plant for the city to gain experience and demonstrate compost's benefits primarily to the surrounding agricultural community. Compost thus produced can also be used along highways and as a cover material. See Table 2-8 for application rates. Transporting compost to distant markets, if any, would be very expensive.

Finally, it must be stated that, if composting is to be practiced under Tacloban conditions, it must only be started as a pilot scheme and any expansion later on, assuming a market for compost is developed, must be set up as a complete resource recovery system.

2.4 Option No. 4: Sanitary Landfill

A sanitary landfill is a solid waste disposal facility, wherein refuse is placed at the greatest possible density and in smallest possible space, for final disposition using a daily cover of earth. While the technique of sanitary landfilling everywhere is generally the same, there are three variations in refuse placement. These, described below, determine the technique of sanitary landfilling.

The "Trench Method" is used on a level or sloping ground. It involves the excavations and filling of successive and parallel long narrow trenches that are separated by a three to four foot dirt wall. Wastes are then deposited at one end of the excavation on a sloped end of the trench. The refuse is spread on a rather shallow inclination, usually about 3 horizontal to 1 vertical and then compacted by placement/ compaction equipment used at the site. In this method, the compacted layers of refuse are covered at the end of the day's operation using the material taken from the stock pile of material removed in the original excavation. When the entire trench has been filled with refuse, a thicker

Table 2-8

Recommended Compost Application Rates
For Different Plants or Crops.

Plant or Crop	Compost Rate in Tons Ha/Yr	Method of Application
Sod, turf, new lawns	100-200	Till into surface before seeding
Sod, turf, established lawns	50-75	Apply onto surfaces as required.
Cereals, (eg., corn)	50	Till into soil prior to planting
Tree nurseries	50-100	-do-
Pastures (new)	500-100 depending upon species	-do-
Pastures	50	Apply into surface periodically.

Source: Night-Soil Composting by Hillel T. Shuval, Charles Gunnersond de-Anne Julius, World Bank, December 1980.

final cover is placed over the completed deposit of refuse. Trenches generally are at least 150 feet long and usually twice the width of the tractor or one-half times the width of the blade of excavation equipment bulldozer or the bucket of the loader used in original trench and in spreading. Depth of the cut depends upon soil conditions, the water table and overall need to conserve space. A normal depth is eight to ten feet, although some fills exceed 20 feet. In such instances refuse is placed in layers of about eight feet after compaction.

The trench method is most suitable for sites that have regular topography, where the ground water table is at a significant depth and there is a deep layer of suitable soil cover.

Over fairly flat terrain, and where the groundwater table is at, or near the surface, the "Area Method" of sanitary landfilling can be utilized by using the existing natural slope of the land. Refuse is dumped on an undisturbed existing ground surface, and the only prior operation in this method may be surface removal of the topsoil and highly organic humus material if available and considered suitable for final cover. After the refuse is dumped from collection and transportation vehicles, it is spread over the ground surface in a uniform layer and then compacted to a higher density. The compacted layer of refuse is covered with soil at the end of an operational day or when the deposition area is filled. When the final cover of refuse has been placed and the entire site is filled, a final cover of greater thickness is placed over the completed fill. Generally, in an area method the cover soil is transported onto the site from another location.

The size of the operating face should be large enough so that no unnecessary delays for collection and delivery of vehicles are caused in places where the daily quantity of garbage to be disposed of is very high. The size of the operating (or working) face will depend upon such operational variables as the site topography, the direction and velocity of prevailing winds, the quantitities and characteristics of refuse being brought to the site, and other factors.

The third method, the "Ramp Method", is a hybrid technique combining both Area and Trench Methods. Before refuse deposition begins, a small

excavation is made in front of the proposed face on an existing slope. The soil removed in this excavation is stockpiled nearby. Refuse is then deposited on the face of the slope, spread and compacted by standard landfilling equipment and then covered with the soil which has been stockpiled from the preceding excavation. The process is repeated again, and again at the face of the newly created slopes, so that a line is drawn across the landfill site because of these successive techniques, the ramp method has also been called the "progressive slope" method. Key elements of sanitary landfilling include:

a) Resource Recovery

Although Sanitary Landfilling is basically a disposal operation, refuse placed in a landfill will, under suitable conditions, decompose and gets transformed to potentially useful recyclable products--such as gas, humus and ferrous metal, unless the latter has been removed before dumping of wastes. If the solid waste contains significant quantities of ferrous metals, mechanical separation may be required. In this case a magnetic force field is created above a moving stream of wastes and the ferrous metal particles are pulled by the magnetic forces from the remainder of the wastes.

Anaerobic decomposition of organic wastes, in sanitary landfilling, produces methane gas along with traces of carbon dioxide, nitrogen and hydrogen sulfide. These gases seek release and pass through whatever fissures there may be. Under some circumstances the gases have been known to migrate large distances horizontally before finding release. In some cases, gases have accumulated in building basements, and have been known to asphyxiate or poison individuals or to explode, especially in buildings near the an active recently or completed sanitary landfill. However, if the sanitary landfill is properly designed and monitored, this danger is minimal or non-existent.

b) Cover Material

The presence of suitable cover material at a particular site does much to create an efficient land filling operation. However a poor cover material should not be used even if transportation costs for bringing better quality material from other areas are high. A good cover material should have easy workability, moderate cohesion and significant strength.

An ideal cover material is a mixture of sand, silt and clay and, generally, a sandy loam is a very desirable cover material.* Clean sands are unsuitable due to high permeability to water. Fine grained soils such as clays and silts cause difficulties in working with such materials, because of the shrink-swell properties. Pure clays, in particular have a strong tendency to shrink and form deep cracks upon drying; such open cracks provide access to deposited refuse for disease vectors such as rodents and insects, allow infiltration of significant amounts of surface water, until they swell and close and permit the escape of gases and odors from the decomposing refuse.

The source of covering material can directly relate to transportation costs, which can be significant. This can account for as high as 60 percent of the costs, even with low wage rates in the Philippines. Access to other suitable and sometimes free cover materials such as ash from power stations, soil from excavations of other land or inert industrial wastes can lower the cost of sanitary land filling. However, their assured supply over the life of the sanitary landfill is essential before embarking upon the project.

c) Leachate Problem

The inflow of water from the surface into a sanitary landfill tends to generate leachates, which may contain dissolved and suspended materials of various types. If this leachate passes through the landfill and reaches a stream, lake, or subsurface water table it may act as a contaminant. For this reason leachate needs to be prevented or carefully controlled. Water inflow to a landfill can be reduced by: 1) lifting the landfill away from groundwater or surface water contact; 2) surface grading at the site to increase runoff; 3) planting vegetation on the final surface cover; 4) Using non-permeable cover material, and 5) providing proper drainage facilities.

Several materials can be used as landfill liners, though these have shown varying degrees of success. Such materials include clays, plastic and asphalt. Each has advantages and disadvantages.

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*American Public Works Association, Municipal Refuse Disposal, 2nd ed. Interstate Printers and Publishers, Danville, Illinois, 1966.

Due to the characteristics of the solid waste generated in Tacloban, including a very high percentage of organic matter, subject to natural degredation, absence of any significant quantities of chemical and hazardous wastes, generally deep water table, generally impervious nature of soils and non-utilization of ground water for the city's water supply, the problem of introduction of pollutants into surface and groundwaters is probably not serious.

The Completed Sanitary Landfill

Unlike an earthfill, which consists primarily of dirt, an Sanitary Landfill is constructed of a wide variety of materials with different physical, chemical and biological properties.*/** In order to design, operate and maintain a successful landfill it is important to understand not only chemical but physical reactions, as well, that occur in it.

Decomposition. Most of the material in a sanitary landfill will decompose, but at different rates and with different results. Decomposition and breakdown of various substrates proceeds as follows:

- Food waste is readily decomposed, moderately compactible and forms organic acids that further aid in decomposition;
- Garden wastes are resilient and difficult to compact but generally they are rapidly decomposed;
- Paper products and wood decay at a much slower rate than food wastes. Wet paper, especially, is easily compacted and pushed into voids;
- Lumber, tree branches and stumps are difficult to compact and also hinder compaction of adjacent wastes; and
- Metallic wastes such as any steel or metal containers slowly rust and their degradation, though slow, is contributed by the acids produced from decomposing organic wastes.

Density. The density of solid waste in a landfill is quite variable. A well constructed landfill, with moderate waste compaction in the case of Tacloban wastes, where initial density is already quite high (358

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*Brunner, D.R., D.J. Keller, C.W. Reid and J. Wheeler, "Sanitary Landfill Guidelines - 1970". Review draft of a Public Health Service Publication, Office of Solid Waste Management Programs. U.S. EPA Washington D.C.

**American Public Works Association, Municipal Refuse Disposal, Third ed., Interstate Printers and Publishers, 1970.

kg/m^3), can achieve a density of 500-600 kg/m^3. The density of the waste, in turn, influences other characteristics of the landfill such as settlement and bearing capacity.

Settling. Settling in a Sanitary Landfill occurs due to waste decomposition, filtering of fines, superimposed loads, and its own weight. Bridging of solid waste during construction of the fill results in voids that are filled, or else collapse, when the waste stabilizes. Decomposition causes the material to collapse. Decomposition in turn depends upon the amount of water present. A landfill will settle at a slower rate when it is anaerobic and has limited water available for chemical and biological waste decomposition.

When a sanitary landfill settles, major problems can occur. Wide cracks can develop in the cover material exposing waste to rats and flies, allowing water infiltration and permitting gas to escape. The topography of the surface can become hummocky, causing rainfall to pond and infiltrate the fill. Structures on the landfill may distort and fail. Because all landfills inevitably settle, the landfill surface should be periodically inspected and soil added and graded when necessary.

Bearing Capacity. Bearing capacity of a Sanitary Landfill refers to the ability to withstand foundation loads without shearing. Data on the bearing capacity of a landfill is very limited but appears to be in the range of 500-800 pounds per square foot. Greater density of solid wastes in the landfill provide greater shearing resistance and hence larger bearing capacities.

It is apparent that many of the problems of landfill construction, operation and planning for future use are associated with the variable nature of the wastes deposited at the site for disposal. It is, therefore, often strongly suggested that a precomminution process prior to the actual landfill be seriously considered. Such a precomminution will increase the density of the wastes, make compaction easier and less costly on equipment, promote more rapid decomposition, reduce the possible formation of gas pockets, and return the completed site to use at an earlier date.

Sanitary Land Filling for Solid Wastes in Tacloban

Present solid waste disposal system in Tacloban is open or crude dumping (called "policy of despair" in the literature) at two sites--San Jose and Cogon. (Shown on Figure 2-1) Open dumping causes environmental and public health risks including surface, river and sea water pollution, odors, airborne litter and waste paper, the presence of disease vectors such as rats and mice, etc., and hence, is generally considered an environmental disaster.

Table 2-9 indicates the likely difference in scale of costs when all transport operations take place within a radius of 8 kms for the various alternatives to an open dump.

Sanitary Landfill is by far the cheapest method and offers the following advantages:

- little or no capital investment is required for a physical plant such as that required for an incinerator;
- Land can be purchased or leased;
- Trucks and heavy equipment are easily accessible generally (from construction industry);
- Operational labor costs are not very high;
- No residue by-products, such as ash from an incinerator, or the soil conditioner from a composting plant;
- Simple operation; and
- Energy recovery is possible.

In order to plan and later develop a sanitary landfill for Tacloban, the following offices were consulted to pick potential sites:

- City Planning Office for Land Use;
- General Services for Solid Waste Management; and
- Water Authority to assess the impacts, if any on surface and groundwater.

Several meetings and discussions were held to review the criteria for selection and ranking of suitable sites for sanitary landfill for Tacloban. The City Planning Office agreed with the following criteria:

1. Review the detailed physical characteristics of "Metro" Tacloban;

2. Identify sites that could be improved by landfilling (raising the level), e.g., sand, and gravel pits, clay pits, quarries and other earth excavations;

Figure 2-1. Existing and Proposed Sanitary Land Fill Sites

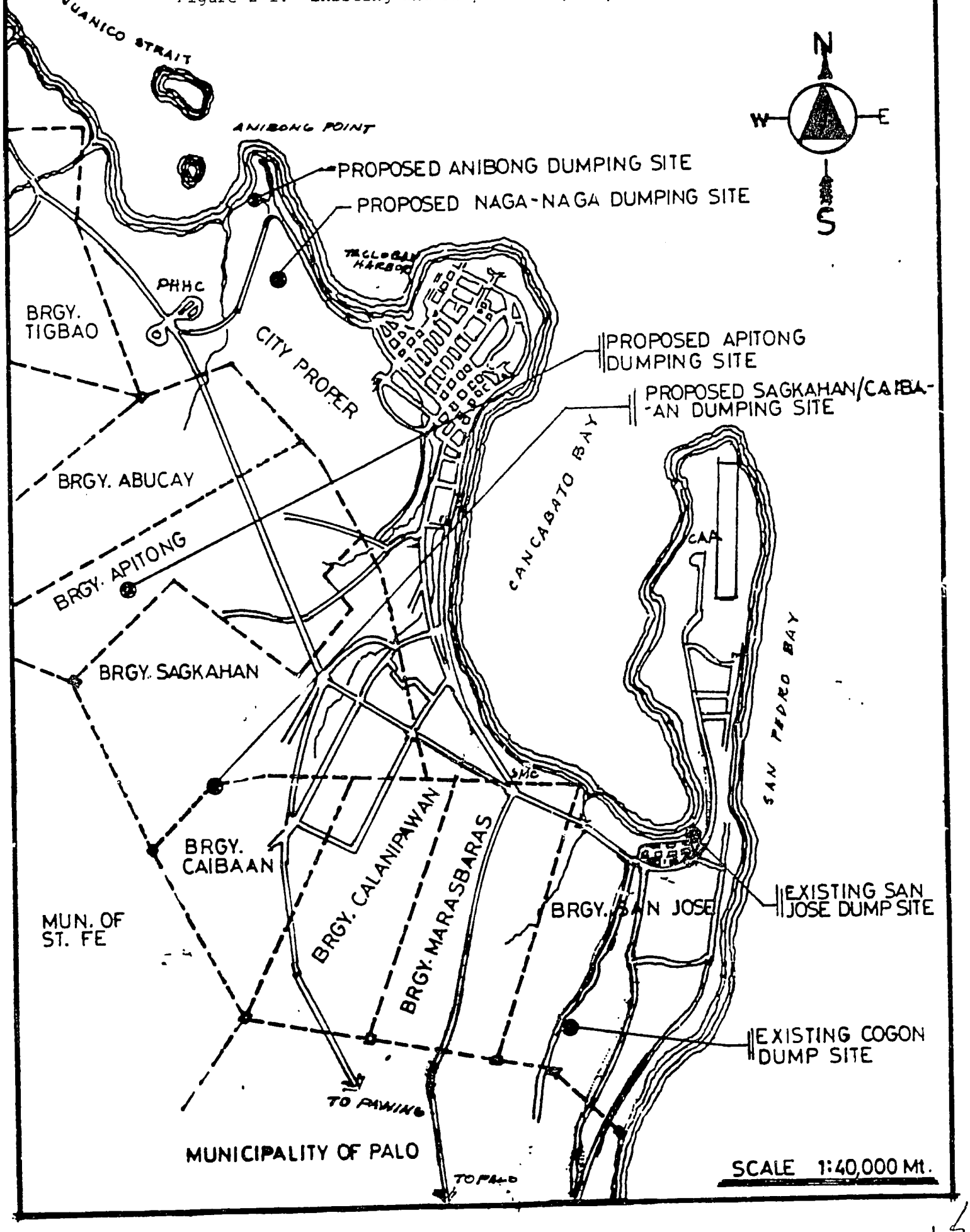

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Table 2-9. Relative Cost for Various Solid Waste Management Options*

Sanitary Landfill	1 unit of cost
Pulverisization/Landfill	5 units of cost
Incineration	15 units of cost
Composting	
Minimum Mechanization	5 units of cost minus income = 2 net approximately
Full mechanization	10 units of cost mimus income = 7 net approximately

*Source: Flintoff, Frank (1976) Management of Solid Waste in Development World Health Organization Regional Publication, Series 1 Page 101, WHO, New Delhi.

3. Select those within a few kilometers of the built up area of the city; and

4. Evaluate long term use of the sites after reclamation and the level to which they can be filled.

The Solid Waste Management Office looked into the following criteria from their point of view, as it seemed to meet their needs.

1. Closeness of the site to the built up area of the city in order to keep transportation costs to minimum. At present, based upon yearly operational costs only, the city spends P30/ton/km and an extra 2 Km. would add 4 Km. to the journey and raise the costs to P120/ton/Km;

2. The site should be close to a road capable of handling the traffic generated by the landfill site;

3. The office would prefer sites that are large in size so that capital expenditures can be spread over a great tonnage; and

4. Sites that are at least 150-200 meters away for the nearest dwelling.

The Water Authority reviewed the sites with the following criteria in mind:

1. The hydro-geology of the sites;

2. Suggested that sites be classified into three categories: approved, disapproved, qualified approval; and

3. Qualified Approval in case approved sites are otherwise found unsuitable may require site engineering as drainage problems of else the use of a specific operating method.

Various potential sites passing the above criteria were subjected to the following criteria for final selection and ranking as sanitary landfill sites for Tacloban:

1. Is any site engineering to avoid water pollution required;

2. Cost of capital works for site operation such as site office, toilet facilities;

3. Operating costs, labor, purchase of covering material and road material, stores and plant operation; and

4. Life of the site keeping in view the projected garbage generation rates.

Sites Surveyed for Sanitary Landfill for Tacloban*

Site No. 1. Anibong Site

This site is located off Jaro Drive, covering an area of twelve (12) hectares with an average depression of 3-4 meters. From the centroid of the garbage generation, the site is a distance of approximately 2 km. The site is an abandoned rice field found uneconomical due to its location, lack of labor and overall non-profitability for rice production. Due to its closeness to the town, the site, if developed, could be an excellent location for new housing development due to raising of its level. This site, in view of the characteristics of the Tacloban waste, would last for 35-40 years. A side benefit of clearing adjoining partial rock, but mostly earth, hill would be an increase in the value of the land presently underneath.

The site, being close to (approximately 100 yards) a hill containing excellent cover material, would minimize transportation costs. The site will however, require development of an access road (dirt) of approximately 100 meters long and 8 meters wide. The projected cost of a dirt road, sand gravel, equipment and labor amounts to P 1,400 per linear meter for the posed width**. The access road will, therefore cost approximately P140,000 (US $16,666.). It is suggested that instead of fencing the entire area to minimize costs, only 2 hectares at the start of the sanitary landfill operation, assuming the site is finally selected, could be fenced. The cost of bamboo fencing 2 hectares according to the city engineer would amount to P 3,600 (US $4,300). Besides these costs the Anibong site will not require any further site engineering.

The Anibong site, according to the City Assessors Office, is currently owned by a couple of investors including Julita Enriquez, Encarnacio Llama, Eugenio Caluta, Marilou Pauc, all of Tacloban city. According to the existing laws and ordinances, the land can be easily acquired by the

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*See Figure 2-1 for location of the sites.

** Tacloban City Engineering Office.

City. The assessed fair market value is P20,000/hectare for a total cost for the site, of P240,000 (US$ 28,580). Due to the land's current non-use and non-profitability, it is believed that the owners would be willing to sell or sign a very long term lease in the interest of improving their land for potential gains.

The site, except for a single house located high on another nearby hill (100 meters away) is more than 150 meters away from residential houses, almost all of are illegal dwellings (shanties) and are liable for removal at any time, by the City, under the Presidential decree. The site, at present, is covered by weeds and grass, requiring some mechanical operations and costs for cleaning.

The site as well as cover material has been classified by the local agricultural soils extension agent as containing sandy loam soils, considered ideal, not only for sanitary landfill, but also as a cover material.

The ground water table at the site, according to the Tacloban Water Authority, is over 30 feet deep. Moreover, the water is not used for the city's water supply or any other significant use. In addition, the nature of Tacloban wastes with its high percentage of vegetable matter and absence of toxic or hazardous waste, would not pose a serious threat to the ground-water and this would therefore, preclude any site engineering such as drainage channels, etc. Environmentally, the site, due to its location has many advantages, and would pose no problems of dust, odor or noise that attend the operation of Sanitary Landfill due to various vehicles and equipment.

Site No. 2. Naga-naga

This site is located behind the mountains on Paseo de Legaspi road and is about 500 meters off the national highway. Covering an area of approximately 20 hectares with an average depression of 2-3 meters over its entire area. The site is easily accessible by a major road, capable of handling the truck traffic. The estimated life of the site at the present and projected garbage generation rate, is approximately 40 years. The filling material is available from the nearby hills (50 yards) and consists of sandy loam. The site is located at a distance of approximately 3 km from

the centroid of garbarge generation. It was formerly a rice field that has been abandoned for the same reason as the Anibong site.

The site, however, will require an additional road from the terminus of the access road of about 500 meters in length. The site at present is covered with grass.

Site No. 3. Apitong

This site is located close to the intersection of Diversion and Apitong Road and near the foot of the mountains. The approximate distance, which forms the width of the site from the road, is over 1 km. The site has an overall area of approximately 30 hectares and is located about 3 km from the centroid of garbage generation. Present city plans call for extending Rizal Avenue, in approximately one year's time which could reduce the travel distance for garbage trucks to 2.5 km. The cover material is available at less than half a kilometer away and consists of sandy loam soils. Some blasting may be necessary to excavate soils as the nearby mountain seems to have a somewhat greater proportion of rocks compared to the Anibong site. However, this is purely a visual estimation and it may be that it does not require blasting. Thus, in evaluating this site in terms of development costs, no blasting costs were included. It was also felt that to avoid blasting to get cover material for the site, the adjoining hill, approximately 100 meters away can be used to provide cover material. This hill requires no blasting, as there seems to be plenty of generally sandy loam soil available. For lack of facilities and expertise no geological evaluations could be made to determine the extent of blasting, if any, required.

The site will require one kilometer of dirt access road and according to the City Engineer's office, an eight meter wide road would cost P1,440,000 (US$171,000).

The Leyte Water Authority considers that the site, if developed as a sanitary landfill would cause no water pollution problems. No site engineering would be required.

Site No. 4. Caibaan Site

The s[illegible]cated off Diversion Road and is an abandoned, low lying (up to [illegible]ch) rice field. The site has an area of approximately 15 hectares and is located at a distance of 5.5 km from the centroid of garbage generation. The site would not require an access road, being located on an asphalt road. The cover material is available from the nearby mountain, and is easily accessible. However, this mountain would require blasting to excavate the cover material for the site. The blasted rocks can either be carried away and, if unable to be sold, would add transportation costs or else, if buried at the Sanitary Landfill, would reduce the area available for the city garbage disposal and, hence, reduce the life of the landfill.

Ranking of Sanitary Land Filling Sites for Tacloban

A survey with the City Engineer, City Planner, land and water authority personnel of Tacloban City and its outskirts and the adjoining area including the suburbs, for potentially suitable, Sanitary Landfill sites revealed a large number of excellent possibilities. However, several of these sites were restricted by a longer (generally over 8-10 km) distance from the centroid of the garbage collection. The four sites: Anibong, Naga-naga, Apitong, and Caibaan were, in light of the site selection criteria mentioned earlier, were finally selected for a more detailed evaluation and ranking.

In ranking the sites for Sanitary Landfill suitability, Anibong appears to offer the most potential. It is the closest from the centroid of garbage generation, approximately 2 km; offers 3-4 meter deep depression, with excellent cover material available from the adjoining mountain. The 100 meters access road which is needed, is much shorter than the 500 meters access road required by, the otherwise very similar Naga-naga site. Thus, the Naga-naga site is rated as second. Apitong, though otherwise suitable, involves longer travelling distance and, hence, higher transportation costs for the garbage trucks. It may also require some blasting, though no access road would be needed. The fair market price, according to the City Amena's Office is also much higher (P29,000/ hectare). All this will increase the costs of garbage disposal. Caibaan seems to offer the least potential among the sites ranked. It is much farther away (5.5 km) than the other sites,

Table 2-10 Cost of Development of Anibong Site For Sanitary Landfill

Item	Cost in Pesos	Remarks
1. Site Development		
a) Levelling & grading		Not required
b) Access road	P140,000	At 1400 P/linear meter, 8 m wide
c) Drainage		None required
d) fencing (bamboo)	P36,000	Only for 2 ha. in the beginning.
2. Facilities		
a) Office space includes toilet (5 x 8 m)	P30,000	Includes garage space for tools, etc.
b) Shed for scavenged mat. temporary structure, roof nipa shingles	P3,500	Nipa shingles (from a variety of palm treem can last for several years
3. Utilities		
a) Electricity/yr.	P300	
b) Water		
Minimum use charges	P360 avg. P550	minimum fixed charges
Maximum use charges, when quantity goes over minimum amount under minimum charges	P740	Max. use for washing equipment, scavenged materials
4. Equipment		
a) Bulldozer (used)	P500,000	Available from excess property, U.S. Naval Base Olongapo city Philippines

Table 2-10 (continued)
Cost of Development of Anibong Site
For Sanitary Landfill

Item	Cost in Pesos	Remarks
b) Utility pay loader vehicle	P4,000	Payloader to be rented; 16 hrs/mo. from Ministry of Public Works & Highways, enough time to haul the filling material
c) Gas, oil & maintenance/yr (for a, b.)	P60,000	
5. Cover Material	P42/day	@ P3/m^3; 1:4 ratio cover material to garbage
6. Cost of Land (if owned)	P20,000/hectare P240,000	
7. Personnel		(in addition to current staff)
a) Driver/operator	P14,600/yr.	Driver/operator to be payload operator during breaks
b) 1 laborer (in addition to the one at San Jose Dump)	P9,125/yr.	

Table 2-11. Annual Operating and Maintenance Costs For the Anibong Landfill Site

(In addition to the costs of the Present System)

Item	Cost in Pesos	Remarks
1. Personnel		
a) Driver/operator (for bulldozer & payloader)	P14,600/yr.	includes salary, wages & fringe benefits. In addition to present staff
b) 1 Laborer	P9,125/yr.	
2. Equipment (bulldozer & payloader)		
a) Gas, oil, etc./yr.*	60,000	for diesel, 50 liters/2 hrs/day total consumptions = approximately 21,000 litres/yr
b) Maintenance & repair/yr.	P10,000	
c) Bulldozer, 2 hrs/day	P81,350	Discounted at 10% for 10 years;
Payloader, 16 hrs/month	P4,000	annual rental fee for payloader
3. Supplies & materials		
a) Cover soil	P15,330	P42/day
4. Capital Items		
a) Facilities and development	P34,096	10 years at 10%
b) Land	P24,542	40 years at 10%
Total Annual Cost	P253,043 P40/ton	

*Rates:

1) Bulldozer consumes 50 litres/2 hrs of work (from past experience). 1 liter costs P3.00. Intended use is 2 hrs/day for 365 days.
2) Payloader 16 hrs/mo./160 litres consumed.

would require blasting to excavate cover materials, and offers no cost advantage, at P20,000/hectare, compared to other Sanitary Landfill sites. It is, therefore, ranked fourth.

Tables 2-10 and 2-11 give the capital and operating cost for the Anibong site. The incremental cost of the landfill would be P 40/ton to be added to the current collection and disposal cost of P 98/ton.

2.5 Option 5. Converting the Present Tacloban City Open Dumps Into Sanitary Landfills

Current garbage disposal is on privately owned land (for which the city pays no rental or leasing costs), in San Jose and Cogon near Tacloban City proper. Moreover, there is no formal agreement, on use of any of these lots as a garbage dumping site, between the city and their respective owners and, hence, continued availability can be at the mercy or whims of the respective owners.

San Jose site is low lying, (2 m average depth), approximately 5 ha., of which 60 percent is already filled. This site was opened after the Philippines Liberation (1945). The other site, Cogon, is low lying (2 m average depth), on abandoned rice fields, and covers an area of approximately 8 ha. It is possible to acquire an additional 8 ha. of adjoining site.

In the San Jose open dump site the garbage deposited earlier is pretty stable and is frequented by scavengers. Tacloban city has one full-time person to level the garbage manually. However, the site is visited by both low and high tides. Even at low tide, manual compaction is incomplete and difficult. Cover material available nearby is sand/sandy and is considered unfit. Suitable cover material is available approximately 3 km away. The site, if changed to a Sanitary Landfill, would not require an access road, however, only 2 ha. now remain of the total and, thus, it is considered potentially unsuitable to a be changed to Sanitary Landfill.

The Cogon site, on the other hand, is larger but being close to residential area, is unsuitable, and also due to the private ownership offers uncertainty of its continued availability. Owners, it seems from

discussions with them, are only interested in getting the level of their low lying lots raised. They may even stop in between and are unwilling to sign a long term agreement. Cover material would have to be transported 8-9 km and regular maintenance, of the existing dirt access road would be required. Thus, it seems both San Jose and Cogon sites are potentially unsuitable for conversion into a Sanitary Landfill. The best choice appears to be closing these sites, with suitable cover material and after proper compaction. Besides using improper solid waste disposal techniques, the sites being located very near (Cogon), or in residential areas (San Jose), are subject to frequent and indiscriminate intense scavenging adding to the environmental and public health hazards.

Chapter 3

Options for Liquid Waste Disposal and Resource Recovery

3.1 Introduction

Unlike the solid waste disposal problem, liquid waste disposal is not viewed as a pressing problem by the City Government in Tacloban. The water supply problem is considered to be much more important. Some concern for pollution of the coastal areas and local water quality problems in some of the open drains have been noted. The disposal of septage from the septic tanks has also surfaced recently as a problem and an opportunity for the city. In our study of Tacloban, we explored six options for liquid waste disposal.

3.2 Option 1: Improving the Present Disposal Systems for Human Excreta in Tacloban

There is no separate sanitary system for Tacloban city. The present storm/drainage system also serves as the Sanitary Sewer System for those houses that have a flush system and a septic tank. In the latter case, the effluents first pass through a leaching chamber, then to a catch basin before they enter the storm drainage pipes. No charges are imposed for tapping or connecting to the storm drainage pipes. Direct connections to drainage pipelines from buildings are however prohibited. The following is a description of various existing systems.

a. Septic Tanks. Approximately 3,500 houses servicing a population of 27,500 people use privately owned septic tanks. This number is higher than the one mentioned in the "Situation Report, December 1981", due to addition of a new housing subdivision. Basically, septic tanks are rectangular chambers, usually sited just below ground level, and receive both excreta and flushwater from flush toilets as well as all other household wastewaters. The mean hydraulic retention time in the septic tank is 1-3 days. During this time, the solids settle down to the bottom of the tank, where they are digested anaerobically. A thick crust of scum is formed at the surface and this helps to maintain anaerobic conditions. Although digestion of the settled solids is reasonably good, some sludge accumulates and the tank must be desludged at regular intervals (usually every 1-5 years), depending upon the use. From a

public health point of view, the effluents from a septic tank, are as dangerous as raw sewage and must be treated before disposal. At present, this is not done in Tacloban and the effluents are directly discharged, in most cases, to the city's storm drainage pipes.

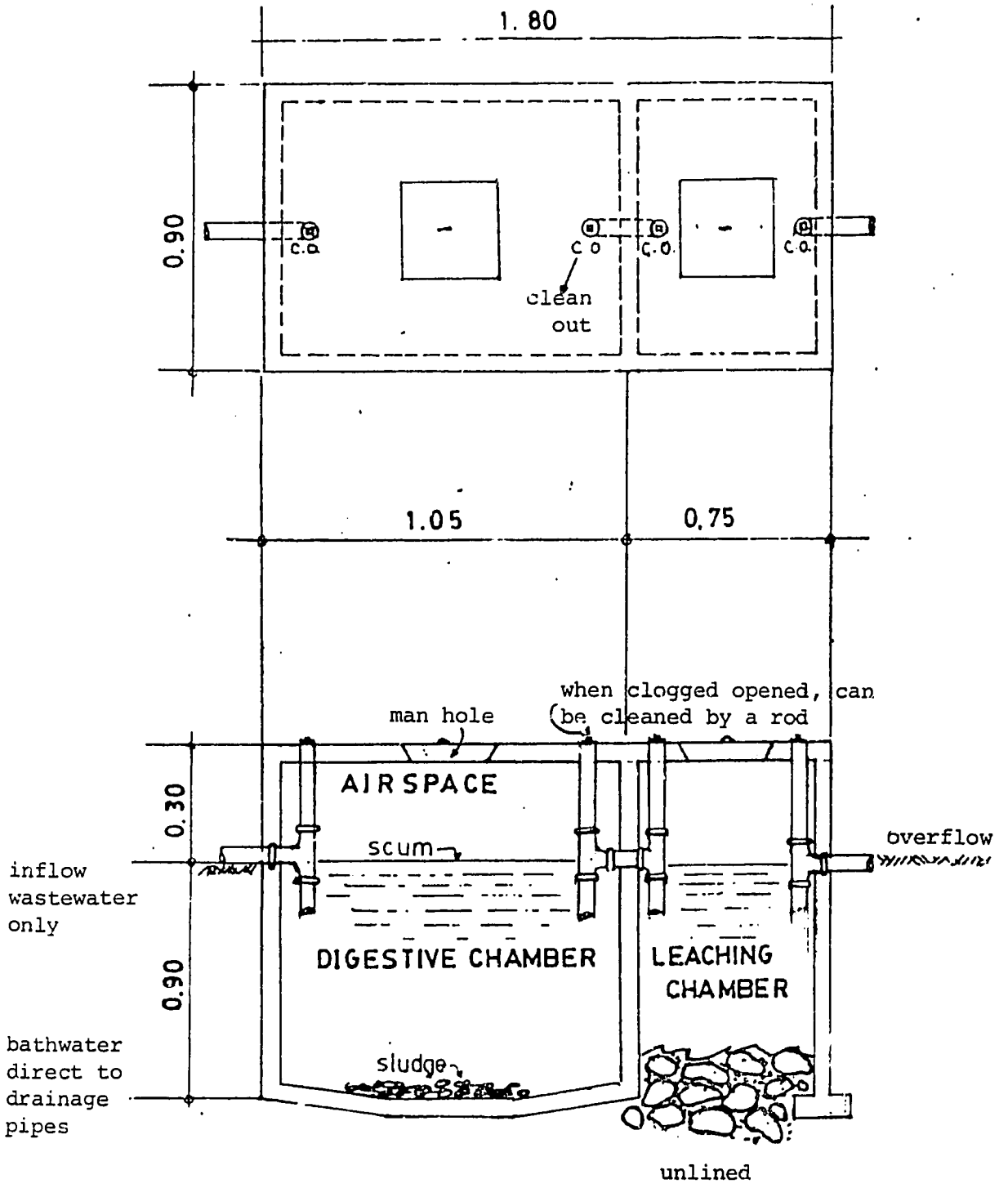
Septic tanks, which are common in Tacloban, (see Figure 3-1) give a lower suspended solid concentration. The first compart- ment is usually twice the size of the second. The liquid depth is 1-2m and the overall length to breadth ratio is 2-3 to 1. Experience has shown that, in order to provide sufficient quiescent conditions for effective sedimen- tation of sewage solids, the liquid retention time should be at least 24 hours. Two-thirds of the tank's volume is normally reserved for the storage of accumulated sludge and scum, so that the size of the septic tank should be based on 3 days retention time at start up; this ensures that there is at least one day retention just prior to each desludging.

Effluent Disposal

Septic tanks are best suited to those houses that have both an in-house water supply and sufficient land for effluent disposal. These two constraints effectively limit the responsible use of septic tanks to low-density urban areas. Common practices of effluent discharges in Tacloban include, discharge to the ground surface, where it ponds, to storm drains and, in very few cases, to open street gutters, where it can be a cause of serious environmental and public health risks. Major causes of septic tank failure in Tacloban have been poor soils, hydraulic and organic overloading, lack of maintenance, increased density, high water service levels and restricted space for drainage fields. On the other hand, properly designed, constructed and operated septic tank systems have worked well. In areas of compact soil conditions, high water table and limited availability of open land, secondary treatment of septic tank effluents is accomplished by sand filters. These systems require frequent maintenance and pumping and, hence, additional costs. In such cases, an aerobic upflow filter (see Figure 3-2) may be successfully used as a simple secondary treatment device for treating septic tank effluent and settled domestic sewage or may be used as a compact sewage treatment unit.*

*Rajput, V.S., and Polprasert C. "Septic Tank and Septic Systems: A State -of-the-Art Review", Environmental Sanitation Review, 1981. Environmental Sanitation Information Center, Bangkok, Thailand, 1982.

Figure 3-1. Typical Septic Tank in Tacloban City
(six to ten persons)

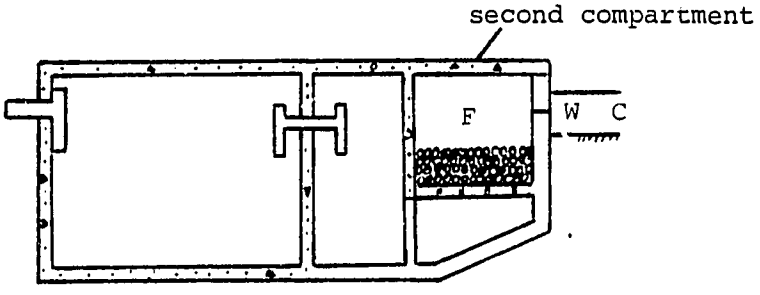


Scale. 1:20 mts.

Overflow

1. Depending upon location, overflow penetrates the ground, provided there is a perforated pipe embedded in a graded soil to prevent clogging.
2. If the owner can afford it, it is connected to the drainage system. This is more common in city houses.
3. Almost no flow to open channels.

Figure 3-2. Septic Tank with Upflow Filter



Septic tank with upflow filter*

F - filter, with effluent weir

C - effluent channel

a) Filter may need to be washed every 18-24 months.

b) Field tests in India have shown that these filters can effect a 70 percent reduction in BOD and can change a malodorous, highly turbid, grey to yellow influent to an odorless, clear, light yellow effluent.

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* Mara, Duncan. Sewage Treatment in Hot Climates, John Wiley and Sons, New York, NY, 1976.

Design and Costs of Septic Tanks in Tacloban (5-6 person family)

The following are the current materials and costs of building one unit septic tank (including inlet and outlet pipes) in Tacloban.

	Cost in Pesos
100 concrete hollow blocks @ 1.50	150
15 pieces, 3/8" diameter X 20 steel bars	225
10 bags of cement @ 32.00	320
2 Kg. tie wire @ 8.00	16
3 Kg nails @ 7.00	21
woodform	200
10 pieces GI pipes 4" X 5" @ 45	450
6 pieces elbow, Y's and T's @ 30 etc.	240
Total materials	1572
Labor	500
Total	P2072

b. Pit latrines are the most common and simplest sanitation systems that are commonly used in the rural municipalities around Tacloban. Pit latrines are considered the cheapest system possible in Tacloban and the system most appropriate (when properly installed and maintained) for self help programs in which individual households are responsible for their own sanitation. However, the two major disadvantages of pit latrines observed in Tacloban, are that they smell and have serious fly nuisances.

Two improved versions of pit latrines are also being used in Tacloban by an estimated 5-6 percent of the population. In surrounding municipalities, almost 35-40 percent of the population are using these versions. These systems are briefly described below:

1) Tacloban's Antipolo Type I Latrines. These latrines are essential pit privy type wherein a pit 5 feet deep and 3 feet wide is dug near the house and a shed made of nipa shingles and bamboo is erected over it for protection from weather and to provide privacy. A squatting plate is placed over the pit and a long bamboo pole to provide aeration is inserted through the roof and into the pit. The pit is generally unlined. However, if the soil is sandy, a lateral support with wooden planks (or an empty oil) drum is placed in the pit. On an average, a pit of this kind can last for 2-3 years in a household of 5-6 people. When

the pit is near full, the shed is moved on to a new location and the pit sealed. Because of socio-cultural reasons, no later use of the digested material compost is made. The cost components of the pit are as follows:

A) Materials		Cost in Pesos
Nipa shingles 20 piece	=	14
Wood or bamboo	=	21
4 piece wooden post	=	40
Siding (made of nipa shingles and bamboo)	=	30
Flooring (wooden)	=	60
		165
B) Labor		
One laborer for 2 days	=	40
Nails, etc.	=	40
		80
Total Cost (A) + (B)	=	245

2) Antipolo, Type 2. In this case the pit is located away from the squatting plate and is connected to it by a pipe (gutter) made of GI sheets or wooden planks. Moreover, the squatting plate is placed on a raised wooden flooring. A long bamboo is placed in the pit to minimize odor and fly problems by providing aeration. If the gutter is gently inclined, water is needed to flush the excreta down to the pit. The cost of this system is about 10-15% more than the first type.

For anal cleansing, toilet paper or coconut husk pretreated by squeezing, and beating for softening, is used. Like Antipolo type I, type II also suffers from some odor and fly problems, though both are decidedly better than open pit privies.

3) Water Sealed Toilet. It is a modification of the unimproved pit latrine in which the squatting plate is made with 25 mm water seal. Approximately 2-3 litres of water for sullage are poured in by hand using pails to flush the excreta into the pit. This type of toilet is very suitable when water is used for anal cleansing. In the Tacloban area an increasing number of people are shifting from Antipolo types to water sealed toilets.

In the Philippines under a Presidential decree, heads of city government departments are required to spend 15 days a year for rural oriented services in rural areas. This year, the Tacloban city heads have adopted introduction and dissemination of this type of latrine in municipalities around Tacloban. This group also contributed P 20 each to a total of P 400 to buy cement (one bag of 94 lbs. costs P 30) to further assist the dissemination of water sealed toilets. Several minor modifications to the existing designs have also been recommended by this group.

The estimated costs of this type of system is P 300. This includes the cost of shed (P 200), labor for installation and pit excavation (P 50) and slab and water seal bowl (P 50). The water sealed bowl, manufactured locally, is placed in a 2'6" x 3'0" x 2.5" thick reinforced concrete slab.

It is estimated that over 1000 houses (1982) in Tacloban use this system. The "Situation Report 1981" mentions a figure of 216, which appears to be a low estimate.

The total number of households in the Metro Tacloban area is estimated to be 17,564. Approximately 20% of the water sealed toilet users have installed these inside their houses, the rest outside, and about 30% use a bamboo for aeration.

4) <u>Other Systems</u> (10-20% of population):

a) Sitting on a newspaper and discarding it to the nearest dumping ground area, such as streets, coastline, etc.;

b) Go out to the field;

c) Go along the shore; and

d) Direct disposal -- Many shanties are built over water on the shore, and they use direct disposal to the sea. Unfortunately, children from the shanties often use that area for swimming.

3.3 Option 2: Night Soil Collection and Disposal in Tacloban

Night Soil (General)

When human feces and urine are collected without dilution or with large volumes of water, it is called "night soil". Since night soil carries a high concentration of the full spectrum of pathogenic bacteria, virus, protozoans and helminths, endemic in the community, it is important that proper systems be used for night soil collection and disposal. Many of the pathogenic organisms are highly resistant to the environmental conditions prevalent in conventional night soil and sewage sludge digestion and storage and can survive for weeks and even months in the soil and fertilized crops.

Any technology adapted for the collection and disposal of night soil must eliminate the public health risks in an economically feasible manner, and it should be significantly less expensive than the water carried waste disposal system. For example, the bucket system an inexpensive disposal system, used in Tacloban is associated with severe health problems, especially when it is used in backyard vegetable gardens as a direct fertilizer. The City Health Office indicates the wide prevalence of enteric diseases, (see Tables 3-1, 3-2, and 3-3) of which this may be one cause. It has been estimated that one fertilized female Ascaris worm living in the human intestines produces 200,000 eggs per day* while a female Ancylostome (hookworm) deposits between 25,000 and 35,000 eggs per day. Thus concentration of the parasites in light soils, while a function of the type of parasite, is also dependent upon the number of infected persons in the community serviced as a source.

Night Soil Composting

Composting has been defined as: "a biological process for converting organic solid wastes into a stable, humus-like product whose chief use is as a soil conditioner". Night soil may be mixed with organic wastes and

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*Craig and Faust, Clinical Parasitology, E.C. Faust, P.F. Russel, R.G. Jung, Lea Febiger (ed.) Philadelphia, PA, 1970.

Table 3-1

Ten Leading Causes of Infant Mortality in Tacloban
(1981 And Average Past Five Years)

	Disease	1981 date	Past Five Years Rate
1.	Pneumonia	27.24	19.09
2.	Bronchitis	1.02	13.05
3.	Sepsis	0.25	12.55
4.	Prematurity	8.99	8.03
5.	Gastroenteritis	4.37	5.77
6.	Measles	6.42	3.51
7.	Congenetal Debility	3.34	3.01
8.	Tetanus Neonatorum	4.11	2.76
9.	Malnutrition	2.70	2.51
10.	Asphyxia	0.51	1.25

Number of deaths.

Table 3-2

Ten Leading Causes of Morbidity in Tacloban
(1981 And Average Past Five Years)

	Disease	1981 date	Past Five Years Rate
1.	Parasitism	126	786.22
2.	Gastroenteritis	626	779.59
3.	Tuberculosis	351	557.21
4.	Pneumonia	628	554.20
5.	Measles	215	224.80
6.	Influenza	32.8	178.63
7.	Urti	127.6	130.89
8.	Malnutrition	33.83	144.60
9.	Bronchitis	485	134.51
10.	Dermatitis	0	91.13

Number of cases per 100,000 population

Table 3-3

Ten Leading Causes of Mortality in Tacloban
(1981 And Average Past Five Years)

	Disease	1981 date	Past Five Years Rate
1.	Pneumonia	68.38	56.97
2.	Tuberculosis	25.44	20.33
3.	Cardio Vascular Arrest	9.76	20.33
4.	Senelity	2.31	19.57
5.	Bronchitis	8.48	16.66
6.	Gastroenteritis	12.33	40.30
7.	Measles	19.02	9.78
8.	Septicemia	10.28	9.78
9.	Malnutrition	3.85	2.78
10.	Cancer	5.91	5.52

Number of deaths per 100,000 population

refuse to help optimize the C:N ratio and composted. Composting can be done in piles or pits. Some important factors have been discussed earlier. Such factors, to be considered in any type of composting, are toxic substances, aeration, water content, carbon to nitrogen ratio, mineral nutrients, composition of organic wastes, the availability of nutrients, moisture content, size of the heap, particle size and degree of aeration and agitation.

Night soil composting, however, is also considered a small scale excreta management system that, like the conventional systems, requires little or no water for its management. The system has been in use for centuries in many parts of the World, in a very crude and unhygienic manner, though more recently a scientific and hygienic approach is being used in China. Composting toilets can usually be used where sewage systems are non-existent and where septic tanks are not practical for various reasons. In these toilets, a modification of the outdoor privy has been made in which excreta is composted. Though several designs are available, they essentially consist of a sizeable storage chamber or chambers in which excreta is deposited. In some cases, a storage chamber may be large enough to accommodate a two or three years output of an average household (5-6 people). An air duct or manual turning provides

the aeration to promote aerobic composting and the attendant benefits discussed earlier. With those providing "passive" aeration, longer stabilization time is provided. The output can be disposed as a soil conditioner which will also improve the nutrient level of the soil.

An absorbent (kitchen waste, straw, etc.) is placed at the bottom of the toilet, either when the chamber is first built and/or as a continuous source thereafter. This can be done by installing a second part through which such an absorbent material can be dropped. A system, where manual turning is used, calls for the addition of an absorbent after each use. Sawdust is commonly used by the handful, as the user prepares to use the facility and throws it into the hole. In Tacloban, lime ashes and sawdust are easily and cheaply available and would be an ideal materials.

Two of the better known systems for night soil composting are Clivus and the Van der Ryan. The Clivus system* bascially consists of a large compost tank having a stopped bottom and equipped with incoming toilet and kitchen waste tubes; an out-going air vent and an unloading door. The main tank is divided into three inter-connecting chambers. The first, receives toilet waste, the second the kitchen waste and the third provides a storage chamber for the combined wastes. When the unit is in operation, the toilet wastes slowly slides downwards into the kitchen wastes and the two combine and further decompose as they slide into the storage chamber. The moisture content of the composting material and the humus should be 40-60 percent. The added organic matter acts both to absorb urine and the water used for latrine and anal cleansing and to achieve a C:N ratio of about 20:1-30:1. The bulky nature of straw helps to provide aerobic composting. An average family of four could use the unit for up to ten years before having to remove the stabilized product.

Although aerobic composting is supposed to occur in the Clivus system, anaerobic composting practically occurs for the most part, even though the chambers are well ventilated. The excellent ventilation effectively prevents the travel of malodors into the bathroom or kitchen. The

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*"The Clivus Multrum Composting Toilet", Compost Science, 15 (5): pp.20-23, November/December 1974.

composting product is fairly stable and has minimum public health risks unless the retention time has been materially reduced or if short circuiting has occured. The product should then be handled with precautions identical to those of night soil.

The Van der Ryan system incorporates aerobic composting in the strict sense if properly operated. The super-structure is much like a conventional privy. It basically consists of two chambers with one receiving the excreta and the second serves as a storage chamber. A container of sawdust or other absorbent material is kept next to the toilet bowl, or "squat plate" and a portion used each time an individual defecates. The chambers are equipped with the removable slabs arranged so that very easy access is had for periodic turning. However, this system requires a considerable amount of dedication and attention on the part of the user.

Utilization of Night Soil Composting for Excreta Disposal in Tacloban

Even with the excellent economics of utilization of night soil composting for excreta disposal in Tacloban, the prospects of its wide acceptance are remote, under the present social and economic conditions. It appears from several discussions with various groups in the city, that the idea of using compost for any purpose (most likely in the backyard) made from night soil is virtually unacceptable. Given this major social barrier, it seems unlikely that the public will install such systems in their houses and even more unlikely that they would take care of the regular maintenance requirements of the compost toilets if they were installed. At present, many of the better houses in poor neighborhoods rely on a modified form of conventional aqua privy wherein excreta is despoited directly into tanks where it is decomposes anaerobically, in the same manner as in a septic tank.

3.4 Sewage Treatment Systems

Sewage, which more commonly now is called wastewater, consists of any wastewater and solids that find their way into the sewers and are transported through the sewer system. Domestic sewage generally refers to sewage that an average town produces, excluding industrial wastes but including water from factories that is of non manufacturing nature.

Chemical or biological wastes resulting from a manufacturing process are classified as industrial wastewater. Some industrial wastewaters can be processed in a municipal treatment plant without any special provisions, while others require considerable pretreatment before going into city sewers.

Fresh domestic sewage is gray colored, dirty looking water, where solids represent about 0.1% of total volume. The organic material in water is in process of decomposition at all times unless the waste is heavily chlorinated or disinfected, otherwise this decomposition process is aerobic or non-septic, as long as the water that transports the wastes has dissolved oxygen present. If the putrefaction consumes all the available dissolved oxygen before reaching the treatment plant, then the process turns anaerobic and putrefaction continues in the absence of oxygen. In both cases, the decomposition is caused by bacteria and other micro-organisms. The essential difference is that different species of bacteria predominate aerobic and anaerobic conditions. Anaerobic bacteria produce foul smelling gases and sewage turns black. If either air containing oxygen or oxygen gas is transmitted into the water in adequate quantities, septic sewage turns dark brown or gray and loses its foul smell. Thus, by artificially supplying adequate air in a sewage, a non-septic state can be maintained at all times.

The modern term for sewage is a preferred term and it also includes mineral matter. The mineral matter may combine with water to form dissolved solids such as chlorides or it may be present as undissolved suspended matter. The mineral matter may contribute to "eutrophication" due to nutrients present in the sewage, it may form unsightly sludge deposits it may contribute to the hardness of the water in the effluents. The decomposition of the organic material consumes available dissolved oxygen in relation to the quantity of waste present. Several parameters that affect this are BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), and other measures of the condition of waste and the demand that it places on a receiving stream for dissolved oxygen. If the dissolved oxygen content of a stream falls below certain levels, the wastewater will kill the aquatic inhabitants, as each dweller has a critical level of oxygen requirement under a given set of accompanying conditions, such as water temperature.

Sewage treatment is a broad term that applies to any process or a combination of processes that can reduce the objectionable properties of water-carried waste, that is wastewater and renders it less dangerous and repulsive to human beings. In the treatment process, a series of graduated screens that remove a large portion of solids would be a form of so-called primary sewage treatment. The most common form of this treatment consists of coarse screens, grit chambers, skimming tanks, and sedimentation basins where the settleable solids could settle out. Secondary treatment usually follows the primary process and involves establishing an environment favorable for rapid degradation of organic material by biological processes. Tertiary treatment usually consists of a more refined treatment of the effluent.

As a system, wastewater treatment is a series of interacting component parts--groups of items or subsystems forming a unified whole to achieve a specified vital function. Thus, in the same treatment plant, it may become necessary to use physical (mechanical) devices, biological processes and chemical treatment to establish a system to meet a given set of conditions. Table 3-4 indicates some of the traditional sewage treatment plant combinations and indicates the percentage of BOD (5 days demand) reduction that each process combination can be expected to achieve.

Figure 3-3 shows the relative costs for various of the treatment options under Indian conditions. As might be expected, the conventional sewage treatment plants are more than 4 or 5 times as expensive per capita than some of the more traditional methods.

Sewer systems can be sanitary, storm or combined sewers. A sanitary sewer carries only wastewater from the homes, commercial establishments and industries served by the sewer system. A storm sewer is presumed to carry waters from precipitation on the watershed served by the sewer, where combined sewers (generally found in the older cities) carry both sanitary and storm flows. A sewer system of any type should be designed for the estimated ultimate tributary population, except for those parts of the system that can be readily increased in capacity. The key design factors include maximum hourly sewage flow, additional flow from industrial plants, if any, groundwater infiltration, topography of the area, location of waste

Table 3-4*

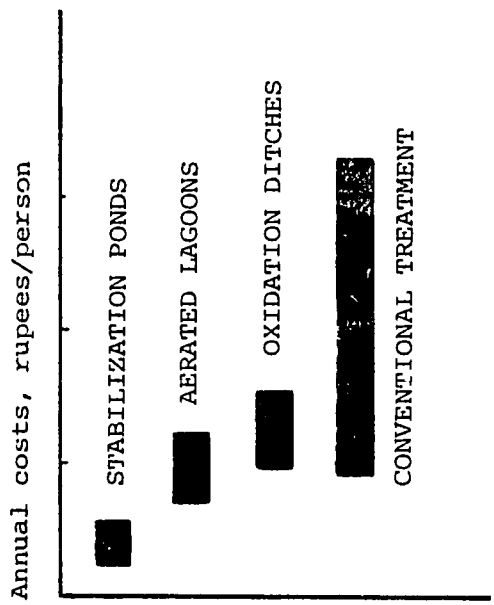
Approximate Percent Reduction Achieved
by Various Types of Sewage Treatment

Type of Treatment	Percent of BOD Reduction
Septic Tank	15 - 25
Imhoff Tank	25 - 40
Sedimentation	25 - 40
Sedimentaton + Trickling Filter	80 - 95
Sedimentation + Conventional Activated Sludge	85 - 95
Sedimentation + Sand Filders	90 - 95
Extended Aeration**	75 - 85
Contact Stabilization (Biosorption**)	85 - 90
Activated Aeration**	80 - 85
Waste Stabilization Lagoon	85 - 95
Oxidation Ditch	90 - 95

*Source: Parker, H.W. (1975), Wastewater Systems Engineering, Page 3, Prentice Hall, Englewood Cliffes, New Jersey.

**Modification of Activated Sludge Process.

Figure 3-3. Annual Costs of Sewage Treatment in India



Reference: Cost of Sewage Treatment (Technical Digest No. 10) Central Public Health Engineering Research Laboratory, Nagpur, INDIA, 1970.

treatment plant, depth of excavation, and pumping requirements. Generally, no sewer should be less that 8 inches in diameter. However, since the design of sanitary sewers and drains is usually based on estimates of future flow, pipe sizes cannot be determined with extreme accuracy. However, in sewer system design, it is imperative that the following requirements be met:

a) The wetted cross section area of the pipe must be sufficiently large to pass the flow at the designed velocity.

b) The velocity must be sufficiently high to prevent the deposition of entrained solids in the pipe, but not high enough to induce excessive turbulence or excessive thrust at changes of direction. Where slopes are very steep, the computed velocity must be less than critical.

c) Where changes are made in horizontal direction of sewer lines, whether in size of the pipe or in the rate of discharge, invert elevations must be matched in such a manner that the energy gradient does not change elevation abruptly or slope upward.

Layout of System

The design of a sanitary sewer includes the layout of a total system or part of a sewer system. The key factors in the development of the layout are as follows:

a) Determination of the total drainage system that will contribute flows into the system.

b) The location of an outlet is usually determined by conditions that will allow all flows from the drainage area to convene at a common outlet for treatment or discharge into an intercepting sewer.

c) Location of trunk lines.

d) Location of lateral lines.

e) Tributary areas outlined.

f) Acreage opf tributary area.

g) System of designation, e.g., giving suitable numbers to the sewer lines.

The sewer pipes can be of any suitable material. This includes clay, concrete, asbestos, cement, cast iron, steel, and a number of plastic compounds. At present, there is no single material that is best for all

applications or does not have some undersirable property. Common problems include corrosion from both liquid and particularly sewer gases present in sewers. Factors that contribute to the development of sewer gases (especially Hydrogen Sulfide) include temperature of sewage, strength of sewage, velocity of flow, age of sewage, pH, and sulfate concentration. Failure to fully and properly evaluate any of the contributing factors may lead to subsequent failure of the sewer lines.

Manholes are essential components of sewer lines and should be installed at the end of each line, at all changes in grade, size, or alignment, at all intersections, and at distances not greater than 400 feet for sewers 15 inches or less in diameters, and 500 feet for sewers 18 inches to 30 inches. Similarly, appropriate drop pipes should be provided for a sewer entering a manhole invert.

3.5 Option 3: Waste Stabilization Ponds

Waste stabilization ponds are one system component that have been found to be extremely cost effective mechanisms for wastewater treatment and disposal in many tropical countries. They appear as an attractive option for Tacloban.

Stabilization ponds are bodies of water, artificial or natural, large and shallow, in which organic wastes are decomposed by a combination of bacteria and algae under the influence of sunlight and air. The wastes fed into a stabilization pond system can be raw sewage, effluent from sewered pour-flush (PF) toilets or aquaprivies. Organic matter contained in the waste is stabilized and converted, in the pond, into more stable matter in the form of biomass, simple organic compounds and algal cells which find their way into the effluent and hence, the term "stabilization ponds".

Ponds have considerable advantages, particularly with regard to costs and maintenance requirements and the removal of fecal bacteria, compared to all other methods of treating the community sewage. A hot climate such as Tacloban is ideal for pond operation.

Ponds can be of several types and they are classified according to the biological processes taking place, namely aerobic, anaerobic and facultative.

a. Aerobic Ponds are shallow, about 0.3 m. depth, and have large area: volume ratio, so that algal growth can be maximized through photosynthesis. Ponds contents need to be mixed, once or twice each day to resuspend any settled solids, and remove algae from the final effluent. Efficient operation requires skilled labor to operate and maintain the algal removal pond. Algal yields are quite high under optimum conditions. One experimental pond in Thailand (depth 0.45 m. and retention time one day loaded with settled domestic sewage at a rate of 450 kg. BOD) had yielded 450 kg. of algae and the final effluent had a BOD 30 mg/l.* Algae removes nitrogen from waste waters and has many uses.

b. Anaerobic Ponds. Anaerobic ponds can take high loadings, however, they preclude photosynthetic algal action and anaerobic conditions prevail throughout the ponds. Anaerobic and facultative bacteria obtain their required oxygen from the chemical compounds present in the waste. Anaerobic ponds, 2.5-4.0 metres, are deeper than aerobic and their effluents have a high BOD effluent, requiring further treatment before their final disposal.

c. Facultative Ponds are relatively shallow ponds, 0.9-1.5 metres, and can be used for treating raw sewage; sewage which has received only pretreatment; settled effluent from septic tanks and anaerobic pretreatment ponds. Faculatative means a mixture of aerobic and anaerobic conditions. Aerobic conditions are maintained within the upper layers, while anaerobic conditions exist towards the bottom. Re-aeration of the upper surface supplies some of the oxygen for aerobic conditions, however, most of it is supplied by the photosynthetic activity of the algae which grow naturally in the pond where considerable sunlight is available. Several bacteria utilize this "algal" oxygen to oxidize the organic waste matter. This metabolism produces carbon dioxide which is used by algae for the photosynthetic reactions, as the demand for carbon dioxide exceeds

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*McGarry, in Water Supply and Waste Treatment in Developing Countries. Asian Institute of Technology, Bangkok, 1970.

the supply from the atmosphere. Thus, there is symbiosis between algae and bacteria in the pond. Since photosynthesis is a light dependent activity, there is a diurnal variation of the amount of dissolved oxygen present in the pond.

The pH of the pond contents also follow a daily cycle increasing with photosynthesis to a maximum which may be as high as 10. This is due to algae removing carbon dioxide from the solution at peak demand more rapidly than it is replaced by bacterial respiration; as a result the bicarbonate ions present dissociate to provide, not only more CO_2, but also the alkaline hydroxyl ions which increases the pH value.

Reactions in Stabilization Ponds

The chemical characteristics of the water waters stimulate the microbiological reactions, that produce the various biochemical changes. Wastewaters generally have a base of necessary microorganisms required for bio-degradation reactions.

When wastewaters are discharged into waste stabilization ponds, there is some dilution of the wastewaters and usually, the heavy suspended solids settle out near the inlet.* The heavy suspended solids then undergo anaerobic metabolism with the production of organic acids and other anaerobic end products. The net reaction depends upon the extent of mixing, which also determines the movement of these products into the liquid moving across the surface of the settled solids. If the solids settle too rapidly, it is possible to build up a continuously increasing sludge layer. The sludge layer in larger quantity, can be detrimental for the proper functioning of the stabilization pond.

The species of bacteria that predominate in a waste stabilization pond are a complex mixture.** Depending upon the conditions in the pond, anaerobic, aerobic or facultative bacteria will thrive and stabilize the organic matter in different ways. The microbes that derive the most

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*Oswald, W.J., Gotaas, H.B., Golueke C.G., and Kellen, W.R., "Algae in Water Treatment", Sewage and Industrial Wastes, 28, 4, pp. 431-455, 1951.

**Gann, J.D., Collier, R.E., and Lawrence, C.H., "Aerobic Bacteriology of Waste Stabilization Ponds", Journal Water Pollution Control Federation, 40, 2, pp. 185-191, 1968.

energy per unit of food metabolize predominatly by simply producing more new cells than any group. Most pathogenic bacteria cannot compete with the normal bacteria and die off because of the simple endogeneous reactions. No unusual conditions or antibiotics are produced to kill the pathogenic bacteria. The lack of adequate nutrient results in a decrease of cells with subsequent death.

An equally important role in stabilization ponds is played by algae which are the most diverse group of microorganisms found in waste stabilization ponds.* Algae, in general, are microscopic organisms possessing an internal green pigment called Chlorophyll which is sometimes hidden or masked by other pigments. In presence of sunlight, the chlorophyll of the algae combines water and carbon dioxide to form starch or other related substances and simultaneously releasing dissolved oxygen.

The large concentration of nutrients, and the large surface area of stabilization ponds enable absorption of large quantities of sunlight and makes it possible for algae to produce massive quantities of algae cells. Soluble organic materials are converted to suspended solids. The algae undergo endogenous respiration, as do bacteria. Approximately 20 percent of the algae protoplasm is not metabolized and remains as inert, non-biodegradable organics. Recycling of nutrients keeps the algae population in ponds much higher than the bacterial population, which it cannot recycle. Yet recycling of nutrients is the prime method of waste removal in stabilization ponds.

Some of the algae in stabilization ponds is motile while the rest is non-motile. Motile algae have the ability to move to optimum light levels and hence, survive under adverse light environments. Non-motile algae are at a disadvantage but are able to survive in competition primarily because of their size and structure.

Of particular significance in stabilization ponds, are the commonly found green Chlorophyta, with Chlorella as an important species, and the

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*Sirva, P.C., Panenfuss, G.F., "A Systematic Study of Algae of Sewage Oxidation Ponds", California State Water Pollution Board, Publication No. 7, 1953.

blue-green algae. In ponds, all algae receiving light and nutrients, grow in relation to their synthesis efficiency. The blue-green algae has the ability to fix atmospheric nitrogen and form filaments or clumps of cells that produce surface mats and block light penetration, thus creating anaerobic conditions below the blue-green mats.

Fungi do not grow readily in waste stabilization ponds simply because bacterial competition is too great. Often fungi is at the edge of the pond, where solid surfaces offer a place for growth, with continuous aerobic exposure.

Physical--Chemical Reactions

Those reactions related to physical characteristics of ponds rather than chemical characteristics are given below.

a. Time is the most important physical parameter affecting waste stabilization ponds.* The incoming wastes must be quickly mixed, if aerobic metabolism is to be sustained. It is normal to have anaerobic zone around the waste inlet. If the wastes have heavy suspended solids that can settle out, the area around inlet should be deepened to permit sludge storage with adequate liquid above the sludge storage to pervent obnoxious odors from being released. Long retention periods beyond those needed for stabilization of the organic matter results in algae recycling and bacteria die off. The recycling of nutrients by the algae effects a slow conversion of active cellular tissue to inert cell tissue with a definite reduction in nutrient availability. Destruction of pathogenic bacteria is in direct proportion to fluid retention time.** Figure 3-4 shows the BOD removal for a multicelled pond.

b. Wind. Wind action on the surface is a prime mechanisms of mixing.*** The site selected should permit unobstructed wind sweeps across

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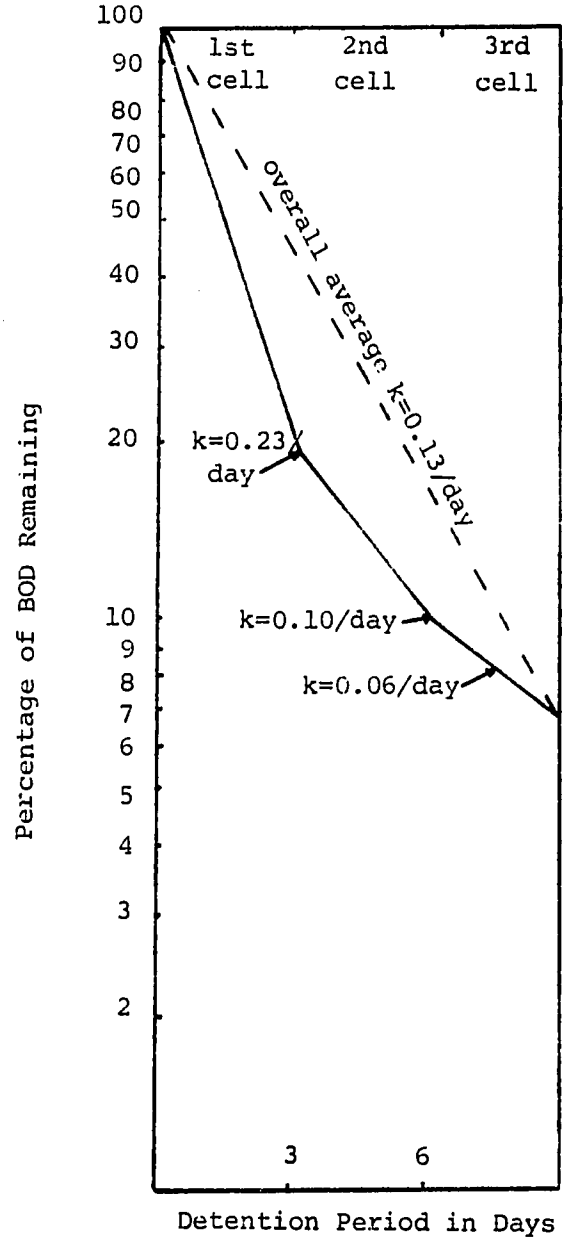
*Meron, A.M., Rebhun and B. Seiss, "Quality as a Function of Detention Time in Wastewater Stabilization Ponds", Journal Water Pollution Control Federation, 37, 12, pp. 1657-1660, 1965.

**Little, J.A., Carroll, B.J., and Centry, R.E., "Bacteria Removal in Oxidation Ponds", Proceedings of Second International Symposium on Waste Treatment Lagoons, Kansas City MO, pp. 141-151, June 1970.

***Porges, R., "Design Criteria for Waste Stabilization Ponds", Public Works 94, 1, pp. 99, 144, 145, January 1963.

Figure 3-4. Rate of BOD Removal in Multicelled Pond



Source: Arceivala, S. J. Waste Stabilization Ponds, Central Public Health Engineering Research Institute, Nagpur, India, page 54, 1970.

the pond. To get maximum benefits of the wind, the longer dimension of the pond should be parallel to the direction of local prevailing winds. Besides mixing wastes throughout the pond, wind also distributes both the end products of bacterial metabolisms and dispersion of nutrients and the oxygen produced by algae. The algae light reactions depending upon the turbidity occur in the upper 6-12 inches of the wastes stabilization pond.* As a rule of thumb it is recommended that a clear distance of 5-8 times the height of any group of trees or brushes from the lagoon, perhaps a minimum clear sweep of 300 feet, free of all but isolated obstructions should provide an adequate wave action.

Artificial mixing can be accomplished by recirculating the pond contents at a velocity rapid enough to suspend the settled solids that are "scouring" the bottom. A velocity of about 1 ft./minute (30 cm/minute) should serve the purpose.

c. Solar Radiation. Solar radiation is important for photosynthetic algae reactions. However, for successful waste treatment, very high light intensity is not needed. Adequate light energy for adequate waste treatment ponds seems to be available not only in Tacloban, but all over the Philippines, due to the geographical location,.

The depth of incident light energy determines how much pond volume will participate in oxygen production. A dense algae growth prevents deeper penetration of sunlight and hence, the aerobic ponds are generally designed shallow and built between 0.9-1.5 meters.**

The efficiency of conversion of visible energy to algae energy is generally small and varies from 4-6 percent of the algae material produced. About six million calories are required to produce 1 kg. algae. Moreover, for every gram of algae material produced, 1.25-1.75 grams of oxygen will be produced simultaneously. It, therefore, implies that the stabilization pond

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*ibid.

**Arceivala, S.J., Lakshminarayana, J.S.S., Alagarsamy, S.R., Sastry, C.A., Waste Stabilization Ponds Design Construction and Operation in India, pp. 118, Central Public Health Engineering Research Institute, Nagpur, India, 1970.

area necessary to produce a certain amount of oxygen to meet the BOD demand, is a function of the visible light striking the pond surface, and the efficiency of conversion of this energy by the algae present.

d. Rainfall. Rainfall by way of cloudy weather may be a consideration though as such it does not seem to have any bearing on the design of stabilization ponds.

Design of a Waste Stabilization Pond for Tacloban

In spite of the apparent simplicity of the stabilization pond, it is indeed a complex biochemical reactor which defies precise design.* Though several rational approaches to design loadings for stabilization ponds have been developed from time to time, due to interplay of several complex factors, each situation requires its own evaluation.

Proper planning is important to keep construction, operation and maintenance costs to a minimum. Generally, rectangular ponds with length to breadth ratio of two to three to one and embankment slopes of one in three are used whenever possible. The embankment can be protected from erosion by wave action by placing precast concrete slab, or stone rip-rap, at surface water level. The pond should be impermeable. In coarse permeable soils, the pond base should be sealed with plastic sheeting or clay. U-notch weirs, rectangular weirs or if necessary Parshall flumes may be installed to measure influent and effluent flows to evaluate performance.

A waste stabilization pond acts as a semi-closed system, with a steady input of wastes and a fairly steady discharge of effluents. Some evaporation and infiltration produces variable volumetric losses and concentration changes. In some areas, waste stabilization ponds are designed so that evaporation equals input. In flow-through ponds, wastes undergo well-established physical and biochemical changes. Initial waste constituents are changed from one form to another, by various groups of microorganisms, though a small amount of gaseous material is produced and lost to the atmosphere. The easily degradable materials are converted to more stable

*ibid

forms, but light energy permits rapid regeneration of stable material back to unstable organic matter. All processes are normal environmental reactions with the production of an environmentally compatible effluent.

Area Requirement of Pond

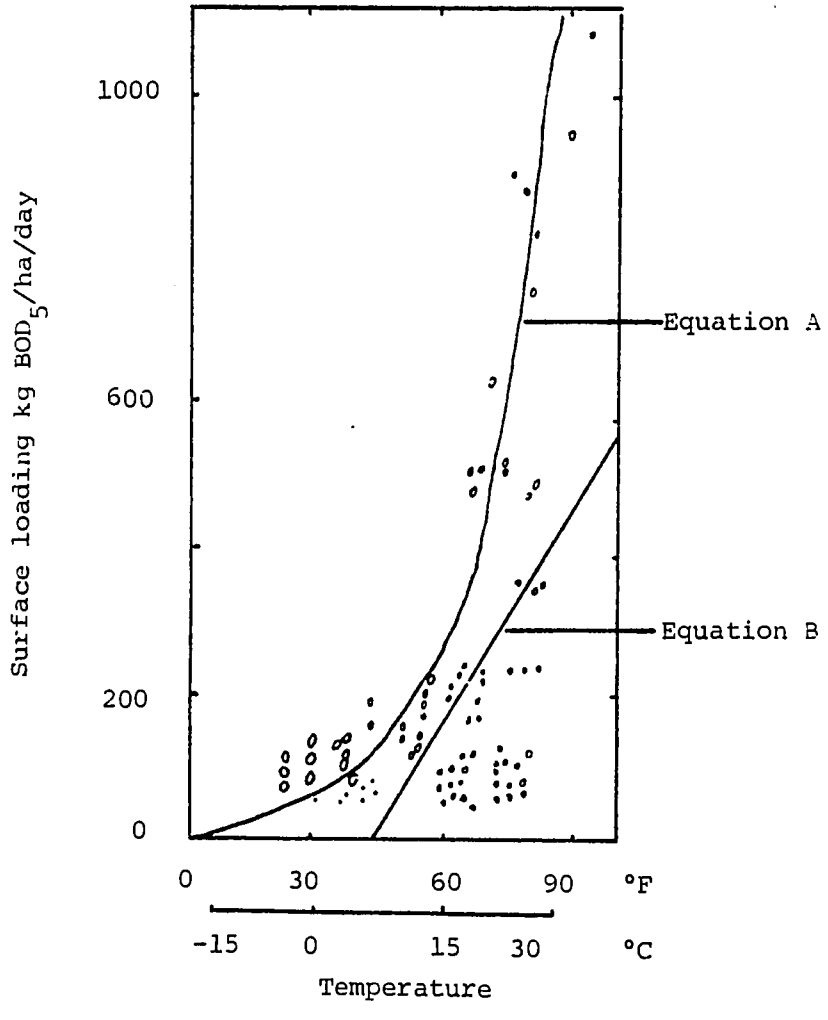
a. Organic loading rate. How much influents can be discharged into waste stabilization pond depends upon the intensity of solar radiation, the type of algae, and its conversion efficiency, nature of sewage, temperature, etc. It is important to evaluate all these factors before embarking upon a loading rate. In India, organic loading of 150-300 kg/ha/day in colder regions and up to 400-500 kg/ha/day in climates similar to Tacloban have given 80-85 BOD reduction. Figure 3-5 shows the relationship of maximum permissible loading rates and temperature for facultative ponds.

b. Hydraulic Loading Rate or Detention Time. Area relates to solar radiation, and oxygen production detention time should be enough for oxygen produced to be used in biochemical reactions, at the pond temperature. For an organic loading of 200-300 kg/ha/day, a depth of 1-15 m. will be given enough detention time. It is advisable to design ponds on the hydraulic as well as organic loading basis and adopt that criteria out of the two that results in a longer detention period. Increase in depth, within limits, will be also help to give longer detention periods.

c. Location of Ponds: Location of stabilization ponds is a key element to the ultimate success or failure of ponds. Simply stated, the following are the relevant key factors:

- Should ensure gravity flow;
- Flat or gently undulating land, keeps earth work minimum, since earth work is the major item of construction;
- Avoid shaded areas;
- Should permit future expansion;
- Preferable location should be 300-400 meters, or more, away from residential areas;
- Pond soil should be relatively impervious. Moreover, prediction of percolation rates, like evaporation, are very uncertain. However, when the seepage rate is more than 10 percent of the flow, the solids that are deposited slowly seal the pond. and
- The stabilization ponds should be at least 20 m. away from drinking water well, so that they may not be detrimental to the groundwater.

Figure 3-5. Performance of Stabilization Ponds



Variations of maximum permissible design loadings on facultative ponds with mean air temperature.

Equation A. $\lambda_s = 11.2\ (1.054)^T$ where λ_s is maximum BOD_5 loading, kg/ha/day, T = temperature in Fahrenheit, °F.

Equation B. $\lambda_s = 20T - 120$ (T in Centigrade).

Source: Mara, Duncan. Sewage Treatment in Hot Climates, John Wiley and Sons, New York, NY, page 83, 1976.

d. Characterization and assessment of various parameters. Generally, in establishing a waste stabilization pond the following parameters should be assessed. Several of these parameters were not used due to lack of facilities for measurement or their non-applicability to the design of stabilization pond for Tacloban.

1. Quantity of waste to be treated (from existing sewerage):

   - Gauging flows in existing systems;
   - Projecting volume to year 2000.

2. Estimate various components that contribute. Such estimates are based on:

   - Per capita water consumption (in Tacloban 31 g/day, however, only 80 percent would reach sewer);
   - Present population, future growth;
   - Industrial waste discharges; and
   - Infiltration into sewers and stabilization ponds.

3. Characteristics of the nature of waste to be treated include:

   - BOD;
   - Suspended solids including grit;
   - pH (acidic or alkaline);
   - Temperature;
   - Presence of toxic substances; and
   - BOD rate constant K.

For example, for domestic sewage under Indian conditions a BOD of 45 gm/cap/day, or 0.1 lb/cap/day, in Bombay suburbs has been observed. For suspended solids the value per capita per day is is 60-90 gms (or (0.15-0.20 lbs). These values help to estimate how the total BOD load and the sludge accumulation and grit decrease the effective volume of the pond from year to year. Their range, as observed in India, is 0.08-0.30 cum/ha/annum. Moreover, sewage may have to be screened before entering a stabilization pond to avoid operational problems. This, however, may not be needed in Tacloban, since it is unlikely to be a problem.

e. Shape, Depth, Number of Units, etc. Any shape, rectangular, square, oval, etc. is considered suitable. A rectangular pond is found to be superior to square or circular or irregular geometries.* Length to breadth ratio of two or three to one is recommended. Moreover, ponds should be rounded at corners, to minimize accumulation of loading materials and idle corners.

- Depth. Facultative ponds can be between 0.9m.-1.5m deep. However, depth can be slightly increased with weaker sewage waste.

- Outlet. An outlet should provide facility of operation at varying depths of the pond. Freeboard is allowed above, except in larger ponds where wind action is more. Freeboard is usually 0.6-0.9 metres and should discharge into a chamber containing a U-notch.

- Multiple Units are sometimes two to three small ponds (0.5 ha). They are considered better than one large pond, as they facilitate better maintenance. Ponds can be arranged in series or parallel. It is recommended that the primary pond be kept 65-70 percent of the total area to avoid anaerobic conditions. The actual number depends upon the magnitude of flow and topography of the site.

- Embankment. Slope of one in three is usually satisfactory in most soils.** Precast concretes can avoid erosion by wave action and stop vegetation that frequently grows and thus prevent breeding of mosquitos, enbankments are easier to maintain.

- Inlet Structure. Should have venturi or Parshall flume to measure inflow and a V-notch to measure the final outflow, to help check pond performance. A pipe supported on piers can convey the sewage. To reduce amount of scum, the pipe should discharge below the pond surface, however, to prevent sludge bank formation, it should be sited away (up to 25 m.) from the embankments.

f. Iterpond Connection. The simplest and cheapest way to establish interpond connection is by the piping arrangement. Connections should pass a flow of 1.5 times the quantity of average flow. Flows greater than the above are then attenuated in the pond and occurrence of floods flushing through a

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*Shindala, A., and Murphy, W.D., Water and Sewerage Works, (10) pp. 394, 1969.

**Mara, Duncan, Sewage Treatment in Hot Climates, p. 87, John Wiley & Sons, NY, 1976.

series of ponds can be prevented. Multiple inlets and outlets are suggested if the length to breadth ratio is less than 2.1.

g. Desludging Frequency. Normally rate of sludge accumulation is approximately 0.03-0.04 m^3/ha/yr. Desludging is required when the pond is one-fourth to one-half full of sludge.*

Figures 3-6, 3-7 and 3-8 show a schematic design for an oxidation pond constructed alongside the Mangonbangon River to provide the equivalent of instream treatment. The River is left as a bypass during heavy rains. In Table 3-5 we estimate the capital costs of such a facility.

Design Calculations for Stabilization Pond at Mangonbangon Creek

The stabilization pond proposed at Mangonbangon Creek will serve approximately 20,000 people. The relevant design calculations based on the principles discussed earlier are given below. It is presumed that there will be no infiltration and/or drainage overflow into the pond and that the City will go ahead as planned in relocating the existing shanty dwellers from the site. Moreover, building a stabilization pond in this area should minimize, by channeling into the pond, the runoffs, including from leaking and illegal waste water discharges, such as the septic tanks.

The Mangonbangon Creek starts from Apitong and Utap area as a natural creek. It then passes through heavily populated areas of the Youngfield districts, passes in front of Leyte National High School and crosses Athletic Field Road, on to Santa Cruz Street, traversing Divine Word University compound. From there on, it crosses Salazar Street, passes Savin district and on the Panlaran Bay. One of the four drainage channels currently existing in Tacloban City drainage system (DD III), as well as the Divine Word University septic tank dicharges into this Creek. Except for these, the creek does not carry significant flow except during the rainy season which can extend over two months. The total length of the

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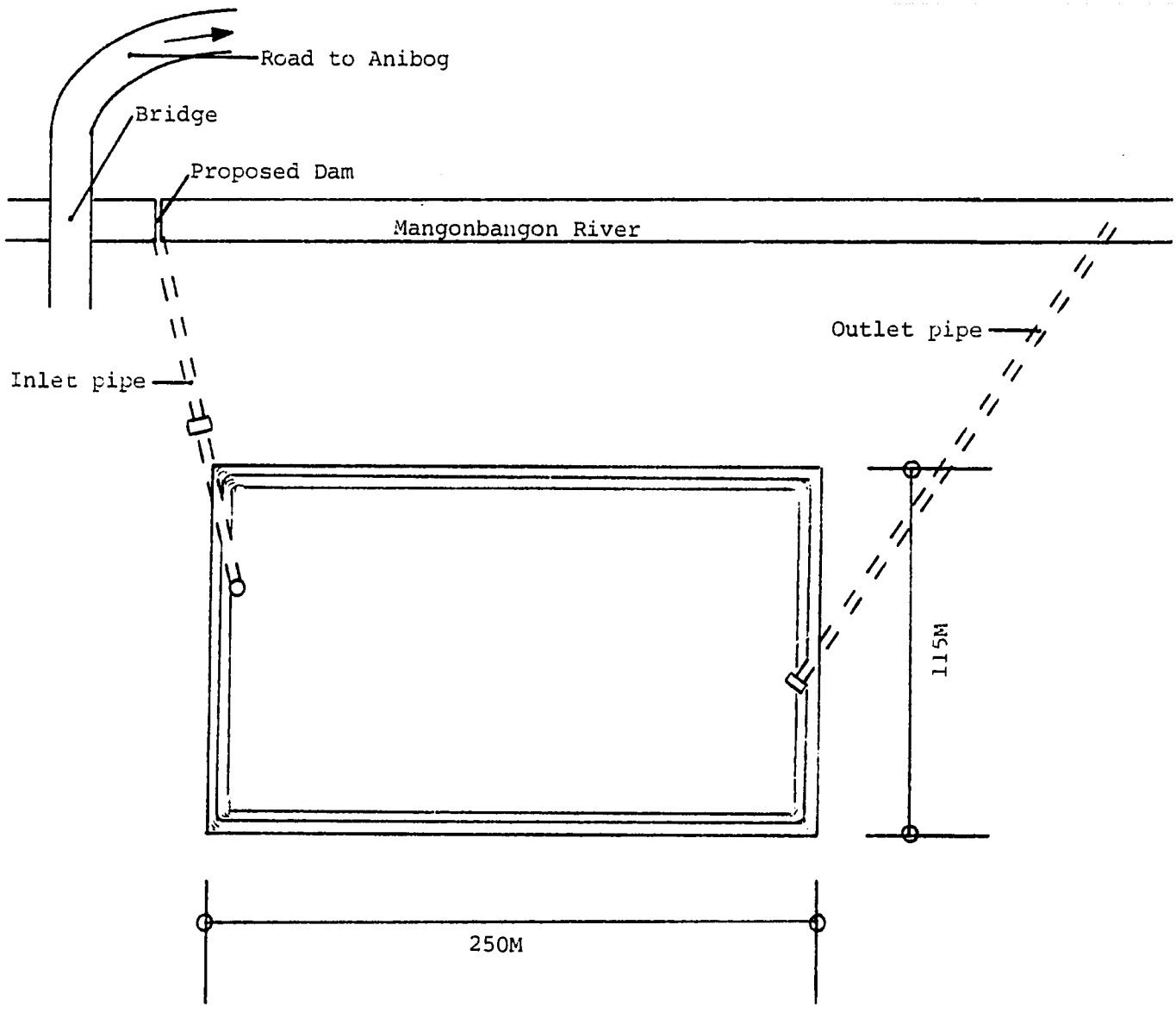
*Vincent, L.J., et al., Proceedings, Symposium of Hygiene and Sanitation in Relation to Housing Commission for Technical Cooperation in Africa, London, 1963.

Figure 3-6. Proposed Oxidation Pond



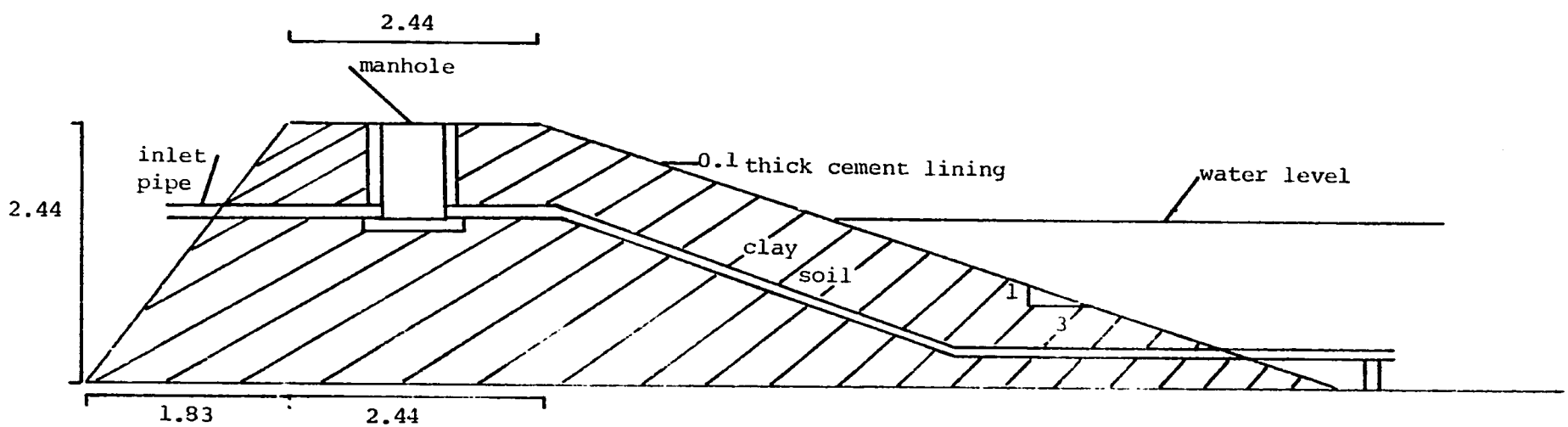


Figure 3-7. Inlet to Oxidation Pond

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Figure 3.8 Outlet to Oxidation Pond

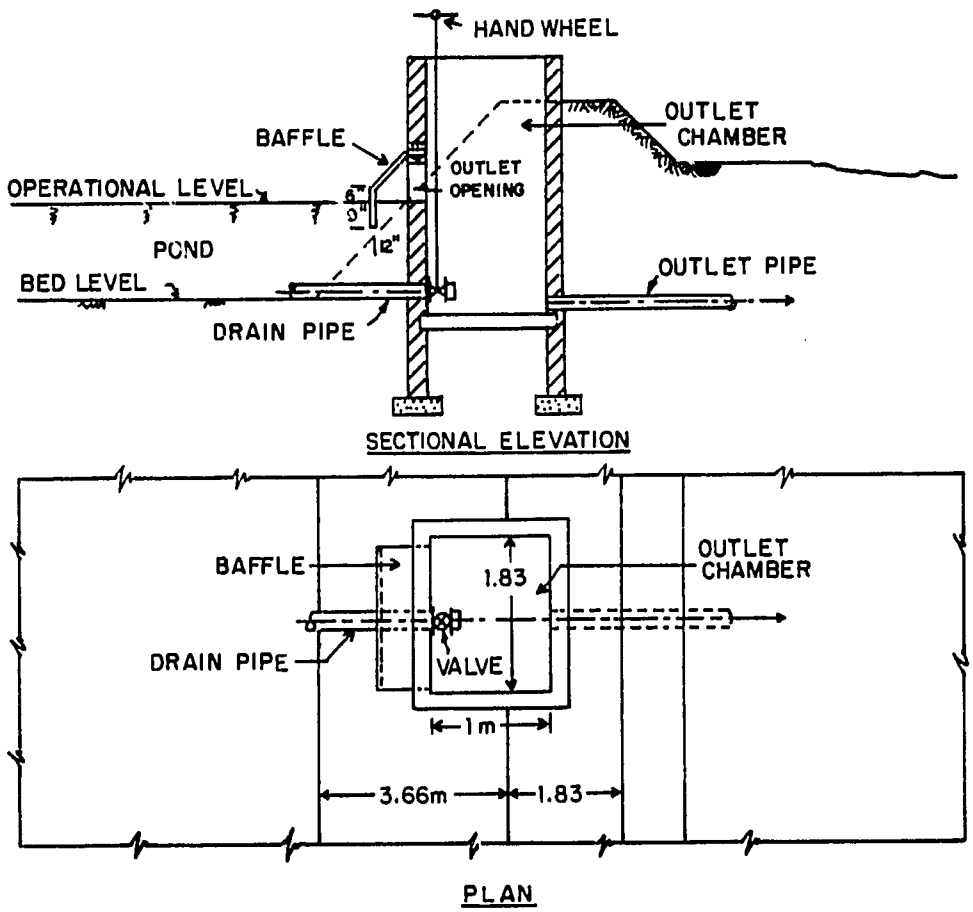

Table 3-5

Costs* of Waste Stabilization Pond on Mangonbangon Creek

	Cost in Pesos
Concrete Dam 10 metres long for Mangobangon Creek	30,000
Removal of 100 shanties, relocation assistance	50,000
Site Preparation for the oxidation Pond	20,000
Embankment** includes:	
- Rolling, compacting, etc. (cost of cover earth material)	200,000
- Cement lining-concrete slabs	100,000
- Piping (all kinds required), concrete inlets and outlets structures	70,000
- Fencing (three sides) 500 metres length, fourth side faces river, wooden posts and interlink doors	25,000
- Effluents to Mangonbangon Creek, 20-inch concrete pipe	30,000
Total	750,000
Number of people served	20,000
Cost per capita	P375
Sludge accumulation 0.04 m^3hd/yr*** Total sludge accumulation = 20,000 X .04	800 cum/yr

*These costs are for a facultative type of pond. Such ponds for the population of 20,000 have been shown to be cost effective under conditions similar to Tacloban.

**Pond site is about 300 metres away from residential areas.

***Mara, op cit., excludes sludge decay factor over time.

Manganbangon Creek is about 3 km andapproximately 20-25 thousand people including shanty dwellers discharge their waste waters into this Creek. During high tide, sea water generally enters the mouth of the Creek.

New Para shanty residents are mostly low paid laborers, vendors and employees of copra (coconut) merchants who have occupied the land illegally. An average shanty has 2-3 small rooms, with an average occupancy rate of 7-8 people and frequently a pig behind a partition in one of the outer rooms. Supported by raised wooden pillars, many shanties especially where the Creek lacks a retaining wall have polluted and stinking water standing underneath. Besides sewage, the Creek carries solid wastes dropped into it mostly by the dwellers alongs its banks. The present situation is a serious health hazard.

Out of the two sites along the Creek considered suitable for a stabilization pond, one site in particular looks more appropriate. This site is located directly across the mountain where the City's large drinking water reservoir is also located. Establishment of a stabilization pond, besides improving the sanitary conditions, will eliminate, by removal of the existing shanties, any danger to them due to accidental failure of the City's reservoir.

The proposed stabilization poond serving approximately 20,000 people will require an area of 2.90 ha; and detention time of approximately 22 days. The detailed calculations are shown below:

Organic load, 5 day BOD at 20°C = 0.11 lb/cap/day*

Flow/person = 28 gallons/cap/day**
= 22 gallons/cap/day (after discounting for losses due to lawn usage, evaporation, etc.

Total Flow = 440,000 gal/day
= 0.44 mgd

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*Housing and Urban Development 1970 "Sewage Lagoons for Developing Countries" Ideas and Methods Exchange No. 62, 302/2/1 Sewage Lagoons, Prepared for Agency for International Development, January 1966, (Revised June 1970), Page 11.

BOD in sewage (in mg/liter BOD)

$$= \frac{\text{Per person/day BOD in lbs}}{\text{Flow in gallons/cap/day}} \times 10^5*$$

= 0.12 x 105 = 545 mg/liter

Permissible loading rate at 27°C in Tacloban

= 375 kg BOD/ha/day*

Total BOD in the flow = 20,000 x 0.12 lbs/cap/day
= 2,400 lbs/cap/day
= 1,091 kg/cap/day

$$\text{Area required for the pond} = \frac{\text{Total BOD in kg/ha}}{\text{Permissible BOD in kg/ha}}$$

$$= \frac{1,091}{375} = 2.90 \text{ ha}$$

It is proposed that the stabilization pond be facultative type with a depth of 1.5M

Volume = Area x depth
= 2.90 x 1.5 x 10,000 (meters)
= 43,500 cum
= 1,534,680 cu ft (1 cum = 35.28 cu ft)

Volume = 1,534,680 x 6.24 = 9.57 million gallons

Retention time required for the above BOD

$$= \frac{\text{Pond Volume}}{\text{Daily Rate of Flow}}$$

$$= \frac{9.57}{0.44}$$

= 21.75 days or 22 days

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*Housing and Urban Development 1970 "Sewage Lagoons for Developing Countries" Ideas and Methods Exchange No. 62, 302/2/1 Sewage Lagoons, Prepared for Agency for International Development, January 1966, (Revised June 1970), Page 11.

**Arceival S. J., et al, 1970 op cit., Appendix II, Page XI.
Mara, Duncan (1976), op cit., Page 73.
Arthur J. P. (1982), "A Review of Waste Stabilization Ponds-Consultants Final Report", International Bank for Reconstruction and Development, Urban Projects Division, Washington, DC, April 1982.

The detention time was checked for its sufficiency, by comparing it with the minimum detention time required for 90 percent removal of BOD (compared to a conventional sewage treatment plant). The following formula was used where, the reciprocal of k value gives the required retention time:

$$t = \frac{1}{k}$$

where

t = detention time

and k = rate of BOD removal per day

Since maximum retention time is required in winter, the 22 days time calculated above, would be checked against average winter temperatures of 24°C prevalent in Tacloban.

The value of k at 24°C was determined with reference to the value at 20°C.**

$$k_{20} = 0.100$$

$$k_{24} = 0.1201$$

$$\text{Hence } t = \frac{1}{k24} = \frac{1}{0.1201} = 8.3 \text{ days}$$

This is the minimum detention time required in the pond during winter operations, with average temperatures of 24°C. However, the pond detention time of 22 days calculated above fully covers this period of lower temperatures and slower stabilization.

**Arceival S. J., et al, 1970 op cit., Appendix II, Page XI.
Mara, Duncan (1976), op cit., Page 73.
Arthur J. P. (1982), "A Review of Waste Stabilization Ponds-Consultants Final Report", International Bank for Reconstruction and Development, Urban Projects Division, Washington, DC, April 1982.

3.6 Option 4: Conventional Sewage Treatment Plant (CSTP)

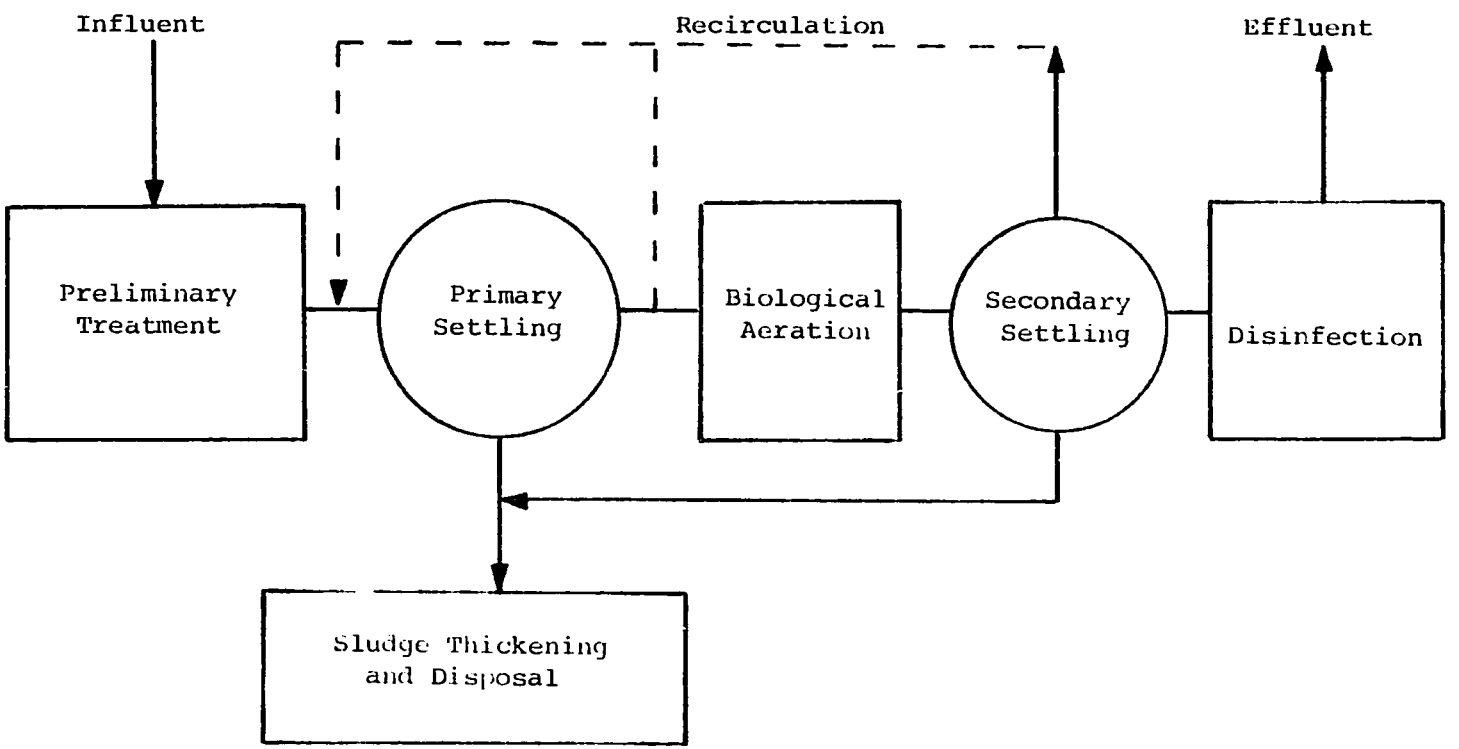
Conventional wastewater treatment consists of preliminary processes (pumping, screening and grit removal), primary settling to remove heavy solids and floatable materials and secondary biological operation to metabolize and flocculate, colloidal the dissolved organics (see Figure 3-9). Waste sludge drawn from these unit operations, is thickened and processed for ultimate disposal.

a) Preliminary Treatment Units--Preliminary processes used in domestic wastewater treatment are coarse screening (bar racks) medium screening, comminution, flow measuring, pumping, grit removal and pre-aeration. If the wastewater flow also includes industrial discharges, floatation, flocculation and chemical pre-treatment are also included.

Screens are used to protect pumps and prevent solids from fouling grit removal units and flumes. The possible arrangement of other units, depends upon the raw wastewater characteristics, subsequent treatment processes and preliminary steps employed. The Primary Treatment Unit of a CSTP is typically sedimentation.

b) Secondary Treatment Units--Primary sedimentation removes 30-50 percent of the suspended solids in raw municipal wastewater. The remaining organic matter is extracted in biological secondary treatment to the allowable effluent residual using the activated sludge process, trickling filters, or biological towers. In the activated sludge method, wastewater is fed continuously into an aerated tank, where micro-organisms synthesize the various organics present. The resulting microbial floc (activated sludge) is separated from the aerated mixed liquor under quiescent conditions in a final clarifier and returned to the aeration tank. The plant effluent is clear, supernatant from secondary settling. Liquid aeration offers several advantages, including high BOD removals, ability to treat high strength wastewater and adaptability for future use in any plant conversion to advanced treatment. On the other hand, a high degreee of operational control is needed, as for example, unexpected (shock) loads may upset the stability of the biological process, and any sustained hydraulic or organic loading could result in process failure.

Figure 3-9. Typical Layout for a Conventional Sewage Treatment Plant



Biological beds can be trickling filters or towers and contain rock or synthetic media to support microbial films. These slime growths extract the organics from the wastewater as it trickles through the bed. Oxygen is supplied from the air moving through the voids in the medium. Excessive biological growth washes out with the underflow and is collected in the secondary clarifier. In colder climates, (perhaps, below 16°C) two stage rock-filled trickling filters are used to achieve efficient treatment. Biological towers may be either single or two-stage systems. Advantages of biological filtration are, ease of operation, and capacity to accept shock loads and overloading without causing complete failure.

3. Sludge Disposal--Primary sedimentation and secondary biological flocculation processes concentrate the waste organics into a volume of sludge which is significantly less than the quantity of wastewater treated. However, disposal of sludge is a major economic factor in wastewater treatment. Generally, construction costs of sludge disposal facilities have averaged 30 percent or more of the total treatment plants.

Conventional methods of sludge disposal have included burial in landfills, incineration, production of soil conditioner and barging to sea. In coastal cities, like Tacloban, ocean dumping could be a highly economical method of disposal. Incineration is generally considered an expensive option, unless it is the only method available, such as in thickly populated urban areas.

4. Chlorination--Disinfection of secondary-treatment-plant effluents may be needed if the water course for their disposal is used for recreation or water supply. Similarly, nutrient removal, like N or P, may be needed to prevent eutrophication and contamination of receiving waters.

Suitability of Sewers and CSTP (Conventional Sewage Treatment Plant) for Tacloban

Conventional sewage, though offering high user convenience, has several constraints for its potential in Tacloban. Perhaps the largest one is the cost. CSTP is an inherently expensive sewage treatment facility. Among the technical constraints, applicable to Tacloban, are its large water requirements and the difficulty of excavation in the densely populated city and also in areas with poor ground. The high water table (general range

5-10 feet), is a problem in laying sewers in farily straight lines through several areas of "unplanned" housing (ever mushrooming shanty development) without substantial demolition; not to mention political costs, the susceptibility of above ground pipes to Tacloban's hot and humid climate and the possible overall poor maintenance will result in problems due to lack of technical skills required for the maintenance of plants are serious drawbacks.

This does not mean, however, that CSTP is totally unsuitable for Tacloban for consideration. In situations, such as highly dense populated "westernized" areas, CSTP may be the most appropriate from the social, economic and technical viewpoints at a future date.

3.7 Option 5: Improvement of Existing Drainage Systems

The present storm/drainage system consists of 10,840 lineal meters of variously sized reinforced concrete culvert pipes. Besides these, there are also 1,800 lineal meters of rip-rap embankment along Lirang and Mangonbangon Creeks which serve to partially channelize these waterways. This embankment, could not be completed due to lack of funds and is scheduled to be completed in 1983. The total cost to the government of drainage system improvement projects implemented since 1974 has amounted to approximately P4 million.

The system utilizes gravity flow to drain runoff and waste water to the outfalls. Mangonbangon Creek exhibits serious problems of loss of flow, stagnating and indiscriminate disposal of solid, liquid and human excreta and occasionally, animal waste and excreta. This causes serious health and environmental problems to approximately 30,000 residents including over 6,000 shanty dwellers who are also a party to this problem.

Areas Without Drainage System. In the city proper, drainage problems generally are small due to the existence of an adequate drainage plan, and the fact that many pipes have already been installed. However, the number of catch basins and curb inlets seems to be inadequate. Moreover, several areas around the city proper have inadequate or no drainage.

1. Establishment of Storm-Water Inlets and Catch Basins

Proper drainage can not result unless storm water is quickly and efficiently collected and introduced into the drainage system. Storm water inlets, therefore, play a critical role. Overdesign and inefficient use of drainage system due to inadequate inlets can be avoided. Debris and leaf stoppage of inlets can be reduced, traffic interference on streets and highways can be minimized. No specific inlet type can be considered best for all conditions of street use. Factors such as street grade, cross slope, and depression geometry affect the hydraulic efficiency. Eliminating stoppages or minimizing traffic interference should take precedence over hydraulic consideration in design.

Ideally, a simple opening across the path is the most effective type of inlet structure. However, such an opening would be unsafe and impractical and an opening must, therefore, be covered with grate or located in the curb. However, grates are known to obstruct the fall of water and often serve to collect debris, while curb openings are not in the direct path of flow.

A common practice is to increase the street cross slope. This will increase the depth of flow of the gutter and gutter depression will concentrate flow at the inlet and curb and gutter openings can be combined. Such modificatons provide increased inlet capacities are likely to be compatible with the volume of Tacloban traffic. At present, four major types of inlets are being built. These are as follows:

a) Curb Inlets--a certical opening in the curb through which gutter flow passes.

b) Gutter Inlet--a depressed or undepressed opening in the gutter section through which the surface drainage falls, covered by one or more grates.

c) Combination Inlet--an inlet composed of both curb and gutter openings, which acts as an integrated unit. Gutter openings may be placed directly in front of the curb opening (contiguous combination inlet) or upstream or downstream of the gutter opening (offset inlet). Combination inlets may be depressed or undepressed.

d) Multiple Inlets--closely spaced interconnected inlets; act as a unit. Identical inlets end to end are called "double inlets".

Many recent studies, both in the laboratory and the field, have developed efficient inlet designs for varying requirements.*/**

Inlets should be constructed at all sumps, and at all street intersections, where the quantity of flow is significant, or where nuisance conditons warrant such construction. Inlets are required at intermediate points along streets, where the curb and gutter capacity would be exceeded without them. Inlet capacities should be equal to or greater than the design flow. Cost of typical catch basins are shown in Table 3-6.

It is projected that installation of about 200 catch basins, spread over the entire drainage system in Tacloban would help provide a smooth functioning of the drainage system. The cost of connecting the drainage pipe (concrete) 12" diameter in P 100.00.

2. Regular Maintenance of the Drainage System

It appears the City has adequate staff to operate and maintain its drainage system efficiently even with technical limitations such as the inadequate number of catch basins. However, it appears from interviews and discussions, some confidential, that some of this staff is engaged in private business during office hours. During these discussions it was asserted that no additional staff would be needed to run the drainage system smoothly. The following is a breakdown of the staff and their salaries (including fringe benefits):

	Position	Yearly Salary
1.	Senior Chief Engineer	P23,000
2.	Capataz (foreman)	25,200
3.	30 Laborers	21,000
	Total	P69,200

Routine drainage activity should include removing obstructions in the system to prevent clogging during periods of heavy rains. Before the onset of the rainy season, check-up and preventive maintenance considered

*"The Design of Storm Water Inlets", the John Hopkins University, Department of Sanitary Engineering and Water Resources, Baltimore, MD, 1976.

**"Baltimore County Design Manual", Baltimore County Department of Public Works, Towson, MD, 1955.

Table 3-6

Typical Catch Basin Cost Beakdown

Elements	Cost in Pesos
One iron grating	600.00
One manhole cover	600.00
Cement	170.00
Five 3/8" steel bars (for reinforcement 1/2 , 3/8) Five 1/2 steel bars	200.00
Sand	60.00
Gravel	150.00
Forms (wooden)	300.00
Tie Wire	50.00
Total	21,300.00
Labor (7 days 5 men)	700.00
Grand Total	28,300.00

or approximately P 30,000

appropriate must be carried out. The city has enough staff, who if properly managed, can be effective in taking care of the system.

3. Clear Waterways of Squatters

Although a Presential Decree outlaws squatters, squatting, especially along the waterways, seems to be rule rather than an exception. The presence by squatters prevents the rapid flow of storm water, besides being a health hazard to the residents, as well as the general public. The city already has plans to relocate these residents. An early implementation of this plan will go a long way in minimizing the adverse impacts.

4. Revetment or Channelization of Waterways

One cause of flooding in Tacloban area, and in many other surrounding municipalities, is the presence of vegetation and siltation in the waterways. The remedy is a costly one and involves clearing the waterways of vegetation, and construction of revetments to prevent erosion of the banks. Revetment/improvement of the banks can be done by driving sheet piles and installing concrete lining or rubble concrete on the banks. However, compared to the first three alternatives, this work entails higher costs and may be as a start done in areas where the problem is extremely

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serious. One site the city is currently working is on Mangonbangon Creek. In 1981, the city spent over one million pesos to build concrete revetments 1.440 linear meter (along 2 sides of creek). The work will be continued next year when the funds become available.

Figure 3-10 shows a scheme to improve the drainage in Mangonbangon Creek by intercepting part of the flow and routing it through Lirang River.

5. Increasing the Gradient

Landfilling low lying areas, away from the outlets to prevent floods can be practiced. However, this is an expensive method. Increased gradient or slope will increase the water flow towards the outlet.

6. Install Pumps at Appropriate Points

This option being prohibitively expensive can not be followed for all areas that have poor drainage and/or flooding. Installation of pumps entails high initial costs and high operation and maintenance. However, pumps can be considered in situations where flooding severely impedes the traffic of else becomes a public hazard. A medium duty pump will cost approximately P 65,000.

7. Alternatives for Areas Lacking A Drainage System

Most of such area is outside the city proper. It includes Sagkahan district, Fatima village, V&G Subdivision, Barangay Marasbaras and San Jose. They use blind drainage and drain it to the offshore areas through their backyards. The cost of drainage layout (excavation, pipes, labor, etc.) has in the past, averaged 20 pesos/foot of the pipe.

The feasibility of construction of drainage sytem where it is lacking should be looked into. At this time, topographic maps that were completed have been mailed to Manila for review of technical design and funding requirements. The next step will be construction of drainage systems.

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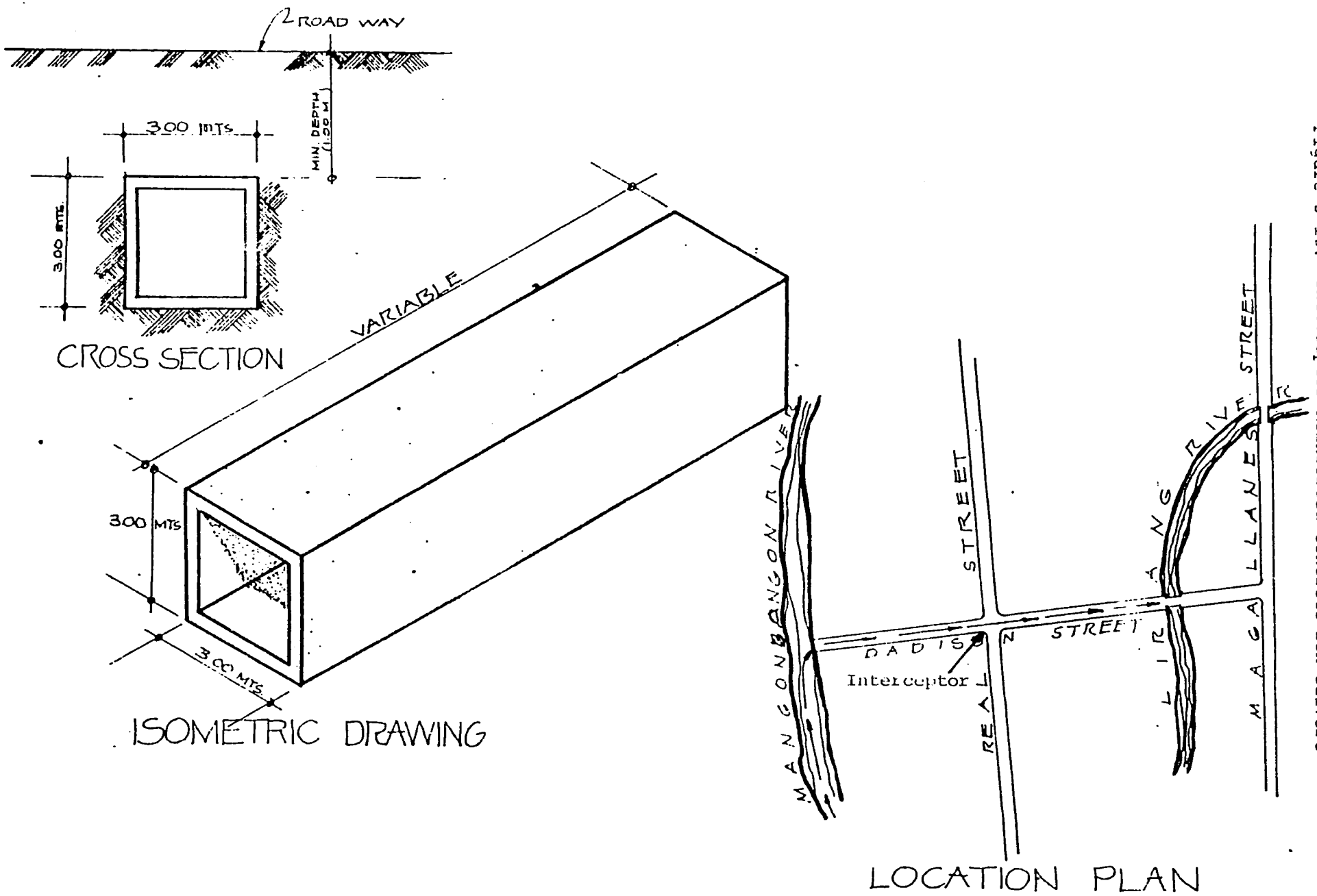

Figure 3-10. Interceptor Reinforced Concrete Box Culvert

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3.8 Option 6: Prevention of Water Pollution by Interceptor Drains and Ocean Outfalls

Ocean outfalls and interceptor drains are one way of reducing the water pollution of coastal waterways. The outfalls, depending upon the characteristics of the flow in them, extend out into deeper waters, where dilution and diffusion into rapid flowing waters takes place rapidly. In some cases, a storage on the shore for drainage effluents is built and the contents released with the outgoing high tide. The outfall can also provide nutrients to the marine life, if properly channeled, and the quality of the flow monitored. Generally, the cost of oeration and maintenance of ocean outfalls is considered lower than the costs of a conventional sewage treatment.

Sewage can be treated at the outfall. However for Tacloban, due to unavailability of land as well as the gradient, utilization of simple technologies such as oxidation pends, without involving highly expensive engineering manipulations, appears to be impractical. On the Northeastern side (Panalaron Bay) the pipes drain into the bay, under the area set for immediately intensive development of Tacloban Harbor. Practically no land is available, and redirecting the flow to some distance (1-2km), to process it via a stabilization pond would require very expensive land gradient manipulations, pumping, as well as piping. On the other side, the drainage drains into Cancabato Bay. The area is marked for immediate development by shoreline reclamation and beautification, offering no possibility of any kind of waste treatment system. The details of sewage treatment using conventional systems are covered above. Figure 3-11 shows a schematic of drainage and interceptor drains with two ocean outfalls. Sketches of the outfalls themselves are shown in Figure 3-12.

Figure 3-11. Proposed Ocean Outfall.

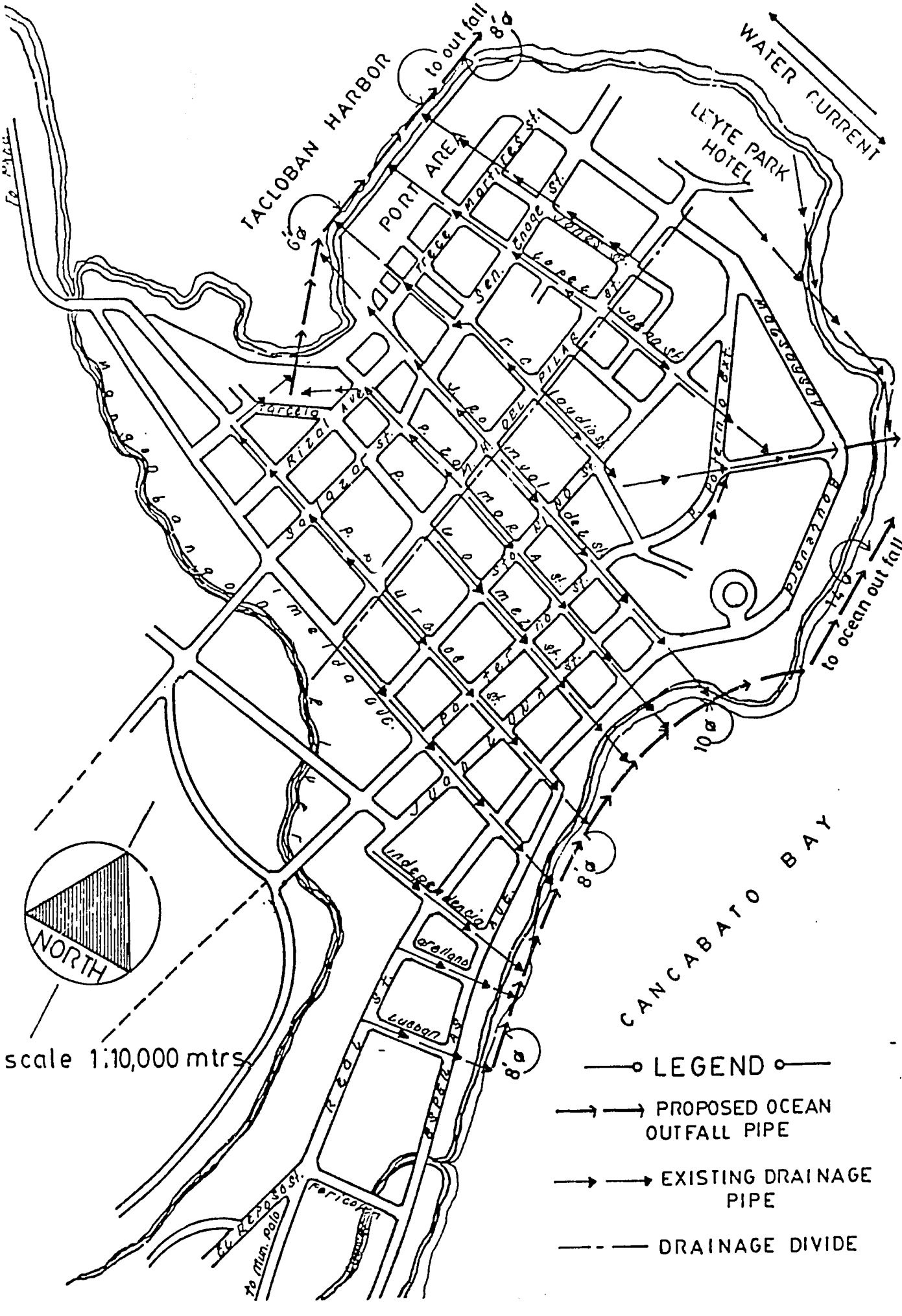
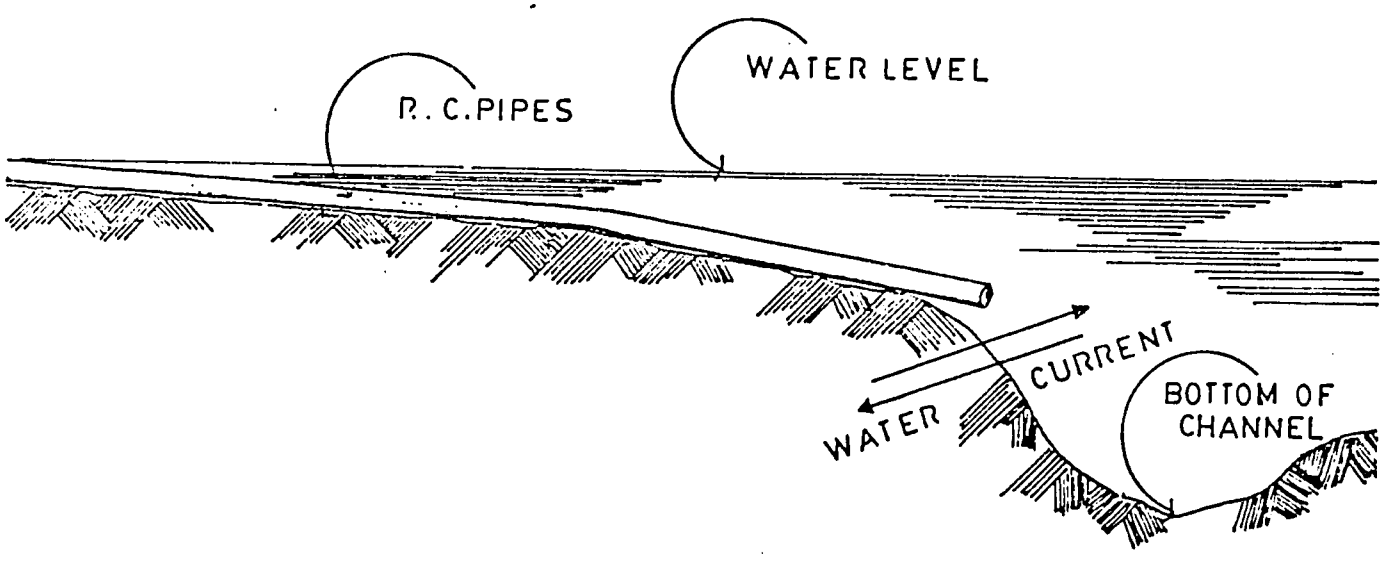


Figure 3-12. Typical Cross Section of Ocean Outfall



Cross section not drawn to scale

Chapter 4

Options for Integrated Wastestream Resource Recovery in Tacloban

4.1 Introduction

It is our hypothesis that by integrating the liquid and solid wastes the potential for resource recovery would be larger than considering the waste streams separately. In the State Of The Art Study* we outlined many different technical options for integrating waste streams and resources recovery from them. Among the methods evaluated, were waste stabilization ponds, biogas plants, combined biogas and stabilization ponds (combies), incineration, compost plants, fish ponds, algae ponds, duck ponds, etc. In our analysis of Tacloban City as a case study, we find that most of the methods discussed in our State Of The Art Report are not appropriate. Recycling of paper, bottles, metals, etc., from solid wastes seems to be well established in Tacloban; but the major problem seems to be, how to recover nutrients from the recovered products from integrated systems, such as compost or algae from ponds. Being a coastal town, there is already an easy availability of fish which makes the fish ponds less attractive. Finally, there is little extensive agriculture close by to absorb the compost, and the sludges produced by some of the processes.

After much discussion with the officials and the people of Tacloban, we have concluded that over the next decade, only the biogas options look at all viable in the Tacloban environment. This chapter, hence, considers biogas as the only truely integraged system of interest and explores two sites where small pilot/demonstration plants could be developed.

4.2 Biogas as an Integrated Resource Recovery Method for Treating Wastes

Biogas is a combustible gas that all organic matter (such as animal manure, human excreta, crop residues, etc.) produces when it ferments and is decomposed by anaerobic bacteria under conditions of uniform humidity, constant temperature and anaerobic conditions. Chemically, biogas is very stable, doe not dissolve in water and is lighter than air. It is a mixture of

* Meta Systems, 1982, op. cit.

gases comprising 60-70 percent methane and the rest is carbon dioxide and small amounts of hydrogen sulfide. Due to the hydrogen sulfide, it smells very slighly of rotten eggs. When the methane and air mixture burns, a blue flame is emitted, and it produces a large amount of heat energy. It is known that one cubic meter (1 m^3) of biogas will generate 5,200-9,500 kcal of heat energy (1 kcal is defined as the heat required to raise the temperature of 1kg. of water by 1^oC). This is considered enough to bring 130 kg of water from 20^oC to boiling or light a gas lamp with a brightness equivalent to 60-100 W for 5-6 hours.

4.3 Biological Processes in Biogas Producion

The various feedstocks such as animal, agriculture wastes and human excreta for biogas production are largely composed of proteins, cellulose, carbohydrates, starches, gum pectin, etc. When subjected to anaerobic digestion, these organic substrates are acted upon by facultative micro-organisms that by, enzymatic hydrolysis, change these polymers into soluble monomers. In the second stage, these soluble monomers are acted upon by non-methanogenic (non-methane forming) acid forming bacteria, converting these monomers into soluble organic acids (principally short chain fatty acids), CO_2, H_2, NH+ and H_2S. These soluble organic acids, primarily acetic acid, are substrate for the final stage of decomposition to form, primarily, methane and CO_2.

$(CH_2\ O_6)$	+	acid forming	$\longrightarrow$ 3 CH_3 COQH +	Methanogenic	$\longrightarrow$ 3 CH4 +	$3CO_2$
carbohydrates		bacteria	organic acid	bacteria		methane

The production of methane takes place through the fermentation of short chain fatty acids, some alcohols, and through respiration involving anaerobic oxidation of H_2 and simple organic acids.

Municipal refuse and solid wastes with high cellulotic and ligno-cellulotic contents specially, if the wastes contain high percentage of wood material (bark, trunks, etc.) may prove resistant to microbial attacks. This can slow the rate of reaction and, hence, lower the quality and quantity of gas produced. Thus, while all organic materials can be anaerobically digested, the required time to do so with many substrates would make the process uneconomical and impractical. It has been noted that sawdust and wood

chips are only slightly affected in a digester operated on a 30 day detention time. The primary reason is the difficulty in breaking down the lignin molecule, making its digestability by micro-organisms extremely difficult. This problem can be tackled by using physical and/or chemical pretreatments to breakdown the complex lignin molecule. These pretreatments result in hydrolysis and partial breakdown of some of the materials and may involve the applications of heat (150°-200°C), pressure (125-220 psi), hydrolysis with strong acids and alkalines, and explosive decompression. Such pretreatment does increase the digestability of substrated, and hence, the amount of biogas produced. The energy balance and economic feasibility of the process have not been fully demonstrated.

For the Tacloban solid waste characteristics, pretreatment for biogas production may not be necessary. The wastes seems to have a very high percentage of non-ligno cellulotic organic matter including vegetable waste, banana peels and trunks, etc. and will not require the kind of pretreatment mentioned earlier. However, once the suitable waste is separated for biogas production, it may be manually chopped before placing it in the digester. Since the particle size of the raw materials affects the amount of gas produced, materials shredded into small pieces will ferment better, and produce greater amounts of gas, by increasing the surface area to bacterial attack. Moreover, it enables the slurry to flow smoothly into the digester with less scum production. The problems due to clogging of inlet and outlet pipes may be minimized by using smaller sizes of the digester materials.

The extent of the total and volatile solids destruction of the biologically degradable fraction of solid wastes matches that accomplished in composting; namely from 20 to 40 percent of the total solids and 30-60 percent of the volatile solids. The total amount of destruction depends upon the degree of segregation of various constituents of the refuse, operating conditions, particularly, the length of detention period, mixing of the digester slurry to prevent accumulation of fines and build-up of scum, expecially troublesome while digesting municipal wastes.

Rate Limiting Factors

Four factors have the potential to become rate limiting. They are as follows:

1. Conversion of insoluble cellulose by extra cellulases into soluble carbohydrates (e.g., glucose);

2. The activity of non-methanogenic bacteria in converting carbohydrates into low molecular weight fatty acids;

3. Conversion of acids by methanogenic bacteria into dissolved methane and carbon dioxide; and

4. Transfer of the dissolved products from the liquid to the gas phase.

The cellulose conversion to simpler monomers can be slow and may require some physical or chemical pretreatment to expedite the process. The acid phase proceeds much more rapidly than the methane phase and is much less susceptible to upset from adverse conditions. The material population active is highly diverse in composition, and is probably common to all anaerobic fermentations in terms of types, if not concentration of individual types. The acid formers are responsible for the initial drop in pH, a characteristic of the anaerobic digester.

The methanogenic bacteria responsible for methane formation are characteristically slow growing and are quite fastidious in their requirements. They posses the following general characteristics.**

1. Strictly anaerobic, not only to molecular oxygen but also to such compounds as nitrates that give oxygen;

2. Generally require a pH range of 6.4-7.2, however, peat bogs where the pH is about 4.0 are know to give some methane;

3. Utilize ammonium salts as nitrogen, if required to balance C:N ratio;

4. Unlike yeast, no known need for nutritional factors;

5. Exhibit extreme substrate specificity, these bacteria are able to utilize only a few very simple compounds;

6. Require the absence of toxic substances (e.g., NH_3) soluble sulfides soluble salts of metals, such as copper. However, only the materials in solution are potential toxin. (See Table 4-1); and

7. Produce methane as a major metabolite.

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* Finne, C.D., and R.S. Efvans II, "Anaerobic Digestion" The Rate Limiting Process and The Nature of Inhibition Science 190, (4219), 1088, 1089, December 1975.

** Barker H.A., Bacterial Fermentations, the Biological Fermentation of Methane, pp. 1-27, John Wesley, NY, 1956.

Table 4-1

Stimulatory and Inhibitory Concentrations of
Alkali and Alkaline Earth Cations

	Concentration in mg/eq		
Cation	Stimulatory	Moderately Inhibitory	Strongly Inhibitory
Sodium	100 - 200	3,500 - 5,500	8,000
Potassium	200 - 400	2,500 - 4,500	12,000
Calcium	100 - 200	2,500 - 4,500	8,000
Magnesium	75 - 150	1,000 - 1,500	3,000

Source: Pfeffer, J.T. 1968. "Increased Loading on Digesters with Recycle of Digested Solids." Journal of Water Pollution Control Federation 37:392 - 406.

Because of methanogenic bacteria's extreme specificity, the methane stage has, generally been regarded as the limiting step in the digestion process, as a whole. However, the continued utilization of the acids produced in the first stage prevents their accumulation to bactericidal level called "Ensilaging".

The fourth rate limiting step is still being investigated experimentally and has not been defined in terms of any meaningful impacts.

The Biogas Digester

General. A biogas digester can be constructed to produce the wastes either, on the site of their origin, or on a site away from it. However, the quantities of wastes the transportation distances and costs must justify an off site location.

The flow of materials must be considered before the system can be designed. Moreover, the materials used in constructing all but the smallest digester should be durable, strong and resistant to corrosion. They should be of such nature that the digester is gas and water tight. The digester unit can be made of any type of blocks capable of being fashioned to contain liquid. Sinking the digester in earth, if otherwise acceptable, may compensate for deficiencies in the structural strength of the digester walls. In fact, where feasible the digester tank should be buried to within top or 2 feet (30-60 cms) to give adequate strength and insulation. In Tacloban where the average monthly temperature is 65°F, insulation aspect may not play any role. Several digester designs are available. However, the required volume of the digester determines, to a large extent, the design of the plant, especially with respect to complexity. Generally, the volume is based on loading rate in terms of dry weight and volatile solids. A rule of thumb estimate of 1 cu. ft. of gas for each 35 pounds of dung (one m^3/53 kg) has been widely used.* However, a somewhat larger volume will be allowed for digesting vegetable wastes because of their relatively low density, and of the large volume of water needed to slurry them. When digesters are constructed above ground, painting them black increases the absorption of solar energy to heat the

* Singh, R.B., "The Biogas Plant Generating Methane from Organic Wastes", Compost Science, 13 (2), 12-16, March/April 1972).

digester. The digester may be classified according to the method of charging it with slurry; into the batch-fed digesters and the continuously fed digesters. Figure 4-1 illustrates the various choices.

Batch fed digesters are suitable where daily supplies of raw materials are difficult to obtain. The digester therefore is charged with fresh slurry to full capacity and sealed for decomposition to occur for the duration of retention time, after which, it is opened and the by-product (sludge) is discharged and the digester refilled. After a start-up interval of about 2 weeks (depending upon the substrate) gas production begins and continues for about three months. It is desirable to have two digesters while using a batch system to keep the gas continuously available.

A batch-fed digester can have one chamber and may be built over ground or underground. It can be charged through a manhole on the top and the sludge is discharged by gravity through an outlet pipe on the side. At the top of the digester, there is a pipe with a cap for replenishing any water evaportation. There is an outlet for the biogas to pass to the gas holder. Each digester is provided with a stirrer to break the scum and with a suitable modification, the same stirrer can be used to stir the digester slurry as well. However, periodic emptying of the digester involves much labor and can be unpleasant. Under the prevailing conditions of biogas feedstock supply, a batchfed digestor is not considered suitable.

Conditions for Biogas Production include the following

1. Presence of right kind of bacteria;
2. Suitable raw materials, well dispersed in water;
3. Absence of air and oxygen to create anaerobic conditions;
4. pH of about seven to eight and temperature range of 25-37°C for mesophilic digestion the ideal being 30-35°C. For thermophilic the ideal is 55-65°C; (see Figure 4-2);
5. Enough retention time to produce biogas optimally;
6. Breaking of scum as the digestion process continues; and
7. Overall appropriate environmental conditions.

Raw Materials

Raw materials must contain organically bound carbon. Suitable raw materials are: (see Table 4-2)

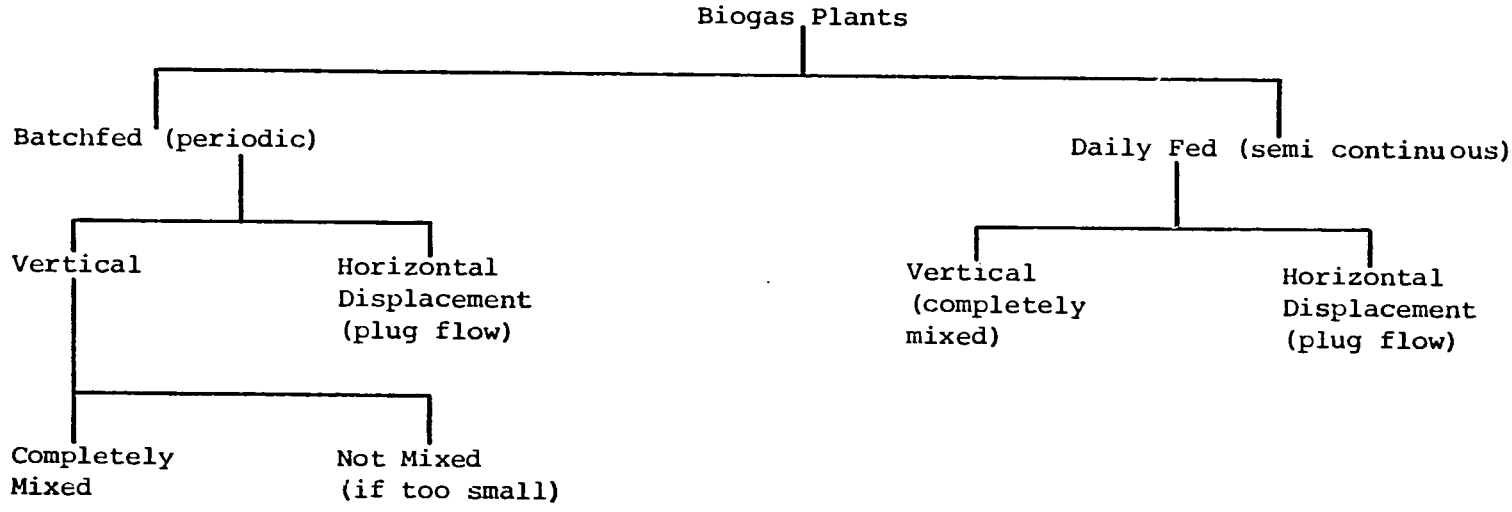
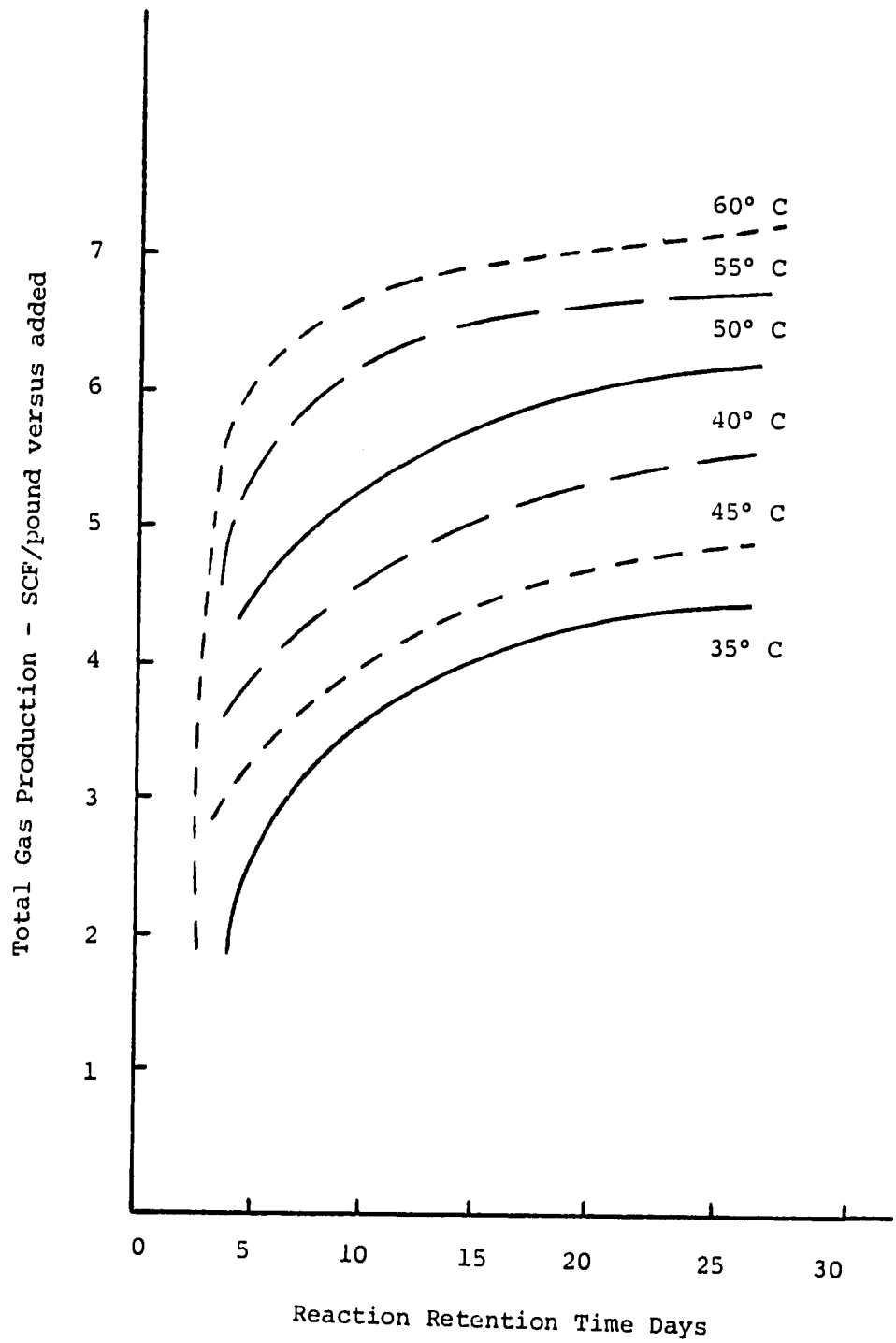


Figure 4-1. Choices for Biogas Digestors

Figure 4-2. Effect of Temperature on Gas Production Anaerobic Digestion



Source: Golueke, C. G. op cit, page 151, 1977.

* Straight line increase between 30-35° C.
** Increase reaches maximum between 35-40° C.

Table 4-2

Composition of Various Feedstocks*

	Total Solids %	Volatile Solids % of Total	C %	N %	C:N Ratio
a) Animal Dung:					
1. Hog	25	80.7	38.3	2.8	13.7
2. Carabao	15	80.5	37.0	1.6	23.1
3. Cow	16	77	35.8	1.8	19.9
4. Chicken	48	77.4	35.7	3.7	9.65
5. Duck	53	23.6	21.9	0.8	27.4
6. Pugo	30	81.8	33.7	5.0	6.74
b) Household Waste:					
1. Night Soil	15	90.0	47.7	7.1	6.72
2. Kitchen Waste					
c) Crop Residues (air dry):					
1. Corn Stalk	86	92	43.9	1.2	56.6
2. Rice Straw	89	79	35.7	0.7	51.0
3. Corn Cobs	82	96	49.9	1.0	49.9
4. Peanut Hulls	90	95.5	52.7	1.7	31.0
5. Cogon (grass)	-	92.8	-	1.07	-
6. Bagasse	-	95.5	-	0.40	-
d) Others:					
1. Kangkong	4	84	33.5	4.3	7.8
2. Water Lily	5	77	33.0	2.9	11.4
3. Grass Trimmings	15	87	39.2	2.5	15.7

*Source: Personal Communication, Mr. Calixto Taganas, Maya Farms Division, Liberty Flour Mills Inc., Metro Manila, Philippines.

a) animal wastes such as dung and urine;

b) vegetable matter crop residues, garbage; and

c) night soil (human excreta).

Biogas Potential in Tacloban

Currently in Tacloban area several types of suitable biogas feedstocks for energy recovery are available. Among the major feedstocks are organic and vegetable wastes, night soil, and piggery waste. Hog manure is usually widely available in Tacloban and is a singularly good materials for biogas production (see Tables 4-3 and 4-4), due to its suitable total solids, volatile solids and C and N contents. Currently, all these feedstocks are being disposed in a most unscientific and unhygienic manner. A streamlined system of collection and delivery can provide a large resource base not only for production of biogas and its various end use applications, but also excellent quality cattle feed and fertilizer. Currently, there are some small commercial piggery farms with an average of 200-300 pigs. However, most of these farms have their own problems of resources mobilizaton and allocation to the specific task of procurement, piggery development, sales, etc. These farms are a significant contributor of pollution, and a total systems approach to handle the waste for better environmental and economic returns is conspicuously needed. An integrated system combining feed, agriculture, fertilizer and energy should be considered as a symbiotic relationship. Biogas can recycle the wastes in order to control pollution and at the same time minimize dependence on external sources for farming requirements of fertilizer, feed and fuel while improving the earning power and raising the standards of living of the farm family.

Utilization of Pig Manure for Biogas

The manure production from a piggery depends upon several factors. Essentially, the manure from a piggery is semi-solid in nature and is a mixture of feces and urine. In smaller animals, feces and urine are 50:50 ratio. With larger animals, the contributions (kg/day) of urine may be more than feces. Basically, the amount of manure generated and its character will be governed by the following:

Table 4-3

Characteristics of Hog Manure*

Amount of Manure in Relation to Hog Weight**			
Hog Weight (kg)	Manure (kg/day)	Faeces (kg/day)	Urine (kg/day)
18-36	2.55	1.23	1.32
36-55	5.22	2.45	2.77
55-73	6.67	2.95	3.68
73-91	8.00	3.86	4.14

Composition	
moisture	75.0% fresh weight
ash	19.3% dry weight
protein	17.5% dry weight
fat	3.3% dry weight
fiber	16.1% dry weight
NFE	43.8% dry weight

Biogas Production Characteristics for Hog Manure			
	Fresh Basis	Dry Basis	Volatile Solid Basis
Total Solid %	25	100	-
Volatile Solid %	20	80.7	100
Organic C%	0.7	38.3	47.5
% N	0.7	2.8	3.47
C:N Ratio	13.7	13.7	13.7
Gas, Liters/kg of material theoretical	200	798	988

* Source: Maya Res. Lab. 1975.

** The quantity of hog manure produced varies according to the feed, ration, and other factors while the composition is dependent upon the type of breed, grazing conditions, feed consumed, and state of health of the animal.

Table 4-4

Composition of Pig Manure*

Source	Organic Matter %	Composition Percentages				
		N	P_2O_5	P	K_2O	K
Pig Manure (fresh)	15.0	0.60	0.40	0.18	0.44	0.37
Pig Urine	2.0	0.30	0.12	0.05	1.00	0.83
Pig Manure (air dried)	34.32	2.12	0.98	0.43	2.45	2.03
Pig Manure (litter)	34.00	0.48	0.24	0.11	0.63	0.52

*Source: FAO Soils Bulletin 1977 FAO, Rome (Reported by Yueh Chi People's Commune, Tiangsu Province.

1. Age and species, up to a certain limit, older animals produce more manure;
2. Composition of feed materials;
3. Water intake and water use in the pig pens;
4. Digestability of animal feed;
5. Levels of productivity amongst animals (number of animals per pen);
6. Environmental factors (temperature, humidity, etc.);
7. Weight; and
8. Management including types of feed lots.

In a scientifically managed piggery, manure production may be 5-7 percent of the body weight of the pig per pay. In the Philippines, and in Tacloban, manure production is about 2 kg/day for a pig of average size.

Piggery wastes when discharged in untreated condition exerts high BOD (.115 kg/day), nitrogen contribution of 0.022 kg/day and 0.008 kg/day of phosphorus per pig to the environment. The carbon content which directly impacts on the quantity of biogas produced is about 38 percent (dry basis) and 25 percent of dry matter. The values were given in Table 4-5 obtained at Maya Farms near Manila. Conversion efficiency may also be taken as the percentage change in volatile solids (non-ash solids)

At present, in Philippines, much less in Tacloban, very little experience of biogas plants or integrated resource recovery systems exists. One very large successful integrated operation is located at Maya Farms in Antipolo Hills of Rizal province, and is based on 15,000 pigs. The Tacloban waste streams, however, do have the requisite characteristics considered suitable for the successful operation of an integrated energy and resource recovery sytem. These are:

- o A relatively high concentration of biodegradable organic matter;
- o Appreciable concentration of nitrogen, phosphorus and other macro and micro nutrients; and
- o High solids content ranging from 1-35 percent.

Table 4-5

Conversion Percentage of Hog Manure to Biogas*

Time (Days)	Biogas Litres	Carbon Conversion %
0	0	0
20	64.9	36.5
30	94.8	53.3
35	100.5	56.5
39	102.5	57.6
Infinite	178.1	100

* Personal communication, Maya Farms, August 1982.

In view of the favorable situation, it was considered appropriate to evaluate possible sites for establishment of biogas as well as other suitable integrated resource recovery sytems in Tacloban. Apart from discussions with city officials and a general tour of the area, a survey to determine the kind and quality of animals, the end-use of gas, the soils and terrain conditions, operational and maintenance costs of various sized units of liquid and solid waste treatment within several sub-areas was conducted. Several sites for biogas generation were considered suitable, though due to the personnel and lack of funds, only the following two sites were evaluated for detailed analysis for biogas production in Tacloban.

4.3 Option No. 1: Biogas Plant at Tacloban Slaughter House

Tacloban slaughter house is located near the outskirts of the city at about a distance of 5-6 km from the city centroid. The average daily slaughter rate is 120-130 pigs and 25-30 cattle, mostly carabaos, and the slaughter house operates from 12PM to 4AM. Apart from the edible meat, the operation generates significant quantities of blood washings, fat, guts, bones, horns (in the case of caraboes) intentines, paunch contents, hooves, useless meat, glands, organs, hides and skin. The patterns of the residue utilization is not well defined in Tacloban. At present, the whole operation is carried out in a crude, unscientific and highly unhygienic manner.

Effluents from the operation are allowed to flow by gravity into a small pond (15-20 feet wide) situated between the building and the coast line. During the high tide some of the pond content gets washed into the bay or gets deposited near the coast line. The existing situation is a serious environmental and public health hazard, not to mention the ever present foul smell.

The City in the very near future, is planning to build a public latrine near the slaughter house for use by nearby about 150 shanty dwellers. This could provide additional feedstock for the biogas and stablization pond integrated energy and resource recovery system being proposed. Such a system could achieve the following:

- Resource recovery from the city's solid and liquid waste;
- Replace the current use of expensive oil and wood for slaughter house operations, such as for providing heat to scalding vats;

- o Minimize the environmental and public health damage;
- o Biogas by-products can provide nutritious feed supplement for nearby fish cannery and/or fertilizer;
- o Test the concept of an integrated biogas/piggery waste/slaughter house waste/night soil and energy and resource recovery system; and
- o Yield useful data for city's long-range planning for solid and liquid wastes. The city can later consider utilization of septic tank wastes in areas where, via blind drains, it is now being openly dumped into the sea.

Quantity of Available Feedstocks for Biogas at Slaughter Houses

The quantity of wastes considered suitable as biogas feedstocks and potentially available daily for the proposed facility is as follows:

i. Animal manure from approximately 100-120 pigs and 10-20 carabos slaughtered daily is about 200 kg/day. It was observed at the slaughter house operation that on the average each pig contains 1-2 kg (wet) of excreta in their stomach and intestines, while a slaughtered cattle, on the average, yields 2-3 kg stored in their pouch.

ii. Approximately 40 kg/day excreta from the holding pen where animals brought in the afternoon for slaughtering, are held for a few hours.

iii. Discarded hair and entrails (intestines are only 20 percent available because the rest are edible and are cooked in pig's blood and eaten) from the slaughter operation. Approximate quantity available is 20 kg/day.

iv. Night soil. It is anticipated that approximately 150 people from nearby shanty dwellers will use the proposed public latrines. This could generate feces and night soil to approximately 250 kg/day and which will be, at present, treated in the stabilization pond because of cultural problems with the collection and utilization of human wastes in biogas. At some point in the future, however, this may change.

Biogas Plant

It is proposed that the biogas plant be built near the large vacant city-owned lot next to (about 20 meters) to the slaughter house. The various wastes would be collected in containers, placed at appropriate locations and would be transferred to a equilibriating/mixing chamber located ahead of the digester to maintain control of the composition of the feedstock. Large sized entrails may require manual chopping to one to one-half inch size pieces, and

should be done before transferring them to the chamber. It may become necessary to store the waste for longer than 1-2 days, and to prevent loss of quality and hence quantity and quality of biogas produced, particularly due to environmental factors such as rain, it is suggested that an appropriate cover be built over the chamber. Quantities up to 2 days loading can be stored in this manner. By the third day methane producing capacity starts to deteriorate. Storage sheds can be constructed of local materials such as bamboo, tree limbs, palm thatch or brick tiles and mortar depending upon the available material or budget limitations.

The amount of gas that can be produced from the projected quantity of 240-280 kg/day of wastes available depends upon several factors. Among these are, the composition of the raw material mixture or the use of raw material itself, as the case may be, the temperature as well as other environmental parameters discussed earlier. The following data shown in Table 4-6 is available from experiments in India and the Philippines. Table 4-7 reports the approximate C:N ratio for various animal wastes.

It is recommended that a biogas plant with a floating gas holder and a masonry digester be built. (See Figure 4-3) The floating dome gas holder has a more constant biogas pressure than fixed dome gas holder. Because the floating gas holder dome is made of steel which is a good conductor of heat, it cools the digester slurry during the night in an integrated type of biogas plant. In Tacloban, where the winter temperature is sometimes below 20°C it may cause a low biogas production. It is projected, from the quantity of feedstock avaiable, that under optimum conditions, as much as 585 cu.ft/day; (16.6 cum/day) of gas in Tacloban can be produced (derived from Table 4-6 using average of cattle and pig values).

Since the gas will be used on a regular basis and will be withdrawn at a relatively constant pressure, the gas holder need have only one-half the volume of the gas production. The storage capacity of the gas holder can be kept at 200 cft/day (5.7 cum/day), on the basis that the gas collected during the day will be used for the slaughter house operations at night. Morover, the weight of the gas holder not compensated by counter weights will compress the gas somewhat so that the actual volume of gas above the surface of the slurry will be less than the design volume. The gas holder when made up of mild steel angles and sheets is designed to give a pressure of about 9.38 cm. of water

Table 4-6

Gas Production for Cattle, Pigs and Poultry Wastes*

Source (animal)	Availability/ day	Gas/kg cuft.	Gas per Animal per/day
Cattle	10 kg	1.3	13
Night soil	400 grams	2.5	1
Pig (45 kg wt)**	2.25 kg	2.8	6.3
(36-55)	5.22	3.2	--
(55-73)	6.67	--	--
(73-91	8.01	--	--
Poultry (2 kg wt)	0.18	2.2	0.4
Spent Deep Litter (from poultry) dry	--	5.3	--

* Source: Directorate of Gobar Gas; Khadi Village Industries Commission, New Delhi, personal visit, October 1982.

** Data from Maya' Farms, Metro Manila, Personal Visit, September 1982.

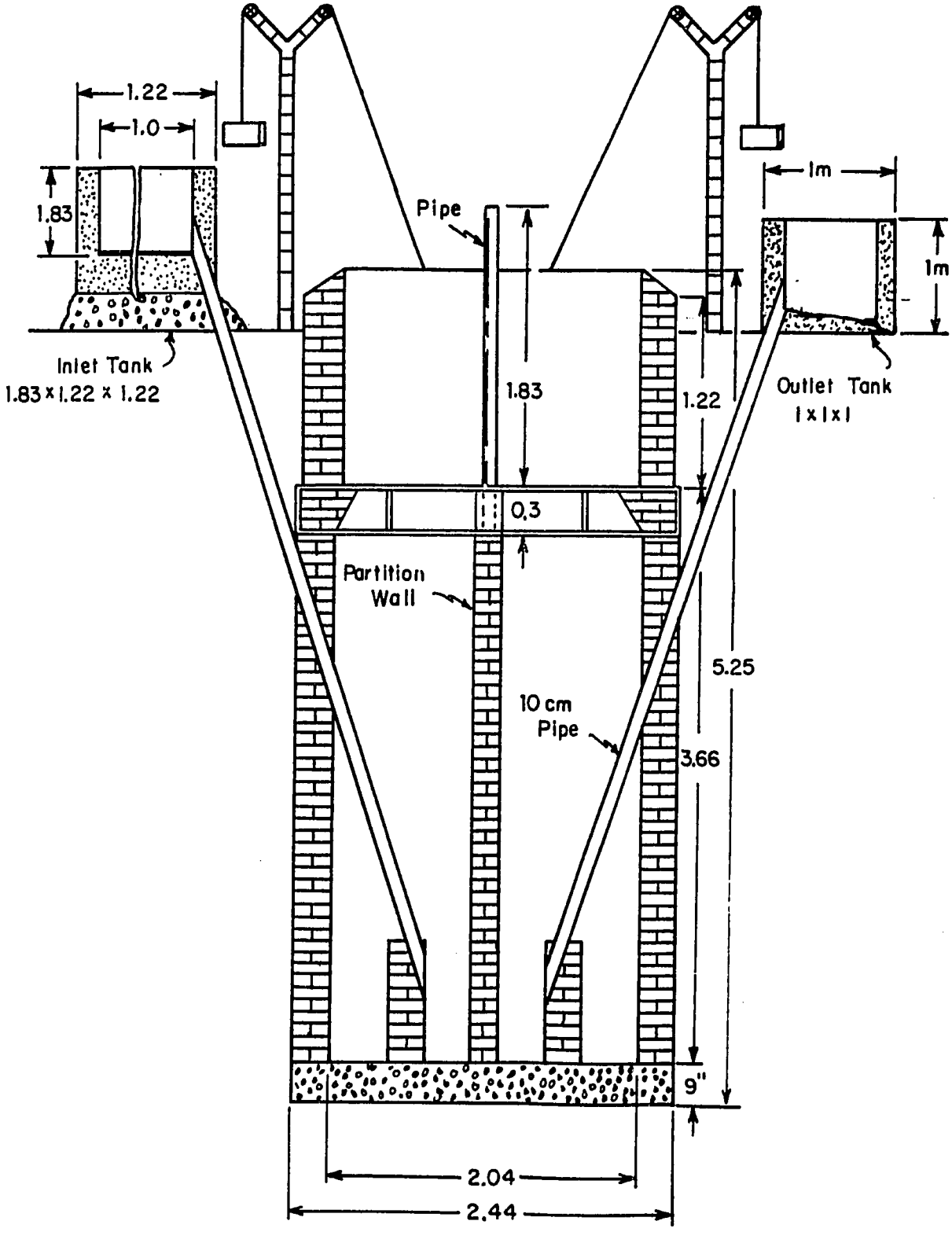
Table 4-7

Approximate Nitrogen Content and C:N Ratios by Weight of Various Raw Materials (Dry Weight Basis)*

Material	N	C/N
A. Animal wastes:		
Urine	15-18	0.8
Blood	10-14	3
Mixed Slaughter House Waste	7-10	2
Poultry Manure	6.3	--
Sheep Manure	3.8	--
Pig Manure	3.8	00
Cow Manure	1.7	18
Horse Manure	2.3	25
B. Night Soil	5.5-6.5	6-10
C. Houshold waste		
Garbage	2.2	25

*NAS, (1977) Methane Generation from Human, Animal and Agricultural Wastes. National Academy of Sciences, Washington, DC, Page 67.

Figure 4-3. Proposed Biogas Plant at Slaughterhouse



volume (18 pounds/sq ft or 90 kg/sqm) over the circular area of the holder. Although steel gas holders are expensive, substitute materials such as, ferro-cement, have not yet been proven their long term usefulness and, hence, can not be recommended. The problem of rusting and corrosion of steel, can be minimized by painting of the gas holder and appropriate maintenance measures.

The digester is intended to be a continuous fed, where the digester is built in the form of a masonry well. Since it must receive 246 kg (541 lbs) of animal wastes daily, and to retain its charge for fifty days, and assuming that 10 lbs of dung when slurried occupies two-sevenths ft^3* the digester volume would equal:

$$\left(\frac{2}{7}\right) \text{ ft}^3 \times \left(\frac{541 \text{ lbs}}{10 \text{ lbs}}\right) \times 50 \text{ days}$$

$$= 772 \text{ cu ft}$$

$$= 21.8 \text{ m}^3$$

In a digester of this volume, and up to $25m^3$/day, the depth can vary from 3.5 to 6 meters, depending upon the quantity available for feeding in the digester. This depth can maintain proper digester temperature regardless of the atmospheric temperature. For larger quantities of gas, the depth can be increased.

The digester can have a partition wall in the middle dividing in into two semi-circular compartments. The partition wall is generally required for digesters having more than 1.60 meters diameter. The two chambers thus formed serve as primary and secondary digestion chambers and also prevent channeling of the slurry through the digester. Two slanting cement pipes reach the bottom of the well, on either side of the partition wall, and have their openings on the surface of the ground by the side of the top of the well (See Figure 4-3). One pipe serves as inlet and the other as outlet. The wastes

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* National Academy of Sciences, 1977, "Methane Generation from Human, Animal and Agricultural Wastes", National Acedemy of Scienc, Washington, DC, page 80.

are mixed with water in the proportion of 4:5 and is led down in the inlet pipe. As the well (digester) gets filled up, an equal quantity of slurry, flows out through the outlet which is lower than the inlet. The partition wall stops short of the top of the well and, thus, it remains submerged in the slurry. The well is designed so as to hold 50 days material and, initially, it is filled up so that whenever any material is put in from one side an equal quantity goes out from the other. When starting the digester first time, seed starter containing methane producing bacteria, 20-30 days old has to be added.

A ledge is built into the digester at a depth equal to that of the gas holder. It arrests the gas holder from going down when no gas is left in it, thus, preventing the slurry from entering the gas pipe. Its most important use is to guide all gas bubbles from digester into the gas holder.

The digester is constructed with brick masonry with foundations of cement concrete at the bottom. The digester is plastered inside by cement mortar. Stone, or another local construction material, can be used in place of bricks. A stirrer can be provided to break the scum, daily, if possible, otherwise the continuous charging itself can break the scum.

The gas produced will be primarily used for slaughter house operations including lighting and water heating. It consists of 55-65 percent of methane which has a heat value of 500-700 Btu/ft^3 (22,000-36,000 kJ/m^3). Comparable values on composition and heating values are given in Tables 4-8 and 4-9. Special designs of biogas burners to take into account the low pressure, and low flame propagation speed of methane, particularly, for smaller plants are available in the Philippines. Excess gas can be converted into electricity or can be fed through an internal combustion engine for various end uses. However, for such a use corrosion problems require the removal of hydrogen sulfide. A simple and effective technique involves passing the gas through a mixture of wood shavings mixed with iron oxide. A volume of 0.1 m^3 of iron sponge will clean approximately 3,300 m^3 of biogas. The iron sponge is commercially available in Tacloban, and can be regenerated by exposure to air. The H_2S scrubber used with a 25 HP engine running about 12 hours a day is changed every six months.

If it is desired to reduce the CO_2 content (up to 45 percent) the gas may be bubbled through a CO_2 scrubber. A mixture of water and ash, or lime,

Table 4-8*

Composition of Biogas and Common Fuel Gases

	Biogas	Natural Gas	Coal Gas	Water Gas	Producer Gas
Methane, %	54-70	96.1-98.1	31.6	0.7	1.5
Carbon Dioxide	27-43	0.8	1.8	3.5	3.5
Carbon Monoxide	0.1	--	6.3	43.5	30.0
Hydrogen, %	1-10	--	53.0	47.3	10.0
Nitrogen, %	1-5	1.1-3.2	3.4	4.4	54.5
Oxygen, %	0.5-1	--	0.2	0.6	0.5
Others, %	trace	--	3.7	--	--

* Biogas Gas Research Station, Ajitmal, Etawah, India, personal visit, October 1982.

Table 4-9*

Heating Value in Btu per cu ft. of Biogas and the Common Fuels

Biogas	546
Natural Gas	967
Coal Gas Town Gas	586
Water Gas Blue Gas	302
Producer Gas	135

* Director Khadi and Village Industries Commission, New Delhi, Personal Visit, October 1982.

can be used in the scrubber to absorb the carbon dioxide. As regular intervals, the mixture should be changed to maintain a high absorbing capacity.

Cost of Various Materials for the Proposed Biogas Plant

The various cost components for the proposed plant are given in Table 4-10. Detailed designs and building techniques including operator training available in the Philippines for example, at Maya Farms, Metro Manila, Philippines.

It must be mentioned that the various costs involved in the proposed plant are only approximate costs and estimates derived after discussion with a few local merchants and the city engineers office. Before any budget and construction activity is planned, the city will do well to check with appropriate personnel in the Natonal Environmental Protection Council or the Maya Farms group for cost, and technical including training details for the biogas technology. Although a simple technology, actual installation, successful operation and maintenance can offer challenges, resulting in failure without proper training.

Integration of Biogas and Stabilization Pond at the Slaughter House

Since the city is planning to build a public latrine near the slaughter house for use by the surrounding shanty dwellers, it is suggested that a small stabilization pond be located near the site of the biogas. This pond will receive raw sewage from the public latrine, blood washings and effluents from the slaughter house as well as the liquid sludge from biogas operation which is quite high in BOD and treatment is required before discharging these into water ways. Therefore a stabilization bond is desirable (see Table 4-11 for details of its composition). Other potential options of liquid sludge disposal such as natural seepage in fish ponds, natural dilution by rain and spill-over to streams, natural evaporation in irrigated crop fields, and as composting liquid, either lack the market for the end product, as in case of compost, or can not be processed economically. Basically, the stabilization pond can be designed and costs calculated using the principals discussed earlier in Chapter 3.

Table 4-10

Costs of Biogas Unit at Slaughter Ho.s

Item	Cost in Pesos
1. Total Cost of 1.83 X 1.22 X 1.22 Equilibriation/ Mixing Chamber (Concrete or Brick)	1400
2. For Gas Holder	
a. Five Mild Steel Sheets (300 cms X 150 cm.)	2500
b. 3 Meters of Iron Rod 2.8 cm	300
c. Two Sockets, 1, Nipple, Angle Iron Rods (30 metres)	400
3. For Supporting Pillars	
a. Four Black Iron Pipes 3.8 cms diameters, 3 m long each	800
b. 20 Angle Iron (5 cm X 30cm X 8mm) or Iron flats (5cm X 30cm X 8mm)	200
c. 8 Iron pulleys, 15 cm diameter	1200
d. Six mild steel sheet (10 cm X 10cm)	150
e. 20 nuts and bolts (8 cm X 12mm)	250
4. a. Sixteen Slotted counter weights of approximately 12 kg each	600
b. Four Cast Iron weight hangers for above	200
5. 12 meters wire rope	300
6. Two cement, conduit pipes, 2.44 m long 10 cm diameter	200
7. Three metres rubber and polyethylene hose	100
8. GI pipes, 2 pieces to connect with main gas line length depending upon end gas use	100
9. G I elbows, bonds	
2 tees for	305
3.0 cm pipe	200
10. Wheelcocks, water tap, etc.	100
11. Anti-corrosive paint (8 litres) Top quality	300
12. Bricks, 5,000	1500
13. 350 hollow blocks	600
14. 40 bags of sand	300
15. 8 bags (400 kg.) of Sahara cement	400
16. Labor skilled and semi-skilled including digging of well for digester	800
Total Estimated Cost	P12,900

150

Table 4-11

Mineral Composition of the Solid and Liquid Portions of a Sample of Sludge*

	Solid Sludge	Liquid Sludge
N, Total Percent	2.07	0.08
P_2O_5	7.31	0.15
P_2O_5 available Percent	4.97	0.15
K_2O Total Percent	0.75	0.03
Ca Percent	4.90	trace
Mg Percent	0.64	--
Fe ppm	0.77	0.66
Cu ppm	0.01	0.18
Zn ppm	145.00	0.28
Mn ppm	0.96	0.47
Organic matter Percent	49.60	0.47

* Maya Farms, Metro Manila, Philippines, personal communications, September 1982.

Use of Biogas at the Slaughter House

The slaughter house presently has five electric bulbs from 75-100 watts each. It also has six concrete stoves for heating water for scalding operations. According to the slaughter house manager, they are currently spending approximately 4 pesos for wood for every ten pigs and 2 pesos for every 15 cattle for heating water. Since, on the average 100 pigs and 10-20 cattle are slaughtered, the expense of wood for heating water averages approximately 42 pesos/day. At the present rate of 3 pesos/4kg for good quality wood, this amounts to 56 kg of wood. Since 1 kg of dry fire wood can be replaced by 0.280 m^3 of biogas* for 56 kg of wood this amounts to 15.60 m^3 approximately of gas per day for scalding operations, only. It has been observed that a 75 watt bulb burning for six hours consumes the equivalent of 3 cu ft. of gas, thus, for the five slaughter house bulbs, it amounts to 15 cu ft/6hrs (0.42 cum/6hrs). This makes it a total of approximately 16 cum/day for slaughter house operations which closely matches our predicted daily production of 16.6 cum/day.

Economics of Gas Production

The preceeding considerations should be reflected in any benefit/cost analysis of biogas generation. This method of value assignment to biogas, on the basis of value substituted, appears to be the only logical method to use. Due to the difficulty of containerization of biogas, the economic benefit derived from its use, is limited to those uses for which it can easily substitute for example, wood in the above case. The higher the cost of such energy sources, the greater are the economic benefits of biogas. Table 4-12 is an indication of various comparative equivalents of biogas with other fuels.

Moreover, it must be recognized that using criteria appropriate solely to the investment decision process focuses to narrowly on a particular system and ignores the positive potential external benefits which may not be readily quantifiable. Such externalities include improved public health, agricultural productivity increases, release of other fuels for other uses, diminished pressures on forest reserves, and increased employment. Such additional benefits can be important for society, as a whole, and should also be factored into the evaluation.

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*KVIC 1979, Gobar Gas, Why and How, Directorate of Khadi and Village Industries Commission, Bombay 400056, (Also see Table 4-12).

Table 4-12. Replacement Values of Different Fuels

Fuel	Unit	Biogas 1m^3	Kerosene 1 litre	Firewood 1 kg	Cow Dung Cakes 1kg	Charcoal 1 kg	Soft Cake 1 kg	Butane 1 kg	Furnace Oil 1 ltr	Coal Gas 1^{3}m	Electricity 1 KwH
Biogas	M^3	1.0	1.613	0.288	0.081	0.686	0.623	2.309	2.398	0.849	0.213
Kerosene	Litre	0.620	1.0	0.178	0.050	0.425	0.386	1.431	1.487	0.527	0.132
Firewood	Kg	3.474	5.603	1.00	0.283	2.383	2.165	8.210	8.33	2.95	0.740
Cow Dung Cakes	Kg	12.296	19.83	3.539	1.0	8.435	7.640	28.387	29.483	10.443	2.617
Charcoal	Kg	1.458	2.351	0.420	0.119	1.0	0.908	3.365	3.495	1.238	0.310
Soft Cake	Kg	1.605	2.589	0.462	0.130	1.101	1.0	3.705	3.848	1.363	0.342
Butane	Kg	0.433	0.699	0.125	0.035	0.297	0.270	1.0	1.039	0.368	0.092
Furnace Oil	Litre	0.417	0.673	0.120	0.034	0.286	0.280	0.963	1.0	0.354	0.089
Coal Gas	M^3	1.177	1.899	0.339	0.096	0.808	0.734	2.788	2.823	1.0	0.251
Electricity	KwH	4.698	7.576	1.352	0.382	3.223	2.927	10.846	11.264	3.99	1.0

Source: (1979) "Gobar Gas--Why and How" Directorate of Gobar Gas Scheme, Khadi and Village Industries Commission, Gramodaya, Irla Road, Villa Parle West, Bombay.

In summary, the following can at this time be stated regarding the economics of Biogas plants:

1. There is a dearth of substantive data on which to evaluate the economic viability of biogas in developing countries.

2. In addition to lack of data, existing economic evaluations suffer from the lack of an agreement on the methodology. Common problems include: lack of data on the effects of technical parameters on plant performance; valuation of inputs; valuation of Biogas substitutable fuels and end uses; valuation of slurry as fertilizer and soil conditioner; marginal utility of output and other secondary benefits.

3. The financial viability depends very strongly whether its output in the form of gas and slurry can substitute for fuels, fertilizers or feeds that were previously purchased with money. If this is so, then the resulting cash savings can pay for capital and maintenance costs.

4.4 Option No. 2: Biogas Digester for Integration of Night Soil and Organic Wastes at the Super Market

Another possible site for setting up a biogas digester is at the Tacloban Supermarket between Quezon Boulevard and Tarcella Street. At this site there is an existing public latrine that had been temporarily closed due to poor upkeep. From past experience, the number of people likely to use it is about 500/day (24 hrs). This includes a large number of travellers in the area, due to Tacloban Port expansion and attendant activity. The site is also close to potentially large available quantities of vegetable wastes from the super market. The various costs for reactiviting the existing public latrine are given in Table 4-13.

There is enough land adjoining the market to install the biogas plant, as well as, a potential market for the biogas, such as lighting for many of the the nearby shops. The biogas effluents can also, either be processed via a small stabilization pond, or else be disposed into the nearby bay. Moreover, setting up of a public latrine (watersealed toilets) will also minimize the indiscriminate and dangerous open excreta disposal into the bay while providing a useful community service. The existing latrine can be reactiviated and appropriate design changes made so that the excreta is delivered directly into the adjoining biogas digester. This will minimize, if

Table 4-13

Latrine and Biogas Digester at the Supermarket

	Cost in Pesos
Restoring Existing Public Latines	
1. Replacement costs of 6 seats with 10 seats, material	5,000
2. Labor P.200/seat	2,000
3. Tiles for floor and wall glazed 11.4 cm X 11.4 cm (for wall), unglazed for floor 7.6 cm X 7.6 cm, labor	3,000
4. Pipes (changing old where needed and installing new)	3,000
5. Showers	
piping, lavatories	1,500
2 shower rooms labor and material	2,500
Operating and Maintenance Costs	17,000
6. Caretaker	
2 laborers/yr	14,000
1 technician	10,000
7. The cost of toilet paper will be covered by a 25 centavos/person charge	
Total operation and maintenance costs for restoring the existing public latrine:	
Labor	24,000/yr
O&M	17,000
Total	P 41,000
Biogas Plant Contruction	
1. As given in Table 4-10 for a 16 m^3/day plant	P 12,900

not totally eliminate direct contact with the night soil, the major cause of socio-cultural bias in using it as feedstock.

Vegetable matter manually chopped along with the night soil and urine would also be fed into the digester. In Tacloban, suitable waste streams available for integration with biogas digesters are:

- Banana waste--is about 25-30 percent of the vegetable waste in the city garbage. It includes banana peelings, banana trunks and parts, (leaves, etc.) from the banana plants found in most back-yard gardens in the city. For the city the total banana waste that is potentially available and considered suitable, (after chopping, etc.) as biogas feedstock; amounts to over 10 cum/day. This is equivalent to approximately 3.85 tons/day. In addition, during severe windy periods, which in the past has averaged 5-8 times a year, the daily quantity of banana waste in the city increases by 3-4 tons.

- Vegetable wastes--primarily generated at the public market and consists of putrescible organic matter. It amounts to 3-4 cum/day, or approximately 1.4 tons/day for the entire city.

- Garden waste--being mixed with refuse, and household waste, this waste cannot be easily separated. It amounts to an average of 20 cum/day or approximately 7.2 tons/day for the entire city. This quantity includes the banana tree trunks, etc., mentioned earlier, which due to their size can be easily separated.

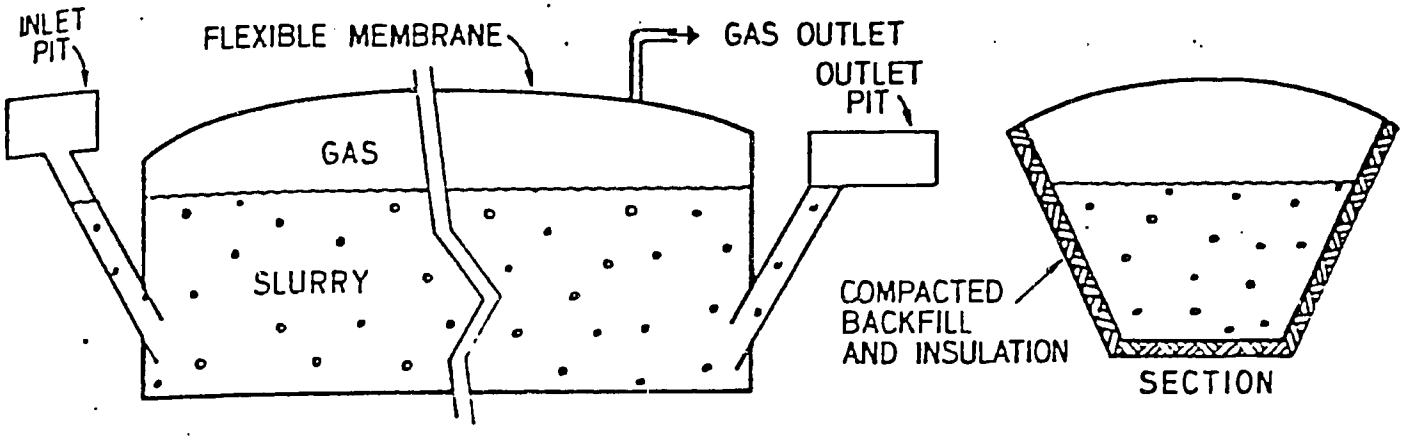
- Other wastes--includes papaya, (leaves mostly), coconut leaves, midribs (the central vein of large, thick leaves), etc. and restaurant waste which is generally sold as pig feed. The total quantity of these wastes potentially available is considered insignificant.

4.5 Plug Flow Digester

A different type of biogas digester which was not considered in the Tacloban case, but which might be an attractive design under Philippine conditions is the Plug Flow Digester. The Plug Flow Digester was probably first used in Africa in 1957. More recently Jewell and co-workers at Cornell University have carried out considerable amounts of development work.

A typical plug flow reactor consists of a trench cut into the ground and lined with either concrete or an impermeable membrane (Figure 4-4). The length must be considerably greater than the width and depth to ensure plug flow conditions. The reactor is covered with either a flexible cover

Figure 4-4. Schematic of a Plug Flow Digester.



anchored to the ground which acts as a gas holder, or with a concrete or galvanized iron top. The inlet and outlet to the reactor are at opposite ends and feeding is carried out semi-continously, with the feed displacing an equal amount of effluent at the other end. Table 4-14 gives the comparison of a completely mixed digester with a plug flow digester in one of the studies. The higher gas production flow rates of plug flow are predictable from its kinetics, resulting from higher temperature and higher loading rates.

Table 4-14.

Comparison of Completely Mixed Digester with Plug Flow Digester*

	Completely Mixed		Plug Flow	
HRT (d)	15	30	15	30
Gas production rate ($m^3m^{-3}d^{-1}$)	2.13	1.13	2.32	1.26
Specific gas production ((m^3kg VS added $^{-1}$)	0.281	0.310	0.337	0.364
Gas composition (% CH_4)	55	58	55	57
Volatile solids reduction (%)	27.8	31.7	34.1	40.6

* Stuckey, David (1983). The Integrated Use of Anaerobic Digestion in Developing Countries. "A State of Art Review" Int. Reference Centre for Waste Disposal, Dubendorf, Switzerland. Page 93.

Overall, the plug flow digester is still in the experimental stage and has very limited use, even with its low costs ($50-80m^3) in developing countries. In view of this situation, this stype of digester, at this time, can not be recommended for Tacloban.

4.6 Integration of Biogas with Other Systems

The concept of integrating biogas plant into a symbiotic unit with stabilization ponds (e.g., for algae production) aquaculture, agriculture and small scale industries in Tacloban was evaluated. such a system, besides being a low cost appropriate technology has multitudes of benefits (Table 4-14) including:

i) eradication of potential health hazards;

ii) maximization of food production;

iii) minimize manufactured energy inputs; and

iv) optimize environmental equilibrium

Among the various options, stabilization with the primary aim of treating the slaughter house and biogas effluents was considered best under the existing needs. Aquaculture was ruled out for lack of market and/or the cheap and easy availability of edible fish both from the Tacloban commercial market as well as the nearby bays. For agriculture and small scale industries integration with biogas while considered desirable was considered to have lesser beneficial impacts compared to biogas and stabilization under existing conditions in Tacloban.

Chapter 5

Prospects for Integrated and Non-Intergrated Resource Recovery Systems in Tacloban

5.1 Introduction

The original intent of this study was to attempt to see which, if any, of the integrated and non-integrated resource recovery methods could be appropriate for waste management in a typical middle-sized city in the developing world. The State Of the Art Report produced by Meta Systems Inc* which was the first part of the study, gives an exhaustive treatment of all the potential systems. Case studies do tend to concretize the abstract, and Tacloban was no exception. Out of all of the possible integrated systems we concluded that for Tacloban, only one of them--the biogas digestion--is likely to be appropriate and acceptable in the next five to ten years. For the non-integrated resource recovery systems, we believe that the current Resource Recovery system for solid wastes could be strengthtned, and a small composting pilot plant could be justified. None of the non-integrated liquid waste disposal options that include resource recovery look culturally, socially or economically feasible for Tacloban.

Based upon the Meta Systems report**, Rogers*** predicted the quantities of wastes that should be available in a city like Tacloban and what the ultimate resource recovery potential could be. Table 5-1 shows the estimates made at that time based upon comparable data from other parts of the world.

On this table, we have also indicated the numbers that we estimated in the small survey carried out during August 1982. This table allows us to estimate how typical Tacloban is, or is not. Looking at the liquid (sanitary) wastes we see that Tacloban, without a night soil collection systems, is about typical for dry latrines, lags in the septic tank category and is much worse on unsanitary disposal practices. We were unable to

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* Meta Systems Inc, "Waste Stream and Integrated Resource Recovery Systems in Developing Countries", a report to USAID, under contract number OTR-1406-C-00-1144-00, August 24, 1982, revised December 1981.

** Meta Systems Inc, op cit.

*** Rogers, Peter, Seminar at the Devine Word University, Tacloban, July 7, 1982.

Table 5-1. Hypothetical City of 70,000 Population with No Sewerage System

	Population Served	Per Capita Daily Quantities	Total Tons/ Day	Yearly Total Amount (tons)
Sanitary Wastes:				
Night Soil	21,000 (0)**	1.2 kgpcd	25.2	9204 (0)
Dry Latrines	28,000 (28,500)	0.25 kgpcd	7.0	2556 (2,602)
Black Water (septage)	14,000 (27,500)	14.0 kgpcd	196.0	71,589 (140,621)
None	7,000 (14,000)			
Solid Wastes:		.52 kg/capital/day	(.28)	13,295 (7,305)
	% composition			
Food and Vegetable Wastes	68% (65%)		24.75	9,039
$Paper/Cardboard				
Plastics, Leather, rubber	7%		2.55	935
$ Glass and ceramics	2%		1.09	398
$ Rags and textiles	2%		0.72	262
$ Metals (ferrous and non-ferrous)	3%		1.09	398
Misc. combustibles	3%		1.09	398
Cinders, sand, dust, and misc, non-combustibles	12%		4.37	1,596
Total Collectible solid and Liquid tons/year				96,644 (150,528)

* Items marked with the $ sign are items for which direct separation is attractive because of existing markets.

** Numbers in parentheses are those measured or estimated by our survey in Tacloban, August 1982.

measure the actual amounts of materials in these sanitary wastes. Tacloban appears to be quite low in solid waste generation per capita (about 50 percent of a typical value) even though the food and vegetable wastes component percentages are nearly as predicted.

Total collectible wastes predicted for Tacloban was a fairly large figure of almost 100,000 tons per year. Based upon the actual observation this figure is expected to be closer to 150,000 tons per year. Rogers* assumed that for complete biogas recovery of all the human wastes, except those with no sanitary facilities, more than 3,000 m^3/day of biogas production can be produced. The putrescible fraction of the solid wastes could produce another 5,000 m^3/day of biogas. For the city as a whole, this could amount to meeting the cooking needs of 29,000 people. This could be worth P35,000 per day, in wood purchases avoided. Based upon our survey data, we estimate that about 5,000 m^3/day of biogas could be produced and meet the cooking needs of 16,600 people and be worth P22,000 per day. Of course this figure assumes that complete recovery of all recoverable wastes be carried out. This is a highly unlikely scenario.

The real prospects in Tacloban seem much less optimistic. We conclude that two small biogas plants producing only 30 m^3/day are likely to be taken up in the near future. These plants are to be viewed as demonstration plants to test out the technology in Tacloban on the local waste streams. Assuming that these plants are successful, it is hard to predict the total size of a concentrated biogas program. The main reason for this is the lack of infrastructure for collection of the sanitary wastes, for use as nitrogen sources to add to the food and vegetable waste fraction of the collected solid wastes. The size of the biogas program would depend upon the success of the proposed pilot compost plant. If the compost project demonstrates an economical demand for the compost, then a subsequent expansion of the compost plant would reduce the amount of putrescible material available for biogas production. Similarly, a successful application of biogas using night soil could influence the compost plant.

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* Rogers, op cit.

5.2 Choices for Integrated Waste Management in Tacloban

Because of the interactions between the various technology options and the various waste streams, it is apparent that a carefully structured decision analysis will be needed once the feasibility of the options being tested out in Tacloban is locally established. In Figure 5-1 we have sketched out the waste management currently being practiced in Tacloban. In essence, this looks like a policy of "benign neglect". Only an open dump and some scavenging and resource recovery are practiced for the solid wastes; nothing is done for the sanitary wastes, except to let those that reach the storm sewer system pass through it into the Bay.

In Figure 5-2, we have overlain the current management practices with the potential options considered in this report for improving the waste management system in Tacloban. In this sketch, we have much more complicated interactions of waste streams and technology options than in the current treatment. It should be remembered that Figure 5-2 does not cover all the potential technology/waste stream interactions, but only those that were deemed to be feasible and appropriate to the City of Tacloban.

Essentially, the choice facing the city government is, as outlined in Figure 5-3, whether to keep the waste streams separate or to integrate them. Keeping the streams separate, the conventionally chosen option, leads to a variety of decisions about the detailed technologies for treating waste streams. Whichever path is chosen, however, there is currently considerable uncertainty in the decision process. Whether the compost option will produce a product that will have a local market or not, or that the biogas plants will function effectively due to fluctuations on the supply of the human and animal waste products necessary to keep the production at a desired level remain to be seen. In addition, the acceptability of by-products from human wastes remains to be demonstrated. In Figure 5-3 there are many branches where there is considerable uncertainty about the outcomes, the proposed pilot plants for biogas and for composting will help resolve some of these uncertainties during the next two to three years.

Figure 5-3 is a bold attempt to pull together all the various parts of our study into one coherent picture. In order to do this, we have had to sketch the limits of the prefeasibility sutdies made for each of the

Figure 5-1. Current Waste Management in Tacloban

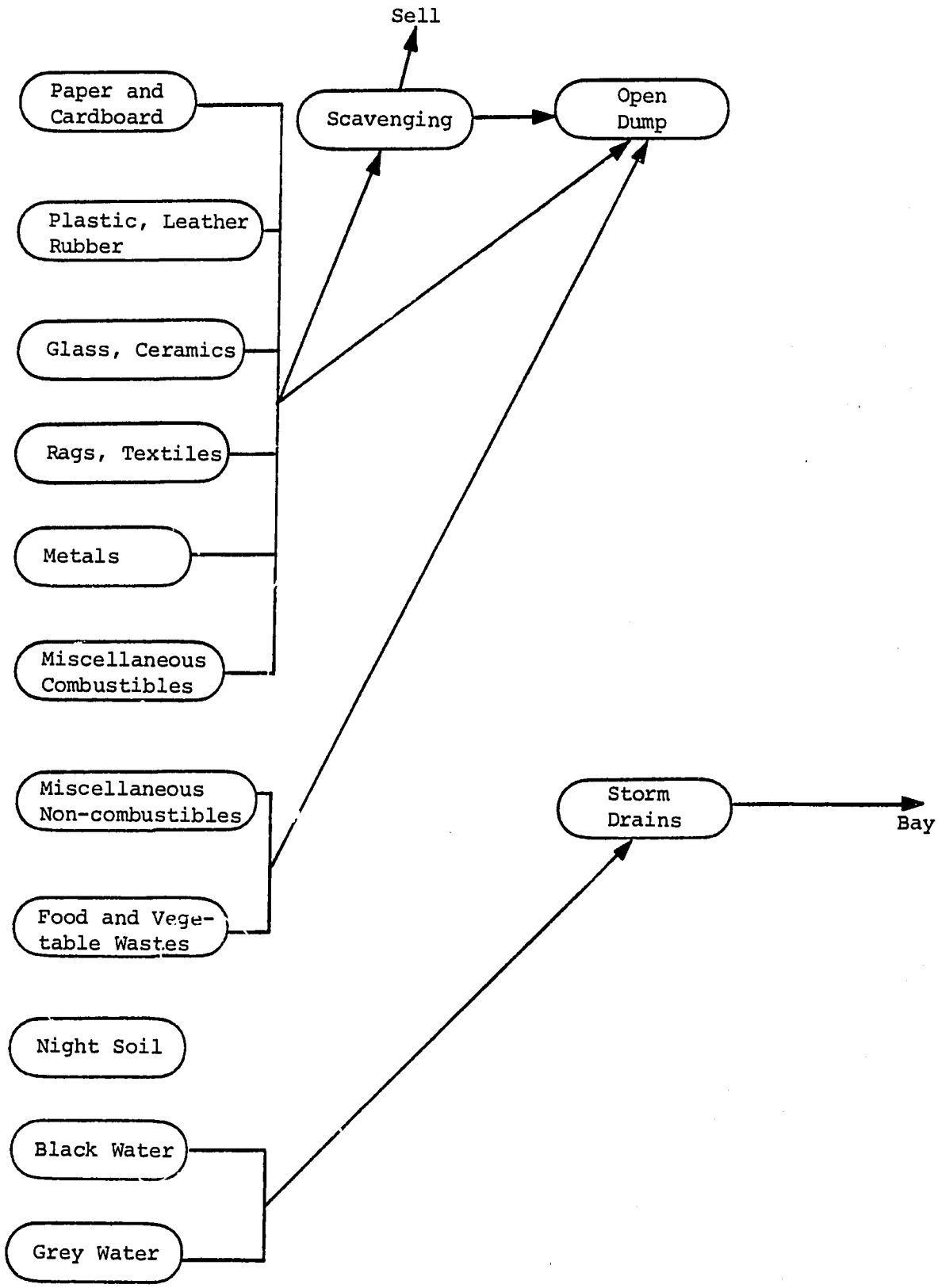
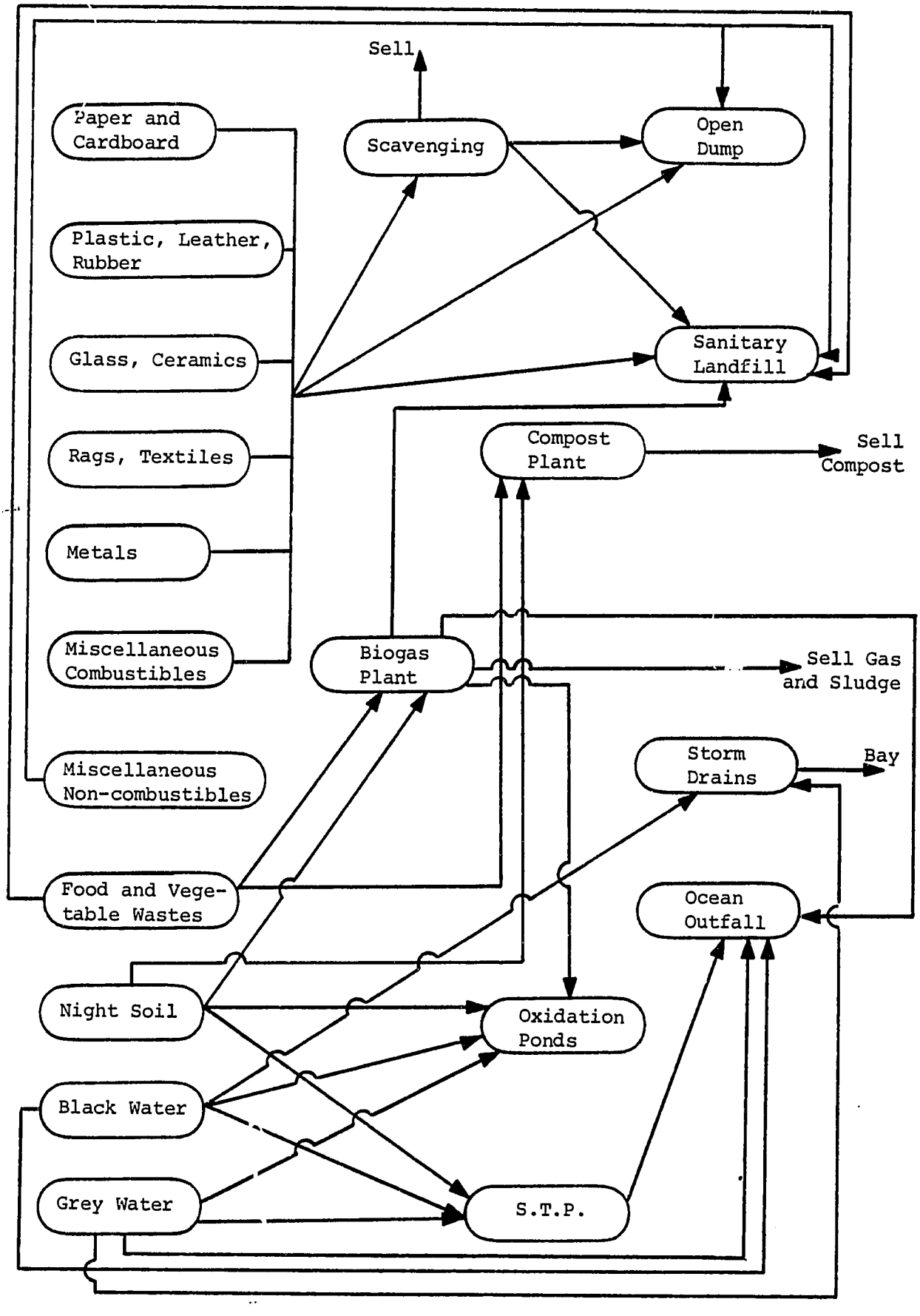
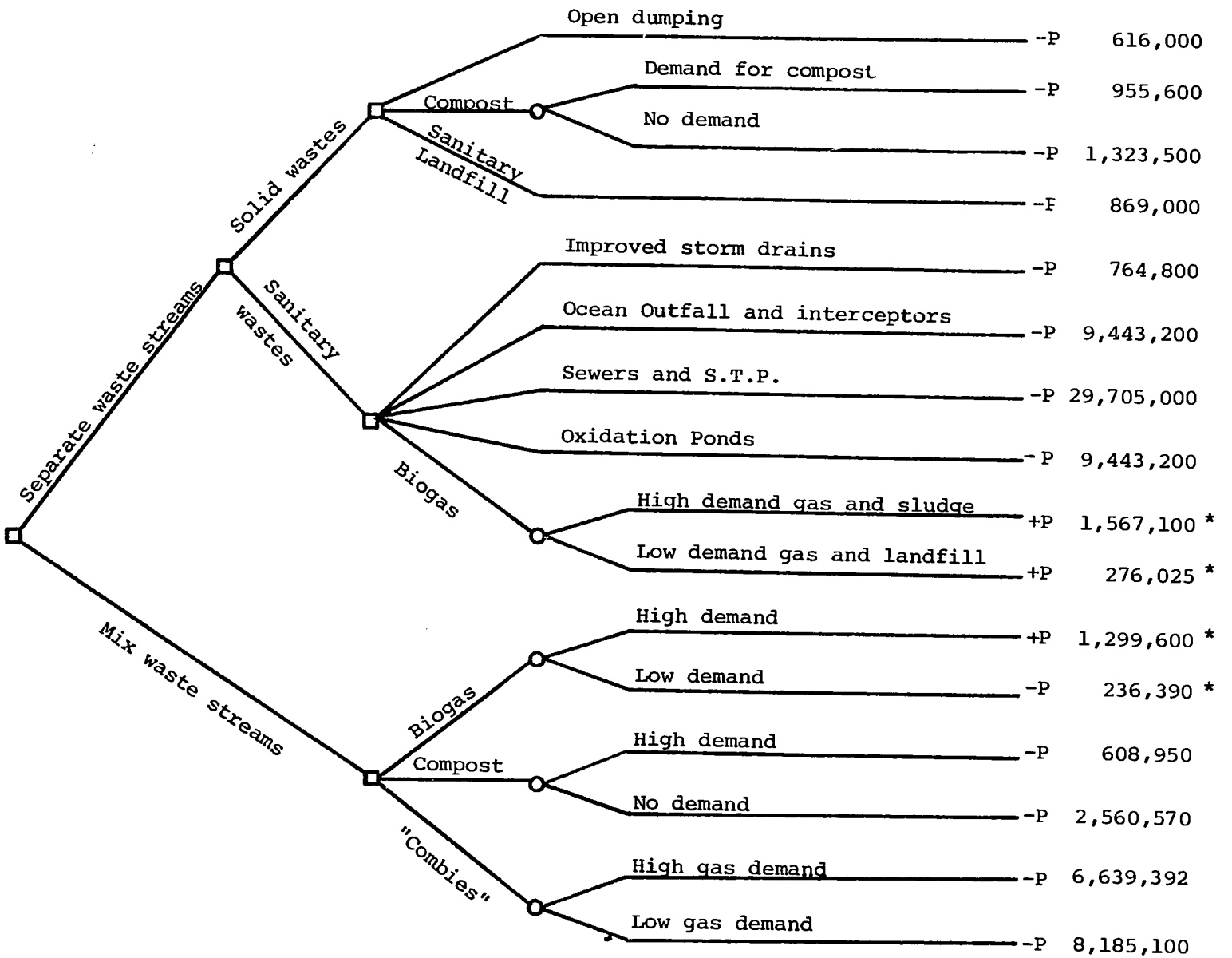


Figure 5-2. Potential Waste Management Systems for Tacloban



165

Figure 5-3. Characterization of Decision Tree for Waste Management in Tacloban



Annual Net Benefits (pesos)

* These options do not include the costs of distributing the biogas to the users. The inclusion of these costs could lead to negative net benefits.

components. In each, these studies of Chapter 2 through Chapter 4 have dealt with small to medium sized units. In Figure 5-3, we are considering Tacloban as a whole. Another assumption that one normally makes with this type of decision-tree is that the outcomes will be roughly equivalent projects, but with differing costs and benefits. This is certainly not true when, for example, one considers open dumping and sanitary landfilling. These give radically different levels of environmental control and with large cost differentials. Nevertheless, we believe it is useful to assay the options in this fashion. For once, the political leadership may be able to get a synoptic view of the available options.

The figures on the ends of the branches represent our best estimates of providing coverage for the whole of Tacloban City proper by the particular technology/waste stream choice. These numbers should be viewed as indications of the relative magnitudes of the costs and benefits and should not be taken too literally. We believe, however, that the ordinal relationships indicated by the numbers are realistic. The numbers themselves, represent the annual net benefits to the city for choosing that particular option.

From Figure 5-3, we can see that Tacloban's current waste strategy--open dumping and disposal of sanitary wastes to the storm drains--is quite cost effective, even if it is not environmentally sound. The most expensive separate schemes are composting for solid wastes and conventional sewage treatment plant and sewer system for the sanitary wastes. The most expensive of the combined resource recovery system is that of the "combies" (these are modified oxidation ponds with a built-in continuous flow biogas digester). In each case, the highest cost systems are those that require the construction of sewers; laterals, mains and interceptors. The point emerges clearly from these costs--try to aboid building sewer collection systems.

Some of the technology/stream combinations show positive yearly net benefits. In each case, these are the biogas option. For these calculations, we have assumed a large program of local biogas digestors which would cover the entire city and the use of human wastes as well as other solid wastes in the system. This would involve a night soil collection system and the continued disposal of grey water into the storm drainage system. The biogas,

moreover, is an untested technology in Tacloban and the benefits could be greatly reduced (as shown on the lower branch of the chance fork) if the sludge has to be landfilled and only 50 percent of the gas could be sold. A major cost which is not charged to th biogas system is the cost of the gas distribution system. If this is included, the biogas option would probably show negative net benefits.

Based upon Figure 5-3, an experienced and conservative manager could argue for the combined strategy of a sanitary landfill and an ocean outfall as the best management strategy for Tacloban. Both of these technologies are well established and are relatively easy and cheap to operate and maintain with low skilled operators. On the other hand, the potential benefits from a well organized and successful integrated biogas program should certainly lead the city to explore this option fully before reaching any decision on its waste management policies.

5.3 Recommendations for Waste Management in Tacloban

Based upon our work in Tacloban, upon our experience elsewhere, and with our review of the State of the Art of Integrated Waste Management and Resource Recovery we have reached the following conclusions about waste management in Tacloban.

1. Sanitary landfilling is by far the most cost effective of the improved methods for dealing with solid wastes in Tacloban. Assuming no market for the compost, it is exactly one-half the cost per ton of the compost option.

2. If a market were to develop for composting solid wastes, the Indore composting process would probably be cost effective (but still not as cheap as the sanitary landfill option). We recommend that a 3 ton/day pilot plant be built.

3. There seems to be plenty of feedstocks for biogas digestion, the climate is appropriate and there is a lot of experience in the Philippines with similar biogas generators. At least one small pilot community biogas plant should be built, probably at the slaughter house. This pilot plant could build local experience with digestion, design, construction and operations, and would also address the questions of cultural acceptability of this technology.

4. We believe that some form of instream treatment be developed for Mangonbangon River. The oxidation pond that we have investigated looks like an appropriate and cost effective way of coping with the water contamination problems in that part of town.

5. The city should wait for the results of the pilot projects before making any major decisions of changing its waste management strategies.

Appendix
Solid/Liquid Wastes Mini Survey--Tacloban City
August 1982

A) RESIDENTIAL AREA SURVEY

Divide the residential area of the City of Tacloban into 20 subdivisions. A subdivision should not represent more than 200 houses (about 500 households). Select 50 houses (not households). On weekends contact the housewife or an adult household member, as opposed to a maid, and ask the following questions.

a) Identify the location of the household in relation to the City as well as garbage collection route.

_____
_____
_____

b) Broadly, what type of garbage does the household generate?

_____
_____
_____
_____

c) Does the household use City Garbage Collection Service?

Yes/No _____

d) If no, why not?

_____
_____
_____

e) How does the household then dispose of its garbage?

_____
_____

f) How long has the household been doing this?

_____

g) If yes, please answer the following:

i) Type of container used

_____
_____
_____

ii) Location of the container (near the house, along the street, etc.)

_____
_____
_____

iii) Frequency of collection

_____
_____
_____

h) Number of members (total) in the household and approximate income level (if possible). Classify income level as per Tacloban economic standards into upper, middle, or lower.

_____
_____
_____
_____
_____

i) Does the household separate any reusable/recyclable items. Yes/No? If yes, what use does the household make of the recovered materials?

_____
_____
_____
_____
_____

j) If no, why not? (Give detailed explanation.)

_____
_____
_____
_____
_____
_____

k) Assuming the City starts buying at nominal price cans, bottles, newspapers, etc., will the household separate these items for weekly sale to the City? Yes/No?

_____
_____
_____
_____
_____
_____

l) If yes, indicate reason, type, approximate quantity, etc., of articles separated.

m) Difficulties experienced?

B) LIQUID WASTES

a) What is sanitary system used in the households, e.g., septic tank, pit privy, etc. Explain fully.

b) What difficulties have they experienced?

c) How long have they been using the system?

d) Explain a centralized collection of sewage treatment system and ask if the household would like the City to build one.

e) Would they share the costs? Explain the total cost and approximate share (explain the advantages, e.g., convenience, health benefits, etc.)?

_____
_____
_____
_____
_____
_____

f) How much of these costs will they share?

_____
_____
_____

g) Explain, if any, the health hazards and environmental risks of continuing use of the present. Note the reactions.

_____
_____
_____
_____
_____

h) Possible explanation of above reactions.

_____
_____
_____
_____

C) COMMERCIAL AREA SURVEY

a) Commercial area selected.

_____
_____
_____
_____
_____
_____

b) Describe the number and types of establishments.

_____
_____
_____
_____
_____

c) Type and quantity of refuse generated.

d) Current mode of disposal.

e) Problems of disposal, including ratings of the City Garbage Collection Service.

f) Type and frequency of scavenging.

g) Who does the scavenging? Explain fully.

h) Type of sanitary system in the commercial area, if any.

i) General observations/remarks (of the survey) regarding all of the above.

D) INSTITUTIONAL

a) Name, type and location with respect to garbage collection service, of the institute (e.g., schools, university, hospital, etc.).

b) Characterize the garbage generated. Indicate any special characteristics.

c) Present practice (including mode) of disposal, difficulties encountered.

d) If the disposal is not via City disposal service, explain why.

e) System of liquid wastes disposal.

f) Who was the respondent?

g) Overall remarks.

_____
_____
_____
_____

E) RESOURCE RECOVERY

a) Type and number of scavengers, including those in the City, at the dump site, collection crew. Classify them accordingly (classification explained verbally to survey aids).

_____
_____
_____
_____
_____

b) Approximate quantity and type of materials scavenged. (Interview scavengers, scrap dealers, etc.)

_____
_____
_____
_____

c) Possible source and location of the scavenged material.

_____
_____
_____
_____

d) Overall range of buying/selling prices for bottles, cans, newspapers, etc. Explain to the dealers your objective of survey assuring him/her that the survey has absolutely nothing to do with Bureau of Internal Revenue.

_____
_____
_____
_____
_____
_____

e) Number of scrap dealers, location, if any, in your area. How long has each been in business? What kind of problems do they have?

_____
_____
_____
_____
_____
_____

f) What percentage of accuracy do you attach to their answers?

_____
_____
_____
_____

g) Overall remarks.

_____
_____
_____
_____

GLOSSARY

ACTIVATED SLUDGE--process removes org ... matter from sewage by injection of air and adding biologically active sludge.

ADSORBTION--is an advanced way of treating wastes in which activated carbon removes organic matter from waste water.

AERATION or ACTIVATED SLUDGE--is a process in which liquid from the primary clarifier is mixed with compressed air and with biologically active sludge containing organisms which multiply and reduce inpurities.

ALGAE--are plants which grow in sunlit waters. They are a food for fish and small aquatic animals and, like all plants, put oxygen into the water by photosynthesis.

BACTERIA--are microscopic living organisms. Bacteria in wastewater consume the organic constituents of sewage.

BOD--or biochemical oxygen demand, is the dissolved oxygen required by organisms for the aerobic decomposition of organic matter present in water. It is used as a measure of the strength of a sample of wastewater before and after treatment.

CHLORINATORS or CHLORINE CONTACT CHAMBERS--are devices for adding chlorine gas to sewage to kill infectious germs.

CLARIFIERS or SEDMENTATION TANKS--are devices in which many solids settle to the bottom by gravity, or float to the surface.

COAGULATION--is the clumping together of solids to make them settle out faster in a liquid medium. Coagulation of solids is brought about with the use of certain chemicals such as lime, alum and iron salts.

COMBINED SEWER--carries both sewage and storm water runoff.

DIFFUSED AIR--is a technique by which air, under pressure, is forced into sewerage in a aeration tank. The air is pumped down into the sewage through a pipe and escapes out through holes in the side of the pipe upwards through the sewerage.

DIGESTION--of sludge takes place in enclosed tanks in the absence of fresh air. The materials decompose, resulting in partial gasification, liquefaction, and mineralization of pollutants.

DIGESTORS or SLUDGE DIGESTION TANKS--are closed tanks which decrease the volume of solids and stabilize raw sludge bacterial action into a material than can be disposed of.

DISTILLATION--in waste treatment consists of heating the effluent and then removing and considering the vapor or steam. The distillate is almost pure water. The pollutants remain in the concentrated residue.

EFFLUENT--is the liquid that comes out of a treatment plant after going through the treatment process.

FLOC--is a clump of solids formed in sewerage. Its formation is enhanced by the use of certain chemicals.

FLOCCULATION--is the process by which clumps of solids in sewage are made to increase in size by chemical, physical, or biological action.

INCINERATION--consists of burning the sludge to reduce it to a safe, non-burnable ash. The ash can then be disposed of safely on land, in some waters, or into caves or other underground locations.

ION--is an electrically charged atom or group of atoms which can be attracted to poles which are oppositely charged.

LAGOONS--are ponds used for wastewater treatment. They are usually made to rigid specifications, in which sunlight, algae and oxygen interact to restore the wastewater to a reasonable state of purity.

LATERAL SEWERS--are the pipes that run under the streets of a city and into which sewers from homes or businesses empty.

MECHANICAL AERATION--uses a mechanical device usually a rotation blade to induce air from the atmosphere into water or wastewater.

MICROBES--are minute plant or animal life. Disease causing microbes may exist in sewage.

ORGANIC MATTER--is the carbonaceous waste contained in plant or animal matter and originated from domestic of industrial sources.

OUTFALL SEWERS--carry wastewater to a point of final discharge.

OXIDATION--is the process of combination of oxygen with organic wastes or chemicals in sewage resulting in the breaking down of matter in stable components.

OXIDATION POND--is a man-made lake or body of water in which wastes are decomposed and stabilized by bacteria. It is used most frequently with other waste treatment processes. An oxidation pond is basically the same as a sewage lagoon.

PACKAGE PLANTS--are prefabricated or prebuilt wastewater treatment plants.

POLLUTANT MEANS CONTAMINATION--or other alteration of the physical, chemical or biological properties of any waters. This includes changes in temperature, taste color or odor of the waters, or discharge into any waters of any liquid, gaseous radioactive, color or other susbtance which may create a nuisance or render such water harmful, detrimental or injurious to public health, safety or welfare.

POLLUTION--results when animal vegetable, mineral or heat wastes or discharges reach water, making it less desirable for domestic, recreation, industry or wildlife uses.

PRIMARY SEWAGE TREATMENT--is the first major (sometimes the only) treatment process in a wastewater treatment plant usually by settling out solids. This reduces pollution about 25-40 percent.

PRIMARY SEWAGE TREATMENT PLANT--may consist of the following units:

Bar Screens of Mechanical Screens--remove large, suspended solids.

Grit Removal Chamters--are used for settling out stones, cinders and sand.

Flowmeters--indicate the rate at which wastewater is flowing through the treatment plant.

Comminutors or Barminutors--grind solids to make them easier to treat.

RECEIVING WATERS--are rivers, lakes, oceans or other water courses that receive treated or untreated wastewaters.

SALTS--are the minerals that water picks up as it passes through the air, over- and underground and through household and industrial uses.

SAND FILTERS--remove some suspended solids from sewage. Air and bacteria decompose additional wastes filtering through the sand. Cleaner water drains from the bed. The sludge accumulating at the surface must be removed from the bed periodically.

SANITARY SEWERS--are pipes in a city that carry only domestic wastewater. The storm water runoff is taken care of by a separate system of pipes.

SECONDARY TREATMENT--is the second step in most waste treatment systems in which bacteria consumes the organic parts of the wastes. It is accomplished by bringing the sewage and bacteria together in a suitable environment such as in trickling filters or in the activated sludge process.

SECONDARY SEWAGE TREATMENT PLANTS--may consist of the following units in addition to those of the primary treatment plant.

Secondary Clarifier, Secondary Settling Tank, Final Settling Tank, and Final Settling Basin--are devices which receive liquid from trickling filter or activated sludge tank and remove settlable solids by sedimentation.

SEDIMENTATION TANKS--help remove solids from sewerage. The solids either settle to the bottom or float to the top as scum. The scum is skimmed off the top, the solids on the bottom are pumped to incineration, digestion, filtration or other means of final disposal.

SEPTIC TANKS--are used for domestic waste when a sewer line is not available to carry them to a treatment plant. The wastes are piped to underground tanks directly from the home or homes. The bacteria in the wastes decompose the organic waste and the sludge settles in the tank. The effluent flows out of the tank into the ground and is disposed of through sewerage from open-jointed drains. The sludge is pumped out of the tanks, usually by commercial firms at regular intervals.

SEWERS--are a system of pipes that collect and remove wastewater from the community to treatment plants or receiving streams.

SEWAGE LAGOONS or SEWAGE STABILIZATION PONDS--are shallow ponds, three to five feet deep, where natural biological processes purity sewage to a degree comparable to that accomplished in a secondary treatment plant.

SLUDGE--is the solid matter that separates out of wastewater in sedimentation tanks and must be disposed of by digestion filtration and incineration or by transport to appropriate disposal sites.

SLUDGE DRYING BEDS--are beds on which the humus-like residue from the digestor is dried. After this, the sludge may be burned or dumped.

STERILIZATION--is the destruction of all living organisms. In contrast, disinfection is the destruction of harmful organisms.

SUSPENDED SOLIDS--are the small particles of solid pollutants which are present in sewerage and which can not be separated from the water by ordinary settling.

TOTAL SOLIDS--the weight of the solid matter remaining after a sampling is dried to a constant weight at $103 \pm 1^{o}C$.

TREATMENT--removes the material that floats or will settle in sewage. It is accomplished by using screens to catch the floating objects and tanks for the heavy matter to settle in.

TRICKLING FILTER--is a support media of a bed of rocks or stones on which bacteria grow and break down the organic waste in wastewater as it is trickled over the bed.

WASTE TREATMENT PLANT--is a system of tanks, screens, filters, and other processes by which pollutants are removed from water.

VIRUS--is the smallest form of micro-organism capable of causing diseases.

VOLATILE ACIDS--the low molecular weight fatty acids.

VOLATILE SOLIDS--the portion of solids volatilized at $550 \pm 50^{o}C$; the difference between the total solids content and the ash remaining after ignition at $550 \pm 50^{o}C$.

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