Chapter 9 – Veracruz Wastewater Treatment Plant

9.1 Design Criteria

The Veracruz Wastewater Treatment Plant (WWTP) will serve a design population of 19,200 residents. This plant is classified as a small to medium size facility. As outlined in Section No. 3, the biological secondary treatment will be utilized in a Sequential Batch Reactor (SBR) activated sludge plant. Waste solids will be stabilized by the aerobic digestion process. The design criteria is summarized below.

Table 9-1
Biological Design Criteria - Veracruz Wastewater Treatment Plant

Design Year	2020
Design Flows	
Annual Average Daily Flow	1.78 MGD
Maximum Month Average Flow	1.90 MGD
Maximum Day Flow	2.30 MGD
Sustained High Flow (4 hour duration)	3.60 MGD
Peak Flow (15 minute duration)	6.20 MGD
Design Loadings	
Maximum Month Average BOD5	2,800 lb/day (177 mg/l)
Maximum Day BOD5	3,840 lb/day (200 mg/l)
Maximum Month Average TSS	2,800 lb/day (177 mg/l)
Maximum Day TSS	3,840 lb/day (200 mg/l)
Maximum Month TKN	400 lb/day (26 mg/l)
Maximum Day TKN	550 lb/day (29 mg/l)
Required Effluent Limits (less than)	
BOD_5	35 mg/l
TSS	35 mg/l
TN	10 mg/l
NH_3-N	3 mg/l
Total Coliform Bacteria	1,000 NTU/100 ml
Anticipated Performance	
BOD_5	15± mg/l
TSS	15± mg/l
TN	<10 mg/l
NH_3-N	1± mg/l

Loadings are more variable in a small plant. The process must be designed to handle hydraulic and organic shock loads expected over a short time duration. In the future, it is common and cost effective utility planning to divert additional wastewater flows from areas outside the original service area to an operating plant. Hence the plant site and process should be selected which is easy to expand.

For example, in south Florida, the City of Homestead operates a 6 MGD SBR activated sludge plant. The Homestead WWTP, which is 3 times larger than the 1.8 MGD SBR plant planned for the Veracruz WWTP, was constantly expanded over 20 years as the service area increased. The original Homestead WWTP was sized for less than 1 MGD flow.

It should be noted that the Veracruz WWTP with the SBR activated sludge process will produce an excellent effluent quality with BOD_5 and TSS levels of 15 mg/liter. BOD_5 and TSS are traditional parameters monitored at treatment works. Effluent limitations for these parameters are 35 mg/liter in Panamá. Effluent quality will be excellent protecting receiving waters and local beaches. The controlling process parameter is 10 mg/liter of TN. The nitrogen composition in the final effluent is outlined below.

Table 9-2
Anticipated Effluent Nitrogen Levels
Veracruz WWTP, Panamá

Nitrogen Compounds	Effluent Concentration mg/liter
Total Kjeidahl Nitrogen (TKN)	3
Oxidized Nitrogen (NOx-N)	7
Total Nitrogen (TN)	10

Ammonia Nitrogen (NH_3-N) levels (which is a component of TKN) will be about 1 mg/liter. Effluent limitation for Ammonia Nitrogen is 3 mg/liter.

9.2 Plant Site

9.2.1 Community Program

The plant is located on a 3.5 HA site situated between the Pacific Ocean and the main road of Veracruz (Calle Principal de Veracruz). See Figure 9-1. A cemetery borders the plant on the east. The west boundary follows a drainage ditch discharging into the Pacific Ocean. The site and plant layout is shown on Figure 9-1.

The cemetery provides a 50 meter buffer to residential homes located east of the plant. Road traffic will be adjacent to the plant's north boundary. Residential homes will be adjacent (now or in the future) to the west boundary.

Due to the close proximity of residential homes and the location of Pacific Ocean, the following minimum requirements for use of this site are as follows.

Odors: The operating units in the headworks structure (screens and grit works) and the aerobic digesters will be either enclosed or covered. Gases or other odorous emissions at these two facilities will be collected and treated prior to discharge to the atmosphere.

Chlorine: Chlorine will be delivered to the plant in 150 pound or 1 ton containers and used to disinfect the final effluent. All containers will be placed in a enclosed building. In the event of an accidental chlorine leak, a gas collection will be activated and chlorine gas will be treated in chemical scrubbers to minimize any potential risk of hazardous gas release to the surrounding community. An alternate means of disinfecting the liquid effluent (UV) may be installed in lieu of chlorine.

Solids Dewatering: It is recommended that sludge drying beds not be installed on the site due to potential odors. Only a small drying bed for 14-days of solids to be used only in emergencies is recommended.

Effluent Discharge: Treated effluent will be discharged through a short ocean outfall to ensure a total 10:1 dilution of effluent and seawater at low tide at the shoreline. Bathing or water contact coliform standards will be met at the shoreline (100 Coli / 100 ml).

Beach Access: A small park with resident access will be constructed along the shoreline (260 meters). Several covered outdoor shelters will be installed for public use.

The goal of these proposed works and facilities is to minimize any potential adverse impacts associated with the treatment plant on the surrounding community. Development of park facilities along the shoreline will allow the local residents to maximize the recreational and scenic benefits of the marine shoreline.

9.2.2 Collection Works

The Veracruz WWSTP will be treating raw wastewater generated and collected in Area 11. Two future minor pump stations identified in the planning process will transfer flow to the Veracruz WWTP. Pump sizing is listed below.

Table 9-3
Area 11 Minor Pump Stations

Pump Station Designation	Projected Flow	
	Liters/sec	gpm
EB-19	21.7	341
EB-20	28.0	442

It is anticipated that one or two additional submersible pump stations will be required either at the plant site or in the general vicinity of the plant to lift flow collected in local gravity sewers into the treatment works. When the design of the local collection system proceeds the location of these small lift pump stations will be confirmed. A construction cost allowance of $300,000 is provided for these two influent pump stations and associated piping works.

9.3 Unit Process Sizing

9.3.1 General Arrangement

On Figure 9-2 the unit processes are illustrated for the Veracruz WWTP. The basic process units are as follows.

- Liquid Stream
  - Screens
  - Grit Removal
  - Biological activated sludge process with the SBR configuration
  - Effluent disinfection with chlorine
  - Outfall to the Pacific Ocean
- Solids Stream
  - Thickening liquid waste activated sludge
  - Aerobic digestion
  - Hauling stabilized liquid solids via truck to land application sites or to the Juan Diaz WWTP.

9.3.2 Headworks

Unit processes that provide preliminary treatment of raw wastewater entering the wastewater plant are as follows.

- Grit Removal
- Screening
- Odor Control

Handling screenings and grit is an unpleasant task for plant operators. Disposal options are limited to hauling captured materials to a sanitary landfill or other environmentally acceptable sites. Maintenance of these front end works is extensive and costly. Due to the warm climate coupled with detention time through the collection and transmission mains, hydrogen sulfide concentrations in the raw wastewater are high. Hydrogen sulfide gas creates unpleasant working conditions (odors) and, in confined spaces, can accumulate to unsafe levels. The accumulation of potentially explosive or toxic gases is always a concern. Screenings and grit contain pathogenic organisms, as well as sharp objects which can result in injury. Concrete and steel are attacked by the sulfurous compounds in the raw wastewater resulting in material destruction under certain circumstances. As a result, plant staff (operations and maintenance) recognize that front end works require extensive allocation of resources and money to keep operational. Typically a utility will make operational and maintenance tradeoff policy decisions between the level and complexity of grit / screening removal necessary versus impacts on downstream equipment longevity, tankage downtime, and increased removal efficiency.

Physical characteristics of the incoming raw wastewater are as follows.

Table 9-4
Headworks Design Criteria

Parameter	Unit
Sewage Characteristics	
Dissolved Oxygen	0.3 – 1.5 mg/l
Temperature	26^o – 28^oC
pH	7.7 to 8.2
Total Sulfides	2 – 14 mg/l
Oil and Grease	20 to 40 mg/l
BOD_5	150 – 200 mg/l
TSS	150 – 200 mg/l
Maximum Solids Sphere	2 inches
Design Flows	
Max Pumpage Rate	6.2 MGD
Average Flow	1.8 MGD

The following sections describe the screening, grit removal, and odor control facilities for the new treatment works.

9.3.3 Screening

Screening devices in wastewater treatment plants are used to remove materials which would damage equipment, and interfere with the satisfactory operation of a process or equipment.

Various types of screening processes are described below. It should be noted that a number of new screens are constantly introduced into the market claiming performance or benefits which include several of these descriptions or functions.

Description	Function
Coarse or trash racks	Large openings (1½ inch to 4 inch) which prevent timbers, rags, other relatively large items from clogging pumps. Usually placed in bypass channels or ahead of stormwater pumps.
Mechanically cleaned bar screens	Medium sized openings (¾ inch to 1½ inch) which constitute the conventional screens used in the front-end works of most wastewater treatment plants.
Fine mechanically cleaned bar screens	Small opening screens (⅛ inch to ½ inch) placed in front of wastewater treatment plants to physically remove debris. These units are limited to specific types of designs, such as plastic flight screens with 3 mm or 6 mm openings or a climber screen with ⅜-inch openings.

Description	Function
Fine specialty screens	These consist of static wedgewire screens, rotary drum fine screens, and a number of new models. Openings vary from 1.0 mm to 3.0 mm. These units act as both a screening device and a preliminary treatment unit. Hence, removing the captured organic material and handling it in a safe and acceptable manner poses many problems. These fine screens have been used successfully at small treatment plants (low flows) and on selective internal sludge streams (waste sludge, digester feed) within larger plants.

All wastewater delivered to the treatment works is pumped at least once at submersible pump stations located in the collection system. Wastewater solids are shredded going through these pumps. Solids in the collection system may be broken down further by biological/chemical processes at warm temperatures. Screening volumes due to physical and chemical factors may be lower than reported at plants located in temperate or cold climates.

We have assumed the following screening quantities to be generated for various screen clear openings for the Veracruz WWTP.

Table 9-5
Estimated Screening Volume versus Bar Screen Clear Opening

Type of Screen	Clear Opening Inches	Screening Volume CF / MG
Mechanical bar screen	3/4	1.8
Mechanical bar screen	1/2	2.7
Mechanical bar screen	3/8	3.5
Plastic Flight	1/4	4.5
Plastic Flight	1/8	6.8
Rotary fine screens	1/16	13.0

At a 1.8 MGD plant flow, the expected loose screening volume will vary from 0.4 to 0.7 cubic meters per day. Three screening options were considered for this application.

(a) Plastic Flight Screen with 1/8-inch openings. This is a conventional screen offered by several manufacturers. All underwater materials and parts are fabricated out of stainless steel or plastic. The 1/8-inch opening size is a good compromise. Solids capture is excellent. Blinding or clogging of the screen has not been a reported problem at operating plants. Alternate acceptable screens are mechanical bar screens are step screens or “climber” configuration screens.

(b) Rotary fine screen with 1/16-inch (0.060-inch) screen openings. Several manufacturers offer competitive units. Raw wastewater is piped into the circular unit. Screenings are captured and moved to a discharge chute. Internal pressure water sprays are used to dislodge material caught in the screen openings. Solids capture is excellent. All fabricated metal is stainless steel. A higher level of operator attention is needed for rotary screens due to their potential to clog.

(c) Macerator. A different approach to capturing solids is to install a mechanical macerator which will shred incoming solids to a smaller size. Solids in the raw wastewater stream have already been broken up passing through pumps located in the collection system. The macerator will reduce solids size, minimizing the impact of clogging on downstream works. A macerator requires high maintenance and is rejected as a viable option.

In the construction estimate, monies have been provided to cover the cost of installing either two (2) conventional Plastic Flight (1/8-inch opening) screens or two (2) step screens (1/8-inch opening).

It is also proposed that compactors be provided to reduce the volume of the loose screenings. Compaction removes water and minimizes odor potential.

The screens will be located outdoors on top of an operating platform. Fiberglass or stainless steel hoods will cover each screen to contain odors. Foul odor gases generated within the screen hood will be drawn off through an 8-inch diameter duct and transported to odor control works.

9.3.4 Grit Removal

The term “grit” may be construed to identify small, coarse particles of sand, gravel, or other minute pieces of mineral matter. In wastewater works practice, the definition of grit is broadened to include a variety of items such as coffee grounds, ground up solid waste, cigarette filter tips, seeds, and similar materials which are not of mineral origin. Such materials have two characteristics which are basic to the classification of sewage grit. They are non-putrescible and have subsiding velocities substantially greater than those of organic putrescible solids.

Grit removal works operating in wastewater pretreatment works serve the following four purposes.

(1) The protection of moving mechanical equipment from abrasion and accompanying abnormal wear (pumps, clarifier scraper arms).

(2) The reduction of pipe clogging caused by deposition of grit particles or heavy sludge in pipes and channels, particularly at changes in direction of the conduit.

(3) The reduction in frequency of digester, aeration, and final settling tank cleaning required as the result of excessive accumulations of grit in these units.

(4) Maintaining process and performance optimization by avoiding the loss of treatment volume in aeration reactors and digester tankage.

Technologies used to separate grit particles from raw wastewater influent flows are as follows.

- **Gravity Settling** - Settling units ranging from shallow tanks with high overflow rates to conventional primary settling tanks in which the heavier grit particles are separated from the primary organic solids via gravity. The capture of grit particles (mesh size) is dependent upon the tank overflow rate and depth.

- **Aerated Grit Chambers** - The incoming raw wastewater is allowed to mix (spiral roll) with the aid of compressed air through a longitudinal tank. The heavier grit particles with their higher settling velocities drop to the bottom of the tank while lighter organic particles are carried with the roll and eventually out of the tank. Typical design criteria is to provide 95 percent removal of Number 60 mesh material.

- **Vortex Chamber** - Raw Wastewater is introduced into a circular tank. Propellers provide energy to allow the incoming stream to swirl, creating a vortex. The heavier grit particles (gravity and vortex forces) settle into a bottom chamber. The lighter organic material remains in the main stream of the flow. Typical performances claimed for these units are as follows.

Percent Capture	Mesh Size
95%	Greater than 50 mesh
85%	50 - 70
65%	70 - 100

Grit volume collected from one of the above units is further processed in a grit classifier (washer) to further reduce the volume. Washed particles are placed in a bin for ultimate disposal to a sanitary landfill or other acceptable land disposal site.

For the Veracruz Treatment Plant, the vortex chamber is the recommended grit removal unit for the following reasons.

1. It is the least costly grit removal works in this size plant. The results of a Present Worth Analysis conducted at a similar size plant are as follows.

	Present Worth Ratio
Vortex Chamber	1.0
Gravity Setting	1.2
Aerated Chamber	1.5

2. It is a very simple mechanical piece of equipment to operate and maintain. A 1.5 hp motor is accessible for maintenance.

3. The 10-foot diameter unit will have an aluminum or fiberglass cover to contain foul gases. A six-inch diameter fitting/piping will be connected to the unit cover to draw off foul gases and convey them to the odor control works.

4. Competition can be expected from 3 to 4 manufacturers who can supply the total vortex/solids classifier system.

Only one 10-foot diameter vortex chamber unit will be installed. The principal maintenance item is the exposed 1.5 hp vertical motor. Construction costs have been estimated based upon a reinforced concrete tank. Optional tank materials are steel or stainless steel.

The total construction cost of the headworks facility, which includes two screens, one vortex grit chamber, a 40 S.M. enclosed building under the operating platform for piping, valves, grit pumps, screening and grit storage, is $500,000.

9.3.5 Odor Control Facilities

Two locations on the plant site have been identified as sources of foul air generation and require odor control facilities. Preliminary criteria is noted below based upon expected hydrogen sulfide (H_2S) concentrations at each plant location.

		Headworks Facility	Aerobic Digestion / Solids Holding Tanks
A)	Closed Tankage and Covered Conduits		
	H_2S	50 ppm	20 ppm
	Air Changes	6 / hour	6 / hour
	Air Volume	160 cfm	800 cfm ±
B)	Manned Enclosure (Buildings)		
	H_2S	2 ppm	--
	Air Changes	12 / hour	--
	Air Volume	800 cfm ±	
C)	Design Conditions		
	Inlet H_2S	10 ppm	20 ppm
	Air Volume	1,000 cfm	1,000 cfm

The characteristics of hydrogen sulfide gas at different concentrations are as follows.

Table 9-6
Hydrogen Sulfide Gas Characteristics

Concentration (ppm)	Impact
0.03	Detectable odor threshold of sensitive people
0.1 to 0.2	Typical odor threshold
1 to 3	Offensive odor (rotten eggs)
10	Max 24-hour exposure limit per OSHA
15	Max 8-hour exposure limit per OSHA
50	Headache, nausea; Max 30-minute per day exposure limit per OSHA
50 to 100	Eye injury
300	Instant death for sensitive people
500 to 2,000	Death

Hydrogen sulfide (H_2S) is one of many compounds which contribute to foul odors generated at wastewater plants. It is an easy compound to measure and used as the primary parameter to assess odor treatment equipment performance.

Four odor control technologies were evaluated for treatment of air streams generated at both plant locations. Low cost odor technologies such as biofilters were rejected due to reported poor odor removals (95% ±), large area requirements, and high operator attention to maintain reliable performance. Hydrogen sulfide (H_2S) removals for each system are summarized below.

Option	Scrubber Technology	H_2S Removal Criteria (percent)	Treated H_2S Stream w/ Inlet Concentration	
			10 ppm	20 ppm
1.	Activated Carbon	99.9%	0.01	0.02
2.	Iron Sponge Media plus Activated Carbon	99.9%	0.01	0.02
3.	Two-Stage Chemical Wet Scrubber Unit	99.9%	0.01	0.02
4.	Iron Sponge Media Scrubber	99.0%	0.10	0.20

The H_2S concentrations are measured at the scrubber unit stack discharge to the atmosphere. The treated gas stream would be further diluted and dispersed as the plume left the plant site. Three technologies reduced the inlet H_2S concentration by 99.9 percent ±. At the 0.01 to 0.02 ppm, H_2S concentration at the stack discharge exit point is at the detectable odor level (threshold for sensitive people). With natural dilution / dispersion, the off-site H_2S levels are reduced to non-detectable levels. The fourth option, iron sponge scrubber, reduces H_2S by about 99 percent. A plant operator would detect low levels of H_2S odors on the plant site. These levels would be well below OSHA levels required for a safe working environment. Residents are located as close as 50 to 75 meters downwind of the odor control works. Dispersion and dilution should reduce odor concentrations by a factor of 10 ± (1-log reduction) if winds carried the gas plume directly into the adjacent residential area. Hydrogen sulfide levels in the residential community under these conditions would be in the 0.002 ppm range or less for scrubber technology options 1, 2 and 3. For technology option 4, the hydrogen sulfide level would be 0.02 ppm. This concentration is below or at the typical detection limit (0.03 ppm ±) of sensitive people.

A present worth cost analysis is presented for all four options.

Table 9-7
Odor Control Present Worth Analysis

	Option No. 1 Two Activated Carbon Systems	Option No. 2 Two Iron Sponge + Activated Carbon Units	Option No. 3 One 2-Stage Wet Scrubber Unit	Option No. 4 Two Iron Sponge Media Scrubber Systems
Number of Units	2	2	1	2
Air Flow/Unit (CFM)	1,000	1,000	2,000	1,000
Total Air Flow (CFM)	2,000	2,000	2,000	2,000
H_2S Removal	99.9%	99.9%	99.9%	99.0%
(A) CAPITAL COST	$ 40,000	$100,000	$ 75,000	$ 60,000
(B) ANNUAL O&M COST				
Iron Sponge Replacement	--	$ 3,500	--	$ 3,500
Activated Carbon	$ 30,000	4,500	--	--
Hypochlorite	--	--	22,000	--
NaOH	--	--	1,000	--
Power	2,000	3,000	2,800	2,000
TOTAL ANNUAL O&M COST	$ 32,000	$ 11,000	$ 25,800	$ 5,500
(C) PRESENT WORTH ANALYSIS				
Capital Cost	$ 40,000	$100,000	$ 75,000	$ 60,000
P.W. of O&M Cost	258,000	89,000	208,000	44,000
TOTAL PRESENT WORTH	$298,000	$189,000	$283,000	$104,000

Note: Present worth of O&M cost calculated using an 12 percent interest rate over a 30-year period (CRF = 0.1241).

The least costly odor control technologies are ranked as follows.

H_2S Removal	Technology Option	Total P.W. Cost	Incremental Cost Increase
99.0%	Iron Sponge Media	$104,000	--
99.9%	Iron Sponge Media plus Activated Carbon	$189,000	182%
99.9%	Two-Stage Wet Scrubber Unit	$283,000	272%
99.9%	Activated Carbon Scrubbers	$298,000	286%

The two least cost alternatives utilize the iron sponge media scrubber technology which is manufactured by the Marcab Company located in Lake Elsinore, California. Several other firms now manufacture competing units. The iron sponge technology uses a hydrated ferric oxide media which is very selective and effective (99%+ removal) in reducing the level of hydrogen sulfide and hydrogen sulfide mercaptans. Lesser removals are reported for other odorous compounds. Iron sponge media replacement for 20 ppm H_2S air stream is projected at four years by the manufacturer (a two-year media replacement life was used in our cost analysis).

The recommended technology is the iron sponge media followed by activated carbon scrubbers. This system will provide 99.9 percent removal of H_2S and other foul odorous compounds. The initial costs are the highest for this system ($100,000), but annual O&M costs are reasonable, thus making this the most cost-effective technology capable of achieving 99.9% performance criteria. It also allows the operators the flexibility to reduce operating cost by utilizing the activated carbon scrubbers only during those periods when maximum foul odors are generated within the plant.

9.3.6 Disinfection

Two viable disinfection options for the Veracruz WWTP are as follows:

(a) Chlorine delivered in 150 pound containers. Chlorine containers would be located in an enclosed building. In the event of an accidental gas release, the building louvers would close and the released gas would be pumped out of the building to an onsite chemical scrubber system. The probability of an accidental gas release, coupled with a malfunction of the emergency gas scrubber, is extremely low.

(b) Installation of an ultraviolet (UV) disinfection system. Ultraviolet energy causes permanent inactivation of bacteria, viruses, and other microorganisms. UV is extremely effective when disinfecting potable water and filtered reclaimed water with low suspended solids concentrations. We expect the treated effluent TSS level from the Veracruz WWTP to average about 15 mg/liter. With plant upsets, the TSS could rise to 30 mg/liter and still meet TSS effluent limits. Bacteria, viruses, and other microorganisms could be enmeshed in the solid particles and be partially protected from UV penetration. Under these conditions the effluent could possibly exceed E. Coli effluent pathogen quality requirements.

We have included the total construction cost of a new enclosed chlorine building with an emergency scrubber system. The construction cost is equivalent to UV works. The final decision of selecting the disinfection technology may be reviewed with respect to risk management and ease of operation criteria.

A chlorine contact tank will be provided to allow proper disinfection prior to discharge of effluent into the Pacific Ocean.

9.3.7 Power Generation

A 300 kW, 480 volt, 3 phase standby diesel generator will be installed on the site. In the event of an electrical power outage, the generator will automatically be activated. An automatic transfer switch will deliver generated electrical power to the treatment plant motor control center. The generator unit will have a 2,000 gallon diesel fuel tank. The entire generator unit will be enclosed in a steel sound attenuating enclosure. No off-site noise nuisance is expected when the generator is placed in operation.

9.3.8 Solids Thickening

The biological waste activated sludge processes will generate about 2,100 lbs/day (dry weight) of waste activated sludge (WAS) at design conditions. WAS will have a typical solids concentration of one percent (10,000 mg/l).

Waste Activated Sludge	
Loading	2,100 lb/day
Concentration	10,000 mg/l
Volume	25,400 gallons/day

WAS solids are thickened to decrease the capital and operating costs of subsequent solids stabilization processing steps by substantially reducing the volume of the waste sludge to be handled. The solids facilities are sized based on this concept. Thickening to a minimum four percent solids concentration (40,000 mg/l) results in a volume reduction from 25,400 gallons to 6,350 gallons.

The four processes most commonly used for small to medium sized municipal wastewater treatment plants are evaluated below.

1. **Dissolved Air Flotation (DAF).** The DAF process concentrates sludge as a result of the attachment of minute bubbles of air to the sludge solids, thereby reducing their specific gravity to less than that of water. The attached particles then float to the surface of the thickener tank and are removed by a skimming mechanism. Power requirements are high. In addition, DAF units are normally installed in an enclosed building. The release of dissolved air bubbles to the atmosphere will generate odors. If the biological process is upset, the odors will be foul. Good ventilation coupled with odor control works are usually required at DAF installations. DAF is rejected as a viable thickening process due to high power requirements and the associated cost of enclosing the units, as well as the foul odor generation potential.

2. **Gravity Belt Thickening.** In gravity belt thickening, sludge becomes concentrated as its free water drains by gravity through a porous horizontal belt. A gravity belt thickener (GBT) resembles the gravity drainage zone of a typical sludge dewatering belt filter press. The critical design parameter for a GBT is the feed sludge hydraulic loading rate

in terms of flow rate per meter of GBT belt width. Typically the gravity belt thickener is enclosed in a building. Odor generation is not as intense as from DAF units. In a small plant, a good ventilation system is adequate to handle off gases from a GBT. GBT power requirements are very low. More operator attention is needed during startup and shutdown procedures.

3. **Centrifugal Thickening.** The liquid/solid separation during centrifugal thickening (CFT) is analogous to the separation process in a centrifugal sludge dewatering machine, except it is performed at lower speeds. Separation results from the centrifugal force driven migration of the sludge solids through the suspending liquid. The critical design parameters for a centrifuge in a thickening application are the hydraulic loading rate and bowl speed. CFT power requirements are moderate. A CFT unit can be installed outside on a reinforced concrete slab (mass needed due to high speed vibrations). All piping is enclosed and odor generation potential is not an issue.

4. **Rotary Sludge Thickener.** In a rotary sludge thickener (RST) unit, solids are fed into a rotating drum. Internal metal parts are fabricated of stainless steel. The unit is enclosed in a stainless steel hood and can be installed outdoors. The unit has low power requirements (0.75 hp). The RST unit does require an internal spray water system.

A present worth analysis of each thickening option was performed to provide an economic basis of comparison.

	Gravity Belt Thickener	Centrifugal Thickener	Rotary Drum
Construction Cost			
Structural	$ 25,000	$ 10,000	$ 8,000
Mechanical	70,000	80,000	65,000
Electrical	8,000	15,000	7,000
Construction Cost	**$103,000**	**$105,000**	**$ 80,000**
Annual O&M Cost			
Power	2,000	9,000	4,000
Polymer	2,000	2,000	2,000
Labor	10,000	2,000	6,000
Total O&M	**$ 14,000**	**$ 13,000**	**$ 12,000**
Total Present Worth			
Construction Cost	103,000	105,000	80,000
Present Worth O&M Cost(1)	113,000	105,000	97,000
Total Present Worth	**$216,000**	**$210,000**	**$177,000**

(1) Total Present Worth of O&M cost calculated at 12% discount rate over 30 years.

The rotary drum thickener is recommended for mechanical thickening waste activated sludge.

9.3.9 Solids Stabilization

Sludge stabilization processes achieve two important results, both of which are critical to the ultimate disposal of the sludge. First, stabilization breaks down unstable, odorous, putrescible organic matter into more stable organic compounds which are easier to dewater. In addition, stabilization processes achieve high degrees of pathogenic organism destruction, thus reducing the health risks associated with subsequent handling and disposal/use of the product.

Quantities of thickened waste activated solids at the design year to be stabilized are as follows.

- Loading 2,100 lb/day (dry weight)
- Concentration 40,000 mg/l
- Solids percent 4%
- Volume 6,350 gallons/day

Two viable stabilization processes are as follows:

- Anaerobic Digestion
- Aerobic Digestion

In medium to larger treatment plants, anaerobic digestion is the more cost effective process due to its low energy usage. In smaller WWTP plants, aerobic digestion is utilized due to its simplicity of operation coupled with low labor cost.

Anaerobic Digestion – The anaerobic digestion process consists of the breakdown of organic matter by anaerobic and facultative microorganisms in the absence of molecular oxygen. Anaerobic digestion is a two-phase process. The first phase involves the conversion of complex organic matter to volatile acids by a group of organisms referred to as acid formers. The second step includes the conversion of volatile organic acids to methane gas and carbon dioxide by a group of organisms referred to as gas formers. The primary end products of anaerobic digestion are methane gas, carbon dioxide and stabilized solids. Total solids are reduced by up to thirty-five percent. The remaining solids are well stabilized and have a low putrefaction and odor potential.

Aerobic Digestion – The aerobic digestion process is a stabilization process in which aerobic biological reactions destroy the biologically degradable organic components of sludges. In practice, this process functions as a completely mixed activated sludge system in the endogenous phase of cell growth. During aerobic digestion, aerobic microorganisms use oxygen and obtain energy from available organic matter. When the mass is aerated under energy limited conditions, aged cells undergo cell lysis which releases degradable organic matter for use by other microorganisms. Aerobic digestion products are mainly carbon dioxide, water, and the remaining non-biodegradable fraction of the sludge. The aerobic digestion process can reduce total solids by up to thirty-five percent.

Design criteria for both solids stabilization systems are tabulated below.

	Anaerobic Digestion	Aerobic Digestion
Loading		
TSS	2,100 lb/day	2,100 lb/day
VSS	1,680 lb/day	1,680 lb/day
Flow	6,350 gpd	6,350 gpd
Volume Criteria	0.08 lb. VSS/c.f.	40 days @ 20^{o}c
Total Volume	21,000 c.f.	35,000 c.f.
Number of Tanks	2	2
Volume per Tank	11,500 c.f.	17,500 c.f.
Capital Cost[(1)]	$715,000	$520,000

(1) Capital Cost is equal to construction cost plus 30% allowance for Project Contingency, Engineering, Administrative Cost, and Construction Extras.

The Present Worth analysis based upon operating cost and solids loading during the initial 5 years versus operation 15 years in the future is as follows.

	Initial Operation		15 Years in Future	
	Anaerobic Digestion	Aerobic Digestion	Anaerobic Digestion	Aerobic Digestion
Capital Cost	$715,000	$520,000	$715,000	$520,000
Annual O&M				
- Power	6,000	23,000	8,000	45,000
- Labor	5,000	2,000	8,000	5,000
- Maintenance	4,000	2,000	11,000	6,000
O&M	$15,000	$27,000	$27,000	$56,000
Total Present Worth				
Capital Cost	$715,000	$520,000	$715,000	$520,000
Present Worth of O&M Cost	121,000	218,000	218,000	451,000
Total Present Worth Cost	**$836,000**	**$738,000**	**$943,000**	**$971,000**

Over the 30-year planning period, the anaerobic digestion alternative Total Present Worth Cost may be 3 to 5 percent less costly than aerobic digestion works.

We recommend that aerobic digestion facilities be installed at this time for the following reasons.

1. The aerobic digestion works initial capital cost is about $195,000 less costly than anaerobic digestion works.

2. The aerobic digestion system is simple to operate and maintain.

3. Aerobic digestion works are a component of several of the ASB biological treatment technologies. Common wall construction can reduce initial construction cost.

4. In the future the utility may modify or change the solids stabilization process due to changes in regulations, market conditions, or technology. Tankage built for the aerobic digestion can be utilized for solids processing and storage or for future biological treatment. Most of the initial capital expenditure can be saved.

9.3.10 Solid Dewatering and Disposal

In the Consolidated Master Plan, stabilized solids would be dewatered on the treatment plant site by sludge drying beds. In this operation, liquid stabilized solids are poured in large open sand filled basins with sealed bottoms. These sand filled basins act as filters. Solids are captured on the top surface of the sand and are removed by mechanical equipment and hauled off-site in open trucks to disposal sites. Liquid which passes through the sand flows to a bottom sump and is pumped to the biological treatment plant.

On the Site Plan (Figure 9-1), the area designated “Space for Future Works” was originally reserved for sludge drying beds. We recommend that the installation of sludge drying beds be postponed in the original project. The Veracruz WWTP is located in close proximity to local residences and public facilities. Odor control works are proposed for the treatment plant headworks and solids aerobic digesters. Sludge drying beds are a potential source of odors, especially in wet weather. We recommend that the decision to install drying beds be postponed until the biological plant and odor control systems have a demonstrated performance record. At that time, the quality of the stabilized solids will be confirmed and potential markets for dewatered solids identified. In addition, the impact of increased potential odors generated at the plant site will be assessed. A decision to add sludge drying beds can be made at that time taking into account potential impacts to local community, capital and O&M cost of the dewatering works, as well as the solids reuse opportunities and cost.

In the initial project, we recommend that stabilized liquid solids be hauled by tanker truck to (a) the Rio Juan Diaz Plant or (b) to cattle ranches and other approved biosolids sites within economical haul distances. As the biosolids reuse program develops, more sites will be identified.

At maximum month loading and at full capacity in the design year (2020), 6,000 gallons per day of liquid stabilized solids will be generated at the Veracruz WWTP. Liquid solids will be hauled off-site by a single tanker truck. In the initial years, 3 to 4 tanker truck trips per week are required. At design conditions, one truck trip a day will be necessary to haul solids off-site.

In the initial project, an emergency sludge drying bed will be installed capable of dewatering solids over a 14-day period. This will be needed if the tanker truck is out of service or diverted to other utility duties. In addition, this drying bed can be used by the plant operators to conduct small scale dewatering trials in order to assess process performance and odor potential.

9.3.11 Sequencing Batch Reactors (SBR)

The SBR is a fill and draw activated sludge treatment process. Sequencing batch reactors can achieve combined carbon and nitrogen oxidation, nitrogen removal, and phosphorous removal. The SBR process involves a single, complete-mix reactor in which all steps of treatment occur, eliminating the need for both secondary clarifiers and a sludge recycle system. The SBR reactor is filled during a discrete period of time and then operated in a batch treatment mode. MLSS remains in the reactor during the treatment cycle, thereby eliminating the need for a separate clarifier.

Each SBR tank carries out the functions of equalization, aeration, denitrification, and sedimentation in a time sequence, rather than in the conventional space sequence of continuous flow systems where these functions are carried out in separate tanks. The design criteria is outlined on the following table.

Table 9-8
Sequencing Batch Reactor
Wastewater Treatment Plant, Veracruz, Panamá

Design Year	2020
Design Flows	
Average Annual Daily Flow	1.78 MGD
Max Month Average Daily Flow	1.90 MGD
Sustained High Flow (4 hour duration)	3.60 MGD
Peak Flow Rate (15 minute duration)	6.20 MGD
Design Loadings	
Average BOD_5	177 mg/l
Average TSS	177 mg/l
Average TKN	26 mg/l
Strong BOD_5 (1)	200 mg/l
Strong TSS(1)	200 mg/l
Strong TKN(1)	29 mg/l
Required Effluent Limits (less than)	
BOD_5	35 mg/l
TSS	35 mg/l
TN	**10 mg/l**
NH_3-N	3 mg/l
Total Coliform Bacteria	1000 NTU/100 ml
Anticipated Performance	
BOD_5	15± mg/l
TSS	15± mg/l
TN	**< 10 mg/l**
NH_3-N	1± mg/l
Elevation	100 feet MSL
Wastewater Temperature (^oC)	$26^o – 28^o$
Total Number of Reactors	3
Sludge stabilization with recycle to SBR units	Aerobic Digestion

(1) Strong denotes wastewater characteristics expected one day in ten (10% of the time).

The controlling criteria is the 1.9 MGD max month flow. Strong BOD_5 and TSS values can be expected to approach 200 mg/liter about 3 days each month. For the maximum month the BOD_5 loading is to be based upon the average value of 177 mg/liter. During days when the influent BOD_5 approaches 200 mg/liter the treated effluent BOD_5 will increase from 15 mg/l to 25+ mg/liter and still meet the 35 mg/liter BOD_5 effluent criteria.

Typical manufacturers of SBR technology are as follows:

- U.S. Filter Jet Tech Products utilizes a jet aeration system
- Fluidyne Corporation utilizes a jet aeration system
- Aqua-Aerobic Systems, Inc. which utilizes a mechanical surface aerator
- Purestream Inc. utilizes a diffused air system
- Sanitaire Corporation which utilizes a continuous feed (inflow) system with intermittent cycles of aeration, settling and decanting. Sanitaire offers fine or coarse diffused air systems.

Each SBR system has its pros and cons. For the preliminary design the following minimum reactor tankage is recommended.

Number of Reactors	3
Minimum Volume per Reactor	0.60 MG
Minimum Reactor Dimensions	
- Width	45 feet
- Length	100 feet
- Side Water Depth	18 feet

Tankage configuration will be modified depending upon the respective SBR system. A separate blower building will be located at grade. Blowers are to be sized to handle both the SBR reactors and the aerobic digestors. The plant layout is shown on Figure 9-3.

9.3.12 Effluent Disposal

Treated effluent processed in the Veracruz WWTP will be discharged into the Pacific Ocean via a short 16-inch diameter marine outfall. Coliforms totals in the final effluent will be less than 1,000 coli./100ml. With chlorination of final effluent, typical coliform levels will be reduced further to 200 coli/100ml. or less. The marine outfall discharge will be located offshore to insure under worst conditions (1 day in 100 days) that the combination of initial dilution coupled with effluent movement with an onshore tide will insure that the maximum coliform level in the beach waters will be less than 100 coli./100ml. This insures contact or bathing water quality at the Veracruz beaches associated with secondary effluent discharges will be equal or better than the majority of international standards.

Local marine topographical and current documentation must be confirmed. Cost are included for a 16-inch ductile iron pipe outfall with subaqueous joints extending offshore 200 meters from the low tide level mark into the Pacific Ocean.

9.4 Project Cost

The recommended process for the new Veracruz wastewater treatment plant is the activated sludge process using Sequencing Batch Reactors and solids stabilization with aerobic digestion. The construction cost estimate for the Veracruz WWTP is $6,000,000 as outlined on Table 9-9. Annual operating and maintenance (O&M) cost are presented in Table 9-10. Power is the major component of O&M cost and will vary with the volume of wastewater flow processed..

Table 9-9
Construction Cost Estimate
New Wastewater Treatment Plant
Veracruz, Panamá

1.	Collection System Pump Station and Piping	$ 300,000
2.	Site Work	600,000
3.	Pretreatment Works	600,000
4.	SBR Biological Plant	2,000,000
5.	Solids Thickening	200,000
6.	Aerobic Digestion	400,000
7.	Chlorination Facilities	400,000
8.	Odor Control	180,000
9.	Chlorine Contact Tank	110,000
10.	Control Building / Laboratory	200,000
11.	Back-up Solids Drying Bed	100,000
12.	Yard Piping	260,000
13.	Switchgear / Generator	300,000
14.	Electrical / Instrumentation	350,000
	Construction Cost	**$6,000,000**

Table 9-10
Operation and Maintenance Cost
Veracruz WWTP, Panamá

	Initial Operation	Build-Out
Flow – MGD	1.0	1.8
Personnel		
Administrative	12,000	16,000
Operations	42,000	42,000
Maintenance	11,000	21,000
Driver	11,000	16,000
Power	$140,000	$250,000
Chemicals		
Chlorine	6,000	10,000
Polymer	1,000	2,000
Odor Control	5,000	8,000
Utilities	2,000	2,000
Solids Disposal	25,000	30,000
Annual Operating and Maintenance Cost	**$255,000**	**$397,000**