National Secondary Schools' Quiz Competition 2012 on Wastewater & Re-use
STUDENT STUDY MANUAL

For use from Preliminaries to Final

WATER AND SEWERAGE AUTHORITY

"Water Security for Every Sector. Deliver it. Sustain it"

Table of Contents

LIST OF FIGURES

LIST OF TABLES

OBJECTIVES

The Water and Sewerage Authority (WASA) of Trinidad and Tobago has embraced as one of its public education strategies, an educational initiative targeting secondary school students and the wider public at large.

The strategy harnesses the use of television as a medium for the hosting of a secondary schools quiz competition. The process addresses two key elements of the Authority's operations, namely water and wastewater.

This document as compiled by the Wastewater Liberty Team, the Corporate Communication Department and specialists in the field within WASA, serves as a study guide for secondary school students who seek to develop a deeper understanding of the elements relating to the wastewater segment of the Authority's operations:

The objectives of the competition are as follows:

- To promote education amongst the secondary school population and by extension, the wider community on the wastewater sector, its systems and treatment processes.
- To keep secondary school children and the wider community informed about topics such as:
    - The nature of wastewater
    - Wastewater collection, treatment and disposal systems
    - Wastewater management
- To promote wastewater as a viable career choice.
- To deepen the appreciation of emerging technologies relating to the linkages between advanced wastewater treatment and increased water availability for improving water supplies, through wastewater reclamation and reuse.
- To promote best wastewater management practices relating to health, sanitation and the environment through increased knowledge and awareness.

Section 1

Wastewater Sector Development

CHAPTER 1

WATER AND SANITATION - THE GLOBAL CONTEXT

The United Nations declared International Decade for Action, Water for Life, 2005-2015; estimated that over 1.1 billion people do not have access to safe drinking water while 2.6 billion lack basic sanitation. These figures are both astounding and frightening. Access to safe drinking water and good hygiene is a fundamental human right. This basic necessity is a luxury for most of the world's poor population.

Globally, the world is poised to play a stronger role in managing freshwater and wastewater resources, as well as to invest monies in its infrastructure. At the core of the challenges faced are the expanding world population, increased industrialization, and inefficient methods of irrigation which have placed significant demands on wastewater services.

Figure 1: Sanitation: A Global Challenge

With this international perspective, WASA has embarked on the second phase of its public education initiative "In the know with H_2O – Wastewater & Reuse. This study manual provides a framework for wastewater education as it highlights the significance of wastewater management and its various interactions from the simple to the complex.

In the global context of water availability versus demand, Trinidad and Tobago is not considered to be a water scarce country, however several challenges exist that inhibit the delivery of full water and wastewater services to its population of 1.3 million

When examined closely man's interactions with water as it passes through the phases of the hydrological cycle can adversely impact on this valuable natural resource.

It is within the framework of knowledge of the negative potential impacts; the development of safe and environmentally compliant processes can be implemented to reduce the risk of unwanted impacts on human and ecological existence. "In the know with H_2O – Wastewater &

Reuse" is a theme that encapsulates the essence of dealing with the challenges faced by the water and wastewater sector from a knowledge position. It is through changing practices and processes that the fundamentals of the problems can be altered in a sustainable manner. As one of many implementation strategies to enhance the knowledge, awareness and practices relating to wastewater management, the adoption of Integrated Wastewater Management (IWM), a collaborative stakeholder approach, to wastewater management at the community level, has been embraced.

Wastewater, which is produced as a bi-product of industrial, commercial and domestic process; if not treated and managed effectively, has the potential to negatively affect the human and environmental health of the nation. With inadequate collection, treatment and disposal of wastewater in Trinidad and Tobago, the potential for contamination of the environment and exposure to illnesses is high.

The inability to meet the demands of the domestic, industrial and commercial sectors for water services presents opportunities for new product development from wastewater. One such product being reclaimed water. With the potential to supply industrial processes with water for cooling, aggregate preparation, concrete works etc., reclaimed water from treated wastewater can replace the current potable water now in common use for these processes. The potable water that would have been used for these industrial processes can now be distributed to the population for domestic use. This option provides a less costly product as compared to desalinated water which is now used in Trinidad.

In the medium to long term development planning horizon for the wastewater sector, the construction of large regional wastewater facilities will make available even more reclaimed water for industrial and agricultural uses. With approximately 80, 000m^3/d of industrial grade water now being produced at the new Beetham Wastewater Treatment Plant, the planned construction of centralized wastewater treatment facilities at San Fernando (reclaimed potential 45,000m^3/d) Malabar and Southwest Tobago can make available a ready supply of reclaimed water to meet the demands of the relevant customer bases.

CHAPTER 2
BACKGROUND OF WASTEWATER SECTOR

Wastewater is understood as any water that has been adversely affected in quality due to anthropogenic (human) influence. It comprises liquid waste discharged by domestic residences, commercial properties, industry and agricultural fields. This wastewater consists of a wide range of potential contaminants of varying concentrations.

WASA is responsible for the collection, transmission, treatment and disposal of wastewater in Trinidad and Tobago and achieves this mainly through its Public Sewerage Systems in Port of Spain, San Fernando, Arima, Point Fortin and Scarborough Tobago.

In 1861, Trinidad's first underground sewer system was constructed along Port of Spain and serviced the immediate western areas of the capital city. The first major sewerage system was done in 1902, which included a low level sewer along Wrightson Road, Port of Spain and the Mucurapo Pumping station, all emptying into the lagoons of Beetham. Over the period 1902-1937, street sewers were constructed in Port of Spain.

Years later, in 1962, the Government of Trinidad and Tobago embarked on a major island wide sewerage project, which focused on extending sewer services to the areas of San Fernando, Port of Spain and Arima. The project comprised the laying of 384 km of sewer.

Not too long after, in the year 1965, WASA was established as a consolidated entity. Prior to its formation, seven (7) agencies were responsible for water and sewerage service provision. The following year, 1966, a million dollar island wide Sewerage Extension Project was undertaken by Lock Joint Ltd. It comprised the installation of over 320 km of street sewers and 5000 manholes in Port of Spain, San Fernando and Arima. The project also included the construction of sewage treatment plants and pumping stations.

In 1980, WASA completed the construction of the Piarco Wastewater Treatment Plant that serviced both the Piarco International Airport and the Caroni Water Treatment Plant. Two years later the Santa Rosa Heights and the Lange Park Housing Development were also completed. Across in Tobago, the Scarborough Wastewater Treatment Plant was completed in 1994.

In 2001, the construction of the new Beetham Wastewater Treatment Plant commenced. Three years later, the plant was completed and now provides service to more than 182,500 individuals. It currently serves customers within the greater Port of Spain and environs, Pt. Cumana, Mt Hope, Diego Martin and Maraval areas.

Figure 2: Aerial view of Beetham Wastewater Treatment Facility

In October 2004, WASA assumed responsibility for 38 Wastewater Treatment facilities previously owned and operated by the Housing Developing Corporation - HDC (previously the National Housing Authority - NHA), Sugar Welfare and UDeCott as a mandate from the government of Trinidad & Tobago.

In keeping with figures presented in recent years, the wastewater infrastructure is capable of servicing 30% of the population. WASA covers 20% while private providers contribute to the remaining 10%. The estimated total number of WASA customers served by central sewer systems is approximately 79,800. Today, WASA owns and operates 88 wastewater facilities spread across Trinidad and Tobago.

YEAR	MILESTONES
1861	First underground sewer system was constructed in Port-of-Spain
1902	First major sewerage works built along Wrightson Road
1962	Construction of Treatment Systems in the areas of San Fernando, Port of Spain and Arima
1965	WASA was established as a consolidated entity
1966	Island wide Sewerage Extension Project undertaken by the Lock Joint Ltd
1980	WASA completed the construction of the Piarco Wastewater Treatment Plant
1994	Scarborough Wastewater Treatment Plant was completed
2001	Construction of the new Beetham Wastewater Treatment Plant commenced
2004	Beetham Plant was completed

Table 1: Summary Wastewater Sector Milestones

CHAPTER 3

KEY WASTEWATER DEVELOPMENT INTERVENTIONS

In Trinidad and Tobago the development of the wastewater sector was influenced by several interventions over its history. With the construction of the first wastewater system in Port of Spain in 1861, Trinidad and Tobago had embarked on the development path for this sector, particularly in its urban centers. In Tobago, planned integrated wastewater initiatives are of very recent vintage and date back to the recent 1990's with the completion of works on the Scarborough Wastewater Treatment Plant in 1994.

3.1 Construction Projects

3.1.1 San Fernando, Arima and Port of Spain wastewater systems

The first major national wastewater development in the country was implemented in the 1960's by Lock Joint America Ltd. This project represented the largest single capital injection into wastewater management and infrastructure over the then one hundred and five (105) year old history of the sector. This project was executed by Lock Joint (America Ltd) in 1966 and saw the construction and expansion of three (3) major sewer collection and treatment systems in Trinidad. The areas sewered in this initiative were Port of Spain, Arima and San Fernando and included the installation of 384 km of street sewers and 5,000 manholes. The major pumping stations and treatment plants supporting the collection system were also constructed during this project with the Arima and San Fernando plants utilizing a trickling filter system to achieve secondary level treatment, while the Port of Spain plant utilized stabilization ponds. Developments and expansion over the years resulted in a length of sewer coverage of 428 km.

3.1.2 New Beetham Wastewater Treatment Plant

The wastewater treatment plant at Beetham serves the greater part of Port of Spain including Maraval, Woodbrook, Central Port of Spain, Belmont, St. Ann's, Morvant, Laventille, Barataria and Mount Hope. At present, the Beetham Wastewater Treatment Plant is the largest sewage treatment plant in the Caribbean; it is also utilizes Ultra Violet (UV) radiation to disinfect the effluent. The treated effluent from the plant is discharged into the environment and poses no threat to this sensitive ecosystem.

The new plant was constructed over the period 2001 to 2004. This project was broken into two (2) phases. The first phase has resulted in the production of an average dry weather flow of 80,000m^3/day which after being treated is suitable for the supply of industrial grade water. The second phase is intended to move the average dry weather flow production by an additional 110,000m^3/day. The key features of the New Beetham plant include:

- A rehabilitated Beetham Pump Station
- New biological treatment plant with nitrification and denitrification
- State of the art UV disinfection which eliminates the need for chemicals
- Waste stabilization lagoons (to be implemented)

At the Beetham Wastewater Treatment plant the treatment process comprises:

- Preliminary Treatment- Mechanically cleaned step screens with 6 mm opening vortex grit removal chambers
- Secondary Treatment- Activated sludge extended aeration plant consisting of a 45,000 m^3 bioreactor and four (4) 39 m diameter secondary clarifiers
- Disinfection- Ultra Violet disinfection, dose rate of 26 m Ws/ cm^2
- Biosolids Treatment- Low rate anaerobic digestion consisting of two (2) 45,000 m^3 earthen basins, biogas removal system (to be implemented)

3.1.3 New Scarborough Wastewater Treatment Plant

The wastewater treatment plant at Scarborough is the largest wastewater treatment facility on the island of Tobago and serves the southwestern parts of the island. This plant was constructed over the period 1992 to 1994; with the 1997 commissioning putting the plant into operation to service a potential population of ten thousand (10,000) individuals. This also included a small contribution from commercial and industrial sources.

Designed to accommodate an average daily flow of approximately 3000 m^3/day, its associated maximum daily treatment is approximately 6300 m^3/day. The facility provides Secondary

Treatment (activated sludge) via its Extended Aeration system with Tertiary Filters and discharges its treated effluent into the Rockley Bay via a 305 m outfall pipeline.

3.2 Studies

The high population concentration along the East-West corridor necessitated the conduct of several studies and investigation over the years. This was a bid to assess and design wastewater systems to meet the current and future needs of communities in these areas.

- Sewerage Facilities; Eastern Main Road Communities: by Millette Engineering (international Ltd. in Joint Venture with Howard Humphreys Ltd. – Commissioned in 1978
- Feasibility Study and Preliminary Designs for the Collection, Treatment and Disposal of wastewater in Tobago- Thames Water International (England) in association with Reid Crowther International (Canada) and ADeB Consultants (Trinidad) - 1994
- Greater Port of Spain Sewerage System Study (GPOSSSS) - Reid Crowther in association with Alpha Engineering - 1998
- Feasibility Study and Preliminary Designs for the Collection, Treatment and Disposal of wastewater in Tobago- American Water Services Engineering Inc. - 2004
- Expansion and Integration of Existing Wastewater Systems in Trinidad along the East-West Corridor and its Environs. ; Safege Consulting Engineering and ADeB Consulting Ltd. - 2005.
- Water and Wastewater Master Planning Intervention - 2009
- Consultancy Services for design of the collection system and wastewater treatment plant in South West Tobago- MAAK Technologies Inc. - 2010
- San Fernando Integration Study - Earth Tech- 2010

3.3 Adoption of private wastewater treatment plants

From the late 1990's to the present time several studies were conducted and recommendations made as it related to private wastewater treatment plants. All studies point to the fact that private developers do not operate the wastewater treatment plant and associated infrastructure in a manner which will result in the wastewater being properly treated and safely discharged into the environment.

Governmental intervention has taken place mandating WASA to take over, upgrade and operate these facilities. The process of adoption includes the transfer of ownership, the upgrade of the facility and the implementation of an operations and maintenance programme. Challenges faced in the implementation of the adoption process mainly surround the issue of ownership and its transfer to WASA.

3.3.1. Rehabilitation of Private Wastewater Treatment Plants (IDB Support)

Over the last 30 years as the population grew and new housing schemes were built without an adequate parallel expansion of the central wastewater systems, the GORTT required residential and industrial land developers to build and operate their own sewers and packaged wastewater treatment plants (in Tobago the wastewater treatment plants are mainly owned by hotels). This would allow WASA time to expand its central wastewater systems, allowing these new housing schemes to connect at a later date to the central wastewater system. However, the developers did not have the authority to collect fees to pay for operation and maintenance (O&M) costs. As a result, in most cases once the developments were completed, O&M ceased and the plants became orphaned, giving rise to low service levels and poor quality effluent being discharged into the environment.

In recent times, WASA has started the takeover of these small plants with the initial adoption of twenty-four (24) wastewater treatment plants and eleven (11) lift stations, which were previously owned by the Housing Development Corporation (HDC). The adoption of these additional plants proved unprofitable due to the high O&M cost and the low wastewater tariffs.

It is estimated that majority of privately-owned wastewater treatment plants are mal-functioning or have been abandoned. Water quality is impacted by the poor performance of the wastewater treatment plants through contamination of the surface water and groundwater sources. Surface water and groundwater sources provide 62% and 27% of the water supply respectively.

The major threat concerning surface water availability is related to watershed management. The continued disposal of untreated wastewater into rivers and coastal waters has an effect on the quality of both human and aquatic life, and in the case of Tobago poses a serious environmental and ecological threat, as well as an economic threat to the tourism sector. Improperly treated effluent has adverse effects on water quality, thereby increasing bacterial and viral contamination, turbidity levels and reducing the dissolved oxygen content.

In light of the preceding circumstances, the Government of Trinidad and Tobago (GORTT) has requested the Inter American Development Bank's (IDB) support to finance a non-reimbursable Technical Cooperation (TC) to assess the condition of all private wastewater treatment facilities in the context of the overall sector, and to develop an action plan for the needed improvement. These activities will be part of a broader effort to modernize the wastewater sector in Trinidad and Tobago and achieve enhanced environmental conditions with an improved quality of wastewater effluent and improve operational efficiencies of the Water and Sewerage Authority.

Section 2

National Wastewater System

CHAPTER 4

NATIONAL WASTEWATER SYSTEM

In Trinidad and Tobago, approximately 30% of the population is sewered and serviced directly by WASA. The remaining 70% of the population is serviced by septic tanks, soakaways and pit latrines.

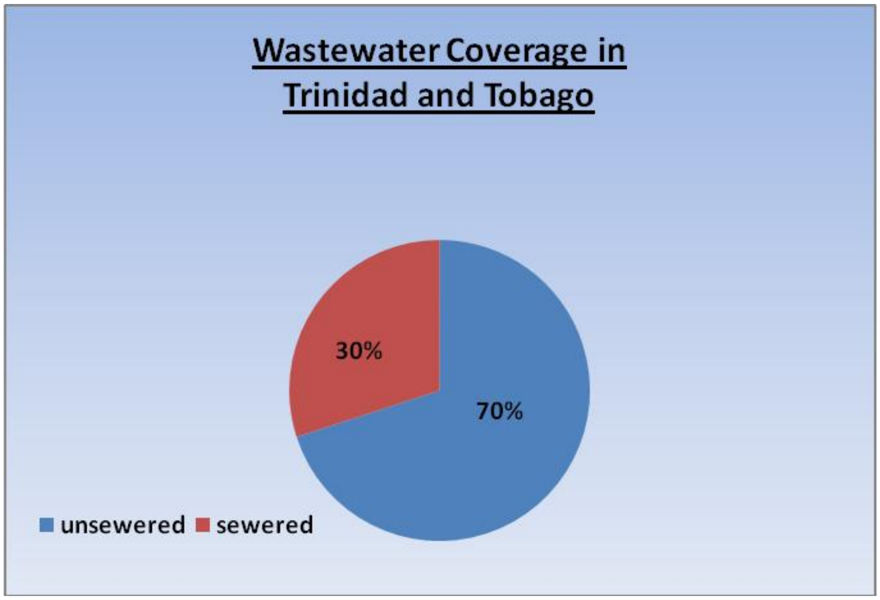

Figure 3: Percentage of Wastewater Coverage

WASA has constructed twelve (12) wastewater systems across Trinidad and Tobago. In addition, there are a significant number of small wastewater treatment facilities that are poorly maintained or abandoned, resulting in improperly treated sewerage being discharged into the environment. WASA is currently in the process of adopting and refurbishing a number of wastewater facilities from various government authorities. These authorities include the former National Housing Authority (NHA), now the Housing Development Corporation (HDC) and the Urban Development Company of Trinidad and Tobago (UDeCOTT). WASA plans to adopt and refurbish over one hundred and fifty (150) sewerage treatment plants within private land developments with the intention to integrate these smaller systems into larger regional sewerage treatment facilities.

With the exception of the Beetham and the Scarborough Wastewater Treatment Plants, the wastewater infrastructure in the urban centers is over twenty five (25) years old. The Arima and San Fernando Wastewater Treatment Plants and collection systems, as well as the collection systems in Port of Spain and environs, are over forty five (45) years old. As such, some sections of the infrastructure have come to the end of their useful life and are in need of replacement. This is evidenced by frequent equipment failure and collapses of sewers, as was the case at Scott Street San Fernando in 2010.

As a result of this aging infrastructure a number of challenges arise. The following are the major challenges associated with the elements of the wastewater system:

- ❖ Collection System
  - Infiltration and Inflow – Infiltration and inflow causes increase in flows during rain events often resulting in flooding of the wetwell and hydraulic overload which impact the treatment process
  - Absence of way-leaves and rights of way – There is a growing problem of properties being built on the sewers and manholes. This prevents access for maintenance and repair works and puts the building at risk in case of collapse
  - Undersized Sewers and poorly constructed sewers – With the growth and development of Port of Spain and San Fernando, some of the sewers are now undersized and are in need of replacement.
  - River Erosion – River erosion has been a major challenge for the infrastructure as some of the sewers were constructed on the banks of rivers. With the continuing erosion of these river banks over the years, the collection system infrastructure has been damaged to the point where there are broken sewers from which raw sewage flows directly into the rivers.
  - Fats, Oils and Grease (FOG) – With the increase in the number of fast foods establishments over the years, the presence of fats, oils and grease in the sewers has created many blockages resulting in overflowing sewers. This is mainly due to the absence of, or poorly maintained, grease interceptors by the owners of the establishment.

- ❖ Lift Stations
    - Malfunctioning equipment
    - No standby equipment
    - Deteriorating physical infrastructure

- ❖ Wastewater Treatment Plants (WWTP)
    - No preliminary treatment – Non functional comminutors and absence of screens. (This often results in damage to pumps)
    - Absence of functional standby generators
    - Deteriorated physical infrastructure
    - Non-functional and malfunctioning pumps and valves
    - Faulty electrical wiring

4.1 Trinidad Wastewater System

In Trinidad, the main wastewater treatment plants are spread across the North, South and East of the island. The Beetham Wastewater Treatment Facility serves the Greater Port of Spain region. In addition to the Beetham WWTP, there are several other sewage treatment installations existing in Port of Spain namely Dundonald Hill, Valley View Hotel, Diego Martin etc. Wastewater from the Diego Martin Area is transferred to the Beetham WWTP via the Diego Martin Pumping Station. Diego Martin is the most developed urban center in the northwestern peninsular of Trinidad and almost eighty percent (80%) of the area has sewerage coverage. Other portions are covered by septic tanks and pit latrines. Waste from the Carenage area is also transferred to the Beetham WWTP via the Diego Martin Pumping Station. It is estimated that almost seventy five percent (75%) of Carenage has sewerage coverage.

The Borough of Arima is mainly served by the Arima WWTP which has a trickling filter design; a WASA owned and operated treatment plant. The effluent from this plant is discharged to the Mausica River, a tributary of the Caroni River. Discharge from this plant can affect raw water quality of Caroni water treatment plant, the largest water treatment plant in Trinidad, as the intake is located downstream of the Wastewater Treatment Plant.

The City of San Fernando is served mainly by a WWTP owned and operated by WASA. The San Fernando WWTP has a trickling filter design and discharges into the Cipero River. The plant provides co-treatment of septage and wastewater.

There are several wastewater treatment plants in the Borough of Chaguanas. Two of them serve housing estates and another three of them serve shopping centers in the area. The package plants are not in satisfactory operational condition. The rest of the population use septic tanks and pit latrines. The use of these systems is not advisable considering that the soil type is clay and there is an elevated water table in the region. During the rainy season, area flooding causes overflow of the septic tank and pit latrines. This contributes to a major source of pollution to the local water courses.

A lift station located in Strikers Village pumps waste from Striker's Village in Point Fortin to the nearby Southern Gardens Wastewater Treatment plant which is owned and operated by the Housing Development Corporation (HDC). In addition, there are other treatment installations located in the Point Fortin region. The majority of the area depends on on-site treatment systems like septic tanks and pit latrines.

The Eastern Main Road area (between Curepe and Sangre Grande along the East-West corridor) is served mainly by activated sludge package treatment plants, which serve small and medium size housing developments. Most of them are owned by private housing developers while some of the others are owned by HDC. The package plants do not operate at a satisfactory level. As a result, most of the wastewater of this region is discharged to watercourses without adequate treatment. This is a cause of major water pollution and public health hazards.

There are several wastewater package treatment plants located within Sangre Grande, Couva, Fyzabad, Siparia and Princes Town. The majority of these communities depend on septic tanks and pit latrines. Mayaro is a rural community consisting mainly of a fishing village with slow commercial developmental growth. Wastewater treatment is generally achieved by the use of on-lot systems (pit latrines and septic tanks). Within the Mayaro community three (3) package wastewater treatment facilities exist to serve the Mayaro Composite School, the Leisure Ville Housing Development and the ABCD development.

In the Chaguaramas area there are approximately five (5) sewage lift stations. There are also some wastewater treatment plants, namely the Point Gourde Treatment Plant, the Granwood WWTP, the Power Boat WWTP, Coast Guard WWTP and the Teteron WWTP.

4.2 Tobago Wastewater System

With few exceptions, wastewater treatment plants in Tobago fall into five broad categories: septic tank and tile drain or soak away systems; septic tanks followed by secondary treatment systems; lagoons; trickling filters and activated sludge package plants. The Scarborough WWTP, serving the Scarborough town area is an extended aeration plant.

The majority of the private properties in Tobago are currently served by onsite systems such as pit latrines, septic tanks and soakaway systems and package plants. There are two housing developments, Milford Court at Bon Accord and Coral Gardens at Buccoo that have their own sewer collection system and package sewage treatment plants.

There is a three stage lagoon treatment system at the Studley Park Landfill site. The treatment train consists of an anaerobic lagoon, a facultative pond and a maturation pond with chlorine disinfection. In the absence of public sewage collection systems, most of the commercial, industrial, hotels, schools, hospitals etc. have to adopt their own sewage treatment and disposal facilities mainly composed of package treatment plants, onsite septic tanks or waste stabilization ponds. Most of these facilities are intended to provide temporary or short-term solutions.

NO.	FACILITY NAME	FACILITY ADDRESS	AREA SERVICED	DESIGN FLOWS (M^3/D)
1	Beetham WWTP	Beetham Highway, Sea Lots	East/West Corridor between Carenage & Mt. Hope - exclusive of Santa Cruz and Upper Maraval	**80,000**
2	San Fernando WWTP	Riverside Drive, San Fernando	City of San Fernando	**17,032**
3	Arima WWTP	Acton Cezair Private Road, Arima	Borough of Arima Dundee Village	**5,450**
4	Scarborough WWTP	Smithsfield Scarborough, Tobago	City of Scarborough	**2,906**
5	Trincity WWTP	Churchill Roosevelt Highway, Trincity	Orange Grove/Samaan Gardens, Trincity Industrial Estate & Mocoya	**400**
6	Santa Rosa WWTP	Pinto Road South, Arima	Santa Rosa Housing Development	**1,590**
7	Lange Park WWTP	Gaston Street Ext., Lange Park, Chaguanas	Lange Park Housing Development	**681**
8	Techier WWTP	Techier Road, Point Fortin	Techier Housing Development	**454**
9	Penco Lands WWTP	Royal Palm Ave., Penco Lands, Chaguanas	Penco Housing Development	**143**
10	Head Office WWTP	Farm Road, St. Joseph	WASA Head Office Complex	**130**
11	Piarco WWTP	Golden Grove Road, Piarco	Old Piarco, Int'l Terminal Bldg. & Caroni Water Treatment Plant	**176**
12	Chaguaramas WWTP	Point Gorude, Chaguaramas	Convention Centre area and upper Macqueripe	**350**

Table 2: List of WASA Wastewater Treatment Plants (WWTP)

4.3 Private Wastewater Systems

In 2009 an assessment of the wastewater sector was conducted. The data derived indicated the existence of more than one hundred of fifty (150) private wastewater systems in Trinidad and Tobago. Private wastewater plants in Trinidad and Tobago are generally in a poor working condition and pose a risk to public health and the environment. Private wastewater treatment plants, as the name suggests, are considered to be all wastewater plants that are not owned and operated by WASA, and include plants owned by governmental ministries and departments, state and private residential developments and those within the industrial and commercial sectors.

The sector distribution of private wastewater treatment plants is generally as follows:

- Private residential developments
- State residential developments (HDC, UDeCOTT), etc)
- State agencies (SWMCOL,TDC, etc)
- Government Ministries (Health, Education, THA, etc)
- Industrial
- Commercial (Malls, Shopping Centers, etc)

4.3.1 Private plant design and process

In the design of private wastewater treatment it is common to find one of the three process types listed below. The main process type is Extended Aeration Activated Sludge (EAAS) treatment.

In the Extended Aeration process, the raw sewage first is sent to the aeration tank for treatment. Settling then takes place at the Clarifiers before treated effluent is discharged. As the name suggests, an extended period of time is spent in exposing the wastewater to air, this can typically be a twenty four (24) hour period of time.

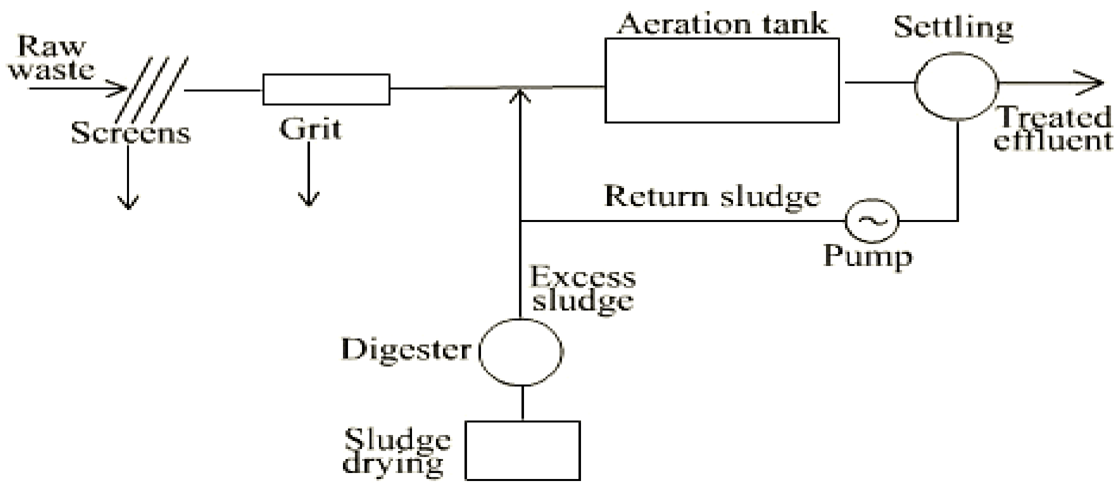

Figure 4: Typical Extended Aeration flow process

4.3.2 Challenges and Interventions

In a bid to meet the demands of the national community for sewage services, WASA, has provided permission to private developers, to construct and operate their own wastewater treatment plants and associated collection systems. This practice still continues today with much closer scrutiny being placed on the developers to ensure compliance with designs and operations guidelines.

The number of private wastewater treatment plants are increasing every year. This coupled with the practice by developers to abandon the operations and maintenance of these facilities once the house plots and or houses are sold pose a critical challenge to WASA and the national community. Instances of total abandonment of private wastewater facilities are now commonplace and result in potential risk of the spread of diseases and contamination of the natural environment.

Interventions have taken place to address the occasions of abandoned or orphaned wastewater treatment plants that are in existence within Trinidad and Tobago. At the governmental level, policy decisions have been taken for WASA to adopt these facilities in a bid to arrest the risk to public and environmental health.

Over the past fifteen (15) years WASA has taken over responsibility for a number of wastewater plants previously owned and operated by state and private concerns. However, the challenge continues to be inadequate funding, difficulties in the transfer of title to WASA and the maintenance of poorly functioning plants. Recent initiatives by WASA are expected to positively impact the funding stream required to rehabilitate some of the critical abandoned private wastewater treatment plants. One such initiative is the collaboration with Inter American Development Bank (IDB) targeting the refurbishment of abandoned private wastewater treatment plants.

Further challenges are faced by the imposition of the Water Pollutions Rules 2006 as it relates to the discharge quality of treated effluent from wastewater treatment plants into the environment. The Environmental Management Authority (EMA) is the state body with the fiduciary responsibility for ensuring compliance with these standards. To fulfill this responsibility, the EMA has commenced a programme of permitting of all wastewater treatment plants in Trinidad and Tobago.

Section 3

Integrated Wastewater Management

CHAPTER 5

NATIONAL WASTEWATER LEGISLATION & REGULATIONS

Currently there exist a number of legislations relating to the wastewater sector. As a result of this, multiple agencies have the responsibility for various activities within the sector. The following is a summary of various segments of legislation which relate to the wastewater sector:

5.1 Water and Sewerage Authority Act

The Water and Sewerage Authority was formed by Act 16 of 1965 and enacted on 1st September, 1965. The Act gave WASA the responsibility to manage the water and sewerage sector of Trinidad and Tobago. This Act brought together several agencies, which were formerly charged with the responsibility of providing water and sewerage facilities to the nation. These are as follows:

- Central Water Distribution Authority
- Port of Spain City Council
- San Fernando City Borough Council
- Arima Borough Council
- County Councils
- Water Division of the Ministry of Public Utilities
- Sanitation Division of the Ministry of Public Utilities

The Act provides for the establishment of an Authority to administer the development and control of sewerage facilities. It addresses a range of issues related to wastewater, including water charges and sanitation. Part (IV) of the legislation deals with sewerage.

5.1.1 National Plumbing Code of Trinidad and Tobago

This regulation was made under the Water and Sewerage Act. 1965 Section 66(7). The objectives of this code are to ensure the protection of public health and provide consistency in the plumbing requirements of Trinidad and Tobago. Present day application of this code requires the submission of planning drawings when a request for a new sewer connection is made to WASA.

5.2 Environmental Management Act

The Environmental Management Authority (EMA) is the statutory body responsible for the protection, conservation and enhancement of the environment of Trinidad and Tobago. It was established with the enactment of the Environmental Management Act of 1995, which was further amended in 2000. The Environmental Management Act, 2000 is divided into nine parts. In Parts IV, V and VI, the Act addresses rules and public participation, environmental management and enforcement which have significance for the management of Wastewater sectors in terms of waste management and pollution control.

This Environmental Management Act, 2000 is considered as the primary legislation from which several subsidiary legislations have evolved. The Water Pollution Rules of 2001 and amended in 2006 is one of the major subsidiary legislation which has significance for wastewater management.

5.2.1 Water Pollution Rules, 2001(Amended 2006)

In the Water Pollution Rules, a list of quantity, condition or concentration of substances or parameters is defined as a pollutant. According to this rule, any water pollutants released into the environment, need to submit a source application 45 days prior to such release.

The maximum permissible pollutant levels to different water environments are assigned and any release outside these permissible levels, may be notified by the authority to apply for a permit. Any person granted a permit, shall be required to pay the associated prescribed fee.

For Environmentally Sensitive Areas, the Water Pollution Rules has more stringent permissible limits than Trinidad and Tobago Bureau of Standards allowable levels for BOD5, TSS and Fecal coliforms. These stringent requirements of Water Pollution Rules, especially for nutrient removal and Faecal Coliforms, required secondary level of treatment with some degree of nutrient removal.

5.2.2 Certificate of Environmental Clearance (CEC) Rules

The Certificate of Environmental Clearance (CEC) Rules were implemented in 2001, as a subsidiary legislation, pursuant to the Environmental Management Act. The CEC Rules have jurisdiction over 44 types of physical development (an Activity). The Rules require that once a proponent intends to undertake any of the Activities identified, a permit known as a Certificate of Environmental Clearance must be obtained prior to the start of works. The activities with respect to wastewater, which fall into one of three components of the legislation, known as the CEC Order (2001), include the establishment of sewage treatment plants.

5.3 Trinidad and Tobago Bureau of Standards

The Trinidad and Tobago Bureau of Standards is a body corporate established under the authority of the Standards Act (Chapter 82: 03 as amended by Act 29 of 1985). The primary role of TTBS is to develop, promote and enforce standards, in order to improve the quality and performance of goods produced or used in the Republic of Trinidad and Tobago, to ensure industrial efficiency and development; promote public and industrial welfare, health and safety; and protect the environment.

The Trinidad and Tobago Bureau of Standards has the following standards regarding wastewater treatment and disposal:

1. Specification for Liquid Effluent from Domestic Wastewater Treatment Plants into the Environment (TTS 417: 1994) – This standard specifies the maximum permissible levels of the 5-day Biochemical Oxygen Demand (BOD5), Suspended Solids, Total Residual Chlorine and Faecal Coliforms for the liquid effluent from domestic wastewater treatment plants into various points of the environment. The Water Pollution Rules (amended 2006) supersedes this standard.

2. Specification for the Effluent from Industrial Process Discharged into the Environment (TTS 547:1998) - This standard specifies the permissible limits for key parameters of the effluent from point source pollution from industrial processes discharged into the environment.

3. Code of Practice for the design and Construction of Septic Tanks and Associated Secondary Treatment and Disposal Systems (TTS 16 80 400 1991) – This standard gives recommendations for the design, location, construction and maintenance of septic tanks and includes methods of treatment and disposal of septic tank effluent from domestic sewage.

4. Recommendations for the Design of Building; Plumbing and Drainage Systems (TTS 16 90 400 1985) - Outlines practices, materials and fixtures to be used in the installation, maintenance, extensions and alteration of all pipes, fixtures and appliances in plumbing and drainage.

5.4 The Regulated Industries Commission Act

The Regulated Industries Commission (RIC) is a statutory body established under the Regulated Industries Commission Act, No. 26 of 1998. Section six (6) of the RIC Act (No. 26 of 1998) empowers the RIC to prescribe standards for services, monitor service providers, conduct checks for compliance and impose sanctions for non-compliance. One such service is the provision of wastewater services. The Service Provider under the jurisdiction of the RIC is WASA, which is the main provider of wastewater services.

5.5 Trade Effluent Standard

The Water and Sewerage Authority has developed the Trade Effluent Standards for discharges into Public Sewers (WASA TES 101:2002). This standard was developed in order to control and manage industrial and commercial discharges into public sewers. The presence of certain constituents in Trade (Industrial and Commercial) Effluent may damage sewers and may hamper the proper operation of wastewater treatment plants. Therefore, it is necessary to limit the concentration of such undesirable constituents in trade effluents discharged into public sewers. In order to prevent the ill effects of untreated trade effluents on sewers and wastewater treatment plants, it is necessary to limit certain constituents potentially present in the trade effluents before allowing them to be discharged into any sewerage system. These standards although evidently required, have not yet been legislated.

5.6 Other ordinances that govern wastewater include:

- The Housing Act
- The Land Acquisition Act
- Town and Country Planning Act
- The Public Health Act
- The Planning & Development of Lands Bill
- Occupational Health & Safety Act

LEGISLATION/ REGULATION	KEY PROVISIONS	YEAR
Water and Sewerage Act (Chapter 54:40)	Gave WASA the responsibility to manage the water and sewerage sector of Trinidad and Tobago. Provides for the establishment of an Authority to administer the development and control of sewerage facilities.	1965
National Plumbing Code of Trinidad and Tobago	Ensure the protection of public health and to make the plumbing requirements of Trinidad and Tobago uniform and simple as possible without lowering the recommended standards of environmental sanitation.	Made under the Water and Sewerage Act. 1965 Sec.66(7)
Recommendations for the Design of Building; Plumbing and Drainage Systems (TTS 16 90 400-4)	Outlines practices, materials and fixtures to be used in the installation, maintenance, extensions and alteration of all pipes, fixtures and appliances in plumbing and drainage.	1985
Code of Practice for the design and Construction of Septic Tanks and Associated Secondary Treatment and Disposal Systems (TTS 16 80 400/1991)	Provides recommendations for the design, location, construction and maintenance of septic tanks and includes methods of treatment and disposal of septic tank effluent from domestic sewage.	1991

Table 3: Listing of Wastewater Legislation/Regulation relevant to Wastewater Sector

(Table 3 continued…)

LEGISLATION/ REGULATION	KEY PROVISIONS	YEAR
Specification for Liquid Effluent from Domestic Wastewater Treatment Plants into the Environment (TTS 417: 1994)	Specifies the maximum permissible levels of the 5-day Biochemical Oxygen Demand (BOD5), Suspended Solids, Total Residual Chlorine and Faecal Coliforms for the liquid effluent from domestic wastewater treatment plants into various points of the environment	1994
Environmental Management Act (Chapter 35:05)	Established the Environmental Management Authority (EMA) as the statutory body responsible for the protection, conservation and enhancement of the environment of Trinidad and Tobago.	1995, amended in 2005
Specification for the Effluent from Industrial Process Discharged into the Environment (TTS 547:1998)	Specifies the permissible limits for key parameters of the effluent from point source pollution from industrial processes discharged into the environment.	1998
The Regulated Industries Commission Act (No. 26 of 1998)	Empowers the RIC to prescribe standards for services, monitor service providers, conduct checks for compliance and impose sanctions for non-compliance.	1998
Certificate of Environmental Clearance (CEC) Rules	Once a proponent intends to undertake any of the Activities identified in the Rules, a permit known as a Certificate of Environmental Clearance must be obtained prior to the start of works.	2001
Water Pollution Rules	Quantity, condition or concentration of which substances or parameters are defined as a pollutant are listed	2001, amended in 2006
	Ensures that any water pollutants released into the environment, a source application 45 days prior to such release is submitted	
Trade Effluent Standard(WASA TES 101:2002)	Developed in order to control and manage industrial and commercial discharges into public sewers.	2002

Table 3: Listing of Wastewater Legislation/Regulation relevant to Wastewater Sector

CHAPTER 6

WASTEWATER MANAGEMENT

The wastewater industry is constantly evolving, as regulations and advancements in technologies vary. The sector now has the responsibility to respond to meet these challenges, adapt new methods and constantly work towards improvement programmes for the treatment process. This is important so as to ensure the ability to meet quality standards, in recognition of the importance of wastewater management. Consequently, these measures would provide the Authority with the ability to meet established quality standards.

The Integrated Wastewater Management Forum (IWMF) is one of the tools that has been used to effectively implement Wastewater Management with the utilization of stakeholder involvement and participation.

The goal of Wastewater Management is:

- To provide suitable wastewater treatment facilities using appropriate technology and
- methodology
- To ensure wastewater does not harm the marine /soil environment and public health
- To have treatment and disposal systems that supports the economic success of the industry
- To achieve compliance with appropriate Acts, Plans and standards

6.1 Integrated Wastewater Management Initiative

The wastewater sector in Trinidad and Tobago is currently presenting several opportunities and challenges, generally characterized by an inadequate level of service coverage and delivery which adversely impacts on Sanitation and the Environment.

The Integrated Wastewater Management Forum focuses on:

- Actions at the local level, which target improved Wastewater Services Delivery, meeting Sanitation requirements and Environmental Enhancement,

- An integrated approach which targets the development of a level of greater understanding of the significance of wastewater management to health, sanitation and the environment in Trinidad and Tobago.

6.1.1 Objective

To impact on Service Levels and Environmental Enhancement by:

- Targeting Communities, assessing the issues affecting them and undertaking relevant actions geared towards the main objective,

- Involving local groups and bodies in actions which would improve the level of service in the short, medium and long term incorporating formal stakeholder interactions and social learning activities,

- Increasing awareness of effective Wastewater Management with respect to Services and Environmental Protection and Enhancement (health, sanitation and the environment).

6.1.2 Benefits

- Improvement of Service to Customers

- Aids in the understanding of the significance of Wastewater Management and its relevance to Health, Sanitation and the Environment

- Facilitates an integrated approach involving local communities and stakeholders

- Allows for Capacity Building and Social Learning Opportunities

- Fosters relevant linkages, associations and relationships

6.1.3 Successes

6.1.3.1 Santa Cruz, Caura and San Fernando and Environs

- Repairs and aesthetic works were carried out on package plants in the areas such as Homestead, Santa Cruz and Pleasantville, San Fernando. Through the forum, continued monitoring of these plants is carried out so that assistance can be provided when needed.

- The school outreach programme incorporated primary schools in the area to spread the message of proper wastewater practices.

- Georeference information of wastewater infrastructure and types of systems existing in impact areas were collected and are being entered into a database that will be utilized to map the area.

- Water quality information of effluent from plants in the area was collected to assess the water quality situation in the area.

Figure 5: Examples of Public Interventions

6.1.4 Community – Based Approach

To effectively operate and maintain our sewer systems, public awareness on the part of the citizens and users of the systems can contribute significantly to the prevention of expensive sewer repairs and the protection of the environment.

6.1.4.1 Key Services from Stakeholders in IWMF

- **Regional Corporations (Cesspool Unit)** – A key service is to provide vacuum-pumped sewage hauling trucks to empty septic tanks. Solids must be periodically removed from the septic tank and disposed of to ensure the tank functions properly.

- **Ministry of Health (Public Health)** – The health of the public is negatively impacted if proper sanitation is not practiced. Sanitation refers to hygienic practices of disposing human waste in ways that do not harm the environment and general public health. Good sanitation greatly depends on household responsibilities to choose, use, and maintain the technology, such as a toilet and a septic tank. A key role of this organization would be to promote public health education.

- **Ministry of Health (Insect Vector)** – The expansion of certain populations of vectors can have a direct effect on human health as well. As vector populations expand, the incidence of certain vector-borne diseases, such as malaria and dengue may increase as well. The improper disposal of wastewater is one of the factors that have to be addressed simultaneously with insect vector control.
- **Ministry of Agriculture** - Where wastewater is insufficiently treated, appropriate irrigation, agricultural, and post-harvest practices would be applied to limit risks to farming communities, vendors, and consumers.

- **Residents/Councilor** – The role of the residents would be to work with the Authority in compiling a needs survey. In this way they would provide feedback and suggestions on wastewater management initiatives. The residents would be responsible for highlighting concerns that might be a problem within their area as well as aid in addressing questions.

CHAPTER 7

WASTEWATER, PUBLIC HEALTH & THE ENVIRONMENT

The degradation of the marine environment, as well as the irresponsible discharge of untreated water have become serious and critical areas of concern globally, regionally and nationally. Treatment of sewage is essential to ensure that the water returning into the environment meets the accepted regulatory standards.

7.1 How Wastewater affects you?

Wastewater may contain many disease-causing organisms and bacteria, harmful chemicals and heavy metals. If untreated this waste would seep into our groundwater or drain into our rivers and would eventually spread diseases and contaminate drinking water sources. In addition, the effectiveness of water treatment can be reduced since the more polluted the water, the more expensive and difficult it is to treat. The following is the potential impacts of wastewater use in various areas:

Impact Areas	Potential Impacts of Wastewater Use
Public Health & Other living organism	Use of untreated sewage water pose a high risk to human health and other living organisms in all groups as it contain pathogenic microorganisms which have the potential to cause diseases.
Crops	Wastewater (treated and untreated) is extensively used in agriculture because it is a rich source of nutrients and provides all the moisture necessary for crop growth. Most crops give higher than potential yields with wastewater irrigation; reduce the need for chemical fertilizers, resulting in net cost savings to farmers.
Soil Resources	Impact from wastewater on agricultural soil, is mainly due to the presence of high nutrient contents (Nitrogen and Phosphorus), high total dissolved solids and other constituents such as heavy metals, which are added to the soil over time. Wastewater can also contain salts that may accumulate in the root zone with possible harmful impacts on soil health and crop yields.

Impact Areas	Potential Impacts of Wastewater Use
Groundwater Resources	Wastewater application has the potential to affect the quality of groundwater resources in the long run through excess nutrients and salts found in wastewater leaching below the plant root zone. Groundwater constitutes a major source of potable water hence the potential of groundwater contamination needs to be evaluated before embarking on a major wastewater irrigation program.
Ecological	When drainage water from wastewater facilities drains particularly into small confined water bodies and surface water, and if phosphates in the orthophosphate form are present, the remains of nutrients may cause eutrophication, resulting in decreases in dissolved oxygen which may lead to changes in the composition of aquatic life, such as fish deaths and reduced fishery.
Social	Social concerns such as food safety, health and welfare, impaired quality of life loss of property values and sustainability of land use, can be impacted by wastewater use.

Table 4: Potential impacts of wastewater use

(a) Human Impacts **(b) Crop Damage** **(c) Fish kill**

Figure 6: Examples of impacts of poor wastewater management practices

7.1.1 Wastewater Environmental and Health Effects

Untreated or improperly treated wastewater contains biological contaminants known to cause diseases. These contaminants are known as germs or pathogens. Pathogens fall into five (5) main categories: - bacteria, viruses, protozoans, fungi and worms. Most of these pathogens use the faecal/oral route to spread disease. Faecal material, including human waste, contains pathogens. The usual method of infection requires you to touch the faecal material with your hands and then transfer it to your mouth, either directly or through food. Pathogens can also contaminate water supplies when the wastewater is allowed to reach the water table before adequate treatment occurs.

- **Bacteria** - Bacteria are microscopic, single celled organisms that are typically round (Cocci), rod shaped (Bacillus), or spiral (Spirochetsia). Bacterial shapes come from three (3) groups. Diplo means two (2) bacteria attached together, Strepto means a twisted chain of bacteria, and Staphylo means a large clump of bacteria. Some diseases caused by bacteria are *cholera*, which causes vomiting, diarrhea, dehydration and even death; *typhoid*, which causes fever, chills, and sometimes death; *salmonella*, which causes fever, nausea, vomiting, bloody diarrhea, cramps and sometimes death; *shigella*, which causes fever, nausea, vomiting and diarrhea; and *staphylococcus*, which causes skin infections and mucus membrane infections.
- **Virus** - Viruses use living cells to reproduce and cause infections. The virus penetrates the cell wall of the host, injects genetic material into it, and the host's infected cell makes more viruses. Diseases caused by viruses include *hepatitis A,* a viral infection of the liver which causes nausea, vomiting, diarrhea, skin and urine discoloration, weakness, and sometimes liver damage; *gastroenteritis*, a viral infection of the intestinal tract which causes fever, nausea, vomiting, diarrhea and pain; and *polio*, which causes inflammation of motor neurons of the spinal cord and brainstem, leading to paralysis, muscular atrophy and deformity, and sometimes death.
- **Fungi** - Fungi are non-photosynthetic living organisms such as yeast. They can be a single cell or a body mass of branched filaments. Diseases caused by fungi include *candidiasis*, which is transmitted by contact with feces or secretions from infected people. Although it usually causes mild infections, occasionally it may cause ulcers in the intestinal tract or lesions in the kidneys, brain or other organs.

- **Protozoans** - Protozoans are large (compared to bacteria) single celled animals which have the ability to move. Diseases caused by bacteria include *amoebiasis*, which causes bloody diarrhea and sometimes death; and *giardiasis,* which causes diarrhea and severe gas. One incidence of sickness caused by a protozoan is "Cryptosporidiosis". Caused by *Cryptosporidium*, the infection in humans can be divided into two distinctly different diseases, depending on the patient's immune status. There are few medications available to fight this disease.
- **Worms** - This category includes hook, round, pin, tape and flatworms. In an *ancylostomiasis* infection, a hookworm penetrates the skin of the feet and travels to the gut. *Ascariasis*, a roundworm, lays eggs in sewage contaminated soil, which is ingested by an individual with dirty hands. The worms develop in the gut, attack the lungs, liver and other organs.

7.1.2 Water Pollution

Failing septic systems allow excess nutrients to reach nearby rivers and streams, promoting algae and weed growth. Algal blooms and abundant weeds make the lake unpleasant for swimming and boating, and affect water quality to the water resources. As plants die, settle to the bottom, and decompose, they use oxygen that fish need to survive. Synthetic cleaning products and other chemicals used in the home can be toxic to humans, pets, and wildlife. If allowed to enter a failing septic system, these products may reach groundwater, nearby surface water, or the ground surface.

In the soil treatment portion of the septic system, bacteria and viruses in the sewage are filtered by the soil and microscopic organisms that occur naturally in the soil. Nutrients are absorbed by soil particles or taken up by plants. These processes only work in unsaturated soil that has air in it. Soil conditions may be saturated near rivers, streams and wetlands, and in areas with seasonal or perched high water tables. In these cases, biological breakdown will be incomplete and nutrients will move much greater distances.

7.2 Wastewater Awareness

The availability and supply of clean, safe potable water is essentially related to the level of sanitation. The management of wastewater disposal has become a fundamental factor in both the social and economic development of the country. Changes in our wastewater behavior will aid in the sustainability of the water resource.

7.2.1 Ways to help safeguard our Sewer Systems

To effectively operate and maintain our sewer systems, public awareness on the part of the citizens and users of the systems can contribute significantly to the prevention of expensive sewer repairs and the protection of the environment.

Protecting our Wastewater System

Do's

- Connect to the Public sewer system if one exists in your area. Very often, homes are allowed to build septic tanks when sewers are absent. However once sewers are introduced to your area, you are required to make the changes needed to connect to the system.
- Ensure that your internal plumbing is not clogged and that water can flow freely at all times.
- Report broken sewer mains or overflowing manholes to the relevant authorities. Call a Licensed Sanitary Contractor first, to determine whether the problem results from the private service connection or WASA's sewerage system. If the problem lies with WASA's system, the Wastewater Department should be contacted.
- Educate all the members of your household on the proper use of internal plumbing fixtures.
- Use a strainer in the sink to catch food scraps and other solids.
- Ensure the excess water, which does not need treatment such as storm water, roof runoff, subsurface drainage and cooling waters, do not enter the sewerage system. The treatment plant is not designed to accept large volumes of water that these sources produce.
- Pay your sewerage rates as long as you are served by a public system. Payment of these bills will ensure that the system is properly maintained. If your system is privately

owned, you should make regular contribution to your private service provider so as to ensure that the system can be properly maintained.

- Use Baking Soda instead of harsh chemicals like Bleach or Lye to clean sinks and toilet bowls. Harsh chemicals kill the bacteria that are needed to treat waste at the sewage treatment plant.

Don't

- Pour substances that are poisonous or flammable down the drain. Flammable substances can easily ignite and cause explosions in the sewers if sparked. Poisons can seep into the ground and enter your ecosystem or flow to the treatment plant, where they kill the useful bacteria there.
- Pour water or waste containing concentrated plating or acid solution as well as waste with high chlorine concentration down the plumbing fixture at your home.
- Pour used cooking oil down the sink. Cooking oil changes into hard waxy substances resembling lard, which block the sewers and can cause sewerage to divert to the streets or into our homes.
- Pour liquids that are highly acidic or alkaline and paints or solvents down the plumbing fixture at your home. Paints or solvents should be disposed of at proper hazardous waste disposal sites.
- Flush sanitary pads, diapers or condoms down the toilet. They cause blockage in the plumbing and the collection system as well as cause damage to the equipment at the treatment plant.
- Discharge solid or viscous (slow flowing) substances or solids such as, ash, cinders, mud, straw, shaving, metal, glass, fabric, wood, garbage, hair etc. into the sanitary sewers. These can clog sewer and cause sewage to backup into the streets and homes.
- Make unauthorized connections to the existing system. Faulty connections will give rise to plumbing problems in the home.
- Uncover manholes; pour any substances or place any objects into them. Manholes are to be used by wastewater workers only, for inspection and servicing of the system.

Figure 7: Aids to maintaining a healthy sewer system

Figure 8: Materials with potential adverse impacts on sewer system

CHAPTER 8

WASTEWATER SECTOR DEVELOPMENT

Several key technical considerations emerge as the Authority seeks to provide greater prominence to the wastewater component of its operations. These are covered below.

8.1 Tariff structure and rates charges

In most countries, the cost of provision of wastewater services doubles that for the provision of water services. In Trinidad and Tobago, historically, the reverse position applies. WASA and the Regulated Industries Commission (RIC) must therefore determine upon the appropriate tariff structure applicable to WASA for the provision of sewer services. This fee structure must consider the following:

- Cost of equipment
- Labour cost
- Materials cost
- Operations and Maintenance cost
- Capital infrastructure cost

8.2 Infrastructure Development

With only 30% of the population served by a centralized Wastewater System, it is evident that there must be considerable rationalization, reconstruction and expansion of plant and equipment to meet the needs of the current and future population. A short term target has been set for achieving 38% national coverage, as a first development milestone. This is to be achieved through the implementation of four (4) initiatives in Malabar (3%), Maloney (1%), San Fernando expansion (2%) and South west Tobago (2%).

Also planned to directly improve the service level to customers in the short term are the following projects;

- *Sewer replacement programme in San Fernando and Port of Spain*
- *Integration and expansion of the Wastewater collection system in Maloney, Tumpuna and Trincity areas.*

  This project will result in the integration of twenty (20) small wastewater treatment plants in three (3) large plants.
- *South West Tobago expansion-Phase1*

  The result of this project would be the upgrade of Coral gardens and Milford Court wastewater treatment plants to reduce the threat of damage to the Environmentally Sensitive Buccoo Bay (Buccoo Reef) as well as cater to the needs of the newly completed Buccoo goat race facility.
- *Refurbishment of the following WASA's wastewater treatment facilities*
  - Arima WWTP
  - San Fernando WWTP
  - Lange Park WWTP
  - Edinburgh 500 WWTP
  - Pleasantville Lift Station
- *Rehabilitation of the following private plants*
  - Point Pleasant Park WWTP
  - Mountain View WWTP
  - Orchard Gardens WWTP
  - Homeland Gardens WWTP
  - Ascot Gardens WWTP
  - Homestead Gardens WWTP
  - Providence Gardens WWTP

- *Rehabilitation of Adopted HDC Wastewater Treatment Plants at*
    - Maloney WWTP
    - Bon Air East WWTP
    - Cantaro WWTP
    - Fredrick Settlement WWTP
    - Orangefield WWTP

Regional plant network (medium –long term)

The medium to long term planning horizon for the national wastewater system incorporates the development of regional wastewater plants throughout the twin island state. These regional plants will result in an overall reduction in the number of wastewater treatment plants to be maintained and operated. As such, the system should require significantly less human resources in comparison to that needed for maintenance and operation of the existing system of small package plants within these regions.

8.3 Rehabilitation of adopted WWTP

This initiative will see the rehabilitation and adoption by WASA of all private wastewater treatment plants in Trinidad and Tobago. This is in support of the development of integrated regional plants and would assure that the coverage by WASA is at a maximum. This should result in improved service provision and enhancement environmental conditions.

8.4 Wastewater Careers – A viable development path

The increased prominence in the wastewater sector brings into focus options for career growth and development at several professional and technical levels. These development paths are required to ensure the acquisition of the best skills and expertise to guarantee wastewater sector sustainability.

8.5 Business Opportunities

In considering various models for the development of the wastewater sector business opportunities need to be identified in striving toward financial viability. Some of these potential opportunities include:

- Sewage extraction and haulage services
- Sewer unclogging and maintenance services
- Increased registration of residential sewer customers
- Fertilizer supplement for the agricultural sector
- Reclaimed water for industrial use
- Training and Capacity Building services

Technical –Operations	Non Technical- Support
Staff Assistants	Human Resources
Operator I/II/III	IT Personnel
Engineering Technician II/III	Legal Practitioners
Sewer Systems Manager	Corporate Service Staff
Treatment Plant Manager	Environmentalists
Sewer Investigation Officer	Financial Officers
Catchment Controller	Communications Officers
Technical Investigation Officer	Asset Maintenance Officers
Treatment Controller	Strategists
Assistant Manager Wastewater	Health and Safety Officers
Manager Wastewater	Project Planners
Quality Control Officers	Customer Care Officers
	Industrial Relations Officers
	Librarians
	Geographic Information Systems
	Audit

Table 5: Careers in the Wastewater Sector

Section 4

Wastewater Collection, Treatment and Disposal

CHAPTER 9

WASTEWATER TREATMENT PROCESSES

A well managed wastewater system provides protection against diseases while a poorly functioning system adversely impacts on the health, sanitation and well being of a community. A poorly functioning wastewater system results in the following:

- Disease causing bacteria/viruses
- Discomfort from foul odors
- Infestation by rodents
- Damage to marine life
- Reduction in recreational activities
- General damage to the environment and waterways

To effectively operate and maintain our sewer systems, public awareness on the part of the citizens and users of the systems can contribute significantly to the prevention of expensive sewer repairs and the protection of the environment.

The first step in understanding wastewater is to first understand what it is and how it works. Wastewater collection systems are the network or pipelines, manholes and pump stations designed to effectively collect and transmit the wastewater from households and businesses to a wastewater treatment plant.

The Treatment Plant is designed to receive wastewater from the collection system and treat it. This treatment process removes undesirable substances, which can cause pollution of rivers and streams and ultimately cause water-borne diseases in humans and other animal life. The Treatment Plant uses living organisms (mainly bacteria) together with mechanical equipment to reduce pollution in wastewater. The treated wastewater, called effluent, is then discharged into the environment.

The Wastewater treatment process begins once used water is flushed into the system. The wastewater proceeds from the premises by way of a lateral line (the property of the owner) to the collector line where it becomes the responsibility of the Authority. Wastewater arrives at the Treatment Plant through a piping system, which collects all sewage from communities. Primary treatment involves physically removing debris and large particles from the wastewater to prepare it for the biological treatment process that occurs during Secondary Treatment.

The following covers the various stages associated with the management of wastewater namely, collection, treatment and disposal

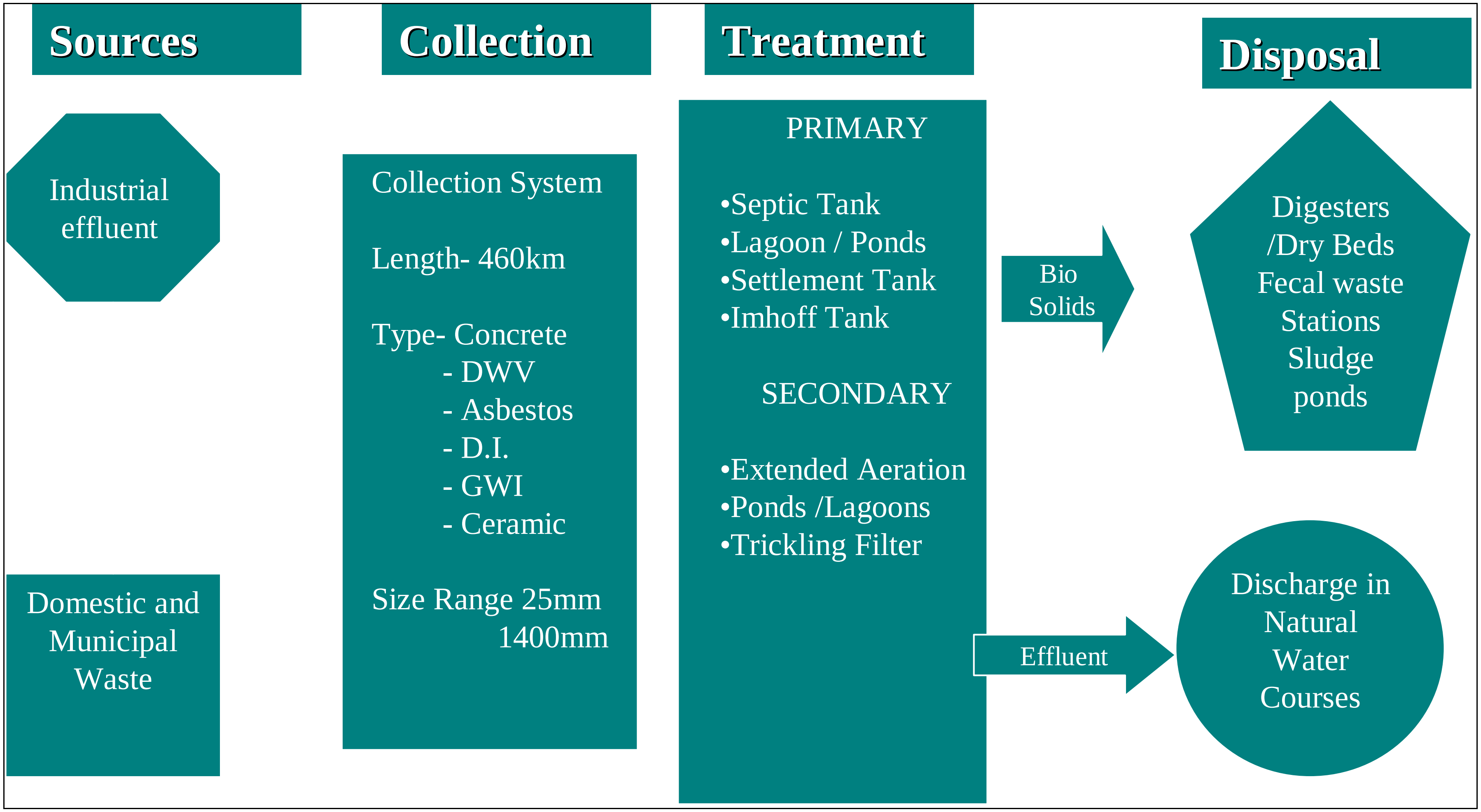

Figure 9: Overview of Wastewater Management Elements

9.1 Collection

Wastewater collection systems are the network of pipelines, manholes and pump stations designed to effectively collect and transmit the wastewater from households and businesses to a wastewater treatment plant nearest to you.

9.1.1Infiltration and inflow

Infiltration is groundwater entering sewers and building connections through defective joints and broken or cracked pipe and manholes. Inflow is water discharged into sewers or service connections from sources such as rain water guttering, yard drains. Excessive infiltration and inflow may create several serious problems such as surcharging of sewer lines with back up of sanitary wastes into buildings, flooding of streets and road areas, overloading of treatment works and bypassing of pumping stations and treatment works.

9.1.2 Types of Wastewater Collection System (Combined sewers, sanitary sewers and small bore sewers)

Combined sewers carry surface water runoff as well as domestic and commercial wastewaters to the treatment works for processing prior to their final disposal. Sanitary sewers transport domestic and commercial wastewater, as well as infiltration to the treatment works for final processing and disposal. Small bore sewer systems are designed to receive only the liquid portion of household wastewater for off-site treatment and disposal. Grit, grease and other troublesome solids which might cause obstruction in the sewers are separated from the waste flow in interceptor tanks installed upstream of every connection to the sewers; the solids which accumulate in the tanks are removed periodically for safe disposal. In Trinidad and Tobago the Authority designs its sewers for Sanitary Sewers.

The pipelines, also called sewers, are installed underground. Sanitary sewers transport wastewater from via gravity flow to treatment facilities. A lateral sewer collects discharges from the building and carries it to another branch sewer and has no tributary sewer lines. Branch sewers receive wastewater from laterals and convey it to large mains, called trunk sewers. These trunk sewers collect wastewater from large areas for final disposal to the treatment plant. A force main is a sewer through which wastewater is pumped under pressure rather than by gravity flow.

Design flows for sewers are based on the population served, these figures include for normal infiltration. The minimum recommended size of the sewer is 200mm diameter. Sewer slopes should be sufficient to maintain self cleansing velocities; this is normally 0.6m/s when flowing full. If the velocity is less than 0.6m/s deposition of solids can occur and septic conditions can be developed in the sewers. Where velocities are greater than 4.5m/s erosion of the sewers can take place.

9.1.3 Manholes

Sewer manholes can be recognized by their circular steel covers. They are placed along the pipeline in the middle (sometimes to the side) of the roadway to permit access to the pipes so that maintenance of the system can be performed. This is done to ensure that the wastewater reaches the treatment plant.

Manholes should be placed: at all changes in sewer grade, pipe size or alignment, at all intersections, at the end of each line and, at distances not greater than 120m for sewers 375mm or less and 150m for sewers 450mm and above.

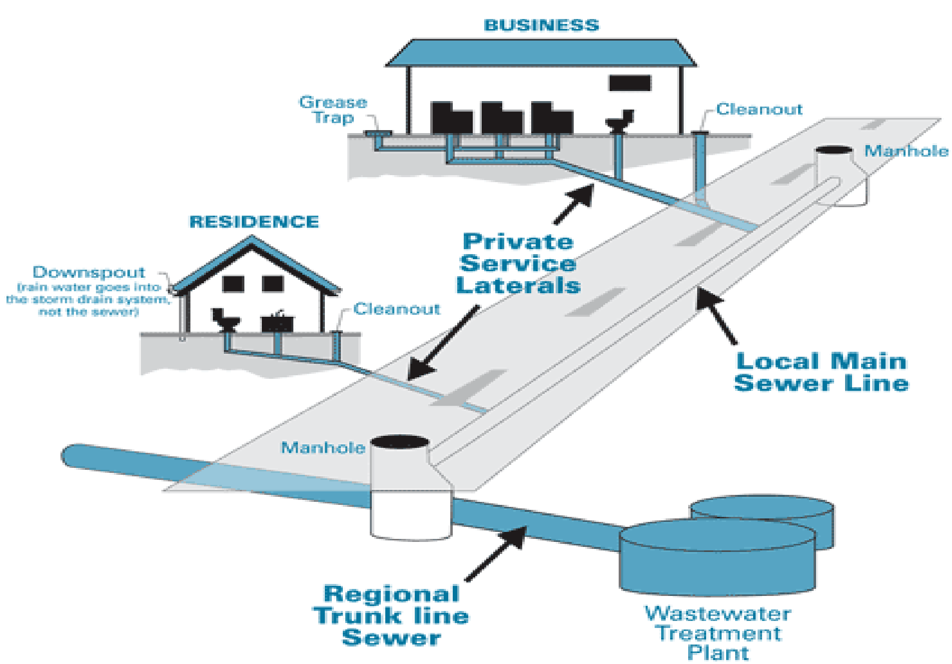

Figure 10: Schematic of a Sanitary Sewer Collection System

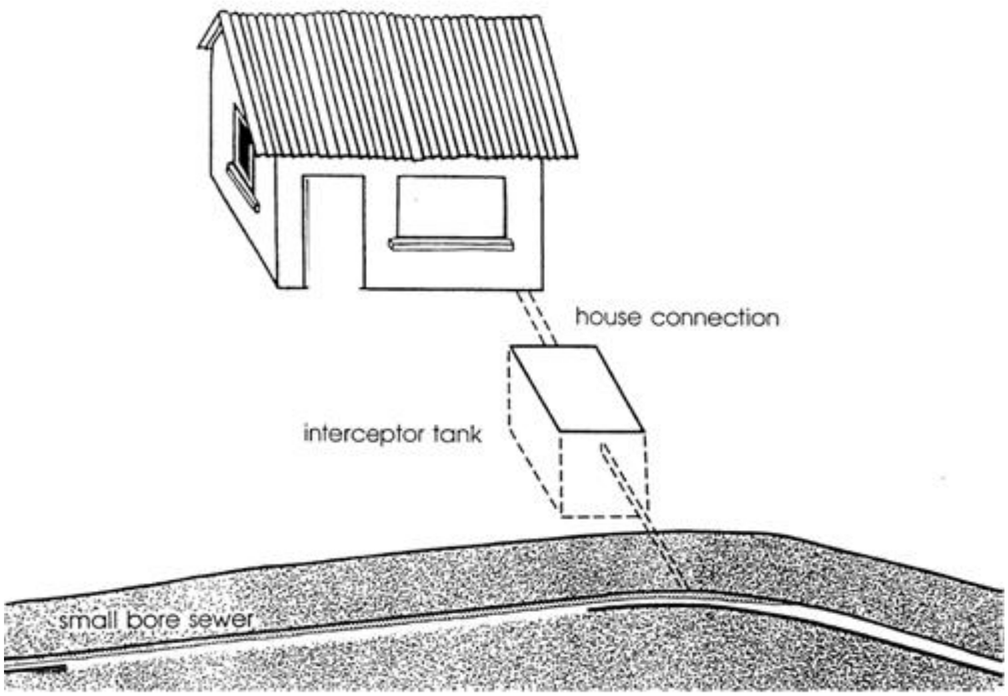

Figure 11: Schematic of a Small Bore Sewer Collection System

9.1.4 Lift Stations/Pumping Stations

Lift stations or Pumping stations are facilities including pumps and equipment for pumping fluids from one place to another. They are used for the removal of sewerage to be pumped to treatment plant sites.

9.1.5 Sewer Maintenance

The efficient collection of wastewater via collection systems is a necessary step in wastewater management. Sewer maintenance is the major component and comprises the inspection and cleaning of the system which is scheduled and performed to operate and maintain the wastewater collection system to:

- Minimize sewer overflows
- Minimize the number of stoppages per mile of sewer pipe
- Minimize flooding and backing up

- Minimize the number of foul odour complaints
- Minimize the number of lift station failures
- Maintain intended flow in the system
- Maintain wastewater flow to the treatment plant

The procedures that are included in the maintenance of the collection systems include:

1. Vacuum mounted trucks, equipped with a pressure washer and a high-powered vacuum are used to clean and flush accumulated solids from the sewer pipes as well as septic tanks that have reached their capacity.
2. Trucks equipped with closed-circuit television (CCTV) and video recording equipment are used to allow inspection of internal conditions to:
    - Pinpoint the location of a sewer line blockage.
    - Find areas that need to be cleared to prevent blockage or backup.
    - Identify pipes that need to be replaced or repaired.
    - Inspect new pipes to make sure it is installed properly and according to specification.
    - Find illegal or improper sewer connection.
3. Rodding machines with steel and cane rods are also used to clear chokes and blockages. These machines are used mainly to clear domestic and some commercial chokes, where rods would be lowered into the pipes and rotated against the walls breaking up the blockage.

9.2 Treatment

The treatment of wastewater is necessary to protect the environment and public health. Wastewater treatment is a combination of physical and biological processes designed to remove inorganic and organic matter from solution. Wastewater treatment can be broken –down into the following steps: preliminary treatment, primary treatment, secondary treatment and tertiary treatment.

Wastewater contains pathogenic organisms similar to those in the original human excreta. Disease prevention programmes have centred upon four groups of pathogens potentially present in such wastes: bacteria, viruses, protozoa and helminths.

9.2.1 Preliminary Treatment

Screening, pumping, flow measuring and grit removal are normally the first steps in processing municipal wastewater. Screens protect pumps and prevent solids from fouling subsequent units, therefore they are always placed first. Flow meters, such as a parshall flume is located ahead of the pumping equipment because the turning on and off of the pumps produces a pulsing force that cannot be graphed by the flow meter.

Grit removal reduces abrasive wear on mechanical equipment and prevents the accumulation of sand, gravel and road material in tanks and piping. Ideally it should be located ahead of the lift pumps to reduce the wear and tear on the pumping equipment. Grit chambers located above ground are economical and offset the cost of pump maintenance.

Screens and Shredders

Manually cleaned bar screens have clear bar openings of about 25mm, they are hand cleaned and are placed at the entrance of the wastewater treatment plant to prevent rags and plastics from fouling the downstream process units. Mechanically cleaned screens have clear openings of about 6-8mm. Collected solids are removed by a travelling rake that lifts them to the top of the unit. Here the screenings are compacted or may be fed to a shredder and deposited in a portable receptacle for hauling to land burial.

A shredder, comminutor, muncher and barminutor cuts solids in the wastewater passing through the device to approximately 6mm size. They are installed directly in a flow channel and are provided with a bypass channel so that the section with the shredder can be isolated for machine maintenance. The channels are equipped with stop gates so that the wastewater can be directed through the fixed screen while maintenance is performed on the shredder.

Grit Chambers

Grit includes sand and other heavy inorganic particulate matter such as seeds, gravel that settle from wastewater when the velocity of flow is reduced. Grit can cause abnormal wear on mechanical equipment and sludge pumps, can clog pipes by deposition and can accumulate in sludge holding tanks and digesters. A variety of grit systems are available.

The aerated grit chamber is a hopper-bottomed tank with the influent pipe entering on one side and an effluent weir on the opposite side. The chamber has a detention time of one minute at peak hourly flow, and is often mixed with by diffused aeration to keep the organics in suspension while grit settles out. Solid are removed from the hopper bottom by an airlift pimp, screw conveyor or a bucket elevator.

A vortex grit chamber is a cyclone separator, where grit slurry is withdrawn from the hopper of the grit chamber. Feed entering tangentically creates a spiral flow thereby throwing heavy solids towards the inner wall for discharge from the apex while the liquid vortex moves in the opposite direction for discharge.

- Vortex Grit Chamber (Sand and Grit Removal)

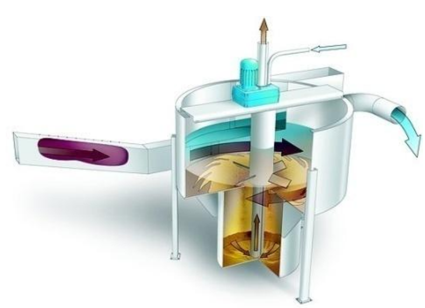

Figure 12: Schematic of a Vortex Grit Chamber

- Screening

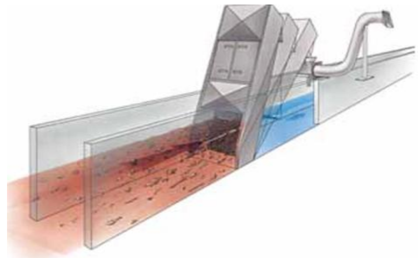

Figure 13: Schematic of Screening Process

- Grease traps

Figure 14: Schematic of Grease Trap

9.2.2 Primary Treatment

Primary Clarifiers

Raw (untreated) wastewater contains materials which will either settle to the bottom or float to the surface when the wastewater velocity is allowed to become very slow. Following preliminary treatment, the wastewater then flows into the primary settling basins, where the wastewater is held under quiescent conditions to permit particulate solids to settle out of suspension. A mechanical skimmer collects and deposits the floating scum in a pit. Settled sludge is slowly moved towards a hopper in the tank bottom by a collector arm. Clarification is performed in rectangular or circular basins. Circular basins are preferred to rectangular tanks in new construction because of lower installation and maintenance costs.

Removal of these organic settleable solids is very important because they cause a high demand for oxygen in receiving waters, or in subsequent biological treatment units in the plant.

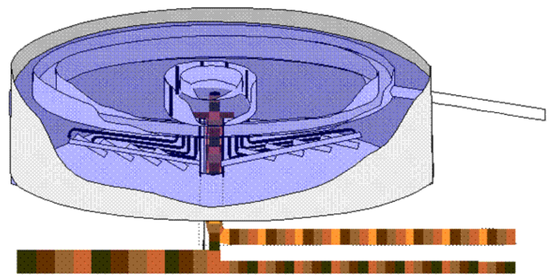

Figure 15: Schematic of Primary Clarifier

Final Clarifiers

The purpose of settling following filtration is to collect biological growth or humus flushed from filter media. These sloughed solids are generally well oxidized particles that settle readily. Settling of activated sludge results in lighter, more buoyant flocs with reduced with reduced settling velocities. This is as a result of microbial production of gas bubbles that buoy up the tiny microbial clusters. Depth of accumulated sludge in a trickling filter final is several centimeters, the blanket of settled solids rarely exceeds 0.3m. In contrast, the accumulated microbial floc in a final basin for separating activated sludge may be up to 1metre thick in a well operating plant

<u>9.2.3 Secondary Treatment</u>

The basic processes are variations of what is called the suspended growth system, “activated sludge” process or fixed film system. “Trickling filters or rotating biological contactors,” which provide a mechanism for bacteria, with air added for oxygen, to come in contact with the wastewater to purify it.

In the activated sludge process, flow from the sewer or primary clarifiers goes into an aeration tank, where compressed air is mixed with sludge that is recycled from secondary clarifiers which follow the aeration tanks.

Fixed Film Systems

Fixed growth biological systems are those that contact wastewater with microbial growths attached to the surfaces of supporting media. Wastewater is sprayed over a bed of crushed rock or synthetic media, the unit is commonly referred to as trickling filter. Another type of fixed-growth system is the biological disk (rotating biological contactor), where a series of circular plates on a common shaft are rotated while partly submerged in a trough of wastewater. Microbes attached to the disks extract waste organics. Although the physical structures differ, the biological process is essentially the same in all of these fixed growth systems.

Biological Process

Domestic wastewater sprinkled over fixed media produces biological slimes that coat the media surface. The films consist primarily of bacteria, protozoa and fungi that feed on waste organics. Sludge worms, fly larvae, rotifers and other biota are also found and during warm weather sunlight promotes algal growth on the surface of a filter bed. The schematic below describes the biological activity. As the wastewater flows over the slime layer, organic matter and dissolved oxygen are extracted, and metabolic end products such as carbon dioxide are released. Dissolved oxygen in the liquid is replenished by adsorption from the air in the voids surrounding the filter media. Although very thin, the biological layer is anaerobic at the bottom. Therefore, although biological filtration is commonly referred to as aerobic treatment, it is in fact a facultative system incorporating both aerobic and anaerobic activity.

Organisms attached to the media in the upper layer of a bed grow rapidly, feeding on the abundant food supply. As the wastewater trickles downward, the organic content decreases to the point where, microorganisms which exist in the lower zone are in a state of starvation. Thus the majority of BOD is extracted in the upper meter of a filter. Excess microbial growth sloughing off of the media is removed from the filter effluent by a final clarifier. Purging of a bed is necessary to maintain voids for passage of wastewater and air.

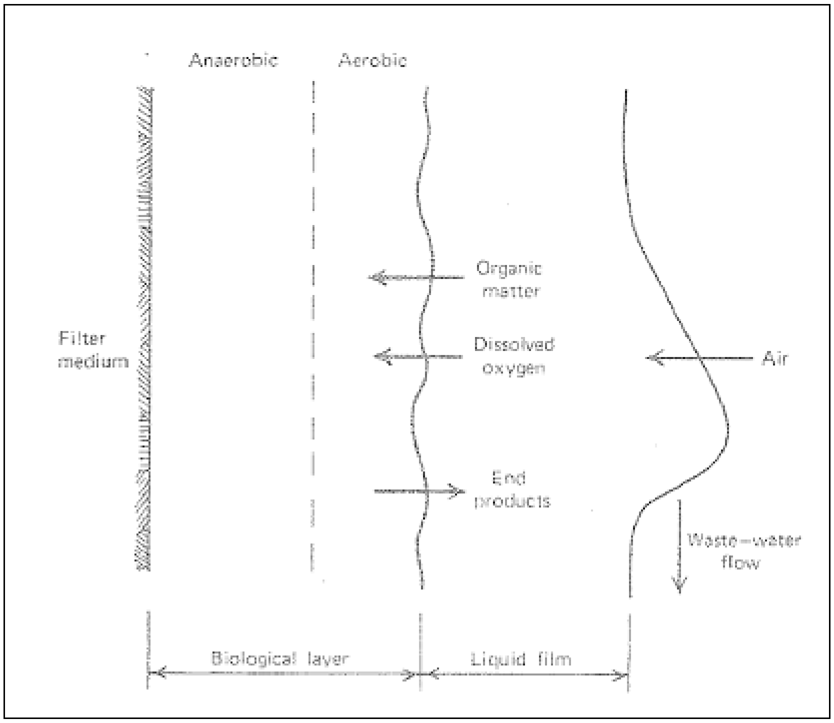

Figure 16: The biological process in a filter bed

Biological Disks

The Rotating Biological Contactor illustrated in Figure 16, is a 3.6m diameter corrugated plastic plate. A series of these, mounted on a horizontal shaft, are placed in a contour bottomed tank and immersed approximately 40 %. The disks are spaced so that during submergence wastewater can enter the separation between the corrugated surfaces. When rotated out of the tank, the liquid trickles out of the voids between the plates and is replaced by air. A fixed-film biological growth, similar to that of a trickling filter medium adheres to the rotating surfaces. Alternating exposure to organics in the wastewater and oxygen in the air during rotation is like the dosing of a trickling filter with a rotating distributor. Excess biomass sloughs from the disks and is collected in a final clarifier. The effluent is recycled to the head of the plant for removal in the primary clarifier.

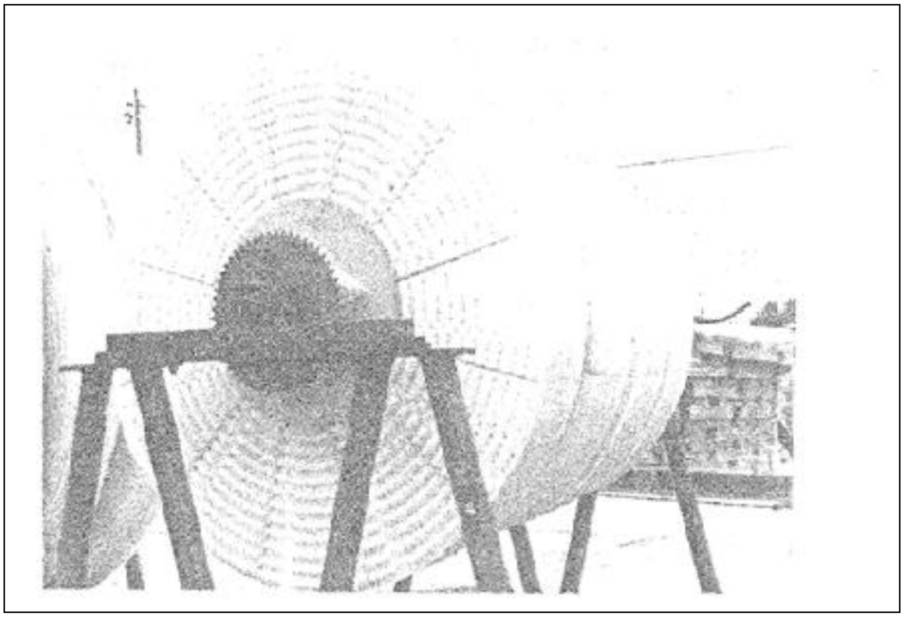

Figure 17: Extract of a Rotating Biological Contactor

Suspended Growth Systems

Raw wastewater flowing into the aeration basin contains organic matter (BOD) as a food supply. Bacteria metabolize the waste solids, producing new growth while taking in dissolved oxygen and releasing carbon dioxide. Protozoa graze on bacteria for energy to reproduce. Some of the new microbial growth dies releasing cell contents to solution for resynthesis. After the addition of a large population of microorganisms, aerating raw wastewater for a few hours removes organic matter from solution by synthesis into microbial cells. Mixed liquor is continuously transferred to a clarifier for gravity separation of the biological floc and discharge of the clarified effluent. Settled floc is continuously returned to the aeration basin for mixing with entering raw wastewater.

The liquid suspension of microorganisms in an aeration basin is generally referred to as mixed liquor and the biological growths are called mixed liquor suspended solids (MLSS). The name activated sludge was originated in referring to the return biological suspension, since these masses of microorganisms were observed to be very “active” in removing soluble organic matter from solution.

There are various types of activated sludge systems, extended aeration, conventional aeration, contact stabilization.

- Activated Sludge Treatment

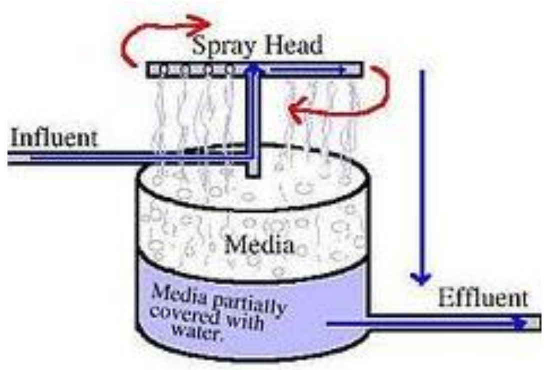

Figure 18: Schematic of Trickling Filter System

9.2.4 Tertiary Treatment

Tertiary treatment is the next wastewater treatment process after secondary treatment. This step removes stubborn contaminants that secondary treatment was not able to clean up. It involves the disinfection of the clarified effluent to kill the harmful bacteria. Disinfection can be achieved by a variety of methods: chlorination, ultra-violet light, and ozone. Wastewater effluent becomes even cleaner in this treatment process through the use of stronger and more advanced treatment systems.

Tertiary treatment technologies can be extensions of conventional secondary biological treatment to further stabilize oxygen-demanding substances in the wastewater, or to remove nitrogen and phosphorus. Tertiary treatment may also involve physical-chemical separation techniques such as carbon adsorption, flocculation/precipitation, membranes for advanced filtration, ion exchange, dechlorination and reverse osmosis.

Process system elements include:

- ✓ Intermittent Slow Sand Filters
- ✓ Constructed Wetland
- ✓ Evapo-Transpiration Beds

Disinfection

Disinfection is the reduction of pathogenic microorganisms in the water.

The main objective of disinfection is to prevent the spread of disease by protecting public water supplies, receiving waters used for recreational purposes, and shellfish growing areas.

- Physical methods of disinfection - heating to boiling, incineration, irradiation with X-ray or ultraviolet
- Chemical methods of disinfection - use of strong acids, alcohols, oxidizing chemicals or surface- active agents. (Chlorine, Ozone)

<u>9.2.5 Stages of the treatment process at a typical wastewater treatment plant</u>

Bar Screens

Step1- Large objects are prevented from entering the Wastewater treatment plant

e.g. Wood, rubber, cans, other large metal & plastic objects

Figure 19: Typical Bar Screen

The Grit Chamber

Step 2 – At this stage, slow mixing of wastewater allows heavy products such as sand to settle to the bottom

Figure 20: Typical Grit Chamber

Bioreactors

Step 3- Vigorous mixing of wastewater and activated sludge takes place here, whereby nutrients are removed further breaking down wastewater

Figure 21: Typical Bioreactor

Clarifier

Step 4 – Here, sludge settles while lighter floc floats. Skimming arms at the bottom of the clarifier collect sludge.

Figure 22: Typical Clarifier

Ultraviolet Disinfection

Step 5- Two channels of ultraviolet light disinfect the water.

Figure 23: Typical Ultraviolet Disinfection System

Effluent

Effluent is the treated final product that is discharged into a nearby river course and eventually flows into the sea. It can be harnessed and reused in the context of sustainable landscaping, irrigation, or to recharge groundwater aquifers. These processes promote sustainability and water conservation.

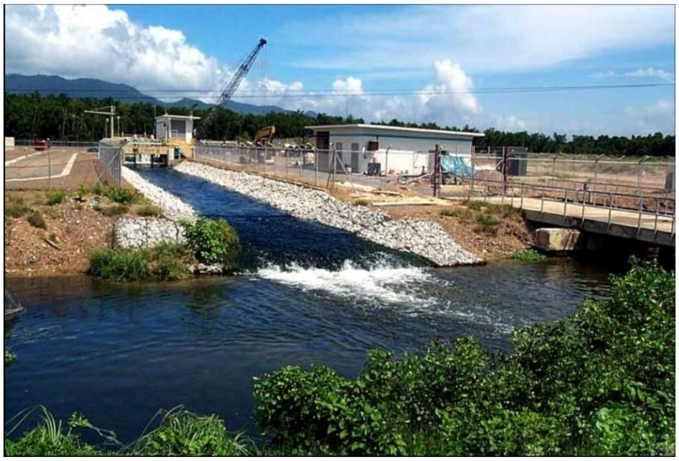

Figure 24: Example of Wastewater Effluent Discharge Configuration

9.3 Disposal (Sludge Management)

Sludge, defined as coarse primary solids and secondary biosolids accumulated in a wastewater treatment process must be treated, dewatered and disposed of in a safe and effective manner. This material may be inadvertently contaminated with toxic organic and inorganic compounds.

When a liquid sludge is produced, further treatment may be required to make it suitable for final disposal. Typically, sludges are thickened (dewatered) to reduce the volumes transported off-site for disposal. Processes for reducing water content include lagooning and centrifugation. Lagooning in drying beds produces a cake that can be applied to land or incinerated, where the sludge is mechanically filtered, often through cloth screens to produce a firm cake. In centrifugation, the sludge is thickened by centrifugally separating the solid and liquid. Sludge can be disposed of by liquid injection to land or by disposal in a landfill. There are concerns about sludge incinerations because of air pollutants in the emissions, along with the high cost of supplemental fuel, making this a less attractive and less commonly used means of sludge treatment and disposal. There is no process which completely eliminates the requirements for disposal of biosolids.

In Trinidad and Tobago, waste products produced by the treatment process (sludge) is usually dried on the treatment plant compound then trucked to a landfill site.

Section 5

Reclamation and Reuse

CHAPTER 10

RECLAMATION AND REUSE – THE NEW FRONTIER

Global water issues and needs will make water reuse one of the crucial components and the New Frontier of water resources management. It is believed that it is essential for wastewater and water supply professionals to evaluate water reuse to a strategic level in their planning process so that this limited resource can be efficiently managed and properly preserved.

Reclaimed water, sometimes called recycled water, is (former) wastewater which includes sewage that has been treated to remove solids and certain impurities, and then used for servicing water demands in various areas. Water reuse and reclamation is a new paradigm in water resources management that incorporates the principles of sustainable development, environmental ethics and public participation in project development. Although the immediate drivers behind water reuse may differ in each case, the overall goal is to close the hydrological cycle on a much smaller, local scale. In this way, the used water after proper treatment becomes a valuable resource.

Rationale and benefits of water reclamation and reuse include the following considerations:

- Water is a limited resource, increasingly there is no longer the luxury of using water only once
- The acknowledgement that water recycling is already happening and the continued need is apparent
- The quality of reclaimed water is appropriate for many non potable applications thus providing a supplemental water source which allows for more effective and efficient use of water
- Allows for more efficient use of energy and resources by tailoring treatment requirements to serve end users of the water
- Augment water sources to meet present and future demands

- Protect aquatic ecosystems through reduction of contaminants entering waterways
- Reduce the need for impounding reservoirs
- Assist with meting environmental regulations by better managing wastewater discharges and water consumption

Water reuse is the use of wastewater for a beneficial purpose, such as agricultural irrigation or industrial cooling. Whereas water reclamation is the collection, treatment and processing of wastewater to make it reusable with definable treatment reliability and meeting appropriate water quality criteria. Treated municipal wastewater provides a more reliable and significant source for reclaimed water as compared to wastewater coming from agricultural return flows, storm water runoff, and industrial discharges. As a result of the Federal Clean Water Act and related wastewater treatment regulations, centralized wastewater treatment has become commonplace in urban areas of the United States. New technologies in decentralized and satellite wastewater treatment have also been developed.

Because of its genesis from municipal wastewater, acceptance of reclaimed water as an alternative water source has to overcome hurdles such as treatment to strict water quality standards to ensure it is non toxic and free from disease causing micro-organisms as well as social acceptance.

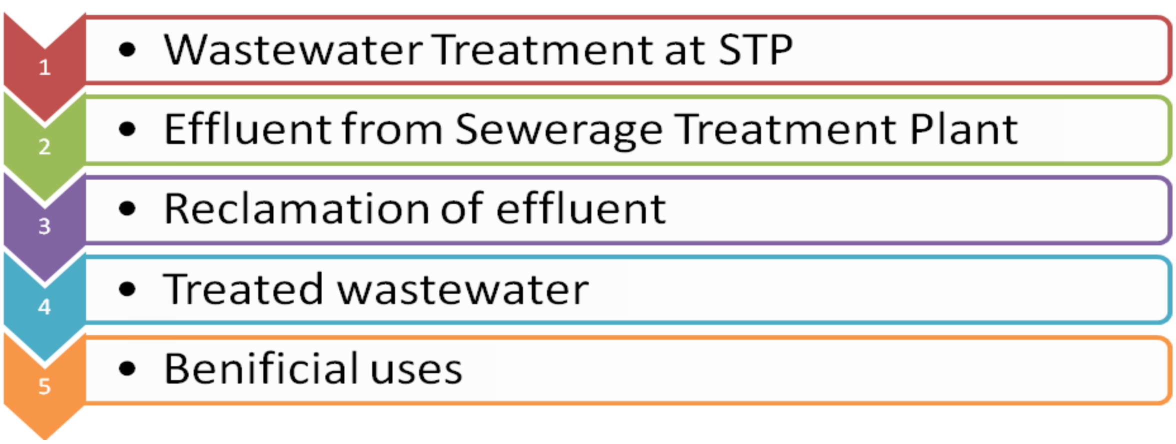

Figure 25: Flow chart for Wastewater Reclamation

CATEGORY	TYPICAL APPLICATION
Agricultural irrigation	Crop irrigation, Commercial nurseries
Landuse irrigation	Parks, School yards, Freeways medians, Golf courses, Ceneteries, Greenbelts, Residential
Industrial recycling and reuse	Cooling water, Broiler feed, Process water, Heavy construction
Groundwater recharge	Groundwater replenishment, Salt water intrusion control, Subsidence control
Recreational/environmental uses	Lakes and ponds, Marsh enhancement, Streamflow augmentation, Fisheries, Snowmaking
Nonpotable urban uses	Fire protection, Air conditioning, Toilet flushing
Potable reuse	Blending in water supply reservoirs, Blending in groundwater, Direct pipe to pipe water supply

Table 6: Water Reuse categories and typical applications

10.1 Integrated Water Resources Management

Increasingly, water-related services need to be provided within the context of an integrated water resources plan because there are few instances in which water, wastewater, reclaimed water and storm water utilities do not affect one another, the environment or water-related recreations.

Reclaimed water typically is reliable in terms of quality, quantity and availability, so it is an important resource to consider when augmenting potable water resources. This option presumably would be considered because existing sources of drinking water supply are not available in sufficient quantity, quality or reliability. Other approaches to consider include improved water delivery and use, non-potable reuse, exchange of reclaimed water for other drinking water sources and acquisition and development of new sources of supply.

There are numerous examples of successful and unsuccessful indirect potable reuse projects. These failures are largely attributed to negative branding because detractors perpetuated negative perceptions and fear of a source of water once considered a “waste”. Most successful indirect potable reuse projects in the United States introduced a natural system between the water reclamation facility and the drinking water production facility. They also demonstrated the benefits of indirect potable reuse.

10.2 Means of Introducing Reclaimed Water to Water Supplies

Reclaimed water may be introduced to water supplies via groundwater recharge or surface water augmentation. Groundwater aquifers can be used to store water (i.e., act as underground reservoirs) without the evaporative losses associated with surface water reservoirs. Moreover, the aquifer itself can function as a water conveyance system, providing lateral movement without pipelines. Depending on site-specific conditions, this method of storage and delivery may be significantly less expensive (in both capital and operational costs) and more desirable than a traditional aboveground storage and distribution facility. Water-quality degradation can be a concern for water held in either surface of aquifer storage systems. Generally, surface water sources are more readily cleansed of contamination than aquifers, but aquifers are less susceptible to rapid and extensive contamination.

Water can be introduced to groundwater aquifers via injection wells, recharge basins or alluvial infiltration. There are three types of injection wells:

- Direct-Injection Wells
- Aquifer Storage & Recovery (ASR) Wells
- Vadose Zone Recharge Wells

Like direct-injection wells, ASR wells deliver reclaimed water directly to the aquifer, but they also can recover water from the aquifer using the same column. Vadose zone recharge wells inject reclaimed water into the unsaturated zone between the ground surface water and the water table of the saturated aquifer.

Recharge basins are shallow basins that receive reclaimed water and allow it to percolate down to the water table. Alluvial infiltration involves releasing water into a stream channel and allowing it to percolate to the water table. Many factors affect the choice of method for a particular site and recharge program. These include land availability, topography, climatic factors, regulatory and permitting constraints, subsurface geology, reclaimed water quantities and quality, cost of facilities, environmental effects and public perception.

Planned indirect water reuse via surface water augmentation is a practice that is gaining favor among water purveyors. It must be done carefully, in a manner appropriate for the distance between delivery and intake points, the volume of water to be reused and watershed characteristics.

10.3 Health and Regulatory Considerations

The perceived and actual risks of using reclaimed water for indirect potable use are higher than those for non-potable reuse because indirect reuse involves supplementing drinking water with reclaimed water. Potable reuse projects also can face challenges related to the water-quality or environmental concerns associated with co-mingling reclaimed water with surface water or ground water.

Despite the prevalence of unplanned indirect potable reuse, some experts believe that water originating from raw wastewater is inherently more risky-even if the reclaimed water meets drinking water standards. Their concerns include the following:

- Disinfection of reclaimed water may create different (often unidentified) byproducts than are found in conventional water supplies

- Only a small percentage of the organic compounds in drinking water have been identified, and health effects of only a few of the identified compounds have been determined

- The health effects of mixtures of two or more of the hundreds of compounds in reclaimed water are not easily characterized.

While these issues are not insurmountable, they do not illustrate the need to acknowledge that there are complex health and regulatory issues that must be evaluated and accommodated in indirect potable reuse projects, from public health, water-quality, and environmental-protection perspectives. Many of these concerns are common to drinking water.

Although wastewater reuse projects can provide many benefits to both communities and water utilities, implementing them requires special attention to public perceptions. Project success depends on a utilities ability to address people’s concern. Effective public outreach can reduce the likelihood of infrastructure underinvestment, facility abandonment, damage to the utility’s reputation and relationship, and negative branding. It also can increase the likelihood that water reuse befits are considered fairly, that reuse proposals are supported adequately, and that reuse projects are chosen when they offer the best value to the community.

CHAPTER 11

INDIRECT POTABLE REUSE

When considering and discussing potable reuse as an option for public water supplies, critical distinctions must be made between "direct" and "indirect" potable use. Conceptually, direct potable reuse is a "pipe-to–pipe" connection between the reclaimed water treatment facility and the potable water distribution system. In indirect potable reuse, highly treated reclaimed water is introduced to a surface water or groundwater system that ultimately uses the water as a potable water supply. In an indirect system, reclaimed water is blended with water in a natural system and there may be a significant delay and more treatment between the points where reclaimed water is discharged and where water is withdrawn into the potable water treatment facility. Reclaimed water is significantly diluted by natural water.

Currently in the US, direct uses of reclaimed water for human consumption are not viable options. However, a small but growing number of communities are planning and implementing indirect potable reuse through surface-water augmentation with added protection by advanced water reclamation technologies prior to blending in a water course or reservoir. The blended water is withdrawn after undergoing further water quality improvements by natural processes in the environment.

Indirect potable reuse refers to the planned introduction of reclaimed water into a raw water supply, such as a potable water storage reservoir or groundwater aquifer, resulting in the mixing and assimilation, thus providing an environmental buffer. Indirect potable reuse is motivated by the need to develop additional sustainable water supplies, as well as by recent advances in water reclamation technologies. Indirect potable reuse through surface water augmentation; a planned activity, can occur when treated reclaimed water is introduced into an intervening stream, followed by withdrawal for municipal water supply or direct discharge to a raw water storage reservoir. In indirect potable reuse, reclaimed water is treated twice prior to its ultimate use for potable purposes. First, it is treated prior to discharge to surface water. Following introduction to and mixing, blending and assimilation with raw water into the environment, reclaimed water is again treated prior to delivery to the potable water system. For planned indirect potable water reuse systems, advanced processes may be used for the treatment of both wastewater and raw water.

Because the quantities of treated wastewater discharged into waterways are increasing, much of the research that is focused on drinking water quality from these water sources is becoming equally relevant to planned indirect potable reuse. It may be argued that planned, rather than unplanned, indirect potable reuse exercises more positive engineering control over water quality, and a conscious effort is made to establish multiple barriers to protect public health.

It is essential that the public is educated about drinking water quality issues and the principles and capabilities of water reclamation and reuse technologies and applications. An educated and well-informed public will recognize the need for integrated water resources management in the region and increase the likelihood of full confidence in the integrity of operating and regulatory agencies. Public outreach and education efforts are, thus, essential to successfully achieve acceptance for proposal indirect potable reuse projects.

The following observations are derived from the experiences gained from the existing indirect potable reuse projects:

1. Transparency and public trust in decision-making are of paramount importance.
2. Stakeholder and public acceptance are absolutely essential.
3. It is of critical importance to demonstrate that the water is safe with respect to chemical and microbiological quality.
4. A comprehensive ongoing monitoring program is an essential part of an indirect potable reuse program. The drinking water standards will serve as a benchmark so that safety can be assured.
5. To deal with constituents unregulated by drinking water standards, reasonable precautions should be applied.
6. Safeguards for unregulated compounds should be implemented based on the significance of occurrence, a public health risk assessment, and the feasibility of risk minimization.

7. Treatment process reliability and system redundancies must be incorporated into indirect potable reuse plans.
8. The multiple barrier approach to protect public health and the environment is an essential part of indirect potable reuse.
9. With proper outreach, education, and a sensible message, it is possible to gain public support for indirect potable reuse.

11.1 Singapore - A world leader in Wastewater Reclamation and Reuse

Water reuse was always an important component of Singapore's water supply from as early as the 1970's. Since 1999 however, the Singapore government, through the Public Utilities Board (PUB) has developed aggressively advanced water reclamation facilities, known as NEWater Factories. Reclaimed water is used to supply the high-tech semiconductor manufacturing sector and to augment the potable water storage reservoirs.

Figure 26: Ulu Panan Water Reclamation Plant in Singapore

The Republic of Singapore, a small city-state (land area: 699km^2) has one of the highest population densities in the world (about 6200 individuals/km^2 based on Singapore Department of Statistics 2006) Singapore has developed most of its natural water sources and buys more that half of its water from Johor, in neighboring Malaysia, under decades-old treaties which begin expiring in 2011. The water trade has sparked occasional disputes between the two nations over pricing and environmental issues.

In 1999, the Singapore government launched a strategic initiative to develop alternative and renewable sources of water, in an effort to ensure reliability of supply and consistency of water quality. This initiative, known locally as the Four Tap Strategy consisted of four (4) steps: Collection and treatment of surface runoff; importing water from Malaysia; Water Reuse; and Seawater Desalination.

The Expert Panel assembled by the Singapore Government arrived at the following conclusions:

- NEWater is considered safe for potable use, based on the comprehensive physical chemical and microbiological analysis of NEWater conducted over a 2 year period. The quality of NEWater consistently meet the latest requirements of the US EPA National Primary and Secondary Drinking Water Standards and WHO Drinking Water Quality Guidelines
- Singapore should adopt the approach of indirect potable reuse on the basis that:
  - Blending with reservoir water will provide trace minerals which have been removed in the reverse osmosis process, necessary for health and taste
  - Storage provides additional safety beyond the advanced technologies used to produce safe, high quality NEWater
  - There is public acceptance.
- The Singapore Government should consider the use of NEWater for indirect potable reuse as it is a safe supplement to the existing water supply
- A vigilant and continuous monitoring and testing program be carried out.

Figure 27: Changi (Sembcorp) NEWater Plant

In light of this, NEWater was formally launched in 2002 and on August 9th 2002, at the National Day celebration, sixty thousand (60,000) bottles of NEWater were distributed. Additionally, more than one million (1, 000, 000) bottles of NEWater have been distributed at public events for the purpose of public education and have received overwhelming public support.

Driven by a vision of what it takes to be sustainable in water, Singapore water supply and sanitation is characterized by a number of achievements in the challenging environment of a densely populated while relatively small island. Access to water is now universal, affordable, efficient and of high quality. Innovative integrated water management approaches such as the reuse of reclaimed water, the establishment of protected areas in urban rainwater catchments and the use of estuaries as freshwater reservoirs have been introduced along with desalination in order to reduce the country's dependence on imported water.

11.2 WASA- Singapore (PUB) Collaboration

Singapore has clearly recognized the critical nature of interventions such as its NEWater program, focused on Water Reclamation and Reuse, which have allowed the country to become today one of the leaders in the water and sanitation sector. In fact, in 2007 the Singapore Public Utilities Board (PUB) received the Stockholm Industry Water Award for its holistic approach to water resources management.

As Trinidad and Tobago seeks to develop its own capabilities in relation to wastewater reclamation and reuse, it is not difficult to foresee an overlay of the Singapore model onto our own local setting, with both having similar climate, geographic setting, and historical beginning in the water and sanitation sector. By implementing sound watershed management, effective water treatment processes and continued investments in Research and Development, Singaporeans have been enjoying good quality water for the last four decades.

The PUB has collaborated with WASA in the past. In fact, when WASA completed construction of the Desalination Plant in Point Lisas in 2002, a team of Singaporeans under the leadership of Chan Yoon Kum, then Assistant Chief Executive-Water Supply at PUB, was sent to learn from the Trinidad experience. Interested in the construction of what was at the time the largest desalination facility in the western hemisphere, producing approximately 100,000 m^3/d of potable water, this knowledge assisted the Singaporeans in the implementation of their first desalination plant. In September 2005, the SingSpring Desalination Plant in Tuas was launched producing 136,000 m^3/d.

The PUB extended an invitation to WASA to attend the 2011 Singapore International Water Week (SIWW) Conference, July 3-8. Founded in 2008 the Conference is the global platform for water solutions that brings policymakers, industry leaders, experts and practitioners together to address challenges, showcase technologies, discover opportunities, network and celebrate achievements in the water world. Themed “Sustainable Water Solutions for a Changing Urban Environment”, the 2011 event which was attended by a WASA delegation, led by its Chief Executive Officer (CEO), Mr. Ganga Singh, reinforced Water Week as a platform for solutions to address the latest and most pertinent water issues amidst a rapidly changing world. It also reflected a broader focus beyond urban water solutions and other issues that affect the urban environment, such as climate change and the management of watersheds and river basins.

Figure 28: Singapore International Water Week Conference and Water Expo, 2011

It is expected that the collaboration between the PUB and WASA will fulfill a number of key objectives focusing on the diversification and strengthening of the Authority. These include:

- Development of a sustainable partnership
- Establishment of a technical cooperation agreement
- Identification of key focal areas for collaboration
- Training and development opportunities
- Adoption of key approaches to water supply and management
- Signing of a Memorandum of Understanding

The primary long term benefit for WASA in engaging in collaboration with PUB is the ability to progressively improve the quality of service provided to customers, through enhancement in several technical areas central to its operations. As previously highlighted, the PUB has become a benchmark in the water industry with the ability to overcome resource disadvantages, high water demands and watershed pollution to the point where all customers have a safe, regular and ample water supply.

Some of the accrued benefits are expected to include:

- Partnership in the development of WASA's Water/Wastewater Sector
- Technology transfer
- Sustainable capacity building
- Information sharing

CHAPTER 12

DIRECT POTABLE REUSE

Direct potable reuse refers to the introduction of highly treated reclaimed water either directly into the potable water supply distribution system downstream of a water treatment plant or into the raw water supply immediately upstream of a water treatment plant. This introduction can be either into a service reservoir or directly into a water pipeline.

The key distinction between indirect and direct potable reuse is that direct potable reuse does not include temporal or spatial separation such as natural (environmental) buffers between reclaimed water introduction and its distribution to the end consumer. Direct potable reuse projects are implemented usually as a result of extreme circumstances, where other potable water alternatives have prohibitive costs or are not available. Depending on the particular conditions, direct potable reuse projects may be temporary as in the event of a drought, or long term, for example where a sufficient local water supply does not exist.

Understandably, direct potable reuse is the most difficult category of water application for a community to accept. A reluctance to accept reclaimed water for potable purposes is to be expected, particularly when there is a perception amongst end users that there is no real dilution, natural purification or loss of identity before the reclaimed water is consumed again. However, with the execution of proper education and public outreach, support for indirect potable reuse can be achieved, as was the case with San Diego, California in 2006.

Recent advances in analytical techniques for the measurement of trace inorganic and organic constituents have far exceeded the corresponding knowledge base of the health impacts of these constituents. Thus, it has been argued that it would be prudent to wait until more is known about the health impacts of the many trace constituents that may be found in reclaimed water, before proceeding with direct potable reuse.

Direct potable reuse implies a confidence in and reliance on the applied technology to always produce water that is safe and acceptable to consume, without the opportunity for any natural processes to further improve the water quality.

To overcome technological concerns, multiple barrier systems, in which sequential redundant processes are used to remove constituents of concern, have been developed, resulting in a high degree of reliability. Also, monitoring technology has improved dramatically, allowing for real-time process monitoring and control. Through scientific studies and technological advances, more robust treatment processes are being developed and implemented, including enhanced membrane systems coupled with advanced oxidation processes, which along with other new technologies are capable of essentially full removal of trace constituents. It is important to note that the technologies that are in place today can be used to produce high-quality potable water which far exceeds current drinking water standards.

The following observations are derived from the experiences gained from the existing direct potable reuse projects:

1. Globally, there is a minimum application of direct use of reclaimed water for human consumption, without the added protection by storage in the environment, for public water supply.
2. Direct use of reclaimed water could well be a cost effective form of water reuse in the long term.
3. Treatment requirements are clearly greater for direct use as compared to indirect use
4. Direct potable reuse will have an advantage, over indirect use, of avoiding the unnecessary cost of duplicate water distribution and storage systems.
5. Direct potable reuse has the potential to readily utilize all the reclaimed water that could be generated and avoid all together the need for excess flow to the environment.
6. The pressure to consider reclaimed water as a source of a potable supply must increase in the future as it seems inevitable that, in time, potable reuse in some form will occur.

12. 1 Namibia– A case of direct potable Reuse

Since 1968, the City of Windhoek in Namibia has been adding highly-treated reclaimed water to its drinking water supply system. The blending of reclaimed water with potable water takes place directly in the line that feeds its potable water distribution network. Internationally, the well-known example of direct potable reuse of reclaimed water is at Windhoek in Namibia, located in the southwestern part of Africa bordering the Republic of South Africa. Windhoek's Goreangab Reclamation Plant has been a pioneer in direct potable reuse and still today is the only commercial scale operation in existence in the world.

The City of Windhoek is the capital of Namibia, which is the most arid country in sub-Saharan Africa. It has a total population of 1.8 million, and is one of the most sparsely populated countries in the world. Water management issues are concerned with climatic conditions as Namibia is semi arid and rainfall occurs only a few months of the year. The groundwater resources are also limited.

In 1969, what was known as the Goreangab Water Treatment Plant was converted to treat not only the water from the Goreangab dam but also the final effluent from the city's Gammams Wastewater Treatment Plant. Thus, the facility became known as the Goreangab Water Reclamation Plant. The reclaimed water was blended with water from the well field. Since the entire city, as well as its informal settlements lies within the catchment area of the dam, the quality of water from this reservoir is often worse than the treated wastewater and is therefore unfit for water reclamation.

From its inception, one of the cornerstones of water reclamation was that the city separated industrial effluent from domestic effluent and diverted industrial effluents to a separate treatment plant. The effluent used for water reclamation therefore, originated mostly from wastewater from domestic and business areas.

Without a doubt, the most important cornerstone of potable reuse is public acceptance and trust of consumers in the quality of reclaimed water. The most difficult task for anyone who wants to emulate the Goreangab approach in Windhoek would be to overcome the psychological barrier of direct reuse of reclaimed water for potable purposes. In the words of Dr Lucas van Vuuren, a pioneer of water reclamation and reuse, “Water should be judged not by its history, but by its quality”.

The Goreangab Water Reclamation Plant is an excellent example of one of the innovations practiced in a country with little resources, both natural and financial. Direct potable reuse has proved in Windhoek that it is possible to overcome public perception and prejudice with persistent and positive marketing. Direct potable reuse in Windhoek is a viable option and fits well into the concept of regional and integrated water resources management.

Chapter 13

RECLAMATION AND REUSE IN TRINIDAD AND TOBAGO

Trinidad and Tobago is not a water scarce country however; the challenge arises in the management of the water resources in the face of competing demands. The water demand is continuously increasing because of population growth and major industrial expansion particularly in the Point Lisas Industrial Estate.

The challenges are more acute as the water resources are not evenly distributed geographically, with greater abundance in the North East and scarcity in South Trinidad. Additionally, potential climate change, weather variability and seasonality of rainfall increase the challenges now and projected into the future. There is also the challenge of increasing pollution of the available water resources and decrease in its availability due to watershed degradation, particularly from hillside development along the foothills of the Northern Range. In fact, trends have indicated a depletion of both ground and surface water resources over the years. Together, these sources account for 63% of the potable water supply for the country.

According to the Water Resources Management Strategy Study published in the year 2000, the total surface water availability can be considered as remaining relatively constant over the years. The major challenges to this component of the water resources are in the areas of water quality and watershed degradation, particularly with reference to the major water sources which are located along the East-West corridor, which make up the Caroni River Basin system. It is pointed out in the study, that major changes took place in land use over three decades leading up to the year in which the assessment was undertaken, 1997. In fact, it was reported that forest cover decreased from nearly sixty percent (60%) to fifty percent (50%) over this period. The Study also indicates that ground water availability is about three percent (3%) of the surface water availability and based on withdrawals at the time of assessment, the groundwater resources utilized were already close to the full potential availability. This situation is compounded by an ever increasing demand, particularly from the industrial sector. It is therefore very obvious that there is a need to expand the portfolio of water sources locally, and within the short term include emerging areas such as desalination, groundwater recharge, rain-water harvesting and wastewater reclamation for the provision of both potable and non-potable water supplies.

The harnessing of reuse water as a specific option for augmenting water supply would provide a sustainable, alternative source, as wastewater increases directly with population growth. Reuse of this water resource will allow for the freeing-up of potable water reserved for domestic and agriculture supply, which will also mean a more reliable supply to customers in the dry season as compared to surface water flows, which diminishes during this period. Climate change and weather variability do not directly impact the volume of wastewater produced. However, they should be considered when embracing the wastewater reclamation approach. Another advantage of using wastewater is in the reduction of the wastewater loading in the country's waterways leading to better water quality and enhancement of the ecological environment. In addition, the occurrence of wastewater is not limited to geographical location, which is a major issue with freshwater resources.

13.1 Wastewater Reclamation Development

In Trinidad and Tobago, escalating water demands particularly from the industrial sector dictate much more prudent management of the country's water resources. Major conflicts in water use have long existed in the central and southern regions of Trinidad. The desalination option has been explored however; it is associated with costly capital interventions and some level of environmental risk. In 2004, WASA commissioned a state of the art Wastewater Treatment Facility at Beetham. The facility includes ultra violet disinfection and is now generating eighty thousand (80,000) cubic meters per day of high quality effluent. The effluent meets all the requirements of the water pollution rules and is being considered for alternative uses to augment the portfolio of fresh water resources and desalinated water.

As the country seeks to expand the coverage of wastewater services, which currently is around 30%, as well as in keeping with technologies and best practices in the international arena, (e.g. Singapore, United States, Namibia, Denmark, Holland) the opportunity now exists to introduce the reuse of wastewater for augmenting water supplies, particularly for applications in the energy and industrial sectors, located in the southwest, southeast and along the western coastline of the country. In these areas adequate and good quality water sources are absent, posing serious constraints to the country's development drive. Such reuse of water, will allow for, the freeing up of existing supplies for meeting domestic, agricultural/irrigation and other needs where the issues of quality and perception of source water are of paramount importance.

For Tobago, the south-western coastal area is subjected to severe stress from sewage pollution mainly generated by domestic and tourism sources. These have a negative impact on the groundwater systems, rivers and some beaches. The south-western region of Tobago is expected to generate further industrial development and also growth in light industries and facilities for the tourism sector.

Properly treated wastewater effluent has been used to meet non-potable water needs in many parts of the United States and other countries for decades. Reclaimed water has been successfully used for a wide range of non-potable uses, including landscape and agricultural irrigation, industrial process water, power plant cooling water, toilet flushing, car washing, augmentation of recreational water bodies, fire protection, commercial cleansing, construction, and habitat restoration. The specific requirements for implementing these systems vary from country to country, but in general, using reclaimed water to meet non-potable water demands is an accepted practice.

The use of treated wastewater effluent is a new paradigm within Trinidad and Tobago. The Water and Sewerage Authority, on behalf of the Government is seeking to incorporate treated wastewater effluent, as part of the Integrated Water Resources Management (IWRM) concept in providing a sustainable source of water. This concept has greater relevance due to increased urbanization, population density; increased industrialization and the lack of fresh water resources, particularly within the Central and Southern Western parts of the country. This is further compounded by inadequate maintenance practices for the network and distribution system, leading to transmission and distribution losses.

More recently, there has been an increasing interest in the use of highly treated reclaimed water to augment potable water resources. With the construction of the Beetham Wastewater Treatment Plant with reuse potential several other projects are being planned to make the use of reclaimed water a reality in Trinidad and Tobago. In cases where, water resources are limited, when compared the potential benefits of recycling reclaimed water outweighs the disadvantages. However, important questions remain about the levels of treatment, monitoring and testing needed to ensure the safety of recycling 'reclaimed water".

The operations at the Beetham Wastewater Treatment facility represents the signature initiative in Trinidad and Tobago and the wider English speaking Caribbean, focusing on water reclamation for intended water reuse by other demand sectors. Some of the key considerations associated with this facility are highlighted below.

Figure 29: Beetham Lagoon Facilities Construction in 1968

Figure 30: Newly Constructed Beetham Wastewater Facilities

Figure 31: Treated Effluent discharge from the Beetham Wastewater Treatment Facility into the Black River

The WWTP employs some of the leading technologies such as reverse osmosis followed by ultra violet disinfection which has been proven to be an effective and an environmentally friendly treatment having higher virus inaction, with no toxic by-products, in meeting the effluent quality standards. This plant is designed to meet effluent quality standards established by the Environmental Management Authority (EMA).

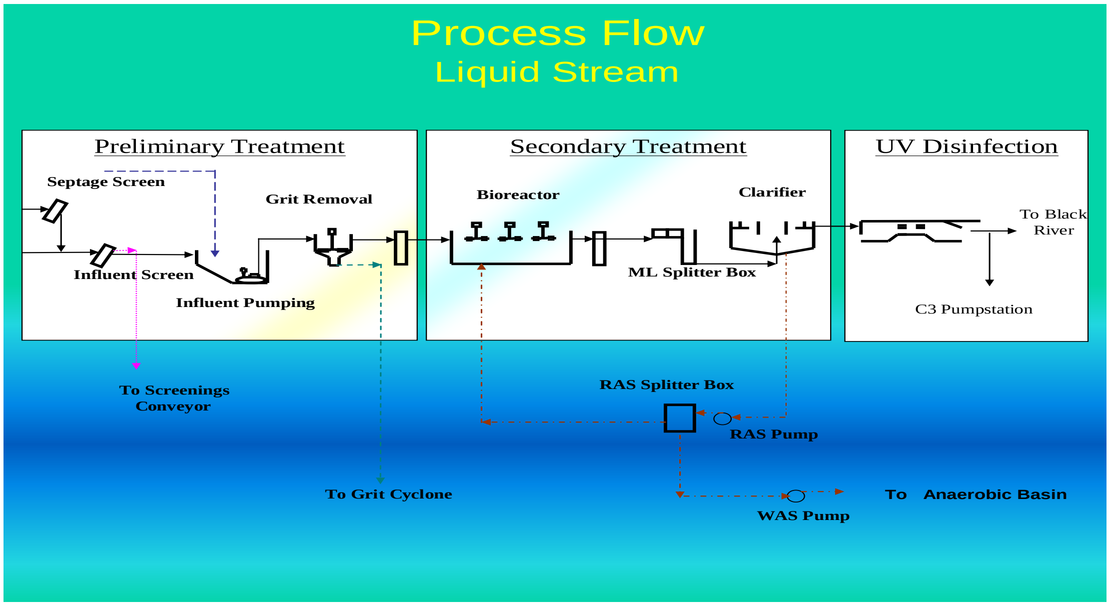

Figure 32: Beetham Wastewater Treatment Process

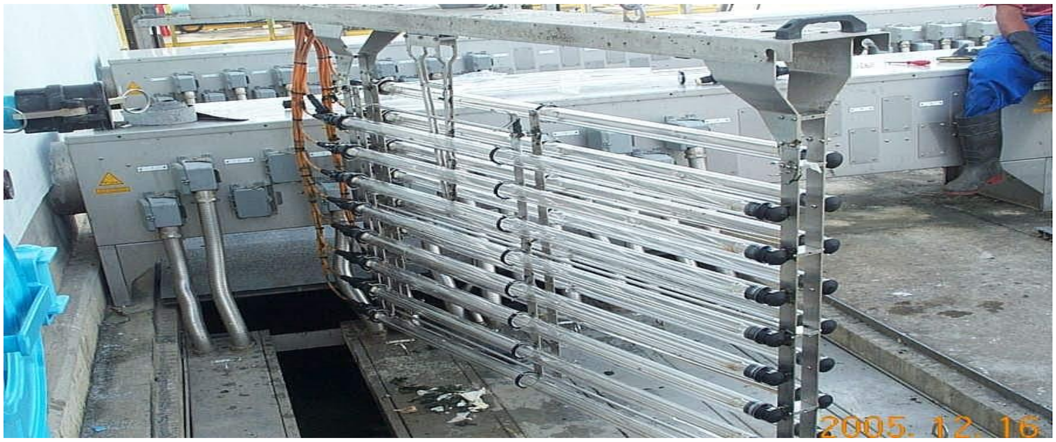

Figure 33: Low Pressure/ High intensity Lamp employed in Ultra Violet Disinfection at the Beetham Wastewater Treatment Facility

DISCHARGE POINT	BOD_5 at 20^oC (mg/L)	TSS (Mg/L)	pH	FAECAL COLIFORMS (counts/100 ml)	TOTAL RESIDUAL CHLORINE (mg/L)
Inland Surface Water	30	50	6-9	400	1
Coastal Near Shore	50	150	6-9	400	1
Marine Offshore	100	200	6-9	400	2
Environmentally Sensitive Areas/ and or Ground Water	10	15	6-9	100	0.2

Table 7: Water Pollution Rules Permissible Levels

The Authority has adopted the Water Pollution Rules as outlined above, as a minimum requirement for discharging treated wastewater effluent into the environment.

Wastewater flows are expected to increase proportionately with the increase in water supply, and for preliminary design purposes, estimates of future wastewater flows by and large will be based on 90% of water consumed being returned as wastewater. This ratio is exclusive of standpipe customers, as all the water utilized is not returned as wastewater.

The planning being under taken represents one of the key elements in embracing the concept of water reclamation and reuse for water supply dev within the country. Other major studies in this direction include:

- San Fernando Wastewater Integrated System
- South West Tobago Wastewater Development
- Malabar/Maloney Wastewater Integrated System
- Chaguanas Wastewater system

It is envisaged that with the development of these centralized Wastewater Systems, wastewater reclamation and reuse can be expanded to present a viable alternative for the development of water supplies nationally and present significant business opportunities for WASA. There is also the opportunity for new business development for the Authority through commercial transfers of reclaimed water to the industrial, agricultural and commercial sectors.

In this way, the country can well be on its way in emulating best practices at the international level which recognize the inextricable link between sound wastewater management practices and increased availability in terms of water supplies, as already exists in countries such as Singapore, and California in the United States. This is in fact a fundamental tenet of the Integrated Wastewater Management approach which considered the balance of the portfolio of water sources on a temporal and special basis, across the multitude of demand sectors.

		END USE HIERARCHY (Highest quality requirement on left to lowest quality requirement on the right)														
		Potable Water Standard		High Quality Industrial Standard	Medium Quality Industrial Standard	Unrestricted Urban Reuse Standard		General Purpose Industrial Standard		Food Crop Irrigation Standard	Indirect Augmentation/ Recharge Standard		Restricted Irrigation and Urban Reuse Standard	
Level of Treatment (Highest level of treatment at the top to lowest level of treatment at the bottom	**Treatment** Processes	Direct surface water augmentation of potable water supplies	Direct groundwater recharge using injection wells	Industrial - High pressure boiler feed	Industrial - Low pressure boiler feed	Urban - Unrestricted irrigation, fire protection, evaporative cooling	Urban - Unrestricted recreational reuse	Industrial - Cooling make up for evaporative cooling	Industrial - Scrubbing and wash water	Agricultural - Food crop irrigation	Indirect surface water augmentation with environmental barrier	Indirect groundwater recharge with environmental barrier	Agriculture - Non-food crops	Urban - Restricted irrigation and reuse
I	Secondary													
	Ultrafiltration													
	Reverse Osmosis													
	Advanced Oxidation													
II	Secondary													
	Ultrafiltration													
	Reverse Osmosis													
III	Secondary													
	Micro/Ultrafiltration													
	High Level Disinfection													
IV	**Secondary**													
	Filtration													
	High Level Disinfection													
V	Secondary													
	Basic Disinfection													

Table 8: Levels of treatment required for re-use purposes

CHAPTER 14

CENTRALIZED WASTEWATER SYSTEMS

A Centralized system is one where all the wastewater is collected and conveyed to a central location for treatment or disposal. Centralized systems are also called conventional systems.

Typical Characteristics of Centralized systems

- Conventional gravity sewers (deeply placed with manholes & lift stations)
- One treatment facility (normally activated sludge variation)
- High capital cost
- Transfers water away from source basin
- Long, disruptive construction
- Highly trained operator needed
- Potential for catastrophic failure

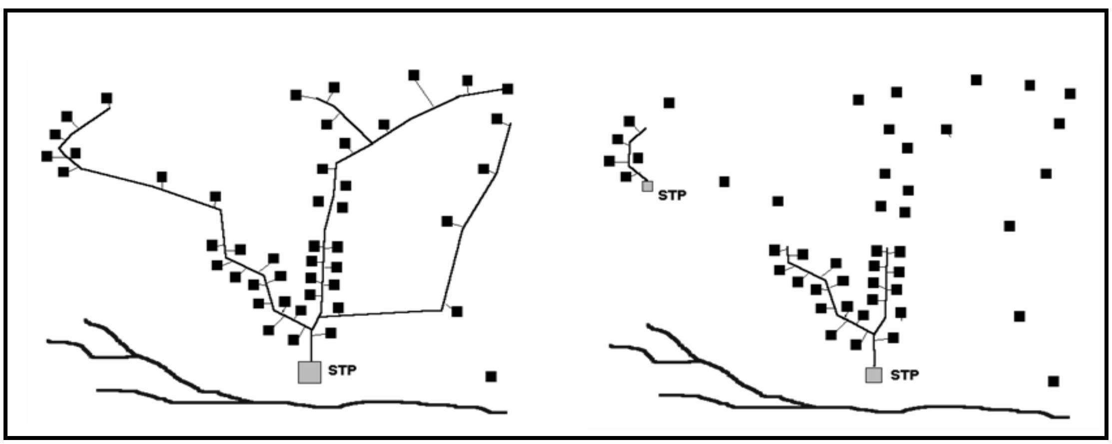

Figure 34: Schematic of Centralized system / Schematic of Decentralized system

The wastewater collection systems in Trinidad collect wastewater produced by residential, commercial, institutional and industrial service areas. Wastewater is collected within relatively localized areas of Trinidad and is directed to the wastewater treatment plants. Since the 1960s, Trinidad's wastewater collection systems have continued to expand. However, much of the expansion has been completed by private developers.

Due to many factors, WASA has been unable to execute any large scale consolidation of wastewater collection systems in tandem with the growth of developments. Developers therefore, have been required to construct their own wastewater disposal facilities sized for their immediate needs. The collection systems within these areas did not typically take into consideration future growth, or adjacent properties.

The total wastewater collection system pipe length in Trinidad is estimated to be in the order of 500 km. The local area collection systems carry wastewater from the source to the larger trunk sewers which deliver the flow to the treatment plants. The majority of the collection systems have been installed since 1962. They are generally installed less than 3.0 m below surface and consist of several different pipe materials. All of these factors: age, installation conditions and material, significantly affect the condition of the existing system.

The total wastewater collection system pipe length in Tobago is estimated to be in the order of 200 km. The existing local area collection mains carry wastewater from the source to the larger trunk wastewater mains with pipe sizes greater than 300 mm diameter. The trunk mains deliver the flow to the treatment plants.

Recent Master Planning assessments have divided the island of Trinidad and Tobago into thirty (30) sewersheds, twenty five (25) and five (5) respectively, for the purpose of planning and development to the provision of centralized wastewater systems to the year 2035. The rationale for developing these sewage catchment areas considers present development locations and probable development locations and intensities. The process in going forward will require consideration inter-alia of the following:-

- Integration of existing systems:

  Where small independent collection and treatment areas would be integrated into regional systems, largely as a result of the failure of the small treatment plants to be operated and maintained effectively. Regional or centralized systems are certainly the conventional and proven method of handling sewage in urban settlements in developed nations.

- Integration of new developments:

New developments will no longer be required to construct independent treatment and disposal works once regional facilities are available. In lieu of being made responsible for treatment plant construction course, developers could be asked to spend the equivalent amount or make contributions towards the regional trunk sewer or treatment works.

- Integration of un-sewered areas:

  Un-sewered areas of Trinidad are typically mixed throughout the community, with the private systems and new developments, and can therefore be easily integrated with proposed collection systems. Costs of work in these areas will be high due to the need to construct local sewers on every street and connections to every residential, commercial and industrial property.

BIBLIOGRAPHY

- A directory of Environmentally sound technology for the Integration Management of Solid Liquid and Hazardous Waste for SIDS in the Caribbean; Caribbean Environmental Health Institute; 2004
- Alberta Environment, Pollution Control Division; Water and Wastewater Operations; Level II Manual; 1987
- Beetham Wastewater Treatment Plant Presentation; Wastewater; 2008
- Consultancy Services for design of the collection system and wastewater treatment plant in South West Tobago- MAAK Technologies Inc.; 2010
- Expansion and Integration of Existing Wastewater Systems in Trinidad along the East-West Corridor and its Environs. ; Safege Consulting Engineering and ADeB Consulting Ltd. August 2005.
- Feasibility Study and Preliminary Designs for the Collection, Treatment and Disposal of wastewater in Tobago- Thames Water International (England) in association with Reid Crowther International (Canada) and ADeB Consultants (Trinidad); 1994
- Feasibility Study and Preliminary Designs for the Collection, Treatment and Disposal of wastewater in Tobago- American Water Services Engineering Inc.; 2004
- Greater Port of Spain Sewerage System Study- Reid Crowther in association with Alpha Engineering; March 1998
- Historical Review of Wastewater Sector; Corporate Communications
- Housing Act, Chapter 33:01; 1962
- Land Acquisition Act, Chapter 58:01; 1994
- Register of Wastewater Systems within Trinidad and Tobago, WASA-Vonetta Shermayne Antoine; February 16, 2001
- San Fernando Wastewater Project Overview Presentation; AECOM; November 2010
- Status of the Wastewater Sector in Trinidad and Tobago, WASA-Wastewater Subdivision; December 2008
- Sewerage Facilities; Eastern Main Road Communities: by Millette Engineering (international Ltd. in Joint Venture with Howard Humphreys Ltd; 1978

- Terms Of Reference for Integrated Wastewater Management Forum; Monitoring and Evaluation Unit; Wastewater Division; 2009
- The Development of a Wastewater Masterplan and Policy for Tobago Alternative Report Draft No.1; Genivar; May 2008
- The Development of a Wastewater Masterplan and Policy for Trinidad Alternative Report Draft; Genivar ;June 2008
- The National Plumbing Code of Trinidad and Tobago; 2005
- Regulated Industries Commission Act, Chapter 54:73; 1945
- The Planning and Development of Land Bill; 1999
- The Occupational Safety and Health Act; 2004
- Town and Country Planning Act, Chapter 35:01; 1960
- Using Reclaimed Water to Augment Potable Water Resources; Second Edition; 2008
- Water Resources Management Strategy for Trinidad &Tobago; Final Report; Main Report; 1999
- Water and Sewerage Authority Act, Chapter 54:40; 1965
- Wastewater Presentation for Schools Outreach Programme; Public Education Centre; 2010-2011
- Wastewater Treatment and Collection 101 Training; Student manual; DFA Infrastructure International; January 2010
- Water and Wastewater Master Plan and Policy; Wastewater Alternatives Report Trinidad and Tobago; Genivar; June 2008

❖ **Websites**

- http://www.biofilters.com
- www.fao.org; Quality Control of Wastewater for Irrigated crop production; chapter 2- Health risk from wastewater use; FAO Corporation- Natural Resource Management and Environmental Department
- http://poweredge2/intranet/index (Departmental pages - wastewater department)
- www.ric.org.tt
- www.ttbs.org.tt

- http://wecleanwater.com; Integrated Engineers, Inc.; Glossary of Wastewater Treatment Terms

APPENDIX 1- COMPENDIUM OF WASTEWATER TERMS

❖ **Sources of Wastewater**

- **Domestic wastewater** originates from homes. It consists of wastes from toilets, baths, showers, laundry, dishwashers, and garbage disposals.
- **Commercial wastewater** is usually similar to domestic wastewater. It may be higher in pollutants (for example, wastes from Laundromats or car washes) or it may contain some "unusual" components (for example, effluent from a photofinishing operation).
- **Institutional wastewater** (from hospitals, schools, penitentiaries, etc.) is usually very similar to domestic wastewater.
- **Industrial wastewater can** be very complex and may contain widely varying types and concentrations of pollutants. Of particular importance are toxic substances (heavy metals, phenols, pesticides, etc.); temperature; pH; BOD loading; and solids. Pretreatment of industrial effluents is often necessary to protect the sewer system and the plant.
- **Infiltration** ("leaking in") can greatly increase the flow to a wastewater treatment plant. Every wastewater collection system ever built has some "bad" joints where water from rain, etc., can get into it. Some systems are much worse than others, and infiltration is a serious problem.

❖ **Characteristics of Wastewater**

Wastewater is a complex mixture of physical, chemical, and microbiological compounds.

Physical characteristics

The physical characteristics of wastewater include temperature, turbidity, colour, odour, and solids content.

- **Temperature:** the wastewater will usually be a few degrees warmer than the potable water supplied to the community. This is because much of it will have been heated (for baths, showers, etc.) before being discharged to the sewer.

- **Turbidity:** this means the "cloudy" or "murky" appearance the wastewater has. It is caused by the very finely divided solid matter carried by the wastewater.
- **Colour:** the colour of fresh domestic wastewater is usually light grey. Septic (partyly decomposed) wastewater is darker in colour, often even black. If large amounts of industrial wastes are present, it could be almost any colour.
- **Odour:** fresh domestic wastewater has a musty odour which is not particularly unpleasant. Septic wastewater has a sulphurous, "rotten egg" smell.
- **Solids content:** all wastewater contains solid material. Some of this is clearly visible (rags, sticks, filter tips, and a great variety of other fairly large solids). Some is quite finely divided, but still in the form of solids suspended in the wastewater. And finally, some is dissolved in the wastewater and is not usually visible unless highly coloured. The amount and type of solids present affects the chemical as well as the physical properties of a wastewater.

Chemical Characteristics

Chemically, wastewater is composed of different organic and inorganic compounds.

- **Organic** substances are usually of animal of vegetable origin, and are quite complex chemically. They always contain carbon, hydrogen, and oxygen, and sometimes various other elements such as phosphorus, sulphur, and nitrogen. Most organic substances can be burned at fairly low temperatures, and are said to be volatile (easily decomposed to gaseous form).

  In the wastewater treatment process, these organic compounds are decomposed to form simpler substances such as carbon dioxide, ammonia, nitrates, and hydrogen sulphide. Most of the strength (degree of pollution) of wastewater is caused by the presence of organic material.
- **Inorganic** substances are relatively inert, and do not burn readily. They are also called inert or fixed substances. An example of an inorganic substances commonly found in wastewater is sand or grit.
- The suspended and dissolved organic and inorganic solids make up the total solids content of the wastewater. The solids content of a wastewater varies widely, depending

on many factors such as the living habits of the population, the amount of infiltration into the sewer system, and the time of day.

- Dissolved gases are usually present in quite small quantities. Among the most important of these is oxygen, which can come from the air dissolved in the original water, from contact with the atmosphere, or from aeration during the treatment process. The presence of oxygen is desirable, because it is an essential part of many wastewater treatment processes. It also helps prevent septic conditions and bad odours from developing.

  Other dissolved gases commonly found in wastewater include carbon dioxide, nitrogen, ammonia, and hydrogen sulphide. With the exception of hydrogen sulphide (which is poisonous and is also responsible for the "rotten egg" odour problem), these gases are not particularly significant to the treatment process.
- Nutrients, mainly compounds of nitrogen and phosphorus, act as fertilizers when discharged with the effluent. This can lead to undesirable growth of algae and other aquatic plants in the receiving watercourse.

Microbiological characteristics

Wastewater contains billions of microscopic, living organisms. Many of these are pathogenic. One of the most important objectives of wastewater treatment is to ensure that these are destroyed, so that the spread of infectious disease is prevented.

APPENDIX II - GLOSSARY OF TERMS

- Activated Carbon – Carbon particles or granules which have been processes so that they have a large capacity for adsorption of certain dissolved substances from wastewater.
- Activated Sludge – Sludge particles produced in raw or settled wastewater by the growth of microorganisms in the presence of oxygen.
- Activated Sludge Process – A biological wastewater treatment process which speeds up the decomposition of wastes by the use of activated sludge.
- Aeration – The addition of air to wastewater.
- Aeration Tank – The tank in which wastewater is mixed with return activated sludge and aerated.
- Aerobic – A condition in which free oxygen is present in the wastewater. Also used to describe organisms which live and grow in the presence of oxygen.
- Air Stripping – A treatment process used to remove dissolved gases and volatile substances from wastewater.
- Algae – Microscopic plants which contain chlorophyll and live suspended or floating in water, or grow on submerged surfaces.
- Anthropogenic - (chiefly of environmental pollution and pollutants) originating in human activity
- Biochemical Oxygen Demand (BOD) – A measure of the amount of oxygen used up by the aerobic microorganisms in wastewater when they decompose organic material, under certain standard conditions. The BOD is often used as a measure of the "strength" of wastewater or polluted waters.
- Blending – A process where treated reclaimed water is mixed or assimilated with raw water in the environment prior to delivery to the potable water system.
- Chemical Oxygen Demand (COD) – A measure of the oxygen-consuming ability of the organic and inorganic matter in wastewater.
- Chlorination – The addition of chlorination to wastewater
- Chlorinator – A device used to add chlorine to wastewater.

- Chlorinated Hydrocarbons – Substances formed when hydrocarbons in wastewater react with chlorine.
- Clarification - A process designed primarily to reduce the amount of suspended matter in wastewater.
- Combined Sewer – A sewer designed to carry both sanitary wastewater and storm water.
- Comminutor – A device to reduce the size of solid particles in wastewater by shredding (comminuting) them.
- Customer – Current or potential buyer or user of wastewater service. It is defined in terms of wastewater connection per household.
- Decomposition – The conversion of chemically unstable materials to more stable forms by chemical or biological action. Organic matter in wastewater is decomposed by anaerobic biological processes.
- Degasification – The removal of dissolved gases from wastewater.
- Detritus – The heavy, coarse material carried by wastewater.
- Direct Potable Reuse – The approach where highly reclaimed water is introduced directly to the potable water supply system.
- Disinfection – The destruction of disease- causing microorganisms in water or wastewater, usually by the use of chlorine.
- Force Main – A pipe which is under pressure, usually conveying wastewater from a pumping station.
- Free Chlorine – The part of the chlorine residual in wastewater which is composed of dissolved chlorine gas, hypochlorous acid, and hypochlorite ion.
- Hydrogen Sulphide – A gas having a typical "rotten egg" odour. It is poisonous, flammable, explosive, and colourless. It is produced from wastewater under anaerobic conditions.
- Indirect Potable Reuse – The approach where highly treated reclaimed water is introduced to a surface or groundwater system which ultimately is used as a potable water supply.
- Individual – A person who is benefiting from the provision of wastewater services.

- Integrated Wastewater Management (IWWM) - Examining wastewater management with a holistic perspective, involving all relevant stakeholders.
- Mixed Liquor – The mixture of wastewater and recycled sludge in the aeration tank of an activated sludge plant.
- Multiple Barrier Systems – These are systems in which sequential redundant processes are used to remove constituents of concern in treated wastewater resulting in a high degree of reliability.
- Nutrient – A substance which promotes growth. Nitrogen and phosphorous are the most important ones.
- Oxidizing Agent – Any substance which will oxidize another substance. The most common oxidizer, in wastewater applications, is chlorine.
- Quicklime – Calcium oxide is used for control of odours and other problems in wastewater treatment.
- Reclaimed/Reused Water - Reusable wastewater from wastewater treatment such as tertiary treatment of wastewater in biological and other systems.
- Septic Systems - The tank's purpose is to provide solid liquid separation and provide some degree of treatment. These systems use gravity to treat and distribute wastewater in the soil and have the lowest cost and require the least amount of maintenance. A septic tank is a chamber made of concrete, fibreglass, steel, etc.
- Sewersheds - An area of suitable development density, both existing and planned, that can naturally collect sewage together by gravity to a single point of treatment and disposal
- Storm Sewer – A sewer designed to carry runoff from storms, street, and washing, hydrant flushing and other relatively unpolluted wastewater.
- Total Dissolved Solids (TDS) – The sum of the amounts of all the matter dissolved in wastewater
- Total Suspended Soilds (TSS) - A measure of the suspended solids in waste water, effluent, or water bodies, determined by tests for "total suspended non-filterable solids”.
- Ultraviolet Disinfection (UV) - The use of ultraviolet light to kills bacteria and other microorganisms in water and wastewater. Typically a final treatment step.