

CHAPTER 1

WASTEWATER TREATMENT PLANT INDUSTRY

1.1 Need for Wastewater Treatment

Wastewater generation is directly related to human activities. As the human population is growing, the development activities to sustain this growth is increasing and consequently the volumes of wastewater.

Wastewater is the most common waste generated due to human activities. It includes domestic liquid waste from residences, industries and agriculture. The term wastewater is used for any water whose quality affected due

to human activities. While nature in itself has regenerative capacity to restore the water quality, the present volumes of wastewater generated by human activities far exceed this regenerative capacity. As a result the wastewater is further contaminating the available water resources. The impact of this is severe. It causes damage to human health, oceans, aquatic life, and fisheries. The issues are not limited to human health and environment alone but extend to economic downfall, thus affecting water availability for industrial operations and basic human needs. This in turn is increasing the extraction of water from freshwater sources. It is a vicious circle.

As per World Health Organization, 80% of the diseases in human being are water borne and water related. Untreated wastewater contaminates water bodies and groundwater.

From a management perspective, water quality is defined by its desired end use. Consequently, water for recreation, fishing, drinking, and habitat for aquatic organisms require higher levels of purity, whereas for hydropower, quality standards are much less important. For this reason, water quality takes on a broad definition, as the "*physical, chemical, and biological characteristics of water necessary to sustain desired water uses*"

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Some types of wastewater also contain harmful chemicals and heavy metals known to cause a variety of environmental and health problems.

It is therefore important that the wastewater is treated at the sources of generation, before it is discharged. **Wastewater treatment plants (WWTPs)** play the critical role of preserving the quality of water resources by reducing the contaminants in wastewater.

1.1.1 What is Wastewater?

Wastewater is generated from the various human activities. Day-to-day activities like bathing, toilet flushing, laundry, and dishwashing at household level generates wastewater. Commercial buildings also generate wastewater, from activities similar to households. Factories that use water in the production processes, also generate wastewater. Water used in agricultural fields also gets contaminated with the components of fertilizers and pesticides and contribute to wastewater.

The wastewater generated from the various sources have different types of contaminants and therefore the nature of the wastewater are also different. Table 1-1 provides an illustration of contaminants from different sources of wastewater.

Table 1-1: Sources of Wastewater

Wastewater sources	Source	Illustration of Contaminants
Domestic sources	Residential buildings, commercial complexes and small businesses	Fecal and vegetable matter, grease and scum, detergents, rags and sediment
Industrial sources	Industrial and manufacturing activities such as chemical, pharmaceutical, oil, mining, and metal industries	Toxic chemicals and metals, very strong organic wastes, or acidic/caustic waste
Agricultural sources	Run-off from agricultural fields and farms	Fertilizer components, pesticides, herbicides

1.1.2 Types of Wastewater Sources

Agricultural wastewater comprises of water runoff from large areas and is difficult to collect and treat. They are known as non-point sources.

Wastewater from domestic and industrial sources are discrete and identifiable and are therefore termed as point sources. The point source wastewater are easier to collect and

treat through WWTPs. These wastewater are also identified using different terms such as

- a) Domestic/Sanitary wastewater – Sewage
- b) Industrial wastewater – Effluent or trade effluent

1.1.3 Potential for Wastewater Treatment Industry

The ever-increasing growth in population along with increase in number of industries is expected to lead to rise in water consumption across sectors. This indirectly leads to the increase in the wastewater generation. *Environment Information System.*

In India, almost 70-80% of fresh water supplied to household is converted to sewage. As per a study published by ENVIS Centre on Hygiene, Sanitation, Sewage Treatment Systems and Technology, as on 2015, the total wastewater (sewage) generated in urban areas is around 61,754 MLD. As on 2015, India had a total of 816 sewage treatment plants with an installed capacity to treat 22,963 MLD of sewage. Thus, around 62% of the total sewage is discharged into nearby water bodies without any treatment.

Millions of Liters per day
In terms of industrial wastewater, all industries are required to treat the wastewater generated in Effluent Treatment Plants (ETPs) prior to discharge. Industries located in the clusters like industrial estates have additionally set up common effluent treatment plants (CETP's). While it is difficult to estimate the number of ETPs in the country, as on 2015 the country had 171 CETP's, providing an estimated capacity to treat 1190 MLD of Industrial effluent. It is also estimated that only 60% of the total generation of industrial wastewater is treated. Thus, **there exists a huge shortage of resources for wastewater management and treatment in India** (Kaur et al, n.d.). More importantly, of this limited treatment capacity, around 39% of the treatment plants do not conform to discharge standards and procedures set by the government, making the problem more serious (Sulabh – ENVIS, 2016). "

Putting the above scenario into perspective and the continued increase in industrial setups across the country, the wastewater treatment industry is expected to grow. Private research indicate a growth rate at 10 to 12% per year, indicating immense potential in this industry.

1.2 Career Prospects in Wastewater Treatment

The increasing emphasis on wastewater treatment both in sewage and industrial wastewater treatment can be met only with skilled technicians and operators. The growth in wastewater treatment industry will also lead to more employment in this sector.

Keeping up with the constant technological evolution of wastewater treatment plants coupled with the need to efficiently tackle the performance of these plants, is a major

challenge. A challenge which requires highly skilled, well-trained personnel to operate and maintain the wide variety of systems now in use. This importance is seen in other countries too, where training is considered essential to smoothly operate a WWTP with no efficiency loss."

Most wastewater operators are employed in public works departments in cities, towns and villages, where they may be responsible for water and sewer line repair and street maintenance. Another potential source of employment are the privately owned and State run industries where WWTPs are installed. CETPs also employ a larger number of work force.

Personnel working in WWTPs are required to maintain, monitor and operate control systems and equipment in these plants. They may work in different capacities and locations depending on their work profile. In small plants, water and wastewater technicians may operate water distribution systems, wastewater collection systems and treatment systems. In larger plants, they are usually assigned to a particular treatment or process area.

This manual aims at giving a vocational understanding of the operation and handling of WWTPs. These skills will enable the candidate to apply for a job in the private or public sector wastewater management plants.

1.2.1 Education and Training Requirements

The minimum educational requirement as per the course are:

- 12th Pass, or
- 10th Pass + ITI/Diploma, or
- 8th pass + 4 years' experience as Wastewater Treatment Plant Helper

1.2.2 Employment Opportunities

Typical entry-level careers in wastewater treatment are at industrial or domestic WWTPs. The various sectors where an operator can find employment opportunities are

- Contractors involved in the installation of water and wastewater systems
- Companies supplying and/or servicing water and wastewater materials and equipment
- Municipal Corporations or Councils managing WWTPs
- Private utility companies
- Large industrial plants
- Engineering consulting firms
- Contractor providing engineering services
- Operator training services

1.2.3 Career Advancement Prospects

As operators gain skills and experience, they are assigned tasks that involve more responsibility for more complex activities. Some technicians advance to become operators. Some operators advance to become plant supervisors or plant superintendents. The qualifications that superintendents need are related to the size and complexity of the plant. In smaller plants, experienced operators with some postsecondary training may be promoted to superintendent positions. In larger plants, educational requirements are increasing along with the sophistication and complexity of their systems, and superintendents usually have bachelor's degrees in engineering or science.

1.3 Roles of Personnel in Field of Wastewater Treatment

The various roles that can be played in wastewater treatment are the following:

1. Plant Manager

A Plant Manager is the head of the WWTP. An individual with a background on environmental engineering or science, and experience of at least three years on similar plant(s) qualifies for the post.

Their main role is to supervise all operations and ensure that the technicians, operators, analysts and helpers working under him carry out their duties effectively. Below are listed the basic responsibilities of the Plant Manager.

- Maintain a thorough understanding of unit operations and application of microbiology and environmental chemistry in the effluent/ sewage treatment
- Take decisions to divert / bypass/ distribute the flow in the event of disruptions / breakdown of mechanical or electrical equipment until resumption is in place and repairs / replacements are successfully carried out.
- Understand and be able to plan and forecast the use of chemicals / nutrients for plant operations and the laboratory.
- Working out dosages of chemicals and nutrients based on the raw effluent quality and change it as the treatment progresses and results start forthcoming
- Prepare a weekly list of duties for each individual and broadly lay down writing the duties and responsibilities of each category of staff
- Ensure that the staff on plant is rotated on different shifts during each month

2. Plant Operator

An operator, is a qualified / trained person with an ability to operate and maintain the wastewater treatment plant. They should be able to sense troubles and function as ears and eyes of the Plant Manager.

Their basic responsibilities are to

- Ensure smooth operation of the processes in the treatment plant such as wastewater treatment, sludge processing and equipment handling
- Ensure that various systems/components of the plant such as screens, grit removal devices, pumps, aerators, valves etc. are running as required
- Monitor control panels and adjust valves and gates manually or by remote control to regulate the flow of wastewater through settling, aeration, and sludge digestion processes
- Collect samples and undertake routine chemical analyses of wastewater at various points in the plant process
- Read and interpret charts, flow meters, and other gauges to determine operating efficiency of equipment
- Prepare the chemicals required for testing of wastewater
- Maintain logs, records, and reports relative to the work
- Raise requisition of supplies and materials
- Assist the electrical and mechanical maintenance technician(s) in carrying out the preventive and breakdown maintenance tasks, if required

A WWTP may have one or more operators depending on the size and scale of treatment.

3. Laboratory Analyst

A lab analyst, is a qualified individual who has knowledge of water and wastewater chemistry and is trained in preparation of laboratory chemicals, use of laboratory instruments, collection and preservation of water / wastewater samples, and conducting analysis for various environmental parameters such as pH, SS, BOD, COD, TDS etc.

4. Electrical / Mechanical Technician(s)

The basic functions of a technician are to carry out preventive maintenance of work equipment and instruments, identify causes and reasons for faults and failure, quickly carry out minor repairs / replacements by reaching, removing, stripping / opening,

repairing, assembling of routine electrical and mechanical machines / equipment including piping and valves

Depending on the size and scale of the plant there may be an individual or a team of qualified maintenance technicians.

5. Labour / Helpers

In addition to the above roles, labour / helpers are required to assist the above individuals for upkeep and maintenance of the various units, structures, areas, floors, rooms, equipment, tanks, vessels, beds etc. and removal, loading, haulage/carriage of wastes, screenings, stores and chemicals and other such material as the need be.

1.3.1 WWTP Operator

It is essential that each WWTP staff be well trained in related tasks and be equipped in the required resources.

The skills for WWTP operation and maintenance (O&M) are acquired mostly through **on-job training**. Trainees generally start as attendants or operators-in-training and learn their skills on the job under the direction of an experienced operator. They learn by observing and undertaking routine tasks such as recording meter readings, taking samples of liquid waste and sludge, and performing simple maintenance and repair work on pumps, electric motors, valves, and other plant equipment. WWTP Operators need mechanical aptitude and should have knowledge of basic mathematics, chemistry, and biology. They must have the ability to apply data to formulae prescribing treatment requirements, flow levels, and concentration levels.

WWTP operation is a **team work**. It requires proper team selection, training need assessment, training, on-job moulding, laboratory and statistical analysis for ensuring desired performance, trouble forecasting and trouble shooting. The O&M staff profile should address all these requirements.

Wastewater treatment plant **operators and technicians** regulate the flow of incoming wastewater by adjusting pumps, valves, and other equipment, either manually or through remote controls. They keep track of various meters and gauges that monitor the purification processes and indicate how the equipment is operating. Using the information from these instruments, they control the pumps, engines and generators that move the untreated water through the processes of filtration, settling, aeration, and sludge digestion. They also operate chemical-feeding devices, collect water samples, and perform laboratory tests, so that appropriate level of chemicals, nutrients and biological mass, are maintained in the wastewater. Technicians may record instrument readings and other information in logs of plant operations. These logs are supervised and monitored by operators. Computers are commonly used to monitor and regulate

wastewater treatment equipment and processes. Specialized software allows operators to store and analyze data, which is particularly useful during system malfunctions.

The duties of operators and technicians vary with the size and type of plant where they work. In small plants one person per shift may be able to do all the necessary routine tasks. But in larger plants, there may be a number of operators, each specializing in just a few activities and working as part of a larger team that includes engineers, chemists, technicians, mechanics, helpers, and other employees. Some facilities are equipped to handle both wastewater treatment and treatment of the clean water supplied to municipal water systems, and plant operators may be involved with both functions.

Other routine tasks that plant operators and technicians perform include **maintenance and minor repairs** on equipment such as valves and pumps. They may use common hand tools such as wrenches and pliers and special tools adapted specifically for the equipment. In large facilities, they also direct attendants and helpers who take care of some routine tasks and maintenance work. The accumulated residues of wastes from the wastewater must be removed from the plant, and operators may dispose of these materials. Some of this final product, or sludge, can be reclaimed for uses such as soil conditioners or fuel for the production of electricity.

Technicians may also survey streams and study basin areas to determine wastewater sources. To assist the engineers they work with, technicians prepare graphs, tables, sketches, and diagrams to illustrate survey data.

1.3.2 Professional Skills Required by a WWTP Operator/Technician

To be successful water and wastewater operator, one must have the knowledge of certain concepts, technical skills and abilities. Let us look at them in detail.

1. Knowledge

- Occupational hazards and safety precautions of facility operation maintenance and repair
- Methods, tools and materials used in the diagnosis, repair and maintenance of wastewater plant equipment
- Equipment, operations, practices and safety precautions relevant to the treatment and disposal of wastewater
- Wastewater plumbing methods and techniques, working knowledge of light and some heavy equipment operating principles, practices and procedures of the hazards and safety precautions
- Minor equipment maintenance and repair functions.

2. Technical Skills

- Perform equipment adjustment and alignments.

- Understand assets, criticality and failure modes
- Use basic technology
- Use computers to monitor automated control systems, query and generate work orders, and to maintain various databases and automated records

3. Abilities

- Perform sampling and basic testing and analysis for process needs
- Handle valve and piping replacement and repairs
- Effectively utilize appropriate safety equipment and procedures
- Drain cleaning, snaking, and process pipe cleaning
- Ability to work independently, direct team activities and to work as a team member
- Understand and follow verbal and written instructions
- Maintain regular and reliable attendance
- Communicate effectively, both verbally and in writing
- Establish and maintain effective working relationships with others
- Communicate frequently with team members and other units across the Organization about processes, equipment or potential problems
- Develop proficiency in unit specific operations and software
- Good hearing
- Good eyesight and colour vision
- Good manual dexterity
- Good health
- Stamina
- Ability to climb ladders, lift, bend and work in awkward positions
- Mechanical aptitude
- Good work ethic and a responsible, conscientious attitude
- Interest in public utilities and facilities
- Good math skills and the ability to perform calculations using formulas, percentages and ratios

1.4 Basic Terminologies used In Wastewater Treatment Industry

The knowledge and understanding of basic terminologies used in the wastewater treatment industry is important. Key terminologies^{iv} that should be understood by a WWTP Operator are provided below

Alkalinity	A measure of a substance's ability to neutralize acid. Water containing carbonates, bicarbonates, hydroxides, and occasionally borates, silicates, and phosphates can be alkaline. Alkaline substances have a pH value over 7.
Backwashing	The periodic operation in a filter, where flow of water is reversed to flush out the accumulated solids by agitating and fluidizing the filter media.
Bacteria	Single cell microscopic living organisms lacking chlorophyll, which digest many organic and inorganic substances. An essential part of the ecosystem including within human beings.
Bioengineering	The use of living plants as part of the system, be it wastewater treatment, erosion control, water polishing, habitat repair and on.
Biosolids	Rich organic material leftover from aerobic wastewater treatment, essentially dewatered sludge that can be re-used.
Backflushing:	Same as backwashing (see above), but more commonly used in the context of membrane filtration systems.
BOD	Biochemical Oxygen Demand is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period.
COD	Chemical Oxygen Demand is the amount of oxygen required to oxidize an organic compound to carbon dioxide, ammonia, and water. This is an indirect measure of the amount of organic pollutants found in water.
Detention Time - Retention Time, Residence Time	How long on average wastewater undergoes the wastewater treatment process. Time varies greatly across various types of wastewater treatment, from minutes to weeks.
Dewatered Sludge	The sludge after it's been dewatered, also known as sludge cake.
Dewatered Sludge Cake	The sludge after dewatering that is cake-like, compressed. The lower the water content the better for wastewater treatment purposes.

Dewatering	Removing water from sludge or other solids.
Digestion	The breaking down of sludge and other waste biologically by microorganisms. Results in by-products such as methane gas, carbon dioxide, sludge solids and water. Aerobic digestion requires oxygen, anaerobic digestion the absence of oxygen.
Denitrification	Biologically removing nitrate converting it to nitrogen gas.
Dissolved Oxygen (DO)	The amount of oxygen dissolved in the water. Measured in milligrams per liter.
E. Coli	A species of bacterium normally present in the intestinal tract of humans and other animals. Water and food contaminated with it may cause diseases.
Effluent	The final output flow of a wastewater treatment plant.
Floc	Particulate and or bacterial clumps forming wooly looking clusters in wastewater. In biological processes such as extended aeration or activated sludge and others the floc contains aerobic or anaerobic microorganisms. For industrial applications flocculants are used.
Flocculation	The process whereby a chemical or other substance is added to wastewater to trap or attract the particulate suspended solids into clusters or clumps of floc or flocculent, wooly looking masses.
Flocculent	Same as flocculating agent, the catalyst substance that causes the chemical reaction with TSS to form flocculent many times encapsulating the solids.
Flocculent	The "floc" or wooly mass of clusters that is formed in flocculation. Many times, used interchangeably with "flocculant" however truly refers to the floc mass and not the catalyst flocculating agent.
F/M	The Food/ Microorganisms ratio, which is to be set for a given .STP. It can be in the range 0.05 to 0.40 (5% to 40%).
Free Water Surface Wetland (FWS)	A constructed wetland or other shallow wastewater treatment pond where the shallow water is exposed directly to the air.

Freeboard	Distance in a closed tank from the sewage level to the top of the tank.
Grease	Fats, soaps, oils, waxes etc. in wastewater
Headworks	The beginning of the treatment plant where the influent begins treatment.
Influent	The untreated wastewater or raw sewage coming into a wastewater treatment plant.
Influent Screens	Screens used to remove large inorganic solids from the waste stream.
MLSS	The contents/ mixture in the aeration tank is called Mixed Liquor. The suspended solids in this Mixed Liquor is called MLSS (which is taken to be the microbes).
O&G	Oil and grease
pH	A measurement that indicates the acidity or alkalinity of any solution. Acidic solutions have a $\text{pH} < 7$; and alkaline solutions have a $\text{pH} > 7$) Solutions with $\text{pH} = 7$ are neutral.
Raw Sewage	Untreated sanitary wastewater
Reclaimed Water	Reusable wastewater from wastewater treatment such as tertiary treatment of wastewater in biological and other systems.
Treatment efficiency	Percentage removal of any pollutant parameter in the STP.
TSS	Total Suspended Solids
Turbidity	A measure of how clear water is in Nephelometric Turbidity Unit (NTU), invisible to the average naked eye until readings in excess of 100 are reached, typically determined by shining light through a sample placed in a turbidimeter.

1.5 Process of Wastewater Treatment

Wastewater from homes, public buildings, commercial complexes in cities and towns are transported through sewer pipes and sent to Sewage Treatment Plants (STPs) and the wastewater generated in industrial plants may be treated at source or transported to common treatment plants for treatment. Post treatment, depending on the quality of water, it may be discharged into water bodies or reused for various processes.

Sewage is wastewater generated from domestic sources such as residential buildings, commercial complexes and small businesses. It contains fecal and vegetable matter, grease

Wastewater treatment is a process of converting wastewater into water that can be either returned to the water cycle with minimal environmental issues or reused.

The basic objective of wastewater treatment process is to separate or remove the undesired contaminants, harmful pollutants and microorganisms from the wastewater making it safe for discharge into water bodies or for use in irrigation. Depending on the characteristics and further treatment, the wastewater maybe even recycled and reused for domestic or industrial use.

While the basic principles of treatment remain same, the type and extent of treatment differs depending on the wastewater characteristics and pollutant. Effluent treatment is a more complex treatment process as compared to that of sewage treatment.

Effluent is wastewater generated from industrial sources such as manufacturing of chemicals, pharmaceutical, oil, mining, and metal industries. It contains toxic chemicals and metals, very strong organic wastes, or

The treatment may include **mechanical, physical, biological,** and **chemical** methods. The first stage is removal of visible solids, everything from rags and plastics to sand and smaller particles found in wastewater. The next stage includes reduction of the organic matter and pollutants by using bacteria and other microorganisms which convert biodegradable organic matter contained in wastewater into simple substances and additional biomass. The biomass along with the absorbed chemical components are then separated from the water. This solid mass that is separated is termed as **sludge**. Post this, the water is further filtered and disinfected before letting it into the waterbodies or using it for irrigation. Disinfection is carried out to ensure that the harmful bacteria do not enter the location where water gets discharged.

The Figure 1-1 explains the basic scheme of wastewater treatment. A wastewater treatment plant is essentially divided into the following sections:

- Primary treatment – physical / chemical processes.

- Secondary treatment – biological processes
- Tertiary treatment – advanced physical / chemical processes
- Sludge treatment

Depending on the properties of the wastewater and the treated water quality requirements, further steps may be necessary, such as removal of phosphates, disinfection, color removal etc.

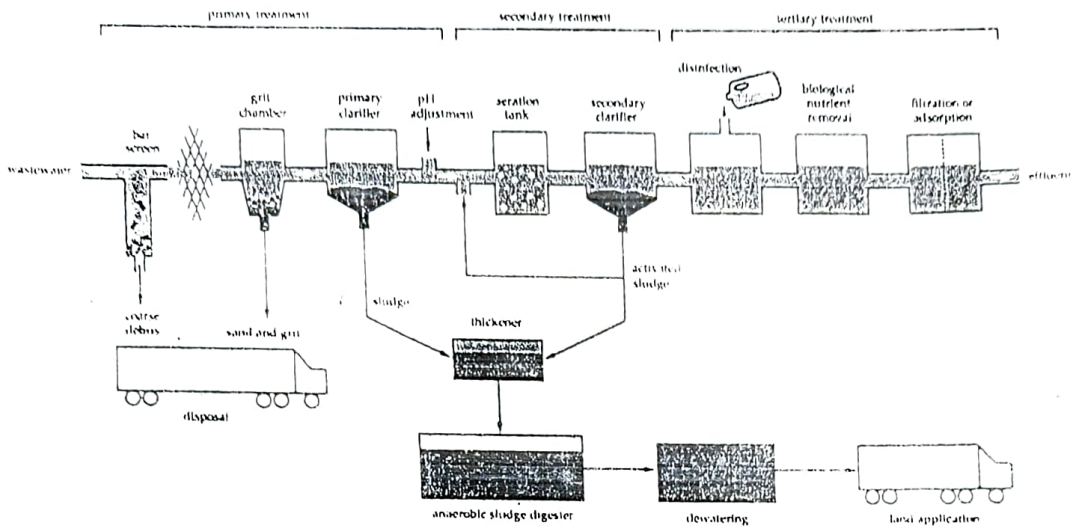


Figure 1-1: Wastewater treatment scheme

Primary Treatment

In the first stage, suspended solids are mechanically removed from the wastewater. Initially, coarse materials such as pieces of wood, plastic bags and fabric are removed using a bar screen. Then the water flows into a grit chamber for separation of mineral solids such as sand and gravel. Organic solids have a much lower settling velocity than sand and, consequently, a low velocity sedimentation step is required to separate them. This process stage is termed primary settling or clarification and the solids which separate at this stage are termed primary sludge. Primary treatment may also processes like neutralization and equalization.

Secondary Treatment

Primary treatment is followed by biological treatment of the wastewater termed as secondary treatment. The principle of biological treatment is based on the fact that microorganisms use the organic matter as a source of nutrient. In this manner, they degrade the organic matter and remove it from the wastewater. The most frequently used method is the Activated Sludge Process or its variation. In this process, *Aerobic / Aeration are terms which mean 'in the presence of air', which contains oxygen required for the treatment*

organic matter is degraded by aerobic micro-organisms. In order to provide them with the necessary oxygen, the wastewater is aerated in the aeration tank. The products of the aerobic metabolism are biomass, water and carbon dioxide. The growing microorganisms form flocs – the so called “activated sludge” – which are continuously removed from the aeration tank together with the wastewater. The activated sludge is separated, by means of sedimentation in the secondary clarifier. The treated water contains only small amounts of organic matter.

Activated sludge process is best suited for the removal of soluble organic matter. The insoluble organic matter can usually be removed more economically in the primary treatment.

Tertiary Treatment:

Tertiary treatment is the final cleaning process that improves wastewater quality before it is reused, recycled or discharged to the environment.

The treatment removes remaining inorganic compounds, and substances, such as the nitrogen and phosphorus. Bacteria, viruses and parasites, which are harmful to public health, are also removed at this stage. These technologies include:

- Adsorption Processes by Activated Carbon
- Chemical Oxidation
- Membrane Processes; and
- Electro-dialysis

The tertiary treatment processes are generally expensive.

Sludge Treatment

The portion of the activated sludge which is removed in the secondary treatment together with the primary sludge from the primary treatment, is further treated to reduce the water content prior to disposal.