An Assessment of Water Utilization and Management in an Industry

By

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Declaration

The work described in this thesis was carried out by me at the Unilever Ceylon Limited, Grandpass site and Faculty of Applied Sciences under the supervision of Mr. Dhammika Welhenge and Ms. Enoka Kudavidanage. A report on this has not been submitted to any other university for another degree.

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Affectionately Dedicated to

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Abstract

Water is a scarce resource, which is essential for all life forms. Industrial sector, being a major consumer of water, could contribute in conserving this scarce resource by adopting proper management techniques. Unilever Ceylon Limited aims at reducing the water consumption through proper management of water. The main management techniques adopted by the Unilever Ceylon Limited to minimize the water consumption include Reduction, Reuse, and Recycling of water. An assessment was conducted to identify the present state of utilization and future prospects of further management of water. To study the options of reducing water consumption through grade wise water classification a water quality analysis was carried out for selected physical, chemical, and biological parameters. Accordingly it was found that some low-grade water requirements could be fulfilled by marginal-grade water, such as recycled wastewater. In order to identify the prospect of using recycled water, a close study on the effluent treatment process and the distribution of recycled water in the factory was done. If the effluent flow from departments could be controlled the effluent treatment plant has the capacity of treating all the effluent produced within the company, which will also eliminate the problem of discharging wastewater to the environment. A control of effluent flow could be gained by the continuous measurement of effluent flow rates. For the effluent flow rate measurement V–notch technique was adopted. In addition to this department wise water meter readings were also recorded, which are related to the amount of effluent flow. The collaboration of all departments on minimizing the water consumption, and accordingly the effluent discharge, will result in a consumption reduction and a high efficiency in the operation of treatment plant. At present the water management of the company is at a good state and conducting a cleaner production audit could add more effectiveness to it. All these methods coupled with increasing workers awareness on water management techniques will contribute in further reduction of water consumption and conservation of this scarce resource.

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Abbreviations

BMD	Bulk Material Department
BOD	Bio Chemical-oxygen Demand
COD	Chemical Oxygen Demand
DAF	Dissolved Air Floatation
DO	Dissolved Oxygen
ETP	Effluent Treatment Plant
TDS	Total Dissolved Solids
TVC	Total Viable Count

Chapter 1

Introduction and Objectives

1.1. Introduction

Water is an essential substance for all life forms existing on earth. Its physical and chemical properties directly impact the interaction of life forms with their environment.

Global number on water availability gives a false sense of security, because water is abundant globally but scarce locally. Total water on the earth is 1,360 million cubic kilometers, 97 percent of which is in the oceans. There are 37 million cubic kilometers of fresh water, and three fourth of this is in glaciers and icebergs. About 8 million cubic kilometers of fresh water is stored as groundwater. Lakes and rivers accounted for only 200,000 cubic kilometers of water (Rosegrant 1997).

For a long time water was treated as an inexhaustible supply. People dumped all used water and got a new supply. Although water is a renewable resource renewal takes time. The rate at which water is used today makes it necessary to protect, conserve, and replenish water supply.

Water problem has arisen mainly due to:

1). Rising demand for water
2). Unequal distribution of usable fresh water
3). Increasing pollution of existing water supplies

New strategies for water development and management are urgently needed to avoid the severe national, regional, and local water scarcities that will reduce agricultural production, disturb the household and industrial sector, damage the environment and cause water related health problems.

Since Sri Lanka also faces a scarcity of water and recently is affected by lack of rain due to environmental change management of available water in relation to the three main water-consuming sectors, viz. domestic, agricultural, and industrial is very important.

Proper water management could reduce industrial water consumption to a great extent.
Due to lack of proper management, water is overused and wasted instead of being treated as a scarce resource. Management practices such as 3 R's viz. Reduction, Reuse, and Recycle combined with modern technology could give a good solution to this water problem.

Unilever Ceylon Limited being a subsidiary of the multinational company Unilever, which operates in all developed markets, put great efforts to minimize and control water resource consumption within the company through good management practices and modern technology. The company's main target, with regard to water consumption, is to reduce the amount of water used per ton of product. At present water used per ton of product is around 2.5 cubic meters. Its target is to reduce this to 2.4 cubic meters per ton of product.

Soaps, detergent powders, edible fats, toothpaste, shampoos, body lotions, and talc are among the products produced at the Unilever Grandpass factory site (Appendix 1). All these products come in different brands and sizes.

As in all other industries in Unilever also water plays a major role in its day to day activities. Although a large variety of products are produced in large amounts, when compared with the total amount of water used per year, only a small fraction of water goes into the products. The remainder is being used for other purposes such as drinking, washing, chemical preparation, toilet flushing, cooking, boiling, and gardening. Even though the fraction of water going out of the company with products could not be avoided water used for other purposes could be reduced by proper management practices.

The company has adopted various techniques and methods in achieving this objective of reducing water consumption at the factory, which in turn give both economic and social benefits.

Present state of water utilization and further management prospects of water could be analyzed by carrying out an assessment of water utilization and management with in the company.

1.2. Objectives

- Grade wise classification of water based on water quality analysis for selected physical, chemical, and biological parameters.

- Identifying the water distribution within the company through studying available maps and an individual study.

- Studying the effluent treatment and recycling of water using secondary data and an individual study.

- Identifying the prospect of reducing wastage of water and increasing recycling of water within the company.

Chapter 2

Sustainable Utilization of Water Resource in Industries

2.1. Importance of water

Water is an essential substance for all life forms existing on earth. The form in which the chemical compound water manifest itself is variously modified by its physical properties, its capacity to dissolve solids, liquids, and gaseous substances and hence by its secondary chemical action. Water also provides a habitat for a wide variety of organisms (Walling and Webb 1998).

Water uses are either consumptive or non-consumptive. Consumptive uses, such as agriculture, lead to direct loss of water from the useful part of the hydrologic cycle either through evaporation, transpiration, or incorporation into some other substance such as plant or animal tissues or industrial products. Most urban industrial uses are relatively non-consumptive. Only one tenth used for industrial purposes and one sixth of water used for domestic purposes is consumed, The rest is restored to streams or underground storage for later use, although usually in a polluted state (Dasmann 1984).

Many water quality problems existing today have arisen through the use of water for domestic, agricultural, and industrial purposes. As a consequence surface, ground, and coastal waters have become polluted with a wide range of contaminants including organic materials, nutrients, radioactive substance, and sediments. Fresh water vulnerability is likely to be most severe when problems of water contamination are combined with those of water scarcity (Walling and Webb 1998).

When it comes to Sri Lanka, the island receives almost all of its fresh water from rainfall. The mean annual rain of Sri Lanka is around 2000 mm which would give an average volume of a little over 130 billion cubic meters of fresh water. By the total volume of water received from rainfall only about 35 percent or around 45 billion cubic meters is used and transpired by natural vegetation and seeps into the soil to replenish the ground water. According to WHO statistics only 50-74 percent of population in Sri Lanka had access to safe water by 1990 (J. on Natural Resources of Sri Lanka 2000).

The world faces sever and growing challenges in maintaining water quality and meeting the rapidly growing demand for water resources. New sources of water are increasingly expensive to exploit, limiting the potential for expansion of new water supplies The water use rates differ from region to region, which causes sever scarcity problems in some regions (Rosegrant 1997).

Table 2.1.1 Water consumption rates by continent, 1950-2000 (km^3 / year)

	1950	***1960***	***1970***	***1980***	***1990***	***2000***
Africa	56	86	116	168	232	317
Asia	865	1,237	1,543	1,939	2,478	3,187
Europe	44	185	294	436	554	673
Latin America	89	63	85	111	150	216
North America	286	411	556	663	724	796
Total	550	1,982	2,594	3,316	4,138	5,189

(Source: Rosegrant 1997)

Industrial sector is one of the major water consumers at present. Therefore water management with regard to this sector is becoming very important. Reduction, Reuse, and Recycle techniques combined with good education on water consumption could manage the water resource requirements in relation to industrial sector (Cunningham and Saigo 1997).

One such technique of water management is the grade wise classification of water, where even wastewater could be reused depending on the water quality requirements of each task at the industry (Gupta 2001).

2.2. Grade wise water consumption

Structural and functional attributes of water, which may be categorized as physical, chemical, and biological, have to be analyzed both quantitatively and qualitatively in order to have a comprehensive evaluation of the water quality. The knowledge of water quality and its content are essential in judging its suitability for various purposes like public health, industry, and environmental safety (Gupta 2001).

All industrial purposes do not need high-grade water. Some purposes could be fulfilled using low-grade water. In order to find out the grades of water, water quality analysis is essential (Rump and Krist 1988).

Physical characteristics of water include colour, temperature, odour, taste, and turbidity. Colour is imparted to water when substance such as acids, metallic ions, weeds, and industrial effluents are present. Temperature affects the chemical and biological reactions in water. Odour and tastes are of prime importance with regard to potable water. Natural water depending on the impurities present exhibit specific odour and tastes. Turbidity is an expression of optical property and suspended matters such as clay and silt, which causes turbidity (Gupta 2001).

Chemical parameters of water include Dissolved Oxygen (DO) and Chemical Oxygen Demand (COD) like parameters. DO measure the amount of oxygen dissolved in water. COD measures the amount of oxygen required to oxidize the chemicals present in water. When the COD and BOD values are high the water is said to be in a polluted state (Eckenfelder 2000).

Biological parameters include Biochemical Oxygen Demand (BOD), Total Viable Count (TVC), coliform count and various other microbiological parameters. BOD measures the amount of oxygen required by the microorganisms to break down the organic matter present in water. The microbiological parameters are important in both health-related studies and pollution controls (Rump and Krist 1988).

Depending on the grade of water requirement treated wastewater also could be used in fulfilling the water requirements. A proper water treatment methodology should be adapted to achieve the required grade of water (Eckenfelder 1989).

2.3. Process of Wastewater Treatment

Any method, technique, or process designed to change the physical, chemical, or biological characters or composition of any hazardous waste, so as to neutralize waste to render such waste non-hazardous, safe for transport, amenable for recovery, amenable for storage, or reduced in volume is called waste treatment. Treatment process that is carried out with regards to wastewater is known as effluent treatment (Cheremisinoff and Ferrante 1992).

The selection of a wastewater treatment process or a combination of process depend upon:

a) The characteristics of the waste water
   This should consider the form of the pollutant (i.e. suspended, colloidal, or dissolved), the biodegradability, and the toxicity of the organic and inorganic components.
b) The required effluent quality
   Consideration should also be given to possible future restrictions such as an aquatic toxicity limitation.

c) The costs and availability of land for any given wastewater treatment problem One or more treatment combinations can produce the desired effluent.Only one of these alternatives, however, is the most cost effective. A detailed cost analysis should therefore be made prior to final process design selection (Eckenfelder 1989).

Depending on the nature of the industry and the projected uses of the waters of the receiving stream, various waste constituents may have to be summarized as follows:

- Soluble organic matter
- Suspended solids
- Colour and turbidity
- Oil and floating material
- Nitrogen and Phosphorous (Eckenfelder 1989)

In any plant there will be statistical variations in the waste flow characteristics. This is due to difference in housekeeping and water reuse as well as to variation in the production process (Saltzberg and Cushnie 1985).

Treatment process could be classified into three main sections i.e. physical treatment, chemical treatment, and biological treatment (Eckenfelder 1989).

2.3.1. Physical Treatment

Physical treatment methods include grit removal, and screening by filters, Dissolved Air Flotation (DAF) method, equalization technique and any other treatment process carried out prior to the chemical and biological treatment (Eckenfelder 1989).

Prior to any other treatment removable waste matter from the effluent should be removed using physical methods. Iron meshes could remove the large particles in the wastewater itself in the gutter. Small particles, up to some extent, could be filtered out (Holmes 1983).

Thickening through DAF method is becoming increasingly popular and is particularly applicable to gelatinous sludge, such as activated sludge. In this method small air bubbles, from the bottom of the tank, is release under pressure. Released air and the liquid are mixed under pressure in a retention tank with a detention time of 1 to 3 minutes. A back pressure-regulating device maintains a constant head on the pressurizing pump. The flotation unit may be either circular or rectangular with a skimming device to remove the thickened, floated sludge (Eckenfelder 1989).

The objective of equalization is to minimize or control fluctuations in wastewater characteristics in order to provide optimum conditions for subsequent treatment processes (Holmes 1983).
The purpose of equalization for industrial treatment facilities are :

- To provide adequate pH control or to minimize the chemical requirements necessary for neutralization.
- To provide continuous feed to biological systems over periods when the manufacturing plant is not operating.
- To prevent high concentrations of toxic materials from entering the biological treatment plant.

The equalization basin should be of a sufficient size to adequately absorb waste fluctuations caused by variation in plant-production scheduling (Holmes 1983).

2.3.2. Chemical Treatment

In the chemical treatment wastewater is treated mainly through coagulation and flocculation. Different types of chemicals are added during this treatment process depending on the nature of the industry (Saltzberg and Cushnie 1985).

Coagulation is employed for the removal of waste materials in suspended and colloidal form. Colloids are presented by particles over a size range of 1nm to 0.1nm. These particles do not settle on standing and cannot be removed by conventional physical treatment process (Holmes 1983).

Colloids present in wastewater can be either hydrophobic or hydrophilic. The hydrophobic colloids (clays) possess no affinity for the liquid medium and lack stability in the presence of electrolytes. They are readily susceptible to coagulation. Hydrophilic colloids, such as proteins, exhibit a marked affinity for water. The absorbed water retards flocculation and frequently requires special treatment to achieve effective coagulation. Colloids possess electrical properties that create a repelling force and prevent agglomeration and settling (Eckenfelder 1989).

The zeta potential is the potential drop between the slipping plane and the body of solution and is related to the particle charge and the thickness of the double layer of the ion (Laak 1986).

Since the vast majority of colloids in industrial waste possess a negative charge, the zeta potential is lowered and coagulation is induced by the addition of high-valence cautions. The optimum coagulation will occur when the zeta potential is zero; this is defined as the isoelectric point. Effective coagulation will usually occur over a zeta potential range of 0.5mv (Laak 1986).

Coagulants such as activated silica and/or polyelectrolite enhances the floc formation.

There are three types of polyelectrolytes:

- A cationic, which adsorbs on a negative colloid or floc particles
- An anionic, which replaces the anionic groups on a colloid particle and permits hydrogen bonding between the colloid and the polymer

- A nonionic, which adsorbs and flocculates by hydrogen bonding between the solid surfaces and the polar groups in the polymer (Eckenfelder 1989).

2.3.3 Biological Treatment

In the biological treatment process microorganisms are employed in the degradation of organic substance in the waste. When organic matter is removed from the effluent by microorganisms two basic phenomena occur: oxygen is consumed by the organisms for energy and new cell mass is synthesized; the organisms also undergo progressive auto-oxidation in their cellular mass (Laak 1986).

Several mineral elements are essential for the metabolism of organic matter by microorganisms. All but nitrogen and phosphorous are usually present in sufficient quantity in the carrier water. Sewage provides a balanced microbial diet, but many industrial wastes do not contain sufficient nitrogen and phosphorous and require their addition as a supplementary source (Eckenfelder 1989).

Filamentous organisms are present in most activated sludge. One of the most common causes of filamentous bulking in industrial wastewater is inadequate nitrogen or phosphorus. Many Filamentous organisms are aerobic and can be destroyed by prolonged periods of anaerobiosis. Most of the bacteria, on the other hand, are facultative and can exist for extended periods without oxygen. Anaerobic or anoxic conditions maintained within the process will restrict the growth of these filaments (Eckenfelder 1989).

Variations in temperature affect all biological processes. There are three temperature regimes:

- The mesophilic over a temperature range of 4 to 39 ^{0} C,
- The thermophilic which peaks at a temperature of 55 ^{0} C, and

- The psychrophillic which operates at temperature below 4 ^{0} C

For economic and geographical reasons most aerobic biological-treatment processes operate on the mesophilic range. In the mesophilic range, the rate of the biological reaction will increase with temperature to a maximum value at approximately 31 ^{0} C for most aerobic waste systems. A temperature above 39^{0}C will result in a decrease the reaction rate of mesophilic organisms (Holmes 1983).

A relatively narrow effective pH will exist for most bio-oxidation systems. For most processes this covers a range of pH 5 to 9 with optimum rates occurring over the range of pH 6.5 to 8.5 The influent waste is diluted by the aeration tank contents and is neutralized by reaction with the CO_2 produced by microbial respiration. In the case of both caustic and acidic wastes, the end product is bicarbonate (HCO^-_3), which effectively buffers the aeration system at near pH 8.0. Application of the complete mixing concept is essential in order to take advantage of these reactions (Holmes 1983).

Aeration basins are the basic structures of activated sludge wastewater treatment systems. The shape of the aeration tanks should be designed by taking into consideration the aeration equipment to be used as well as these aspects necessary for assuring hydraulically favourable flow conditions (Saltzberg and Cushnie 1985).

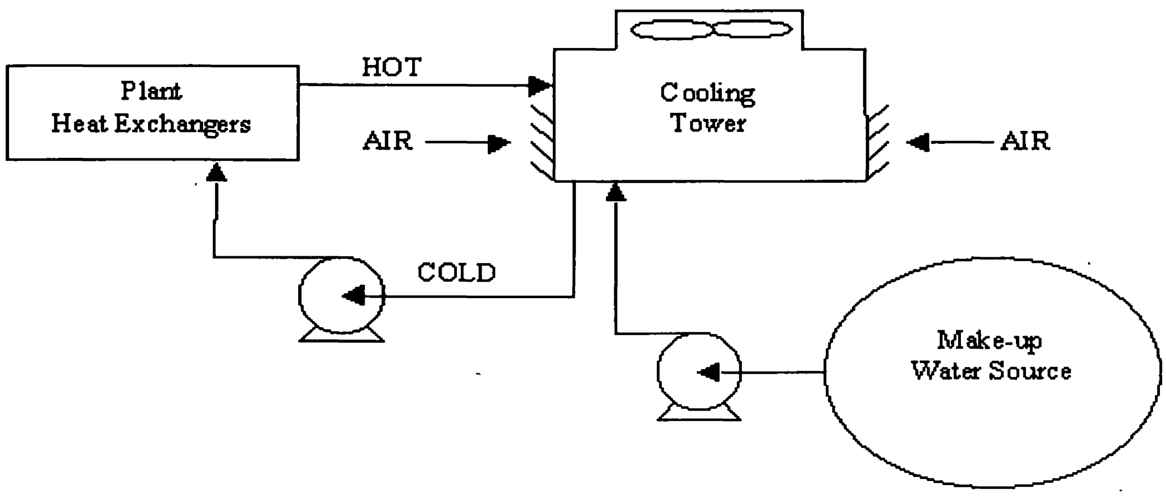
The treated wastewater could be used as recycled water with in the company to fulfill the low-grade water requirements such as floor washing, bathroom flushing and fulfilling the make-up water requirement of cooling towers (Our History 2003).

2.4. Cooling Towers

In product manufacturing industries water is used for the purpose of cooling heated equipment. The water absorbs heat produced by the equipment and flow in to the cooling system, where it once again gets cool and recirculates. For the purpose of cooling either spray ponds or cooling towers are employed. Spray ponds are rarely used except in large installations, where as cooling towers have the advantage of ease of operation and relative small size. In either case, advantage is taken by the evaporation of a small part of the water in contact with the air to cool the remainders (Vilbrand 1991).

The heat transfer from water to air, with out any change in the physical phase of water, is called the sensible heat. The heat transferred to air when water evaporates is called the latent heat, where the liquid phase transforms in to gaseous phase. The sensible heat is less when compared with the latent heat. In the cooling tower operation both this heat transfer techniques are employed in cooling the receiving condensates. The water falling from the top of the cooling tower, get exposed to air and evaporation takes place. The fan added over the water encourage moisture-loaded air to exit the tower and replace it with new air, which enhances the cooling effect more. The heat is removed more when evaporation is high (Frater 2001)

New water or make-up water should be added to replace the water that is loss through evaporation. On the other hand this newly added water or make-up water helps in bringing down the receiving condenaste's temperature through mixing. Water losses form the tower include evaporation, drift (water enter in to the discharged vapor), and blowdown (water released to discard solids). Drift losses are estimated to be between 0.1 and 0.2% of water supply (Frater 2001)



(Source: Frater 2001)

Figure2.4.1 Cooling Tower Operation

These towers utilize large fans to force air through circulated water. The water falls downward over fill surfaces which helps in increasing the contact time between the water and the air. This helps maximizing heat transfer between the air and water. The make-up water source is used to replenish water lost to evaporation. Hot water from heat exchangers is sent to the cooling tower. The water exits the cooling tower and is sent back to the exchangers or to other units for further cooling (Frater 2001).

Cooling towers are often categorized by the way they make air and water interact:

- The counter flow towers has air and water passing in opposite directions. The water falls vertically down while the air travels vertically up
- In the cross flow tower, water flow remains vertically down while the airflow is vertical

Counter flow towers tend to be the most compact. This is because the coldest air is in intimate contact with the entire cross section of water just before it falls in to the basin. Less space is needed due to this increased efficiency. Cross flow towers enjoy considerable popularity due to their operational cost savings. They often have the lowest initial cost as well as convenience in design (Thermal Analysis 2000).

The water being cooled is reused in factory processes, which reduce the amount of water required at the industry. Recycled water could be used as make-up water, which will also reduce the cost of operation and conserve water (Vilbrand 1991).

The use of treated water for the purpose of filling the water loss of the cooling tower reduces the water consumption since new water withdrawal is not required. Water gets recirculated within the company in a closed system. For the purpose of further reduction of water, keeping track of wastewater flow is also important. On the other hand effluent flow measurements could help in controlling the amount of effluent entering the treatment plant or otherwise the plant will get over-loaded (Chow 1989).

2.5. Flow rate measurement

An open channel is a conduit in which water flows with a free surface. Classified according to its origin a channel may be either natural or artificial. Natural channels include all watercourses that exist naturally on the earth. The hydraulic properties of natural channels are generally very irregular. Artificial channels are those constructed or developed by human effort such as irrigation canals and flumes, drainage ditches, flood ways, and gutters (Chow 1989).

The need for open channel flow meters arises in water works and sewage works. In the industrial undertakings open channel flow meters are frequently used for metering boiler feed water in small works and for measuring the quantity of effluent discharge into the sewers (Linford 1989).

The hydraulic properties for artificial channels could be either controlled to the extent desired or designed to meet given requirements. Therefore the application of hydraulic theories for open channels will produce results fairly close to actual conditions hence they are reasonably accurate for practical design purposes (Chow 1989).

Artificial channels are usually designed with sections of regular geometric shapes. The trapezoid is the commonest shape for channels since it provides side-strips for stability. The triangular are special cases of the trapezoid. The triangular is used only for small ditches, gutters, and laboratory work (Chow 1989).

Wastewater flow in a channel is approximately equal to water used. Open channel flow meters could be employed in measuring the effluent flow rates and accordingly the amount of water being used (Laak 1986).

Two forms of open channel flow meters are available, both of which enable a continuous registration of the flow to be obtained:

a) The weir
b) The venturi flume

The weir consist of a dam which is constructed across the open channel, the water to be metered flowing over the top of the crest. The depth of flow over the crest is a measure of the flow rate.(Linford 1989).

The weirs are classified in accordance with the shape of the opening through which the water to be metered must pass. Triangular weirs are in the form of a V-notch with the apex of the V at the lowest point. The objective of this construction is to increase the depth of flow over the vertex of the weir at the lowest flow rate. The angle of the V-notch is determined by the required depth / flow relationship.

In view of this construction it will be apparent that the maximum flow, which can be measured, is restricted (Linford 1989).

Flow measuring structures are designed so that discharge is made available to behave according to certain well-known hydraulics laws. For example, the discharge per unit length over a weir is function of the head over the weir. Many specialized weirs, such as V-notches, have been designed to provide accurate discharge data by observation of water surface level upstream of the weir (Wilson 1991).

When the waste flows through a sewer, it is frequently possible to measure the velocity of flow and the depth of water in the sewer and calculate the flow from the continuity equation, since $Q = AV$ where:

Q = Amount of discharge

A = Area of the water flow

V = Velocity of water flow (Wilson 1991)

In gutters or channels, either a small weir can be constructed or the flow can be estimated as above by measuring the velocity and depth of flow in the channel. Total waste flow from an industry plant can be measured by use of a weir. In certain instances the daily waste flow can be estimated from water consumption records (Eckenfelder 1989).

All the above methods and techniques contribute in the sustainable utilization of water in any industry. Modern technology coupled with the above methods will result in sound management of water.

Chapter 3

Materials and Methodology

3.1. Study Site

Unilever Ceylon Limited has a long history of business activity in Sri Lanka through Lever Brothers, Lipton, Brooke Bond and Aqua products (Technical brief 1995). It has a good reputation built up over the decades by the company's consistent good corporate behaviour and professionalism complemented by the quality of its management, products, and services. Unilever Ceylon operates in four manufacturing sites viz. Grandpass, Agarapatna, Katana, and Sapugaskanda (LINDEL).

Company's core business could be classified as consumer processed foods, consumer detergents, bakery, and catering products. The local manufacturer of these products is handled in three main sections viz. Edible product section making consumer processed foods, bakery, and catering products, Detergent section making consumer and industrial detergents, and personal product section making consumer personal products (Technical brief 1995).

Grandpass factory site produces a large range of products and separate departments, as described below, fulfill specific functions:
Toilet soap department and Hard soap department accounts for manufacturing soaps while Soap Powder department produces sunlight detergent powder. Pan Room, base soap manufacturing area, produces and pumps the required mixture of soap to carry out the production processes of the above three departments. Edible Refinery and Edible Packing departments are engaged in manufacturing edible fats. All other personal products are produced in the Personal Products department. The Bulk Material Department (BMD) does the supply, maintenance,

and storage of oils and perfumes. Boiler House fulfill all the steam requirements at the factory. All chemical analysis, with regards to production and water, is carried out by the company's laboratory.

Pahapur Marley and Heenen Marley, the two cooling towers, and Effluent Treatment Plant (ETP) are responsible in fulfilling a large fraction of water requirement in the company through supplying recycle water. Warehouse and general stores are used in storage purposes of raw materials and finished goods. Apart from these Canteen, Office. Quality Assurance, and Development are some of the functional units in the Unilever Ceylon Limited.

Three main sources viz. Town water/ Municipal water, Well water, and ETP water fulfill the daily water requirement within the company. In a situation where there is a water shortage bowzer water is used after treating it.

In order to achieve the company's aim of reducing water consumption per ton of product management of water resource is essential. Water management techniques include water reduction, reuse, and recycle. Grade wise water consumption contributes in reduction of water consumption. To find the quality of different water types used at the company water quality analysis could be done.

3.2. Grade wise Water Classification

In order to identify the grades of water laboratory tests were conducted. Four sample points were selected to collect samples viz. Town water line, Well near the gate (Well No.1), Well in the yard (Well No.2), ETP water line. Sampling for all the above sources was done for three days in triplicates. Finally an average result or a range of results were obtained.

Following parameters were tested against the four samples:

Table 3.2.1 Water Classification Parameters

Parameters	***Town Water***	***Well Water***	***ETP Water***
Colour	✓	✓	✓
Hardness	✓	✓	✓
Total dissolved solids (TDS)	✓	✓	✓
pH	✓	✓	✓
Salinity	✓	✓	✓
Residual Cl_2	✓		✓
Dissolved Oxygen (DO)			✓
Chemical Oxygen Demand (COD)			✓
Biological Oxygen Demand (BOD)			✓
Total Viable Count (TVC)	✓		✓

These tests were done by methods given below:

I. Colour

- Measured using the Lovibond scale
- A colour range for all samples were obtained

II. Hardness

- Measured using the EDTA method (Appendix 2)

III. pH

- Measured using the Kent EIL 7020 pH meter (Appendix 2)

IV. Salinity

- Measured using multi-purpose Orion TDS meter

V. Residual Cl_2

- Measured using the DPD tablet (Appendix 2)

VI. DO

- Measured using the Winkler's method ((Appendix 2)
- Calculation

$$\text{DO in mg/l} = \frac{40*B}{A}$$

A = Volume of $Na_2S_2O_3$ used in the standardization

B = Volume of used in the test sample

VII. COD

- Measured using the chemical method (Appendix 2)
- Calculation

$$\text{COD mg/l} = \frac{b-s*N*8000}{V}$$

b = Amount of O_2 consumed by blank titration

s = Amount of O_2 consumed by titration

V = Volume of the sample

N = Normality of Ferrous Ammonium Sulphate (FAS)

VIII. BOD

- Measured using the chemical method (Appendix 2)
- Calculation

$$\text{BOD mg/l} = \frac{(S_1-S_2) - (B_1-B_2)\ N1000}{V_{EF}*0.0125}$$

S_1 = DO concentration sample before incubation

S_2 = DO concentration sample after incubation

B_1 = DO in blank sample before incubation

B_2 = DO in blank sample before incubation

V_{EF} = DO in blank sample after incubation

IX. TVC

- Cultured using the Maconkey Broth Purple Medium (Appendix 2)

3.3. Department wise Water Consumption Measurement

Departmental water consumption was measured in both direct and indirect methods by obtaining water meter readings and effluent flow rate measurements respectively.

3.3.1. Water Meter Readings

From the three water sources both town water supply and well water supplies were measured using water meters at specific locations. Since ETP water is recycled and consumed itself by the company department wise measurements are not done with regards to it.

A separate line from the town water goes through UV radiation and gets microbiologically treated. This water is used for the purpose of drinking at the company.

Weekly records were taken on water consumption and monthly reports were prepared. Depending on the records proper action on reducing the water consumption could be taken. For the purpose of this study water meter reading for one month was obtained.

3.3.2. Flow Rate Measurements

Except for the water used in the products all department wise water consumption is approximately equal to the wastewater flow (Laak 1986). When it comes to Unilever Grandpass factory site apart for the water being used for the production and few other purposes, such as drinking, wastewater flow approximately equals the department wise water consumption. Therefore by measuring the flow rates of each department, indirectly could find the water consumption of each department.

In addition to this, effluent flow rates are important in controlling the effluent flow to the effluent treatment plant. Treatment plant has the capacity of treating around 300 tons of effluent per day. If there is no control over the amount of effluent flow plant will not operate at its highest efficiency. On the other hand, reduction of effluent means reduction of water consumption. Therefore effluent flow rate measurements are important in water management. For the purpose of flow rate measurement a triangular weir system called V-notch has being constructed.

V-notches are triangular flow measuring weirs with the apex of the V-notch at the lowest point. The angle of the V-notch is determined by the required depth/flow relationship (Linford 1989).

At the Unilever Grandpass site there are 14 V-notches with 13 of them having an angle of 90^0 and one V-notch having an angle of 120^0. At each department, where production processes are carried out, one V-notch is constructed.

The depth of the water flow was measured in mm by placing the ruler on the apex of the V-notch. Then by using the following equation flow rates were calculated.

$$Q = k H^{5/2}$$

Where,

Q = Flow Rate (m^3/ hour) k = A constant/ 1.42

H = Depth of water in the V-notch (Linford 1989)

The above equation could be derived from the Bernoulli's equation (Appendix 3).

Flow measuring structures are designed in a way so that stream discharge is made to behave according to certain well-known hydraulic laws (Wilson 1991).

During one working day four V-notch readings, in specific time periods, were obtained to calculate an average wastewater depth per day. Accordingly, weekly total flow rate per hour is calculated and recorded. Afterwards proper action could be taken if effluent flow, with regards to one department, increases dramatically. For this study one months V-notch readings were obtained.

Precipitation water flow separately from wastewater of the factory. Wastewater from departments flow to the main drain, where it is then pumped to the treatment plant. In some places drain route runs underground and while in some places effluent from several drains get connected and flow through a V-notch. In order to trace the route and the connection of drains a water-soluble dye was used. The dye, after dissolving in water, was put in to one point and the flow route was tracked. In the case of under ground flow man holes had to be opened. The colouring substance was put into one manhole and traced from the next manhole. Accordingly the route of effluent flow in relation to each department was traced.

3.4. Operation of Effluent Treatment Plant (ETP)

A stepwise study on the effluent treatment operation and distribution of treated water in the company was done by collection of secondary data and an individual study.

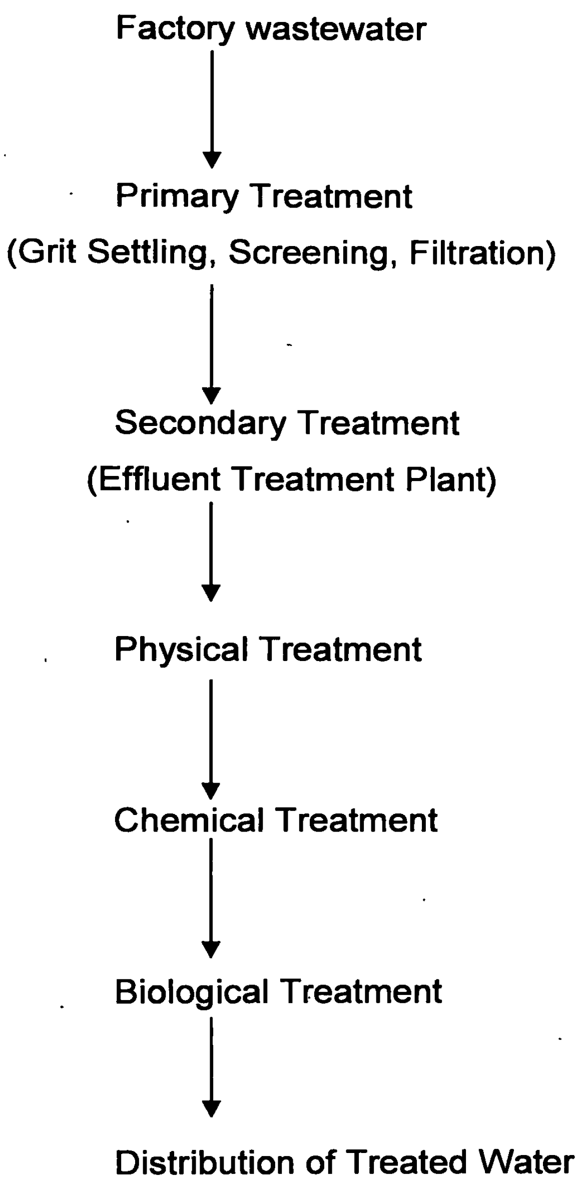


Figure 3.4.1 Main Operational Steps of Effluent Treatment

Chapter 4

Results and Discussion

4.1. Grade wise Water Classification

Table 4.1.1 Test Results of Physical and Chemical Parameters of Water Samples

	Town Water	Well No.1	Well No.2	ETP Water
Colour	0R/0Y	0.1R/0.1Y	0.2R/0.2Y	Variable
Hardness	19ppm	38ppm	194ppm	12ppm
TDS	38mg/l	80mg/l	556mg/l	2100mg/l
pH	7.2	5.6	6.1	7.1
Salinity	0.0%	0.1%	0.6%	2.1%

Table 4.1.2 Test Results of Chemical and Biological Parameters of Water

	Town Water	ETP Water
Residual Cl_2	0.5mg/l	_
TVC	0	_

Table 4.1.3 Test results of Chemical and Biological Parameters of Treated Water

	DO	COD	BOD
ETP Water	240mg/l	48mg/l	30mg/l

The company receives water from three main sources viz. Town water supply, Well water supply, and ETP water supply. These three water types exhibit different physical, chemical, and biological characteristics. In other words, they are of different grades.

Water requirement, at the company, for different purposes could be fulfilled using different grades of water. For example water used in the product needs to be of high-grade while floor washing could be done using comparatively low-grade water.

Pure water has no colour, such as in the town water sample where the colour is 0 Red/ 0 Yellow. But in well water a small colour range could be observed. The presence of humic acid, fulvic acid, metallic ion, suspended matter, phytoplanktons, weeds, and industrial effluent may cause colour in natural water (Gupta 2001).

The colour range of ETP water is highly variable and it depends up on the extent of treatment. In circumstances such as a large chemical discharge the final clarifier water will not be clear due to the presence of dead cells of microbes.

Hardness value is very low in ETP water because the coagulation of hardness forming ions, such as Ca^{2+} ions, during the chemical treatment processes. Water hardness is mainly caused by Ca^{2+} ions (Gupta 2001). In town water hardness has been reduced by chemical treatment. Well water exhibits the highest hardness. From the two wells, well No.2 i.e. the well in the yard has a high hardness value when compared with the well near the main gate i.e. well No.1.

Salts like carbonates, bicarbonates, chlorides, sulphates, phosphates, and nitrates of calcium, sodium, and iron are dissolved in natural water. They reduce solubility of gases, like oxygen, and utility of water for drinking and industrial purposes (Rump and Krist 1988). The TDS value in ETP water is very high. This is due to the large amount of chemicals dissolved during its treatment and the presence of dead microbial cells. In the wells also there is a difference in the TDS value. The yard well exhibits a high TDS value.

Both town water and ETP water has a neutral pH value the well water pH values are slightly acidic.

Salinity gives the amount of salts dissolved in water. Salinity is zero in town water while all other water types exhibits salinity.

Chlorine (Cl_2) is used as a disinfectant to treat drinking water and also some times wastewater. Cl_2 in the form of dissolved elementary chlorine or as hypochlorite ions is referred to as residual chlorine. Cl_2 should be present in drinking water with in the range of 0.2 to 0.5mg/l (Rump and Krist 1988).

Although Cl_2 is added to both town water and ETP water the detection of this is difficult since the amounts added become low during distribution and due to mixing of water.

Total Viable Count gives an idea of the amount of viable bacterial colonies present in water. In some cases town water there are about two colonies per one culture. But normally colonies are not present. Especially coliform count should be zero in town water.

In treated water it is hard to take a viable count since a large amount of colonies are present in 1ml of water. In order to carry out this count, a series of dilution need to be done.

Dissolved oxygen (DO) is an index of physical and biological processors going on in water. Non-polluted surface waters are normally saturated with oxygen.

There are two main sources of DO in water:

- Diffusion from air
- Photosynthetic activity within water (Gupta 2001)

Oxygen is a limiting factor in water where there is a high load of organic matter. In the effluent sent in to the ETP plant DO value is very low. After the treatment processes this value becomes high.

The BOD is the amount of oxygen required to biologically oxidize organic contaminants in to carbon dioxide and thus is a measure of suspended, colloidal, or dissolved organics (Jaward and Asano 1996). Higher the BOD values the higher the organic content of the wastewater. The BOD value of the wastewater entering the ETP is around 613mg/l. After treatment this value is reduced to 30 mg/l. According to the general standards the value of BOD should be 30mg/l (Gupta 2001). The treatment process conducted by the ETP achieves this value.

COD is an oxidation-reduction reaction. It measures the total organic carbon with the exception of certain aromatics, such as benzene, which are not completely oxidized in the reaction (Eckenfelder 1989). When the influent enter in to the ETP it has a COD value of around 1600mg/l. When the effluent goes out of the treatment plant it has a COD value of around 48mg/l. The general standard COD value for effluent discharge for industrial waste is 250mg/l (Gupta 2001). This means that after the treatment process a very low COD value, even below the discharge standards is achieved.

When the overall qualities exhibited by different types of water is considered town water could be classified as the high-grade water and ETP water could be considered as a low grade water, while well water exhibit qualities in between the above two.

When the economy of water consumption is concerned town water has to be gained from the municipal line by paying a price. If certain water requirements could be substituted by well water and ETP water there will be a large economic saving from the side of the company. On the other hand the use of treated water back at the company will help to conserve the water resource while at the same time reduce the problem of effluent discharge to the environment. Even the requirement of discharging it out of the company arises, there won't be any environmental problem since water complies the discharge standard given for industrial effluent discharge.

Water required for purposes such as drinking, and production process need high-grade water. If quality of water used in the products is low as a result the demand for product will reduce. Also the potable water has to be of good quality or otherwise health problems will disturb the functioning of the company. Therefore the above high-grade water requirements should be fulfilled using town water, which is already done in the company.

But still for the purpose of drinking, water from the well near the front gate could be used. Though the hardness of water is little high, by adding chemicals it could be reduced. Yet before using it studies should be carried out to find its compliance with other drinking water parameters and the possibility of water from the near by canal mixing with the well.

At present for the purpose of steam generation only town water is being used. One problem of using well water in producing steam is the generation of scales in boilers due to the comparatively high hardness. Even before town water, which is less hard, being used in boilers it needs to be treated to reduce the hardness. If the cost of town water plus the cost of this treatment is higher than the cost it takes to treat well water it will be economical to use well water at least for one boiler. In order to do this a detailed cost-benefit analysis has to be done. Apart from it the amount of water that could be withdrawn from well, without depleting the resource, should be calculated.

Well water could be used in bathrooms for washing purposes as it is been used at present in workers bathrooms. The water in the yard well should be closely studied before being used in any purpose because it consist of low-grade water when compared with the other well.

When it comes to wastewater reclamation and reuse, ETP water could be used in several purposes. In principle, wastewater or any marginal quality waters could be used for any purpose provided that they meet the water quality requirements for the intended use (Gupta 2001). Floor washing, gardening, fulfilling the make-up water requirement in cooling towers, and bathroom flushing could be done using the treated water.

Biological characteristics of treated water should be continuously studied to avoid health hazards. Since disinfectant is added to the treated water, a health threat won't arise and at the same time clogging of bacteria when it is pumped from the plant to other sites will not occur.

Some discharges require special discharge permit prior to discharge in to the treatment plant. Then the amount of chemicals added to the treatment process could be adjusted in a way to avoid harm to microbes. The quality of treated water will reduce when there is a large discharge of chemicals, or leaks due to the malfunctioning, or death of microbes. Then it needs to be recirculated again to go through the whole treatment process. On one hand this increase the cost of water treatment and on the other hand the wastewater produced during that day would have to be stored until the recirculation ends. Long storage of wastewater will further deteriorate its qualities. In a time like this treated water can not be pumped back to the factory. Therefore strict regulations should be imposed on special discharges.

4.2. Operation of the Effluent Treatment Plant (ETP)

Today reducing waste has become one of the greatest challenges faced by processing industries because water is one of industrial major waste product. The ability to reclaim wastewater for reuse is an important step toward overall waste reduction. Identifying and deploying optimal water reuse is a challenge faced by factories at present.

Complex industrial waste generated in manufacturing processes require dependable industrial waste management systems. Therefore Unilever Ceylon Limited, Grandpass has make a large investment in establishing an effluent treatment plant (Our History 2003).

The volume and strength of industrial wastewater are usually defined in terms of units of production (e.g. Gallons per ton of pulp, cubic meters per ton of pulp, BOD per ton of pulp). Unilever Grandpass site measures and records the amount of effluent per ton of product. Effluent from all departments, except for few exceptional cases, get collected in the collection sump and goes through filters to fulfil the purpose of removing large solid particles before water being pumped to the ETP. Large solids are removed by screening, and grit is allowed to settle out.

Grandpass site ETP plant has a capacity of treating effluent at a rate of 300 tons per day. Though in the beginning treated water from the ETP plant was released to the nearby canal at present it is being used in the factory as recycled water. This water is used for purposes such as bathroom flushing, gardening, floor washing and in cooling towers.

Primary treatment, before the wastewater being pumped to the ETP plant, is very important to carry out the latter treatment processors with fewer disturbances. Primary treatment i.e. screening and grit settling, starts in drains itself. Steel meshes, present in drains, which trap large solid particles, do screening. Allowing the water to stand still for some time in the drain itself does grit settling. At the main drain effluent goes through filters in order to filter out the untrapped particles. After this effluent is pumped into the ETP from the main drain sump.

In order to tackle the liquid discharges, gaseous emissions, and solid wastes that are generated by factories, 3 pollution control strategies are followed up viz.

(i) Eliminating or reducing effluent at the source of generator
(ii) Recycling effluent
(iii) Treating effluent (Our History 2003)

Effluent treatment facilities are provided at most factory sites that generate liquid effluents. The treated water is used in fulfilling the low-grade water requirements at the factories; such as gardening, flow washing etc (Our History 2003).

Secondary effluent treatment process, at the Unilever ETP site, could be classified into main three steps 3 viz.

(1) Physical Treatment
(2) Chemical Treatment
(3) Biological Treatment

4.2.1. Physical Treatment

Physical treatment starts with effluent entering into the pH 5-reactor tank. In this tank pH is adjusted to 5 by adding HCl acid to the effluent. Normally the effluent is basic due to its contents such as soap, caustic, and chemicals. In the physical treatment process addition of HCl helps in breaking oil into fatty acids and glycerol. Then oil suspended with water starts to float on the top, which is skimmed off.

Effluent is then pumped into the Dissolved Air Floatation (DAF) tank where oil particles get connected with air bubbles and starts floating on the effluent. In the DAF unit air bubbles emerging to the top under pressure get attached with the suspended oil in water and bring these oil particles to the top of the tank, where they are easily skimmed off. This technique is a great help in removing the suspended oil particles and also it reduces the amount of chemicals need to be added in the chemical treatment to remove oil. The air compressor helps in building up the required pressure.

In the DAF cell when the pressurized air liquid mixture is released to atmospheric pressure in the floatation unit, minute air bubbles are released from the solution. The sludge flocs, suspended solids, or oil globules are floated by these minute air bubbles, which attach themselves to and become enmeshed in the floc particles. The air-solid mixture rises to the surface, where it is skimmed off (Eckenfelder 1989).

Effluent then enters the intermediate transfer vessel. A portion of effluent from intermediate transfer vessel goes into the air saturator. This portion is then again get recircualted through the DAF cell. Only after this recirculation occurs for several times overflow from the intermediate transfer vessel enters the pH adjustment tank. An air compressor supply compressed air to the air saturator. When flocculent sludge is to be clarified pressurized recycle will usually yield a superior effluent quality (Eckenfelder 1989). Similarly in the treatment plant at Unilever achieve a superior quality to the effluent by recirculation of effluent between DAF cell and the air saturator.

In the pH adjustment tank caustic (NaOH) is added to the effluent until the pH between the range of 8 - 9. Caustic added effluent is then transferred to the equalization tank.

The equalization is important in controlling the fluctuations in wastewater characteristics to provide optimal conditions to the subsequent treatment processors (Eckenfelder 1989).

By equalization of wastewater large chemical or physical variations could be avoided which otherwise will adversely affect chemical or biological treatments.

The purpose of equalization for industrial treatment facilities are :

- To provide adequate pH control or to minimize the chemical requirements necessary for neutralization.
- To provide continuous feed to biological systems over periods when the manufacturing plant is not operating.
- To prevent high concentrations of toxic materials from entering the biological treatment plant (Holmes 1983).

Afterward effluent enters chemical treatment section.

4.2.2. Chemical Treatment

Partially treated effluent enters the flash mixture. In here lime ($CaCO_3$) and polyelectrolite is added. The amount of chemicals added depends on the characteristics of effluent. Proper mixing of these chemicals and sampling for pH checks is very important. pH value at this stage should be around 8 to 9. In the flash mixture fatty acids present in effluent coagulate with lime producing a coagulant, which settle down in the tank. Polyelectrolite brings positive and negative ions in the effluent together, forming a molecule, making them flocculate.

Polyelectrolytes are high molecular weight polymers, which contain absorbable groups and form bridges between particles or charged flocs (Eckenfelder 1989). The amount of polyelectrolite added depends on the properties of the effluent.

Under special conditions like a shampoo discharge the amount of polyelectorlite added is increased. If not this will adversely affect the biological flocs.

Then effluent enters the clariflocculator where chemicals flocculent are removed and water is clarified to certain extent. The removed chemical sludge is pumped in to the chemical sludge storage tank. This chemical sludge is then passed through a filter-press and the remaining solid waste is disposed out.

From there effluent enters to the neutralization tank where HCl is added to reduce the pH value to 7. This neutralization is essential prior to effluent enters to the biological treatment process. Many industrial wastes contains acidic or alkaline materials that require neutralization prior to discharge to receiving water or prior to chemical or biological treatment. For biological treatment pH in the biological system should be maintained between 6.5 and 8.5 to ensure optimum biological activity (Laak 1986).

Chemical treatment process ends from this step with partially treated water entering biological treatment process.

4.2.3. Biological Treatment

pH adjusted waste water enters to the anoxic zone of the biological treatment system where urea and phosphoric acids are added to enhance the microbiological growth. Both algal colonies and protozoa colonies could be found in the biological treatment area. Urea consists of nitrogen which enhances algae growth and phosphoric acid contains phosphorous which enhances protozoa growth. Growth of these microorganisms should be closely studied and monitored in order to balance the spread and growth of microbes. When microbes are healthy both types carry out the normal functions and helps in breaking down the organic matter.

Normally wastewater contains nitrogen and phosphorus substances, which enhances the microbial growth. At Unilever also, since the produce detergent products and edible fats, both these nutrients are present. But in order to gain large colonies of microbes, to treat the large amount of effluent produced, the amount of nutrients present is not sufficient. Therefore supplementary supply of nutrients is essential.

These microbes present in effluent increase their colonies by feeding on the organic matter and nutrients present in wastewater. In order to balance the growth and spread of microbs they should be closely studied and monitored.

If the microbs are healthy they produce colonies and settle in the bottom of the aeration tank. In case of a large imbalance discharge of chemicals or waste microbes could die. Microbial death could be easily notified because dead cells start floating on the water.

One of the factors essential to the performance of the activated sludge process is effective flocculation of the sludge, with subsequent rapid settling and compaction. McKinney related flocculation to the food /microorganisms in ratio and showed that certain organisms normally present in actuated sludge flocculate rapidly under starvation conditions. More recently, it has been shown that flocculation results from the production of a sticky polysaccharide slime layer to which organisms adhere (Eckenfelder 1989).

In presence of organic matter and nutrients filamentous microorganisms starts growing in the effluent which disturbs the organic break down and there by the treatment process. The use of an anoxic zone and addition of nutrients to this zone is done to prevent the filamentous growth as much as possible. Many filamentous organisms are aerobic and grow in situations where there is an inadequate nitrogen and phosphorous supply. Using an anoxic zone combined with sufficient nutrient supply could minimize their growth. Since most bacteria are facultative and therefore can exist in anaerobic conditions.

The aeration equipment commonly used in the industrial waste field consist of air-diffusion units, turbine aeration systems in which oxygen transfer is accomplished by high surface turbulence and liquid sprays (Eckenfelder1989). In the Unilever Ceylon Limited surface turbulence systems is used in the purpose of aeration. At the ETP two surface aerators carry out plant aeration. Normally one aerator works for half an hour and in the next half an hour the other aerator keeps working. This aeration helps in oxidation of the reduced matter present in wastewater or in other words it reduce the BOD of effluent. In a special situation such as a shampoo discharge both aerators are switched on to increase the efficiency of aeration or otherwise it will destroy the biological floc.

In the final clarifier water get clarified with microbs getting settled in the bottom of the tank. Dead cells keep floating on the effluent and it is skimmed off. During an adverse effect the number of floating cells increases and the water clarity become poor. Microbial sludge collected at the bottom of the tank is sent to the sludge sump. In the case of excess biological sludge and dead cells, they are sent in to the biological sludge storage tank. Finally a solid waste is gained after sending the sludge through a filter press, which is discarded.

By the chlorination of treated water it becomes safe to be used back at the factory. This disinfecting is very important since microbs are used in the treatment process. This recycled water is distributed throughout the factory (Appendix 4).

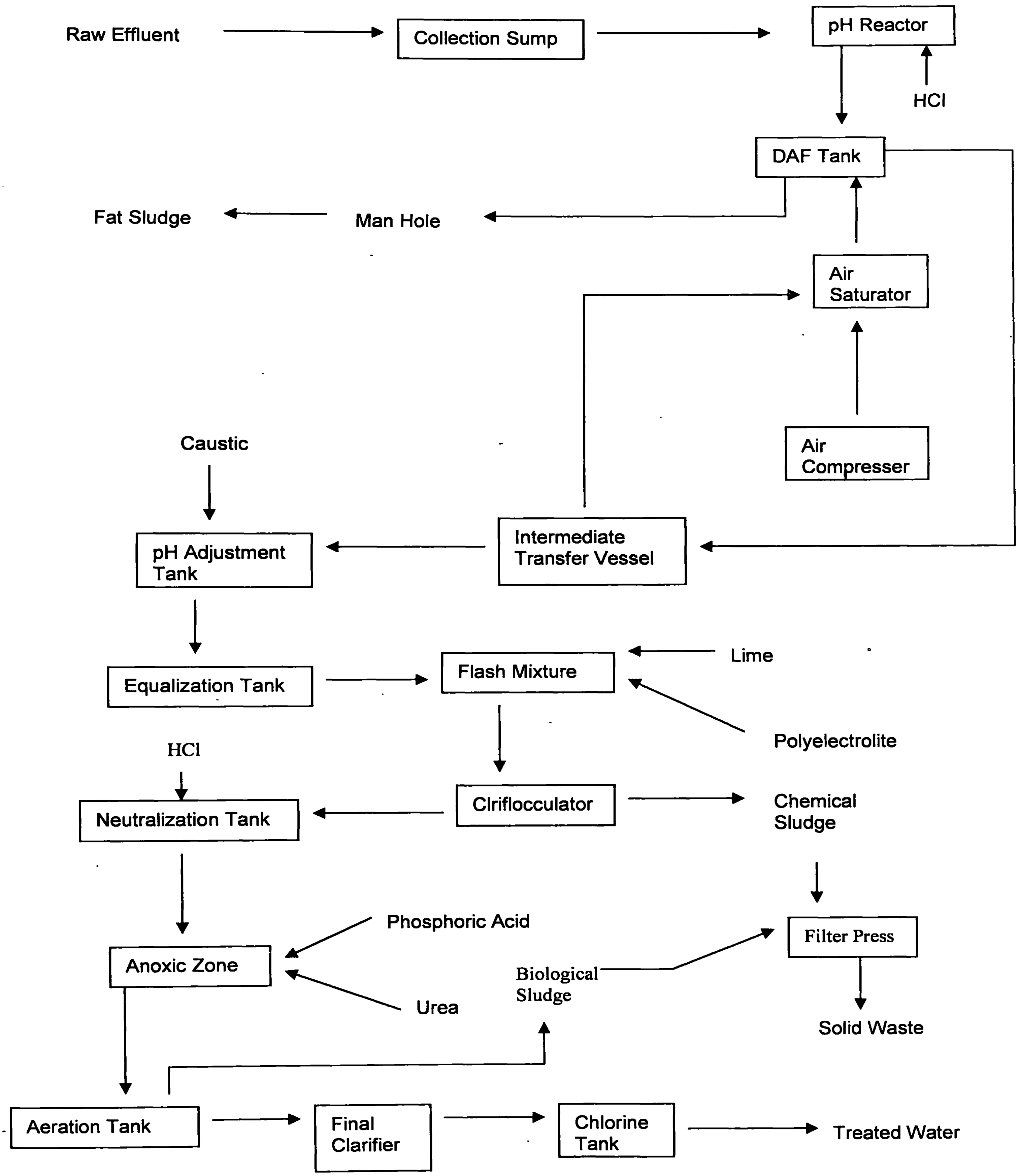


Figure 4.2.1 ETP Flow Diagram

4.3. Water consumption at the factory

After obtaining the weekly records of water meter readings a cumulative average for monthly water consumption for the whole company could be calculated. With dividing this monthly water figure by the total monthly production water per ton of product could be achieved.

$$\text{Water per ton of Product} = \frac{\text{Total Monthly Water Consumption}}{\text{Total Monthly Production}}$$

By plotting a graph using this data the trend of water consumption could be easily noticed. This monthly trend needs to be justified taking the total monthly production in to consideration. The following graph shows the monthly water consumption trends for the year 2003.

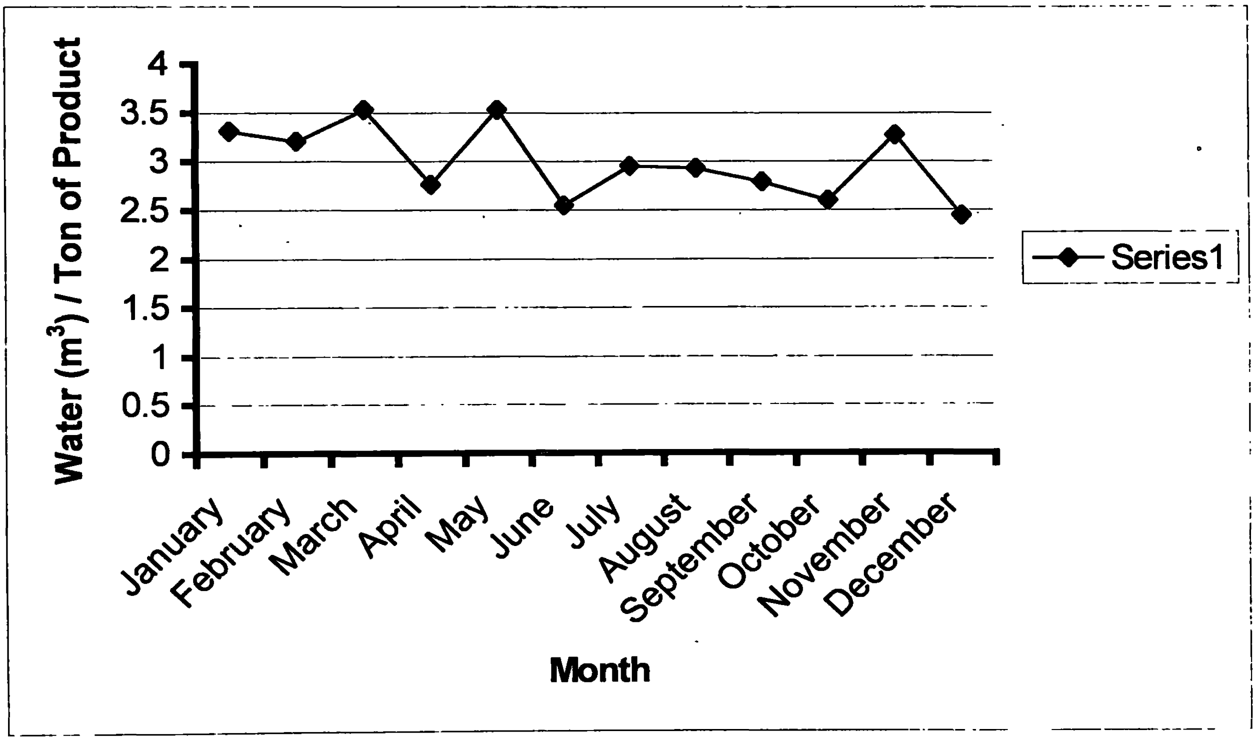


Figure 4.3.1 Water Consumption Trend for 2003

As it is seen by the graph in the month of March, May, and November peaks of water consumption could be observed. These months are either festive seasons or closer to festive seasons where the production at the company increases dramatically, therefore the water consumption during these months normally increases per ton of product. The lowest water consumption is recorded in the month of December. But when the amount of products produced during that month is concerned this is not a true reduction of water consumption, since production during the month is comparatively low. There is a reduction of water consumption during July to October, where production is approximately similar i.e. there is a true reduction in water consumption trend during these 4 months.

With more organized water management planning the trend of water could be reduced in months where production is comparatively low.

Table 4.3.2 Water Meter Readings for December 2003

Location	Town Water (m^3)	Well Water (m^3)
Base Soap Production	26.42	
Glycerin	402.375	
Hard Soap	63.346	
Toilet Soap	67.496	1.575
Soap Powder	74.092	
Personal Products	319.531	
Edible Packing	650.4	
Edible Refinery	15.827	
Bulk Material Dept. (BMD)	16.896	
Engineering Services	29.189	
Boilers	5217.8	
Lab	61.1	
Edible Bathrooms	925.1	
BMD Bathrooms	943.6	

Monthly reports made with regards to water consumption will reveal the state of water consumption by each department. Accordingly each department could be asked to account for the substantial differences of the water consumption on the particular month.

4.4. Flow Rate Measurement

Equation for flow rate measurement:

$$Q = kH^{2.5}$$

Where,

Q = Flow Rate   k = A constant/ 1.42

H = Depth of water in the V-notch (Linford 1989)

Calculation:

Depth of water in V-notch 1 in the BMD department	=	7mm
Flow rate measurement equation	=	$kH^{2.5}$
Flow Rate / hour	=	$1.42*(7*10^{-3})^{2.5}*3600$
	=	$0.021\ m^3$ /hour

Accordingly all V-notch measurements could be obtained for each department. Then dramatical fluctuations of effluent flow with regards to each department could be traced. This will help in controlling the effluent flow of each department.

Table 4.3.3 V-notch Measurement for the 3rd week of December

	Depth of Water (mm)	Flow Rate M^3 /Hour
Ammonia Plant	15	0.141
Bleachry	2	0.001
BMD	7	0.021
Development	5	0.009
Packing	16	0.166
Refinary	44	2.076
Glycerine	10	0.051
Hard Soap	13	0.099
Pan Room	23	0.410
Quality Assurance	17	0.193
Soap Powders	35	1.172
Toilet Soap	3	0.003

Certain requirement as given below should be fulfilled to use the above theoretical equation to calculate the effluent flow over a V-notch:

- Discharge should be free
  In other words the waste flow over the weir must have a free overflow
- The discharge should not be disturbed by turbulent flows
- Upstream and downstream of the V-notch should be clean
  Trapped soil particles or waste would affect the water depth measurement (Linford 1989)

Therefore in the case of V-notch measurements the compliance to aforesaid requirements should always be evaluated and proper actions should be taken to eliminate the chance of obtaining a wrong water depth reading. Keeping the drains clean and continuous supervision of V-notch system should be done to obtain good results.

Plotting a graph could easily do flow rate comparison of one department for two weeks.

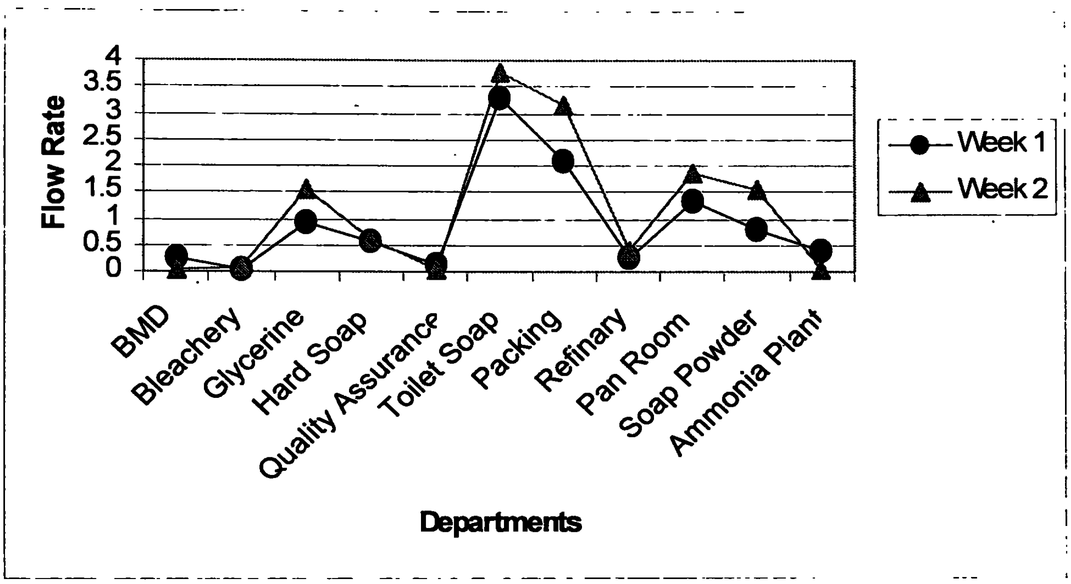


Figure 4.4.1 Flow Rates Comparison for Two Weeks

From the above graph it could be seen in some departments the effluent flow rate varies from time to time. The department could be requested to account for any dramatical differences in flow rates in order to control the effluent flow rates.

In this way, keeping track of all department wise flow rates will be important to control the effluent production and there by increasing the efficiency of the treatment plant. Therefore V-notches should be constructed to measure flow rates of all the departments, which produces effluent.

The amount of treated water pumped per day from the treatment plant should be approximately equal to the effluent flow during that day. Obtaining the treated water meter reading of the plant and the total V-notch flow during a particular day could do this comparison. This comparison would also help in finding leaks, mixing of precipitation water with effluent or any other substantial changes in effluent flow rates if the V-notch system is properly constructed and maintained.

In addition to these 3 R's company also have introduced modern technological practices to reduce the water consumption. These include pressurized flow washing mechanism, dual-flushing system, self-closing tap system. These techniques will contribute very favourable results to the company only if the workers are educated on the operation and the importance of these techniques.

Chapter 5

Conclusion and Recommendations

According to the assessment of water utilization and management, it could be concluded that the Unilever Ceylon Grandpass site has a sound management system on water resource utilization. The company could easily achieve its main target of further reduction of water consumption per ton of product if it sticks to these management practices.

Grade wise water consumption, use of recycled wastewater, minimization of effluent production, and closed system water circulations are among the main sound management practices with in the company. Apart from the benefit of reusing at the company, wastewater treatment also contributes in eliminating the problem of wastewater being discharged to the environment.

Introducing modern technology to the factory site in order to minimize wastage of water is very important. But at the same time the workers have to be educated on the operation and importance of using these techniques. Otherwise the expected out come will not be achieved.

Another very important aspect of water management is the contribution of the whole factory in managing water. All departments could take individual actions necessary to minimize the water consumption apart from compliance to the general management practices.

Immediate actions to reducing water wastage through leaks and once through water will bring good results to the company. Apart from these conducting a cleaner production audit will help in further correction of weak points in the water management system.

Only the implementation of a sound water management system in any industry will not result in water management itself. Monitoring the compliance to those management practices, making favourable changes with the advancement of technology, and whole company's contribution towards achieving the goal of sound water management is essential for the success.

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Appendix 1

Range of Products Produced at Unilever Ceylon Grandpass Site

Sunlight
- Sunlight Green
- Sunlight Yellow

Lux
- Green
- Orange
- Pink
- White

Signal
- Large
- Medium
- Economy
- Herbal
- Sachet

Sunlight Powder
- 1kg
- 500g
- 200g
- 50g

Rexona
- Allovera
- Herbal

Lifebuoy
- Active
- Herbal
- Gold Pink
- Gold White
- Protein
- Talc

Sunsilk Shampoo
- Egg protein
- King Coconut
- Lime and Dill
- Herbal

Edible Fats
- Astra
- Flora

Vim
- Liquid

Ponds
- Talc
- Body Lotion

Pears Baby

Apple

Orange

Strawberry

White

Cologne

Cream

Oil

Powder

Shampoo

Appendix 2

Water Analysis Laboratory Tests

PROCEDURES

Total Dissolved Solids

- Hydrometer was washed with distilled water
- 450 ml – 500 ml of each sample viz. municipal water, well water, and ETP water was taken separately to measuring cylinders
- Hydrometer was inserted, kept for it's value to become constant and reading was recorded.

pH Measurement

- First pH meter was calibrated using pH 7,4, and 9 standards solutions.
- It was then washed with distilled water and put into the sample.
- pH meter was kept undisturbed until it gives a stable value and the reading was recorded.

Hardness

- Approximately 100ml of the sample was filtered using a Whatman No. 1 paper
- 100ml of the sample was measured using a graduated cylinder.

- Approximately 2ml of Ammonia Buffer Solution was added to the sample until the pH value become between 9 and 10
- Afterwards Eriochromic Black Indicator was added.
- If the solution turns purple in colour it was triturated until a blue colour end point was obtained.

$$\text{Total Hardness} = \frac{1000 \times \text{ml of } 0.02 \text{ EDTA}}{\text{Volume of sample in ml}} \text{ ppm}$$

Residual Cl_2 measurement

- Cell was washed with distilled water and thereafter with a portion of the sample
- 2ml of the sample was inserted to the cell
- DPD tablet was dissolved in it and then diluted to 10ml with distilled water.
- Cell was then inserted to the cell compartment of the comparator.
- Colour of the solution in the cell was matched with the colour scale given and the reading was noted down.

Dissolved Oxygen

- The sample was poured into the glass topper bottle in a way not to trapped air bubbles and the bottle was closed.
- 2 ml of Manganous Sulphate was added to it using a pippet.
- 2 ml of Alkaline Azide reagent was added in the same manner.
- Stopper was replaced without air being trapped.
- Bottle was shaken for 20 – 25 seconds by inverting the bottle once in each second.
- It was then left for settling until a brown precipitation settle, leaving a clear suppressant.

- 200ml of the sample was poured into a conical flask and titrated with a standard $Na_2S_2O_3$ solution until a pale straw colour was obtained.
- Starch was added as the indicator and titration was continued until a pale green end point was obtained.
- The amount of $Na_2S_2O_3$ used was recorded. (B)

Calculation

$$\text{Dissolved Oxygen in mg /l} = \frac{40\,B}{A}$$

A = Volume of $Na_2S_2O_3$used in the standardization test

B = Volume of $Na_2S_2O_3$ used for the sample

Chemical Oxygen Demand (COD)

- Sample was homogenized for 2 minutes.
- 2 ml of sample was placed in a round bottom flask.
- 1 ml of $HgSO_4$ and 4 ml of $K_2Cr_2O_7$ was added to the sample.
- 12 ml of $AgSO_4$/conc H_2SO_4 solution was added to the same and was mixed well.
- A blank sample was prepared using 5 ml of distilled water.
- Sample and blank sample were refluxed for two hours.
- Condenser was rinsed with distilled water and was allowed to cool.
- Flask was removed from the condenser and two drops of Ferroin indicator was added.
- This was titrated with N/200 Ferrous Ammonium Sulphate (FAS) solution until a faint pink end point is achieved.

Calculation

$$COD = \frac{(b-s) \times N \times 8000}{V}$$

b = amount of oxygen consumed by sample / blank titration

s = amount of oxygen consumed by sample / sample

N = normality of FAS solution

V = amount of FAS solution used

Bio Chemical Oxygen Demand (BOD)

- The sample was diluted with aerated water containing nutrients and microbiological seed.
- BOD bottle was washed twice with the sample to be analysed.
- Water was allowed to overflow from the top of the bottle, which was stopped at once.
- Stopper was removed from the bottle and 2ml of Manganous Sulphate were added to it, with placing the top of a pipette below the surface of the liquid.
- Alkaline acid reagent was also added in the similar manner.
- Stopper was replaced without trapping air.
- The bottle was shaken for 20-25 seconds inverting the bottle about once in each second.
- This was allowed to settle for 2-3 minutes until a brown precipitate settles, leaving a clear supernant.
- Then the stopper was removed and 2ml of conc H_2SO_4 was added and mixed well after replacing the stopper.
- After the precipitation dissolves 200ml of the sample was measured to a conical flask and was titrated with standard $Na_2S_2O_3$ solution until a pale straw colour was obtained.

- Starch was added as an indicator and titration was continued until a pale green end point was obtained.
- The value of $Na_2S_2O_3$ used was recorded (B).

Calculation

$$BOD = \frac{[(S_1-S_2) - (B_1-B_2)]N * 1000}{V_{EF}-0.0125}$$

S_1 = DO mg/l in sample before incubation

S_2 = DO mg/l in sample after incubation

B_1 = DO mg/l in blank sample before incubation

B_2 = DO mg/l in blank sample after incubation

V_{EF} = Volume of effluent used

N = Normality of the $Na_2S_2O_3$ Solution

Appendix 3

Equation for V-notch Measurement

$$Q = kH^{2.5}$$

Q	=	Flow Rate	k	=	A constant/ 1.42
H	=	Depth of water in the V-notch			

This equation is derived from the Bernoulli's equation i.e.

$$\frac{P}{\rho} + \frac{V^2}{2g} + Z = k$$

P	=	Pressure	ρ	=	Density
G	=	Gravitational Acceleration	V	=	Velocity
Z	=	Elevation	k	=	A constant

$$\frac{P}{\rho} + \frac{V_1^2}{2g} + Z_1 = \frac{P}{\rho} + \frac{V_2^2}{2g} + Z_2$$

$$\frac{V_1^2}{2g} + Z_1 = \frac{V_2^2}{2g} + Z_2$$

$$V_2^2 - V_1^2 = 2g(Z_1 - Z_2)$$

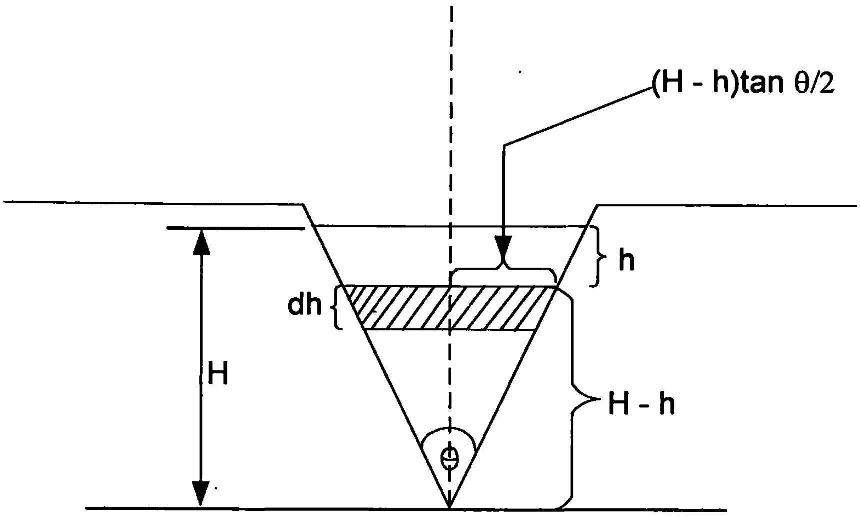
$$V_2 - V_1 = 32gh$$

Since

$V_1 = 0$

$V_2 = 32gh$

Diagram 17



Area of the strip $= 2 * dh * (H-h) \tan \frac{\theta}{2}$

Discharge through the strip $= Cd\ 32gh * 2 * dh * (H-h) \tan \frac{\theta}{2}$

Cd = co-efficient of discharge / 0.6

By the integration of the above equation;

$$Q = 8/15 * Cd * 32g * \tan \frac{\theta}{2} * H^{5/2}$$

$\theta = 90^0$

$\tan \frac{\theta}{2} = 1$

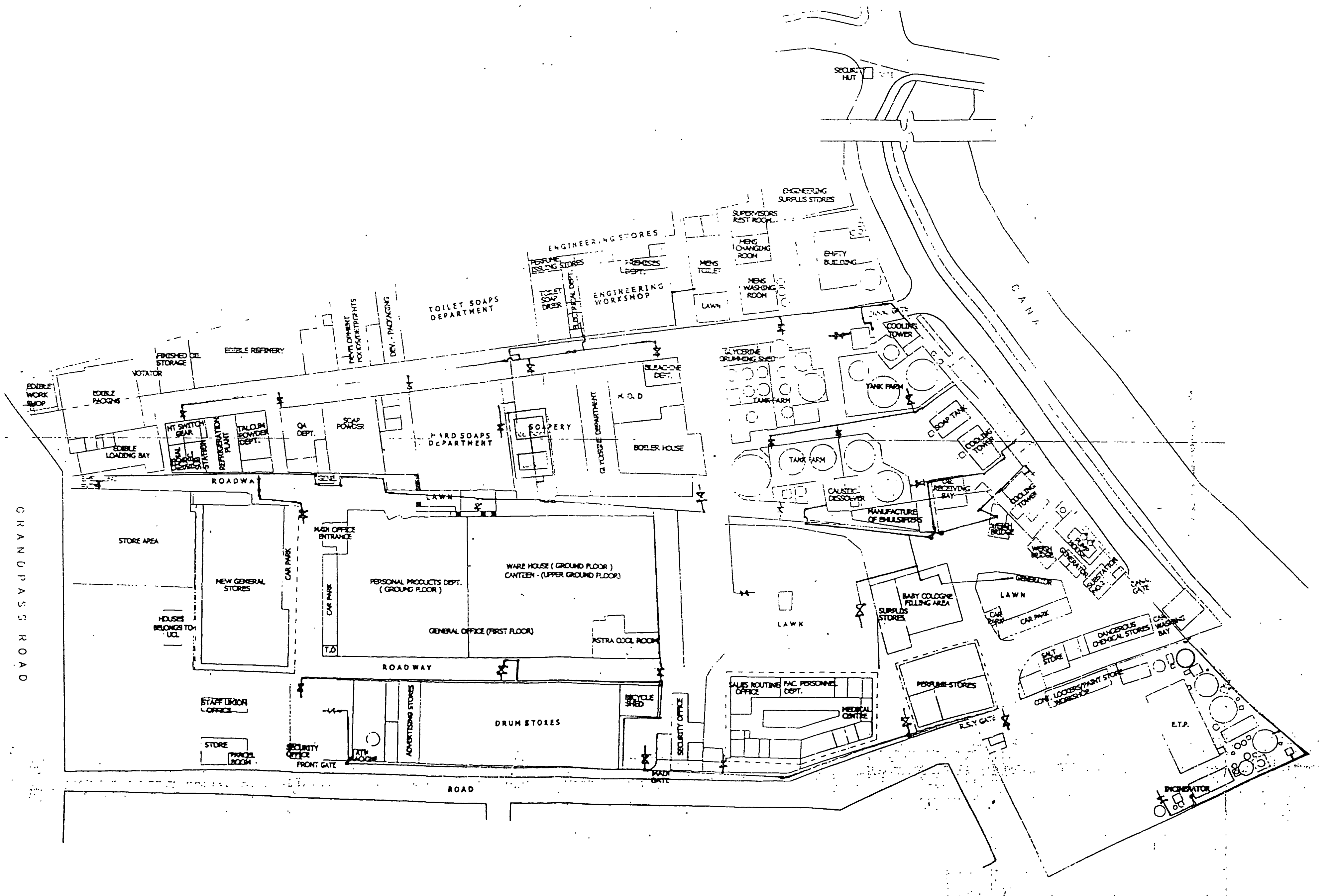
$g = 9.81\ ms^{-1}$

$8/15 * Cd * 32 * 9.81 * H^{5/2}$

$= k\ H^{5/2}$

EXISTING LINES

EXISTING TREATED WATER DISTRIBUTION LINES



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