ESIGN OF DOMESTIC WASTE WATER TREATMENT PLANT TO TREAT 300,000 LITRE OF RAW WATER PER DAY

BY

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2003/14928EH

DEPARTMENT OF CHEMICAL ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

NIGER STATE, NIGERIA

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A DESIGN PROJECT SUBMITTED TO

THE DEPARTMENT OF CHEMICAL ENGINEERING,

SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY,

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA,

NIGER STATE

DECLARATION

I, Adeoye Toyosi Aderinsola with matriculation number 03/14928EH declare that this Plant Design project report is my original work and has not been presented elsewhere to the best of my knowledge.

Adeoye T. Aderinsola

Signature

CERTIFICATION

This plant design project by Adeoye Toyosi Aderinsola has been examined and certified under the supervision of Engineer Muktar Abdulkadir to be adequate in scope

And quality for the partial fulfillment of the requirement for the Award of Bachelor of Engineering in chemical Engineering.

For: Engr. Muktar Abdulkadir

Project Supervisor

6/11/08

Date

Dr.M.O. Edoga

Head of Department (HOD)

Date

External Examiner

Date

DEDICATION

I dedicate this report to the glory of God who is the major source of my strength and inspiration to push on and forge ahead and most especially for making this program successful.

ACKNOWLEDGEMENT

My utmost thanks go to God Almighty for his faithfulness over my life by making everything to always work together for good for me. And without whom this project would not have been possible.

I am registering my profound thanks to my supervisor Engr Mukhtar Abdulkadir and my H.O.D Dr. M.O.Edoga and the entire lecturers of chemical engineering department for their contributions to the completion of this project, may God reward your efforts.

My gratitude to my parents Mr/Mrs J.O. Adeoye knows no bound for their care and support (both financially and morally) and also for their ceaseless prayer which has led to the success of this work. I also say a big thank you to my siblings Mr. Sunkanmi,Mrs Funmi,Lanre,Sesan,Odunola,Jumoke,Bayo and Shola.You are indeed very wonderful.

I am also saying thanks you to my friends like Charity Odion, Feyi Ogundeji, Bose Ibiyeye, Kafayat Akade, Dupe Nurudeen and the rest. And of course this section would be incomplete without making reference to my pals like Kingsley Umoh, Picanto de desperado, Momoh, and the rest, God bless you all.

ABSTRACT

Water is primary and indispensable natural resources. Water quality plays an important role in the preservation of adequate water supply at an acceptable standard of purity.

Flow diagram of a suitable domestic water treatment plant was designed and the detailed of the filtration tank showed that the height, diameter, area and volume are 4.88m, 3.72m, 74.187m^2 and 40.594m^3 respectively and the cost was estimated to be N56, 469.04.

The need to improve the coagulant and disinfectant process techniques to optimize performance was recommended.

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CHAPTER ONE

1.0 INTRODUCTION

Water is a universal solvent in which most chemical dissolve, and account for almost 75% of the total weight of plant and Animals (Horal,1978), hence the top on the list of basic necessity of life. Its presence in it's needed for domestic and commercial consumption used, which is also in cognizance with the need of the people.

Increase recognition of both the need for technical and economic efficiency in the allocation and utilization of resources and the role that appropriate water treatment can be play in the health and sanitary sector has led to the inclusion of portable water supply and development in the activities of united nation international water supply and sanitation (I.D.W.S.S)(Charles,1981)

Water treatment plant consists of several units namely: The pre chemical section, aeration, flocculation sedimentation, filtration, disinfection, distribution units all are arranged in a way to allow easy flow of material in and out of the treatment plant.

Wastewater is not just sewage, all the water used in the home that goes down the drains or into the sewage collection system is wastewater. This includes water from, showers, sinks, dish washers, washing machines, and toilet. Small businesses and industries often contribute large amount of waste water to sewage collection systems, others operate their own wastewater treatment system in combined municipal wastewater stream. Waste water is about 99 percent water by weight and is generally referred to as effluent as it enters the wastewater treatment facility.

Sewage is the wastewater released by residence businesses and industries in a community. The cloudiness of sewage is caused by suspended particles, which in untreated sewage ranges from 100 to 350mg/L.

A measure of the strength of the wastewater is biochemical oxygen demand, or BODs which measures the amount of oxygen, micro-organism requires in five days to break down sewage, untreated sewage has a BOD ranging from 100mg/L to 300mg/L, pathogens or disease-causing organisms are present in sewage.

Sewage treatment is a multi-stage process to renovate waste water before it. re-

Sewage treatment is a multi-stage process to renovate waste water before it, re-enter a body of water, is applied to the land. The goal is to reduce organic matter, solids, disease-causing organism and other pollutant from waste water. Each receiving body of water has limits to the amount of pollutant it can receive without degradation. Therefore, each sewage treatment plant must hold a permit listing the allowable level of BOD, suspended solids, coliform bacterial and other pollutants, waste water treatment system have evolved from the pit privies used widely throughout history to installation capable of producing a disinfected effluent that is fit for human consumption. Though achieving such a level of effluent quality is seldom necessary, the ability of wastewater treatment system to remove settleable solids, floatable grease and scum, nutrient and pathogens from wastewater discharges define their important in protecting human health and environmental resources. In the modern era, the typical wastewater treatment system has consisted primarily of a septic tank and a soil absorption field, also known as a sub-surface wastewater infiltration potentially dangerous for drinking and food preparation. Septic systems are a potential source of this pollution, as are livestock yards. A properly installed and maintained system for treating and disposing of containerized domestic waste water will minimize the impact of that system on ground water and surface water.

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1.2 PROBLEM STATEMENT

The problem statement of this project is to design a plant that will treat ....tones of containerized domestic waste water so that the product is used for washing , cleaning and watering of plants.

1.3 OBJECTIVE

The objective of this work is to design a domestic wastewater treatment plant that will meet quality standards stipulated in applicable discharge permits. Specifically, the plant must be easy to operate and maintain, require few operating personnel, and need a minimum of energy to provide treatment. Plants should be capable of treating normal laundry wastes together with sanitary wastewater.

1.4 JUSTIFICATION OF WORK

Potential contaminants in containerized domestic waste water include disease – causing bacteria, infectious viruses, household chemicals, and excess nutrients such as nitrate. Viruses can infect the liver, causing hepatitis, or infect the lining of the intestine, causing gastroenteritis (vomiting and diarrhea). If coli form organisms (a group of indicator bacteria) are found in well water, the water is potentially dangerous for drinking and food preparation. Septic systems are a potential source of this pollution, as are livestock yards. A properly installed and maintained system for treating and disposing of containerized domestic waste water will minimize the impact of that system on ground water and surface water.

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CHAPTER TWO

2.0 BACKGROUND THEORY

2.1 WASTE WATER

Wastewater is considered as used water. However much of the water used by homes, industries and businesses must be treated before it is released back to the environment.

The term 'wastewater treatment' is confusing, one might think of it as "sewage treatment", nature has an amazing ability to cope with small amount of water wastes and pollution, but it would be overwhelming if we did not treat billion of gallons of waste water and sewage produced everyday is untreated before releasing it back to the environment. Treatment plants reduce pollutants into the environment. Treatment plant reduce pollutants in wastewater includes substances such as human waste, food scraps, oils, soaps and chemical, in homes, this includes water from sinks, showers, bathtubs, toilets washing machines and dish washers. Business and industries contribute their share of used water that must be cleaned.

2.1.1 Preliminary Treatment

Preliminary treatment from screen out, grind up, or separate debris is the first step in wastewater treatment. Sticks, rags, large food particles, sand, gravel, toys, etc., are removed at this stage to protect the pumping and other equipment in the treatment plant. Treatment equipment such as bar screen, comminitors and grit chambers are used as the wastewater first enters a treatment plant. The collected debris is usually disposed off in a land fill.

2.1.2 Primary Treatment

Primary treatment is the second step in treatment and separates suspended solids and grease from wastewater. Wastewater is held in a quit tank for several hours allowing the particles to settle at the bottom and the grease is allowed to float to the top.

The solid drawn off the bottom and skimmed off the top received further treatment as sludge. The clarified wastewater flows on to the next stage of wastewater treatment clarifiers and septic tank are usually used to provide primary treatment.

2.1.3 The Primary treatment Processes

1. **Pumping:** The wastewater system relies on the force of gravity to move sewage from your home to the treatment plant. So wastewater treatment plant are located on low ground, often near a river into which treated water can be released if the plant is built above the ground level. The wastewater has to be pumped up to the aeration tank. From here on gravity takes over to move the wastewater through the treatment process.

2. **Aeration:** One of the first steps in wastewater treatment is just to shake up the sewage and expose it to air. This caused some dissolved gases that taste and smell bad to be released from the water. Wastewater enters a series of long parallel concrete tanks, each tank is divided into two parts. In the first part, air is pumped through the water.

   As organic matter decays, it uses up oxygen. Aeration replenishes the oxygen; budding oxygen through water also keeps the organic material suspended while it forces grit to settle out. Grit is pumped out of tanks and taken to land fill.

3. **Sludge Removal:** Wastewater then enters the second part or sedimentation tank. Here the sludge settles out of the waste water and is pumped out of the tank. Some of the water is removed in a step called thickening and then the sludge is processed in large tanks called digesters.

4. **Micro-organism Removal:** The wastewater flow into an ozone contact tank where ozone is added to kill bacteria, which could pose a health risk just as is done in swimming pool. The ozone is mostly eliminated as bacteria are destroyed.

2.1.4 Secondary Treatment

Secondary treatment is a biological process to remove dissolved organic matter from waste water. Sewage micro-organisms are cultivated and added to the wastewater. The micro-organism organic matter from sewage as their food supply. Three approaches are used to accomplish secondary treatment, fixed film, suspended film and lagoon systems.

2.1.5 Final Treatment

The fluid treatment focuses on removal of disease causing organisms from wastewater. Treated wastewater can be disinfected by adding using ozone or adding chlorine, High level of chlorine may be harmful to aquatic life in receiving streams. Treatment system often adds a chlorine-neutralizing chemical to the treated waste water before stream discharge.

2.2 PROCESS ROUTES OF DOMESTIC WASTE WATER TREATMENT.

The various process involve in domestic waste water treatment are:

1. Chemical Process
2. Biological Process
3. Physical Process

2.2.1 CHEMICAL PROCESS

This is a process in which chemical reagents are used in treating waste water includes: Alum, Chlorine etc. this process also involves the application of physical process such as filtration, screening and aeration.

Procedures used in treating waste water using chemical process:

a. ***Coagulation Process:***

It involves the addition of alum to the waste water so as to coagulate the particles together.

b. ***Sedimentation Process:***

In this process the coagulated particles are sediment down the tank so as to enable water movement to the next stage which is liming.

c. ***Liming Process:***

Liming involves the addition of lime, calcium oxide (CaO) to increase the pH of the water to 7 and to remove the hardness of the water.

d. ***Disinfectant Process:***

This process ensures disease free of the water causing micro-organisms, disinfectant in this process involves any of the following:

i. Chlorination which involves addition of chlorine

ii. Ultraviolent light (UV) and

iii. Ozonation (O_3)

2.2.2 BIOLOGICAL PROCESS

This is a process of applying biological method in treating domestic waste water. It also involves the use of physical process.

a. ***Biological Aeration:***

This process involves the combination of filtration with biological carbon reduction, nitrification or denitrification. It usually involves a reactor filled with a filter media. The media is either in suspension or supported by a gravel layer at the foot of the filter.

b. ***Membrane Bioreactor:***

This component uses low pressure micro-filtration or ultrafiltration membrane and eliminates the need for clarification and tertiary filtration. It also effectively overcomes the limitation associated with poor settling of sludge in conventional activated sludge processes.

c. ***Biological Sedimentation:***

This can be done in two ways namely:

i. Thermophilic digestion which involves fermenting the waste water at a temperature of $55^{O}C$

ii. Mesophilic digestion which involves fermenting the waste water at a temperature of around $36^{O}C$

2.2.3 PHYSICAL PROCESS

This involves processes where no gross chemical or biological changes are carried out and straightly physical phenomena are used to improve or treat the waste water. Examples include:

i. ***Coarse Screening:***

It is used to remove larger entrained objects

ii. ***Physical Sedimentation:***

In this process of sedimentation, physical phenomena relating to the settling of solids by gravity are allowed to operate. Usually these consist of simply holding the waste water for a short period of time in a tank under quiescent conditions, thereby allowing the heavier solids to settle and removing the clarified effluents.

iii. **Aeration**

This is a process of physical adding air, usually to provide oxygen to the waste water.

iv. **Filtration**

Usually the waste water is passed through a filter medium to separate solids. An example is the use of sand filters to further remove entrained solids from treated waste water.

2.2.4 JUSTIFICATION OF THE SELECTED METHOD

From the following under listed researches below, chemical method (process) of waste water treatment is preferable.

1. **Removal of Microorganisms**

Physical process as a process of domestic waste water treatment cannot be used to remove micro-organisms. However, both biological and chemical method can be used to remove micro-organisms (pathogens) from waste water.

2. **Acid Reduction**

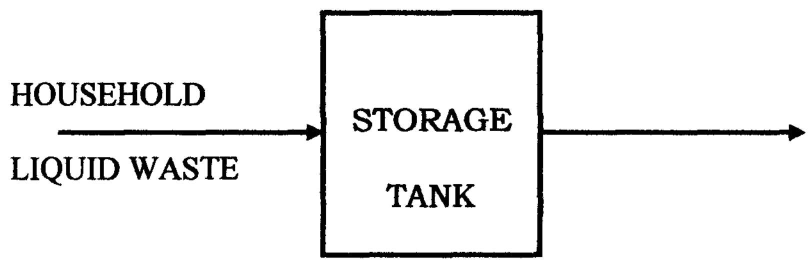
Acid reduction is only applicable in chemical process, it is used to increase pH value of water to 7 by the addition of lime ($Ca(OH)_2$)

3. **Disinfection of Waste Water**

The mosophilic or thermophilic method of disinfection under biological process of treatment is not common due to its cost however; chemical disinfection using ozone is less expensive and has high germicidal effectiveness which is the greatest of all known substance even against resistance organism such as virus and cysts.

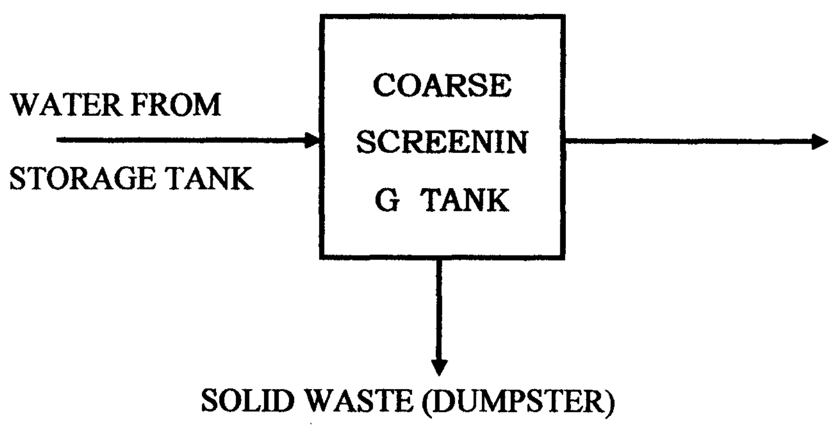
2.3 DETAILED DESCRIPTION OF CHEMICAL METHOD OF DOMESTIC WASTE WATER TREATMENT

2.3.1 THE RAW WATER STORAGE TANK



The raw water storage tank as shown above is a tank used to store waste water from different areas of the environment, such as household waste liquid from toilet, baths, showers, kitchens, sinks and so forth disposed off via sewers. The waste water is further transferred from the storage tank to the screening tank.

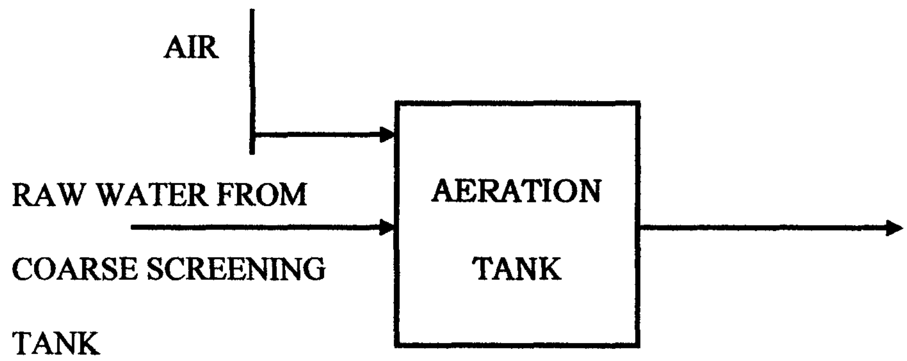
2.3.2 COARSE SCREENING TANK



This is a primary process used to remove larger entrained objects ranging from 100 – 1000mm in size that are deposited in the waste water tank, such as rags, sticks, tampons, cans, fruits etc this is most commonly done with a manual or automated, mechanically raked screen. The raking action of a mechanical bar screen is typically.

Paced according to the accumulation on the bar screens and flow rate. The bar screen is used because large solids can damage or clog the equipment used in waste water treatment. The solids are collected in a dumpster and later disposed in a landfill. In this unit the velocity of the incoming waste water is carefully controlled to allow sand grit and stones to settle, while keeping the majority of the suspended organic material in the water column. The unit is also called a detritor or sand catcher. Sand grit and stones need to be removed early enough in the process to avoid damage to pumps and other equipments in the remaining treatment stages.

2.3.3 AERATION TANK



As it is applied to domestic waste water treatment, aeration can be defined as the process by which a gaseous phase usually air and water are brought into intimate contact with each other for the purpose of transferring volatile substances to or from the water. These volatiles substances include oxygen, carbohydrate, nitrogen, hydrogen sulphate, methane and various unidentified organic compounds responsible for taste and odour.

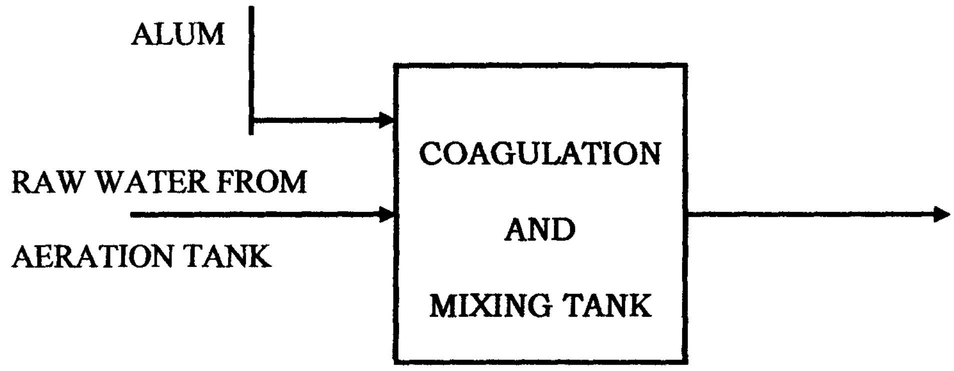
The purposes of this unit are as follows:

a. removal of concentrated hydrogen sulphide and certain volatiles organic compounds

b. To increase the oxygen content of water for oxidation of iron, manganese, hydrogen sulphide and to a limited extent of organic matter.

c. removal of carbon dioxide prior to lime softening

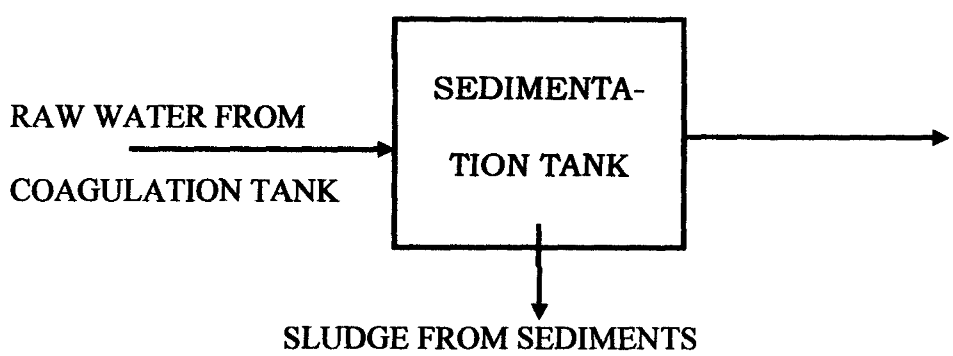
2.3.4 COAGULATION AND MIXING TANK



Coagulation is the driving together of colloidal particles by chemical forces. This process is speedy and occurs within seconds of the application of a coagulating reagent (alum) to the aerated water. For this reason, intense mixing is necessary at the point of chemical application in order to assure uniform chemical distribution and exposure of fine particles in the water to the coagulating agent before the coagulation reaction is completed. However, this is the work of rapid mixing.

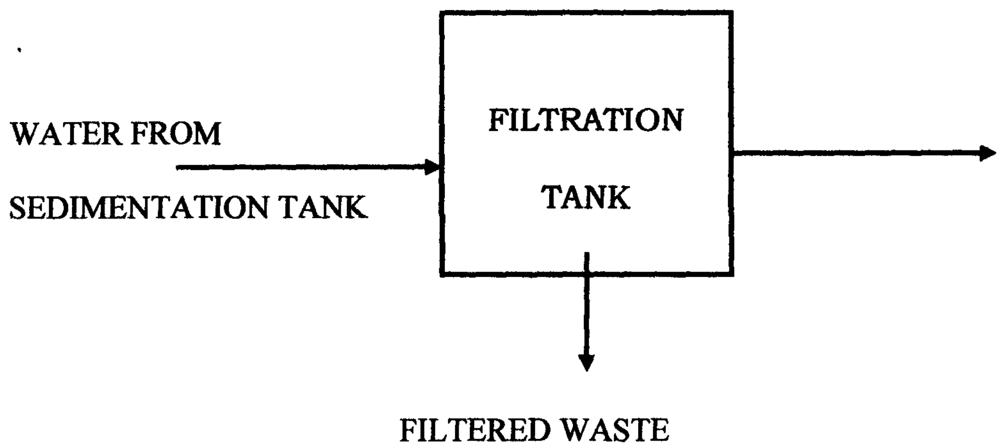
Flocculation involves the assembling of coagulated particles into floc particles. The objective of both coagulation and flocculation is to attain almost complete envelopment of suspended particles within the floc particles and to condition the floc particles so that they will readily be removable in the subsequent processes of sedimentation or filtration.

2.3.5 SEDIMENTATION TANK



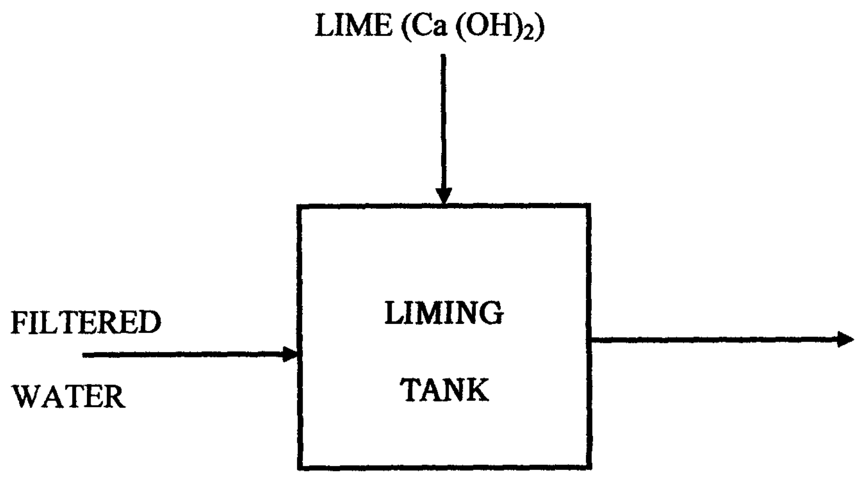
This process unit is used to reduce the amount of settleable solids by chemical treatment, such as the addition of coagulant to remove colour and turbidity, this unit is large enough that he sludge can settle and floating materials such as grease and oil can rise to the surface and be skimmed off. The purpose of this unit is to produce both a generally homogeneous liquids capable of being treated and the sludge can be separated, treated or processed.

2.3.6 FILTRATION TANK



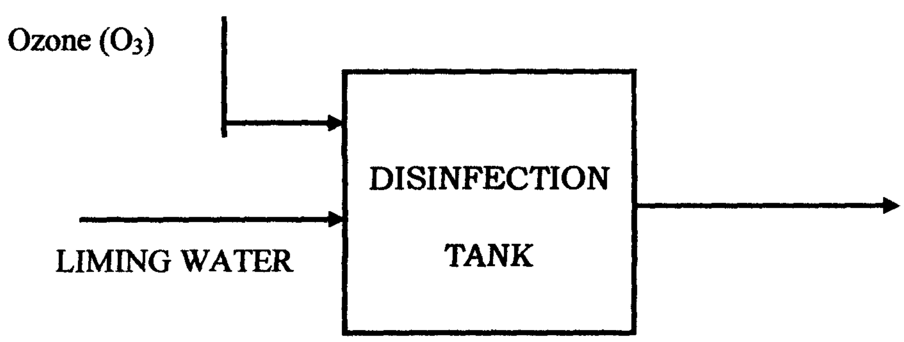
This is a physical, chemical and in some cases biological process for separating suspended and colloidal impurities from waters by passage through a porous medium usually a bed of sand or other ground material (activated carbon). Water fills the pores of the medium and the impurities are left behind in the openings or upon the medium itself. It is an important and active process in the natural purification of domestic waste waters and it is an essential unit process utilized under controlled conditions in water treatment plants throughout the world. Granular activated carbon filter is been used during filtration process due to its effectives and size of its surface area i.e. (8 x 30 for liquid phase application). It is used in water treatment for deodorization and separation of component of flow system.

2.3.7 LIMING TANK



This unit helps to increase the pH of the water to 7 due to the acidity of the water from the filtration tank. The dosage of the lime added is determined by laboratory test. The liming process also helps to remove hardness of the water by dissolving the calcium as magnesium ions are present in the water.

2.3.8 DISINFECTION TANK



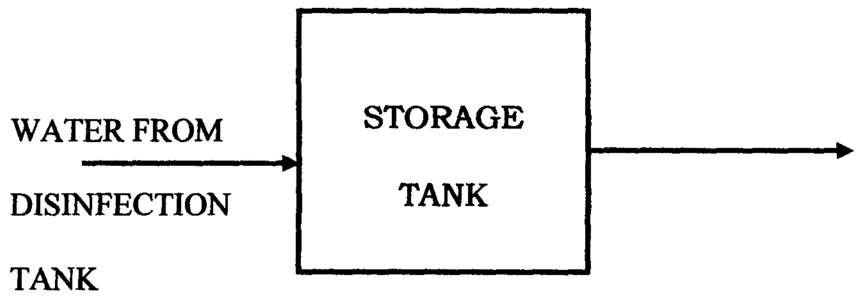
This is the last unit in the purification of domestic waste water treatment however, in this process ozonation takes place.

Ozone is one of the strongest oxidizers and kills bacteria, spores and viruses (in particular poliomyelitis virus). This use of ozone for disinfection of municipal drinking water actually antedates chlorination.

The advantages of using ozone are that it has high germicidal effectiveness which is the greatest of all known substance, even against resistant organisms such as viruses and cysts. Its ability to ameliorate many problems of odour, taste and colour in water supplies and the fact that upon decomposition, the only residual materials is ore dissolved oxygen. In addition its potency is unaffected by pH or ammonia content.

Ozone (O_3) is prepared in an ozonizer, an apparatus in which atmospheric air is acted upon by a silent electric discharge and must be produced at its point of usage.

2.3.9 FINAL STORAGE TANK (PURIFIED WATER)



The final storage tank is the tank or container where the purified water is been kept for use (for different domestic purposes).

CHAPTER THREE

STEADY STATE MATERIAL BALANCE

Taking a basis of 300,000 liters/day of water

Density of water = $1000kg/m^3$

$$SH_2O = \frac{Mass}{Volume}$$

But, Volume = 300,000litres/day

1litres = $1000cm^3$

Volume = $300,000,000cm^3/day$

100cm = 1m

$1m^3$ = $1,000,000cm^3$

Using dimensional analysis:

$$Volume = \frac{300,000,000cm^3}{day} \left| \frac{1day}{24hr} \right| \frac{1m^3}{1,000,000cm^3}$$

Volume = $12.5m^3/hr$

$$SH_2O = \frac{Mass}{Volume}$$

$$1000kg/m^3 = \frac{Mass}{12.5m^3/hr}$$

Basis = 12500kg/hr

Assuming plant attainment of (90 - 95)%

Plant attainment of 25%

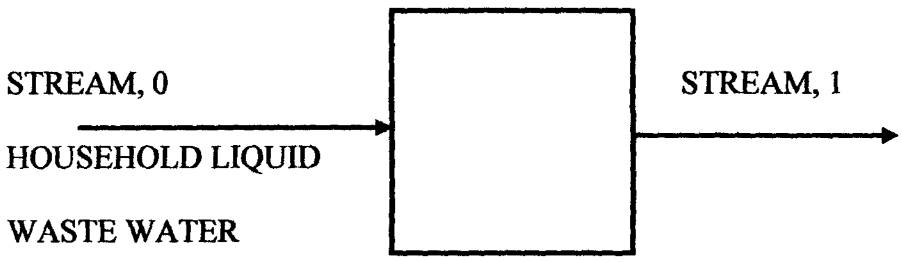
95% = 0.95 x 365days = 347days

Set S = components in stream, and

j = streams i.e. S = (O, - - - 10)

and j = (O, - - - 16)

UNIT 1: *Raw Water Storage Tank*



Components contained in unit 1 (from ELGA LABORATORY)

Impurities	Percentage (%)
Dissolved inorganic salt	5
Micro – organism	5
Pyrogens	5
Suspended particles	10
Dissolved organic compounds	5
Water	70
Total	*100%*

Components present/added and their molecular weight

Components	molecular weight (kg/kgmol)
Water	18.02
Suspended particles	31.99
Dissolved inorganic salt	87.01
Dissolved organic compounds	78.11
Micro-organism	20.179
Pyrogens	20.179
Air	29.01
Alum	76.14
Ozone	48.01

STREAM, 0

Calculating for mass flow rates: % for each component x basis

For Dissolved Inorganic Salts

0.05 x 12500kg/hr = 625kg/hr

For Micro-organism

0.05 x 12500kg/hr = 625kg/hr

For Pyrogens

0.05 x 12500kg/hr = 625kg/hr

For suspended particles

0.10 x 12500kg/hr = 1250kg/hr

For dissolved organic compounds

0.05 x 12500kg/hr = 625kg/hr

For water

0.07 x 12500kg/hr = 8750kg/hr

Total mass flow rate in stream, 0:

= 625 + 625 + 625 + 1250 + 625 + 8750 = 12500kg/hr

Calculating the mass composition for stream, 0

$$\text{Where: mass composition} = \frac{\text{Mass flow rate for each component}}{\text{Total mass flow rate in stream, 0}}$$

For Dissolved Inorganic Salt:

$$\frac{625\text{kg/hr}}{12500\text{kg/hr}} = 0.05$$

For Micro-Organism

$$\frac{625\text{kg/hr}}{12500\text{kg/hr}} = 0.05$$

For Pyrogens

$$\frac{625\text{kg/hr}}{12500\text{kg/hr}} = 0.05$$

For suspended particles

$$\frac{1250\text{kg/hr}}{12500\text{kg/hr}} = 0.1$$

For dissolved organic compounds

$$\frac{625kg/hr}{12500kg/hr} = 0.05$$

For water

$$\frac{8750kg/hr}{12500kg/hr} = 0.07$$

Calculating the molar flow rate of stream, 0

I.e. $\frac{\text{Mass flow rate}}{\text{Molecular weight}}$ (kgmol/hr)

For dissolved inorganic salt:

$$\frac{625}{87.01} = 7.183kgmol/hr$$

For micro-organism

$$\frac{625}{20.179} = 30.973kgmol/hr$$

For pyrogens

$$\frac{625}{20.179} = 30.973kgmol/hr$$

For suspended particles

$$\frac{1205}{31.99} = 39.075kgmol/hr$$

For dissolved organic compounds

$$\frac{625}{78.11} = 8.002kgmol/hr$$

For water

$$\frac{8750}{18.02} = 485.572kgmol/hr$$

Total molar flow rate:

$$= 7.183 + 30.973 + 30.973 + 8.002 + 485.572$$

= 601.778kgmol/hr

Calculating the molar composition for stream, 0

$$\text{Molar composition} = \frac{\text{Molar flow rate}}{\text{Total molar flow rate}}$$

For dissolved inorganic salt

$$\frac{7.183}{601.778} = 0.012$$

For micro – organisms

$$\frac{30.973}{601.778} = 0.051$$

For pyrogens

$$\frac{30.973}{601.778} = 0.051$$

For suspended particles

$$\frac{39.075}{601.778} = 0.065$$

For dissolved organic compounds

$$\frac{8.002}{601.778} = 0.013$$

For water

$$\frac{485.572}{601.778} = 0.807$$

Total molar composition

= 0.012 + 0.051 + 0.051 + 0.065 + 0.013 + 0.807

= 0.999 or 1.000

STREAM, 1

Calculating the mass flow rate for stream, 1

Stream, 0 = Stream 1

i.e. For dissolved inorganic salts

0.05 x 12500kg/hr = 625kg/hr

For micro – organism

0.05 x 12500kg/hr = 625kg/hr

For pyrogens

0.05 x 12500kg/hr = 625kg/hr

For suspended particles:

0.10 x 12500kg/hr = 1250kg/hr

For dissolved organic compounds:

0.05 x 12500kg/hr = 625kg/hr

For water

0.07 x 12500kg/hr = 8750kg/hr

Total mass flow rate in Stream, 1

= 625 + 625 + 625 + 1250 + 625 + 8750

= 12500kg/hr

Calculating the mass composition for Stream, 1

Stream, 0 = Stream, 1

i.e. For dissolved inorganic salt:

$$\frac{625\text{kg/hr}}{12500\text{kg/hr}} = 0.05$$

For micro-organism:

$$\frac{625\text{kg/hr}}{12500\text{kg/hr}} = 0.05$$

For pyrogens:

$$\frac{625\text{kg/hr}}{12500\text{kg/hr}} = 0.05$$

For suspended particles:

$$\frac{1205\text{kg/hr}}{12500\text{kg/hr}} = 0.1$$

For dissolved organic compounds:

$$\frac{625kg/hr}{12500kg/hr} = 0.05$$

For water:

$$\frac{8750kg/hr}{12500kg/hr} = 0.7$$

Calculating the molar flow rate of Stream, 1

i.e. Stream, 0 = Stream, 1

$$\frac{\text{Mass flow rate(kgmol/hr)}}{\text{Molecular weight}}$$

For dissolved inorganic salt:

$$\frac{625}{87.01} = 7.183kgmol/hr$$

For micro-organism:

$$\frac{625}{20.179} = 30.973kgmol/hr$$

For pyrogens:

$$\frac{625}{20.179} = 30.973kgmol/hr$$

For suspended particles:

$$\frac{1250}{31.99} = 39.075kgmol/hr$$

For dissolved organic compounds:

$$\frac{625}{78.11} = 0.002kgmol/hr$$

For water:

$$\frac{8750}{18.02} = 485.573kgmol/hr$$

Total molar flow rate for Stream, 1

$$= 7.183 + 30.973 + 30.973 + 39.075 + 8.002 + 485.572$$

= 601.778kgmol/hr

Calculating the molar composition for Stream, 1

i.e. Stream, 0 = Stream 1

$$\text{Molar composition} = \frac{\text{Molar flow rate}}{\text{Total molar flow rate}}$$

For dissolved inorganic salts

$$\frac{7.183}{601.778} = 0.012$$

For micro – organisms:

$$\frac{30.973}{601.778} = 0.051$$

For pyrogens:

$$\frac{30.973}{601.778} = 0.051$$

For suspended particles

$$\frac{39.075}{601.778} = 0.065$$

For dissolved organic compounds:

$$\frac{8.002}{601.778} = 0.013$$

For water

$$\frac{485.572}{601.778} = 0.807$$

Total molar composition of Stream, 1

= 0.012 + 0.051 + 0.051 + 0.065 + 0.013 + 0.807

= 0.999 or 1.000

SUMMARY OF MATERIAL BALANCE IN UNIT 1

INPUT

COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	SCALE UP	MOLE PERCENT
Dissolved inorganic salts	625	7.183	892.857	1.2
Micro-organism	625	30.973	892.857	5.1
Pyrogens	625	30.973	892.857	5.1
Suspended particles	1250	39.075	1785.718	6.5
Dissolved organic compounds	625	8.002	892.857	1.3
Water	8750	485.572	12500	80.7
Air	-	-	-	-
Alum	-	-	-	-
Ozone	-	-	-	-
TOTAL	**12500**	**601.778**	**17857.146**	**100**

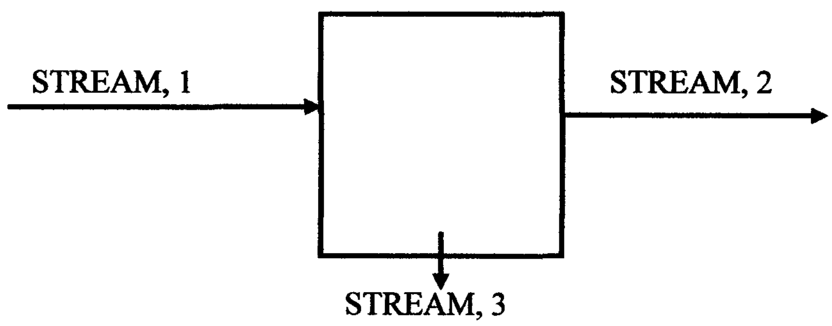
OUTPUT

COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	SCALE UP	MOLAR COMPOSITION
Dissolved inorganic salts	625	7.183	892.857	1.2
Micro-organism	625	30.973	892.857	5.1
Pyrogens	625	30.973	892.857	5.1
Suspended particles	1250	39.075	1785.718	6.5
Dissolved organic compounds	625	8.002	892.857	1.3

Water	8750	485.572	12500	80.7
Air	-	-	-	-
Alum	-	-	-	-
Ozone	-	-	-	-
TOTAL	**12500**	**601.778**	**17857.146**	**100**

UNIT 2: ***Coarse Screener***

It is assumed that 49.80% of suspended particles was removed from this unit.



STREAM, 2

Calculating the mass flow rate for Stream, 2

Mass flow rate for suspended particles:

i.e. Basis x the percentage of removed suspended particles

$$12500 \times \frac{49.50}{100} = 618.75\text{kg/hr}$$

Calculating the mass composition for Stream, 2

The mass composition for suspended particles

i.e. $\dfrac{\text{Mass flow rate of suspended particles}}{\text{Total mass flow rates}}$

$$\frac{618.75\text{kg/hr}}{618.75\text{kg/hr}} = 1$$

Calculating the molar flow rate for Stream, 2

The molar flow rate for suspended particles i.e. $\frac{\text{Mass flow rate of suspended particles}}{\text{Molecular weight}}$

$= \frac{618.75}{31.99} = 19.342\text{kgmol/hr}$

Calculating the molar composition for Stream, 2

$\frac{\text{Molar composition of suspended particles}}{\text{Total molar flow rate}}$

$= \frac{19.342}{19.342} = 1.0$

Calculating the mass flow rate of Stream, 3

Where mass flow rate = % of each components x basis

For dissolved inorganic salt:

The same as in stream, 0 = 625kg/hr

For micro-organisms

The same as in stream, 0 = 625kg/hr

For pyrogens

The same as in stream, 0 = 625kg/hr

For suspended particles

$\frac{49.50}{100} \times 1250\text{kg/hr}$

$= 618.75\text{kg/hr}$

Amount left = 1250kg/hr – 618.75kg/hr

= 631.25kg/hr

For dissolved organic compound:

The same as in stream, 0 = 625kg/hr

For water

The same as in stream, 0 = 8750kg/hr

Total mass flow rate:

= 625 + 625 + 625 + 631.25 + 625 + 8750

= 11881.25kg/hr

Calculating the mass composition of stream, 3

i.e. Mass composition = $\frac{\text{Mass flow rate}}{\text{Total mass flow rate}}$

For dissolved inorganic salts:

$\frac{625\text{kg/hr}}{11881.25\text{kg/hr}} = 0.053$

For micro-organisms

$\frac{625\text{kg/hr}}{11881.25\text{kg/hr}} = 0.053$

For pyrogens:

$\frac{625\text{kg/hr}}{11881.25\text{kg/hr}} = 0.053$

For suspended particles:

$\frac{631.25\text{kg/hr}}{11881.25\text{kg/hr}} = 0.053$

For water:

$\frac{8750\text{kg/hr}}{11881.25\text{kg/hr}} = 0.736$

Total mass composition

= 0.053 + 0.053 + 0.053 + 0.053 + 0.053 + 0.736

= 1.001 or 1.00

Calculating the molar flow rate of stream 3

i.e. Molar flow rate = $\frac{\text{Mass flow rate}}{\text{Molecular weight}}$

For dissolved inorganic salts:

$\frac{625\text{kg/hr}}{87.01\text{kg/hr}} = 7.183\text{kgmol/hr}$

For micro-organisms:

$$\frac{625kg/hr}{20.179kgmol/hr} = 30.973kgmol/hr$$

For suspended particles:

$$\frac{631.25}{31.99} = 19.733kgmol/hr$$

For dissolved organic compounds:

$$\frac{625}{78.11} = 8.002kgmol/hr$$

For water:

$$\frac{8750}{18.02} = 485.572kgmol/hr$$

For pyrogens:

$$\frac{625}{20.179} = 30.973kgmol/hr$$

Total molar flow rate

$$= 7.183 + 30.973 + 19.733 + 8.002 + 485.572 + 30.973$$

$$= 582.436kgmol/hr$$

Calculating the molar composition for stream, 3

i.e. $\text{Molar composition} = \frac{\text{Molar flow rate}}{\text{Total molar flow rate}}$

For dissolved inorganic salts:

$$\frac{7.183}{582,436} = 0.012$$

For micro-organisms:

$$\frac{30.973}{582.436} = 0.053$$

For pyrogens:

$$\frac{30.973}{582.436} = 0.053$$

For suspended particles:

$$\frac{19.733}{582.436} = 0.034$$

For dissolved organic compounds:

$$\frac{8.002}{582.436} = 0.014$$

For water:

$$\frac{485.572}{582.436} = 0.834$$

Total molar composition

$= 0.012 + 0.053 + 0.053 + 0.034 + 0.014 + 0.834$

$= 1.00$

SUMMARY OF MATERIAL BALANCE IN UNIT 2

INPUT

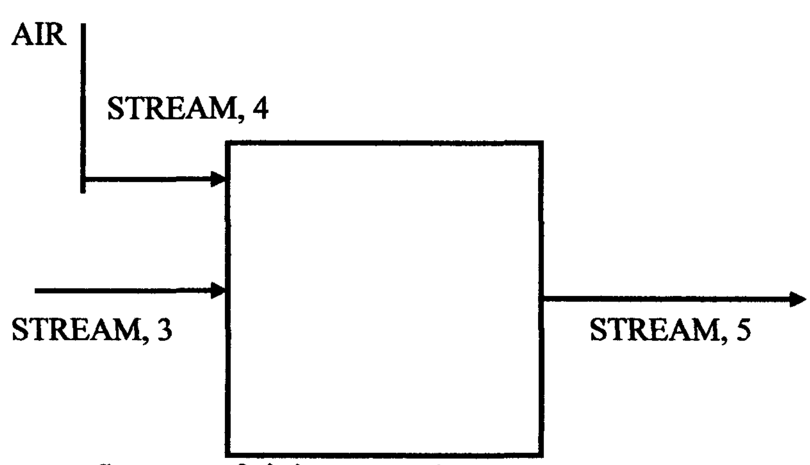
COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	MOLE PERCENT	SCALE UP
Dissolved inorganic salts	625	7.183	1.2	892.857
Micro-organism	625	30.973	5.1	892.857
Pyrogens	625	30.973	5.1	892.857
Suspended particles	1250	39.075	6.5	1785.718
Dissolved organic compounds	625	8.002	1.3	892.857
Water	8750	485.572	80.7	12500
Air	0	0	0	0
Alum	0	0	0	0
Ozone	0	0	0	0
TOTAL	**12500**	**601.778**	**100**	**17857.146**

OUTPUT

COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	MOLE PERCENT	SCALE UP
Dissolved inorganic salts	625	7.183	1.2	892.857
Micro-organism	625	30.973	5.3	892.857
Pyrogens	625	30.973	5.3	892.857
Suspended particles	631.25	19.733	3.4	1785.718
Dissolved organic compounds	625	8.002	1.4	892.857
Water	8750	485.572	83.4	12500
Air	0	0	0	0
Alum	0	0	0	0
Ozone	0	0	0	0
TOTAL	**11881.25**	**582.436**	**100**	**16973.214**

UNIT 3: ***Aeration Tank***

It is assumed that air is added to the waste water in the ratio of 2:1 to achieve a high degree of transfer of volatile substances to or from the water.



STREAM, 4

Calculating the mass flow rate of air in stream, 4

During aeration, and based on the ratio above 2:1

2 x mass flow rate of the waste water

= 2 x 11881.25kg/hr

= 27376.50kg/hr

Calculating the mass composition of air in stream, 4

i.e. $\frac{\text{Mass flow rate of air}}{\text{Total ass flow rate of air}}$

$= \frac{27376.50\text{kg/hr}}{27376.50\text{kg/hr}}$

= 1.00

Calculating the molar flow rate of air in stream, 4

i.e. $\frac{\text{Mass flow rate of air}}{\text{Molecular weight of air}}$

$= \frac{27376.50\text{kg/hr}}{29.01\text{mol}}$

= 819.114kgmol/hr

Calculating the molar composition of air in stream, 4

i.e. Molar flow rate

Total molar flow rate

$= \frac{819.114\text{kgmol/hr}}{819.114\text{kgmol/hr}}$

= 1.00

STREAM, 5

Calculating the mass flow rate of stream, 5

For dissolved inorganic salts:

The same as in stream, 3 = 625kg/hr

For micro-organisms:

The same as in stream, 3 = 625kg/hr

For pyrogens:

The same as in stream, 3 = 625kg/hr

For suspended particles:

The same as in stream, 3 = 631.25kg/hr

For dissolved organic compound:

The same as in stream, 3 = 625kg/hr

For water:

The same as in stream, 3 = 8750kg/hr

For air:

The same as in stream, 4 = 23762.50kg/hr

Total mass flow rate

= 625 + 625 + 625 + 631.25 + 625 + 8750 + 23762.50

= 35643.75kg/hr

Calculating the mass composition of stream, 5

$$\text{Mass composition} = \frac{\text{Mass flow rate of each component in stream, 5}}{\text{Total mass flow rate of stream 5}}$$

For dissolved inorganic salts:

$$= \frac{625\text{kg/hr}}{35643.75\text{kg/hr}}$$

= 0.018

For micro-organisms:

$$= \frac{625\text{kg/hr}}{35643.75\text{kg/hr}}$$

= 0.018

For pyrogens:

$$= \frac{625\text{kg/hr}}{35643.75\text{kg/hr}}$$

= 0.018

For suspended particles:

$$= \frac{631.25\text{kg/hr}}{35643.75\text{kg/hr}}$$

$= \quad 0.018$

For dissolved organic compounds:

$$= \frac{625kg/hr}{35643.75kg/hr}$$

$= \quad 0.018$

For water:

$$= \frac{8750kg/hr}{35643.75kg/hr}$$

$= \quad 0.245$

For air:

$$= \frac{23762.50kg/hr}{35643.75kg/hr}$$

$= \quad 0.0667$

Total mass composition

$= \quad 0.018 + 0.018 + 0.018 + 0.018 + 0.245 + 0.667$

$= \quad 1.002$ or 1.00

Calculating the molar flow rate stream, 5

$$\text{i.e. molar flow rate} = \frac{\text{Mass flow rate of stream, 5}}{\text{Molecular weights of each component}}$$

For dissolved inorganic salts:

$$\frac{625}{87.01}$$

$= \quad 7.183kgmol/hr$

For micro-organisms:

$$\frac{625}{20.179}$$

$= \quad 30.973kgmol/hr$

For pyrogens:

$$\frac{625}{}$$

20.179

= 30.973kgmol/hr

For suspended particles:

$$\frac{631.25}{31.99}$$

= 19.733kgmol/hr

For dissolved organic compounds:

$$\frac{625}{78.11}$$

= 8.002kgmol/hr

For water:

$$\frac{8750}{18.02}$$

= 485.572kgmol/hr

For air:

$$\frac{23762.50}{29.01}$$

= 819.114kgmol/hr

Total molar flow rate

= 7.183 + 30.973 + 30.973 + 19.733 + 8.002 + 485.572 + 819.114

= 1401.55kgmol/hr

Calculating the molar composition of stream, 5

i.e. Molar composition = $\frac{\text{Molar flow rate of stream, 5}}{\text{Total molar flow rate of stream, 5}}$

For dissolved inorganic salts:

$$= \frac{7.183}{1401.55}$$

= 0.005

For micro-organisms:

$$= \frac{30.973}{1401.55}$$

$$= 0.022$$

For pyrogens:

$$= \frac{30.973}{1401.55}$$

$$= 0.005$$

For suspended particles:

$$= \frac{19.732}{1401.55}$$

$$= 0.014$$

For dissolved organic compounds:

$$= \frac{8.002}{1401.55}$$

$$= 0.006$$

For water:

$$= \frac{485.572}{1401.55}$$

$$= 0.346$$

For air:

$$= \frac{819.114}{1401.55}$$

$$= 0.0584$$

Total molar composition

$$= 0.005 + 0.022 + 0.022 + 0.014 + 0.006 + 0.346 + 0.584$$

$$= 1.00$$

SUMMARY OF MATERIAL BALANCE IN UNIT 3

INPUT

COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	MOLE PERCENT	SCALE UP
Dissolved inorganic salts	625	7.183	0.5	892.857
Micro-organism	625	30.973	2.2	892.857
Pyrogens	625	30.973	2.2	892.857
Suspended particles	631.25	19.733	1.4	901.786
Dissolved organic compounds	625	8.002	0.6	892.857
Water	8750	485.572	34.6	12500
Air	23762.50	819.114	58.4	33946.429
Alum	0	0	0	0
Ozone	0	0	0	0
TOTAL	**35643.75**	**1401.55**	**100**	**50919.643**

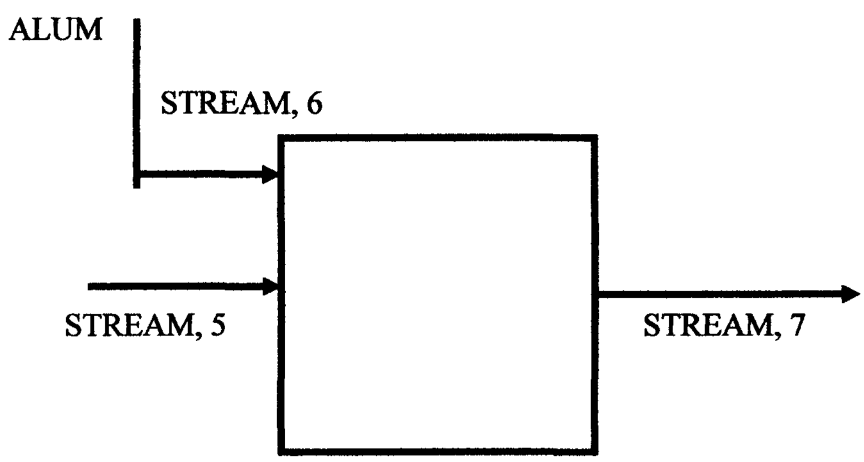
OUTPUT

COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	MOLE PERCENT	SCALE UP
Dissolved inorganic salts	625	7.183	0.5	892.857
Micro-organism	625	30.973	2.2	892.857
Pyrogens	625	30.973	2.2	892.857
Suspended particles	631.25	19.733	1.4	901.786
Dissolved organic compounds	625	8.002	0.6	892.857

Water	8750	485.572	34.6	12500
Air	23762.50	819.114	58.4	33946.429
Alum	0	0	0	0
Ozone	0	0	0	0
TOTAL	**35643.75**	**1401.55**	**100**	**50919.643**

UNIT 4: ***Rapid Mixing and Coagulation***

It is assumed that the alum is added during the coagulation in the ratio of 3:1 with the quantity of suspended particles present in the waste water.



STREAM, 6

Mass flow rate of alum added = 3 x mass flow rate of the suspended particles in stream, 5

Calculating the mass composition for stream, 6

Mass composition of alum added

$$= \frac{1893.75 kg/hr}{1893.75 kg/hr}$$

$$= 1.00$$

Calculating the molar flow rate for stream, 6

$$\text{Molar flow rate of alum added} = \frac{\text{Mass flow rate of alum}}{\text{Molecular weight}}$$

$$= \frac{1893.75}{76.14}$$

= 24.872kgmol/hr

Stream, 7

Calculating the mass flow rate for stream, 7

For dissolved inorganic salt:

The same as in stream, 5 = 625kg/hr

For micro-organisms:

The same as in stream, 5 = 625kg/hr

For pyrogens:

The same as in stream, 5 = 625kg/hr

For suspended particles:

The same as in stream, 5 = 631.25kg/hr

For dissolved organic compounds:

The same as in stream, 5 = 625kg/hr

For water:

The same as in stream, 5 = 8750kg/hr

For air:

The same as in stream, 5 = 23762.50kg/hr

For alum:

The same as in stream, 6 = 1893.75kg/hr

Total mass flow rate for stream, 7

= 625 + 625 + 625 + 631.25 + 625 + 8750 + 23762.50 + 1893.75

= 37537.5kg/hr

Calculating the mass composition for stream, 7

i.e. Mass composition = $\dfrac{\text{Mass flow rate of stream, 7}}{\text{Total mass flow rate of stream, 7}}$

For dissolved inorganic salts:

$\dfrac{625\text{kg/hr}}{37537.5\text{kg/hr}}$

= 0.017

For micro-organisms:

$\dfrac{625\text{kg/hr}}{37537.5\text{kg/hr}}$

= 0.017

For pyrogens:

$\dfrac{625\text{kg/hr}}{37537.5\text{kg/hr}}$

= 0.017

For suspended particles:

$\dfrac{625\text{kg/hr}}{37537.5\text{kg/hr}}$

= 0.017

For dissolved organic compounds:

$\dfrac{625\text{kg/hr}}{37537.5\text{kg/hr}}$

= 0.017

For water:

$\dfrac{8750\text{kg/hr}}{37537.5\text{kg/hr}}$

= 0.233

For air:

$$\frac{23762.5kg/hr}{37537.5kg/hr}$$

= 0.730

For alum:

$$\frac{1893.75kg/hr}{37537.5kg/hr}$$

= 0.050

Total mass composition for stream, 7

= 0.017 + 0.017 + 0.017 + 0.017 + 0.017 + 0.233 + 0.730 + 0.050

= 1.00

Calculating the molar flow rate for stream, 7

Where: Molar flow rate = $\frac{\text{Mass flow rate kgmol/hr}}{\text{Molecular weight}}$

For dissolved inorganic salt:

$$\frac{625}{87.01}$$

= 7.183kgmol/hr

For micro-organisms:

$$\frac{625}{20.179}$$

= 30.179kgmol/hr

For pyrogens:

$$\frac{625}{20.179}$$

= 30.179kgmol/hr

For suspended particles:

$$\frac{631.25}{31.99}$$

= 19.733kgmol/hr

For dissolved organic compounds:

$$\frac{625}{78.11}$$

= 8.002kgmol/hr

For water:

$$\frac{8750}{18.02}$$

= 485.572kgmol/hr

For air:

$$\frac{23762.50}{29.01}$$

= 819.114kgmol/hr

For alum:

$$\frac{1893.75}{76.11}$$

= 24.872kgmol/hr

Total molar flow rate for stream, 7

= 7.183 + 30.973 + 30.973 + 19.733 + 8.002 + 485.572 + 819.114 + 24.872

= 1426.422kgmol/hr

Calculating the molar composition for stream, 7

i.e. $$\frac{\text{Molar flow rate of stream, 7}}{\text{Total molar flow rate of stream, 7}}$$

For dissolved inorganic salts:

$$\frac{7.183\text{kgmol/hr}}{1426.422\text{kgmol/hr}}$$

= 0.005

For micro-organisms:

$$\frac{30.973\text{kgmol/hr}}{1426.422\text{kgmol/hr}}$$

= 0.022

For pyrogens:

$$\frac{30.973\text{kgmol/hr}}{1426.422\text{kgmol/hr}}$$

= 0.022

For suspended particles:

$$\frac{19.733\text{kgmol/hr}}{1426.422\text{kgmol/hr}}$$

= 0.014

For dissolved organic compounds:

$$\frac{8.002\text{kgmol/hr}}{1426.422\text{kgmol/hr}}$$

= 0.006

For water:

$$\frac{485.572\text{kgmol/hr}}{1426.422\text{kgmol/hr}}$$

= 0.340

For air:

$$\frac{819.144\text{kgmol/hr}}{1426.422\text{kgmol/hr}}$$

= 0.574

For alum:

$$\frac{24.872\text{kgmol/hr}}{1426.422\text{kgmol/hr}}$$

= 0.017

Total molar composition for stream, 7

= 0.005 + 0.022 + 0.022 + 0.014 + 0.006 + 0.340 + 0.574 + 0.017

= 1.00

SUMMARY OF MATERIAL BALANCE IN UNIT 4

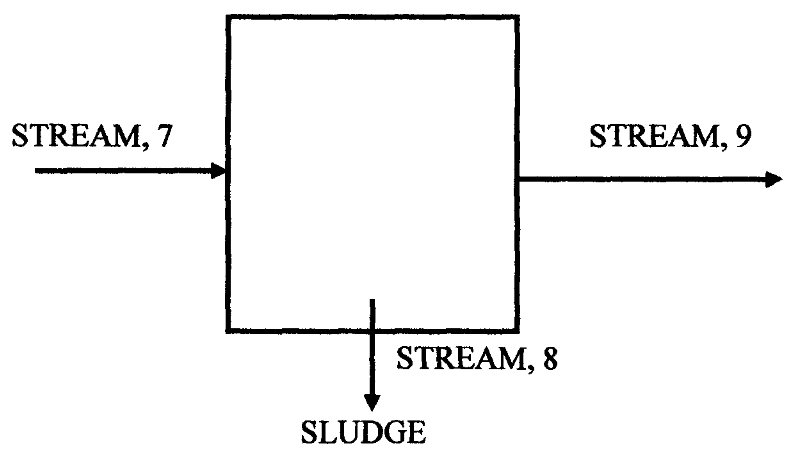
INPUT

COMPONENTS	**MASS FLOW RATE (kg/hr)**	**MOLAR FLOW RATE (kgmol/hr)**	**MOLE PERCENT**	**SCALE UP**
Dissolved inorganic salts	625	7.183	0.5	892.857
Micro-organism	625	30.973	2.2	892.857
Pyrogens	625	30.973	2.2	892.857
Suspended particles	631.25	19.733	1.4	901.786
Dissolved organic compounds	625	8.002	0.6	892.857
Water	8750	485.572	34.0	12500
Air	23762.50	819.114	57.4	33946.429
Alum	1893.75	24.872	17.0	2705.357
Ozone	0	0	0	0
TOTAL	**37537.5**	**1426.422**	**100**	**53625.000**

OUTPUT

COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	MOLE PERCENT	SCALE UP
Dissolved inorganic salts	625	7.183	0.5	892.857
Micro-organism	625	30.973	2.2	892.857
Pyrogens	625	30.973	2.2	892.857
Suspended particles	631.25	19.733	1.4	901.786
Dissolved organic compounds	625	8.002	0.6	892.857
Water	8750	485.572	34.0	12500
Air	23762.50	819.114	57.4	33946.429
Alum	1893.75	24.872	17.0	2705.357
Ozone	0	0	0	0
TOTAL	**37537.5**	**1426.422**	**100**	**53625.000**

UNIT 5 *Sedimentation Tank*



STREAM, 8

Calculating the mass flow rate of stream, 8

i.e. it was assumed that 45% of suspended particles wee removed.

Mass flow rate of suspended particle remove become:

$$\frac{45}{100} \times \frac{631.25}{1}$$

= 284.063kg/hr

It was also assumed that 15% dissolved organic compound were remove hence, mass flow rate of dissolved organic compound is:

$$\frac{15}{100} \times 625$$

= 93.75kg/hr

It was also assumed that 15% dissolved inorganic salts were removed therefore, mass flow rate of dissolved inorganic salts is:

$$\frac{15}{100} \times 625$$

= 93.75kg/hr

It was assumed that 5% of micro-organisms were removed

Mass flow rate of micro-organism removed is:

$$\frac{5}{100} \times 625$$

= 31.25kg/hr

It was also assumed that 90% of alum was removed

Mass flow rate of alum removed is:

$$\frac{90}{100} \times 1893.75$$

= 1704.357kg/hr

STREAM, 9

Calculating the mass flow rate for stream, 9

It was assumed that 45% of suspended particles were removed from stream, 8. Therefore, amount left:

$(100 - 45)\% = 55\%$

$$\frac{55}{100} \times 631.25$$

$= 347.188kg/hr$

Mass flow rate of suspended particles = 347.188kg/hr

For dissolved inorganic salts:

It was assumed that 15% of dissolved organic compound was removed

Amount left = (100 - 15)% = 85%

$$\frac{85}{100} \times 625$$

$= 531.25kg/hr$

For dissolved organic compounds:

It was assumed that 15 of dissolved organic compounds was removed

Amount left = (100 - 15)% = 85%

$$\frac{85}{100} \times 625$$

$= 531.25kg/hr$

For micro-organisms:

It was assumed that 5% of micro-organism was removed

Amount left = (100 - 5)% = 95%

$$\frac{95}{100} \times 625$$

$= 593.75kg/hr$

For pyrogens:

It was assumed that 5% of pyrogens was removed

Amount left = (100 - 5)% = 95%

$$\frac{95}{100} \times 625$$

$= 593.75kg/hr$

For Alum:

It was assumed that 10% of alum was removed

Amount left = (100 - 10)% = 90%

$$\frac{90}{100} \times 1893.75$$

= 189.375kg/hr

For water:

The same as in stream, 7 = 8750kg/hr

For air:

The same as in stream, 7 = 23762.5kg/hr

Total mass flow rate for stream, 9

= 347.188+ 531.25 + 531.25 + 593.75 + 593.75 + 189.375 + 8750 + 23762.5

= 35299.063kg/hr

Calculating the mass composition for stream, 9

$$\text{Where mass composition} = \frac{\text{Mass flow rate of stream, 9}}{\text{Total mass flow rate of stream, 9}}$$

For dissolved inorganic salts:

$$\frac{531.25}{35299.063}$$

= 0.015

For micro-organisms:

$$\frac{593.75}{35299.063}$$

= 0.017

For pyrogens:

$$\frac{593.75}{35299.063}$$

= 0.017

For suspended particles:

$$\frac{347.188}{35299.063}$$

= 0.010

For dissolved organic compounds:

$$\frac{531.25}{35299.063}$$

= 0.015

For water:

$$\frac{8750}{35299.063}$$

= 0.248

For air:

$$\frac{23762.50}{35299.063}$$

= 0.673

For alum:

$$\frac{189.375}{35299.063}$$

= 0.005

Total mass composition

= 0.015 + 0.017 + 0.017 + 0.010 + 0.015 + 0.248 + 0.673 + 0.005

= 1.00

Calculating the molar flow rate of stream, 9

$$\text{Where molar flow rate} = \frac{\text{Mass flow rate}}{\text{Molecular weight}}$$

For dissolved inorganic salts:

$$\frac{531.25}{87.01}$$

= 6.106kgmol/hr

For micro-organisms:

$$\frac{593.75}{20.179}$$

= 29.424kgmol/hr

For pyrogens:

$$\frac{593.75}{20.179}$$

= 29.424kgmol/hr

For suspended particles:

$$\frac{347.188}{31.99}$$

= 10.853kgmol/hr

For dissolved organic compounds:

$$\frac{531.25}{78.11}$$

= 6.801kgmol/hr

For water:

$$\frac{8750}{18.02}$$

= 485.572kgmol/hr

For air:

$$\frac{23762.50}{29.01}$$

= 819.114kgmol/hr

For alum:

$$\frac{189.375}{76.14}$$

= 2.487kgmol/hr

Total molar flow rate for stream, 9

= 6.106 + 29.424 + 29.424 + 10.853 + 6.801 + 485.572 + 819.114 + 2.487

= 1389.781kgmol/hr

Calculating the molar composition for stream, 9

$$\text{Where molar composition} = \frac{\text{Molar flow rate of stream, 9}}{\text{Total molar flow rate of stream, 9}}$$

For dissolved inorganic salts:

$$\frac{6.106}{1389.781}$$

= 0.004

For micro-organisms:

$$\frac{29.424}{1389.781}$$

= 0.021

For pyrogens:

$$\frac{29.424}{1389.781}$$

= 0.021

For suspended particles:

$$\frac{10.853}{1389.781}$$

= 0.008

For dissolved organic compounds:

$$\frac{6.801}{1389.781}$$

= 0.005

For water:

$$\frac{485.572}{1389.781}$$

$= \quad 0.349$

For air:

$$\frac{819.114}{1389.781}$$

$= \quad 0.589$

For alum:

$$\frac{2.487}{1389.781}$$

$= \quad 0.002$

Total molar composition of stream, 9

$= \quad 0.004 + 0.021 + 0.021 + 0.008 + 0.005 + 0.349 + 0.589 + 0.002$

$= \quad 1.00$

SUMMARY OF MATERIAL BALANCE IN UNIT 5

INPUT

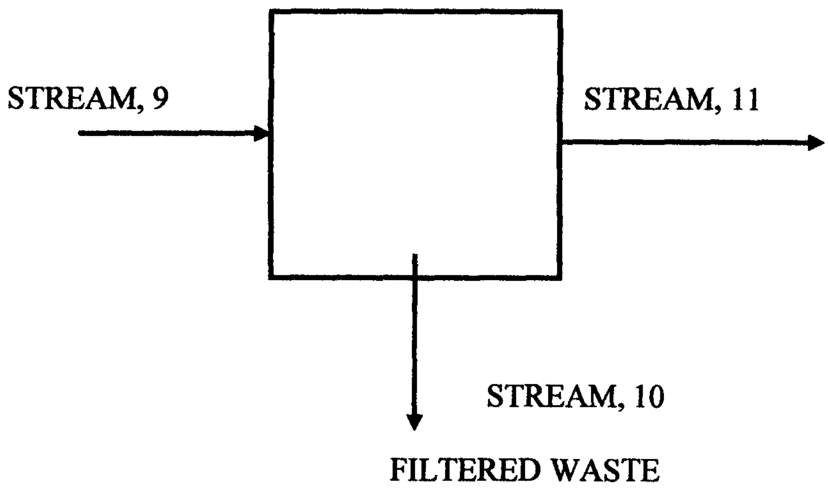
COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	MOLE PERCENT	SCALE UP
Dissolved inorganic salts	625.00	7.183	0.5	892.857
Micro-organism	625.00	30.973	2.2	892.857
Pyrogens	625.00	30.973	2.2	892.857
Suspended particles	631.250	19.733	1.4	901.786
Dissolved organic compounds	625.00	8.002	0.6	892.857
Water	8750	485.572	34.0	12500
Air	23762.5	819.114	57.4	33946.429
Alum	1893.75	24.872	17.0	2705.375
Ozone	0	0	0	0
TOTAL	**37537.5**	**1426.422**	**100**	**53625.000**

OUTPUT

COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	MOLE PERCENT	SCALE UP
Dissolved inorganic salts	531.25	6.106	0.4	758.929
Micro-organism	593.75	29.424	2.1	848.214
Pyrogens	593.75	29.424	2.1	848.214
Suspended particles	347.189	10.853	0.8	495.984
Dissolved organic compounds	531.25	6.801	0.5	758.929

Water	8750	485.572	34.9	12500
Air	23762.5	819.114	58.9	33946.429
Alum	189.375	2.487	0.2	270.536
Ozone	0	0	0	0
TOTAL	**35299.063**	**1389.781**	**100**	**50427.235**

UNIT 6: ***Filtration Tank***



STREAM, 10

Calculating the mass flow rate of stream, 10

Where: Mass flow rate =

Mass flow rate of components x percentage of the removed particles

For suspended particles:

It was assumed that 99.99% of suspended particles was removed form the unit 6.

$$\frac{99.99}{100} \times 347.188$$

$= 347.153$kg/hr

For dissolved inorganic salts:

It was assumed that 98% of dissolve inorganic salts was removed:

$$\frac{98}{100} \times 531.25$$

$= 520.625$kg/hr

For dissolved organic compound:

It was assumed that 98% dissolved organic compounds was removed:

$$\frac{98}{100} \times 531.25$$

= 520.625kg/hr

For micro-organisms:

It was assumed that 35% of micro-organisms was removed:

$$\frac{35}{100} \times 593.75$$

= 207.813kg/hr

For pyrogens:

It was assumed that 45% of pyrogens was removed:

$$\frac{45}{100} \times 593.75$$

= 267.188kg/hr

For alum:

It was also assumed that 99.99% of alum was removed:

$$\frac{99.99}{100} \times 189.375$$

= 189.356kg/hr

STREAM, 11

Calculating the mass flow rate for stream, 11

For dissolved inorganic salts:

It was assumed that 98% was removed, amount left (100-98) % = 2%

$$\frac{2}{100} \times 531.25$$

= 10.625kg/hr

For micro-organisms:

Amount left = (100-35) % = 65%

$$\frac{65}{100} \times 593.75$$

= 385.938kg/hr

For pyrogens:

Amount left = (100-45) % = 55%

$$\frac{55}{100} \times 593.75$$

= 326.563kg/hr

For suspended particles:

Amount left = 347.188 - 347.153

= 0.035kg/hr

For dissolved organic compound:

Amount left = 531.25 - 520.625

= 10.625kg/hr

For water:

The same as in stream, 9 = 8750kg/hr

For air:

The same as in stream, 9 = 23762.5kg/hr

For alum:

Amount left = 189.375 - 189.356

= 0.019kg/hr

Total mass flow rate for stream, 11

= 10.625 + 385.938 + 326.563 + 0.035 + 10.625 + 8750 + 23762.5 + 0.019

= 33246.305kg/hr

Calculating the mass composition for stream, 11

For dissolved inorganic salts:

$$\frac{10.625}{33246.305}$$

$= \quad 3.19 \times 10^{-4}$

For micro-organisms:

$$\frac{385.938}{33246.305}$$

$= \quad 1.16 \times 10^{-3}$

For pyrogens:

$$\frac{326.563}{33246.305}$$

$= \quad 9.8 \times 10^{-3}$

For suspended particles:

$$\frac{0.035}{33246.305}$$

$= \quad 1.05 \times 10^{-6}$

For dissolved organic compounds:

$$\frac{10.625}{33246.305}$$

$= \quad 3.19 \times 10^{-4}$

For water:

$$\frac{8750}{33246.305}$$

$= \quad 0.263$

For air:

$$\frac{23762.5}{33246.305}$$

$= \quad 0.715$

For alum:

$$\frac{0.019}{33246.305}$$

$= \quad 5.71 \times 10^{-4}$

Total mass composition for stream, 11 = $3.19 \times 10^{-4} + 1.16 \times 10^{-3}$

$+ 9.8 \times 10^{-3} + 1.05 \times 10^{-6} + 3.19 \times 10^{-4} + 0.263 + 0.715 + 5.71 \times 10^{-4}$

= 1.000

Calculating the molar flow rate for stream, 11

Where: molar flow rate = $\frac{\text{Mass flow rate}}{\text{Molecular weight}}$

For dissolved inorganic salts:

$$\frac{10.625}{87.01}$$

= 0.122

For micro-organisms:

$$\frac{385.938}{20.179}$$

= 19.126

For pyrogens:

$$\frac{326.563}{20.179}$$

= 16.191

For suspended particles:

$$\frac{0.035}{31.99}$$

= 0.00109

For dissolved organic compounds:

$$\frac{10.625}{78.11}$$

= 0.136

For water:

$$\frac{8750}{18.02}$$

$= 485.572$

For air:

$$\frac{23762.5}{29.01}$$

$= 819.11$

For alum:

$$\frac{0.019}{76.14}$$

$= 0.00025$

Total molar flow rate for stream, 11

$= 0.122 + 19.126 + 16.191 + 0.00109 + 0.136 + 485.572 + 819.11 + 0.00025$

$= 1340.26$

Calculating the molar composition for stream, 11

Where: Molar composition $= \frac{\text{Molar flow rate of stream, 11}}{\text{Total molar flow rate of stream, 11}}$

For dissolved inorganic salts:

$$\frac{0.122}{1340.26}$$

$= 9.1 \times 10^{-3}$

For micro-organisms:

$$\frac{19.126}{1340.26}$$

$= 0.0143$

For pyrogens:

$$\frac{16.191}{1340.26}$$

$= 0.0121$

For suspended particles:

$$\frac{0.00109}{1340.26}$$

$= \quad 1.42 \times 10^{-6}$

For dissolved organic compounds:

$$\frac{0.136}{1340.26}$$

$= \quad 1.01 \times 10^{-4}$

For water:

$$\frac{485.572}{1340.26}$$

$= \quad 0.362$

For air:

$$\frac{819.11}{1340.26}$$

$= \quad 0.611$

For alum:

$$\frac{0.00025}{1340.26}$$

$= \quad 1.86 \times 10^{-7}$

Total molar flow rate for stream, 11 $= \quad 9.10 \times 10^{-5} + 0.0143 + 0.0121 + 1.42 \times 10^{-6} + 1.01 \times 10^{-4} + 0.362 + 0.611 + 1.86 \times 10^{-7}$

$= \quad 1.000$

SUMMARY OF MATERIAL BALANCE IN UNIT 6

INPUT

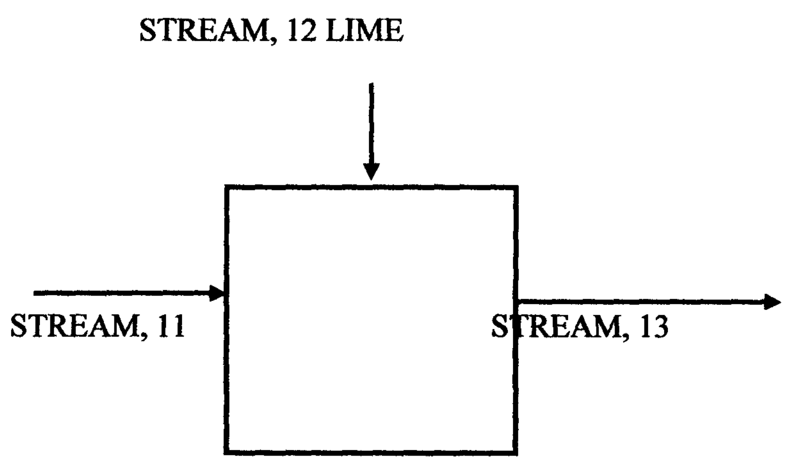
COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	MOLE PERCENT	SCALE UP
Dissolved inorganic salts	531.25	6.106	0.4	758.929
Micro-organism	593.75	29.424	0.1	848.214
Pyrogens	593.75	29.424	2.1	848.214
Suspended particles	347.189	10.853	0.8	495.984
Dissolved organic compounds	531.25	6.801	0.5	758.929
Water	8750	485.572	34.9	12500
Air	23762.5	819.114	58.9	33946.429
Alum	189.375	2.487	0.2	270.536
Ozone	0	0	0	0
Lime	0	0	0	0
TOTAL	**35299.063**	**1389.781**	**100**	**50427.235**

OUTPUT

COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	MOLE PERCENT	SCALE UP
Dissolved inorganic salts	10.625	0.122	9.1×10^{-3}	15.179
Micro-organism	385.938	19.126	1.43	551.340
Pyrogens	326.563	16.191	1.21	466.519
Suspended particles	0.035	0.00109	1.42×10^{-4}	0.050

Dissolved organic compounds	10.625	0.136	1.01×10^{-2}	15.179
Water	8750	485.572	36.2	12500
Air	23762.5	819.11	61.1	33946.426
Alum	0.019	0.00025	1.86×10^{-5}	0.027
Ozone	0	0	0	0
	0	0	0	0
TOTAL	**33246.305**	**1340.258**	**100**	**47494.723**

UNIT 7: ***Liming Tank***



STREAM, 12

It was assumed that the rate of lime added to water was on the ratio of 1:9

Hence, mass flow rate of lime used

$$= \frac{1}{10} \times 8750$$

$$= 875\text{kg/hr}$$

The composition of lime

$$= \frac{875}{875}$$

$$= 1.00$$

The molar flow rate of lime

$$= \frac{875}{57.09}$$

$$= 15.327$$

The molar composition of lime

$$= \frac{15.327}{15.327}$$

$$= 1.00$$

STREAM, 13

Calculating the mass flow rate of stream, 13

Where: Mass flow rate = Percentage of Component x Basis:

For dissolved inorganic salts:

It was assumed that 80% was removed form the water

$$\text{Amount left} = \frac{20}{100} \times 10.625$$

$$= 2.125\text{kg/hr}$$

For micro-organisms:

It was assumed that 10% of micro-organisms were removed form the water in unit 7.

$$\text{Amount left} = 90 \frac{\times}{100} 385.938$$

$$= 347.344\text{kg/hr}$$

For pyrogens:

It was assumed that 10% of pyrogens was also removed from the water:

$$\text{Amount left} = 90 \frac{\times}{100} 326.563$$

$$= 293.907\text{kg/hr}$$

For suspended particles:

It was assumed that 99.99% of suspended particles were removed from the water:

$$\text{Amount left} = 0.01 \times \frac{0.035}{100}$$

$$= 3.5 \times 10^{-6}\ \text{kg/hr}$$

For dissolved organic compounds:

It was assumed that 75% of dissolved organic compounds were removed:

$$\text{Amount left} = 25 \times \frac{10.625}{100}$$

$$= 2.656\text{kg/hr}$$

For alum:

It was assumed that 99.99% of alum was removed from the water

$$\text{Amount left} = 0.01 \times \frac{0.019}{100}$$

$$= 1.9 \times 10^{-6}\text{kg/hr}$$

For water:

The same as in stream, 11 = 8750kg/hr

For air:

The same as in stream, 11 = 23762.5kg/hr

Total mass flow rate for stream, 13

$= 2.125 + 347.344 + 293.907 + 3.5 \times 10^{-6} + 2.626 + 1.9 \times 10^{-6} + 8750 + 23762.5 =$

34033.53kg/hr

Calculating the mass composition for stream, 13

$$\text{Where: Mass composition} = \frac{\text{Mass flow rate of each component}}{\text{Total mass flow rate of stream, 13}}$$

For lime:

$$\frac{875}{34033.53}$$

$$= 0.026$$

For dissolved inorganic salts:

$$\frac{2.125}{34033.53}$$

$= \quad 6.24 \times 10^{-5}$

For micro – organisms:

$$\frac{347.344}{34033.53}$$

$= \quad 0.010$

For pyrogens:

$$\frac{293.907}{34033.53}$$

$= \quad 8.64 \times 10^{-3}$

For suspended particles:

$$\frac{3.5 \times 10^{-6}}{34033.53}$$

$= \quad 1.03 \times 10^{-10}$

For dissolved organic compounds:

$$\frac{2.656}{34033.53}$$

$= \quad 7.80 \times 10^{-5}$

For alum:

$$\frac{1.9 \times 10^{-6}}{34033.53}$$

$= \quad 5.58 \times 10^{-11}$

For water:

$$\frac{8750}{34033.53}$$

$= \quad 0.257$

For air:

$$\frac{23762.5}{34033.53}$$

$= \quad 0.698$

Total mass composition for stream, 13

$= \quad 0.026 + 6.24 \times 10^{-5} + 0.010 + 8.64 \times 10^{-3} + 1.03 \times 10^{-10} +$

$7.80 \times 10^{-5} + 5.58 \times 10^{-11} + 0.257 + 0.698$

$= \quad 1.00$

Calculating the molar flow rate of stream, 13

Where: molar flow rate $= \dfrac{\text{Mass flow rate of stream, 13}}{\text{Molecular weight}}$

For dissolved inorganic salts:

$$\frac{2.125}{87.01}$$

$= \quad 0.024$kgmol/hr

For micro-organisms:

$$\frac{347.344}{20.179}$$

$= \quad 17.213$kgmol/hr

For pyrogens:

$$\frac{293.907}{20.179}$$

$= \quad 14.565$kgmol/hr

For suspended particles:

$$\frac{3.5 \times 10^{-6}}{31.99}$$

$= \quad 1.09 \times 10^{-7}$kgmol/hr

For dissolved organic compounds:

$$\frac{2.656}{78.11}$$

= 0.034kgmol/hr

For alum:

$$\frac{1.9 \times 10^{-6}}{76.14}$$

= 2.4×10^{-8}kgmol/hr

For water:

$$\frac{8750}{18.02}$$

= 485.572kgmol/hr

For air:

$$\frac{23762.5}{29.01}$$

= 819.114kgmol/hr

For lime:

$$\frac{875}{57.09}$$

= 15.327kgmol/hr

Total molar flow rate of stream, 13

= $0.024 + 17.213 + 14.565 + 1.09 \times 10^{-7} + 0.034 + 2.4 \times 10^{-8} + 485.572 + 819.114 + 15.327$

= 1351.849kgmol/hr

Calculating the molar composition of stream, 13

Where: Molar composition = $\dfrac{\text{Molar flow rate of stream, 13}}{\text{Total Molar flow rate of stream, 13}}$

For dissolved inorganic salts:

$$\frac{0.024}{1351.849}$$

= 1.78×10^{-5}

For micro-organisms:

$$\frac{17.213}{1351.849}$$

= 0.013

For pyrogens:

$$\frac{14.565}{1351.849}$$

= 0.011

For suspended particles:

$$\frac{1.09 \times 10^{-7}}{1351.849}$$

= 8.06×10^{-11}

For dissolved organic compound:

$$\frac{0.034}{1351.849}$$

= 2.52×10^{-5}

For alum:

$$\frac{2.4 \times 10^{-8}}{1351.849}$$

= 1.78×10^{-11}

For water:

$$\frac{485.572}{1351.849}$$

= 0.359

For air:

$$\frac{819.114}{1351.849}$$

= 0.606

For lime:

$$\frac{15.327}{1351.849}$$

= 0.011

Total molar composition of stream, 13

= $1.78 \times 10^{-5} + 0.013 + 0.011 + 8.06 \times 10^{-11} + 2.52 \times 10^{-5} +$

$1.78 \times 10^{-11} + 0.359 + 0.606 + 0.011$

= 1.000

SUMMARY OF MATERIAL BALANCE IN UNIT 7

INPUT

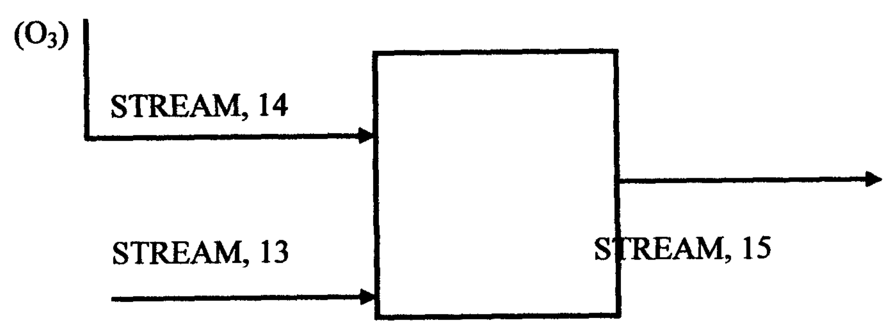
COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	MOLE PERCENT	SCALE UP
Dissolved inorganic salts	10.625	0122	9.1×10^{-3}	15.1785
Micro-organism	385.938	19.126	1.43	551.340
Pyrogens	326.563	16.191	1.21	466.519
Suspended particles	0.035	0.00109	1.42×10^{-4}	0.05
Dissolved organic compounds	10.625	0.136	1.01×10^{-2}	15.1785
Water	8750	485.572	36.2	12500
Air	23762.5	819.11	61.1	33946.426
Alum	0.019	0.00025	1.86×10^{-5}	0.027
Ozone	0	0	0	0

Lime	875	15.327	1.1	1250
TOTAL	**34033.532**	**1351.849**	**100**	**48619.332**

OUTPUT

COMPONENTS	**MASS FLOW RATE (kg/hr)**	**MOLAR FLOW RATE (kgmol/hr)**	**MOLE PERCENT**	**SCALE UP**
Dissolved inorganic salts	2.125	0.024	1.78×10^{-3}	3.036
Micro-organism	347.344	17.213	1.3	496.206
Pyrogens	293.907	14.565	1.1	419.867
Suspended particles	3.5×10^{-6}	1.09×10^{-7}	8.06×10^{-9}	5.0×10^{-6}
Dissolved organic compounds	2.656	0.034	2.52×10^{-3}	3.794
Water	8750	485.572	35.9	12500
Air	23762.5	819.114	60.6	33946.429
Alum	1.9×10^{-6}	2.4×10^{-8}	1.78×10^{-2}	2.71×10^{-6}
Ozone	0	0	0	0
	875	15.327	1.1	1250
TOTAL	**34033.532**	**1351.849**	**100**	**48619.332**

UNIT 8: *Disinfection Tank*



STREAM, 14

It was assumed that the ratio of ozone to that of micro-organisms was 5:1 in quantity

Mass flow rate of ozone in stream, 14

$$5 \times 347.344 = 1736.72 kg/hr$$

Molar flow rate of ozone in stream, 14

$$\frac{1736.72 kg/hr}{48 kg/kgmol}$$

$$= 36.182 kgmol/hr$$

Molar composition of ozone

$$\frac{36.182}{36.182}$$

$$= 1.000$$

Mass composition of ozone

$$\frac{1736.72}{1736.72}$$

$$= 1.000$$

STREAM, 15

Amount of dissolved inorganic salts:

It was assumed that 99.999% of the dissolved inorganic was removed from the water

$$\frac{99.999}{100} \times 2.125$$

$$= 2.1249875$$

$$2.125 - 2.1249875$$

$$= 2.125 \times 10^{-5} kg/hr$$

Amount of micro-organism:

It was assumed that 99.999% of the micro-organisms were removed from the water

$$\frac{99.999}{100} \times 347.344$$

$= \quad 347.3405266$

$347.344 - 347.3405266$

$= \quad 3.473 \times 10^{-3} kg/hr$

Amount of pyrogens:

It was assumed that 99.999% of pyrogens were removed from the water

$$\frac{99.999 \times 293.907}{100}$$

$= \quad 293.9040609$

$293.907 - 293.9040609$

$= \quad 2.93907 \times 10^{-3} kg/hr$

Amount of suspended particles:

It was assumed that 99.999% of suspended particles were removed form the water

$$\frac{99.999 \times 3.5 \times 10^{-6}}{100}$$

$= \quad 3.499965 \times 10^{-6}$

$3.5 \times 10^{-6} - 3.499965 \times 10^{-6}$

$= \quad 3.5 \times 10^{-11} kg/hr$

Amount of dissolved organic compounds:

It was assumed that 99.999% of dissolved organic compound was removed from the water

$$\frac{99.999 \times 2.656}{100}$$

$= \quad 2.65597344$

$2.656 - 2.65597344$

$= \quad 2.656 \times 10^{-5} kg/hr$

Amount of alum:

It was assumed that 99.999% of alum was removed from the water

$$\frac{99.999}{100} \times 1.9 \times 10^{-6}$$

$$= 1.899981 \times 10^{-6}$$

$$1.9 \times 10^{-6} - 1.899981 \times 10^{-6}$$

$$= 1.9 \times 10^{-11} kg/hr$$

Amount of lime:

It was assumed that 99.999% of lime was removed form the water

$$\frac{99.999}{100} \times 875$$

$$= 874.99125$$

$$875 - 874.99125$$

$$= 8.75 \times 10^{-3} kg/hr$$

Amount of air:

It was assumed that 95% of air was removed from the water

$$\frac{95}{100} \times 23762.5$$

$$= 22574.375 kg/hr$$

$$23762.5 - 22574.375 kg/hr$$

$$= 1188.125 kg/hr$$

Total mass flow rate in stream, 15

$$= 2.125 \times 10^{-5} + 3.473 \times 10^{-3} + 2.93907 \times 10^{-3} + 3.5 \times 10^{-11} +$$

$$2.656 \times 10^{-6} + 1.9 \times 10^{-11} + 8.75 \times 10^{-3} + 8750 + 1188.125$$

$$= 9938.14$$

$$\text{Mass composition} = \frac{\text{Mass flow rate}}{\text{Total mass flow rate}}$$

For dissolved inorganic salts:

$$\frac{2.125 \times 10^{-5}}{9938.14}$$

$$= \quad 2.138 \times 10^{-9}$$

For micro – organisms:

$$\frac{3.473 \times 10^{-3}}{9938.14}$$

$$= \quad 3.495 \times 10^{-7}$$

For pyrogens:

$$\frac{2.93907}{9938.14}$$

$$= \quad 2.957 \times 10^{-4}$$

For suspended particles:

$$\frac{3.5 \times 10^{-11}}{9938.14}$$

$$= \quad 3.522 \times 10^{-15}$$

For dissolved organic compounds:

$$\frac{2.656 \times 10^{-5}}{9938.14}$$

$$= \quad 2.673 \times 10^{-9}$$

For water:

$$\frac{8750}{9938.14}$$

$$= \quad 0880$$

For air:

$$\frac{1188.125}{9938.14}$$

$$= \quad 0.1196$$

For alum:

$$\frac{1.9 \times 10^{-11}}{9938.14}$$

$= \quad 1.912 \times 10^{-15}$

For lime:

$$\frac{8.75 \times 10^{-3}}{9938.14}$$

$= \quad 8.804 \times 10^{-7}$

Total mass composition = 1.00

$$\text{Molar flow rate} = \frac{\text{Mass flow rate}}{\text{Molecular weight}} \text{ kgmol/hr}$$

For dissolved inorganic salts:

$$\frac{2.125 \times 10^{-5}}{87.01}$$

$= \quad 2.442 \times 10^{-7}$kgmol/hr

For micro-organisms:

$$\frac{3.473 \times 10^{-3}}{20.179}$$

$= \quad 1.721 \times 10^{-4}$kgmol/hr

For pyrogens:

$$\frac{2.93907}{20.179}$$

$= \quad 0.145$kgmol/hr

For suspended particles:

$$\frac{3.5 \times 10^{-11}}{31.99}$$

$= \quad 1.094 \times 10^{-12}$kgmol/hr

For dissolved organic compounds:

$$\frac{2.656 \times 10^{-5}}{78.11}$$

$= \quad 3.4 \times 10^{-7}$kgmol/hr

For water:

$$\frac{8750}{18.02}$$

$= \quad 485.572$kgmol/hr

For air:

$$\frac{1188.125}{29.01}$$

$= \quad 40.96$kgmol/hr

For alum:

$$\frac{1.9 \times 10^{-11}}{76.14}$$

$= \quad 2.495 \times 10^{-13}$kgmol/hr

For lime:

$$\frac{8.75 \times 10^{-3}}{59.02}$$

$= \quad 1.483 \times 10^{-4}$kgmol/hr

Total molar flow rate

$= \quad 2.442 \times 10^{-7} + 1.721 \times 10^{-4} + 0.145 + 1.09 \times 10^{-12} + 3.4 \times 10^{-7} + 485.572 +$

$40.96 + 2.495 \times 10^{-3} + 1.483 \times 10^{-4}$

$= \quad 526.676$kgmol/hr

$$\text{Molar composition} = \frac{\text{Molar flow rate}}{\text{Total molar flow rate}}$$

For dissolved inorganic salts:

$$\frac{2.442 \times 10^{-7}}{526.676}$$

$= \quad 4.637 \times 10^{-10}$

For micro-organisms:

$$\frac{1.721 \times 10^{-4}}{526.676}$$

$= \quad 3.268 \times 10^{-8}$

For pyrogens:

$$\frac{0.146}{526.676}$$

$= \quad 2.772 \times 10^{-4}$

For suspended particles:

$$\frac{1.094 \times 10^{-12}}{526.676}$$

$= \quad 2.077 \times 10^{-15}$

For dissolved organic compounds:

$$\frac{3.4 \times 10^{-7}}{526.676}$$

$= \quad 6.456 \times 10^{-10}$

For water:

$$\frac{485.572}{526.676}$$

$= \quad 0.922$

For air:

$$\frac{40.96}{526.676}$$

$= \quad 0.078$

For alum:

$$\frac{2.495 \times 10^{-3}}{526.676}$$

$= \quad 4.74 \times 10^{-6}$

For lime:

$$\frac{1.483 \times 10^{-4}}{526.676}$$

$= \quad 2.816 \times 10^{-7}$

Total molar composition = 1.00

SUMMARY OF MATERIAL BALANCE IN UNIT 8

INPUT

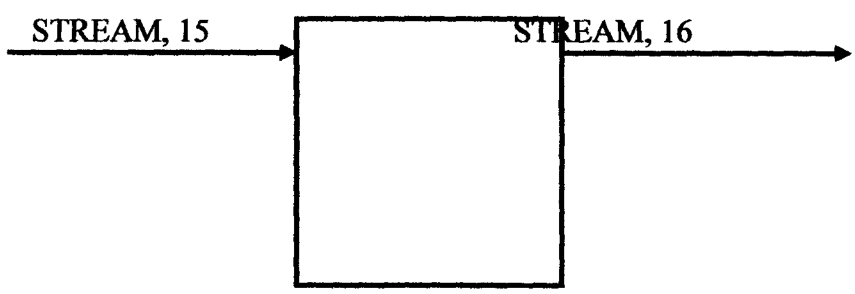
COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	MOLE PERCENT	SCALE UP
Dissolved inorganic salts	2.125	0.024	1.78×10^{-3}	3.036
Micro-organism	347.344	17.213	1.3	496.206
Pyrogens	293.907	14.565	1.1	419.867
Suspended particles	3.5×10^{-6}	1.09×10^{-7}	8.06×10^{-9}	5.0×10^{-6}
Dissolved organic compounds	2.656	0.034	2.52×10^{-3}	3.794
Water	8750	485.572	35.9	12500
Air	23762.5	819.114	60.6	33946.429
Alum	1.9×10^{-6}	2.4×10^{-8}	1.78×10^{-2}	2.71×10^{-6}
Ozone	1736.72	36.182	5.103×10^{-3}	2481.03
Lime	875	15.327	1.1	1250
TOTAL	**34035268.72**	**1388.031**	**100**	**48619.332**

OUTPUT

COMPONENTS	MASS FLOW RATE (kg/hr)	MOLAR FLOW RATE (kgmol/hr)	MOLE PERCENT	SCALE UP
Dissolved inorganic salts	2.125×10^{-5}	2.442×10^{-7}	4.673×10^{-8}	3.036
Micro-organism	3.473×10^{-3}	1.721×10^{-4}	3.268×10^{-6}	496.206
Pyrogens	2.939×10^{-3}	1.045	2.772×10^{-2}	419.867
Suspended particles	3.5×10^{-11}	1.094×10^{-12}	2.077×10^{-13}	5.0×10^{-6}
Dissolved organic compounds	2.656×10^{-5}	3.4×10^{-7}	6.456×10^{-8}	3.794
Water	8750	485.572	92.2	12500
Air	118.125	40.96	7.8	33946.429
Alum	1.9×10^{-11}	2.495×10^{-13}	4.74×10^{-4}	2.71×10^{-6}
Ozone	0	0	0	0
	8.75×10^{-3}	1.484×10^{-4}	2.816×10^{-5}	1250
TOTAL	**9938.140**	**526.677**	**100**	**48619.332**

UNIT 9 ***Final Storage Tank***

This is where the purified water is stored before been pumped for distribution.



STREAM, 16

Amount of dissolved inorganic salts = as in stream, 15

Amount of micro-organisms = as in stream, 15

Amount of pyrogens = as in stream, 15

Amount of suspended particles	= as in stream, 15
Amount of dissolved organic compounds	= as in stream, 15
Amount of water	= as in stream, 15
Amount of air	= as in stream, 15
Amount of alum	= as in stream, 15
Amount of lime	= as in stream, 15
Total mass flow rate	= as in stream, 15

Mass composition for stream, 16

Amount of dissolved inorganic salts	= as in stream, 15
Amount of micro-organisms	= as in stream, 15
Amount of pyrogens	= as in stream, 15
Amount of suspended particles	= as in stream, 15
Amount of dissolved organic compounds	= as in stream, 15
Amount of water	= as in stream, 15
Amount of air	= as in stream, 15
Amount of alum	= as in stream, 15
Amount of lime	= as in stream, 15
Total mass flow rate	= as in stream, 15

Molar flow rate for stream, 16

Amount of dissolved inorganic salts	= as in stream, 15
Amount of micro-organisms	= as in stream, 15
Amount of pyrogens	= as in stream, 15
Amount of suspended particles	= as in stream, 15
Amount of dissolved organic compounds	= as in stream, 15
Amount of water	= as in stream, 15
Amount of air	= as in stream, 15
Amount of alum	= as in stream, 15
Amount of lime	= as in stream, 15
Total mass flow rate	= as in stream, 15

Molar composition for stream, 16

Amount of dissolved inorganic salts	= as in stream, 15
Amount of micro-organisms	= as in stream, 15
Amount of pyrogens	= as in stream, 15
Amount of suspended particles	= as in stream, 15
Amount of dissolved organic compounds	= as in stream, 15
Amount of water	= as in stream, 15
Amount of air	= as in stream, 15
Amount of alum	= as in stream, 15
Amount of lime	= as in stream, 15
Total mass flow rate	= as in stream, 15

There is no Energy Balance (i.e. CHAPTER FOUR) since the temperature and pressure are kept constant

CHAPTER FIVE

5.1 PLANT LAYOUT

Domestic Waste water treatment plant layout the economic construction and operation of a process depend on how well the domestic waste water treatment plant equipment specified on the process flow sheet and laid out the principal factors to be considered are:

a) Economic consideration: Construction and operational cost

b) The process equipment

c) Convenience of operation

d) Convenience of maintenance

e) Fure expansion

f) Modular expansion.

Cost:

The cost of construction can be minimized by adopting a layout that gives shortest run of connecting pipes between equipment, and adopting the least amount of structural steel work.

Process Requirement:

All the required equipment has to be placed properly within process; even the installation of auxiliaries should be done in such a way that it will occupy the least space.

Operation

Equipment that needs to have frequent operation should be located convenient to the control room. Valves, sample points, and instrument should be located at convenient position and height sufficient working space and head room must be provided to allow easy access to equipment.

Maintenance

Equipment that requires dismantling for maintenance, such as compressors and large pumps should be placed under cover.

CHAPTER SIX

6.0 EQUIPMENT DESIGN

UNIT 6

EQUIPMENT SPECIFICATION

This given the size of each equipment that is to be determined using the quantity of species into the equipment. The choice of material for construction as well as the type of specific equipment is considered.

DESIGN OF A FILTRATION TANK

The total mass flow rate of stream 9 (F) = 35299.063kg/hr

The average density of component present in water is considered to be the density of water (Dvag) = 1000kg/m^3

Volumetric flow rate in filtration tank Vp

$$Vp = \frac{35299.063}{1000}$$

$$Vp = 35.299m^3$$

Allowing for 15% safety allowance

$$\frac{15}{100} \times 35.299$$

$$= 5.295m^3$$

$$V\ total = (5.295 + 35.299)m^3$$

$$= 40.594m^3$$

Considering a cylindrical shape

Surface area of a close cylinder (A)

$$A = \pi DL + \pi \frac{D^2}{2}$$

D = Vessel diameter

L = Vessel height

The objective function given as:

$$\pi DL = \pi DL + \pi D^2/2$$

$$DL = DL + \pi \frac{D^2}{2}$$

$$F(DL) = DL + \pi \frac{D^2}{2}$$

Volume of a cylinder

$$V = \pi r^2 h = \pi \frac{D^2 L}{2}$$

$$L = \pi \frac{4V}{D^2}$$

Substitute the value of L into the objective function

$$F(DL) = DL + \frac{D^2}{2}$$

$$F(D) = D \times \pi \frac{4V}{D^2} + \frac{D^2}{2}$$

$$F(D) = \pi \frac{4V}{D} + \frac{D^2}{2}$$

Differentiating with respect to D and equating to zero

$$\pi \frac{4V}{D^2} + D = 0$$

$$D = \sqrt[3]{\frac{4V}{\pi}}$$

$$D \text{ filtration tank} = \sqrt[3]{\frac{4 \times 40.594}{\pi}}$$

$$D \text{ mixer} = 3.72m$$

From literature, the ratio of tank diameter to height of a cylinder is given by:

$$\frac{D}{H} = 0.83$$

$$H = \frac{D}{0.83}$$

$$H = \frac{3.725}{0.83}$$

$$H = 4.488m$$

CHAPTER SEVEN

7.0 EQUIPMENT OPTIMIZATION

7.1 MATERIAL SELECTION

The characteristic to be considered when selecting a material for construction are:

1. Mechanical properties such as tensile strength, stiffness, toughness, elastic modulus, hardness, fatigue, resistance and creep resistance.

   - Tensile Strength: is a measure of the basic strength of a material. It is the maximum stress that the material will withstand, as measured by standard tensile test.

     The design stress for a material is based on tensile strength and the tensile strength for monel steel used for this design is $650N/mm^2$

   - Stiffness: is the ability to resist bending and buckling. It is a function of elastic modulus of the material and shape of cross section of member. The value of modulus of elasticity used in the design is $170KN/mm^2$.

   - Hardness: The surface hardness, as measured in a standard test is an indication of a material's ability to resist wear. This will be an important property. In design of wastewater treatment plant as it contains liquid containing suspended solids and the value used for this design is (120 – 250) Brinell.

   - Creep: is the gradual extension of material under a steady tensile stress, over a prolonged period of time. It is usually and it is only important at a high operating temperature.

   - Fatigue: is likely to occur in equipment subjected to cyclic loading; for example, pump used in waste water treatment plant hence to solve this problem is solved by selecting material that is to crack propagation in the wastewater treatment plant.

CORROSION RESISTANCE

The condition that cause corrosion can arise in a variety of ways. Corrosion is classified into the following categories:

1. General wastage corrosion or uniform corrosion
2. Galvanic corrosion
3. Pitting – localized attack
4. Intergranular corrosion
5. Stress corrosion.

What is considered as an acceptable rate of corrosion will on the material cost, duty as regards to safety and economic life of the plant. The corrosion rate will depend on temperature and concentration of the corrosive fluid an increase in temperature usually result in an increased rate of corrosion. In waste water treatment plant, there is no increase in temperature of water.

In this design, Monel, a classic nickel-copper alloy with the metal in the ratio 2:1 is probably after stainless steels, is the most commonly used alloy for chemical plant. It is easily worked and has good mechanical properties up to 500^0C. it is more expensive than stainless steel but it is not susceptible to stress-corrosion cracking. Monel has good resistance to dilute mineral acid and can be used in reducing condition. It is used for equipment handling such as alkalies, organic acid salts and water treatment equipment

CHAPTER EIGHT

8.0 HAZARD CONTROL AND DESIGN SAFETY

Before any project can be said to be practically feasible, it must conform with safety rules. This poses danger to environment and human health. One of the objectives of this design is to incorporate all safety devices in appropriate locations. The possible top event in wastewater treatment plant are leakages in pipe and storage tank loss prevention techniques of the design are:

i) Identification of major hazards.

ii) Assessment of hazards

iii) Control of hazards by appropriate means

iv) Control of process (i.e. prevention of hazardous conditions.

v) Limitation of losses during accident

8.1 CONTROL MEASURES

Experimental testing is usually required for applications involving process control, cost control, historical data or requirement of regulatory agencies. Sampling lines are brought directly to the analytical laboratory where the samples are to be analyzed.

A sampling sunk in the laboratory with sample from various parts of the process running continuously for immediate sampling access. Regular analysis of process stream, intermediate treated wastewater and sludge is carried out in order to assured or obtain a high quality product.

CHAPTER NINE

9.0 INSTRUMENTATION CONTROL

The main aim of any control system is to ensure smooth operation of keeping tight control on the variable of operation. In defining the behaviour of a controller, the main parameter to be examined to determine the system stability or not is the character of the loop or system.

9.1 Controllers

Fundamentally, the function of the controller is to compare signal from the transmitter with set point signal and if there is indeed a different or error and if error exist it send a signal corresponding to this signal to a control valve for appropriate correction.

The primary objectives of the design when specifying instrumentation and control are:

1. Safety plant operation:
   a) To keep the process variables within safe operating limits.
   b) To detect dangerous situation as they develop and to provide alarms and automatic shutdown system.
   c) To provide interlocks and alarms to prevent dangerous operating procedures.
2. Cost: To operate at the lowest production cost, commensurate with other objectives in a typical chemical process plant, these objectives are achieved by combination of automatic control manual monitoring and laboratory analysis.
3. Access: The site will be selected such that in all, weather that is dry and rainy season, road is available or can be provided for access to the plant. Available rail sidings will be utilized and it practical consideration should be given during layout of buildings, roads, fencing and appurtenances to winter conditions especially of snow drifting and removal.
4. Space requirement: Sufficient space must be allocated not only for suitable arrangement of the units and associated plant piping but also to accommodate future

expansion includes the provision of increased capacity for existing processes and the addition of new types of units known to be required for upgrading.

5. State regulation: Most states requires a minimum of secondary treatment for all domestic waste water in critical areas various types of advances wastewater treatment processes for the removal of phosphorus and Nitrogen will be imposed by the state regulatory agencies to protect their water resources.

6. Local Regulations: In general, local government do not have specific requirement for wastewater treatment facilities parse. Design of wastewater must conform to applicable zoning, occupational and health administration.

The procedure used when drawing up preliminary control and instrument diagram are:

1. Identify and draw in those area control loops that are obviously needed for steady plant operation such as:
    a) Level controls
    b) Flow controls
    c) Pressure control
    d) Temperature control
2. Identifying the key process variables that need to be collected to achieve the specific product quality, include control loop using direct measurement of the control variable where possible, if not practicable, select a suitable dependent variable.
3. Identify and include those additional control loops required for safe operation.
4. Decide and show the auxiliary instruments needed for the monitoring of plant operation by operators and for trouble shooting and plant development.
5. Decide on the location of sample points and need for recorders and location of readout points, local or control room.

INSTRUMENTATION

Instruments are provided to monitor the key process variables during plant operation. They may be incorporated in automatic control loops, or used for the manual monitoring of the process operation. Instrument monitoring critical process variables will be fitted with automatic alarms to alert the operator to critical and hazardous situations.

9.3 CONTROL SYSTEM

The two basic control systems needed in storage tank are the flow control and level control. Flow control is needed to maintain a constant output from the storage tank or other equipment.

9.4 LEVEL CONTROL

In any equipment where an interface exists between two phases e.g. liquid-vapour some means of maintaining the interface at the required level must be provided. This may be incorporated in the design of the equipment, as usually done for decanters or by automatic control of flow from the equipment.

9.5 FLOW CONTROL

Flow control is usually associated with inventory in a storage tank or other equipment. A reservoir is put in place to take up the changes in flow rate. A by-pass control is also used to provide flow control on a compressor or pump running at a fixed speed and supplying a near constant volume output.

9.6 SOLID INVENTORY CONTROL

Proper and effective control of solid inventory within each unit processes of a domestic waste water treatment plant is the most important techniques that can be used by plant operating personnel to control the process. Control of solid inventory has a direct effect on plant performance process capacity, and system operating cost. It is essential first step in optimizing the domestic waste water treatment plant. An effective solid inventory control can enhance the following:

a. It allows additional capacity to be realized in individual unit process.

b. Potentially allow nitrification to be achieved without the construction of additional biological treatment capacity.

c. It reduces the energy use and cost associated with aeration.

d. Reduces biosolids management cost by reducing the quantity of solid requiring processing.

e. Result in an overall improvement in effluent quality.

f. Improve the settling characteristic of biomass.

g. Improve ease and stability of plant operations.

A sludge accountability analysis compares the amount of solids leaving a domestic waste water treatment plant as biosolids in the plant effluent, and through other routes with the theoretical amount of solids that should have been produced by the plant without proper and effective solid inventory control optimization of the performance and capacity of individual unit process that comprises the waste water plant cannot be achieved.

Despite the importance of effective solid inventory control to realizing optimum performance and capacity, other factors such as temperature, wet weather, pH, dissolved oxygen concentration, and chemical dosages.

CHAPTER TEN

10.0 ENVIRONMENTAL ACCEPTABILITY

10.1 IDENTIFICATION OF POSSIBLE POLLUTANTS

The suitability of any process plant depends on its impact to life, properties and environment. The possible pollutants in domestic waste water treatment plant are:

a. Sludge from the process

b. Odour

c. Air pollution

d. Particulate solids

e. Acidic gases.

10.1.1 POLLUTION TREATMENT

For a process to be suitable to the environment there is need for these pollutants to be controlled of the pollutant in domestic waste water treatment plant. The treatment methods are:

a. Sludge Drying:

Sludge drying is a unit operation that involves reducing water content through vaporization of water to air. The purpose of heat drying of the sludge is to remove the moisture from wet sludge, it can then be processed into fertilizer.

b. Air pollution and odour control.

The two most important control measures are associated with heat drying of sludge. To achieve destruction of odour(s), the exhaust gases must reach 730^0C. And at low temperature, partial oxidation of odour processing compounds may occur resulting in an increase in the intensity of odour produced.

c. Waste Disposal:

The various waste material produced by individuals plant may be classified as solids particles, gaseous substances. The disposal of solids wastes is related to land pollution while gaseous and solid wastes contribute to air and water pollution. Some of the steps that can be taken in dealing with waste are:

i) Recovery of waste product: This involves considering the possibilities of recovering parts of the waste products and reused before discircle.

ii) Regulation of waste flow fit dilution: This involves storing the waste before being released or incinerated in a more favorable period, so as to reduce the effect of pollution and to maintain acceptable pollution control.

iii) Waste treatment: this makes use of alternative source of disposal so that full advantage is taken.

iv) Waste treatment: this is the final method used in a situation where non of the earlier mentioned methods are not considered. It involves chemical and physical treatment of the waste, depending on the types of waste involved and amount of removal necessary to be taken.

d. Waste Management

The management of waste occurs at different stages during the process of treating the raw water. The first occurs with purification and removal of larger object through the coarse screener to avoid damage of the equipment and the last occurs at the disinfectant unit where ozone as disinfectant use removed to remove odour, colour, micro-organism and other unwanted constituents.

CHAPTER ELEVEN

11.0 START UP AND SHUTDOWN PROCEDURE

Start up time can be defined as the time span between end of construction and the beginning of normal operations; startup and shutdown procedures must proceed safely and be flexible enough to be carried out in various ways. In other words, shutdown and start up procedures of the plant is such that it can be easily and safely operated, such that operating limit will not be exceeded.

11.1 START UP PROCEDURE FOR DOMESTIC WASTE WATER TREATMENT PLANT

i. The pumping machine is operated to pump the raw Domestic waste water from the source to the storage tanks ready for subsequent treatment.

ii. From the storage tank the water is passed to the coarse screened where of the suspended particles is removed, and the domestic waste water is channel to the aeration unit.

iii. In the aeration tank, the waste water is properly aerated by air to remove odour the water is channel to another tank called rapid mixing and coagulation tank.

iv. In the rapid mixing and coagulation tank alum is added to water in the ratio of 3:1 to achieve desired mixing. And the resulting mixture is channel to another tank known as Sedimentation tank where the clumps of particles are removed and channeled to another tank.

v. After Sedimentation, the next operation is filtration most of the particles are filtered off.

vi. The next unit is the liming tank, lime is added in the ratio 1:9 units to reduce the water hardness and then the water is channeled into disinfectant.

vii. In the disinfectant units

CHAPTER TWELVE

12.0 SITE CONSIDERATION

The major factor in the selection of suitable site includes the following:

1. **Access:** the site will be selected such that in all weather that is dry and raining season, road is available or can be provided for access to the plant. Available rail sidings will be utilized and it practical consideration should be given during layout of buildings, roads, fencing and appurtenances to winter condition.

2. **Space Requirement:** Sufficient space must be allocated not only for suitable arrangement of the units and associated plant piping but also to accommodate future expansion including the provision of increased capacity for existing processes and the addition of new types of units known to be required for upgrading.

3. **State Regulation:** Most states require a minimum of secondary treatment for all domestic waste water in critical areas. Various types of advanced waste water treatment processes for the removal of phosphorus and Nitrogen will be imposed by the state regulatory agencies to protect their water resources.

4. **Local Regulation:** In general, local government do not have specified requirement for waste water treatment facilities parse. Design of wastewater must conform to applicable zoning, occupational and health administration.

12.1 JUSTIFICATION OF THE SELECTED SITES TRANSPORTATION

Good means of transporting the raw water will ensure effective process. Pipe line, and tankers are used and this aids effective transportation of raw water.

Access

Availability of the raw material in domestic water treatment plant is an important consideration. Sitting the plant in an estate, makes raw water available for treatment.

Availability of Labour

Area selection for location must be region with youth that are skilled and unskilled that is to say that all kind of labour must be available.

Utilities

The major raw materials used in the plant is domestic waste water hence plant should be sited where there will be frequent supply of domestic waste water such as an estate and not where industries are located.

Climate

The present of adverse weather condition such as high temperature or wind loads the plant should be sited in such area such as the northern parts of the country for market forces.

12.2 FACILITY CONSIDERATION IN SITE LOCATION

The major factor in the selection of suitable facility includes the following:

1. Availability of suitable discharge point and maintenance of reasonable distance from living quarters.
2. Working areas of proposed facilities as reflected by the master plan. The siting criteria for the water pollution control facility should consider state well head protection requirement for drinking water sources. In absence of state requirement, a minimum distance of 500 feet should be maintained between a drinking water source and any proposed water pollution control facility.

CHAPTER THIRTEEN

ECONOMIC ANALYSIS

13.0 Costing of Equipment

The cost are based on cost data of 2007 which were available in Dollars

Exchange rate ER

$120\text{Naira} = 1\text{Dollar}$

13.0.1 Purchased Cost Data:

The purchased cost data for process equipments is given below as:

13.0.2 Purchased Cost data for Pressure Vessels, Reactors and Columns

$$PC = \frac{M\_S}{280} \times \left(101.9 \cdot D^{1.066} \cdot H^{0.802} \cdot F_C\right)$$

Where

D = Diameter of the column (ft)

H = Height of the column (ft)

M_S = Marshall and Smith Index

$$F_C = 1.00 + F_m + F_p$$

F_m		F_p	
CS	1.00	<50 psia	1.00
SS	3.67	200	1.15
Monel	6.34	400	1.35
Titanium	7.89	600	1.60

Purchased Cost of the Raw Water Storage Tank:

Purchase cost PC is given by the relation below

Marshal and Swift index is:

$$M\Omega S = 11.0$$

The material of construction selected is Monnel steel:

$$F_m = 6.34$$

$$F_p = 1.35$$

$F_c = 1 + F_m + F_p$

$F_c = 8.69$

Diameter of the tank:

$D_{Raw\_water\_tank} := 2.745m$

Height of the tank:

$H_{Raw\_water\_tank} := 3.307m$

$$PC_{Raw\_water\_tank} = \frac{M\Omega S}{280}\left(101.913 \cdot D_{Raw\_water\_tank}^{1.066} \cdot H_{Raw\_water\_tank}^{0.802} \cdot F_{c}\right.$$

$PC_{Raw\_water\_tank} = 31,969.63$ Naira

Purchased Cost of the coarse screener

Purchase cost PC is given by the relation below

Marshal and Swift index is:

$M\Omega S = 11.0$

The material of construction selected is Monnel steel:

$F_m = 6.34$

$F_p = 1.35$

$F_c = 1 + F_m + F_p$

$F_c = 8.69$

Diameter of the tank:

$D_{-Coarse\ -screener} := 2.745m$

Height of the tank:

$H_{Coarse\ -Screener} := 3.307m$

$$PC_{Coarse\text{-}Screener} = \frac{M\Omega S}{280}\left(101.913 \cdot D_{Coarse\text{-}screener}{}^{1.066} \cdot H_{Coarse\text{-}Screener}{}^{0.802} \cdot F_{c}\right.$$

$PC_{Coarse\text{-}Screener}$ = 31,969.63 Naira

Purchased Cost of aeration

Purchase cost PC is given by the relation below

Marshal and Swift index is:

$M\Omega S = 11.0$

The material of construction selected is Monnel steel:

$F_m = 6.34$

$F_p = 1.35$

$F_c = 1 + F_m + F_p$

$F_c = 8.69$

Diameter of the tank:

$D_{\text{-}Aeration} := 2.745m$

Height of the tank:

$H_{\text{-}Aeration} := 3.307m$

$$PC_{Aeration} = \frac{M\Omega S}{280}\left(101.913 \cdot D_{Aeration}{}^{1.066} \cdot H_{Aeration}{}^{0.802} \cdot F_{c}\right.$$

$PC_{Aeration}$ = 45,529.08 Naira

Purchased Cost of the Mixer:

Purchase cost PC is given by the relation below

Marshal and Swift index is:

$M\Omega S = 11.0$

The material of construction selected is Monnel steel:

$F_m = 6.34$

$F_p = 1.35$

$F_c = 1 + F_m + F_p$

$F_c = 8.69$

Diameter of the tank:

$D_{mixer} = 3.961m$

Height of the tank:

$H_{mixer} = 4.772m$

$$PC_{mixer} = \frac{M\Omega S}{280}\left(101.9 \cdot D_{mixer}{}^{1.066} \cdot H_{mixer}{}^{0.802} \cdot F_c\right) \times ER$$

$PC_{mixer} = 63{,}422.44$ Naira

Purchased Cost of the Sedimentation Tank:

Purchase cost PC is given by the relation below

Marshal and Swift index is:

$M\Omega S = 11.0$

The material of construction selected is Monnel steel:

$F_m = 6.34$

$F_p = 1.35$

$F_c = 1 + F_m + F_p$

$F_c = 8.69$

Diameter of the tank:

$D_{sedimentation} = 3.961m$

Height of the tank:

$H_{sedimentation} = 4.772m$

$$PC_{sedimentation} = \frac{M\Omega S}{280}\left(101.9 \cdot D_{sedimentation}{}^{1.066} \cdot H_{sedimentation}{}^{0.802} \cdot F_c\right) \times ER$$

$PC_{sedimentation} = 63,422.44$ Naira

Purchased Cost of the Filter Tank

Purchase cost PC is given by the relation below

Marshal and Swift index is:

$M\Omega S := 11.0$

The material of construction selected is Monnel steel:

$F_m = 6.34$

$F_p = 1.35$

$F_c = 1 + F_m + F_p$

$F_c = 8.69$

Diameter of the tank:

$D_{filter\_tank} = 3.72m$

Height of the tank:

$H_{filter\_tank} = 1.048m$

$$PC_{filter\_tank} = \frac{M\Omega S}{280}\left(101.9 \cdot D_{filter\_tank}{}^{1.066} \cdot H_{filter\_tank}{}^{0.802} \cdot F_c\right) \cdot ER$$

$PC_{filter\_tank} = 56,469.04$ Naira

Purchased Cost of the Liming Tank

Purchase cost PC is given by the relation below

Marshal and Swift index is:

$$M\Omega S = 11.0$$

The material of construction selected is Monnel steel:

$$F_m = 6.34$$

$$F_p = 1.35$$

$$F_c = 1 + F_m + F_p$$

$$F_c = 8.69$$

Diameter of the tank:

$$D_{lime} = 3.837m$$

Height of the tank:

$$H_{lime} = 4.623m$$

$$PC_{lime} = \frac{M\Omega S}{280}\left(101.9 \cdot D_{lime}^{1.066} \cdot H_{lime}^{0.802} \cdot F_c\right) \cdot ER$$

$$PC_{lime} = 59{,}768.104 \quad \text{Naira}$$

Purchased Cost of the Disinfection Tank:

Purchase cost PC is given by the relation below

Marshal and Swift index is:

$$M\Omega S = 11.0$$

The material of construction selected is Monnel steel:

$$F_m = 6.34$$

$$F_p = 1.35$$

$F_c = 1 + F_m + F_p$

$F_c = 8.69$

Diameter of the tank:

$D_{Disinfect} = 3.898m$

Height of the tank:

$H_{Disinfect} = 4.696$

$$PC_{Disinfect} = \frac{M\Omega S}{280}\left(101.9 \cdot D_{Disinfect}^{1.066} \cdot H_{Disinfect}^{0.802} \cdot F_c\right) \cdot ER$$

$PC_{Disinfect} = 61{,}550.28$ Naira

Purchased Cost of the Storage Tank

Purchase cost PC is given by the relation below

Marshal and Swift index is:

$M\Omega S = 11.0$

The material of construction selected is Monnel steel:

$F_m = 6.34$

$F_p = 1.35$

$F_c = 1 + F_m + F_p$

$F_c = 8.69$

Diameter of the tank:

$D_{storage\_tank} = 2.571m$

Height of the tank:

$H_{storage\_tank} = 3.096m$

$$PC_{storage\_tank} = \frac{M\Omega S}{280}\left(101.9 \cdot D_{storage\_tank}^{1.066} \cdot H_{storage\_tank}^{0.802} \cdot F_c\right) \cdot ER$$

$PC_{storage\_tank}$ = 28,278.50 Naira

Total Purchased Cost of equipments

$$PC_{equip} = PC_{Raw\_water\_tank} + PC_{mixer} + PC_{sedimentation} + PC_{filter\_tank} \cdots + PC_{lime} + PC_{Disinfect} + PC_{storage\_tank}$$

PC_{equip} = 442,380.146 Naira

13.1.0 ECONOMIC ESTIMATION OF TOTAL CAPITAL INVESTIMENT

The total capital investment can be given by

$$T_{inv} = TFC + WC + TLC$$

Where, TFC =total fixed cost

WC=working capital

TLC=total land cost

13.1.1 Total fixed cost

The factorial method can be used with the relationship below

Total physical plant cost (Direct cost)

$$PPC = 6 \times PC_{equip}$$

PPC = 2,654,280.876Naira

Fixed Capital cost (Indirect cost)

$$TFC = 3 \times PPC$$

TFC = 1,327,140.438 Naira

Working capital

$$WC = 2 \times TFC$$

WC = 884,760.292Naira

Total land cost

$$TLC = 0.02 \times TFC$$

$$TLC = 26542.80876 \text{ Naira}$$

$$T_{inv} = TLC + WC + TFC$$

$$T_{inv} = 2{,}238{,}443.5 \text{ Naira}$$

13.1.2 Operating cost

This is divided into Fixed and Variable operating cost

Let the plant life be 15yrs

$$n = 15yr$$

13.2.0 Fixed operating cost

Direct labour cost

$$Lb_c = 0.06 \times TFC$$

$$Lb_c = 79628.4263 \text{ Naira}$$

Plant maintenance and repairs

$$M_c = 0.08 \times TFC$$

$$M_c = 106{,}171.235 \text{ Naira}$$

Laboratory cost

$$Lab_c = 0.2 \times Lb_c$$

$$Lab_c = 15{,}925.6853 \text{ Naira}$$

Supervision

$$S_c = 0.2 \times Lb_c$$

$$S_c = 15{,}925.6853 \text{ Naira}$$

Plant overhead cost

$$POH_c = 0.5 \times Lb_c$$

$$POH_c = 39{,}814.213 \text{ Naira}$$

GENERAL EXPENSES

i. **administrative**

$$ADM_c = 0.25 \times Lb_c$$

$$ADM_c = 19{,}907.106 \text{ Naira}$$

ii. Research and development

$$RAD_c = 0.015 \times TFC$$

$$RAD_c = 19{,}907.106 \text{ Naira}$$

Total fixed operating cost

$$TFO_c = RAD_c + ADM_c + POH_c + Lab_c + M_c + Lb_c + S_c$$

$$TFO_c = 297{,}279.457 \text{ Naira}$$

Annual fixed operating cost

$$TFO_{annum} = \frac{TFO_c}{n}$$

$$TFO_{annum} = 19{,}818.6305 \ \frac{\text{Naira}}{\text{yr}}$$

13.2.2 Variable operating cost

Cost of raw materials CRMc

$$Alum_{\_cost} = \left[(5.625)\cdot\frac{kg}{hr}\right] \times \frac{0.35\ ER}{kg}$$

$$Alum_{\_cost} = 236.25\ \frac{Naira}{hr}$$

$$Ozone(O3)_{cost} = \left(2.895\cdot\frac{kg}{hr}\right) \times \frac{20\,ER}{kg}$$

$$Ozone(O3)_{cost} = 6{,}948\ \frac{Naira}{hr}$$

$$Raw\_water_{cost} = \left(18.75\frac{kg}{hr}\right) \times \frac{0.25\ ER}{kg}$$

$$Raw\_water_{cost} = 562.5\ \frac{Naira}{hr}$$

$$CRM_c = Alum_{\_cost} + Ozone(O3)_{cost} + Raw\_water_{cost}$$

$$CRM_c = 7746.75\ \frac{Naira}{hr}$$

$$ACRM = \left(CRM_c\right) \times \left(8322\ \frac{hr}{yr}\right)$$

$$ACRM = 64{,}468{,}454\ \frac{Naira}{yr}$$

Miscellaneous

$$Ms_c = 0.05 \times Lb_c$$

$$Ms_c = 3{,}981.4213\ Naira$$

Utilities cost

$$Ut_c = 0.02 \times Lb_c$$

$$Ut_c = 1592.57 \text{ Naira}$$

Packaging

$$PA_c = 0.001 \times Lb_c \cdot Naira$$

$$ACRM := ACRM \cdot yr$$

$$PA_c = 79.628 \text{ Naira}$$

Total variable operating cost

$$TVO_c = PA_c + Ms_c + ACRM + Ut_c$$

$$TVO_c = 6{,}448{,}915.6 \text{ Naira}$$

Annual variable operating cost

$$TVO_{annum} = \frac{TVO_c}{n}$$

$$TVO_{annum} = 429{,}927.71 \frac{Naira}{yr}$$

Total annual operating cost

$$AOC_c = TFO_{annum} + TVO_{annum}$$

$$AOC_c = 449{,}746.34 \frac{Naira}{yr}$$

13.2.3 Profit analysis

Annual sales of Product or Revenue (A_{sp})

Sales of Purified Water

$$Water_{sales} = \left(13.572 \cdot \frac{kg}{hr}\right) \times \frac{0.55 \cdot ER}{kg}$$

$$Water_{sales} = 895.75 \frac{Naira}{hr}$$

Total Sales

$$Tot_{sales} = Water_{sales}$$

$$Tot_{sales} = 895.75 \frac{Naira}{hr}$$

Annual sales of product

$$As_p = Tot_{sales} \times \left(7992 \frac{hr}{yr}\right)$$

$$As_p = 7{,}454{,}431.5 \frac{Naira}{yr}$$

Profit before tax (PBT)

$$PBT = As_p - AOC_c$$

$$PBT = 7{,}004{,}685.2 \frac{Naira}{yr}$$

Annual depreciation (Depr)

Let S = Salvage Value after n years of the plant. Assume plant life of 15 yrs

Then

$$S = 1 \cdot 10^3 Naira$$

$$n = 15$$

$$Depr = \frac{T_{inv} - S}{n}$$

$$Depr := Depr \cdot \frac{Naira}{yr}$$

$$Depr = 149{,}162.9 \frac{Naira}{yr}$$

Tax payable (TP)

Assume tax ratio of 20% and depreciation is tax allowable, hence

$$Tax\_ratio = 0.2$$

$$TP = (PBT - Depr) \times Tax\_ratio$$

$$TP = 1{,}371{,}104.5 \ \frac{Naira}{yr}$$

Profit after tax (PAT)

$$PAT = PBT - TP$$

$$PAT = 5{,}633{,}580.7 \ \frac{Naira}{yr}$$

Net income (NIN)

$$NIN = PAT + Depr$$

$$NIN = 5{,}782{,}743.6 \ \frac{Naira}{yr}$$

Pay back period (PBP)

$$PBP = \frac{T_{inv}}{NIN}$$

$$PBP = 0.39 \ yr$$

Rate of Return (ROR)

$$ROR = \frac{NIN + Depr}{T_{inv}} \times 100$$

$$ROR = 265\%$$

CONCLUSON ON ECONOMIC VIABILITY

The payback period for running this plant will be 0.39 years, therefore in less than 1 year the company will yield profit and this is a viable venture for anyone to invest into.

CHAPTER FOURTEEN

RECOMMENDATION TO THE INDUSTRIALIST

Having carried out the design of lime plant, the following recommendations are made to the industrialists to be noted during the construction, start up and operating phases of the work.

i) The plant should be sited close to the estate where raw materials are available.

ii) The water should be monitored regularly to ensure compliance with environmental protection agency standard.

iii) Procurement of raw material and equipment should be based on strict regulation of specification and maximum quality.

iv) Personnel should undergo routine training about new work ethics and equipment to improve their knowledge of the process plant operation.

v) The implementation of design work must be adequately supervised by the experts.

vi) Adequate data and technological parameter should be at the possession of the domestic waste water plant operation at all time to forestall any unwanted accident.

vii) Routine turn around the domestic waste water plant maintenance should be of paramount importance in the design. An articulate and organized maintenance team should safeguard quick plant shut down and ensured equipment salvage value.

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