

Proposal of Wastewater Treatment Process and Design for Soap Industry

Su Sundy Maung, Tin Tin Htwe

Abstract - This study presents the wastewater treatment plant for soap industry. Soap industry generates relatively large quantities of wastewater that may contain various potentially organic matters. Therefore, the proper management of industrial wastewater is essential. The quality and quantity of wastewater from this industry are studied and the suitable method for wastewater treatment system is considered. The wastewater from soap industry is collected for three times and analysed at the laboratory of ISO TECH in Yangon (Myanmar). Physical, chemical and biological parameters of wastewater are measured. Then, the results are compared into public sewer of Indian Standards. According to the experimental results, the concentrations of pH, suspended solids, BOD, COD are higher than acceptable level of Indian Standards. The wastewater production from the soap industry is 595000 l/day with the BOD content of 43000 mg/l and COD content of 99200 mg/l. Based on the test results and wastewater discharge, there are two proposes of wastewater treatment plant in the study. The first propose is wastewater treatment including neutralization basin, upflow anaerobic sludge blanket, alum dosing, flocculation, primary settling, activated sludge process and final sedimentation tank. After passing the treatment plant, the effluent BOD, COD and suspended solids are 347 mg/l, 3456 mg/l and 430 mg/l. Alternatives propose includes screening, alum dosing, flocculation, primary sedimentation tank, trickling filter, aeration tank and secondary sedimentation tank with effluent BOD (347 mg/l). The result values of two methods are less than the acceptable BOD quality of 350 mg/l for discharging into public sewer.

Index Terms — Industrial wastewater, soap industry, unit operations and processes, wastewater treatment

I. INTRODUCTION

Wastewater or sewage is essentially the water supply of the community after it has been fouled by a variety of uses. Wastewater may be defined as a combination of the liquid or water carried wastes removed from residences, institutions, and commercial industrial establishments, together with such groundwater, surface water, and stormwater as may be present. The wastewater production from urban areas is about evenly divided between industrial and municipal sources. Therefore, the use of water by industry can significantly affect the water quality of receiving waters.

Soap industries are the major sources of pollution in all environments. Based on the type of industry, various levels of pollutants can be discharged into the environment directly or indirectly through public lines. Wastewater from industries includes employees' sanitary waste, process wastes from manufacturing, wash waters and relatively uncontaminated water from heating and cooling operations.

Manuscript received May 19, 2014.

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Industries consumes huge amount of fresh water, depleting a valuable resource required for everyday human activities. In addition, wastewater effluents loaded with pollutants often pose significant hazards to the environment. It is therefore important to have high-performance and low-cost wastewater treatment plants to treat and reuse industrial effluents. The strength of the wastewater is determined by measuring the amount of suspended material in the water and the amount of organic material in the water.

If the industrial wastewater is thrown away without any treatment, there will be much pollution to the environment. Due to this condition, treatment plant is essentially needed from the aspect of public health. The objective of this study is to reduce wastewater pollution and environmental pollution. The raw materials for the manufacturing process of soap are pead fatty acid distillate, refined bleached deodorised palm stearine, coconut oil, and tallow. These materials react with caustic soda, salt and water. The soap manufacturing process flow diagram is shown in figure 1.

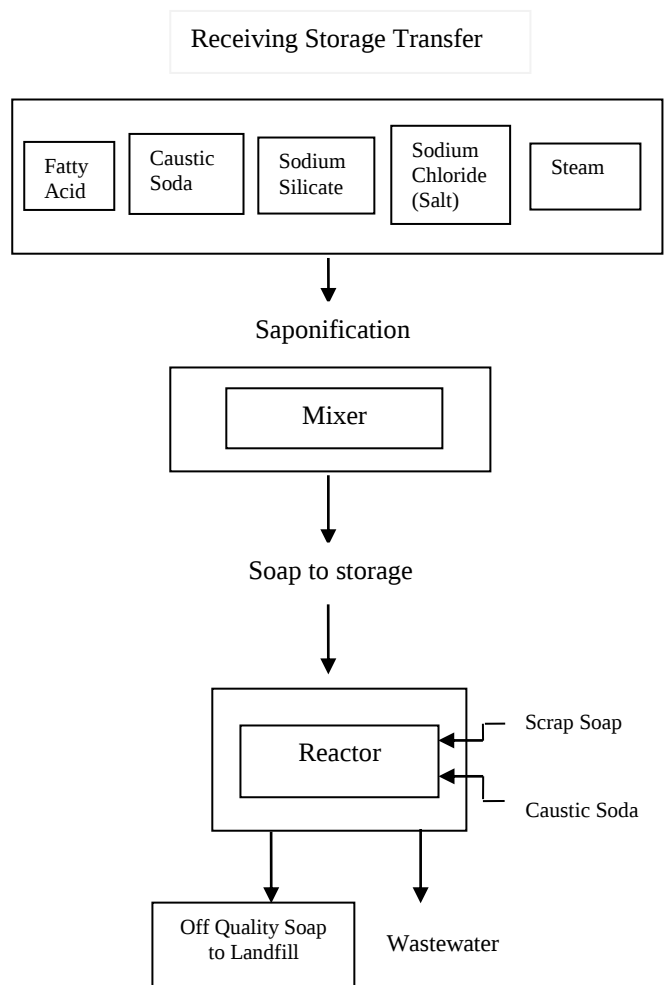


Figure 1. Manufacturing Process of Soap Industry

II. WASTEWATER CHARACTERISTICS

Wastewater is characterized in terms of its physical, chemical, and biological composition. The physical, chemical and biological examinations are performed to know the wastewater characteristics.

A. Total Solids

The total solids in a wastewater consist of the insoluble or suspended solids and the soluble compounds dissolved in water. The suspended solids content is found by drying and weighing the residue removed by the filtering of the sample. When this residue is ignited the volatile solids are burned off. Between 40 and 65 % of the solids in an average wastewater are suspended. Settleable solids, expressed as miligram per litre, are those that can be removed by sedimentation [1].

B. Colour

Colour is a qualitative characteristic that can be used to assess the general condition of wastewater. Wastewater that is light brown in colour is less than 6 h old, while a light-to-medium grey colour is characteristic of wastewaters that have undergone some degree of decomposition or that have been in the collection system for some time [1].

C. Odour

The determination of odour has become increasingly important, as the general public has become more concerned with the proper operation of wastewater treatment facilities. The odour of fresh wastewater is usually not offensive, but a variety of odorous compounds are released when wastewater is decomposed biologically under anaerobic conditions [1].

D. Temperature

The measurement of temperature is important because most wastewater treatment schemes include biological processes that are temperature dependent. In addition, oxygen is less soluble in warm water than in cold water [1].

E. Alkalinity

Alkalinity in wastewater results from the presence of the hydroxide, carbonates, and bicarbonates of elements such as calcium, magnesium, sodium, potassium, or ammonia [1]. The alkalinity in wastewater helps to resist changes in pH caused by the addition of acids.

F. Dissolved Oxygen

Dissolved oxygen is required for the respiration of aerobic microorganisms as well as all other aerobic life forms. However, oxygen is only slightly soluble in water [4].

G. Biological Oxygen Demand (BOD)

Biological oxygen demand (BOD) is the quantity of oxygen used by microorganisms in the aerobic stabilization of wastewaters and polluted waters. The standard 5-day BOD value is commonly used to define the strength of wastewaters, to evaluate the efficiency of treatment by measuring oxygen demand remaining in the effluent, and to determine the amount of organic pollution in surface waters [5].

H. Chemical Oxygen Demand (COD)

The chemical oxygen demand (COD) of wastewater or polluted water is a measure of the oxygen equivalent of the organic matter susceptible to oxidation by a strong chemical

oxidant. The organic matter destroyed by the mixture of chromic and sulphuric acids is converted to CO₂ and water. The COD test is also used to measure the organic matter in industrial and municipal wastes that contain compounds that are toxic to biological life [2].

The results of soap wastewater characteristics are shown in table I. The test results are described that they contain highest pollutants such as BOD, COD, suspended solids and total solids.

TABLE I. RESULTS OF WASTEWATER ANALYSIS

Characteristics	Unit	Results			Into Public Sewers of Indian Standard
		1 st Time	2 nd Time	3 rd Time	
Temperature	°C	25.5	25	24.5	45
Chemical Oxygen Demand (COD)	mg/l	128000	101000	99200	10000
Biological Oxygen Demand (BOD)	mg/l	51200	48200	43000	350
Dissolved Oxygen (DO)	mg/l	3.8	4.2	5.4	-
pH	-	14	13.6	11.2	5.50-9.00
Colour (True)	TCU	2200	1800	1200	-
Turbidity	NTU	8230	7920	6320	-
Total Hardness	mg/l as CaCO ₃	12800	11620	10600	-
Total Alkalinity	mg/l as CaCO ₃	9200	9000	7880	-
Phosphate	mg/l	1.8	1.00	0.8	-
Chloride (Cl)	mg/l	16400	16220	12860	1000
Sulphate (SO ₄)	mg/l	13200	12800	10010	1000
Total Solids	mg/l	59200	59900	50380	2700
Suspended Solids	mg/l	12800	11100	10080	600
Dissolved Solids	mg/l	59200	48800	40300	2100

III. TREATMENT METHOD

Wastewater treatment objectives are based primarily on aesthetic and environmental concerns. The objectives of reduction and removal of BOD, suspended solids and pathogenic micro-organisms continued but at higher levels. The degree of treatment can be determined by comparing the influent wastewater characteristics to the required effluent wastewater characteristics. A number of different treatment and disposal or reuse alternatives are then developed and evaluated, and the best alternative is selected.

Wastewater treatment is a combination of physical, chemical, and biological processes. Methods of treatment in which the application of physical forces predominate are known as unit operations while methods of treatment in which chemical or biological activities are involved are known as

unit processes. There are three types of unit operations and processes: 1. Physical unit operations, 2. Chemical unit processes, and 3. Biological unit processes.

A. Physical Unit Operation

Treatment methods in which the applications of physical forces predominate are known as physical unit operations. Because most of these methods evolved directly from man's first observations of nature, they were the first to be used for wastewater treatment. Screening, mixing, flocculation, sedimentation, flotation, filtration, and gas transfer are typical unit operations [5].

B. Chemical Unit Processes

Chemical unit processes are those in which removal of contaminants are brought about by chemical activity. In the field of wastewater treatment, chemical unit operations are usually used in conjunction with physical unit operations and biological unit processes. Precipitation, absorption, and disinfection are the most common examples used in wastewater treatment [5].

C. Biological Unit Processes

Biological unit processes are those in which removal of contaminants are brought about by biological activity. In biological treatment of wastewater, the objectives are to coagulate and remove the non-settleable colloidal solids and to stabilize the organic matter. Basically, these substances are converted into gases that can escape to the atmosphere and into biological cell tissue that can be removed by settling [5].

In order to treat wastewater, it is necessary to know the function of treatment process.

i. Collection Tank

In this study, storage tank is considered as tank on ground with concrete.

ii. Screening

The first step in wastewater treatment is the removal or reduction of coarse solids. The usual procedure is to pass the untreated wastewater through bar racks or screens. A screen is a device with openings, generally of uniform size, that is used to retain the coarse solids found in wastewater. The screening element may consist of parallel bars, rods or wires, grating, wire mesh, perforated plate, and the openings may be of any shape but generally are circular or rectangular slots. The materials removed by these devices are known as screening.

iii. Coagulation and Flocculation

Coagulation is employed for the removal of waste materials in suspended or colloidal form. Colloids are presented by particles over a size range of 1 nm (10⁻⁷ cm) to 0.1 μ m (10⁻⁸ cm). These particles do not settle out on standing and cannot be removed by conventional physical treatment processes. Coagulation reduces the net electrical repulsive forces at particle surfaces by adding coagulant chemicals,

whereas flocculation is agglomeration of the destabilized particles by chemical joining and bridging.

In wastewater treatment, coagulation and flocculation are used to destabilize turbidity, color, odor-producing compounds, pathogens, and other contaminants in surface waters. Flocculation is agitation of chemically treated water to induce coagulation. In this manner, very small suspended particles collide and agglomerate into larger heavier floc that settles out by gravity. Flocculation is a principal mechanism in removing turbidity from water.

iv. Primary Sedimentation Tank

The objective of treatment by sedimentation is to remove readily settleable solids and floating and thus reduce the suspended-solids content. Sedimentation is the removal of solids particles from suspension by gravity. In water treatment, the common application of sedimentation is after chemical treatment to remove flocculated impurities and precipitates. In wastewater processing, sedimentation is used to reduce suspended solids in the influent wastewater and to remove settleable solids after biological treatment.

v. Trickling Filter

Trickling filters are used for biological treatment of domestic sewage and industrial wastes which are amenable to aerobic biological processes. Trickling filters, also known as percolating filters or sprinkling filters are similar to contact beds in construction, but their operation is continuous and they allow constant aeration. The trickling filter is always preceded by primary sedimentation along with skimming devices to remove the scum. This will prevent the clogging of the filter by settleable solids. The effluent from the filter is then taken to secondary sedimentation tanks for settling out organic solids oxidized while passing through the filter.

vi. Activated Sludge Process

The activated sludge is the sludge which is obtained by settling sewage in presence of abundant oxygen so as to be supercharged with favourable aerobic micro-organisms. The activated sludge process of sewage treatment is based on providing intimate contact between the sewage and biological active sludge.

The effluent from the primary settling tank is mixed with a dose of activated sludge and is aerated in an aeration tank for a period of some hours. During the aeration, the micro-organisms in the sewage multiply by assimilating part of the influent organic matter. In this process, part of organic matter is synthesized into new cells and part is oxidized to derive energy. The synthesis reaction, followed by subsequent separation of the resulting biological mass and the oxidation reaction are the main mechanisms of BOD removal in the activated sludge process.

The biomass is generally flocculant and quick settling. It is separated from the aerated sewage in a secondary settling tank and is recycled continuously to the aeration tank as an essential feature of the process. The BOD removal is evaluated based on the BOD₅ of the aeration tank influent and the BOD₅ of the final effluent after sludge separation. The

effluent is of high quality, usually having a lower BOD than that of a trickling filter. The BOD removal is up to 80-95 percent and the degree of bacteria removal is up to 90-95 percent.

vii. Neutralization

Many industrial wastes contain acidic or alkaline materials that require neutralization prior to discharge to receiving waters or prior to chemical or biological treatment. For biological treatment, a pH in the biological system should be maintained between 6.5 and 8.5 to ensure optimum biological activity. The biological process itself provides a neutralization and a buffer capacity as a result of the production of CO₂, which reacts with caustic and acidic materials. The degree of preneutralization required depends, therefore, on the ratio of BOD removed and the causticity or acidity present in the waste.

viii. Upflow Anaerobic Sludge Blanket (UASB)

Anaerobic decomposition involves in the breakdown of organic wastes to gas (methane and carbon dioxide) in the absence of oxygen. The quantity of organic matter converted to gas will vary from 80 to 90 percent.

In the upflow anaerobic sludge blanket wastewater is directed to the bottom of the reactor where it must be distributed uniformly. The wastewater flows upward through a blanket of biologically formed granules which consume the waste as it passes through the blanket. Methane and carbon dioxide gas bubbles rise and are captured in the gas dome. Liquid passes into the settling portion of the reactor where solids-liquid separation takes place. The solids return to the blanket area while the liquid exists over the wires. To keep the blanket in suspension, an upflow velocity of 2 to 3 ft/h (0.6 to 0.9 m/h) has been used.

IV. PROPOSAL AND DESIGN OF WASTEWATER TREATMENT PLANT

Depending on the constituents that must be removed, an almost limitless number of different flowsheet can be developed using unit operations and processes. In the study, there are two types of proposed flowsheet for soap wastewater treatment.

In order to design wastewater treatment plant, it is necessary to determine the design discharge. In this study, the discharge from soap wastewater is considered for the treatment plant. According to wastewater generation standards, 1 kilogram (1kg) of soap produces 23.4L of wastewater. The soap production per day is 25424 kg. Therefore, wastewater flow rate from soap industry is 595 m³/day.

A. Proposal 1

Based on the characteristics of soap wastewater, the appropriate treatment process such as neutralization, anaerobic process, alum dosing and flocculation, primary settling, activated sludge processes are chosen and designed

according to their respective design criteria to obtain the acceptable wastewater quality of into public sewers Indian Standards. In secondary treatment, activated sludge process (suspended growth process) is used. In this process includes aeration tank, secondary clarifier and returned sludge line. The proposal 1 for the treatment plant of soap industry is shown in figure 2.

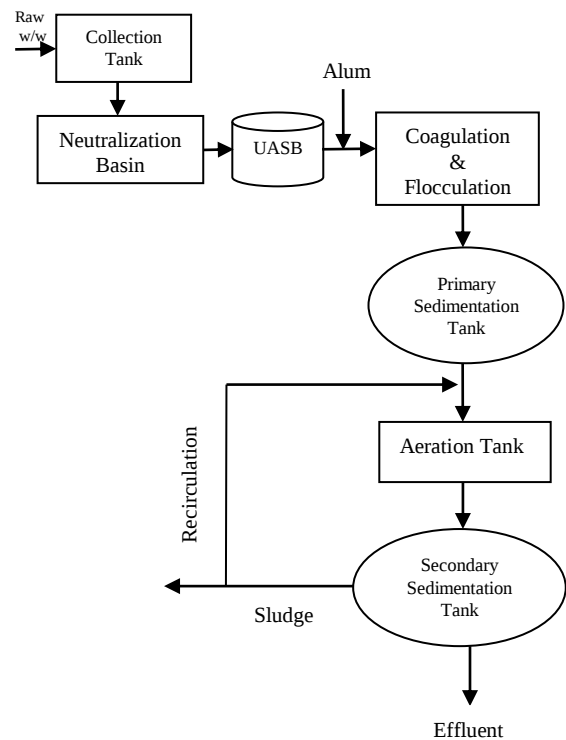


Figure 2. Proposal 1 for treatment plant of soap industry

i. Design of Collection and Neutralization Tank

Raw wastewater from the industry flows into the collection tank. In this study, collection tank is considered as tank on ground with concrete. For the design of the collection tank, wastewater is stored for 1hrs. Dimension of tank is 2 m × 8.5 m × 1.5 m. For the design of neutralization tank, wastewater is passed for 6 minutes with the average air rate (0.6 m³/min-m²). Dimension of tank is 1 m × 1 m × 2.5 m.

ii. Design of Upflow Anaerobic Sludge Blanket (UASB)

To keep the blanket in suspension, an upflow velocity of 2 to 3 ft/h (0.6 to 0.9 m/h) has been used with retention time (4 hours). Dimension of tank is 5 m diameter and 4.95 m depth. After passing this tank, the effluent BOD and COD are 4300 mg/l with removal efficiency (90%) and 9920 mg/l with removal efficiency (90%).

iii. Design of Alum Dosage Per Day

The required dosage of alum varies from 75mg/l – 250 mg/l depending upon the condition [2]. Chemical precipitation (alum coagulant) can be removed from 40 to 70% of BOD, 80 to 90% of suspended solids and 30 - 60 % of COD. Considering for the average percentage removal, the effluent BOD is obtained as 1720 mg/l, effluent suspended solids is 1512 mg/l and effluent COD is 5456 mg/l. Alum is in

more use than other coagulants because it is very cheap. It reduces taste and odor in addition to turbidity. Alum required per day is 59.5 kg/day.

iv. Design of Flocculation Tank

Flocculation is an essential operation designed to force agitation in the fluid and induced coagulation. For the design of flocculation tank, wastewater is passed for 30 minutes. Dimension of tank is $4\text{ m} \times 2\text{ m} \times 1.5\text{ m}$ and provide revolving paddles attached to two horizontal shafts transverse to basin length. Let each shaft should be located at mid depth of tank. Let provide three paddles to each shaft. Paddle size is 0.03 m wide and each of length 1 m with 31 watts of power requirement.

v. Design of Primary Sedimentation Tank

Sedimentation tanks are designed to reduce the velocity of flow so as to permit suspended solids to settle out of water by gravity. In this study, the circular shaped primary sedimentation tank is used radically flow. Dimension of tank is 4.5 m diameter and 3 m depth with detention time (2 hours). The effluent BOD, COD and SS become 1118 mg/l, 3546 mg/l and 403 mg/l respectively.

vi. Design of Aeration Tank

It is a biological treatment process in which biologically activated mass, called activated sludge is continuously mixed with the sewage flow in the aeration basin in the presence of oxygen. The oxygen is supplied to the mixed liquor either by diffused compressed air or by mechanical aeration. In the study, conventional activated sludge process is used. Conventional activated sludge processes can be removed 80 to 95 % of BOD, 80 to 90 % of suspended solids, 80-85 % of COD and 10- 25 % of phosphorus. Tank dimension is $6.5\text{ m} \times 38\text{ m} \times 4.5\text{ m}$. Total air required is $16\text{ m}^3/\text{min}$. Standard diffuser plates of $0.3\text{ m} \times 0.3\text{ m} \times 25\text{ mm}$ passing 1.2 m^3 of air/ m^2 with pore sizes of 0.3 mm are chosen. Total number of plates is 148 plates.

vii. Design of Secondary Sedimentation Tank

In conventional activated sludge process, the aeration tank is followed by the secondary sedimentation tank. Tank dimension is 4 m diameter and 4.5 m depth with detention time (2.28 hours). The final effluent of BOD is 347 mg/l with 69 % removal efficiency.

B. Proposal 2

Alternative method of wastewater treatment plant is considered. Based on the characteristics of soap wastewater, the appropriate treatment process such as screening, alum dosing and flocculation, primary settling, trickling filter, aeration tank and secondary sedimentation tank are chosen and designed according to their respective design criteria to obtain the acceptable wastewater quality of into public sewers Indian Standards. In secondary treatment, activated sludge process (suspended growth process) is used. In this process includes aeration tank, secondary clarifier and returned sludge line. The proposal 2 for the treatment plant of soap industry is shown in figure 3.

i. Design of Collection Tank

Raw wastewater from the industry flows into the collection tank. In this study, collection tank is considered as tank on ground with concrete. For the design of the collection tank, wastewater is stored for 1hrs. Dimension of tank is $2\text{ m} \times 8.5\text{ m} \times 1.5\text{ m}$.

ii. Design of Screen

A screen is a device with openings generally of uniform size. In this study, fine screen of rotary drum type is used and designed according to the criteria. Dimension of drum screen is 1.5 m diameter and 2.45 m length. The effluent of BOD and SS are 34400 mg/l and 7812 mg/l.

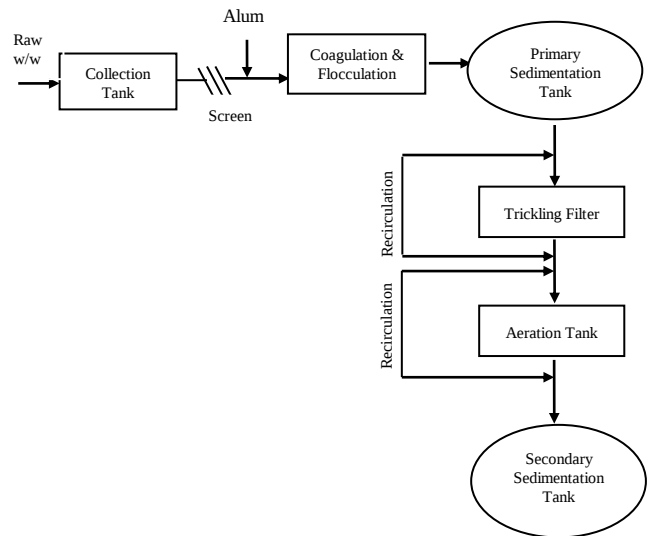


Figure 3. Proposal 2 for Treatment Plant of Soap Industry

i. Calculation of Alum Dosage Per Day

Considering for the average percentage removal, the effluent BOD is obtained as 13760 mg/l, effluent suspended solids is 1172 mg/l and effluent COD is 54560 mg/l . Alum is in more use than other coagulants because it is very cheap. It reduces taste and odor in addition to turbidity. Alum required per day is 59.5 kg/day.

ii. Calculation of Flocculation Tank

Flocculation is an essential operation designed to force agitation in the fluid and induced coagulation. For the design of flocculation tank, wastewater is passed for 30 minutes. Dimension of tank is $4\text{ m} \times 2\text{ m} \times 1.5\text{ m}$ and provide revolving paddles attached to two horizontal shafts transverse to basin length. Let each shaft should be located at mid depth of tank. Let provide three paddles to each shaft. Paddle size is 0.03 m wide and each of length 1 m.

iii. Design of Primary Sedimentation Tank

Sedimentation tanks are designed to reduce the velocity of flow so as to permit suspended solids to settle out of water by gravity. In this study, the circular shaped primary sedimentation tank is used radically flow. Dimension of tank is 4.5 m diameter and 3 m depth with detention time (2 hours).

The effluent BOD, COD and SS become 8256 mg/l, 35464 mg/l and 469 mg/l respectively.

iv. Design of High Rate Trickling Filter

In the first stage of secondary treatment, high rate trickling filter is designed according to the criteria. Dimension of filter is 37 m diameter and 3 m depth. The effluent BOD, COD and SS are 1651 mg/l, 7092.8 mg/l and 117.25 mg/l respectively.

v. Design of Aeration Tank

Conventional activated sludge processes can be removed 80 to 95 % of BOD, 80 to 90 % of suspended solids, 80-85 % of COD and 10- 25 % of phosphorus. Tank dimension is 6.5 m × 56 m × 4.5 m. Total air required is 27 m³/min. In this process, mechanical aeration is used with paddle mechanism. Provide revolving paddles attached to three horizontal shafts running parallel to the length. Let each shaft should be located at mid depth of tank. Let provide thirty paddles to each shaft. Paddle size is 0.58 m wide and each of length 0.6 m with 4128 watts of power requirement.

vi. Design of Secondary Sedimentation Tank

In conventional activated sludge process, the aeration tank is followed by the secondary sedimentation tank. Tank dimension is 4 m diameter and 4.5 m depth with detention time (2.28 hours). The final effluent of BOD is 347 mg/l with 79 % removal efficiency.

V. DISCUSSION AND CONCLUSION

From the test result, the value of BOD, COD, suspended solids and total dissolved solids are 43000 mg/l, 99200 mg/l, 10080 mg/l and 40300 mg/l respectively. These are high content over the limit for public sewer of Indian Standard. Based on the characteristics, the appropriate treatment processes are chosen to design the soap wastewater treatment plant. In the study, two types of treatment processes are considered. In proposal 1 includes neutralization, anaerobic process, alum dosing and flocculation, primary settling, activated sludge processes. After passing through the treatment process, the effluent of BOD, COD and SS become 347 mg/l, 3546 mg/l and 403 mg/l respectively. In proposal 2 includes screening, alum dosing and flocculation, primary settling, trickling filter, aeration tank and secondary sedimentation tank. After passing treatment plant, the effluent BOD, COD and SS become 347 mg/l, 7092.8 mg/l and 117.25 mg/l respectively. The effluent BOD of two types of treatment is the same with the value of 347 mg/l. But the effluent COD of the first treatment process is lower than the second. And then, neutralization basin is the reduction of alkalinity for the soap wastewater. . Finally, the results of effluent are within the BOD (350 mg/l), COD (10000 mg/l), SS (600 mg/l) and dissolved solids (2100 mg/l) for disposal into public sewer of Indian Standard.

ACKNOWLEDGMENT

The author would like to express her heart felt gratitude to Dr. Kyaw Moe Aung, Associate Professor and Head of Civil Engineering Department, Mandalay Technological University. The author is deeply grateful to her supervisor Dr. Tin Tin Htwe, Associate Professor, Department of Civil Engineering, Mandalay Technological University, for her valuable guidance, criticisms, encouragement comments, suggestions and advice throughout the whole length of the research work. The author would like to her gratefulness to all people in soap industry (Mandalay). Finally, specially thanks to her parents, for their moral support, patience, understanding and encouragement.

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