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Revitalisation And Sustainable Development Of Villages By Using Sludge Biogas Plant

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Abstract: India is slowly emerging as a global superpower and is on its way to become a developed nation. But it has forgotten its own heart and soul - the villages. A large population of India lives in the villages and heavily relies on agriculture. A nation cannot be stated as developed if all fields are not completely developed. The farmers and villagers face many problems – the prices of fertilisers and pesticides, poor production of crops, unavailabile safe drinking water, employment opportunities and unsanitary conditions. This has led to large migration of people to the cities leading to increase in poverty. Through this project, we plan to construct a sludge-biogas plant where the wastewater is treated. The treated water will then be sent to the fields for farming and sludge is sent into the biogas unit which is on further reaction produces biogas.

***Index Terms* - Sewage Treatment Plant, Sludge, Biogas Plant, Biogas.**

I. INTRODUCTION

There are 6,00,000 villages in India out of which 1,25,000 villages are backward. New ways of improving the lives of people are introduced in the urban areas, keeping the rural areas in the shadows. This leads to improper sanitation, lack of employment opportunities and reverse development of the villages, forcing them to migrate to towns and cities. In developing countries, approximately, 80% of the diseases are caused by bad quality of water. This leads to water-borne diseases, health problems, which can further lead to epidemics.

The subsidised fertilizers and pesticides provided by the government are not able to reach the farmers. Due to this, they have to take huge debts to buy these from traders at high rates. Even though, fertilizers and pesticides improve the plant's growth, but they make the soil infertile if used for a long period of time. Even now, getting electricity is considered a luxury in many remote villages of India. Many villagers still use wood for cooking.

Not only these issues raise concerns, but the world is also facing water shortage crisis and drastically reduce the water table. Hence, there is a need to design a village that can sustain itself. Keeping these issues in mind, we plan to install a Sewage Treatment Plant (STP) to treat the sewage water and supply it to the fields and a biogas plant which can be used to provide electricity and provide fuel for cooking.

In India, it has been estimated that the total potential of biogas production from different organic wastes is about 40,734Mm^3/year. The country has potential of installation of about 12 million household type biogas plants. About 4.75 million of biogas plants have already been installed to the year 2014, which is about 40% of total potential. It is estimated that India can produce power of about 17000 MW using biogas which is about 10 % of country's energy requirement.

II. LITERATURE REVIEW

In this chapter following research papers have been studied for the conduction of this project.

Mr. Zahra Amirossadat (2014) studied **'Introduction of preliminary and Secondary Treatment'** by introducing various advanced methods of preliminary and secondary treatment.

Mr. Dadrasnia A. (2014) studied on **'Wastewater Treatment by Biological Methods'.** He has researched on the primary and secondary treatment of wastewater, and also on the biological wastewater treatment such as oxidation ponds, anaerobic ponds and aerobic ponds.

Swati Shree Samal (2016) studied on **'Design of Sewage Treatment Plant'.** They designed a wastewater treatment plant for the Metro Satellite, Palasuni, Bhubaneshwar. It aims to produce an environmental safe atmosphere by treating sludge or effluent which will be suitable for disposal or use. This involves the designing of STP and its stages or components which are responsible for sewage treatment like screening, grit chamber, skimming tank, sedimentation tank, secondary clarifier, activated sludge tank and sludge drying beds.

Mr. B. P. Mishra (2016) has presented **'Biogas Plants in Chattisgarh (India): A Case Study'.** A case study was carried out in the state of Chattisgarh, India. They evaluated the performance of biogas plants of various districts in Chattisgarh of randomly selected biogas plant.

Mr. Zhang Hanjie (2010) worked on **'Sludge Treatment to increase Biogas Production'.** Here, he emphasised on the fact that the sludge should undergo a pre-treatment in order to increase the rate of production of biogas by facilitating the process of hydrolysis. List of possible sludge pre-treatment includes thermal, chemical, biological and mechanical processes, as well as combination of these. They also showed the effects of various pre-treatment by testing these methods.

S. Luostarinen (2008) worked on **'Increased biogas production at wastewater treatment plants through co-digestion of sewage sludge with grease trap sludge from a meat processing plant'**. An experiment was conducted which showed that the feasibility of co-digestion grease trap sludge from a meat-processing plant and sewage sludge was studied in batches and reactor at 35˚C. Grease trap sludge had high methane production potential, but the methane production was slow. When mixed with sewage sludge, methane production started immediately and the potential increased with increasing grease trap sludge content.

A. Maria Jackson (2008) worked on **'Design and Analysis of a Digester in a Biogas Plant'**. They analysed the digester in a biogas plant using ansys,creo,cfd and obtained the flow of fluids,time of filling and drining and also performed the stress analysis. We calculated the diameter of the digester which helped us to find the load distribution and methane produced. We use floating balloon type digester to easy up the way of finding whether the methane gas is obtained or not. We mount the blades inside the digester horizontally so that we reduce the stress that is distributed in the walls and it does not interrupt with the flow.

Mr. Thockhom Subhashchandra Singh (2015) worked on **'A Review on Advancements in Biogas Technologies'.** The aim is to bring out the various methodologies applied in generating biogas and technologies used in improving the quality. Various feed materials are used as a biomass, ranging from MSW to kitchen waste is provided in detail. The usage of AD reduces the GWP considerably.

III. RESEARCH METHODOLOGY

1. Sewage Treatment Plant

1.1 Primary Treatment

1.1.1 Screening

Floating matter such as sachets, plastic sheet bits, rags, leaves, fibres, etc. needs to be removed by the process of screening. Floating matters can cause objectionable shoreline conditions when discharged into the sea. Screens are the first step in all STPs, even before pumping stations and meters. A screen is a device with uniform opening, which may consist of parallel bars, rods, grating or wire mesh or perforated plates.

1.1.1.2 Coarse Screens

Coarse screen serves as protective device, usually bar screens. A bar screen is horizontal and vertical bars placed at equal intervals through which the sewage flows, generally with a large opening of 25mm.

1.1.1.3 Medium Screens

Medium bar screens have a clear opening of 12mm. They are usually 10mm thick on upstream side and taper slightly to the downstream. These screens are used before all pumps and treatments such as the stabilisation ponds.

1.1.1.4 Fine Screens

Fine screens are unsuitable for raw sewage due to the possibility of clogging. They are very closely spaced bars with clear openings of 5mm, which can be of drum or disc type, mechanically cleaned and continuously operated.

1.1.2 Grit Removal

1.1.2.1 Introduction

The process of grit removal is necessary to protect the moving mechanical equipments and pump elements from abrasion, resulting in abnormal wear and tear. It also reduces the frequency of cleaning the digesters and settling tanks.

1.1.2.2 Composition of Grit

Grit consists of sand, ash, clinkers, egg shells, bone chips and many inert materials inorganic in nature. The specific gravity of grit varies from 2.4 to 2.65. It is non-putrescible and possesses a higher hydraulic subsidence value than organic solids. Hence, gritty material can be separated from organic solids by differential sedimentation in a grit chamber.

1.1.2.3 Clearing of the Grit

Manual Cleaning should be avoided except in the case of small STPs of less than 1MLD where velocity controlled channels can be cleared by the operated using a shovel and walking on a platform along the length. Mechanical clearing is preferred and these are provided for not only collection but also washing of grit and can be operated on either collected or intermittent basis. The grit is collected by scraper blades or ploughs rotated by a motor drive.

1.1.3 Settling

1.1.3.1 General

Settling tanks, sedimentation tanks and clarifier are generally used in water treatment. They are used to separate the suspended solids, which can settle by gravity when the sewage is held in a tank. The primary clarifier is located after screens and grit chamber reduces the organic load on secondary treatment units and are used to remove inorganic suspended solids, Organic and residual inorganic solids, free oil and grease and Chemical flocs produced during chemical coagulation and flocculation.

Secondary clarifier is located after the biological reactor and is used to separate the bio-flocculated solids or bioflocs of biological reactors. Septic tanks, Imhoff tanks and clarigester are combined where digestion of organic matter and settling are combined in the same unit and is used for small installations.

1.1.3.2 Characteristics of settleable solids

The primary or secondary clarifier removes settleable solids are organic and flocculent in nature. Their specific gravity varies from 1.01 to 1.02. The finely divided organic solids reaching primary clarifiers are low specific gravity solids which are incompletely flocculated but are susceptible to flocculation.

1.1.3.3 Sludge withdrawal using thickeners and clarifier

1.1.3.3.1 Scum Removal

A distinct feature of primary clarifiers is the skimming device, which can be operated by the same drive mechanism as the sludge scraper arms at the bottom of the tank.

1.1.3.3.2 Performance

Primary clarifiers can accomplish 30% to 45% removal of BOD and 60% to 70% removal of suspended solids depending on concentration and characteristics of solids in suspension. Secondary clarifier removes more than 99%.

1.1.3.3.3 Unit operations

The process consists of three unit operations, which is, mixing and proportioning of chemicals, flocculation and sedimentation.

In the mixing process, the dose of chemicals is weighed and fed to sewage by means of proportioning and feeding devices, ahead of the mixing unit. It is mixed in a rapid or flash mixing unit provided with paddles, propellers or by diffused air and having detention period of 0.5 to 3 minutes.

The principle of flocculation in sewage is same as that of water purification. The flocs formed after flash mixing with chemicals are made to coalesce into bigger sizes by either air or mechanical flocculation.

1.2 Secondary Treatment

1.2.1 Aerobic Treatment of Sewage

1.2.1.1 Activated Sludge Process

1.2.1.1.1 Introduction

Aerobic suspended systems are of two types, those which employ sludge recirculation, which is, conventional activated sludge process and those which do not have sludge recycle, which is aerated lagoons. The sewage containing organic matter is aerated in an aeration basin in which micro-organisms metabolise in which the soluble and suspended organic matter. Part of the organic matter is synthesised into new cells and part of it oxidised to carbon dioxide and water to derive energy.

In small plants, intermittent operation of extended aeration system can be adopted by:

i. Closing of inlet and aerating the sewage
ii. Stopping aeration and allowing the contents to settle
iii. Letting in fresh sewage which displaces an equal quantity of clarified effluent.

1.2.1.1.2 Conventional Method

The conventional system always precedes with primary settling. The plant consists of primary clarifier, an aeration tank, a secondary clarifier, a sludge return line and an excess sludge waste leads to a digester. The BOD removal varies from 85% to 92%. The plant uses plug-flow regime, which is achieved by a long and narrow configuration of the tank with length equal to 5 or more times the width. The sewage and the mixed liquor enter at the head of the tank and are withdrawn at the end.

1.2.1.1.3 Types of Aeration

Diffused aeration involves the introduction of compressed air into the sewage through submerged diffusers of fine bubble or coarse bubble type. In the fine bubble type, the compressed air is released at near the bottom of the aeration tank through porous tubes or plates made of aluminium oxide or silicon oxide cemented together in a ceramic matrix. Coarse bubble aerator has lower aeration efficiency than fine bubble aerator, but is cheaper in capital cost and is less liable to clogging; hence it does not require filtration of air.

Surface aerators are available in both fixed and floating types. Their advantages are higher oxygen transfer capacity, absence of air piping and air filter and simplicity of operation and maintenance. Surface aerators generally consist of large diameter impeller plates revolving on vertical shaft at the surface of the liquid with or without draft tubes.

1.2.1.1.4 Secondary settling

Secondary settling is important in the activated sludge process as the efficient separation of the biological sludge is necessary not only for ensuring final effluent quality but also for return of adequate sludge to maintain the MLSS level in the aeration tank.

1.2.1.1.5 Nitrification

Activated sludge plants are ordinarily designed for the removal of only carbonaceous BOD. However, there may be incidental nitrification in the process. Nitrification, may be required in specific cases, e.g. when ammonia has to be eliminated from the effluent in the interest of pisciculture or when nitrification cum denitrification is proposed for elimination of nitrogenous matter from the effluent for control of eutrophication. In such cases, plug flow systems have been developed for efficient removal of both carbon and nitrogen.

The denitrification is achieved as an integrated nitrification-denitrification process as a variation of the typical activated sludge process.

1.2.1.1.6 Phosphorous Removal

The phosphorous can be removed by a process called as the luxury uptake.

1.2.1.1.7 Aerated Lagoons

Aerated lagoons are provided in the form of simple earthen basins with inlet at one end and outlet at the other to enable the sewage to flow through while aeration is usually provided by mechanical means to stabilize the organic matter. The major difference between activated sludge system and aerated lagoon is that settling tanks and sludge recirculation are absent in the latter. Aerated lagoons are of two principal types depending on how the microbial mass of solids in the system is handled: Facultative Aerated Lagoons and Aerated Lagoons.

1.2.2 Anaerobic Treatment of Sewage

Anaerobic treatment of sewage has a number of advantages over aerobic treatment processes. These are:

i. Lesser electrical energy input of the system because oxygen is not required and hence, aeration is not needed
ii. Methane gas, which has a thermal value produced from which electrical energy can be generated.

However, there is a disadvantage that Hydrogen Sulphide gas is produced from the sulphate present in the sewage. Anaerobic digestion as a unit process in municipal sewage treatment has been used since the beginning of this century. It is used for stabilization of sludge solids from primary and secondary sedimentation tanks either in closed digesters or open lagoons. Anaerobic lagoons are also used for treatment of industrial waste.

The following are the types of anaerobic methods used:

i. High Rate Anaerobic System
ii. Anaerobic Contact Process
iii. Anaerobic filter
iv. Anaerobic fixed film reactor
v. Fluidised and Expanded Bed Reactor
vi. Up flow anaerobic sludge blanket reactor

1.3 Tertiary Treatment

This step involves the removal of constituents beyond removal in secondary treatment. These are Chemical Precipitation and Membrane Technologies.

1.3.1. Chemical Precipitation

This method is required to remove the phosphorous for control of eutrophication in receiving waters, salts if the treated sewage is to be used for industrial purposes and heavy metals.

The chemical precipitation of phosphorous is by the use of Ferric or Aluminium salts using a two-step process. For each Kg of phosphorous 0.9 kg of Aluminium or 1.8 kg of Iron is needed, showing that the sludge production is less by half by using Aluminium. The chemical equations are as under:

$Al_2(SO_4)_3 \cdot 18H_2O + 2H_3PO_4 \rightarrow 2AlPO_4 + 3H_2SO_4 + 18H_2O$

$FeCl_3 \cdot 6H_2O + H_2PO_4^- + 2HCO_3^- \rightarrow FePO_4 + 3Cl^- + 2CO_2 + 8\ H2O$

It is added either in the primary clarifier or the aeration tank or in the tertiary stage.

1.3.2. Disinfection

1.3.2.1. Need for disinfection

Disinfection of treated sewage may be needed when the receiving water quality may be affected by the Coliforms after the discharge. The following methods are used for disinfection.

Chlorination

This is the most widely used technology in both water supply and sewage treatment. As the treated sewage is fresh from secondary aerobic biological treatment, the chlorination of such effluents does not result in hazards.

De-chlorination

Excess of residual chlorine if any is nullified by de-chlorination chemicals like sulphur dioxide (SO_2) gas or salts as sodium Thiosulfate ($Na_2S_2O_3$), Sodium Sulphite (Na_2SO_3), Sodium Bisulfite ($NaHSO_3$), Sodium Metabisulfite ($Na_2S_2O_5$), Calcium Thiosulfate (CaS_2O_3), Ascorbic acid (Vitamin C) and Sodium Ascorbate. Sodium Bisulfite is used by some utilities due to its lower cost and higher rate of de-chlorination.

Ultraviolet Radiation Disinfection Ultraviolet rays are most commonly produced by a low pressure mercury lamp constructed of quartz or special glass which is transparent and produces a narrow band of radiation energy at 2537 A^0 emitted by the mercury vapour etc. Though this is a standard chemistry, in actual practice, its efficiency is largely constrained.

Ozone Systems

It is a faint blue gas of pungent odour. Being unstable, it breaks down to normal oxygen and nascent oxygen. This nascent oxygen is a powerful oxidizing agent and germicidal agent. Ozone is produced by the corona discharge of high voltage into dry air and being unstable has to be produced on-site.

2 Biogas Plant

2.1 Introduction

Biogas is a well established, sustainable source and widely-popular source of energy globally by virtue of its production from waste, and available cattle dung. It is a carbon neutral, sustainable and renewable source of energy that can be produced and consumed without any adverse effect on the environment. It is also known as "marsh" gas as it was first discovered getting released from swamps and marshes. It is generated by the *methanogenesis* bacteria on organic matter by the decomposition of organic matter in anaerobic, damped and oxygen depressed environments. The main constituent of biogas is methane and other gases such as carbon-dioxide, H2S, water vapour, NO, SO etc.

2.2 Properties

The gas emitted from fermented animal, plant, and human waste in anaerobic conditions (the absence of oxygen) is called biogas. Its main active ingredient is methane (CH_4). In addition to methane, biogas includes carbon dioxide (CO2), hydrogen sulfide (H_2S), and other gases such as hydrogen (H_2), oxygen (O_2), and nitrogen (N_2).CO_2 and contaminant concentration profiles can be used as a measure of biofilter performance. Biogas combustion temperature is about 700 and the flame temperature is 870 like other gases, is combustible and it is mixed with air at a ratio of 1 to 20 with high combustion speed.

2.3 Biogas Production Process

Anaerobic conversion of organic materials and pollutants is an established technology for environmental protection through the treatment of wastes and wastewater.

2.4. Principle

Anaerobic microbiological decomposition is a process in which micro-organisms derive energy and grow by metabolising organic material in an oxygen-free environment resulting in the production of methane (CH4). The anaerobic digestion process can be subdivided into the following four phases, each requiring its own characteristic group of micro-organisms:

1.**Hydrolysis:** In this very first step, long chains of the complex carbohydrates, proteins and lipids are broken into shorter ones as sugars, amino acids and fatty acids respectively. Hydrolysis is relatively slow step and it can limit the rate of overall anaerobic digestion process.

$C_6H_{10}O_4 + 2H_2O \rightarrow C_6H_{12}O_6 + H_{22}$

2. Acidogenesis: The products of hydrolysis used as substrate and further converted into higher organic acids such propionic acid butyric acid to acetic acid by acidogenic bacteria.

$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$

$C_6H_{12}O_6 + 2H_2 \leftrightarrow 2CH_3CH_2COOH + 2H_2O$ $C_6H_{12}O_6 \rightarrow 3CH_3COOH$

3. Acetogenesis: The acetogenic bacteria convert the gases into acetic acid and hydrogen gas.

$CH_3CH_2COO^- + 3H_2O \leftrightarrow CH_3COO^- + H^+ + HCO_3^- + 3H_2$

$C_6H_{12}O_6 + 2H_2O \leftrightarrow 2CH_3COOH + 2CO_2 + 4H_2$

$CH_3CH_2OH + 2H_2O \leftrightarrow CH_3COO^- + 3H2 + H^+$

4.**Methanogenesis:** In this final step methane is formed by methanogenic bacteria metabolize acid, alcohols, carbon monoxide, carbon dioxide and hydrogen into Methane. The methanogenic bacteria are sensitive to the environment as they only work in a strict anaerobic condition.

$CH_3COOH \rightarrow CH_4 + CO_2$

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

$2CH_3CH_2OH + CO_2 \rightarrow CH_4 + 2CH_3COOH$

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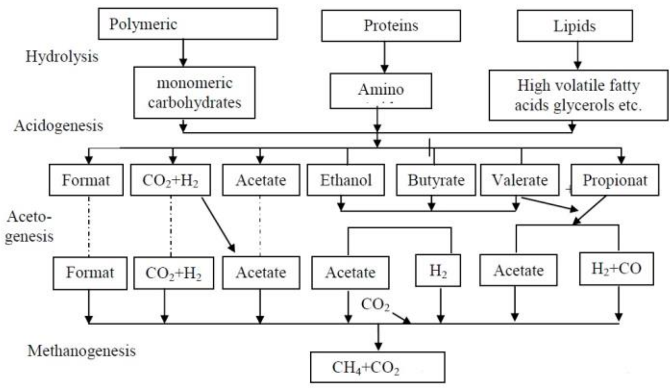

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2.5 Factors affecting anaerobic digestion

Temperature: As anaerobic digestion is a biological process, it is strongly influenced by environmental factors. Temperature, pH and alkalinity and toxicity are primary control factors. Controlled digestion is divided in psychrophilic (10-20 ºC), mesophilic (20-40 ºC), or thermophilic (50-60 ºC) digestion.

pH: Methane-producing microorganisms are very sensitive to the environment pH. The best range for PH for biogas production is between 7 & 7.2. If pH reduces to lower than 6.6, it will have a significant negative impact on methane production and pH of less than 6.2 is very toxic and dangerous for methane bacteria.

Ratio of Carbon to Nitrogen: The carbon to nitrogen ratio in initial organic composition of materials is effective on the methane percentage. The ideal C:N ratio required by bacteria is 25 to 30. When this ratio increases, nitrogen is finished earlier than carbon and the remaining carbon acidifies the environment. On the other hand, when this ratio decreases, nitrogen leaves the environment as ammonia gas and causes an alkaline state, and the gas production stops due to the lack of carbon.

Solid Concentration: Organic materials need to become diluted to be able to be absorbed by bacteria. The best concentration of materials for anaerobic fermentation process in biogas tanks is about 7 to 9% of solids. Increasing the concentration of materials causes adhesion and inhibits the bacterial growth, and reducing the concentration would result in a layered solution that requires constant stirring.

2.6 Types of Anaerobic Digestion

Systems used to digest solid waste are classified according to the percentage of Total Solids (TS) in the waste stream:
1.15-25% low solids anaerobic digestion: wet fermentation
2.>30% high solids anaerobic digestion: dry fermentation

IV. DESIGN & PLANNING

1. Selection of Site and Location

For the designing of the sludge biogas plant, we have taken the statistics and location of village Dahegaon, Near Guru Nanak Institute of Technology, Nagpur in the state of Maharashtra, India. If the model is taken into consideration for design, please note that the model can be a central sludge-biogas plant with the cluster of approximately 3-4 villages.

2. Design of STP Units

2.1 Population Forecasting of the Site

The population of Dahegaon for the year 2011, was 1410. The design period for the plant is 30 years. We are taking an annual growth in population of 50 people. By using Arithmetic Increase Method, the population for the year 2020 is:

$P_n = P_o + nx$

$P_{2020} = P_{2011} + nx = 1410 + 9\times50$

$P_{2020} = 1860$ people

After 30 years,

$P_{2050} = P_{2020} + nx = 1410 + 9\times50$

$= 3360$ people

Hence, the forecasted population for the design period of 30 years is 3360 people.

2.2 Calculation of Sewage Generation

The water supplied per capita = 100 lpcd

Average water supplied per day = 3360 × 100
= 336000 l
= 0.336 MLD
= 336KLD or m^3/day

Average sewage generation per day = 85% of water supplied = 0.85 × 0.336
= 0.2856 MLD
= 285.6 m^3/day
= 11.0 m^3/hectare

Maximum sewage generation per day = 285.6 × 3
= 856.8m^3/day
$= \frac{856.8}{24\times60\times60}$
$= 9.9\times10^{-3}$
= 35.7 m^3/hectare

UNIT 1: Receiving Chamber

The detention time for the sewage is taken as 4 hours

Hence, volume required=max. sewage generation × detention time =35.7×4

=142.8 m^3

Take depth of the receiving chamber as 5m and assume freeboard as 0.5m

∴ Depth of tank=5+0.5=5.5m

Area=$\frac{Volume}{Depth}$=$\frac{142.8}{5}$=28.56

L:B=2:1

Area=Length × Breadth

28.56=2 × B^2

B=3.9m

L=7.8m

Check:

Volume designed=L×B×D

$V_{designed}$=7.8×3.9×5

=152.1 m^3

$V_{designed} > V_{required}$ (safe)

∴ Dimensions of Receiving Chamber=7.8m×3.9m×5.5m

UNIT 2: Coarse Screen Bar

The following points need to be kept in mind while designing the unit:

- The screen chamber must have sufficient cross-sectional opening area to allow passage of sewage at peak flow rate should be 2.5 to 3 times the average hourly flow rate.
- The screen must extend from the floor of the chamber to a minimum of 0.3 m above the maximum design level of sewage in the chamber under peak flow conditions.

Peak discharge of sewage=35.7m^3/hr

The average velocity should not exceed 0.8m/s

Take detention time=6 min

Volume=peak discharge of sewage (per min)×time

=$\frac{35.7}{60}$ × 6=3.57m^3

Take depth=1m

Volume=Area × Depth

Area=3.57m^2

2B×B=3.57 (L: B=2:1)

∴B=1.35m & L=2.7m

Bar screen size=1×1.35×2.7

Bar dimensions=75mm×10mm (10mm in the direction of flow)

The clear spacing of bars is 30mm at 60˚ inclination

Q_{max}=9.9×$10^{-3}$$m^3$/s

At peak flow, the net incline area required=$\frac{9.9\times10-3}{0.8}$=0.0124$m^2$

Gross inclined area=0.0124×1.5

=0.0186m^2

Gross vertical area required=0.0186×sin60˚

=0.161m^2

Submerge depth=0.7m, width=0.055≅0.10

Head loss for sewage water=h_L=0.1 to 0.4m

Clear opening between bars=300mm=0.3m

Clear Area=$\frac{0.0124}{1.6\times sin60°}$=0.00895 (1.6m/s is the max. velocity)

Provide 20 bars in chamber of size 1×1.35×2.7 @20mm clear opening with length of the chamber as 60cm

UNIT 3:

1. Design of Grit Chamber

Peak flow discharge=0.0099m^3/s

Assume average detention period=360s

Aerated volume=0.0099×360

=3.564m^3

In order to drain the channel periodically for routine cleaning, two chambers are used

Volume of an aerated chamber=$\frac{3.564}{2}$

=1.782m^3

Assume depth as 3m & width to depth ratio as 2:1

Width of channel=2×3=6m

Length of channel=$\frac{1.782}{3}$ × 6

=3.56m≅3.6m

Increase the length by about 20% to account for inlet & outlet

Provide length=3.6+0.72

=4.32m≅4.3m

Hence, the dimensions for grit chamber is 4.3m$\times 6m \times$ 3m

2. Design of Skimming Tank

The required surface area of the tank is,

A=$6.22\times10^{-3}\times\frac{q}{Vr}$

Where, q=rate of flow of sewage in m^3/day

V_r=minimum rising velocity of the oily material to be removed in m/min

q=$0.0099\times 60 \times 24$ =855.36m^3/day

V_r=0.25m/min=0.25×60×24=360m/day

A=$6.22\times10^{-3}\times\frac{855.36}{360}$

=$0.014m^2\cong0.001m^2$

Provide depth of skimming tank as 1.5m and the length: breadth ratio as 1.5:1

L=1.5B

L×B=$1.5B^2$

0.001=$1.5B^2$

B=0.08m, L=0.12m

The size of the skimming tank is 0.12m×0.08m×1.5m

UNIT 6: Design of Fine Screen

Design flow=0.0099m^3/s or 35.7m^3/hr

An inclined bar screen is provided with 5-10mm opening having Width 15mm & Depth 50mm. The degree of inclination provided is 40˚ having maximum velocity of 0.8m/s.

Average area required=$\frac{0.0099}{0.8}$=0.0124m^2

Depth=50mm=0.7m+0.5(Freeboard)=1.2m

SWD=0.7m (Peak velocity=1.4m/s)

Clear area=$\frac{0.0099\times1.4}{sin40°}$=0.022$m^2$

Clear opening=6mm=0.006m

No. of bars=$\frac{0.022}{0.006} = 3.66 \cong 6$

Width of channel=(6×6)+(7×9) =36+63=99mm=0.099m

Therefore, the size of the screen is 0.099m×1.2m

1. Primary Sedimentation Tank

Average Design flow=285.6m^3/day

Detention time=2hrs

Volume of sewage=$\frac{Max.Quantity\ of\ sewage}{Detention\ time}=\frac{285.6}{24\times2}$

Volume=5.95m^3

Provide depth=2m+0.5(freeboard)=2.5m

Surface area=$\frac{Volume}{Depth}=\frac{5.95}{2}$=2.975$m^2$

Dimensions of the circular tank:

Area=$\frac{\pi}{4}\times d^2$=2.975m

d=1.95m

Dimensions of tank are 1.95m×2.5m

2. Design of Aerator

Design flow=9.9×10^{-3}

For ASP unit, we know that

Initial BOD=180mg/l

Final BOD=13mg/l

Efficiency=$\frac{180-13}{180}\times 100 = 92\%$ (safe when between 82% to 92%)

We have $F/_M = 0.3$ & MLSS=2000mg/l

So, $\frac{F}{M} = \frac{Q\times Vo}{V\times xt}$

Where, Q=856m^3/day, V_o=180 & x_t=2000mg/l

0.3=$\frac{856\times180}{V\times2000}$

∴Volume (V)=256.8m^3

Check for HRT (Hydraulic Retention time):

$$t = \frac{V}{Q} = \frac{256.8 \times 24}{856} = 7.2hrs$$

Check for Volumetric Loading Rate:

VLR=$\frac{0.856\times0.180}{0.2568}$=0.6kg/day/$m^3$

Return Sludge Ratio:

Assume, SVI=Sludge Volume Index=100ml/g

r=$\frac{Qr}{Q}=\frac{xt}{\frac{10\wedge6}{SVI}-xt} = \frac{2000}{\frac{10\wedge6}{100}-2000} = 0.25 = r$

Check for Solid Retention Time:

V×x_t=$\frac{\propto y.Q(Yo-Yc)}{1+Ke\times\theta c}$

$V=256.8m^3$, $x_t=2000$, $K_e=0.66$, $Y_o=180mg/l$, $Y_c=13mg/l$, $\alpha_y=1$, $Q=856m^3/day$

$256.8\times2000=\frac{1\times856(180-13)}{1+0.66\times\theta c}$

$\theta_c=23days(safe)$ (10-25days is within period)

Tank Dimensions:

Let d=3m, b=4.5m

Total depth of aeration tank$=\frac{V}{bd}=\frac{256.8}{4.5\times3}$

L=19m

Providing 2 baffled wall which creates 2 sections

Length of each tank$=19/3=6.34m$

Provide thickness of baffle=0.2m

Total width=(3×6.34)+(3×0.2)=19.62m

Depth=3+0.5(freeboard)=3.5m

For air required, assume $100m^3/day/kg$ of BOD required

Air required=0.856l/day×(180-B)×100

Air required=$9.93m^3/min$

UNIT 7: Design of Secondary Sedimentation Tank

The main criterion for clarification of the mixed liquor in the clarifier is the cross-sectional area of the clarifier. Clarifier cross-sectional area is kept between 12 – 18 $m^3/hr/m^2$ of thorough flow of sewage. For small domestic STPs, 16 may be taken. The depth of clarifier is kept between 2.5 to 3m.

No. of clarifiers=1

Average flow=$285.6m^3/day$

Recirculated flow, say 50%=$142.8m^3/day$

Total inflow=285.6+142.8=$428.4m^3/day$

Provide hydraulic detention time=2hrs

Volume of tank$=428.4\times\frac{2}{24}=35.7m^3$

Assume liquid depth=3.5m

Area$=\frac{35.7}{3.5}=10.2m^2$

Surface loading area of average flow$=\frac{285.6}{25}$

$=11.42m^2\cong 11.5m^2$

Provide the greater value

∴Diameter of circular tank(d)$=\sqrt{\frac{11.5\times4}{\pi}}$

$d=3.827m\cong 4m$

Actual area provided$=\frac{\pi}{4}\times4^2$

$=12.56\cong 13m$

Check for weir loading:

Average flow=$285.6m^3/day$

Weir loading$=\frac{285.6}{\pi\times4}$

$=22.727\cong 23m^3/day/m$

It's ok, as it is less than 185 $m^3/day/m$

Check for solid loading:

Recirculated flow=$856m^3/day$

Average flow=$285.6m^3/day$

MLSS solids flow=2000mg/l

Total solids inflow=(285.6+142.8)×2

=856.8kg/day

Solid loading$=\frac{856.8}{11.5}=74.504kg/day/m^3$

Provide a clarifier of 4m dia having liquid depth as 3.5m

Hopper slope shall be 1:12

Freeboard is taken as 0.3m

3. Design of Biogas plant

UNIT: Design of Digester

$V_d=S_d\times R_T$

S_d (Substrate input)=(biomass(B)+water(W)) m^3/d

Mixing ratio=1:3

Total animals=632

Cows=200, Buffalo=100, Goat=100, Cock & Hen=100, Birds & small animals=50, Pigs=50, Dogs=32

Sewage sludge=100 l/kg

Substrate	Quantity	Volatile Solids
Cow dung	600kg/day	$85.2 m^3/day$
Buffalo dung	300kg/day	$41.57\ m^3/day$
Poultry dung	10kg/day	$3.69\ m^3/day$
Pig manure	50kg/day	$10\ m^3/day$
Sewage sludge	50kg/day	$240\ m^3/day$
Total		**380.7 kg/day**

$S_d=4.5\ m^3/day$
$V_d=S_d \times R_T$
$V_d=4.5\times40days$
$V_d=180\ m^3$
By fluctuation we get
$V_d=234\ m^3$
Digester Loading,
$L_{dT}=\frac{Ts/d}{Vd}=\frac{4000}{234}=17.09kg/m3/day$
Specific gas production (G_p)
$G_p=G/V_d$
$G=\frac{\gamma \times Vd \times S}{1000}$
From table, $\gamma=4.75$, $V_d=240\ m^3$
Total feedstock volume=$4m^3$
Feedstock retention time = $\frac{Digester\ volume}{Total\ daily\ feedstock\ volume}=\frac{234}{4}=58.5 \cong 60days$
Digester Loading, $L_{dT}=kg/m^3/day$
$G=m^3/day$ or $G_h=4.39m^3/hr$
Sizing of the gas holder:
60% of 105.59=$\frac{60}{105.59}\times 105.59$
Capacity=$63.354\ m^3/day$

V. RESULTS & DISCUSSION

This research is carried out for the better understanding of present condition and to improve the aspect technically for the betterment in future aspect. By conduction of this study & analysis of data following result has been made based on experimental investigation and research.

- Making the water suitable for agricultural purposes by removal of contaminants and toxins
- Production of approximately 60%-70% biogas.
- Production of natural fertilisers from biogas at low cost.
- Provided healthy & hygienic environment for villagers.
- Sufficient availability of biofuel for domestic purposes.

This is an attempt to combine several of environmental, biological and chemical and civil engineering.
The plant is designed perfectly to meet the future expansion for the next 30years in accordance with the Indian Codal provision. This project consists of the design of the complete components of a Sewage Treatment Plant and Biogas, that is, receiving chamber, screening chamber, grit chamber, skimming tank, sedimentation tank, secondary clarifier, active sludge tank & sludge drying beds for sewage and gas holder, mixing tank and digester for biogas plant.

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