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DESIGN AND FARICATION OF A MODEL SEWAGE TREATMENT SYSTEM WITH OIL SEPERATOR AND RBC

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Abstract- *Now a days many water resources are polluted by anthropogenic sources including household, agricultural waste and industrial processes. The level of water scarcity is different depending on the region of the world with the amount and type of contaminants found in water bodies will rely on the different industrial activities realized in the area, the urban development and the type of treatment facilities found around it. Several conventional wastewater treatment techniques have been applied to remove the pollution however there are still some limitations especially that of high operation costs. This paper reviews the use of waste water treatment technologies & investigate the potential of proposed system with an addition of floating oil separator & RBC which represents an efficient alternative to either conventional sewage or on-site wastewater treatment/disposal technologies.*

Keywords: Anthropogenic, Water scarcity, Wastewater treatment, RBC, Oil Separator.

1. INTRODUCTION

From the last few decades, the amount of wastes generated by human population became insignificant due to population densities coupled with the fact that there are very high exploitation in natural resources. Common wastes produced during early ages were mainly ashes and human and biodegradable waste and these were released back into the ground locally, with minimal environment impact. Notwithstanding the rising quality of life and high rates of resource consumption patterns have an unintended and negative impact on the urban environment. As a fact cities are grappling with the problems of high volumes of waste as well as the impact of waste on the local and global environment. The reason is that the important sector like public health has been left alone when major upgrading projects improved the water supply systems in many countries and provinces. Two reasons appear to be the major cause firstly, wastewater collection and treatment is costly and their benefit often hard to show; and secondly, even if low-cost solutions are being implemented many projects fail to deliver the expected outcome. Here either the technology was not appropriate, so the beneficiary was not involved or the responsibilities within government were not resolved to ensure the necessary support. In a second world country like Bangladesh it is expected that small scale wastewater treatment system with certain conditions are the solution for these problems. So here this project aims to introduce an effective small scale treatment process which is less complex, cost effective, technology appropriate & the beneficiary involved under certain circumstances. While it is hard to resolve the problem of government responsibilities for practitioners in the sanitation engineering field, the problem of non-delivery may be relieved through ensuring beneficiary project planning and implementation.

2. SCOPE AND OBJECTIVE

In this paper, the proposed project has been designed to introduce an effective and economic treatment system so its validity and effectiveness is studied over existing one. This paper illuminated the energy regeneration scope & identify conditions under which a certain number of biomass & waste oil can be recovered from sewage which could be refined for reuse. So here the project is trying to develop an idea with available conditions which may be an efficient alternative to costly conventional sewage or on-site wastewater treatment/disposal technologies. So here I have tried to investigate the potential of proposed system by treating wastewater containing household & industrial by products.

3. CONVENTIONAL WASTEWATER TREATMENT SYSTEM

The implementation of suitable methods for the disposal of wastewater dates back to the times of Roman civilization. However, it was only in the later part of the 19th century that a spurt of activity in the realm of wastewater treatment took place. The growth of the human population, urbanization and industrialization necessitated the treatment of wastewater [1]. It became evident that the untreated wastewater which was discharged directly into water bodies caused pollution and posed health hazards. A lot of research followed in the late 19th century and led to the development of the biological treatment process using aerated suspended biomass, known as activated sludge process (ASP) [2]. This was adapted for large-scale treatment applications and involved separate aeration and recirculation mechanisms. In 1923, Los Angeles became one of the first big cities to use an activated sludge process in its wastewater treatment plant [3]. Then there are several other methods developed one after another to meet the requirements of treating waste with growing civilization such as oxidizing beds, constructed wetlands, membrane bioreactors, lagoon system & many more.

4. PRPOSED METHOD

In this proposed project the mentioned processes are done by three stage treatment considering filtration & sedimentation, Oil separation & RBC treatment. From 'figure 1' it is clear that we have used some basic screening & filtration mechanism for the primary stage which deals with debris and solid material. The purpose of it is to remove those separable components before further treatment of sewage provided. The second stage is an energy recovery process. Here the floating oil from the surface of raw water is separated & collected by means with a rotating impeller for further refining & reuse which is done by a rotating oil separator. Then in RBC treatment the organic material that remains in the wastewater is reduced biologically. RBC treatment actually involves harnessing and accelerating the natural process of waste disposal whereby bacteria convert organic matter to stable forms. The aerobic processes plays the vital role here to boost up the process in presence of access oxygen & sunlight. Followed by the polishing process where treated effluent is further purified to acceptable levels for discharge e.g. nitrogen or phosphorus or specific industrial pollutants by open UV ponds.

Where in conventional sewage treatment system requires much costly infrastructure with high precision technological advancement, proposed method aims to the suitable technology with economical beneficiary involved. The major advancement of proposed system over conventional is that it recovers two types of energy from same amount of waste water where consuming less space with RBC method than conventional lagoon system. Running cost of proposed method is also a very crucial criteria over conventional systems as less maintenance cost required due to suitable technology.

Fig.1: Model of proposed plan with Rotating Biological contactor

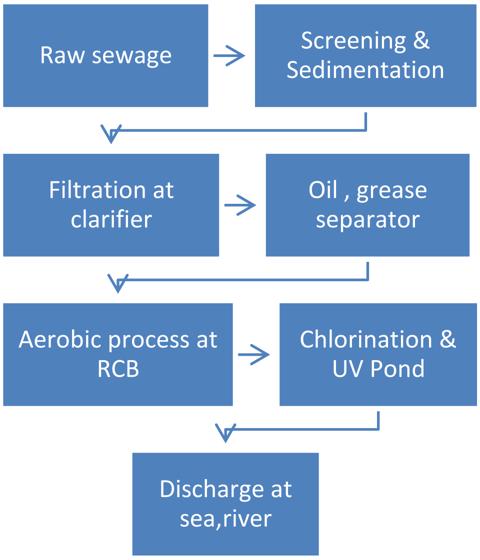

Fig.2: Flow diagram of proposed treatment method.

4.1 Filtration & sedimentation

It is mainly the removal of solids by settlement. Simple filtration & settlement of the solid material in sewage can reduce the polluting load by significant amounts. It can reduce BOD by up to 40%. Usually BOD is measured as BOD5 meaning that it describes the amount of oxygen consumed over a five-day measurement period [4]. Suspended Solids describes how much of the organic or inorganic matter is not dissolved in water and contains settle able solids that sink to the bottom in a short time and non-settle able suspended solids. It is an important parameter because Suspended Solid causes turbidity in the water causing clogging of filters etc. [5]. This is usually performed by screening (usually by bar screens) and grit removal. Their removal is important in order to increase the effectiveness of the later treatment processes and prevent damages to the pipes, pumps and fittings.

4.1.1 Screening

A fine mesh of screen acts here for separating the larger pieces of solids for e.g. diapers, cloth, etc. in wastewater. Screens require cleaning at very short intervals. Materials captured through screening collected in a place to be separated as biomass for disposal in biogas plant.

4.1.2 Sedimentation

Separated solids settle by gravity, predominantly through sedimentation. Coarse and heavy particles settle within a few hours while smaller and lighter particles may need days to sink to the bottom. A sedimentation tank is there to collect them.

4.1.3 Filtration

Filtration done for removing suspended solid particles that cannot be forced to settle or float within a reasonable time. The filters have a double function, they provide a fixed surface for treatment of bacteria and they form a physical obstacle for the smaller solid particles by creating adhesion of particles to their surfaces. Filtration here is downstream. Filters allow the wastewater to descend in a downward direction through the filter material. The speed at which filtration occurs depends on the shape & size of clarifier.

4.1.4 Oil Separator

It is a unique advance idea of separating extra floating oil particles to a nominal level by using the principle of force draft mechanism. Here an impeller is introduced with a submergible motor in a separator tank at a standard level. When the water surface reached the impeller level, the impeller start to rotate with a fixed rpm. The rpm varies with the density of processes water. As due to chemical property oil & water doesn't get mixed together so oil always float at the water surface. So when the impeller rotates it splash the upper surface of sewage water with floating oils. A collector shell collects the water mixed oil & store it for further separation. Thus after refining a good amount of oil can be restored from waste one for reuse. As the upper level separated with floating oil & grease particles now the remaining water is good to go for further treatment.

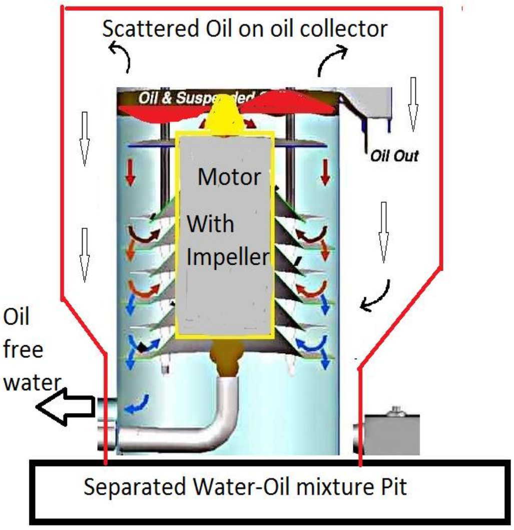

Fig.3: Schematic diagram of water-oil separator [6].

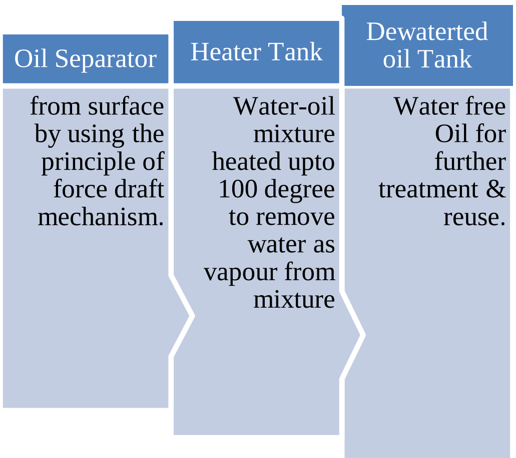

Fig.4: Flowchart of Oil separation process.

Fig.5: Model of proposed water-oil separator.

Table 1: Separated oil mass vs. rpm of impeller vs water density with inlet water mass at 30 degree Celsius.

Experiment	Separated Oil mass(gm)	Impeller rpm	Inlet Water mass (gm)	Water Density ρ (kg/m^3)
Data 1	175	2200	2500	998
Data 2	222	1500	2500	998
Data 3	231	1800	2500	998
Data 4	155	1200	2500	998
Data 5	181	2200	2500	994
Data 6	228	1500	2500	994
Data 7	236	1800	2500	994
Data 8	159	1200	2500	994
Data 9	183	2200	2500	992.5
Data 10	230	1500	2500	992.5
Data 11	238	1800	2500	992.5
Data 12	161	1200	2500	992.5
Data 13	184	2200	2500	992
Data 14	232	1500	2500	992
Data 15	240	1800	2500	992
Data 16	162	1200	2500	992

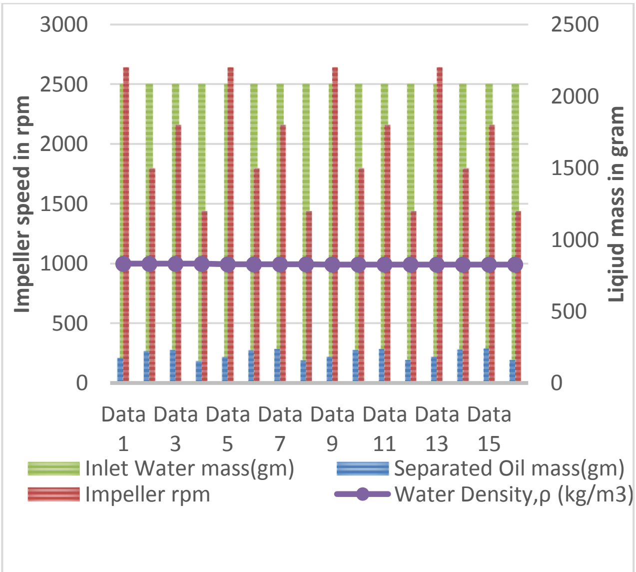

Fig.6: Separated oil mass vs. rpm of impeller vs water density with Inlet Water mass at 30 degree Celsius.

'Figure 5' represents the amount of separated oil, grease particles from process water surface of various density with varying speed of impeller. Here it seems that when the impeller speed is minimum the amount of separated oil is less. At same impeller diameter with increasing speed the amount of separated oil particle also increased. But above a certain speed the amount of oil decrease. This speed depends on the density of fluid. Amount of separated oil is maximum when density of sewage is minimum.

This stage is energy recovery process where the waste oil is separated & recovered for further use as energy source. This separated oil could be reused in industrial sectors after proper heat treatment & distillation. So this process not only separates the oil from waste water to treat it but also generate a great scope to recover a part of waste energy for economically beneficial interest.

4.2 Rotating Biological Contactor

The rotating biological contactor (RBC) is a unique adaptation of the aerobic process in moving-medium for the growth biofilm system which offers an alternative technology to the conventional aerobic treatment process. It is form of several corrugated discs with biofilm attached to the surface are mounted on a common shaft partially submerged in the wastewater and rotated through contoured tanks in which the wastewater flows on a continuous basis. The principal advantage of the RBC system stems from its high oxygen transfer efficiency which provides greater economy in the long run compared to other processes employing surface aerators or diffusers. It is operationally very economical and efficient at low power consumption values. Though RBC systems are inclined to be sensitive to temperature, and involve capital costs initially, they have proved to be very efficient systems with excellent sludge quality and pH adjustment in the secondary clarifier [7]. Estimations reveal that RBCs require about 40-50% of the energy requirements of an activated sludge system [8] and 70-80% of a Trickling filter system. The first instance of the use of RBC as a biofilm remediation technology is documented in 1928 [9]. There are several different designs available today world-wide depending upon specific requirement criteria. More than 16% of all wastewater treatment plants in Switzerland and nearly 31% of the small treatment units with a capacity of the equivalent of a population of 5000 are RBCs.

Here from figure 6 it is seen that, I have used the simple mechanism of rotating disc on a shaft drowning 60% under medium surface. A motor is used to rotate the shaft along with disc so that each baffles of disc can get sufficient environment for aerobic process. A supplementary air blower is attached to meet the additional oxygen requirement of the tank medium.

4.2.1 pH correction in RBC system

Oxygen remains as one of the most limiting substrates in biofilm treatment, and the deeper and faster the oxygen diffusion is inside the biofilm, the better the aerobic treatment. The advantages of this system are extremely low cost for mixing and high oxygen provision [10]. The repeated rotation of the disc media by the shaft not only supplies oxygen to the micro-organisms in the biofilm but also to the suspended biomass in the bulk liquid. The discs made of plastic and are contained in a trough so that about 40% of their area is typically immersed in wastewater. They are arranged in groups with baffles in between them to reduce surging or short-circuiting [11]. Here RBCs are designed and operated in a series of stages, ranging from three to four stages, separated by baffles [12]. As the first stage always receives the highest organic loading and provides maximum organic removal efficiency, the latter stages are used for nitrification as well as residual organic carbon removal. After the fourth stage, improvement of organic removal is insignificant. To protect the biofilm from exposure to temperature extremities and heat loss and to prevent the growth of algae, RBC units are always kept covered. It is also important to protect the plastic discs from direct exposure to UV rays and weather [12]. Here this design is used especially for denitrification effects & pH correction [13]. The most influential parameters controlling biofilm growth and decay are wastewater temperature, oxygen supply, organic and hydraulic loading rates [14]. Here the technical parameter (pH) of treated water measured to identify the effectiveness of RBC. A portable pH meter (PHS-25, China) is used with a time period of 22 days.

Table 2: Day wise pH correction data in RBC at different temperature.

Time (day)	**Temp T1, (°C)**	**Water pH**	**Temp T2,(°C)**	**Water pH2**
Day1	30.4	9.2	22.8	9.2
Day2	30.6	9.2	22.7	9.2
Day3	30.7	9	22.8	9.2
Day4	30.5	9.02	22.9	9.1
Day5	30.6	8.92	23	9.1
Day6	30.1	8.88	23.2	9.05
Day7	30.3	8.43	23.1	9.02
Day8	30.6	8.12	23	9
Day9	30.4	8.05	22.8	9
Day10	30.2	7.83	22.7	8.9
Day11	30.2	7.2	22.6	8.6
Day12	30.1	7.03	22.5	8.5
Day13	30	7.01	22.6	8.3
Day14	30.2	7.01	22.7	8.1
Day15	30.1	7.01	22.8	8
Day16	30.1	7.01	22.7	7.8
Day17	30	7.01	22.5	7.6
Day18	30.2	7.01	22.6	7.4
Day19	30.2	7.01	22.8	7.1
Day20	30.2	7.01	22.7	7
Day21	30.1	7.01	22.9	7
Day22	30.3	7.01	22.8	7

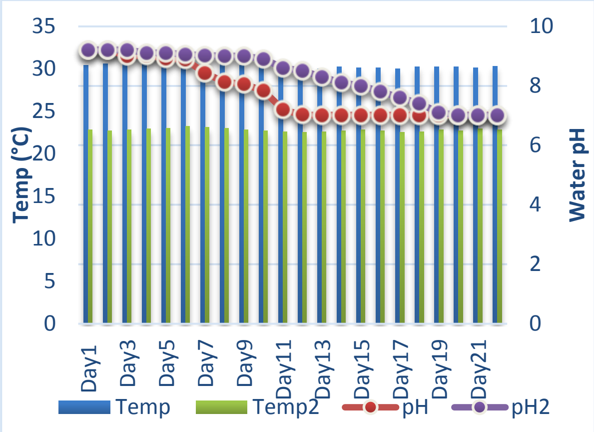

Fig.6: Day wise pH correction data in RBC at various temperature.

From 'figure 6' it is clear that for a warmer temperature (30-31 °C) pH correction takes only 10-11 days RBC treatment to reduce the pH value of water from 9.2 to 7.01. On the other hand for a lower temperature (22-23 °C) after 10 days the pH value still 8.9 for the same amount of waste water. Moreover at that temperature it took additional 8-10 days to lower the pH value from 8.9 to 7.01. So in conclusion we can say that a warmer environment with additional air supply is required to complete the RBC cycle on time for pH correction.

4.3 UV pond

It is the polishing process whereby treated effluent is further purified to acceptable levels for discharge. It is usually done for the removal of specific pollutants e.g. nitrogen or phosphorus or specific industrial pollutants [16]. UV pond treatment processes is used here as last treatment processes. Pathogens present in many forms in water e.g. bacteria, viruses and protozoa. They accumulate in the sediment sludge and are largely retained inside the treatment system where they stay alive for several weeks. Most bacteria and viruses caught in the sludge die after shorter periods. Those bacteria, which are not caught in the sludge but remain suspended in the liquid portion, are hardly affected, meaning, these bacteria and viruses exit the plant fully alive [17]. Exposure to UV rays has a substantial hygienic effect. High pathogen removal can also be experienced in shallow ponds with long retention times.

5. OUTCOME

(a) Oil recovery

Mathematical expression for oil recovery percentage calculation

$$\frac{Mass\ of\ Oil\ separated}{Mass\ of\ inlet\ waste\ water} = \%\,\frac{Oil\ recover\ from\ sewage}{100} \qquad (1)$$

According to Table no. 1 amount of reusable oil recovered from sewage water accordingly 184gm, 232gm, 240gm &161 gm where the volume of inlet raw sewage is 2500 gram at different density.

By using Eq. (1), we get the oil recovery percentage is 7.36%, 9.28%, 9.6% & 6.5% accordingly. Oil recovery is maximum when the influent concentration is less & impeller speed is in moderate range (1500-1800rpm). At a high or lower impeller speed as 2200 or 1200 rpm the rate of oil removal decreases for same density of waste water. So before oil separation stage it is necessary to separate the small dissolved or floating particle to lower the sewage density so to get the maximum oil recovery. From above outcome it is clearly visible that approximate 9.6gm oil have been recovered from 100gm of waste water. Usually the grade of oil changes after its usage in industry, so this recovered oil could be a good source with some refining & grade adjustment treatment. With this oil recovery stage not only we are getting a reusable energy source but also treating the waste water from industrial oil. By further treatment & distillation of these recovered oil in oil refineries a good amount of energy could be restored. Moreover this recover energy source could be a part of turning table of nation's economy.

(b) Temperature effect on pH correction

This experiment aims to develop an alternative of conventional aerobic process which is less time consuming & also economically beneficial. Factors affecting treatment of a RBC process includes the kind of wastewater, influent concentration, RBC reaction time, and temperature. From table no. 2 & 'Figure 6' it is visible that the pH correction of waste water for same concentration take a long time, 21-23 days at a lower temperature (22-23 °C) where at a higher temperature (30-31 °C) the time requires 11-14 days. This is due to that the rotating baffles causes sufficient sunlight & oxygen to come at the biofilm surface which boost up the aerobic reaction process time. Thus with the help of a warmer environment the lead time can be reduced & more effluent could be treated. Here the time span is crucial because it shorten the process time which will make this process more efficient as well as cut the running cost with economically beneficial output. Once the pH adjustment is done then the treated water is ready to go for discharging in UV ponds. Once the pH adjustment done then the treated water is ready to go for discharging in UV ponds.

(c) Energy recovery in biogas plant

The separated waste products & sludge at primary treatment stage by proposed sewage treatment system is a large source of raw material for bio gas plants [18]. Biogas technology cannot only provide fuel, but is also important for comprehensive utilization of biomass forestry, animal husbandry, fishery, agricultural economy, protecting the environment, realizing agricultural recycling, as well as improving the sanitary conditions, in rural areas. As the material breaks down, methane (CH4) is produced [19]. This energy source could be used in various field of our developing economy, in some cases tapping this potential source of fuel to power gas turbines, thus generating electricity.

6. CONCLUSION

In this paper, we studied the effect on disposal of residual waste liquid from household & factory with proposed treatment plant and examined the influence of some process variables.

This project tried to focus on simplicity of technology & economic beneficiary thus implementation as well as sustainability can be achieved. A simple separator & filter arrangement is used to separate a good amount of organic matter from it which could be a large source of raw material in biogas plant. The proposed oil separator can achieve up to 9.60% oil recovery from waste oil at ambient temperature of 28°C to 32°C where impeller speed & water density are major factors. Proposed RBC technology reduces organic concentration significantly which is advantageous on traditional lagoon treatments. Compared with lagoon treatment method or traditional other methods, RBC can significantly decrease treatment cost for its less space requirement, less time consumption & technical suitability. Data observations show that the pH correction of waste water take less time at normal ambient temperature when it takes long time at a low temperature. Developing countries like ours where the usage of renewable energy is so low due to costly investment, proposed type of plant with oil recovery system could be a remarkable achievement as energy source. Moreover the separated biomass from primary stage also be a good source to produce biogas in small plants where space & cost are major concern. In densely populated country like ours where water scarcity is a curse we have to create some breathing space under these immense pressure of population growth & industrialization. This could only be done if a plant meet both the requirement of effective treatment and economically beneficial requirements. Thus in recent future many other private farms will also march forward along with government aid to setup such efficient plants & make the world green again.

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8. NOMENCLATURE

Symbol	Meaning	Unit
M	Mass	(Kg)
ρ	Density	(kg/m3)
S	Speed	Rpm
T	Temperature	(°C)
gm	Mass in gram	-
pH	Potential of Hydrogen	-