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A Study on Upflow-Anaerobic Sludge Blanket (UASB) Reactor in Comparison with Conventional Activated Sludge Reactor

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ABSTRACT

In this research work, Upflow-Anaerobic Sludge Blanket (UASB) reactor was compared with the conventional Aeration reactor. The UASB reactor had recovered the energy from sewage. The UASB process reduces the volume of the tank and also reduces the size of the plant. The total power requirement of the plant was 2800 kWh per day for the design flow of 8.70 MLD. Though the space requirement is quite comparable to the conventional digestor, it enables quicker sludge digestion. Moreover, biogas produced as a by-product can be used to produce electricity.

Keywords: Activated sludge process; Disposal plant; Effluent; Sewage; UASB reactor.

1. INTRODUCTION

The Sewage Treatment Plant is a facility built to receive the waste from domestic, industrial and commercial sources and to eliminate material that damage water quality and compromise public health and safety when discharged to water receiving systems. Sewage is a system of industrial and domestic wastes. It is more than 99% water, but the rest contains a number of ions, suspended solids and harmful bacteria to be eliminated, before the water is released into the sea. Sewage is generated by the residential, commercial and institutional and industrial establishments. It has household waste liquid from toilets, showers, kitchens, sinks, etc. which are disposed through sewers. The draining and separation of household waste to greywater and blackwater are becoming more common in the developed world, together with greywater being allowed for use for watering plants or recycled for flushing toilets. Sewage may include storm water runoff. Sewerage systems capable of handling storm water are called Combined sewer systems. Combined sewer systems are usually avoided now because precipitation causes widely varying flows decreasing sewage treatment plant efficiency. Combined sewers require much large and more expensive treatment facilities compared to sanitary sewers. Heavy storm runoff may overwhelm the sewage treatment system, resulting in a spill or overflow. Sanitary sewers are usually much smaller compared to combined sewers, and they aren't designed to transport stormwater. Backups of raw sewage may happen if excess infiltration/inflow is allowed into a sanitary sewer system. Modern sewer developments are provided with separate storm drain for rain. As rain travels over roofs and the ground, it might pick up different contaminants, including soil particles and other sediments, heavy metals, organic compounds, animal wastes, oil and grease.

2. LITERATURE STUDY

Daud *et al.* 2018, studied the treatment of domestic sewage using the UASB reactor as the core component, to identify future areas of research. The merits of anaerobic and aerobic bioreactors were highlighted, and other sewage treatment technologies were compared with UASB on the basis of performance, resource recovery potential and cost. Rizvi et al. 2015, studied the upflow anaerobic sludge blanket reactors seeded with cow dung manure and activated sludge of a dairy wastewater treatment plant to treat raw domestic wastewater of medium strength. The rate of removal of these parameters, however, gradually declined with increasing hydraulic retention time. The UASB technology provides a low-cost system for the direct treatment of municipal wastewater and can be applied in small communities. Kanhaiya Kumar Singh *et al.* 2018, studied the upflow anaerobic sludge blanket reactor seeded with endemic consortia created from municipal wastewater isolates to treat raw domestic wastewater of medium strength. The UASB innovation gives a minimal effort framework to the immediate treatment of municipal wastewater and can be connected in a small fraternity.

3. CHARACTERISTICS OF SEWAGE

The quality of sewage can be assessed and examined by studying its physical, chemical and biological characteristics according to the agreement the expected Raw Sewage Quality along with the agreed Treated Sewage.

Characteristics shall be as follows:

S. No.	Parameter	Strong	Medium	Weak
1	Total solids	1200	700	350
2	Dissolved	850	500	250
3	Suspended solids	350	200	100
4	Nitrogen	85	40	20
5	Phosphorous	20	10	6
6	Chloride	100	50	30
7	Alkalinity	200	100	50
8	Grease	150	100	50
9	BOD	300	200	100

3.1 Physical Characteristics of Sewage

Physical examination of sewage is carried out so as to determine its physical characteristics, including the tests for determining:

(a) Turbidity,
(b) Color
(c) Odor
(d) Temperature

3.2 Chemical Characteristics of Sewage

Test conducted for determining the chemical characteristics of sewage indicates the stage of sewage decomposition and its own strength and type of treatment required for making it secure to the point of disposal.

This includes the tests for determining:

(a) Total solids, suspended solids and settleable solids
(b) pH value
(c) Chloride content
(d) Dissolved oxygen
(e) BOD
(f) COD

3.3 Biological Characteristics of Sewage

The biological characteristics of sewage are due to the presence of micro-organisms which include bacteria and other living micro-organisms such as algae, fungi and protozoa.

4. COMPOSITION OF SEWAGE

For example, if 280,000 cumec of sewage arrives every day, during winter storms this can swell up to 800,000 cumec, of which, 99 % is water. The remainder is mostly organic matter (800-1000 gm^{-3}), which constitutes the bulk of the suspended solids (250-400 gm^{-3}). The biological process which breaks down this organic matter requires oxygen, and the amount of oxygen required is calculated as the waste water's "biochemical oxygen demand" (BOD). Sewage coming into the plant (influent) has a BOD between 200 and 400 gm^{-3} (i.e., 200 to 400 grams of oxygen are required to oxidize each cubic meter of influent). The remaining organic matter consists of fat and grease that form a scum on the surface of the influent. As well as organic matter, small amounts of inorganic ions are also found: The most significant of these are chloride (100-200 gm^{-3}) and sulfide (0.1-0.7 gm^{-3}). Sulfide, despite its low concentration, is of greater concern than chloride because it is very foul-smelling even at this level. The influent generally contains no dissolved oxygen; hence it must be added at various stages of the process to enable the organics to be broken down.

5. PROCESS OF TREATMENT

5.1 Primary Treatment

Pre-treatment removes materials which is easily collected in the raw wastewater before they damage or clog the pumps and sewage lines of primary treatment clarifiers (garbage, tree limbs, leaves, branches etc.).

5.1.1 Screening

The influent sewage water passes through a bar screen to remove all large objects such as cans, rags, sticks and plastic packets, carried in the sewage stream. This is most commonly performed with an automated mechanically raked bar screen in modern plants serving large populations, while in smaller or less-modern plants, a manually cleaned screen might be used. The raking activity of a mechanical bar screen is typically paced according to the accumulation on the bar screens and/or flow rate. The solids are collected and later disposed off in a landfill or incinerated. Bar screens or mesh screens of varying sizes may be used to optimize solids removal. If gross solids are not removed, they become entrained in pipes and moving parts of the treatment plant and can cause substantial damage.

Table 1. ISI Standards for discharge of sewage

S. No.	Characteristics of the Effluent	Limit for sewage effluent discharged as per IS 4764-1973	Limit for Industrial effluents discharge into: Inland surface water as per IS 2490-1974	Limit for Industrial effluents discharge into: Public sewers as per IS 3306-1974
Unit		Mg/l	Mg/l	Mg/l
1	BOD5	20	30	500
2	COD	-	250	-
3	pH value		5.5 – 9.0	5.5 – 9.0
4	Total suspended solids	30	100	600
5	Temperature	-	40C	45C
6	Oil or Grease	-	10	100
7	Phenolic compounds	-	1	5
8	Cyanides	-	0.2	2
9	Sulphides	-	2	-
10	Fluorides	-	2	-
11	Total residual chlorine	-	1	-
12	Insecticides	-	0	-
13	Arsenic	-	0.2	-
14	Cadmium	-	2	-
15	Chromium	-	0.1	2
16	Copper	-	3	3
17	Lead	-	0.1	1
18	Mercury	-	0.01	-
19	Nickel	-	3	2
20	Selenium	-	0.05	-
21	Zinc	-	5	15
22	Chlorides	-	-	600
23	% Sodium	-		60%
24	Ammoniacal nitrogen	-	50	50

5.1.2 Grit removal

Pre-treatment might include a sand or grit channel or chamber, where the velocity of the incoming wastewater is corrected to allow the settlement of sand, grit, stones and broken glass. These particles are removed because they might damage pumps and other equipment. For small sanitary sewer systems, the grit chambers might not be necessary, but grit removal is desirable in larger plants.

5.1.3 Primary sedimentation

At the primary sedimentation stage, sewage flows through big tanks, commonly called "pre-settling basins", "primary sedimentation tanks," or "primary clarifiers". The tanks are used to settle sludge while grease and oils rise to the surface and are skimmed off. Primary settling tanks are often equipped with mechanically driven scrapers that continually drive the collected sludge towards a hopper at the base of the tank, from which it is pumped into sludge treatment facilities. Grease and oil in the floating substance can sometimes be recovered for saponification. The dimensions of the tank should be designed to effect the removal of a considerably higher percentage of the floatables and sludge. A typical sedimentation tank can remove from 50 to 70% of suspended solids and from 30 to 35% of biochemical oxygen demand (BOD) in the sewage.

5.2 Secondary Treatment

Secondary treatment is designed to substantially degrade the biological material of the sewage, which can be derived from human waste, food waste, soaps and detergent. The majority of municipal plants treat the settled sewage liquor utilizing aerobic biological processes. Secondary treatment systems are classified as fixed-film or suspended-growth systems.

5.2.1 Secondary treatment process

Secondary treatment is designed to substantially degrade the biological content of the sewage, which is derived from human waste, food waste, soaps and detergent. The bacteria and protozoa consume biodegradable soluble organic contaminants (sugars, fats, organic short-chain nano-carbon molecules, etc.). Secondary treatment methods are categorized as:

- Suspended growth process (Aerobic & Anaerobic)
- Attached growth process (Aerobic & Anaerobic)
- Both suspended and attached growth processes (Aerobic & Anaerobic)

Table 2. Raw sewage quality

S. No.	Parameter	Value	Unit of measurement
1	BOD	204 to 212	Mg/l
2	COD	177 to 178	Mg/l
3	Total suspended solids	160	Mg/l
4	Total kjeldahl Nitrogen	95-108	Mg/l
5	Ammonia Nitrogen	86-99	Mg/l
6	Total Phosphorous	9-11	Mg/l
7	Sulphate	72-94	Mg/l
8	Fecal coliform	TNTC	MPN/100ML
9	Total coliform	7000 to 10000	MPN/100ML
10	Chlorides	280-320	Mg/l
11	pH	6 to 7.5	Mg/l
12	Oil and grease	42	Mg/l
13	Total dissolved solids	1430-1510	Mg/l

Table 3. Treated effluent quality

S. No.	Parameter	Value	Unit of measurement
1	BOD	20 or less	Mg/l
2	Total suspended solids	30 or less	Mg/l
3	COD	250 or less	Mg/l
4	Ammoniacal nitrogen	Less than or equal to 50 mg/l	Mg/l
5	Total phosphorous	5 or less	Mg/l
6	Total coliform	7000 to 10000	Mg/l
7	pH	5-5.9	Mg/l
8	Oil and Grease	Less than or equal to 5 mg/l	Mg/l

5.2.2 Suspended-growth process

It converts soluble and insoluble organic and inorganic compounds to flocculent and settleable microbial suspension to remove the biomass by gravity. Suspended-growth systems include activated sludge, where the biomass is combined with the sewage and may be operated in a smaller area than trickling filters which treat the identical amount of water. Roughing filters are intended to treat particularly strong or variable organic loads, typically industrial, to allow them to then be treated by conventional secondary treatment processes.

Characteristics include filters full of media to which wastewater is applied. They are designed to allow high hydraulic loading and a high degree of attraction. On larger installations, air is forced through the media using blowers. The resultant wastewater is generally within the normal range for the conventional treatment process.

A filter removes a small percentage of their suspended organic matter, although the vast majority of the organic matter undergoes a change of character, just due to the biological oxidation and nitrification occurring from the filter. With this particular aerobic oxidation and nitrification, the organic solids gets converted to coagulated suspended mass that is heavier and bulkier and will settle to the bottom of the tank. The effluent of this filter is therefore passed through a sedimentation tank, also called a secondary clarifier, secondary settling tank or humus tank. Examples: 1. Aeration tank Oxidation Pond, Oxidation ditch (Aerobic process) and 2. Septic tank, UASB (Anaerobic process).

5.2.3 Attached growth process

It results in the conversion of colloidal, dissolved and residential attached organic matter into stable inorganics. e.g., Trickling filter, Rotating Biological contactor.

5.2.4 Activated sludge process

Generally, activated sludge plants encompass many different mechanisms and processes using dissolved oxygen to promote the growth of biological content, which substantially eliminates organic material. More than 80% of the existing wastewater treatment plants have the activated sludge process in which the suspended bacteria oxidize the carbonaceous and nitrogen compounds so that effluents in accordance with the imposed standards are obtained. The biological process was improved during the last few years. One of these new processes is obtained by the addition of specially designed mobile elements into the aeration tank that provides the carriers for biological growth. This is best applied at extended aeration plants or conventional activated sludge facilities. For this process, an oxygen-deficient zone (typically 15% of the aeration tank volume) is created to allow the activated sludge bacteria to use the nitrate to oxidize waste BOD. From this process, nitrogen gas is created as denitrification occurs.

Advantages

1. Allows good nitrification since COD is uniformly low.
2. Able to handle peak loads and dilute toxic substances.
3. Used in smaller systems, like package plants.

Disadvantages

1. Larger volume, high aeration costs.
2. Less operational flexibility.
3. Associated with biomass instabilities like sludge bulking.

6. PROCESS DONE IN KOYEMBEDU WASTE DISPOSAL PLANT AND FAILURE

6.1 The process done in the Koyembedu waste disposal plant

1. The vegetable waste was collected and taken into the treatment plant.

2. The waste was taken into the hopper, and vegetables are ground and cut in the hopper and then taken into the flocculation chamber.

3. The waste was treated and the chemicals such as methane and alkane and biogas were collected and used for electricity purposes.

4. Their main aim was to supply electricity on a large scale, which was collected from vegetable waste but it was not possible due to the inefficiency of the machines which are provided, so the current supply was done only to the treatment plant.

5. The odors from the flocculation chamber were removed by passing those waste to coconut shell fibers which are shown in direct sunlight.

6.2 Failure of Koyembedu waste disposal plant

1. The plant faced glitches with the engine failing, and for few years, the biogas was not put to any use.

2. From 2008 until 2011 the plant functioned only for 4 months because the machine was not working and the quality of waste fed into it was poor.

3. They were unable to run the plant owing to a lack of space for source segregation and composting.

7. UASB PROCESS

Anaerobic treatment is now becoming a popular treatment method for industrial wastewater because of its effectiveness in treating high-strength wastewater and because of its economic advantages. In recent years, the number of anaerobic reactors in the world were increasing rapidly and about 72% consist of reactors based on UASB and EGSB technologies. In UASB process, a high concentration of biomass is maintained through the formation of highly settleable microbial sludge aggregates. The wastewater flows upwards through a layer of very active sludge to cause anaerobic digestion of organics of their wastewater. At the top of the reactor, a three-phase separation between gas-solid-liquid takes place. Any biomass leaving the reaction zone is directly recirculated in the settling zone. The process is suitable for both soluble wastewaters as well as wastewaters containing particulate matter. From the UASB process, the entire waste is passed via the anaerobic reactor in an upflow mode, using a hydraulic retention time (HRT) of only about 8-10 hours of average flow. No prior sedimentation is required. The anaerobic unit does not have to be full of stones or any other media; the up-flowing sewer itself creates thousands of small “granules" or particles of sludge that are held in suspension and provide a large surface area on which organic matter could attach and experience biodegradation. A high solid retention time (SRT) of 30-50 or more days occurs within the unit. No mixers or aerators are required. The gas produced can be accumulated and utilized, if desired. The anaerobic system functions satisfactorily when temperatures inside the reactor are above18-20 ºC. Surplus sludge is removed from time to time through a separate pipe and sent to a simple sand bed for drying. The methane generated can be used as a gas for domestic or industrial use. It may also be used for the generation of electricity for running the plant after appropriate dehydration and cleaning. This process can be reactivated even after the plant remains shut down for days or months or after power breakdowns and interruptions in wastewater supply.

The sludge granules have many advantages over conventional sludge flocs:

- Dense compact bio-film
- High settleability (30-80 m/h)
- High mechanical strength
- Balanced microbial community
- Closely associated syntrophic partners
- High methanogenic activity (0.5 to 2.0 g COD/g VSS.d)

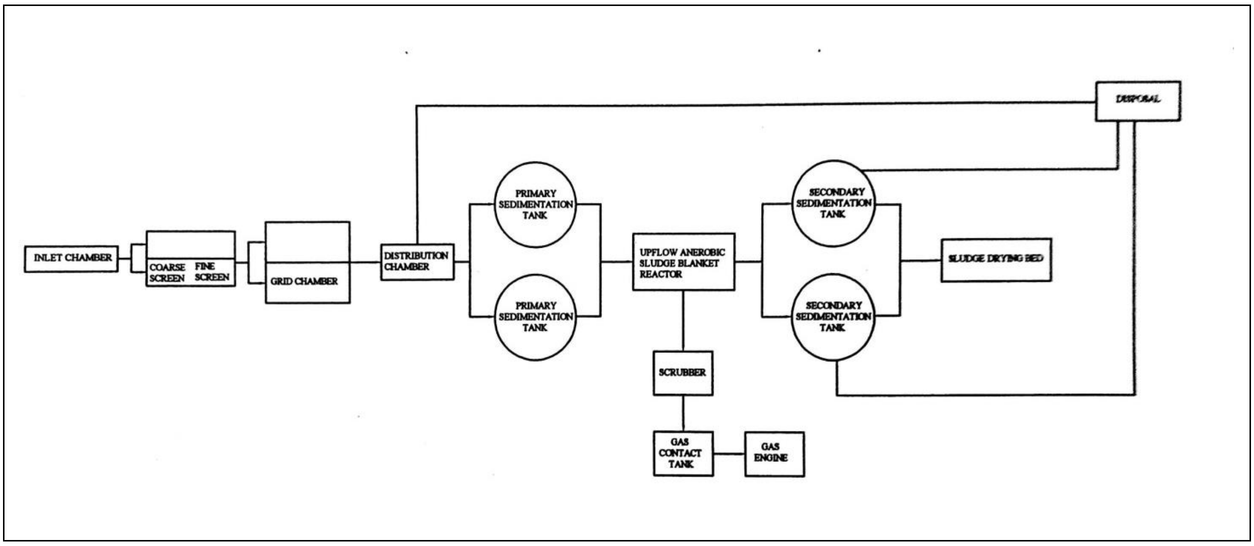

Fig. 1: Sewage treatment process

8. LIMITATIONS

1. The system helps to lower only two parameters of wastewater viz, BOD and suspended solids.
2. Like all other anaerobic high-rate systems, the UASB reactor also requires a large quantity of organic matter as compared to anaerobic reactors.
3. The acids produced during the breakdown of organic matter in a UASB reactor may cause corrosion of the reactor.
4. Pre-treatment of wastewaters with screening and grit removal is usually found necessary for direct anaerobic treatment.
5. The system responds well in high-temperature climate areas because the activity of methanogenic bacteria is strongly influenced by temperature. However, high micro-organism in high-rate anaerobic reactors like UASB, compensates for the decreased activity of anaerobic organisms at lower temperatures.
6. The installation of UASB plant should be made a mandatory requirement for developing every new colony or township, having a population of more than 5000.
7. It is evident that a higher solid retention time (SRT) is necessary for the treatment of sewage by anaerobic processes because of the low specific growth rates associated with anaerobic bacteria.
8. Fixed-film microbial growth provides intimate contact between the various anaerobic bacteria, thereby providing rates of reaction and degrees of stability that cannot be obtained in suspended growth systems.
9. In general, the UASB reactor cannot be used as primary treatment, unlike anaerobic expanded or fluidized bed reactors. The reason for this lies in the mechanisms of particle entrapment and hydrolysis in the two systems.
10. Anaerobic sewage treatment may be economically feasible only in warmer conditions.

9. CONCLUSION

1. Anaerobic treatment often is environment-friendly and very cost-effective in reducing discharge combined with the production of reusable energy in the form of biogas.
2. Anaerobic treatment of domestic wastewater can also be very interesting and cost-effective in countries where the priority in discharge control is in the removal of organic pollutants.
3. The space requirement is quite comparable to that of an Activated sludge system.
4. The system requires lesser and simpler electromagnetic parts as compared to the ones required in the Activated sludge plant leading to lesser operation and maintenance costs.
5. Electricity consumption in this system, like all anaerobic system is quite low, and the system is quite capable of withstanding long power failures.
6. Sludge production is low and produced sludge has quick dewatering characteristics.
7. It enables quicker sludge digestion as compared to conventional digestors.
8. Biogas is produced in this system as a by-product, which can be used to produce electricity.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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