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Applying Up-flow Anaerobic Sludge Blanket (UASB) in Domestic wastewater treatment: A Review

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Abstract: Among other treatment approaches, the UASB process has been perceived as a key component of sophisticated technology for protection of the environment. this review displays the Operating conditions and basic concepts for design and the factors affecting the UASB in details. Temperature, granulation, OLR, HRT, pH, and mixing, as well as their influences on the operation of the hydrogen production and UASB reactor were all shown in order to achieve the best outcomes. Additionally, post-treatment procedures that can effectively discharge and/or reutilize treated water are highlighted. this review was presented to find the best mechanism to develop the UASB reactor.

Keywords: Up-flow Anaerobic Sludge Blanket. UASB, Domestic wastewater treatment

1. INTRODUCTION

The food production techniques, industrialization, and continuous population growth improved living levels, and inefficient water utilizes tactics have resulted in an environmental squeeze in terms of global warming and water quality around the turn of the twenty-first century. The population growth, urbanization, and rapid industrialization led to increasing volumes of industrial wastewater and untreated domestic being emptied into the canals and rivers and therefore deteriorating ground and surface water quality [1]. The quality of polluted water would continue to influence groundwater, endangering the safety of drinkingwater and hence the health of rural and urban populations, as well as having a negative impact on the ecosystem, especially biospheres and aquatic life [2]. The lack of management of wastewater has a direct influence on the aquatic ecosystem's biological diversity, disturbing the fundamental integrity of support systems of our life, on which a wide extend of industries, from urban growth to food production, rely. To work across sectors and marine and freshwater boundaries, wastewater management must be seen as part of an integrated ecosystem-basedmanagement. Domestic sewages are water that have been used by a community and contains all of the materials and substances that have been added to it through that time. It consists of human waste (urine and feces) mixed with the water utilized to flush toilets, as well as sullage, which is wastewater from food preparation, laundry, personal washing, and kitchen equipment cleaning. Fresh wastewater is a turbid grey liquid with an earthy but not unpleasant odor [3]. Smaller suspended solids (like partially decomposed feces, vegetable peel, paper), and very small solids in colloidal suspension, and large floating and suspended materials (like maize cobs, plastic containers, feces, rags) as well as pollutants in true solution, are all present. Its appearance is unattractive, and its content is hazardous, owing to a large number of pathogenic organisms it contains. In hot regions, wastewater can quickly losing its dissolved oxygen content and become septic. The odor of septic wastewater is usually hydrogen sulfur. [4]. Anaerobic sewage Treatment is a method of biological sewage treatment that does not use oxygen or air. It was created with the goal of eliminating organic contaminants from sludge, wastewater, and slurries. anaerobic microbes are used to convert Organic pollutants into "biogas," which consist of carbon dioxide and methane. Anaerobic Microorganisms Convert Organic Pollutants to Biogas. These benefits include excellent removal efficacy even at low temperature and high OLR, resulting in a lower reactor volume, and low cost. Methane/hydrogen gas is utilized to create energy due to the availability of building supplies and other components in the area, low maintenance and operating costs and simple construction, strength in processing efficiency, and wide application. To save money on operating, the boilers are heated by energy generated. When no external temperature control is required, there is less energy consumption. Less CO_2 emissions as a result of lower energy consumption and Generating additional energy in the form of biogas, which may be utilized to power the system. there is less sludge produced when compared to processes of aerobic. The produced stabilized sludge has good dewatering properties and can be stored for long periods of time and utilized as an inoculum for seeding UASB reactors. Ability to treating sewage because of micro- and macronutrients availability and pH stability without any chemicals, and quick starting time (approximately one week) using granular anaerobic sludge as seed [5]. This review displays the Operating conditions and basic concepts for design and the factors affecting the UASB Reactor in details.

The UASB Reactor

The reactor is a digester producing methane or type of anaerobic digester utilized in sewage treatment by anaerobic process to produce granular sludge, which is then digested by anaerobic bacteria as shown in figure (1) **[6].**

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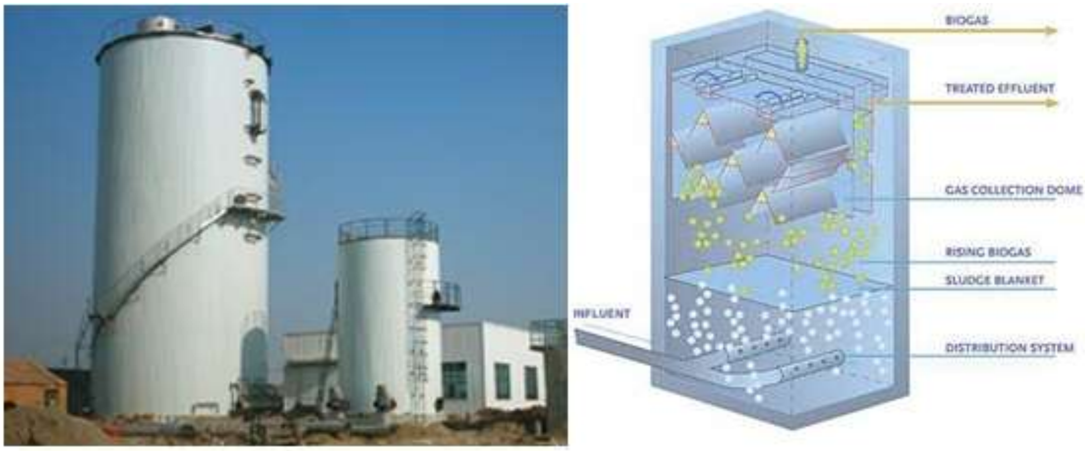

Figure 1: Up flow-Anaerobic Sludge Blanket Reactor [6].

The Operating conditions and basic concepts for design

The UASB reactor is built on separating sludge, gas, and water mixes in high-turbulence environments through a three-phase separator. This allows for cheaper and compact designs as shown in figure (1). For the separation of biogas, the reactor features numerous gas hoods. As a result of the exceptionally large water/gas interfaces, turbulence is considerably reduced, allowing for reasonably high OLR of 10–15 kg/m^3.d. The UASB demands only 1.0 m of height for separation, that eliminates flotation influences and, as a result, floating layers. Typically, the substrate goes through an extended sludge bed consisting a high percentage of biomass before being treated in the UASB reactor. The residual substrate then passes through the sludge blanket, a layer of less dense material **[7].** A Peristaltic pump pumps the influent to the UASB reactor from the bottom of the reactor. The influent rises and contacts the biomass in the sludge bed, then continues to climb, contacting the biomass in the sludge blanket, that has a lower biomass concentrations than the sludge bed below. The sludge blanket's volume must be sufficient to channel sewage bypassed from the bottom layer of the sludge bed for further treatment. At the same time, it will aid in preserving a consistent wastewater quality. Over the sludge blanket, a three-phase separator (gas-liquid-solid or GLS) separates solid particles from the composition (liquid, gas, and solid) after treatments, allowing gas and liquid to exit the UASB reactor. Then, the treated sewage will be assembled by the effluent collection system, which will discharge it to the main launder provided at the reactor's periphery via a number of launders spread throughout the discharge region. And the biogas produced will be assembled for use as a valuable fuel or disposed of. The average wide-range design loading was 10 kg COD/m^3.d for the reactor for 682 full-range stations surveyed **[8].**

Height and Area of UASB Reactor

The reactor should be as high as feasible to reduce the GLS separator and reduce the plan area, Land cost, the arrangement of influential distribution, etc. The sludge bed height should be sufficient to reduce channeling and to ensure that the upper flow velocity of the liquid remains within the maximum permissible limits (1.2-1.5 m/h). So that, the height of the sludge bed must be at least 1.5 to 2.5 m, and the height of the reactor must be limited to 4 m to provide easy reach to the sludge blanket, sludge bed, and three-stage separator. According to the specification, the maxmum height of the UASB reactor is around 8 meters; however, in normal operation, the acceptable height is between 4 and 6 meters. Furthermore, the sludge bed cover 25-60% of the overall reactor capacity, the sludge blanket occupies 20-30% of the total volume, and the GLS occupies the remaning 14-30% of the total volume **[9].**

GLS Separator

The fundamental goal of this concept is to make sludge returns as simple as possible without the use of any additional energy or control devices as shown in figure (2). The Gas-Liquid Solid separator's function is to enable proper solids recycling into the reactor by providing enough gas-water interfaces within the gas dome, enough settling area outside the dome to control surface overflow rate, and enough orifice openings at the bottom to prevent turbulence in the separator due to high liquid inlet velocities. The geometry and hydraulics of the GLS separator must be carefully considered to achieve optimal performance. **[10].**

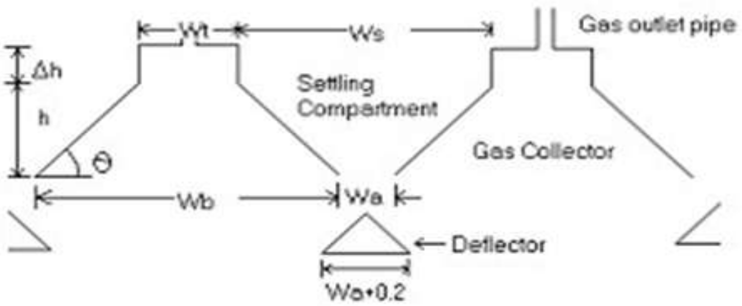

Figure 2: Gas-Liquid Solid (GLS) Separator [10].

Process of UASB

While forming a blanket of granular sludge that suspends in the tank, UASB uses an anaerobic process as shown in figure (3). The treated wastewater flows into the reactor from bottom to top through an activated sludge blanket, which is usually in the form of granular aggregates. When sewage interacts with the granules, the sludge aggregates are extremely stable and do not wash off under usual circumstances, leading to excellent treatment efficiency **[11].** Internal mixing is aided by the gases (carbon dioxide and methane) produced in anaerobic circumstances, which helps in the development and maintenance of bio-granules. However, since the gas formed in the blanket sticks to the granules, a GLSS must be installed on top of the reactor to effectively separate liquid, gas, and granules **[12].** In GLSS, the gas-encased particles collide with the bottom of the degasing baffles, falling back into the blanket, and the treated water exits the reactor. In comparison to high-strength wastewater, sewage produces less gas, leading to less gas circulation to facilitate the formation of biogranules. Controlling channeling is therefore critical for weaker sewage **[13].**

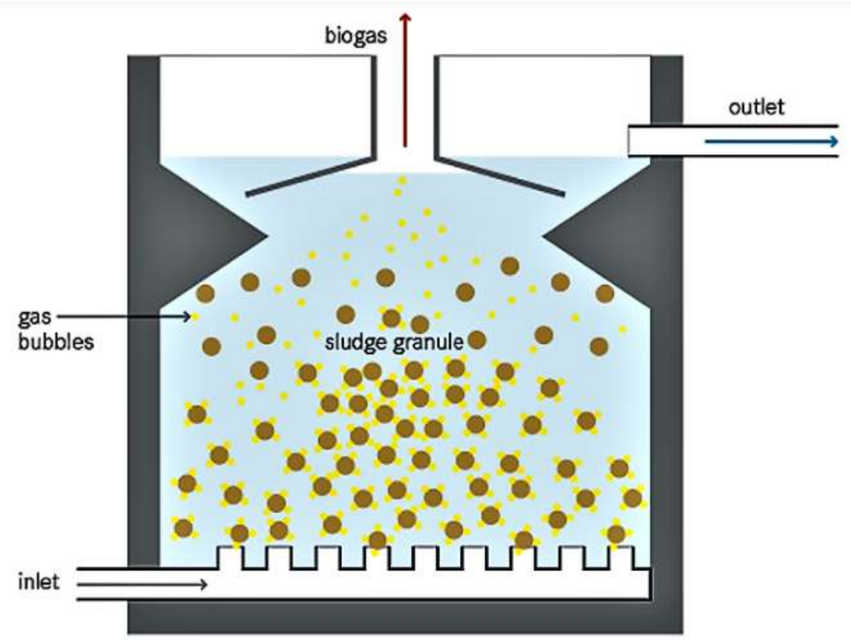

Figure 3: Cross-section of UASB reactor [12].

Treatment of UASB Process

Although UASB technology has been successfully employed to treat a wide range of wastewaters, incomplete biodegradability of complex wastewaters is a major stumbling block. The UASB method has proven to be particularly active in treating sewage with high carbohydrate content. Organic sewage containing carbohydrates, such as wastewater or starch from the caning industry, is easily digested by bacteria, thus provides a nutrient-rich feedstock for anaerobic hydrogen production **[13].** Therefore, the up flow anaerobic sludge blanket reactor has become one of the most widespread designs for treating sewage from food conversion plants. Anaerobic reactors can endure changes in effluent quality as well as complete reactor shutdown during the off-season. Fang looked at the microscopic inspections of biogranules taken from various UASB reactors (SEM and TEM). The thermodynamics and kinetics of specific substrates were discovered to have a considerable influence on microbial dispersion in granules. **[14].** Biogranules that break down carbohydrates had a stratified distribution, with hydrolytic/fermentative acidogens on the surface, syntrophic colonies in the middle, and acetotrophic methanogens in the interior, whereas bacteria were equally dispersed and not stacked on substrates with a rate-limiting hydrolytic/fermentative phase. **[15].** The findings show that granules form as a function of development rather than random accumulation of suspended microorganisms. Additionally, experimental data demonstrates that biogranules that are capable of digesting carbohydrates are more resilient to the toxicity of aromatic pollutants, heavy metals, and hydrogen sulfide than suspended sludge. Approximately half of the organic matter in home sewage is made up of black water, which is rich in nutrients. Large rate reactors are the best and are frequently used because they can handle short HTRs, low energy needs, and high OLRs. **[16].** Many full-scale plants, mostly in tropical and subtropical climes, are now in operation, and several more are being developed. The UASB technology's fundamental goal is to produce anaerobic sludge with excellent settling qualities and the capacity to hold highly active bacterial agregation without the aid of a support material. Throughout 61% of full-scale anaerobic treatment plants in operation around the world use the UASB design concept to handle a variety of industrial sewages. Approximately 793 UASB reactors have been installed globally, out of a total of 1229 additional anaerobic applications such as EGSB reactors, hybrid reactors, anaerobic contact filters, and fluidized bed reactors. Tropical and subtropical regions account for around half of these installations (338 out of 793). This technology is preferable to others technologies due to its overall low investment, operation, and maintenance costs, strong TSS, BOD, and COD elimination, and potential for energy generation, especially in underdeveloped nations **[17].** New studies in this field have shown that this method can successfully cleanse low-strength wastewater. COD levels in home wastewater are typically low, suspended solids are high, and methane output is low, necessitating first hydrolysis to convert suspended solids to soluble substrate. The limiting step is usually hydrolysis when the temperature is low. Since greater temperatures are required for UASB reactor for residential sewage treatment with a high level of suspended particles, it can also be necessary to employ an external heat source **[18].** With a better understanding of the process and operational knowledge of granule structure. Greater organic loads can now be applied, resulting in a quicker startup and a more sustainable operation.. Its global performance demonstrates that it is a reliable and efficient wastewater treatment system **[17].**

The influence of Different indicators on the UASB Reactor's Efficiency

The growth of the sludge bed is influenced by a variety of elements such as wastewater characteristics, seed sludge acclimation, pH, nutrients, presence of hazardous substances, loading rate, HRT, upflow velocity (Vup), reactor design, and liquid mixing.

1. Effect of Temperature

Microorganisms' growth and survival are heavily influenced by temperature. All three temperature ranges (mesophilic, thermophilic, and psychrophilic) can be used for anaerobic treatment; however, low temperatures reduce methanogenic activity and the maximal specific growth rate. Because methanogenic activity at these temperatures is 11 to 21 times lower than at 34°C, increasing biomass in the reactor (11 to 21 times) or running at longer HRT and sludge retention time (SRT) are required to give the same efficiency of COD removal as at 34°C. Theoretically, lowering the temperature slows hydrolysis and reduces maximal growth and substrate consumption rates. **Kalogo and Verstraete [19]** discovered that COD removal effectiveness was lower at temperatures between 10 and 15 degrees Celsius than at 34 °C. **Lettinga and Van Lier [20]** evaluated the influence of a transient temperature increase the performance of a UASB reactor containingmesophilic bacteria.With an increase in temperature, there was an increase in methane generation due to increased methanogenic activity. However, as the reactor temperature rose beyond 45°C, bacterial inactivation reduced the activity of mesophilic granular sludge, resulting in a sharp decline in ethane synthesis..

2. **Effect of OLR**

The major parameter that has a substantial impact on microbial ecology and the UASB process is OLR. The OLR is commonly implemented in the range of 1.0–2.0 $KgCOD/m^3day$ in the case of sewage. The UASB reactor is recommended because it has the ability to treat sewage with minimal suspended particles and produces more methane. Reactors seeded with granular activated sludge can provide high performance immediately after initiation and respond quickly to increased OLR. The impact of OLR on the perfomance of a UASB is influenced by a variety of parameters, some of which have opposing, if not conflicting, effects on the perfomance of a UASB reactors. Authors have discovered that raising OLR improves the activity of high-rate anaerobic reactor. However, above a specific OLR, excessive foaming and sludge bed flotation in the GLSS occur; thus, for a given temperature range and sewage, a range of optimum OLR is usually advised. At an OLR of 1.6 kgCOD/m3day (COD influent = 1550 mg/L) and a HRT of 24 hours, **Halalsheh [21]** assessed the perfomance of UASB reactor for the treating of strong residential sewage at an OLR of 1.5 kgCOD/m3day (COD influent = 1500 mg/L) with a considerable number of suspended particles (approximately 80%). In July (25C), even with a somewhat longer HRT, the reactor only removed 62% of COD. The sludge washout was to blame for the relatively low efficiency. When the OLR is higher than it should be, biogas accumulates in the sludge bed, generating gas pockets that eventually induce sludge float. **Seghezzo [22]** conducted pilot-scaleUASB reactor with an OLR of 0.7 $kgCOD/m^3day$ (COD influent = 153 mg/L, HRT of 6 hours,) at a low temperature of 18°C and achieved a maximum efficiency of COD removal of 63%.

3. **Effect of HRT**

HRT is one of the most critical characteristics influencing reactor performance, especially when dealing with municipal wastewater. The upflow-velocity (Vup) is proportional to HRT and is critical for entrapping suspended materials. A drop in Vup leads to a rise in HRT, which improves the system's suspended solids (SS) removal efficiency. Because increased Vup decrease the contact duration between sewage and sludge, as well as the of sludge granules smashing and the subsequent higher washout of particles, the efficiency of COD removal of a UASB reactors drops. However, some scientists claim that HRT has no influence on the UASB reactor's treatment efficiency. The scientific community's differences of opinion are due to differences in reactor design, operating techniques, and HRT range. The hydraulic retention time is also maintained by flow rate, which is a significant operational element. If the diameter of the reactor is excessively big in the UASB process, liquid channeling may occur, resulting in insufficient contact between the biomass and substrate. As a result of insuffcient mixing within the reactor, a big reactors will result in lower sludge washout and biogas output. More height, on the other hand, may facilitate substrate mixing and optimal interaction of the substrate with microorgnisms, leading in increased organic matter breakdown and biogas generation. The Vup helps maintain the hydraulic retention time by ensuring appropriate mixing of the biomass and substrate without chaneling. According to several studies, the maximum permissible upflow velocity is 0.5–1.5 m/h. Researchers have reported satisfactory process of a UASB reactor for the treatment of municipal sewages at 0.32–0.427 m/h Vup after 3.5–4.5 hours of HRT. The performance of an up-flow anaerobic sludge blanket (UASB) reactor for the treatment of household wastewater was evaluated by **Lew et al., [18],** various operation temperatures (11, 15, 21, 29°C) and loading rates who found that the Effluent of total suspended solid concentration increase with increasing the Hydraulic Retention Time and Upflow Velocity at 28°C as shown in figure (4). **Salazar-Peláez et al., [23]** used a pilot UASB reactor connected with external ultrafltration (UF) membrane to investigate extracellular polymeric substances (EPS), the produced concentrations of COD, total solids, and soluble microbial for domestic sewage treatment under three different HRT. They discovered that the highest concentrations were obtained when the reactor (UASB) was worked under the shortest HRT (4 hours) as shown in figure (5).

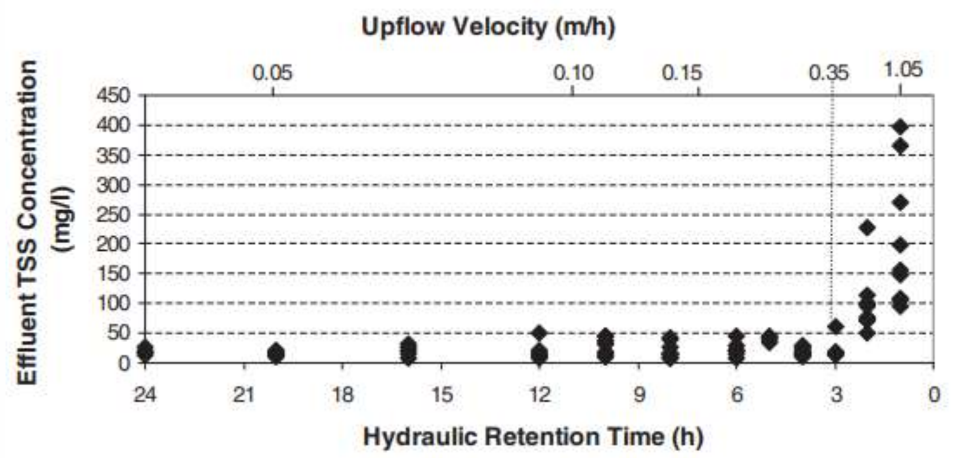

Figure 4: TSS concentration in the effluent as a Upflow Velocity and function of HRT at 28°C[18].

Figure 5: Characterization of influent, UASB effluent and permeate at the different HRTs applied [23].

	HRT 4 hours			HRT 8 hours			HRT 12 hours		
	Influent	UASB effluent	Permeate	Influent	UASB effluent	Permeate	Influent	UASB effluent	Permeate
pH	7.2 ± 0.3	7.2 ± 0.1	7.3 ± 0.10	7.3 ± 0.3	7.5 ± 0.1	7.6 ± 0.1	7.5 ± 0.2	7.4 ± 0.2	7.5 ± 0.1
Alkalinity (mg/L $CaCO_3$)	243 ± 24	282 ± 67	231 ± 60	289 ± 79	278 ± 121	245 ± 89	194 ± 40	349 ± 145	316 ± 97
COD_t (mg/L)	738 ± 453	218 ± 89	101 ± 22	993 ± 532	157 ± 51	80 ± 33	906 ± 1,182	109 ± 29	51 ± 24
COD_s (mg/L)	158 ± 23	148 ± 40	101 ± 22	98 ± 50	117 ± 25	80 ± 33	45 ± 14	70 ± 29	51 ± 24
TS (mg/L)	1,440 ± 796	477 ± 74	369 ± 112	2,030 ± 1,230	433 ± 107	321 ± 69	766 ± 601	416 ± 78	303 ± 74
VTS (mg/L)	1,138 ± 802	150 ± 54	46 ± 7	1,379 ± 977	154 ± 56	46 ± 15	329 ± 406	135 ± 38	47 ± 16
TSS (mg/L)	1,084 ± 818	53 ± 13	<MDL*	1,222 ± 961	38 ± 19	<MDL*	641 ± 620	26 ± 9	<MDL*

4. Influence of pH

The pH of an anaerobic reactor is important because the methanogenesis process can only advance at a high rate if the pH is maintained between 6.3 and 7.8. Due to the buffering ability of the carbonate system in the acid-base system, the pH of sewage naturally maintains this range without the use of chemicals. In terms of pH and buffering capacity, reactors (UASB) utilized for sewage treatment in subtropical and tropical regions are thought to be especially stable. The hydrolysis and acidogenesis rates of household wastewater treated in an anaerobic reactor increase, and the optimal pH for anaerobic digestion is 7, which eliminates more than 80% of the TOC and COD **[17, 24].**

5. Effect of Mixing

Mixing allows microorganisms and wastewater to have more contact time, reduces mass transfer barriers, prevents the growth of repressive by-products and maintains a consistent environment. If correct mixing is not done, pockets of substrate will obstruct the main process rate at different digestion stages, resulting in temperature and pH fluctuations at each stage. Mechanical mixing or recirculation of slurry or methane gas can be used. A number of studies have found that considerable mixing has an impact on the performance of anaerobic reactor. Mixing improved the performance of anaerobic systems processing sewage with high COD concentrations; also, slurry recirculation outperformed impeller mixing mode and biogas recirculation. When compared to unmixed digesters, mixing increases biogas production. When used in big municipal and farm waste digesters, discontinuous mixing is preferable to vigorous mixing [17, 25]. Fluidization causes the production of sludge granules. Methanogens are less efficient under these settings, therefore vigorous mixing is not recommended. Similarly, mixing during the starting period reduces the digester pH, resulting in unsteady performance and a longer startup duration, according to **Karim et al. [26].**

6. Effect of Granulation

It has been demonstrated that the growth of granular sludge in UASB reactors is adversely affected by long HRTs. Very brief HRTs, on the other hand, result in biomass washout. Both of these scenarios are incompatible with getting the best outcomes from the UASB reactor. Despite the fact that granulation is thought to be necessary for the successful treatment of residential sewage in reactor (UASB), these reactor have been discovered to be functional even without them. Granule manufacturing helps shorten startup times during startup processes. The creation of an active sludge in the reactor's lower section is what gives the UASB reactor its excellent performance. The development of a sludge bed is the result of the accumulation of incoming suspended materials and bacterial growth under specific conditions. This is due to the naturally occurring aggregation of bacteria in flocs and the evolution of granules in the form of a layered structure. During UASB operation, these granules are not flushed out of the reactor. The granulated sludge particles have been discovered to have a diameter of 1.0 to 3.0 mm. Granular suspensions have higher settling velocities (20–80 mh^{-1}) than up-flow velocities (Vup = 0.1–1.0mh^{-1}). As a result, the reactor can hold a huge amount of biomass. As a result, with a short HRT, a high sludge loading rate (SLR) (up to 5 $gCODgVSS^{-1}day^{-1}$) might be used (less than 4 hours). In the reactor, the formation of activated sludge, whether granular or flocculent, is critical for ensuring acceptable removal efficiency even at high OLR **[17, 27].**

7. CONCLUSION

An economical wastewater treatment method, the upflow anaerobic sludge blanket reactor connects predicted anaerobic decomposition to produce biogas and reduce waste volume. It has a wide range of applications in the treatment of wastewater from induistrial and agricultiural operations. According to the literature, the UASB gives high removal efficiency even at low temperature and high OLR, which requires a smaller volume of the reactor; low maintenance and operation costs, and simple construction due to local construction material availability and other parts; robustness in treatment efficiency and broad applcability from small to large scales; and robusitness in treatment efficency and broad applcability from small to large scales.. this review was presented to find the best mechanism to develop the UASB reactor.

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