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Applying Up-Flow Anaerobic Sludge Blanket (Uasb) in Domestic Wastewater Treatment: A Review

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Abstract: It has been said that the UASB procedure is a crucial part of cutting-edge technology for environmental protection, among other treatment methods. This review explains the UASB's influencing variables, operating conditions, and fundamental design concepts. To achieve the best outcomes, temperature, granulation, OLR, HRT, mixing, and their effects on the operation of the UASB reactor and hydrogen generation were all proven. Additionally included are post-treatment techniques that successfully release and/or reuse treated water. The review put for t determine the optimal method for creating the UASB reactor.

Keywords: Up-Flow Uasb Anaerobic Sludge Blanket; Domestic Wastewater; Anaerobic Sludge Blanket.

1. INTRODUCTION

Around the turn of the twenty-first century, improvements in living standards due to food production methods, industrialization, and ongoing population increase, and ineffective water management practices created environmental pressure on water quality and global warming. Because of the population increase, urbanization, and rapid industrialization, more home sewage and industrial waste are being thrown into canals and rivers untreated, which has a negative impact on the quality of ground and surface water [1]. The ecosystem, particularly biospheres and aquatic life, would suffer due to the quality of dirty water continuing to affect groundwater, placing at risk the security of drinking water and, as a result, the health of those living in rural and urban areas [2]. Inadequate wastewater treatment immediately affects the watery environment's diversity of life ecosystems, endangering integrity systems that support life and are used by many industries, from food production to urban development. In order to cross sectors and boundaries between freshwater and marine habitats, integrated ecosystem-based management must include wastewater management. Domestic sewage is water that has been used by a community and contains all of the substances that have been added to it throughout time. Wastewater from dishwashing, laundry, personal washing, and cleaning kitchen appliances makes up this substance and sullage, which is human waste (urine and faeces) combined with toilet flushing water. Fresh wastewater smells earthy but not terrible and is a turbid, greyish liquid [3]. Smaller suspended materials (like paper, vegetable peel, and partially decomposed excrement), very tiny solids in colloidal suspension and pollutants in true solution are all present, in addition to bigger floating and suspended items (such as maize cobs, plastic containers, faeces, and rags). Because it includes so many infectious organisms, it has an unpleasant look and a dangerous composition. Wastewater can easily become septic in warmer climes by losing its dissolved oxygen concentration. Water from septic systems typically smells of hydrogen sulfur. [4]. An alternative to using oxygen or air for biological sewage treatment is anaerobic treatment. It was developed to get rid of organic impurities from sludge, wastewater, and slurries. Anaerobic bacteria transform organic contaminants into "biogas," composed of methane and carbon dioxide. Organic pollutants are converted to biogas by anaerobic bacteria. The low price, strong OLR, reduced reactor volume, and excellent removal efficacy, even at low temperatures, are some of these benefits. Due to the proximity of building materials and other necessary components, the ease of construction, cheap maintenance and running costs, high processing efficiency, and extensive application of methane/hydrogen gas, it is used to produce energy. The energy generated is used to warm the boilers to lower operating costs. Less energy is wasted when external temperature control is not required. fewer emissions of CO2 since the energy of consumption are lower and more energy is made in biogas, which might then be used to run the apparatus. Compared to aerobic processes, less sludge is produced. The resulting stabilized sludge can be used because of its effective dewatering capabilities as an inoculum to seed UASB reactors. Additionally, it has a long shelf life. Sewage can be treated thanks to when employing granular anaerobic sludge as seed, macro- and micronutrient availability, pH stability without the use of chemicals, and a speedy start-up period (about one week) [5]. In-depth explanations of the operating conditions, core design concepts, and influencing factors for the UASB Reactor are given in this study.

UA SB REACTOR

The reactor, shown in figure (1), is an anaerobic digester that can produce methane or another type of anaerobic digester used to process sewage to create granular sludge that anaerobic bacteria then consume [6].

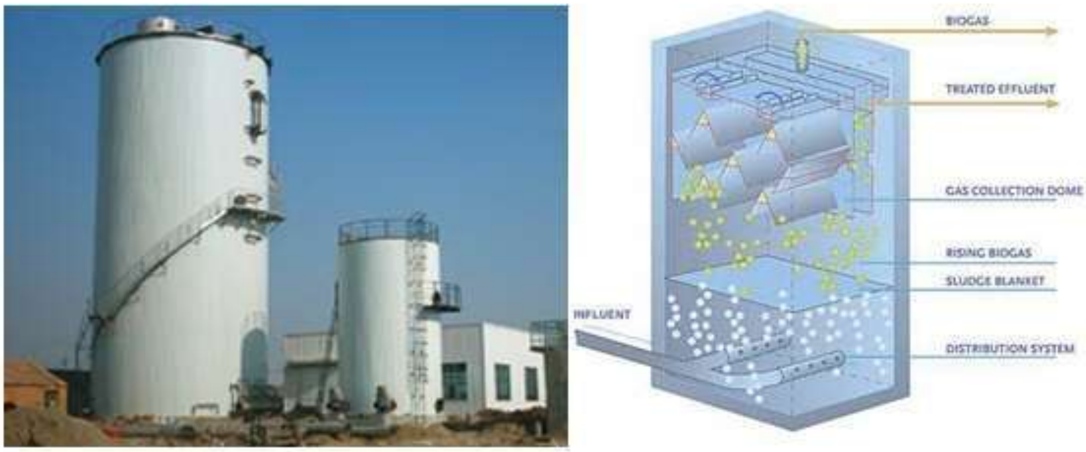

Figure 1: Anaerobic sludge blanket reactor with up-flow [6].

OPERATING CIRCUMSTANCES AND FUNDAMENTAL DESIGN PRINCIPLES

Sludge, gas, and water are supposed to be separated using a three-phase separator in the UASB reactor. Water mixtures in highly turbulent settings. This enables less expensive and smaller patterns, as shown in figure (1). The reactor has some gas hoods for the biogas separation process. The unusually broad water/gas interfaces significantly reduce turbulence, allowing for a respectably high OLR of 10-15 kg/m3.d. Because flotation impacts and, thus, floating layers are eliminated, the UASB requires 1.0 m of height for separation. Before being processed in the UASB reactor, the substrate frequently passes through a protracted sludge bed that contains a large amount of biomass. The sludge blanket, the following layer, is made up of less dense material and passes through the remaining substrate [7]. The influent is transferred from the reactor's base to the UASB reactor using a peristaltic pump. The sludge blanket, which has a lower concentration of biomass than the sludge bed below, is the first place the influent contacts the biomass after rising and establishing a connection with it in sludge bed. The sludge blanket's volume must be sufficient to convey sewage bypassed from the bottom layer of the sludge bed for additional treatment.

Additionally, it will support preserving a stable level of wastewater quality. After treatments, the composition's solid particles are separated from the composition's liquid, gas, and reliable components in a three-phase separator (GLS), allowing the liquid and gas to depart the UASB reactor. Launder's number distributed across discharge region by effluent collection system will subsequently be used to discharge the assembled treated sewage to the primary washer situated at the reactor's edge. Furthermore, the biogas will be combined or used as valuable fuel or dumped. 10 kg COD/m3.d was the wide-range design loading for the reactor 682 full-range stations surveyed [8].

UASB REACTOR HEIGHT AND AREA

The reactor needs to be as tall as is practical to minimize the GLS separator, Plan size, land price, the organization of influencing distribution, etc. The sludge bed height should be sufficient to avoid channeling and maintain the liquid's upper flow velocity within the allowed limits (1.2-1.5 m/h). To provide simple access to the sludge blanket, sludge bed, and three-stage separator, The height of the reactor shall not exceed 4 m, and the height of the sludge bed must be between 1.5 and 2.5 m. Although a UASB reactor specifies a maximum height of about 8 meters, during regular operation, any height between 4 and 6 meters is suitable. In addition, a Sludge blanket takes up 20–30% of the total volume, a sludge bed makes up 25–60% of the total reactor capacity, and GLS makes up the remaining 14–30% of the volume [9].

SEPARATOR GLS

As depicted in figure, this design's main objective is to make sludge returns as straightforward as possible without requiring extra energy or control techniques (2). The Gas-Liquid Solid separator contributes to proper solids recycling into the reactor by offering 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 as a result of high liquid inlet velocities. To achieve optimal performance, the geometry, the hydraulics of GLS separator must be properly taken into account [10].

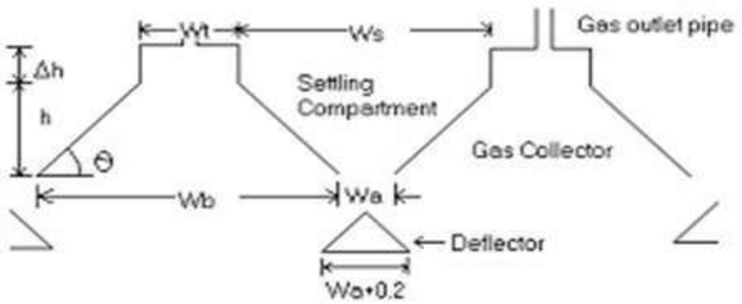

Figure 2: Gas, Liquid, and Solid Separator [10].

PROCESS OF UASB

UASB uses an anaerobic procedure to create a layer of suspending granular sludge in the tank, as seen in figure (3). The active sludge blanket, typically made of granular aggregates, is passed through as the treated wastewater is injected into the reactor from bottom to top. Because they are stable, the sludge aggregates usually do not wash away when sewage interacts with the granules, resulting in great treatment efficiency [11]. Anaerobic conditions produce methane and carbon dioxide, which encourage internal mixing and aid in the formation and stability of bio granules. A GLSS must be mounted to separate liquid from gas on top of the reactor, and particles since the blanket's created gas adheres to the granules [12]. In GLSS, the treated water can leave the reactor because the gas-encased particles strike the bottom of the degassing baffles and sink back into the blanket. Sewage creates less gas than high-strength wastewater, It reduces the flow of gas necessary for the formation of bio granules. For weaker sewage, channeling control is therefore crucial. [13]

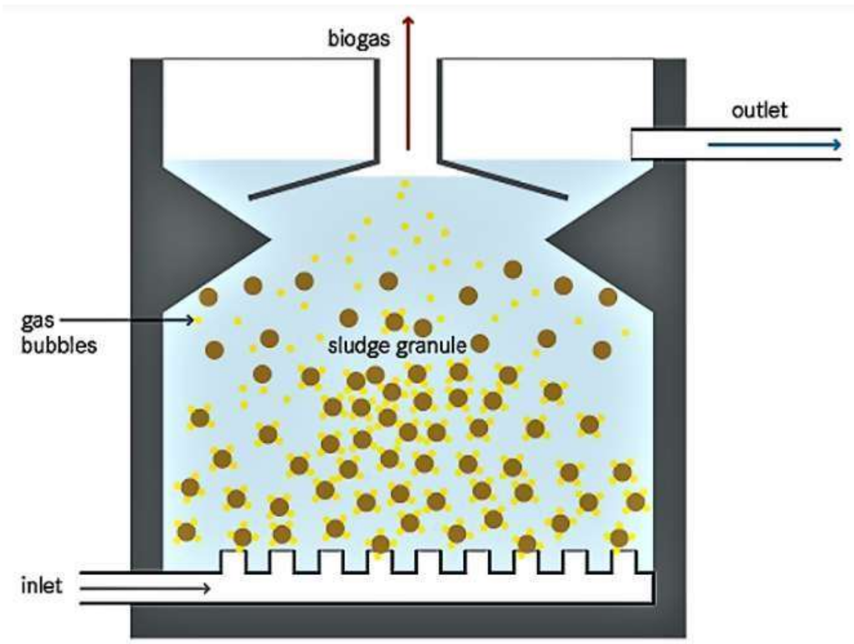

Figure 3: UASB reactor cross-section [12].

UASB PROCESS TREATMENT

Although a range of wastewater has been effectively treated using UASB technology, a significant barrier is the incomplete biodegradability of complex wastewater. Sewage with a high carbohydrate content can be effectively treated using the UASB process. Wastewater or cane industrial flour, two examples of organic sewage containing carbs, are quickly broken down by microorganisms and used as a nutrient-rich feedstock to produce anaerobic hydrogen. [13]. One of the methods used the most frequently to treat sewage from food conversion facilities is the up-flow anaerobic sludge blanket reactor. The use of anaerobic reactors withstand partial shutdown during the off-season and fluctuations in the effluent quality. Fang used a microscope to examine the bio granules taken out of different UASB reactors (SEM and TEM). It has been discovered that microbial dispersion in granules is greatly influenced by the thermodynamics and kinetics of specific substrates [14]. Contrary to bacteria, Bio granules 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, in contrast to substrates with a rate-limiting hydrolytic/fermentative phase, which were evenly dispersed and did not stack [15]. The results demonstrate that granule formation is a function of development as opposed to a chance accumulation of suspended microorganisms. Additionally, studies show that bio granules that can digest carbohydrates are less than suspended sludge; it is more vulnerable to aromatic contaminants, heavy metals, and hydrogen sulfide toxicity. Blackwater, which is nutrient-rich, makes up around half of the organic matter in domestic sewage. Large-rate reactors are the best and are employed the most frequently because they can handle short HTRs, low energy needs, and high OLRs [16]. Mainly in tropical and subtropical climes, numerous large-scale plants are already running, and countless others are being prepared. The primary objective of the UASB method is to create anaerobic sludge with improved settling characteristics and the ability to support highly active bacterial aggregation without using support material. The UASB design concept is used to manage different industrial sewages in 61% of full-scale anaerobic treatment facilities that are now in use worldwide. EGSB reactors, hybrid reactors, anaerobic contact filters, and fluidized bed reactors are among the additional 1229 anaerobic applications, about 793 UASB reactors have been built globally. Almost half of these installations are located in tropical and subtropical areas (338 out of 793). This technology is preferred owing to its minimal investment, operating, and maintenance expenses, potency for energy generation, particularly in developing countries, and strong TSS, BOD, and COD elimination [17]. Recent investigations have demonstrated that this technique effectively cleans low-strength effluent. Because household wastewater often has low COD levels, large suspended solids, and poor methane emission, it must first go through hydrolysis to transform suspended particles into a soluble substrate. When the temperature is low, hydrolysis is frequently the limiting step. Additionally, since UASB reactor temperatures must be greater for residential sewage treatment with a significant amount of suspended particles [18], it could be essential to use an extra heat source. They had a deeper comprehension of the procedure and experience with granule structure. Operations can start up more swiftly and sustainably now that bigger organic loads can be utilised. Its total efficacy demonstrates that it is a reliable and successful technique for treating wastewater [17].

THE EFFICIENCY OF THE UASB REACTOR AS AFFECTED BY VARIOUS INDICATORS

Numerous factors, including wastewater properties, the acclimation of the seed sludge, the pH, the nutrients, the presence of dangerous compounds, the loading rate, the HRT, the upflow velocity (Vup), the reactor design, and the liquid mixing, have an impact on the formation of the sludge bed 1.Temperature effect

Temperature has a considerable impact on the survival and growth of microorganisms. Although methanogenic activity and the maximum specific growth rate can be exploited for anaerobic treatment in three different temperature ranges (mesophilic, thermophilic, and psychrophilic), low temperatures inhibit these processes. Methanogenic activity is 11 to 21 times lower at these temperatures than at 34°C. Therefore either the reactor's biomass must be increased by this amount or its HRT and SRT must be extended to achieve the same COD removal efficiency at 34 °C. Lowering the temperature should theoretically lessen the rates at which the organism can grow and consume the most substrate, and it also speeds up hydrolysis. At temperatures between 10 and 15 °C, COD removal efficiency was less effective than at 34 °C by Kalogo and Verstraete [19]. Van Lier's and Lettinga's [20] evaluation of how a temporary temperature increase may affect how a UASB reactor with mesophilic bacteria operates found that methane generation increased with temperature due to higher methanogenic activity. However, mesophilic granular sludge activity dropped because of bacterial inactivation when the reactor temperature rose beyond 45°C, which resulted in a considerable decrease in ethane synthesis.

Effect of OLR

OLR is a key factor that significantly affects the UASB process and microbial ecology. Regarding sewage, the OLR is frequently implemented at 1.0–2.0 KgCOD/m3day. Because It creates more methane and can filter sewage with less suspended particles, the UASB reactor is advised. Granular-activated sludge-seeded reactors can deliver good performance immediately and respond swiftly to an increase in OLR. Some factors, How OLR affects a UASB's performance is influenced by several factors, some of which have conflicting, if not contradictory, effects on a UASB reactor's performance. Research shows that a high-rate anaerobic reactor performs better when the OLR increases. However, at a specific OLR, the GLSS experiences substantial foaming and sludge bed floating. Because of this, a range of optimal OLR is frequently suggested for a particular temperature range and sewage. With a significant amount of suspended particles (approximately 80%), In order to treat residential solid sewage at an OLR of 1.6 kgCOD/m3day (COD influent = 1550 mg/L), Halalsheh [21] assessed the performance of the UASB reactor, and an HRT of 24 hours. The reactor only removed 62% of COD in July, despite a somewhat longer HRT (25C). The sludge washout was the cause of the efficiency's comparatively low level. Biogas builds up in the sludge bed when the OLR is higher than it should be, creating gas pockets that eventually cause the sludge to float. When operating a pilot-scale UASB reactor at a low temperature of 18°C with a HRT of 6 hours and an OLR of 0.7 kgCOD/m3day (COD influent = 153 mg/L), Seghezzo [22] achieved a maximum efficiency of COD removal of 63%.

HRT effect

In treating municipal wastewater, one of the most important elements influencing reactor performance is HRT. For entrapping hanging objects, the upflow-velocity (Vup), which is proportional to HRT, is crucial. When Vup falls, HRT rises, enhancing the system's capacity to remove suspended particles (SS). The effectiveness of COD removal in a UASB reactor decreases because greater Vup shortens the time that sewage and sludge are in contact, reduces the likelihood of sludge granules shattering and causes a more significant washout of particles. Some scientists, however, contend that HRT has no impact on the effectiveness of treatment provided by the UASB reactor. Variations in reactor design, operating practices, and HRT range are to blame for the differing opinions among scientists. The flow rate also maintains the hydraulic retention time, an essential operating factor. If the reactor's diameter is excessively large, liquid channeling may occur during the UASB process, insufficient contact between the biomass and substrate as a result. Large reactors' lack of internal mixing will cause them to produce less biogas and sludge washout. On the other hand, increased height might promote substrate mixing and ideal contact between the substrate and microorganisms, causing the decomposition of organic waste more quickly and biogas production. By appropriately combining the biomass and substrate without chaneling, the Vup aids in maintaining the hydraulic retention time. According to numerous research, the maximum permitted upflow velocity is 1.5 to 0.5 meters per hour. 3.5–4.5 hours of HRT later researchers reported that at 0.3-0.427 m /h Vup, a UASB reactor for the treatment of municipal sewages was successfully in operation. Using a variety of 11°C, 15°C, 21°C, and 29°C are the operational temperatures, respectively. Lew et al. [18] evaluated how well a UASB reactor—an up-flow anaerobic sludge blanket—performed at treating domestic wastewater. At 28°C, the concentration of total suspended solids in the effluent increased with rising upflow speed and hydraulic retention time. This is shown in figure (4). Salazar-Peláez et al. [23] employed a small UASB reactor connected to an external ultrafiltration (UF) membrane to evaluate extracellular polymeric substances (EPS), the produced concentrations of COD, total solids, and soluble microbes for home sewage treatment under three different HRT. The shortest HRT when the reactor (UASB) was in operation (4 hours), they found that the highest concentrations were achieved (5).

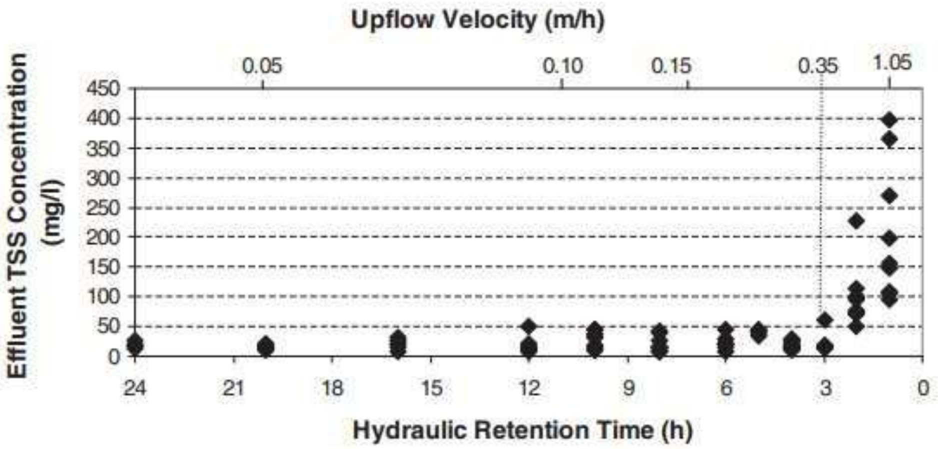

Figure 4: TSS content as a function of HRT at 28 °C in the effluent and upflow velocity[18].

	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*

Figure 5: Influence, UASB effluent, and permeate characteristics at the various applied HRTs [23].

pH influence

Because the anaerobic reactor's pH must be maintained between 6.3 and 7.8, it is essential for the speedy progress of the methanogenesis process. Because of the carbonate system's ability to act as a buffer, the acid-base system naturally maintains the pH of sewage within this range. without the need for chemicals. Reactors (UASB) used to treat sewage in tropical and subtropical regions have exceptionally stable pH and buffering capacities. The ideal pH for anaerobic digestion for treating domestic wastewater in an anaerobic reactor is 7, which lowers more than 80% of the TOC and COD, and boosts the hydrolysis and acidogenesis rates [17, 24].

Mixing Effect

Thanks to mixing, increased contact time between wastewater and microorganisms also reduces barriers to mass transfer, stops the development of repressive byproducts, and maintains a stable environment. The primary process rate will be slowed by substrate pockets at various stages of digestion if proper mixing is not done. Causing changes in temperature and pH at each stage. It is possible to use mechanical mixing, slurry recirculation, or methane gas. Numerous investigations have revealed that thorough mixing affects the effectiveness of anaerobic reactors. processing high COD sewage through anaerobic systems functioned better when mixed; slurry recirculation also performed better than impeller mixing mode and biogas recirculation. The output of biogas is higher in mixed digesters than in unmixed ones. Discontinuous mixing is preferred to strong mixing in large urban and agricultural waste digesters [17, 25]. Granules of sludge are produced as a result of fluidization. Because methanogens are less effective in these conditions, violent mixing is not advised. Karim and others [26] claim that mixing at starting reduces the pH of the digester, leading to variable performance and a longer startup time.

Granulation Effect

Long HRTs have been shown to have a negative impact on the growth of granular sludge in UASB reactors. However, relatively brief HRTs result in biomass washout. The UASB reactor cannot be used to its full capacity under these two scenarios. Although it has been discovered that these reactors can still function without them, granulation is thought necessary for appropriate home sewage treatment in reactors (UASB). Production of granules helps shorten starting periods for new processes. The outstanding performance of the UASB reactor is due to the formation of an active sludge in the reactor's lower part. A sludge bed develops as a result of the buildup of incoming suspended material and the proliferation of bacteria in particular circumstances. This results from the growth of granules into a layered structure and the emergence of bacterial flocs on their own. While UASB is running, These granules are not removed from the reactor by flushing. The diameter of the granulated sludge particles was discovered to range from 1.0 to 3.0 mm. (Vup = 0.1–1.0 mh-1) Granular suspensions settle more quickly than up-flow velocities do (20–80 mh–1). Therefore, The reactor has a large amount of biomass storage capacity. This allows for the use of a brief HRT and a high sludge loading rate (SLR) of up to 5 gCODgVSS-1day-1 (less than 4 hours). For a reactor to achieve appropriate removal efficiency even at high OLR, activated sludge production is required, whether it is granular or flocculent [17, 27].

2. CONCLUSION

An efficient method of treating wastewater, In order to generate biogas and decrease waste volume, the up-flow anaerobic sludge blanket reactor uses anticipated anaerobic decomposition. It has some uses, including the treatment of agricultural and industrial waste. According to the literature, the UASB offers robust Low maintenance and operation costs, high removal efficiency even at low temperatures, high OLR, and wide applicability from small to large scales, all of which need for a smaller reactor volume. The goal of this review was to determine the most efficient way to construct the UASB reactor.

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