UASB/EGSB APPLICATIONS FOR INDUSTRIAL WASTEWATER TREATMENT

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ABSTRACT

Installation of the upflow anaerobic sludge bed (UASB) and expanded granular sludge bed (EGSB) for industrial wastewater has grown very rapid by over the past (15-20 years). The UASB (Upflow Anaerobic Sludge Blanket) process and (EGSB) with high liquid and/or gas upflow velocities require biomass with excellent settling characteristics. Typically, granular sludge or anaerobic sludge grown on inorganic support is used for these processes. Considerable research has been done on parameters affecting the initiation and development of granular sludge. In particular, in most reactor configurations, a high TSS/COD ratio is known to compromise the granulation process and thus the performance of the reactor, requiring a preliminary TSS removal. This systems takes full advantage for very high biomass density in the reactor-allows very high organic loading rated and biogas productivity and provided highly efficient COD and BOD removal and optimal spatial organization of different trophic groups within the granules,

* Up to 30kg COD/m^3/d – UASB; 100 kg COD/m^3/d – EGSB.
* Up to 20 m^3 biogas/m^3/d.
* Typically achieve 80-99% COD removal.
* It apperas that under controlled conditions, considerable amounts of suspended solids can be treated in an UASB without compromising the process, omitting the need for a pre-settling and consequently decreasing the investment and operational costs of the plant.
* UASB/EGSP treated wastewater is either discharged to the municipal sewer for final treatment prior to discharge or subjected to aerobic polishing, NPK removal, etc. by the industry prior to discharge to the receiving waterbody.

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INTRODUCTION

UASB/EGSB are part of the high-rate reactor systems, Figure 1, which are:

A- Anaerobic filter/fixed bed reactor;
B- Downflow stationary fixed-film reactor;
C- Expanded bed/fluidised bed reactor;
D- Upflow anaerobic sludge blanket reactor; Expanded Granular Sludge Bed (UASB/EGSB);
E- Hybrid sludge bed/fixed bed reactor.

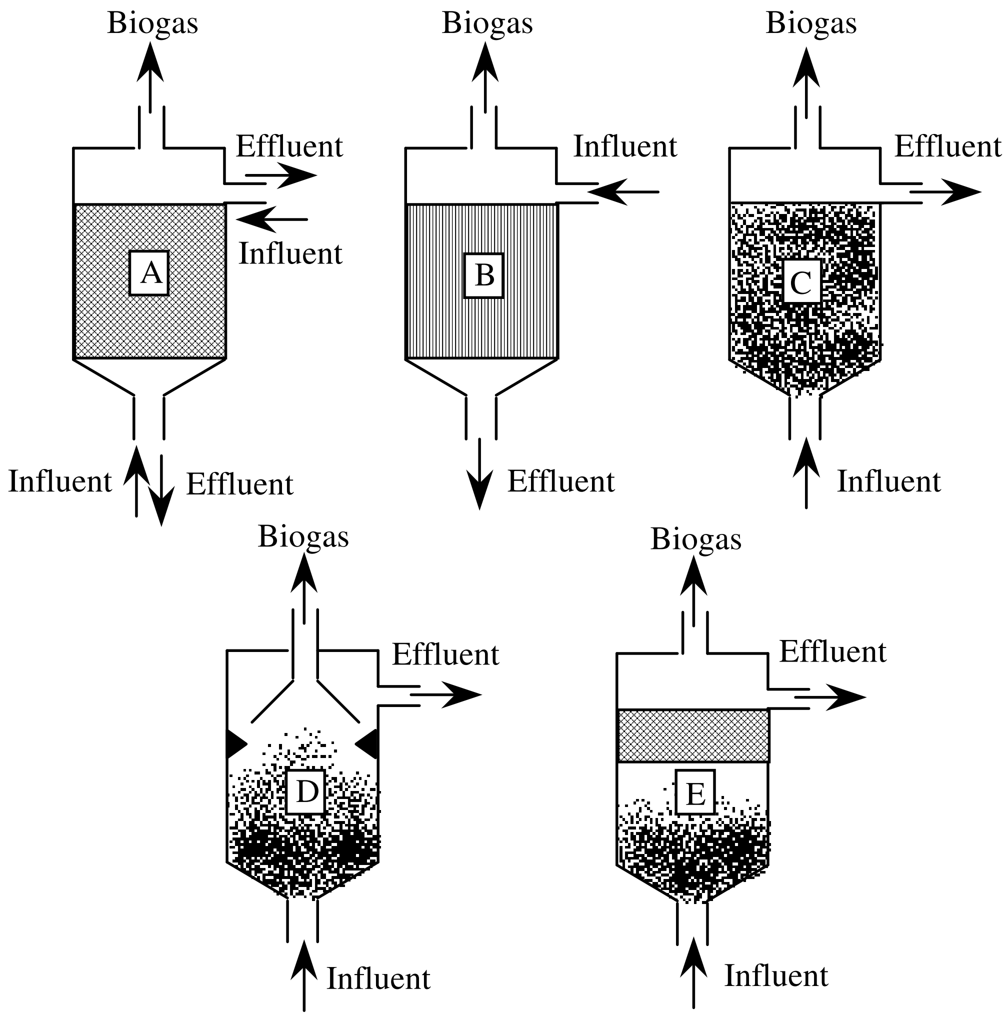

Figure 1. High-Rate Reactor Designs

ADVANTAGES OF ANAEROBIC TREATMENT

- Minimum place requirement, due to compact design.
- Easy adaptation to change of loadings and no effect from electrical shortage.
- Less energy and nutrient consumption.
- 1/10 less sludge production than aerobic treatment.
- No odor, noise or aerosol arising due to closed structure.
- Simple and secure energy production from biogas.
- Lower maintenance costs.
- Full automatic operation with computerized system.
- Rapid startup and suitable for seasonable operation.
- No filling media.
-Settler self-cleaning system.
- Easy pre-treatment application.

UASB

Anaerobic granular sludge bed technology refers to a special kind of reactor concept for the "high rate" anaerobic treatment of wastewater. The concept was initiated with upward-flow anaerobic sludge blanket (UASB) reactor. A scheme of a UASB is shown in Figure 2 below. From a hardware perspective, a UASB reactor is at first appearance nothing more than an empty tank (thus an extremely simple and inexpensive design). Wastewater is distributed into the tank at appropriately spaced inlets. The wastewater passes upwards through an anaerobic sludge bed where the microorganisms in the sludge come into contact with wastewater-substrates. The sludge bed is composed of microorganisms that naturally form granules (pellets) of 0.5 to 2 mm diameter that have a high sedimentation velocity and thus resist wash-out from the system even at high hydraulic loads. The resulting anaerobic degradation process typically is responsible for the production of gas (*e.g.* biogas containing CH_4 and CO_2). The upward motion of released gas bubbles causes hydraulic turbulence that provides reactor mixing without any mechanical parts. At the top of the reactor, the water phase is separated from sludge solids and gas in a three-phase separator (also known the gas-liquid-solids separator). The three-phase-separator is commonly a gas cap with a settler situated above it. Below the opening of the gas cap, baffles are used to deflect gas to the gas-cap opening.

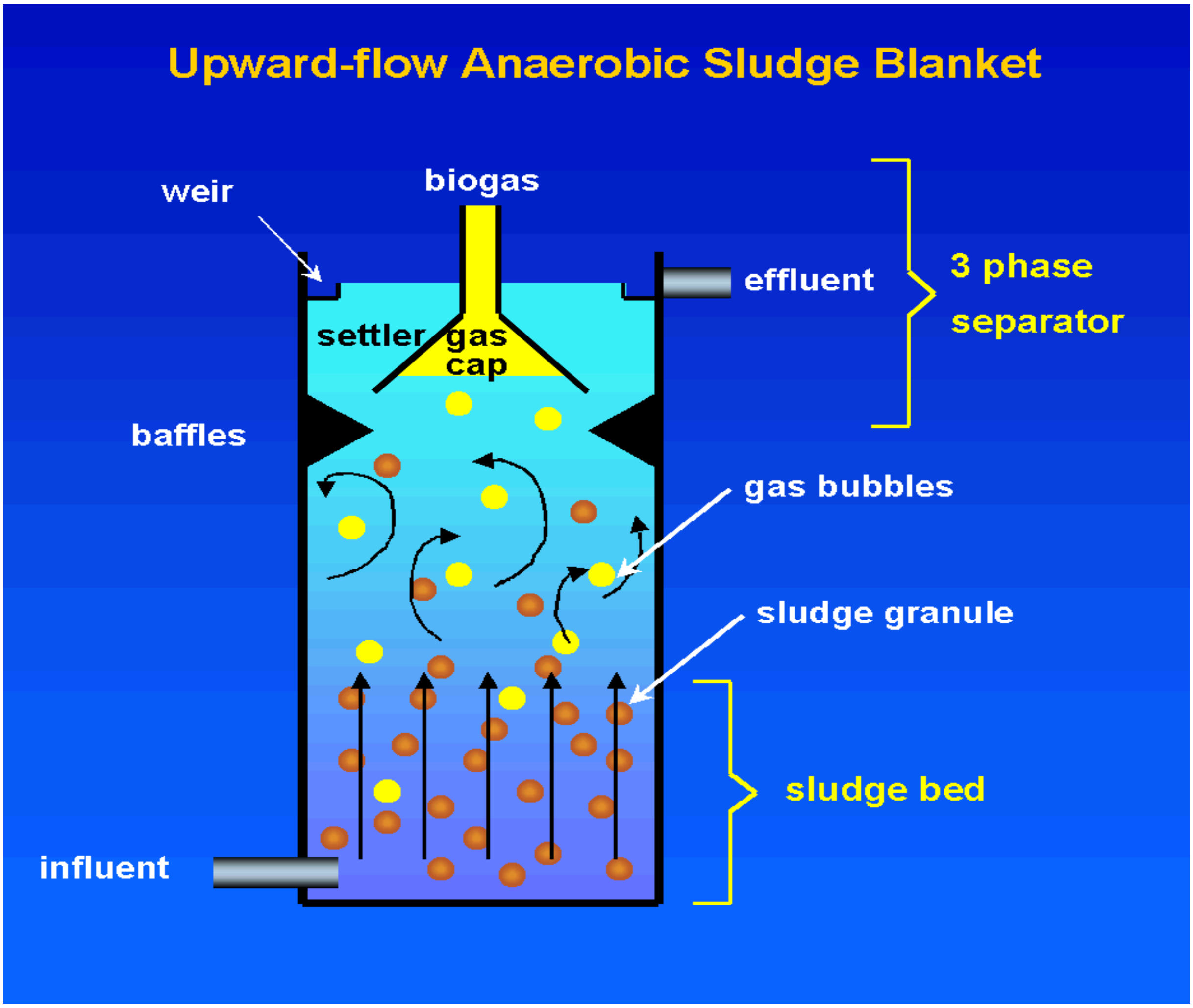

Figure 2. The upward-flow anaerobic sludge bed (UASB) reactor concept

EGSB

An expanded granular sludge bed (EGSB) reactor is a variant of the UASB concept (Kato *et al*. 1994). The distinguishing feature is that a faster rate of upward-flow velocity is designed for the wastewater passing through the sludge bed. The increased flux permits partial expansion (fluidization) of the granular sludge bed, improving wastewater-sludge contact as well as enhancing segregation of small inactive suspended particle from the sludge bed. The increased flow velocity is either accomplished by utilizing tall reactors, or by incorporating an effluent recycle (or both). A scheme depicting the EGSB design concept is shown in Figure 3. The EGSB design is appropriate for low strength soluble wastewaters (less than 1 to 2 g soluble COD/l) or for wastewaters that contain inert or poorly biodegradable suspended particles which should not be allowed to accumulate in the sludge bed.

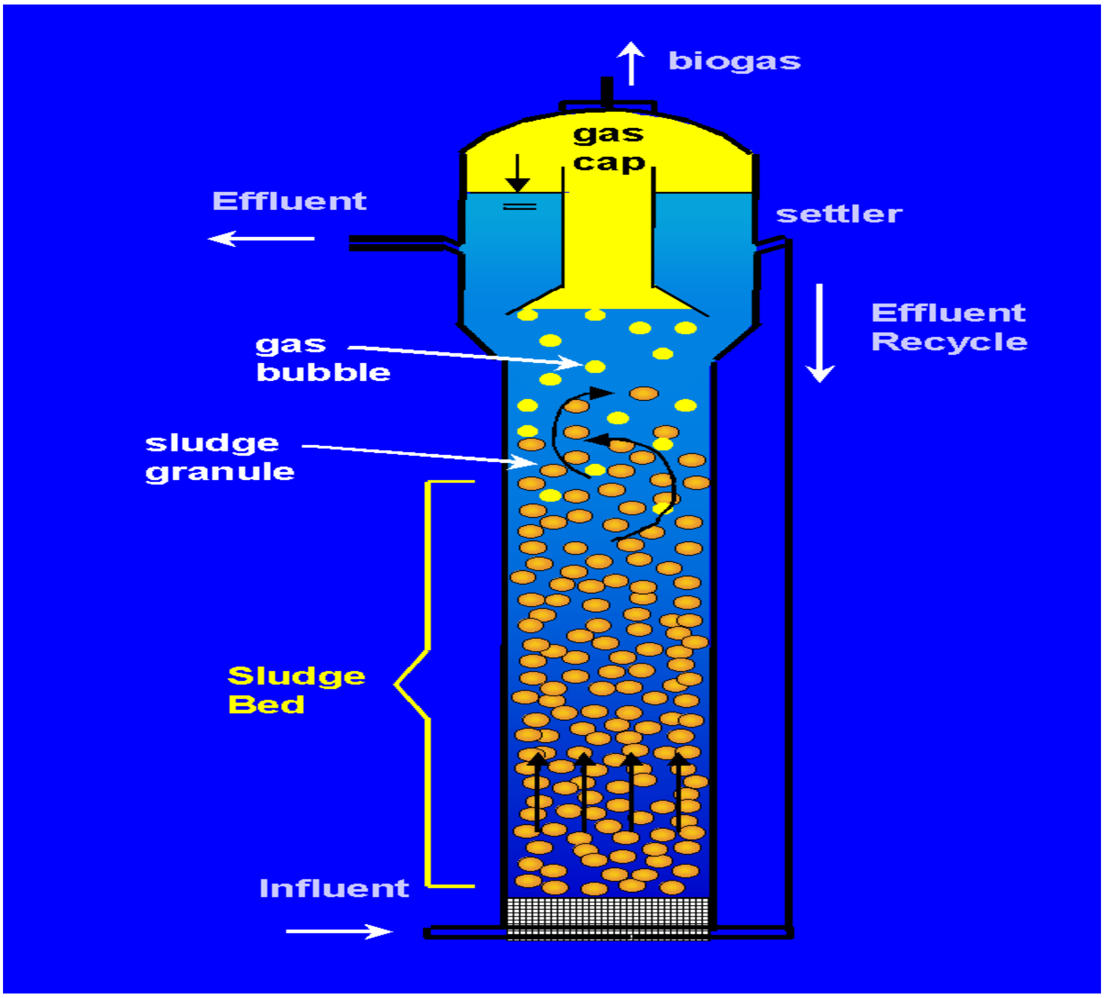

Figure 3. The expanded granular sludge bed (EGSB) reactor concept

SYSTEM OPERATION

The difference of EGSB from UASB process is operation capability in higher loadings and accordingly the reactor of EGSB is taller and slender. In both systems, the wastewater prepared in conditioning tank via mixing with nutrients and anaerobic effluent is controlled by means of pH and temperature and pumped into the reactor. The required upflow velocity and homogeny of the pumped wastewater is accomplished by a specially designed distribution system (patented). The organic substances in the wastewater are decomposed to biogas as they are flowing through several meters of biomass in granular bacteria bed. Together upwards movement of produced biogas and wastewater accelerated by the distribution system blends the whole reactor volume without any mechanical mixing device. The patented three phase separator (settler) at the top of the reactor ensures an excellent separation of treated water, biogas and biomass. The relatively higher density of the biomass eases the return to the sludge bed (with minimum sludge loss), where the treated water is returned into the conditioning tank in order to prepare the raw wastewater and will be discharged or transferred into the next treatment step.

The biogas is collected on top of the reactor and used in production of energy or burned in the flare without any fan required after reducing the sulphur concentration if necessary

The system has a reliable construction. The corrosion possibility is minimized for the reactor working oxygen free and hermetically closed conditions, which is partially in UASB and completely in EGSB. The steel components inside the reactor are protected with special epoxy coating against corrosion.
Moreover, the special design of the separator also provides safety for the whole system preventing any possible gas leakage.

ANAEROBIC REACTOR DESIGN

There are many new concepts in anaerobic reactor design. Specialized literature is available and covers a broad range of technologies and process options. The most popular design, the so called UASB (Upflow Anaerobic Sludge Blanket Reactor) has no secrets at all, and is very simple to build and operate. The main design parameters and features of these reactors are:

- Volumetric Organic Load: this refers to the daily quantity of organic compounds, symbolized generally by COD, applied to the reactor's volume, and is expressed in kg COD/d.m³ (or lb/d.ft³); the number for this parameter is usually in the 5 - 15 kg COD/d.m³ (0.3 - 0.9 lb/d.ft³) , and the recommended values vary with the type of wastewater and expected BOD and COD removal rates; very high BOD removal efficiencies are reached at low volumetric organic loads, like 2 kg COD/d.m³ (0.12 lb/d.ft³).
- Raw Effluent Bottom Distribution: that is a very important concept, as far as the wastewater to be treated must be evenly distributed in the bottom of the reactor, to allow close contact between the organic molecules and the anaerobic bacteria blanket; values between 2 - 4 m²/injection point (22 - 44 ft²/point) are usually found; Acqua Engenharia reactor design adopt individual inlets for each injection point, being each inlet placed at the top of the reactor and fed by triangular weirs; this is a very nice design that makes possible to visually verify if any of the injection points are clogged, and assure that the flow distribution is even at any moment.
- Velocities Inside the Anaerobic Reactor: wastewater flow inside of the reactor must be verified in each step of its course; some basic numbers are:

  - upflow velocity at the bottom of the tank: 1.0 $m^3/h.m^2$ max. (0.3 ft/h)
  - velocity through the gas/liquid/solids separator 3 - 5 $m^3/h.m^2$ (0.9 - 1.5 ft/h)
  - upflow velocity at the upper settling area: depends on sludge quality, up to 1 - 3 $m^3/h.m^2$ for granulated sludge (0.3 - 0.9 ft/h).
- Treated Wastewater Collection System: as well as the bottom distribution, even collection of the treated wastewater at the surface of the Anaerobic Reactor is highly important; collection channels are distributed all along the water level, each one including adjustable weirs to make any adjustment possible.
- Gas/Liquid/Solids Separator Design and Gas Collection System Design: must be properly designed to avoid clogging and water and scum drag-out.

ANAEROBIC REACTOR OPERATION AND CONTROL

In fact, some of the anaerobic plants that do not operate correctly have some of their problems caused by misinformation of the users, and a high dosage of prejudice. This paradigm was created in the past because of the "black box syndrome" above cited.

Nowadays, operation of Anaerobic Reactors can be considered very simple, if some basic concepts are understood.

The main basic concept regards the principle of anaerobic digestion, that is, complex organic compounds are broken down into organic ("fat") acids, and then these acids are transformed into methane, CO_2, water and anaerobic bacteria cells. This can be simplified as follows (actual reactions are more complex and include other sub-reactions):

Complex Organic Compounds

↓

Fat (Organic) Acids

↓

$CH_4 + H_2O + CO_2$ + Cells

Once one understands the above acidification/methanisation concept, it becomes easy to understand that to control process is rather simple if based on daily analysis of the following parameters:

- COD in and out: representing how much organics were removed in the Anaerobic Reactor: must be over 80% under proper operating conditions; COD (or organic compounds) are removed only when they are converted to CH4; if conversion is partial, complex organic compounds are converted into organic acids, as a consequence the COD tests will still present high values, and the pH will lower.
- Volatile Fat Acids and Total Alkalinity at the bottom and upper parts of the reactor: it represents how high or low is the organic acids level through the reactor; these figures, if checked against pH, COD removal and methane generation, give a clear picture of the organics/acids/methane equilibrium; the easiest way to determine a good operating condition is the VFA/TA (Volatile Fat Acids to Total Alkalinity ratio), that can represent:
  - bellow 0.15 ===> stable condition: most of the organic compounds are converted to organic acids and then to CH4.
  - between 0.15 and 0.20 ===> operation requires care; reactor is just a step from being overloaded.
  - between 0.20 and 0.25 ===> maximum attention must be taken: reactor is almost overcharged (the terms overloaded, or overcharged, mean that the ratio between the organic load and the amount of anaerobic bacteria present in the reactor are so high that the microorganism can not "eat" the organic compounds and convert then totally to CH4).
  - above 0.25 === > the reactor is "acidified", what means that conversion is mostly to organic acids, that are not converted to CH4; too much acidification for too little methanisation.
- pH: as acidification and methanisation determines the biochemical reactions equilibrium in an Anaerobic Reactor, pH monitoring is essential; when "acidification" occurs, the first action is often to increase inlet pH, what most of the time is a wrong decision, since it will not solve the main probable cause of overcharging.
- Methane Flowrate: by checking methane generation against organic load (hourly or daily) it is possible to know exactly whether an Anaerobic Reactor is working properly or not; theoretical conversion is about 0.45 Nm3 CH4/kg COD (7.2 ft^3/lb COD); acknowledgment of instant variation of methane flowrate makes possible to detect methanogenic activity of the anaerobic bacteria, and even instantly diagnose toxic or inhibitory loads.

- Biogas Composition: plays almost the same role as the item above; a "good" composition should be 60 - 65 % CH_4.
- Reactor Start-up: must be carried out following all the above concepts, with gradual increase in inlet flowrate and organic load; seeding of granular sludge from other operating reactor is highly recommended, in order to lower start-up time. Operation must start with a very low inlet flowrate, and the hydraulic load in the reactor maintained by means of treated wastewater recirculation; inlet flowrate can be increased as far as all control parameters are attained.

CONCLUSIONS

Anaerobic wastewater treatment is a low cost process, and is finally ready to be considered simple and reliable. The main advantages over the conventional aerobic processes are reduced required area, lower energy consumption, lower nutrients requirements, and the possibility of energetic application of the biogas.

It is also a great option for aerobic plants upgrading, when an anaerobic unit can be placed ahead of the existing aeration tanks.

The UASB reactor can achieve a loading rate 7.2 kg COD/cu.m/d HRT 3-4 days. The best performance loading rate is 4 kg COD/cu.m/d.

The COD and BOD reduction were about 80-95% and 97-99% respectively.

Bio-gas production was in the range of 0.70 - 0.98 cu.m/kg. COD/removal or 0.61 - 0.88 cu.m/kg COD input.

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