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ANAEROBIC FILTERS, ANAEROBIC FLUIDIZED BED REACTORS, UPFLOW ANAEROBIC SLUDGE BLANKET REACTORS - ANAEROBIC REACTOR FOR INDUSTRIAL WASTEWATER TREATMENT

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Annotation. *This paper reviews the development and evolution of commonly used anaerobic reactors - anaerobic filters (AF), anaerobic fluidized bed reactors, upflow anaerobic sludge blanket (UASB) reactor - for wastewater treatment. The successful application of anaerobic technology to the treatment of industrial wastewater is critically dependent on the development and type of anaerobic reactor used. Since the original design was developed, many codifications have been made in reactor design in order to enhance both the efficiency and reliability of the reactor. In this paper, the ain alteration and modifications of anaerobic reactor would be documented.*

1. INTRODUCTION

An anaerobic process is a process where organic matters in wastewater are converted to methane and carbon dioxide through a series of reactions involving a consortium of obligate and calculative anaerobic microorganisms. Anaerobic systems can be categorized according to how the biomass is retained in the system and type of biomass they depend on. Systems where the bacteria grow and are suspended in the reactor liquid are called suspended-growth processes. Typically, suspended-growth systems have sludge that is considered to be flatulent or granular in nature-oftentimes both flatulent and granular sludge coexist in a reactor. Granular sludge exhibits high activity rates and settling velocities that reduce required reactor volumes and increase allowable organic loading rates. [1]

The loading rates permissible in an anaerobic waste treatment process are primarily dictated by the sludge retention in an anaerobic reactor. The maintenance of high sludge retention time (SRT) has been the major problem in the practical application of the process, especially for waste with chemical oxygen demand (COD) below about 3000 mg/L. Obviously, a waste treatment process for low-strength

wastes is an economical one if large volume of waste can be forced through the system in a relatively short time period. For this purpose process are required in which the biomass retention time can be controlled independently of the wastewater flow rate. Conventional anaerobic treatment processes of the flow-through type are therefore inadequate to treat low-strength wastes.

Advances in the understanding of how anaerobic system function, improved understanding of mixing and mass transfer, and anaerobic reactor design, has led to the evolution of a new generation of high-rate anaerobic processes e. g. anaerobic filters, anaerobic fluidized bed reactors, upflow anaerobic sludge blanket reactor etc. These systems have been schematically presented in Figure 1.

One common feature of all high-speed processes is their ability to provide a high SRT to hydraulic retention time (HRT). High biomass concentration is maintained in a reactor with relatively low treatment time. In fluidized beds and anaerobic filters, this is achieved by development of biofilm on support surface. This is accomplished in UASB systems by the development of flocs or granules that have exceptionally good settling properties. Among the other improved high-rate anaerobic treatment methods, UASB has secured an important place. [2]

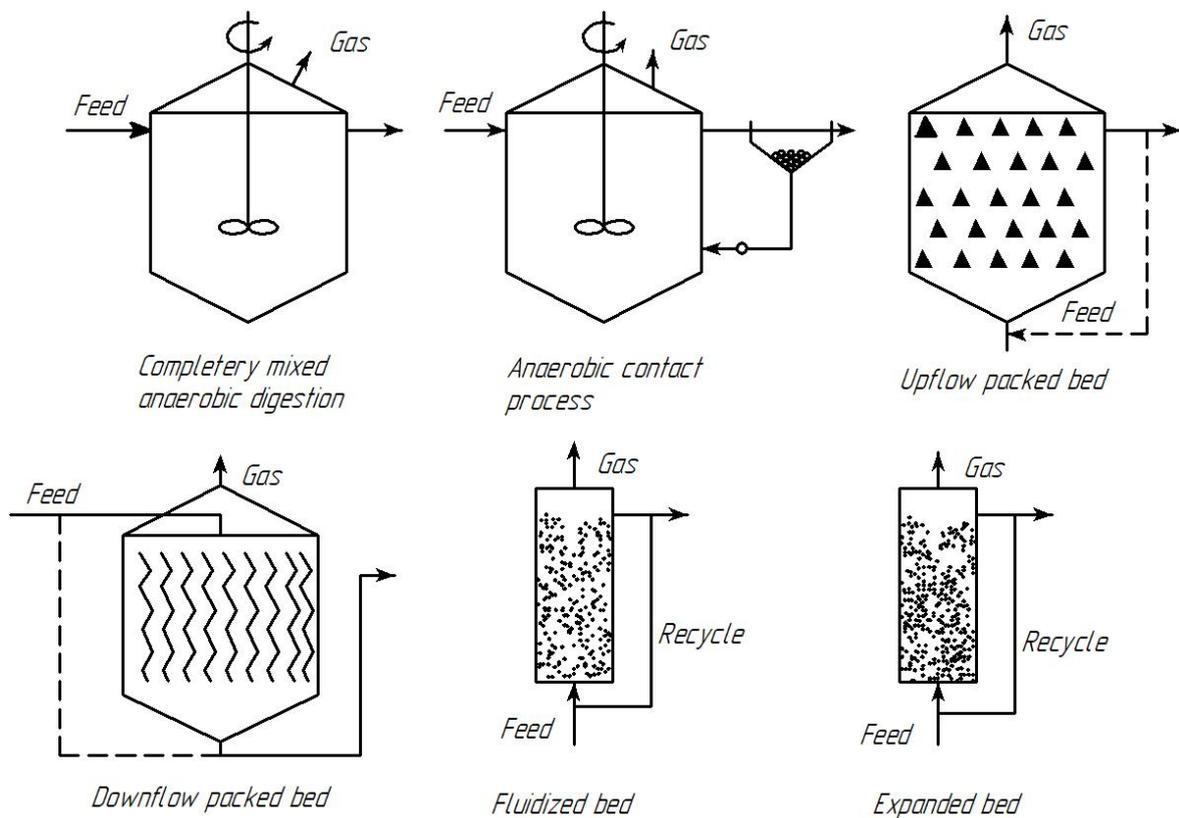


Fig. 1. Typical reactor configurations used in anaerobic wastewater treatment

2. ANAEROBIC REACTORS

First conventional anaerobic digester was used in 1881 to liquidify the solid components of sewage. Then, in 1891 the first septic tank is built to retain solids in sewage and followed by development of the „Imhoff“ tank in Germany on 1905. In 1930s, digesters were started to be mixed and heated to improve the digestion of solids in the sewage. Few years later, in 1955, anaerobic contact process was developed to treat soluble organics and dilute wastewaters. Anaerobic reactors can be divided into conventional anaerobic digestion (AD) or high-rate AD. [3, 4]

2.1 Anaerobic filters (AF)

Anaerobic filter (Fig. 2) is a fixed-film biological wastewater treatment process where fixed matrix (support medium) provides an attachment surface that supports the anaerobic microorganisms in the form of a biofilm. As wastewater flows upwards through this bed and dissolved pollutants are absorbed by biofilm, treatment occurs. Anaerobic filters were the first anaerobic systems that eliminated the need for recycle and solids separation while providing a high SRT/HRT ratio. Various types of support material can be used, such as sand, plastics, sand, reticulated foam polymers, stone, granite, granular activated carbon (GAC), and quartz. These materials have exceptionally high surface area to volume ratios ($400 \text{ m}^2/\text{m}^3$) and low void volumes. It's resistance to shock loads and inhibitions make anaerobic filter suitable for the treatment of both dilute and high strength wastewaters. [5, 6]

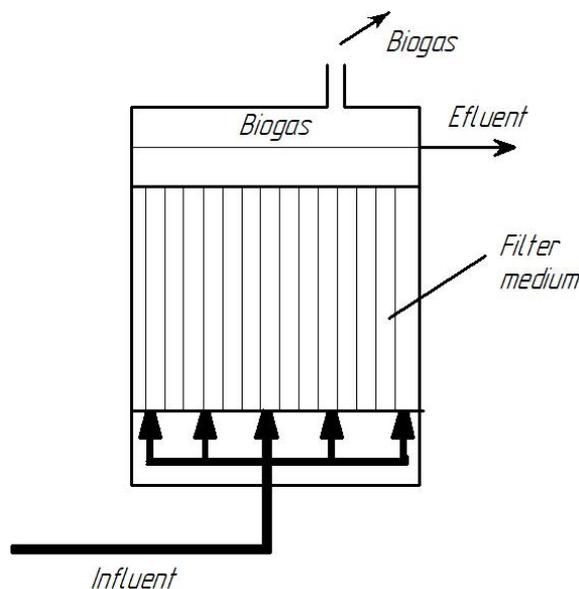


Fig. 2. Anaerobic filters

2.2 Fluidized bed reactors (FBD)

Fluidized bed reactors (Fig. 3) is a biological reactor that accumulates a maximum active attached biomass yet still handling fine suspended solids without blocking. By maximizing the surface area available for cell attachment and minimizing the volume occupied by the media, a maximum specific activity of attached biomass may be achieved for a given reactor volume. [7]

In FBR, biomass is attached to surface of small particles (anthracite, high density plastic beads, sand etc.) which are kept in suspension by upward velocity of liquid flow. Effluent is recycled to dilute incoming waste and to provide sufficient flow-rate to keep particles in suspension. Large surface area of support particles and high degree of mixing that results from high vertical flows enable a high biomass concentration to develop and efficient substrate uptake. Biomass concentration: 15-40 g/l.

The greatest risk with FBR is the loss of biomass particles from the reactor following sudden changes in particle density, flow rate or gas production. If flow is interrupted and the bed allowed to settle, there is a tendency once flow is restarted for the entire bed to move upward in plug-flow rather than fluidizing. In practice, considerable difficulties were experienced in controlling the particle size and density of flocs due to variable amounts of biomass growth on particles.

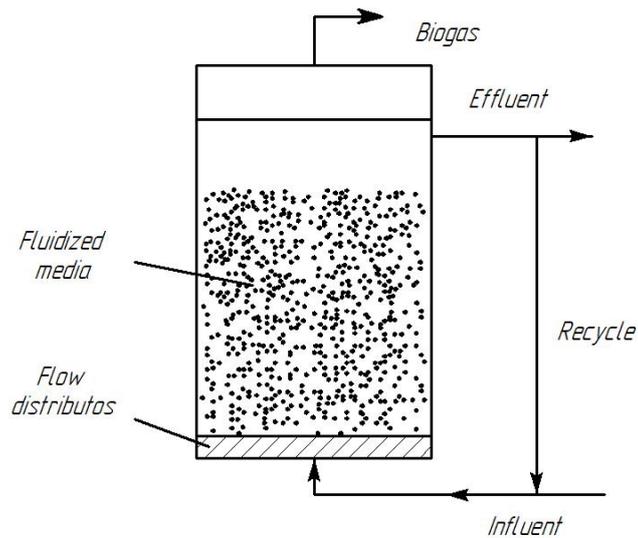


Fig. 3 Fluidized bed reactors

2.3. Upflow Anaerobic Sludge Blanket (UASB) Reactor

The problem associated with anaerobic filters and FBRs (Fig. 4) has led to development of new unpacked reactors that still incorporate an immobilized form of particulate biomass. In 1970s, the concept of an unpacked high-rate reactor called UASB reactor was developed [8]. It is consider as the most widely used high-rate anaerobic system for domestic and industrial wastewater treatment worldwide.

UASB reactor is based on that anaerobic sludge exhibits inherently good settling properties, provided the sludge is not exposed to heavy mechanical agitation. Adequate mixing is provided by an even flow-distribution combined with a sufficiently high upflow velocity, and by agitation that results from gas production.

Wastewater flows upwards through a sludge blanket located in lower part of reactor, while upper part contains a three phase (solid, liquid, gas) separation system. Three-phase separation device is the most characteristic feature of UASB reactor. It facilitates the collection of biogas and also provides internal recycling of sludge by disengaging adherent biogas bubbles from rising sludge particles.

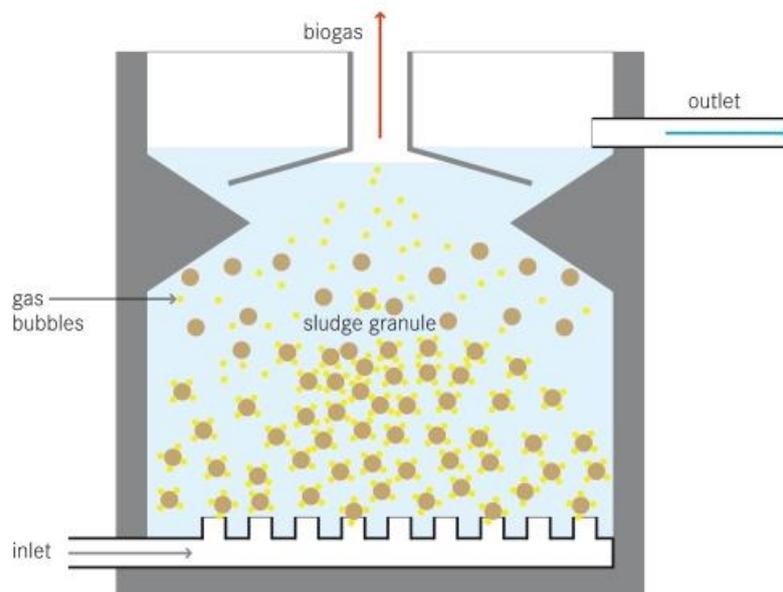


Fig. 4. Upflow anaerobic sludge blanket reactor [9]

3. CONCLUSION

All presented designs of the anaerobic reactor show that it is able to purify various waste waters of various strengths. The physical structure of the reactors allows various modifications to be made that providing the capability to treat wastewaters that currently require at least two separate units, therefore substantially reducing capital costs.

Although these types of little disclosed in the modern literature, but they are still widely used in the treatment of industrial, chemical and agricultural wastewater.

References:

- [1] Wilén BM, Liébana R, Persson F, Modin O, Hermansson M. (2018) The mechanisms of granulation of activated sludge in wastewater treatment, its optimization, and impact on effluent quality. *Appl Microbiol Biotechnol*, (102 (12)), 5005-5020. <https://doi.org/10.1007/s00253-018-8990-9>.
- [2] Mainardis M, Buttazzoni M, Goi D. (2020) Up-Flow Anaerobic Sludge Blanket (UASB) Technology for Energy Recovery: A Review on State-of-the-Art and Recent Technological Advances. *Bioengineering (Basel)*, (7 (2)), 43. <https://doi.org/10.3390/bioengineering7020043>.
- [3] Barker D.J., Stuckey D.C. (1999) A review of soluble microbial products (SMP) in wastewater treatment systems. *Water Res.*, (33), 3064-3082 [https://doi.org/10.1016/S0043-1354\(99\)00022-6](https://doi.org/10.1016/S0043-1354(99)00022-6).
- [4] Barber W.P., Stuckey D.C. (1999) The use of the anaerobic baffled reactor (ABR) for wastewater treatment: A review. *Water research*, (33), 1559-1578. [https://doi.org/10.1016/S0043-1354\(98\)00371-6](https://doi.org/10.1016/S0043-1354(98)00371-6).
- [5] Young, J.C., McCarty, P.L. (1969) The Anaerobic Filter for Waste Treatment. *Stanford University Technical Report*, (87), CA, 1–235 https://www.chempap.org/file_access.php?file=543a159.pdf.
- [6] Bodik, I.; Herdova, B.; Kratochvil, K. (2000) The application of anaerobic filter for municipal wastewater treatment. *Chemical Papers - Slovak Academy of Sciences*, (54(3)), 159–164.
- [7] Werther J, Hartge E-U, 2004 Modeling of Industrial Fluidized-Bed Reactors. *Ind Eng Chem Res* 43:5593-5604 <https://doi.org/10.1021/ie030760t>.
- [8] Lettinga G, van Velsen AFM, Hobma SW, de Zeeuw W, Klapwijk A. (1980) Use of the upflow sludge blanket (USB) reactor concept for biological wastewater treatment, especially for anaerobic treatment. *Biotechnol and Bioeng*, (22), 699-734.
- [9] Вилучено з Wikipedia: Upflow anaerobic sludge blanket digestion https://en.wikipedia.org/wiki/Upflow_anaerobic_sludge_blanket_digestion#/media/File:Schematic_of_the_Upflow_Anaerobic_Sludge_Blanket_Reactor_UASB.jpg.