MOVING BED BIOFILM WASTEWATER TREATMENT TECHNOLOGIES (MBBR) PRESENTATION OF SELF-DEVELOPED MBB

Moving Bed Biofilm Reactor (MBBR) systems are modern, highly efficient versions of biofilm wastewater treatment systems. Before presenting the MBBR systems, we briefly present the basic principle of cleaning (biofilm), as well as the development of biofilm systems, as well as how this design has evolved over the course of history. MBBR IS PRESENT AS A BIOFILM CARRIER IN THE WATER PURIFICATION SYSTEM.

ABOUT BIOFILM SYSTEMS

Activated sludge technology is currently widespread in wastewater treatment. A possible direction for the development and intensification of wastewater treatment is the creation of biofilm systems and activated sludge/biofilm hybrid systems. Immobilization of microorganisms has several advantages; on the one hand, the conversion of pollutants can be improved, and on the other hand, the growth and age of biomass can be better controlled. The system is also more stable, weil the microorganisms fixed in the biofilm are more resistant to toxic substances and sudden changes in the load than the microbes in activated sludge.

While the microorganisms in the activated sludge occupy their place in loose flakes, "floccles", in the biofilm, microorganisms adhering to a natural or artificial surface they form a thin layer. The biofilm itself is a complex "living community" in which bacteria, algae and protozoa are also found. In the membrane, the cells of the mentioned microorganisms are the carrier they stick to its surface with the help of a kind of glue, the extracellular polymer matrix that surrounds them. This matrix provides the main mass of the biofilm, its constituents are mainly polysaccharides, proteins, amino acids and lipids. It is responsible for the mechanical stability of biofilms, the composition of which naturally depends on the microorganisms species, the age of the biofilm and various environmental factors, such as pH, temperature, nutrient concentration, presence of toxic substances, etc. The same material is responsible for the showers and faucet drains also for the formation of - not very unpleasant - slippery slimes in pipe sections (in fact, these are biofilms).

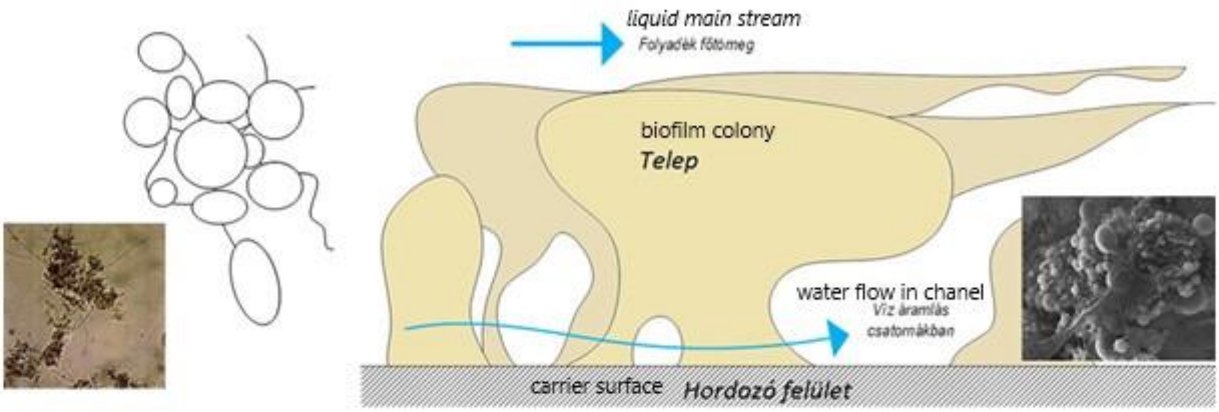
The thickness of the biofilm ranges from sometimes 100 micrometers to 1-2 millimeters, due to slow diffusion a nutrient concentration gradient is formed (just like in an activated sludge flake). Organic matter binds in the upper layer, then hydrolyzes there, and finally its derivatives of smaller molecular size they can diffuse into the deeper biofilm layers, where further decomposition takes place. Oxygen, ammonium, and in the case of the nitrate produced from the latter, a suitable concentration gradient is formed a in biofilm, in which nitrate can penetrate the deepest. As a result of the above, the biofilm is different environmental conditions develop depending on the depth. In the case of adequate depth, the innermost layers either oxygen or they can also be nitrate-free (anaerobic). Accordingly, the biofilm the environmental conditions are favorable for very different processes to take place in its different layers, so several cleaning processes can take place simultaneously (removal of organic carbon, nitrification and denitrification at the same time).

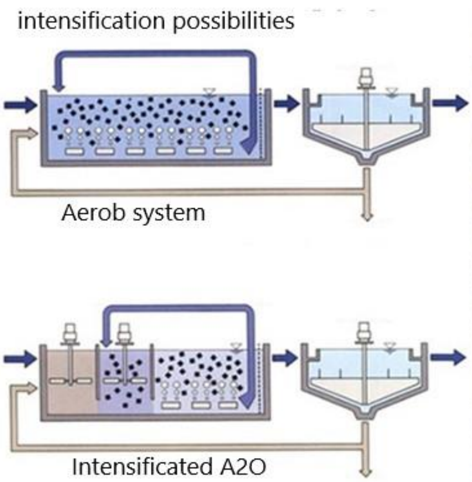
THE MAIN OBJECTIVE OF USING BIOFILMS IS TO INCREASE NITRIFYING CAPACITY. The experience shows that the specific nitrification capacity, or nitrogen removal in biofilms it is more a function of the surface (biofilm carrier) than of the sludge mass formed on it. Biofilms that work well in the case of 1-2 g/m^2/Day specific nitrifying capacity is also available. Of course, this can be immediately converted into volume also for performance. With the formation of 200 m^2 of biofilm in one cubic meter of cleaning volume, it is extremely nitrifying performance is achieved. Compared to the average

performance of activated sludge systems of 100 g/m^3/D a nitrifying biofilm can oxidize 200-400 g/m^3 of nitrogen if a surface area of 200 m^2/m^3 is provided.
IN THE CASE OF THE MBBR MEDIUM MANUFACTURED BY OUR FACILITY, THIS IS 960 m^2/m^3 IN THE CASE OF 900-1 900 g/m^3/D INDICATES NITROGEN OXIDATION.

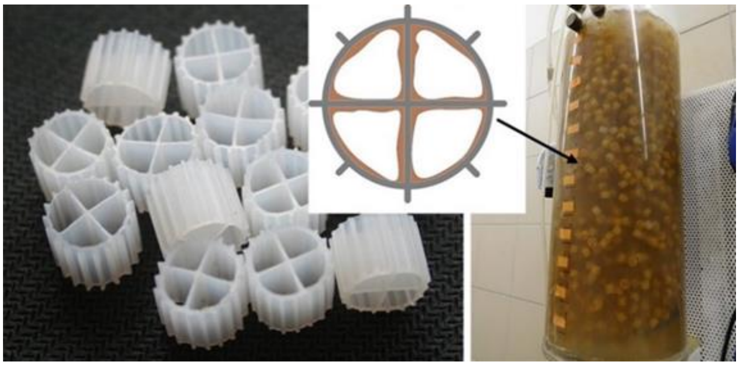
HOW MBBR TECHNOLOGY WORKS

In the MBBR technology, the biofilm carrier medium is not fixed, but similar to water due to its density - it floats in it and moves due to the flow. With proper sizing and available with a protective grid to keep the filling pieces in the biological pool and into the post-settler do not get out (at most the pieces of biofilm that break off). In this way, with MBBR TECHNOLOGY IN AN EXISTING ACTIVATED SLUDGE SYSTEM, THE SLUDGE CONCENTRATION CAN BE INCREASED, THE SYSTEM PERFORMANCE - OF COURSE WITHIN CERTAIN LIMITS - CAN BE IMPROVED, THE SYSTEM CAN BE INTENSIFIED. At the same time, the load on the post-settler does not increase, since the the amount of detached biofilm pieces is small, and they form a sludge that settles well anyway. With this the MBBR system, which is the subject of this chapter, was practically realized concept. The possibilities of this type of intensification are presented in the block diagrams and pictures below:

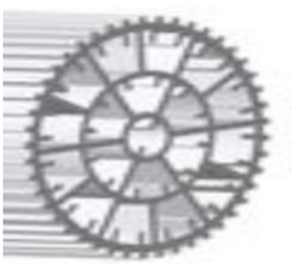




Several requirements had to be met at the same time in MBBR mode intensified purifiers. The specific gravity of the filling (including the attached biomass) must be slightly heavier than the wastewater, so that the mixing system or the supplied air flow can pick them up and circulate them. For this, plastics are a are most suitable. The filling should be as small as possible, but its structure should allow a rapid flow of liquid in the internal parts as well, ensuring adequate material transport both in water, both from a gas phase point of view. It is also important that the swirling elements do not obstruct the flow of air bubbles are hindered, as this would result in an increase in energy demand. THE BIOFILM CARRIER SURFACE ROUGHNESS IS ALSO ADVANTAGEOUS IN ITS DESIGN. THIS PART IS THE SPECIFIC SURFACE IT CAN BE INCREASED, AND ON THE OTHER HAND, BIOMASS ALSO ADHERES MUCH BETTER TO UNEVEN ON THE SURFACE.

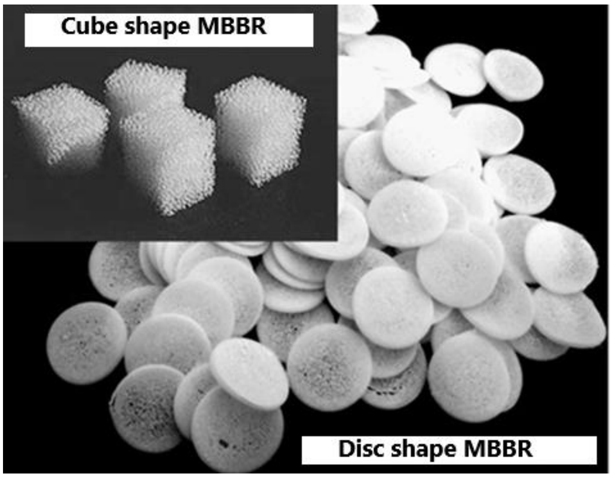


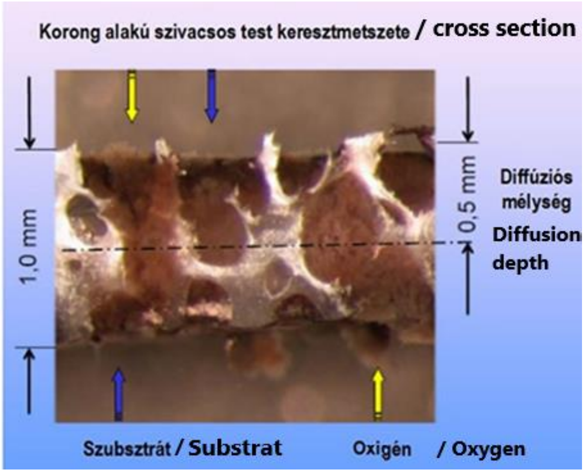
THE MBB WITH THE PROFILE DEVELOPED BY US CHARGES THE ABOVE DESIGNED WITH MAXIMUM CONSIDERATION OF REQUIREMENTS, IT HAS THE FOLLOWING PROFILE AND SURFACE DESIGN:



Technical details	
Size:	25 MM X 12 MM
SPECIFIC WEIGHT OF BASIC MATERIAL	0,97 - 0,98 G/CM³
BASIC MATERIAL	SINGLE USE, CLEAR HDPE
DOSING VOLUME RATIO:	15 % - 70 %
UNIT QTY:	> 145 000 PIECE/M³
ACTIVE SURFACE:	960 M²/M³
LIFE TIME:	> 15 YEAR
NITRIFICATION EFFICIENCY:	900-1900 G NH4-N/M³/DAY

In addition to hard, rigid plastic fillings, the other option is soft, plastic foam creating a structure, the most common versions of which nowadays are the thin (1-2 mm thick) disks. In this way, an even larger specific surface of up to 2 000-3 000 m^2/m^3 can be provided for the biofilm.





In the case of these two main types of biofilm carriers, the MBBR is an input cost with the given carrier surface varies in direct proportion, essentially the disc-shaped medium has 3x surface area, which is 3x the inclusion it also involves additional costs. In addition to the design, size, and material of the carrier, the amount of filling is also an important consideration in planning. In general, with such systems, the pool is approx. It fills 1/3-1/2 of the carrier, while the remainder is the free liquid volume. The carrier must also be washed out prevent it, filters placed at the appropriate points are used for this purpose.

CHARACTERISTICS OF MBBR SYSTEMS

MBBR systems can also be built during the intensification of existing purifiers, but they are now widespread technologies based on such a concept. The reason for their success is their simplicity and high degree of flexibility, that pure MBBR systems can be created, but also existing activated sludge systems they can be intensified in this way (e.g. by creating hybrid systems). For flooded systems (drip body), a turbulent flow can be formed in the MBBR, which fills the biofilm with nutrients, it makes it more permeated with air (less dead space is formed), in addition to the excessive thickness of the filmprevents (overgrowing or decaying biomass sooner, in smaller pieces, continuously breaks off), so the need to backwash the reactor occurs much less. The reactor layout as a result, the hydraulic resistance is significantly lower than with fixed film systems.

The biggest advantage of the MBBR design is undoubtedly that the biomass remains in the reactor at most, only a small part is washed away, which can be removed in its entirety as excess sludge. The recirculation can therefore be practically omitted, or in the case of hybrid systems, for smaller recirculation there is a demand (only the activated sludge part has to be calculated), so a smaller post-settlement plant can be planned, or for the intensification of the activated sludge system, it can be used without any special construction modification existing retrofitter. What's more, the smaller amount and structure of the sludge allows other, new development sludge separation methods - membrane bioreactor with an external separation module –its application. Due to the slow leaching, the average sludge age is also higher, which on the one hand ensures nitrification well (in addition to adequate ventilation, of course), however, the conversion of slowly decomposable organic substances also improves.

Mbbr systems can be used successfully with a proper reactor configuration all organic matter, therefore biological oxygen demand (boi), all ammonium for its oxidation, even for the removal of nitrate and all nitrogen content together with it. The non-aerated moving bed biofilm also denitrifies with a good degree of effectiveness, if the general conditions of denitrification (high nitrate content, easily presence of decomposable nutrients) are given. In the presence of a biofilm, the deeper slud layers its hydrolysis also provides nutrients for denitrification, so the lower it can be performed in addition to KOI/TKN ratio.

SYSTEM CONFIGURATIONS

The MBBR system can be designed in several configurations, such as, for example, straight-flow systems detailed and widespread A/O or A2/O design, but also a batch (SBR) cleaner. These are usually of a mixed, hybrid design, i.e. they combine the activated sludge cleaner with the biofilm. In the anaerobic sections, the MBBR design is not typical, given that it does not exceed a traditional activated sludge system, mainly in aerobic pools need. In aerobic systems, rotors cannot be used for aeration, since a would destroy the carrier. It is also less suitable for providing very fine bubbles application of membrane quilts. HOWEVER, COARSE BUBBLE IS DEFINITELY PREFERRED VENTILATION WHICH CAN CREATE TURBULENT FLOW, I.E. WITH VENTILATION MOVEMENT OF CHARGES CAN ALSO BE PROVIDED AT THE SAME TIME.

MBBR systems can be used well in reactor cascades where each element differs conditions (DO) must be provided. Because here - and this is the main difference, the direct flow compared to systems – there is no recirculation, i.e. the carriers and the biofilm are not once anaerobic, and once in an aerobic environment. In this way, a biofilm optimal for the given conditions is formed on the substrates, which is an indisputable advantage over activated sludge systems where within a sludge flake different microorganism consortia compete simultaneously. Biofilm systems are like that they have greater flexibility, since they contain a concentrated microorganism culture you can perform the cleaning during the available hydraulic residence time. The organic matter the efficiency of removal (conversion per unit of volume, per unit of time) is also far greater than the in suitable activated sludge systems.

Such an increase in the capacity of the biofilm system acan be explained by the following factors:

- relatively active biomass can develop on the biofilm support;
-with the thickness of the biofilm, its weight can be significantly increased;
- its adequate supply of nutrients can be increased with the help of the bubble movement;
- air movement and fluid turbulence also increase this.

Such a solution is better for the types of nutrients in individual reactors or purification stages they enable the development and formation of a specialized sludge mass on the biofilm carrier. Thus, overall, it can be concluded that USING MBBR SYSTEMS OPTIMUM, GOOD EFFICIENCY CLEANING IS ACHIEVED WITH REGARD TO THE REACTOR VOLUME.

IN TERMS OF CLEANING, THE EFFECTIVENESS OF EACH COMPONENT DEPENDS ON:

- the composition of the wastewater to be cleaned, which limits the design of the technological steps;
- in case of appropriate reconstruction or intensification of the available biological pool system;
- efficiency or quality requirements required from cleaning.

The technology equipment recommended for each cleaning task is listed in the table below:

Cleaning aspect	Technology description
Removal of carbonaceous materials	Single MBBR unit
	Biofilm pre-cleaning before the activated sludge unit
Nitrification	Single MBBR unit
	Nitrifying biofilm after activated sludge unit
	Integrated biofilm/activated sludge unit
Denitrification	MBBR unit with pre-denitrification
	MBBR unit with post-denitrification
	MBBR unit with pre- and post-denitrification
	Post-denitrification of nitrified wastewater

Activated sludge is used in the MBBR system to remove the appropriate amount of organic matter systems, a somewhat higher DO level is required. This is because in the case of biofilm it is the proper diffusion of oxygen requires a suitable level of dissolved oxygen, which is even without nitrification it is recommended to set it to 2-3 mg/liter. In this case, BOI5 removal is also possible under heavy load can be carried out, of course, if nitrification is also required, it cannot be with too high a BOI5 load count.

The balance of organic matter and nitrogen load was investigated and analyzed by a Norwegian research group. THE load for biofilm systems is usually given per surface unit, so organic material-in the case of load, usually in units of g BOI5/m^2×day. Some are commonly used design guide value is given in the table below.

Organic matter removal %	Organic matter load (g BOI5/m2×day)
High load (75-80% BOI5 removal)	>10
Normal load (80-90% BOI5 removal)	5-10
Low load systems (stable nitrification)	<5

The amount of load that can be selected is for the removal efficiency, as well as from the biofilm that breaks off during the operation it also affects the settleability of the resulting sludge. Among the figures below, the one on the left is the load efficiency shows its effect. It can be observed that the loading and removal rates are initially linear following the correlation, with the further increase in load, the reaction speed becomes less and less can be increased. The other factor that cannot be neglected is the settleability of the detached biofilm, which is the load with its growth, it shows a relatively rapid deterioration, so it is necessary to administer coagulants and flocculation agents need. The two factors listed are the previously mentioned limitations of a cleaner the possibilities of its intensification are also limited.

NITRIFICATION IN MBBR SYSTEMS

In general, it can be said that the process of nitrification is basically the load of organic matter influence. In the case of a high load of organic matter (mostly industrial wastewater), nitrification is the case suppressed due to autotrophic/heterotrophic competition, however, additional chemicals must also be considered. For this reason, it is widespread in high-load systems (>10 g BOI5/m^2×day). solution is the use of two aerobic pools. Aeration in the first basin is moderate, which it is sufficient to remove a significant part of BOI5, but not enough to start nitrification (DO usually < 1 mg/l). In the second pool, the DO level is significantly higher (e.g. 2-3 mg/l). would be set, which is optimal for nitrification, in addition due to the reduced content of organic matter heterotrophs interfere less with autotrophs. In the case of medium organic matter load (5-10 g BOI5/m^2×day) already in addition to organic matter removal nitrification can be ensured even at a temperature of around 10 °C. In the case of an even smaller load practically completely stable nitrification is characteristic. In addition to the organic matter load, the rate of nitrification is strongly affected by the oxygen level and temperature it depends. In a well-nitrifying system, the rate of nitrification can be as high as 1-2 g NH_4-N/m^2×day can reach depending on the oxygen content and temperature.

DENITRIFICATION IN MBBR SYSTEMS

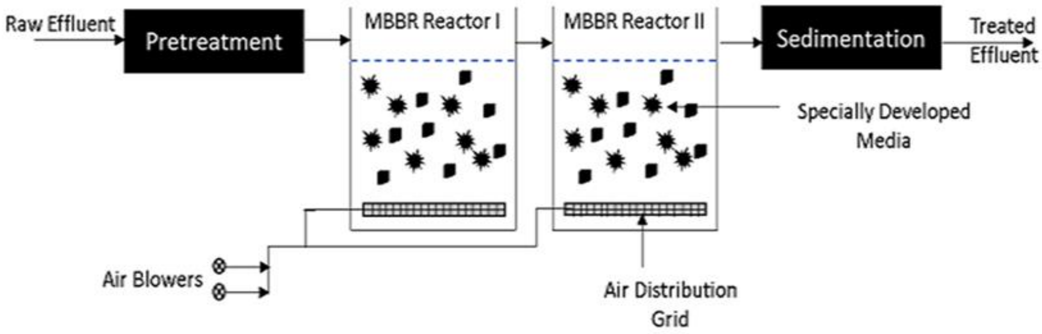
Moving bed biofilm reactors can be used for denitrification without any difficulty. Not those must be aerated, and even proper recirculation of the nitrified liquid is required (or an SBR system must be built, with intermittent aeration). In straight-flow systems, the denitrifying (anoxic) reactors should be placed before the aerated reactors (pre-denitrification, which practically it can also be found in common A/O or A2O systems). In the pre-denitrification unit, it is thus good organic material and nitrate supply can also be provided. Well-built pre-denitrification units 50-70% nitrogen capable of removal. It is not necessary to use a particularly high internal recirculation ratio for this. 1:1-3:1 recirculation of nitrated water is usually sufficient. In pre-denitrification systems a denitrification rate usually varies between 0.15-1.0 g NO_3--N/m^2×day.
Another option for nitrate removal is post-denitrification. This is also the case with moving biofilm reactors may be suitable even for activated sludge systems. However, there is also an adequate supply of organic nutrients here needs the nitrate's oxygen to consume it, so - since it has already been used up - in this case some an auxiliary nutrient must be used. The maximum nitrate removal rate in such cases is up to 2g NO_3-It can exceed -N /m_2×day. Up to 100% nitrate removal with post-denitrification possible, although this solution is less widespread due to the need for auxiliary nutrients.

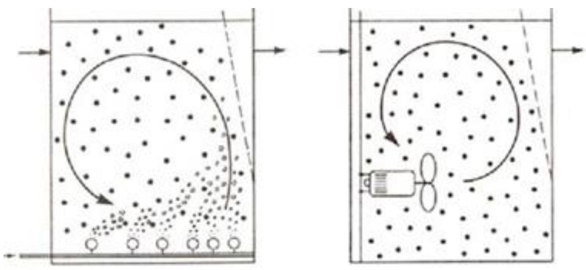
SMALL SIZE MBBR SYSTEM CLEANERS (SBR)

Where the sewage network cannot be found (and cannot be built economically) - e.g. holiday resorts, forest houses, farms - wastewater is still collected in septic tanks in many places, with all its economic and environmental disadvantages. As an alternative to outdated "cesspools" it is in recent decades, unique wastewater treatment systems have started to spread rapidly, where the treated with certain limitations, water can even be used for irrigation, and significantly less often for sniffing is needed, which significantly reduces operating costs. Individual small appliances (large small cleaners with an average capacity of 4-50 person) can be purchased ready-made, currently already in Europe many manufacturers specialize in these. Due to their simplicity, the small devices are mostly SBR systems, of which there are many an intensified sub-version has also been developed in the last decade or two, including the moving bed biofilm types as well. In the case of small treatment plants, these intensified systems are mainly concentrated wastewater (the drain of a catering unit) or recommended in case of special cleaning needs.

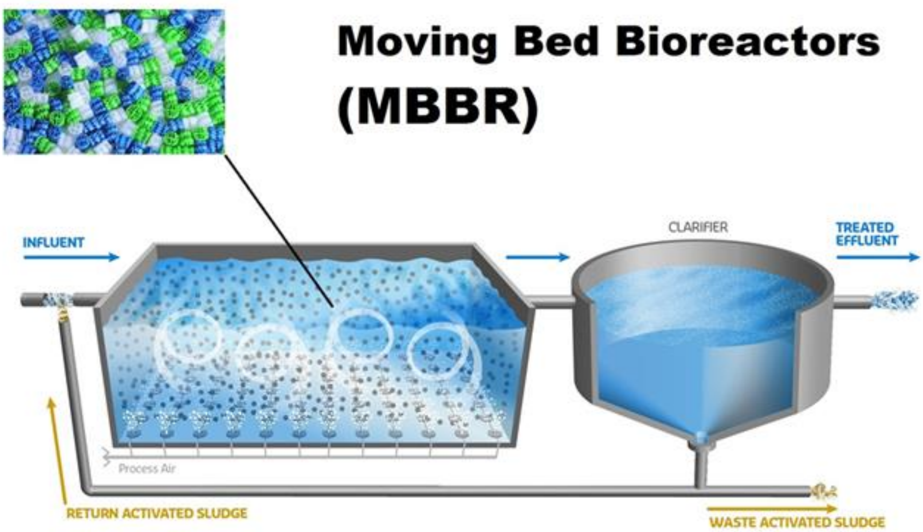
TECHNICAL BASIC CONDITIONS FOR THE APPLICATION OF THE MBBR SYSTEM

The widely used existing activated sludge systems can also be intensified, their efficiency is MBB can be significantly increased with filling. These are activated sludge +MBBR hybrid systems. By combining MBBR, by placing each m^3 of MBBR medium in the system, 1-2 kg/day of nitrogen derivatives can be removed. Biological filtration spectrum and efficiency of wastewater treatment using MBBR can be increased. Systems operating purely with MBBR technology differ in many design features from hybrid systems. The main design possibilities of MBBR systems:





a. Aerobic reactor b. Anoxic and anaerobic reactor



MAIN MBBR SYSTEM COMPONENTS ARE THE FOLLOWING:

1. Existence of wastewater pre-filtration

2. Reactor tank for receiving the MBBR medium (concrete pool), which is the MBBR filling also ensures its retention, with a design that prevents the medium from being washed out of the reactor water space (optimized grid protection on the inflow and outflow sides)

3. Aeration forming coarse air bubbles (placed at the bottom of the reactor basin can be achieved by air atomization or air mixing combined with water flow), the purpose of the MBBR keeping the medium in constant motion, supplying the biofilm with O_2 and the thickened periodic detachment of biofilm layers.

4. Optimally sized air turbine, air compressor, passive air supply options

5. The system can be supplemented with a compact mixing and water flow extinguishing device, which is convenient in space separate from the biofilter elements in order to prevent direct surface damage.
6. Post-filter, sludge separator; a floating layer of biofilm that detaches intermittently from the surface of the biofilter elements forms sludge, which must be removed from the system by post-filtering after the MMBR reactor (post-settler pool, drum filter, flocculator, sand filter, membrane filter)

Existing recirculation can be reduced to the degree of intensification of wastewater treatment, total MBBR can be omitted if efficiency is achieved. A possible example of mixing equipment:

The listed system elements are general elements of MBBR's wastewater treatment technology for its application, in the case of intensification of sewage plants, given in the light of the unique characteristics system may require specific technological designs.