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A Comparative Study of a Moving Bed Biofilm Reactor and Bio-shaft Technology for a Wastewater Treatment Process: A review

Rana Hasan Najy
M.Sc. student
College of Engineering
University of Baghdad
Baghdad-Iraq
r.naji 1901m@ coeng.uobaghdad.edu.iq

Dr. Basim Hussein Khudair Al-Obaidi
Assistant Professor
College of Engineering
University of Baghdad
Baghdad-Iraq
dr.basimal-obaidy@coeng.uobaghdad.edu.iq

Dr. Mohammed Sadeq Salman
Assistant Professor
Environmental Engineering
Baghdad-Iraq
Dr.mhammed@avic.uobaghdad.edu

ABSTRACT

In addition to the primary treatment, biological treatment is used to reduce inorganic and organic components in the wastewater. The separation of biomass from treated wastewater is usually important to meet the effluent disposal requirements, so the MBBR system has been one of the most important modern technologies that use plastic tankers to transport biomass with wastewater, which works in pure biofilm, at low concentrations of suspended solids. However, biological treatment has been developed using the active sludge mixing process with MBBR. Turbo4bio was established as a sustainable and cost-effective solution for wastewater treatment plants in the early 1990s and ran on minimal sludge, and is easy to maintain. This has now evolved into a technology that has proven successful worldwide with trouble-free operation and improved Turbo4bio technology, an advanced high-intensity ventilation system fully enclosed and non-mechanical, ensuring odor-free operation, simple and environmentally friendly operation and long life of domestic and commercial wastewater treatment And the municipality. In this paper, a comparison between MBBR and T4B treatment system was made. As a general review of previous research and experiments, it is possible to reduce the total cost based on building all plant structures to obtain concentrations within the permissible limits of pollutants at the final outlets. It is clear that the use of MBBR has contributed to the realization of simultaneous biological phosphorous and nitrogen removal experiments, which aim to change the more significant methods developed from conventional methods, from the advantages of the Turbo 4 Bioreactor with low cost and high production performance, with less energy consumption and lower operating costs because it does not require Chemicals for processing, cleaning, and disinfection. It only takes small amounts of chlorine, the use of a compressor system for air, and rapid recovery providing high rates of generation of biomass to restore the plant quickly.

Keywords: MBBR bed movable reactor, Turbo 4Bio reactor, comparative study.

*Corresponding author
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دراسة مقارنة لمفاعل الحيوي ذو الاوساط المتحركة وتقنية العمود الحيوي لعملية معالجة مياه الصرف الصحي: مراجعة

رنا حسن ناجي
طالبة ماستر
جامعة بغداد /كلية الهندسة المدنية

د .باسم حسين خضير العبيدي
استاذ مساعد
كلية الهندسة جامعة بغداد

د.محمد صادق سلمان
مساعد استاذ
كلية الهندسة البيئية جامعة بغداد

الخلاصة

وبعد المعالجات الابتدائية تاتي مرحلة المعالجة الثانوية البايولوجية لتقليل المواد العضوية و الغير العضوية في مياه الصرف الصحي. عادة ما يكون فصل الكتلة الحيوية عن المياه العادمة المعالجة أمرًا مهمًا ، لتلبية متطلبات التخلص من النفايات السائلة ، لذلك كان نظام مفاعل الأغشية الحيوية المتحركة (**MBBR**) أحد أهم التقنيات الحديثة التي تستخدم ناقلات البلاستيك لنقل الكتلة الحيوية بمياه الصرف الصحي ، والتي تعمل في بيوفيلم نقي بتركيزات منخفضة من المواد الصلبة العالقة. ومع ذلك ، تم تطوير المعالجة البيولوجية باستخدام عملية خلط الحمأة النشطة مع **MBBR**. تم إنشاء **Turbo4bio** كحل مستدام وفعال من حيث التكلفة لمحطات معالجة مياه الصرف الصحي في أوائل التسعينيات ويعمل على الحد الأدنى من الحمأة ويسهل صيانته. لقد تطور هذا الآن إلى تقنية أثبتت نجاحها في جميع أنحاء العالم من خلال التشغيل الخالي من المتاعب وتقنية **Turbo4bio** المحسّنة وهي نظام تهوية متقدم عالي الكثافة المصنع مغلق تمامًا وغير ميكانيكي ، مما يضمن التشغيل الخالي من الروائح والتشغيل البسيط والصديق للبيئة والعمر الطويل لمعالجة مياه الصرف المنزلية والتجارية والبلدية. في هذه الورقة ، تم إجراء مقارنة بين نظام المعالجة **MBBR** ونظام **T4B** كمراجعة عامة للبحث والتجارب السابقة ، من الممكن تقليل التكلفة الإجمالية على أساس بناء جميع الهياكل النباتية من أجل الحصول على التركيزات ضمن المسموح به حدود الملوثات في المنافذ النهائية. من الواضح أن استخدام **MBBR** قد ساهم في تحقيق تجارب إزالة الفوسفور البيولوجي المتزامنة والنيتروجين ، والتي تهدف إلى تغيير الطرق الأكثر أهمية المطورة من الطرق التقليدية ، من مزايا مفاعل **Turbo 4 Bio** بتكلفة منخفضة وإنتاج عالي الأداء ، مع استهلاك أقل للطاقة وتكاليف تشغيل أقل لأنه لا يتطلب مواد كيميائية للمعالجة والتنظيف والتطهير. لا يتطلب الأمر سوى كميات صغيرة من الكلور ، واستخدام نظام ضاغط للهواء والاستعادة السريعة مما يوفر معدلات عالية من توليد الكتلة الحيوية لاستعادة المصنع بسرعة.

1. INTRODUCTION

Wastewater treatment has become a pressing necessity in recent years for a variety of purposes, including the preservation of water and a clean and healthy environment, as well as the use of the water generated by the treatment process as an unusual source of water; it is used in a variety of areas All of this is under relentless cost-cutting strain **(Helens, H, et al,.2005)**. Scientists have worked hard over the years to develop biological therapies for the purification and disposal of contaminants, the most notable of which are MBBR and T4B.

MBBR originated in Norway and originated within a business known as Kaldnes Milj'teknologi or Anox Kaldnes within the University of Science A Norwegian technology. The first MBBR was in 1989, albeit a modern technology by contrast, but it has been introduced in the United States since 1995. There are currently more than four hundred wastewater treatment plants worldwide, each with more than thirty-six municipal and industrial departments in North America (**Borkar, R., et al., 2013**). The idea, however, was to develop the MBBR system to boost the reliability and most effective features of the activated sludge method in conjunction with the opportunity-providing biofilter method and the benefits that can be obtained from an efficient technology for wastewater treatment **(Odegaard, H. 2006)**. Also, the MBBR approach takes advantage of this feature because of the distinct ability of this organism to bind the surface to create stable polymer layers to protect itself from peeling **(Henze, M., P; Harremoës, et al., 1997).** This function is taken advantage of by the MBBR method and extended to the growth of microorganisms above the media holder in the biofilms that move freely inside the wastewater health **(Helness, H, 2007).** Moving Bed Biofilm Reactor (MBBR) has been used in wastewater treatment research areas and is gaining more interest in researching its applications to remove degradable organic matter. Simultaneously, in different implementations, the approach has undergone several degrees of modification and growth. However, the biobed reactor (MBBR) for industrial waste materials in terms of gas removal was the first use of the move **(Helness, H. et al., 2005).** Various applications were subsequently developed, including an improved MBBR for skeleton removal, phosphorus removal, nitrification, and de-nitrification for municipal and industrial waste treatment **(Helness, H. et al., 2005**).

Turbo4bio Bio Shaft System stands to define as "Turbo-Reactor for Biofilm Intensive Treatment" which is a highly efficient wastewater treatment technology most suitable for treating low and medium loads industrial wastewater, through which high-quality wastewater is generated [WWW.BIOSHAFT.COM] Turbo4bio provides complete, correct. High-quality design solutions with guaranteed results, Turbo4bio is the only method invented so far where associated bacteria can grow and build a homogeneous saturated biomass layer that acts as an enzyme plant in a conventional equilibrium tank that digests the sludge. Still, it is the most compact. It eliminates at 98 percent of growth suspended. The system's specific design features include the self-cleaning ability of the T4b-Turbo reactor against any potential clogging and rendering of maintenance-free, and the air biofilms and T4b bio-carrier develop and deepen the non-oxidative bioassay within the media [WWW.BIOSHAFT.COM]. The group of heterocyclic microbes allows the extraction of organic matter and nitrogen. There is simultaneous nitrification by autotrophic bacteria in the layer attached to the bearing wall and de-nitrification by autotrophic bacteria in the oxygen layer. The improvements in the stability and/or oxygen transport, but nothing comes close to a sludge problem like T4b (even MBR containing> 10% sludge). This system is very competitive, easy, with cost-effective installations and an integrated package that supports extremely low operating costs with minimal heat production. High warmth production, as technological advantages, also provide a quick biological start as the plant is handled; compared to many factories, it is processing complete flows almost immediately. Over days, and sometimes as the device is suitable for new formulations, the packaging and sealing of any needs will increase and can be updated to increase performance. The sanitation uniformity standards of care are improving, as this technology eliminates the need for treatment production efficiency (**Metcalf, 2014**).

The main objective of this study was to conduct a general review about the MBBR reactor, the bio-shaft reactor, to find common points, differences, and the extent of development of the Bio-sift. Some recent researches in this field are**: (Awad, Saad and Al-Obaidi, B. 2020, and Jasim, N., and Ibrahim, J. 2020)**

2. MBBR CONCEPT

The bed bioreactor (MBBR) is a new approach to biological wastewater treatment technology to protect water. The carrier parts in this system (MBBR) are constructed to be slightly heavier but are often lighter in density than fluid or water-containing, but are often created with a wide range that allows them to pass freely through the water or separate the liquid into the reactor. According to Lucido and Zopolis **(Henze, M., 1997)**, the biomass can fully expand in these vectors by the free rotation movement mechanism of the bearing parts suspended in the water. Likewise, the MBBR process system corresponds to the combined sludge activation hard film method (IFAS), while IFAs give a somewhat different approach. The active yield consists of IFAS systems' arrangement, and the sludge stream carried out by IFAS. Schmidt and Schichter **(Helness, H., 2005)** showed in the MBBR process that more than 90% of the biomass would potentially be confined and cultured in a medium rather than suspended in a liquid. It can be related to the behaviour in which the carriers must remain inside the reactors in the places of use due to the vacuum holes or the sieve arrangement (**Fang, H., H., P., 2011**, **Horan, N.J., Gohar, H. and Hill, B., 1997**). A small polyethylene-like material can have a high-quality surface area to accommodate it, so; the biofilm growth is deliberately constructed for the vector. In order to determine optimal biomass concentrations, this also removes the need for reactor sludge recycling while only allowing excess biomass to be easily separated from the effluent. The amount of sludge output is usually less than the standard active sludge process that can be performed since then, which means lower sludge disposal costs in MBBR than normal activated sludge systems. However, as observed by (**Borkar, R., P., and Gulhane, 2013)** conveyor movement inside the reactor, ventilation can be performed indoors in aerobic reactors, as shown in **Fig.1 (a)** while it is produced by a mechanical drive in anaerobic or hypoxic reactors as shown in **Fig. 1 (b).** MC's research in the literature shows an informational gain on the benefits of the MBBR method.

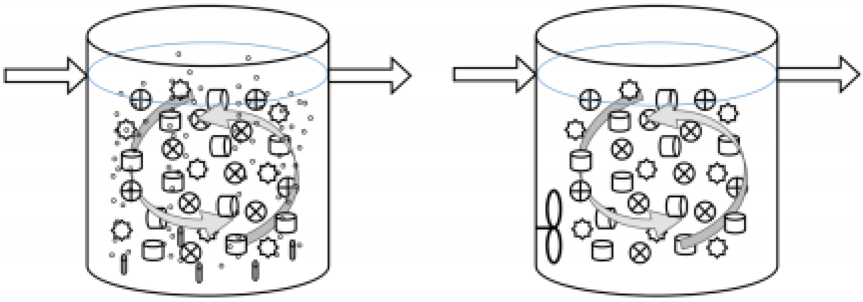

Figure 1. Mechanisms of the moving bed bioreactor.

(Loukidou, M. X., 2001) described some points worth noting, and the MBBR process is characterized by higher biomass concentrations, lower sensitivity to toxic compounds, and the absence of long sludge sedimentation periods. **(Schmidt, T.,M., et al., 2011)** suggested that fewer pathways appear to cause process disturbances, which do not appear in other processes, than poorly deposited biomass. (**Fang, H., H., P., 2011**) technique is usually considered cost effective, compared to other known methods. Additionally, (**Horan, N., J., 1997**) accepted that removal of organic and ammonia is successful and may be performed in the MBBR system simultaneously. Additionally, compared to activated sludge treatment, the biofilm filter is transported in a small area. It has a small characteristic area that only requires one-fifth to one-third of the Revue-4 area..

3. TURBO4 BIO CONCEPT

It is a bioreactor that does most of the treatment. The removal of the remaining suspended solids is used in arranging the preparation work to dilute the effluent and recycle the collected sludge back from the apparatus, which is usually given in two copies. Air compressors supply oxygen to bacteria and provide liquid for mixing and pumping up to 10 mm and are held in the direction of the turbine. MBBR and IFAS or HYBAS, RBBR, and MBBR processes use the same validated biofilm conveyor technology used in all MBBR systems. Still, this mixture, known as IFAS or HYBAS active sludge, is held onto suspended solids through the process of conventional activated sludge described. The hybrid MLSS is equivalent to the superior MLSS. The hybrid method of activated sludge and biotransformation technology achieves incomparable biodegradation efficiency with conventional equivalent volume activated sludge systems, resulting in the ideal single-path MBBR procedures for enhancing urban wastewater treatment facilities (**Metcalf, 2014**) MLSS equals MBBR 6000 to 10,000 mg / L, so half or one-third of activated sludge is actually an MBBR process, which is a return biomass reactor containing the yield RBBR, as the attached growth stage of 100 percent is not attributable to the sludge. Still, the performance is zero because the dynamic shaft system is superior due to the aeration tanks. Hybrid CAS is used to provide energy, odorless and sludge over all competitors, including MBR and MBBR [WWW.BIOSHAFT.COM]]

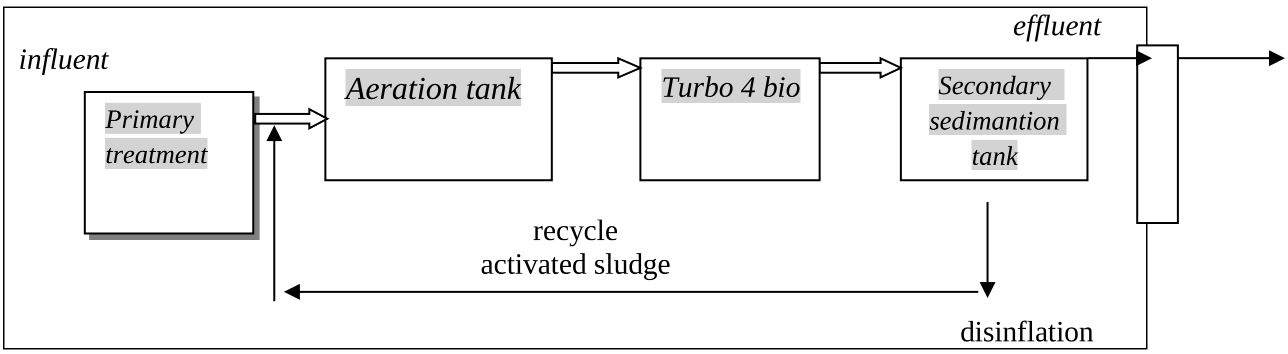

Figure 2. Plane Bio-Shaft Station.

The food/microorganism ratio (F/M ratio) is defined as the food or substrate (BOD) load delivered per day per unit biomass in the reactor ratio in the organic loads. It can maintain maximum stability several times higher of conventional systems such as sludge activate ratio in organic loads. It can maintain maximum stability many times higher than conventional systems like activated sludge, intermittent RBCS filters, ABF, etc.; compared to the old traditional methods, the change of this function is crucial to the process. To reduce the increase in pregnancy temperature, this regimen requires less HRT. The size of the aeration tank can be optimally reduced by organic wastewater, so MBBR can be used to increase the capacity of the wastewater treatment plant (WWTP) and upgrade it to improve effluent efficiency (WWW.BIOSHAFT.COM).

Moreover, the residual aeration tank will reduce the resulting nutrient rate to a suitable level by combining this method with anaerobic systems. WWTP upgrade, where the specific area is chosen to reduce the necessary time, as it does not include known problems such as high temperature, high foaming, poor sedimentation, carrier clogging, need for backwashing regarding operating characteristics, high shock resistance and no need for re-humidification, make [WWW.BIOSHAFT.COM]. The operation of the machine is simpler due to the consistency of the two-hour liquid HRT waste, which can be used to meet the requirements of the condition and protect the environment in disposing of the organic matter. However, conventional systems require large amounts of aeration and sedimentation, indicating a need for larger spaces than conventional energy-saving activated sludge systems **(Sofia A., 2009).** The areas and volumes required for successful treatment have been significantly reduced, and this can be seen with the introduction of sludge tanks that are faster, more efficient, and therefore more economical to manufacture activated sludge. The reduction of floor area may be very important. This is the main difference in the two-column process and the fact that sludge tankers are directly responsible for the second unique feature of the TURBO4BIO reactor, which involves designing the cavity sludge tankers to allow the presence of anaerobic bacteria in the turbine system, even in oxygen-rich regions. These aerobic bacteria are important for the process of reducing sludge production, and, unlike traditional competitive methods, they must be removed off-site and have a very low yield. In addition to reducing sludge production, there is a significant decrease in phosphorus during the process of oxygen entering the turbine, which is used as a nitrification process to obtain a high proportion of oxygen TSH in biomass (IHE) and reduce ammonia (total N) to zero levels. Two additional biological responses occur when anaerobes in the effluent work with organic matter and these bacteria have acidic formations produced from volatile acids where the volatile acids are metabolized by the anaerobic bacteria, resulting in the release of carbon dioxide and methane (**Ødegaard, H., 2006**)

3. COMPARISON BETWEEN MBBR AND TURBO 4BIO

The efficacy of the process in the MBBR biofilm system depends on the concentration of the active organism, the efficiency of mass transfer, and the system's preparation, such as feed distribution and mixing. In a stable phase, the concentration of species is relatively constant, depending on the feed substrates and the mass of the biofilms on the carriers, which is less than 20 g / m2 on average. For example, in a device with a scale, the carrier mass value may be higher where the active organisms are primarily present on the outer surface of the measuring block. Owing to the slow growth rates, the mass per area may be lower for processes such as nitrification or Anamox. The organic loading rate of MBBR generally depends on SPF, such as gCOD/m^2/day. Depending on biofilm condition and loading history, the rate of organic loading can be up to 100 g/m^2/day. In a high-load system where oxygen supply could be a limiting factor, low removal efficiency would be expected.

MBBR can retain higher sludge concentrations per reactor volume compared to the activated sludge system. The sludge content is around 7 g/L for a surface area of 500 m^2/m^3 carriers, with an average of 20 g/m^2 biofilm on the conveyor surface and a filling amount of 70 percent. This is done without sludge return and thereby decreases process complexity and eliminates sludge return equipment. The MBBR method has also been produced by traditional nitrification processes, de-nitrification, and Anamox for ammonia extraction **Fig. 3. (Metcalfe, 2014**). In the conventional de-nitrification process, the ammonium ion is oxidized to nitrate by complete nitrification, and nitrates are thus reduced to nitrogen gas by pre/post-de-nitrification.

Usually, in two separate reactors, nitrogen is removed. To perform ammonium oxidation, the inorganic carbon is supplied as an alkali naturally. As the electrophilic acceptor, the de-nitrification process calls for easily degradable organic matter such as methanol. Partial nitrification is referred to as nitrification and ammonium anaerobic. To extract nitrogen from waste water in a single reactor, oxidation can also be accomplished by treating the dissolved oxygen content in the biofilm. This implies that nitrite oxidation to nitrate is prevented, and de-nitrification will occur according to the "abbreviation" in **Fig. 3** (**Metcalfe, 2014**).

However, this removal was observed with rates of up to 1.2 kg N/m^3 for lateral stream rejection and can be achieved with MBBR. Wastewater treatment in urban applications (**Lemaire R., et al., 2013**). Nitrite formation is phase restriction, and it is important to regulate well-dissolved oxygen so that the process is advanced controlled. Effective MBBR Anammox solutions are needed. MBBR has also been applied to remove biological phosphorous in Norway by physically moving carriers with biofilms from the anaerobic phase to the aerobic phase and back to the anaerobic level to carry the same accumulating species P. cycles, as in the Bio-P phase of activated sludge (**Rudi K, et al., 2019**).

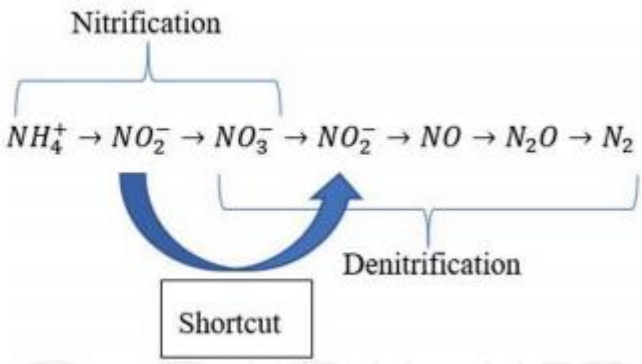

Figure 3. Nitrification and de-nitrification with shortcut mechanism illustrated **(Metcalf, 2014).**

The system creates considerably less sludge than traditional treatment plants, and the less and removal of sludge results in substantial operating cost savings. Inside the turbine reactor, the patented membrane aeration system secures the oxygen needed for the decomposition process. Also, it ensures the efficient flow of liquid waste through the biological filter, thus preventing clogging. A simple air compressor provides the air required for this process. It is distributed by diffusers in the turbine to form a large number of microscopic bubbles. Most of the air used is not pumped directly into the center riser (see figure), and this creates the flow and recirculation needed within the turbine.

While the bio shaft station was, the air is often used to move the sludge around the facility, a design feature that removes this by mechanical pumps whenever possible. The following cross-section shows the preferred composition configuration, with the turbine reactor (column) partially submerged in the ground to allow the system to flow through gravity. The only pumping needed is in the stabilizer inlet tank.

Inside the turbine reactor, the patented diaphragm aeration system secures the oxygen required for the decomposition process. Also, it ensures the effective flow of effluent through the biological filter, thereby preventing clogging. A simple air compressor supplies the air required for this process. It is distributed by diffusers in the turbine to form a large number of microscopic bubbles. Most of the air used is not pumped directly into the center riser tube, which creates the flow and recirculation needed within the turbine. Finally, the air is often used to transfer sludge around the facility, a design mechanism that, where possible, removes this by mechanical pumps. The following cross-section shows the desired configuration of the installation, with the turbo reactor (column) partially immersed in the ground to allow the system to flow through gravity, and the only necessary pumping is in a stabilizer tank, from the door.

Figure 4. T4B reactor by [16].

Each of the effluent treatment plants is designed to accomplish effluent treatments with observable levels of toxins downstream. No exception to this is Turbo4bioAll governmental, national and international discharge levels must be strictly compliant technology feasible for operations. The system usually treats domestic wastewater until it reaches the effluent treatment quality standards of 10 mg/L BOD5 (ATU) and 10 mg/L of suspended solids with ammonia is less than 5 mg/L nitrogen. For each test system, a computer model is designed. It includes local approval of vacuum and plant requirements. If possible triple treatment options, such as reed beds and wetlands, can be combined to obtain high-quality treated wastewater requirements and sand filters suitable for industrial applications such as district cooling, etc.

The system generates considerably less sludge than traditional treatment plants, and the less frequent removal of sludge results in substantial operating cost savings.

1. The MBBR reactor contains biomass that grows inside the reactor as a biofilm on small, freely moving plastic elements **(Odegaard, H., 1996).** Continuous running, non-clogging biofilm reactor, and low head loss are key characteristics of MBBR with a high-quality biofilm surface **(Rudi K., et al., 1994).** The reactors are designed as a continuous flow

stirred tank reactor with biomass/biofilms growing on polyethylene carrier media to achieve the characteristics. Via aeration in aerobic reactors and through mechanical mixers in oxygen and anaerobic reactors, the

2. The media is thoroughly mixed when the reactor is coiled to a maximum of 70% (volumetric filling), and the specified biofilm growth area with maximum efficacy is approximately 350 m^2/m^3.
3. F/M parameter-sensitive is in Bio Shaft for organic loads. It can retain its maximum stability many times greater than traditional systems such as activated sludge, trickling filters, RBCs, etc. This is deemed a very significant benefit of the operation. Compared to the MBBR and conventional processes, this system requires less HRT to reduce organic wastewater load to the optimal level. This can lead to decreased volume of aeration tank. Therefore, MBBR can be used to increase the capacity of WWTPs and upgrade them to improve effluents quality **(Metcalf, 2014).**
4. The production nutrient rate can also be decreased to an appropriate level by combining this method with anoxic and anaerobic (in the remaining aeration tank) systems. Therefore, the new WWTPs should be updated in the treatment phase and thus reduce the cost of treatment.
5. The specific surface of the carriers is a crucial parameter, so, when selecting carriers, enough attention should be paid to choose the appropriate particular area to reduce the required time for the treatment process and consequently reduce the treatment costs (**Ødegaard, H., 2006**).
6. In terms of operational characteristics, T4B does not have typical problems such as sludge bulking and rising, foaming, bad sludge settling, clogging of carriers, and the need for backwashing the MBBR.
7. Good impact resistance and no need to return the sludge make it much easier to run the system.
8. Considering the quality of the effluent, even with an HRT of 2 h, the system can meet the country standards and EPA in the elimination of organic materials.

5. CONCLUSIONS

1. In recent years, MBBR technology has been commonly used in many countries to treat wastewater under various loading and operating conditions.

i. The results of biological phosphorous removal experiments, nitrogen, and organic matter installed in a moving biofilm reactor (MBBR) can be achieved as a continuous flow

ii. Simultaneous nitrification tends to be more important than the traditional method of nitrification/de-nitrification to remove ammonia from wastewater lacking organic matter.

iii. Compared to a suspended growth system such as activated sludge, MBBR maintains a higher biomass content in the reactor, which may reduce the overall cost of a small footprint of the reactor.

iv. All effluent treatment plants are built to achieve a specific observable amount of pollutant levels at downstream outlets.

2. While the main advantages of Bioshaft are that the design of the shaft system is elegantly simple. Less than one KgO_2 per Kg BOD is needed compared to a minimum of (2.5) KgO_2 required by conventional systems. The Bioshaft system nearly eliminates sludge production and uses minimal electromechanical components.

i. It is low operating cost and high-efficiency plant, with very low energy consumption, which leads to lower operating costs.

ii. No chemicals are required, and no chemical cleaning is required. Only low-dose disinfection of chlorine is required to maintain the residual chlorine level and minimal maintenance,

iii. Almost the only component of maintenance is the air compressor system and rapid shock recovery. High biomass generation rates lead to rapid plant recovery from toxic shocks, although this only applies to industrial effluents.

iv. No operators are required; the plant operates without supervision and requires no special training for those who perform infrequent checks on the system.

v. Installation can be concealed entirely underground, especially useful when the ground is too expensive or invisible and hassle-free. Flexible to any desired capacity - suitable for small home installations ranging from 10 to 1000 m^3/day and can be installed in a parallel modular design to cover installations larger than 1000 - 100000 m^3/day. Significant energy reduction is 0.44 kWh/m^3. Much less land space required capital expenditures lower than the competition: $ 0.1/m^3 total. It eliminates bad odors, reduces operating expenses, and fully automated minimal operator attention required for new wastewater treatment plants, sustainable technology retrofit, and upgrade

Description of symbols

	Descriptive
MBBR	Moving bio bed reactor
RBBR	Biomass returning the moving bed
RBCs	Reactor biofilm contractor
MBR	Moving bioreactor
IFAS	MBBR fixed biomass reactor
HYBAS	MBBR

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