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Review on Application of Rotating Biological Contactor in Removal of Various Pollutants From Effluent

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Abstract

Biological wastewater treatment is an essential area of research in the environmental sector due to its distinct benefits and applicability. Two-thirds of the world is at risk of water shortages, so safe disposal and reuse of wastewater is the most challenging task. Rotating biological contactors (RBC) comprise a unique and ascendant alternative for wastewater treatment and removal of various pollutants. This review paper discusses the application of several aspects of the (RBC) system with detail to its features, operating parameters, as well as factor affected efficiency with related to media, system configuration, flow rate design, biofilm mechanism, and influent characterization, which are presented in this paper. The review of research carried out the outline of common applications such as nitrification, denitrification, and phosphorus removal and focus on recent utilization of (RBC) in high load industrial wastewater treatment, pharmaceuticals and complex compound removal, and chemical agriculture waste bioremediation. In addition to that, mentioning the integration with other biological technology to increase the efficiency and attaining high effluent quality. Novel (RBC) units include approaches for energy generation as the direct current generation. (RBC) has been used very successfully in lab-scale and some consideration in scale-up. Full nitrification is attainable under suitable process conditions while phosphorus removal and denitrification as yet necessitate extra exploration. This review is an ideal contender for the hybrid system which provide a relation between specialist and debate latest developments in RBC research to achieve high-quality stream, reducing energy consumption and make the most of efficiency.

Keywords: Rotating biological contactors (RBC), Biological wastewater treatment, Biofilm, Nitrification, Denitrification, RBC integrated application.

1. Introduction

Wastewater treatment (WWT) is crucial for our environment and our own health. It influencing the living standard of people due to correlated with urbanization, An accelerated increase in the population, and industrialization progress[1]. (WWT) adapt to the standard of sustainable development, which mainly goals to satisfy the basic needs of current and future generations, without disturbing the natural equilibrium [2].

Discharged Wastewater without treating directly into water bodies posed pollution and harm affected by public health [1]. Water contamination decreases the presented amount of clean water for both persons and ecosystems. Clean water shortage is at present a certainty in third world nations. The United Nations expects that 67 % of the global population will live in water-scarce regions in the next five years. To bypass this problem, It must implement a suitable method for the disposal and reuse of wastewater [3]. Diversity of optical and biochemical methods are used for wastewater remediation. Improvement and sustainable technologies for wastewater treatment can increase the efficiency of pollutants removal, minimizing cost, long term treatment plant capacity, and improve effluent quality [4,5]. The biological processes are the most attractive and effective system**.** it employed worldwide to treat domestic and industrial wastewater [6,7].

Biological processes in secondary wastewater treatment consist of attached growth and suspended growth processes. In the first process, microorganisms are attached to a solid surface while for the second, the microorganisms are in suspension[4]. Biological processes utilize a wide range of microorganisms, essentially bacteria. Bacteria convert biodegradable organics into basic material and more biomass[8]. Since several organic materials in the wastewater are unaffected by biological degradation or poisonous, the conventional biological processes don't continuously provide suitable results[6]. Application of non-conventional systems in developing countries are the key to the solution of the problem of (WWT). Rotating biological systems (RBC) consider one of such systems that were originally established includes simultaneous disposal and extensive confidently[2].

The rotating biological contactor (RBC) is a promising tool utilized in secondary wastewater treatment. It is an unrivaled modification of the attached growth biofilm system. RBC is a recognized process for nitrification and denitrification as well as organics biodegradable matters. It has a lot of benefits compared to other technology, it is simple to monitoring, low maintenance and operational cost, great biomass concentration, no sludge reprocess, and not vibrant with toxic loads and shock. RBC turn out to be very common and multi of RBC units were employ across all the world[8].

Countless offered studies have been reviewed the wastewater treatment progression using RBCs [7]. These Related studies have largely focused on the part of the process plan and in especially providing satisfactory oxygen in the system and guaranteeing the wastewater can flow through the system without impediment or any unfavorable impacts to the media [9,10]. Studies [11,12] presents the growing evidence submits that the RBC can deal with explicit impurity remediation for heavy metals, definite aromatics atoms containing hydrocarbons, and drugs under suitable process conditions. RBC can takeover (BOD) removal for domestic and high strength wastewater. Other reviews on RBCs focused on assessing the overall performance and highlighted some performing parameters related to it [13-15].

The Application of RBCs for natural wastewater biotreatment to eliminate several pollutions and starts at a lower scale and developed as time progress[16,17]. The additional paper offers an overview of the limits of organic carbon, submersion percent, and rotational speeds as well as investigated the optimized selection of media type and novel configurations of media which lead to an increase in the evolution of certain bacterial populaces could raise the efficiency of treatment process[18 -22].

Despite investment and research, RBC is yet to accomplish maximum capacity. In this audit, a basic understanding of the key boundaries impacting RBC performance for wastewater treatment as well as active and operative application. It offers an overview of rotating biological contactors (RBCs) and main characteristics, advantages, and limitations, some features about design and scale-up in addition to that this study presents general application areas of this reactor. What distinguishes this study that it has highlighted the integration of RBC with other advanced technology and discusses its efficiency in the treated specific type of wastewater. However, to avoid the length of these threads, without disturbing their quality, this paper primarily focuses on recently published papers.

2. Rotating biological contactors (RBCs)

The RBC was initially created in Germany in the 1920s and was earliest portrayed as a “rotating aerobic mass” mounted to a media uphold. The primary system was recorded in the United States(US). Commercial position in RBC was small, until the development of the drip body immersion system which leads to the development of the first trial pilot scale of RBC[4]. In the last fifty years, a rotating biological contactor (RBCs) turned to be renowned and a large number of RBC systems have functioned across the world. Due to their advantages, the latest distributions are depicting the augmentation of the enlargement of RBC technology and development to achieve advanced levels of treatment. Nowadays can be reliably upgraded and expanded in interest from both scholarly and business sources [23].

RBC involves two main brands; integral and modular. Integral systems have a treatment limit of ≤250 populace counterparts (PE) and comprise of a solitary unit joining all three stages i.e., primary settlement, RBC biological region, and final clarifier. Modular systems consist of discrete units for primary treatment, RBC biological region, and solids treatment and require a treatment limit of PE >1000. The treatment capacity allows more flexible structures but the size and weight restrictions usually bounded RBCs to a degree of 3.5 m plate measurement. Operating particular RBCs be utilizing parallel stream division between units permitting activity inside adequate loading limits. Figure (2.1) show the RBCs types [7].

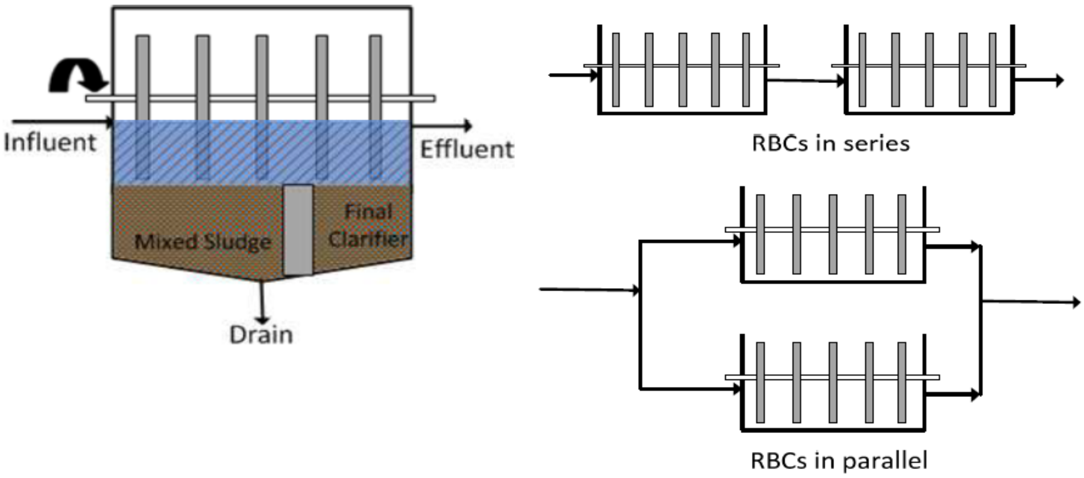

Figure 2.1: RBCs Types [7]

2.1 Characteristics and Mechanisms of RBC

(RBCs) is a treatment method commonly used as an auxiliary treatment of home and industrialized wastewater. Microorganisms are attached to the media through the attached growth process. RBC constitutes a precise distinguishing and superior auxiliary process for nitrogen removal as well as a biodegradable matter[4]. Circular plate biomass is liable for the debasement of organic materials. It consists of a distinctive size glass holder named reactor and a sequence of roundabout plates of polymer or plastic materials. These circles are fixed on a level shaft and pivoted by an electric motor with adjustable speed. RBC comprises only one or several stages [3].

The formulation of media is a wavy disc or regular flat. Biofilm linked to the surface is fixed on a horizontal shaft lowered in the range 40% in the influent and pivoted through concrete tanks in which the wastewater runs consistently. An average explicit surface area of RBC systems is about 150-250 m2/m3 of liquid[1].

The circular plate media or shaped segments are narrowly distributed to confirm an abundant surface area inside relative to a minor space, but extremely sufficient separated to evade clogging and channel obstructing due to biological spanning. The plate is implicating in a tank and turn at two to five rpm. Turning with rotation assistances to reduce abundance solids. The discs have a measurement from two to four meters and a thickness of up to10 mm. Figure (2.2) illustrate the construction and component of RBC[6].

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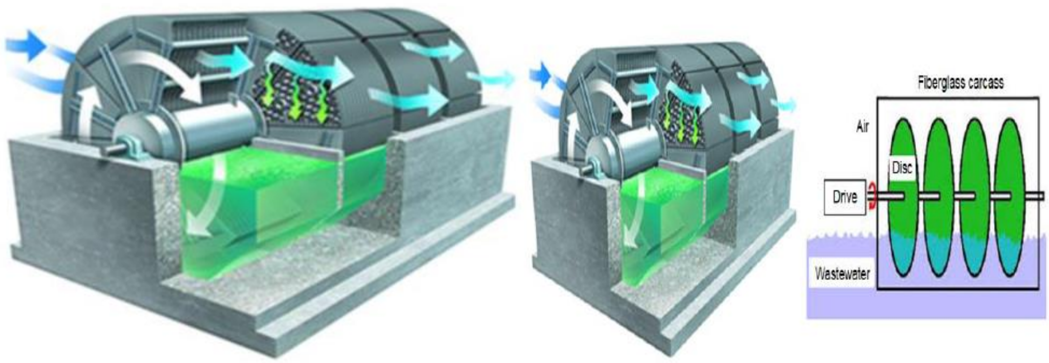

Fig (2.2): Scheme of rotating biological contactors (RBCs) [6]

Aerobic metabolism was implemented by filters out the layer of microorganisms constituents from influent. The rotation movement conveys the wastewater to the air. Microbial building upon the layer by transferring oxygen. when re-immersed into the wastewater, redundant waste substances are removed as sloughing by transferring it with the flow of our stream. Energy consumption of RBC required approximately 25% compared to the activated sludge requirement. It is worth mentioning that using a series of contactors is sufficient to attain the standard of treated effluent rather than a single contractor[24].
Wastewater effluent from the RBC is handed through final clarifiers where the micro-organisms are separated by settling out as sludge. Sludge was relocated from the sedimentation tank to additional treatment most commonly, for use as fertilizer or soil amendment. The rotor must work without a long breakdown to avoid demolition or lower the efficiency of the function of bacteria because it needs an incessant nutrition source as well as a constant inflow of effluent from the reactor or wastewater. The treated effluent disposed of owing a pump directly to the environment by taking into consideration that disposal does not cause any inconvenience[25].

2.2 Advantages and Limitations of RBC

Rotating Biological Contactors has many features that qualify them to be an influential technology in the wastewater treatment field. It organizes a very distinctive selective for decomposable matter and nitrogen evacuation [9]. RBC is a compact system that efficiently reduces organic matter. RBC can treat multi-type of wastewater (grey, black and other types).RBC can attain biological oxygen demand (BOD) elimination up to 90 %. As well nitrification and following denitrification is also exist eliminated since mutually aerobic nitrifying and anaerobic denitrifying microorganisms can instantaneously alive in the attached biofilm, whether it is located on the lowest of the film and close to the disc up keeping or at the upper of the film opens to the air[26].
The study [4] indicated that some of the probable benefits of RBC referred to activated sludge process and trickling filters such as high biomass concentration, low land requirement, simple monitoring, slight maintenance costs, good sludge feature, and little sludge size, short hydraulic retention time and no need of sludge reuse.

As well, the study [1] refers to the high oxygen transfer rate which reduced budget over the long operation contrasted to other systems utilizing outward aerators. It is the operational cost is exceptionally affordable and appropriate at small energy consumption values.

Moreover, a properly designed system, attain a high ability to resist changes ascending in the influents features and to frustrate shock loadings.

Optimization and versatility under various ecological conditions and influent attributes are the required plan for effective utilization and RBC design [9]. Some drawbacks of RBC that is difficult in large scale, leisurely system turn on, pre-treatment and secondary clarifier necessary and restricted system flexibility. Furthermore requires specialized worker for repairs and operation (however fewer than the needed by activated sludge process) also should be secured against sunlight and downpour. It is sensitive to industrial wastes and performance susceptible to wastewater characteristics. Indeed, these reactors have a bigger number of favorable circumstances than inconveniences [9, 23].

The maintenance cost and operational expenses of the RBC are fewer if compared with the Activated sludge (AS) process. Aeration cost in AS systems is much higher which increases the operative cost of the total process while in RBC, no aeration is obligatory due to rotation of the disks which give direct contact of media with the air. Capital outlay for RBC is inversely proportional to the individual counterparts. Whereas it is less than the AS systems because of the less requirement of material. The energy consumption in RBC is about 50% of the AS process in line for no need for aeration [7]. Table (2.1) summarized the Advantages and Limitation of (RBCs):

Table (2.1): Advantages and Limitation of (RBCs) [9,23]

Advantages	Limitations
Land use relatively small	Challenging in scale-up
Easy building and enlargement	Slow system start-up
Consolidated design with discrete parts	obligatory secondary clarifier
Simple operating and monitoring	Restricted practice flexibility
Low maintenance cost	Must be protected against sunlight, rain, and snow
better recovery from shock loadings	Performance susceptible to wastewater features
Great biomass focus per bulk reactor	Adequate primary treatment
Low sludge volume	
No necessity for sludge recirculation	
Struggle the toxic loads and chocks	
No problems with malodors and flies	
Short hydraulic retention time	

3. Factors Affecting on (RBCs)

The treatment process of influent via Rotating biological contactors (RBCs) depends on several issues, touching the efficiency of performance, and improving productivity. Below we review the most prominent of these factors and Particularly significant like RBC media, rotational speed, hydraulic and organic loading, temperature, staging, level of dissolved oxygen (DO), submergence ratio, retention time (HRT) and effluent and solids recirculation [3,9].

3.1 RBC media

In the RBC system, the Disc material is considered an important parameter affecting the energy-intensive and price. Progressive examinations were directed on disc materials to be both less expensive and lighter in order to have an economic framework and less energy utilization. The lighter is the plate material, the lower is the power demanding to pivot it. A number of materials researched were; stainless steel, a cylinder with wooden, polystyrene, propylene pall rings, hard polythene plates, slats, PVC, and acrylic plastic circles [27-31]. The study [32] tested polyethylene froth as a novel disc substantial. It is satisfactory and 80% cheaper than other utilized material. It utilizes minimum energy and not heavier compared with the traditionally utilized circle material.

The essential purpose of RBC media is to expanse extra surface area per unit volume to enhance microorganisms' grow which increases the removal efficiency. Rising surface area encourages the interaction among the wastewater and the microorganisms, and to accomplish oxygen transfer between air and wastewater. Altered types of media are in use and should be considered the cost while selecting one. A plenty density polyethylene is furthermost commonly used material as media in different shapes and structure also it suggestions the benefit as enhanced structural stability and improved mass transfer [4,33].

RBC media have evolved over the years. The original design made from wood then introduced various materials of plastic (polyethylene, polycarbonate, polystyrene, etc.). Alternating from traditional flat disks in excess of rippling to cellular meshes as in figure (3.1.a). coalescence of bacteria has made known that it's in rippled media is tougher than cling to flat surfaces in addition to that, biofilm develop is faster on rough surfaces because it certifies regions of low shear pressure where appended bacteria are safe from the Influences that could confiscate it[23]. Positive results regarding substrate removal have been composed at a lab-scale. Guimar aes et al. [34] joined a stratum of polyurethane froth on plastic plates. Too Tawfik and Klapwijk [35] analyzed the performance between polyurethane froth and polystyrene in RBC media. They found that using polyurethane disk is preferred in ammonium and Escherichia coli expulsion due to the characteristics of its material which encompass channels and pores. This given a positive practical effect in the nitrification and denitrification mechanism and increases the efficiency of transferring the material as well as enlarged the general performance of the systems likewise Chen et al. [18] verified the occurrence of simulation nitrification and denitrification process by covering the RBC disks with a net-like auxiliary elastic substantial with 97% porosity. Cylindrical plastic elements, Pall rings, and saddles are types of packing media that presented attractive results but at a large-scale, some functioning difficulties can take place, leading to a lot of variable biofilm progress. The study [26] investigated that with the usage of wool and polypropylene as bio media, the surface area for the evolution of microorganisms improved. This outcome enlarged the COD removal

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efficiency in the system. Henceforth, polypropylene shall be reflected as a feasible medium on a large scale of wastewater treatment.

Cloth media filtration as illustrated in figure (3.1.b) technology has been utilized for progressive primary treatment. It masses well compared to other approaches, which incorporate artificially upgraded arrangements that present extra working expenses and fine screens that take away rarer solids[36]. It is necessary for the design stage of the RBC system to appraise the features of the influent designate to consuming and the treatment process goals especially the terms mentioned in the review such as power consumption, costs, mass exchange quantity, and the included zone offered to match it with different kinds of biofilm-supporting media. This could permit the stakeholder to select the most suitable kind of medium [9,23]

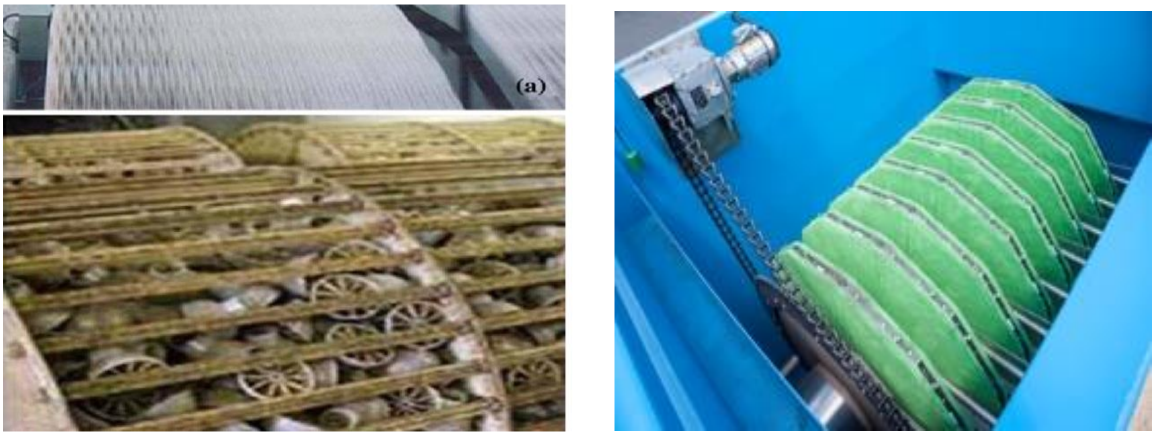

Fig. 3.1 (a) RBC with a unsystematic packed medium [9] (b) cloth media filtration technology [36].

3.2 Factor Related to Flow Rate

Overall performance and pollutants removal of RBC systems depend upon many factors related to flow rate. It takes account of hydraulic and organic loading rates as well as pH and Ammonium loading rate[1].

3.2.1 Hydraulic Loading Rate (HLR)

HLR acting a dynamic role in describing the performance of the bioreactor. It is known as the flow of influent presented through an RBC per surface area item. Rising the flux amount over the effluent decreases the system's retention time which has a reduction in abstraction effectively. In specific situations, Attached microorganisms at the media surface have increased as the hydraulic loading rate was increased [4,23]. HLR is associated with the removal substrate, the design of the RBC, and streaming quality. A relationship between effluent quality and HLR was developed by manufacturers to characterizing the full-scale system and for the sequence of lab-scale experiments. THE typical HLR extent suggested by RBC industrialists is 1.292 m3/m2/h to 6.833 m3/m2/h. A large amount of biological mass of microorganisms gives good stability during toxic or high loadings [37].

3.2.2 Organic Loading Rate (OLR)

The organic loading rate (OLR) has a connotation as one of the main parameters directing the treatment process. It must realize during the designing and planning phase. OLR is characterized as the utilization of solvent and fine particle organic matter. It is normally expressed on an area foundation as pounds of BOD5 per area per time, for example (lb/ft2 /day). OLR is varied by exchanging the access stream rate or the hydraulic retention time. through the increase in OLR, the material evacuation rate increments but the expulsion effectiveness diminishes. This decrease in material deduction means an impediment in dissolved oxygen. In the first phase of the RBC, the carbonaceous substrate is essentially removed [28].

To bypass oxygen transfer limitations, As per the American Society of Civil Engineers (ASCE) besides the Federation of Water Environment, the first phases configuration load must be restricted to five days (BOD5). The rated load is 30 g BOD5/m2 day or to a dissolvable BOD5 load from 12 until 20 g BOD5 / m2 day.

High loading in first stage cause difficulties like odor problems, dissolved oxygen depletion, decay in process performance, sub-standard treatment, unnecessary biofilm thickness, and growth of unwanted microorganism such as Beggiatoa. To vanquish the overloading problems, recycling from the last stage and additional air systems also reducing surface loading and increases oxygen transfer through remove barriers between the first and second stages [31].

Nitrification in RBC correlated with organic loading, particularly in high initial stages. It occurs when soluble BOD load reduces sufficiently. The study [23] showed that the organic load enacted to the RBC system ought to not go above 4 and in value of 2.5 g BOD 5/ m2 day to attain an out discharge quality of 15 or 10 mg ammonia / L. Nowak at his study [38] offered that an OLR of 2.5 g BOD5/m2 day is wanted to preserve the ammonium concentration in wastewater below 5mg N–NH+ 4 /L, by the side of temperatures more than 12◦ C. Study [24] show that the removal efficiency for the RBC system will be high at low organic loading rate and the results indicated the removal efficiency of the nitrate-nitrogen for high and low organic loading rates respectively were 79.2%, 83.4%.

3.2.3 Hydraulic Retention Time(HRT)

Hydraulic retention time is straightly interrelated with the organic and hydraulic loading of the influent wastewater. As longer HRT as degradation of the substrate and enhance the efficiencies. This tendency is validated with heavy metals substrates and toxic. In otherwise short HRT have insignificant treatment. The choice of the augmented HRT is very essential in obtaining the desired effluent quality with consideration of economic trends if realize the long HRT is costly[4, 7]. A good advantage obtainable by full-sized RBCs is to needed short hydraulic retention times (commonly < 1 h) [9].

3.3 Factors related to System Configuration

3.3.1 Rotational Speed

The rotational speed of the RBC modules is one of the fundamental factors related to RBC efficiency due to its responsibility for oxygen mass transfer inside the biofilm and affects the intercourse regime in the RBC unit. Several studies examined the significance of rotational speed and extracted from these studies that increasing the rotational speed could increase the dissolved oxygen concentration existing to the organisms and as an outcome, they are capable of substrate degradable at an upper rate [9]. The study [17] shows when a disk rotational speed rises from 3 to 11 rpm, chemical oxygen demand (COD) enlarged from 62.7 % to 93.7%.
Through the rise of rotation speed, high shear stress occurs also the detrition of substrates at an upper rate is normally achievable that consequences in a higher concentration of dissolved oxygen. While the increase of rotation speed higher power consumption and cost, which cost viable for various wastewater treatment systems. Furthermore, immoderate rotation speed will too affect the deduction of the microbial layer and let down the total efficiency of the treatment procedure [24]. The managerial principle is to implement the least speed proportionate with adequate treatment. The employ of adaptable rotational rates or the capability to inverse shaft rotation has been recommended to improve the sloughing of biofilm [23]. In RBC units with according to Mature and Patwardhan in their studies [29], Naturally rotational speeds are in the range 1 to 10 rpm for system media with plates of 1 up to 4 meters diameter fixed on shafts long round 5 to 10 m.

3.3.2 Staging

Staging of RBC is very important in the design phase to improved efficiency.it is defined as a physical barrier utilized to isolate the influent chemistry between or inside reactors which prompts a stepwise decrease in the bioaccessible substrate to where the reactor attitudes to idealized flow without any mixing of particles of fluid [9].
Several stages of RBC in sequence accomplish larger constituent reduction than a single stage of the same condition. This series arrangement enables the microorganism populace to separate as to be familiar with the different circumstances in the treatment process. Staging can allow the enriched capability to control shock loads giving the biomass has an adequate substrate. The confident effect of staging on RBC acting was negligible after four stages, even though this is reliant on wastewater load and composition[39].
In each stage localization of microbial populations adapted with physical and chemical features which Leeds to enhance removal rate and stability at higher organic loads. The variance of thickness and color of biomass showed that there is high removal efficiency was reached in the first phase. The biofilm in the first

compartment was intensive and creamy color. Then, in two and three stages the color was brown and tinny which only upkeep 15% of the deduction rate [40].

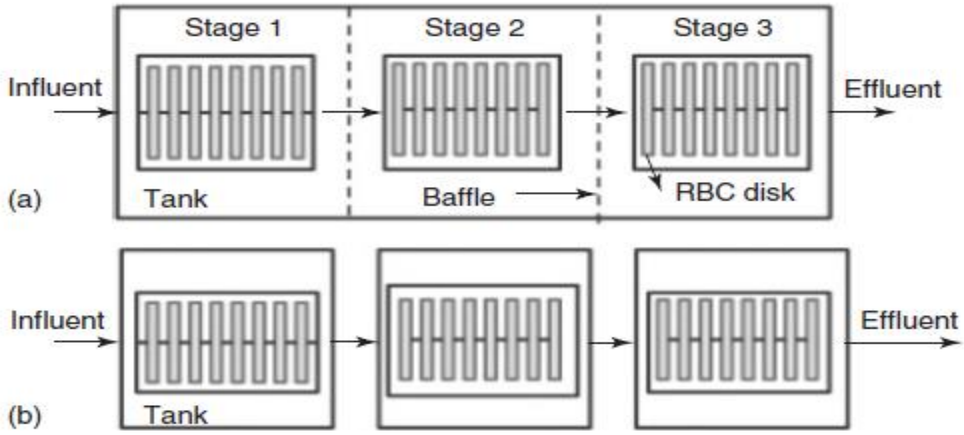

Figure **(3.2)** (a) stream parallel to shaft, unique RBC unit, three phases; (b) stream parallel to shaft and three RBC units [23]

3.3.3 Medium Submergence and Step Feeding

Disk submergence influences the natural cycle. By and large, incompletely lowered RBC's are utilized for nitrification and completely submerged for denitrification. The test was employed with three submergence levels as 23.7, 31.4, and 36%. The removal efficiency of COD improved and the result acquired were 74.9 to 87.5 % and 89.5% to and 93.75% individually when the submergence rate was expanded from 31.4 to 36 %. For high-impact RBC submergence over half isn't conceivable as the orientation holding the pole will be inundated in wastewater and can get decayed influencing the working of the shaft [40]. Normally submergence of 40% is applied. By expanding the submergence as shown in Figure(3.3) the situations in the reactor become progressively anaerobic which could good turn processes that involve decreased oxygen levels such as denitrification [7]. In order to stave off depleted degrees of dissolved oxygen in the system, the wastewater stream is step feeding into the bioreactor. This process of step feeding not just accomplishes adequate DO levels in the influent but increases the cycle capacity and can avoid the Shock loading [4]. Step feeding has a more robust performance due to diminishing the underlying viable substrate concentration however, it has the least impact on the removal of COD removal rate which solutions by staging [7].

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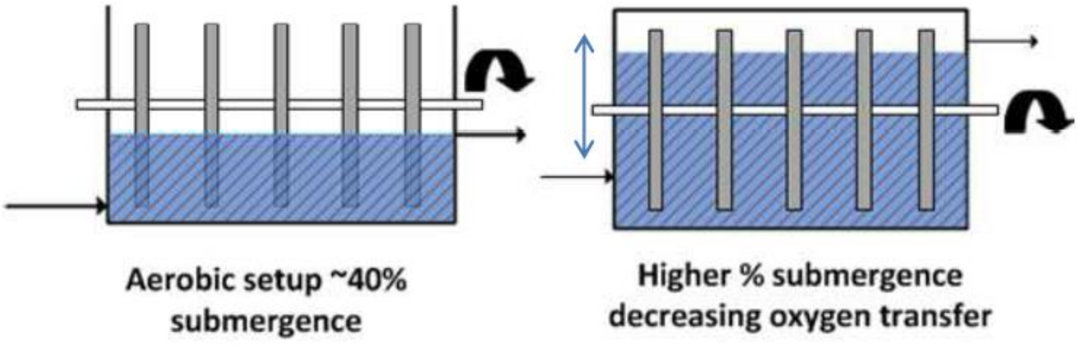

Fig. (3.3) Effect of expanding the submergence rate [7].

3.4 Factor Related to Influent and Biofilm

This is a group of factors related to the characteristics of the wastewater required to be treated, as well as the biomass associated within. It forms a pivotal aspect of the parameters that affect the general performance and efficiency of the outputs. The prominent parameter includes the nature of the wastewater, the characteristics of the biofilm, and temperature.

The concentration of influent and the existence of various materials are significant to system activity. This existence of material will in general minimize the flux in light of it consumes space and consequently diminishes the degradation process. Also, a huge amount of material increases the retention time [4].

Understanding the vital role of biofilm in the treatment system is important. Biofilm thickness is governed by organic loading and applied shearing forces. It has a gelatinous feature and usually greyish color in the initial phase while in the last stage are thinner and seems as a brown dye or at times reddish. Growth factors correlated with the concentration of pollution which is expressed as COD or BOD5. The inside layer is more identical and compact and has a few microbial densities compared to the outer layer. The outer layer turns aerobic but the inner turns anaerobic [9]. The optimum thickness biofilm is 0.5 to 4.5 mm to escape clogging and material stresses and after accomplishment limiting thickness, microorganisms are not capable to take nutrients and oxygen, they can't be attached to the disc and slough off. The width of biofilm is not uniform since the collapse method happens unsystematic. Figure 3.4 illustrated the decrees of biofilm thickness[16,41].

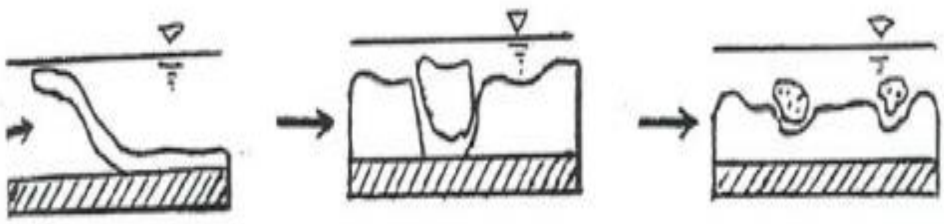

Figure (3.4): Decrease of Biofilm Thickness

Dissolved Oxygen Levels are another very important term and if we omit it, may because of a process failure. Oxygen transfers from the air to the system in the case of oxygen absorption when the biofilm exists in the air and by natural oxygen interface air to water, too by absorption by the microorganisms through the air contacts[23]. When augmented the rotational speed, the dissolved oxygen concentration was increased. There is an inverse relationship between dissolved oxygen and organic loading, the greater the loading there is a high decrease in dissolved oxygen [40]. If the oxygen in the RBC unit is not adequate which affects treatment productivity, it could observe secession of biomass and bad odor in the next sew day moreover at little speed insufficient aeration take a place. The optimum rotational speed for Aeration is 3 – 25 rpm [28].
Temperature forms an axial element controlling the treatment process. When the temperature was increased, the viscosity of sludge is decreased. The optimum temperature is from 15 – 36 ◦C. at lower temperatures nitrogen removal degrees will decrease and has a bad effect on biofilm establishment mainly in its initial phases[40]. Rotating contactors required roofed to keep up the biological growth from cold temperatures or extreme hotness, which hurries media corrosion. Covers aids to diminish heat loss, simple odor control, and curtail algae evolution [9].

On other hand, effluent recirculation is used in the RBC system that needs to upgrade performance. Recirculation takes steps forward in COD, BOD5, and ammonia removal. This progress has been attributed to the reduction of wastewater decomposable organic carbon. Although being elective, recirculation should be watchful in the design phase for opposing circumstances. The normal recirculation is around 25% of the design flow. Recirculation of the RBC may avoid overloading in a specific condition. Enhanced ammonium removal has been irregularly stated when recirculation is functional, growing with recirculation expanded either earlier or after the sedimentation tank. Recycling established solids assists bacterial retention as removed biomass is returned to the RBC unit[9, 23].
The study [5] examined increasing the efficiency of the process in a situation of a high strength influent, a fifty percent recirculation was done and the specific surface area was also extended. Figure (3.5) displays the efficiency of COD removal for the given organic load and retention time of 24 after extended the surface area and stratify the recirculation in comparison to initial operation.

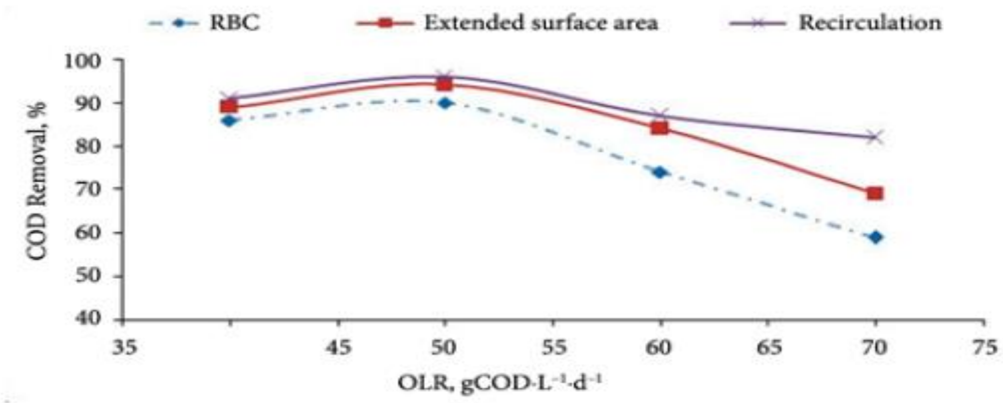

Figure (3.5): COD removal with extended surface and recirculation at HRT of 24 h [5].

With the scale-up consideration, the approach takes in building RBC units with divergent sizes and is common yet is most costly. Dutta et al. in their study [42] constructed three RBCs units with various sizes to describe the oxygen transfer measurement at not the same scales. the main drawback of this experiment is that oxygen transfer must be properly categorized on scale-up, which is not often the case. Otherwise, the design of the large reactors should have dynamic, geometric, and chemical to endeavor the optimum scale [7]. Examination of the dependency of plate biomass thickness and density on the shear strength spreading seems the following step for enlightening and solving the RBC scale-up impasse [9]

4. Advanced Application of RBC

Numerous novel application has been employed using RBC technology. It introduces choice to generate electricity and create energy from biogas on a pilot-scale [43] Cheng et al. [44] incubate a biochemical RBC reactor for subsidiary energy achieving also Christenson and Sims [45] developed a technique for indirect energy generation and exclusion of nitrogen and phosphorus employing an algal RBC reactor. Also, RBC has been utilized in distinctive applications such as biological remediation of landfill leachate, mining, nuclear and electronics industries, effluents decolonization of wastewaters as textile dyes, nitrification uses, denitrification, phosphorus removal as well as successfully employment in industrial and municipal wastewater treatment[23,46-48].

4.1 Nitrification and Denitrification

Nitrification and Denitrification of the ambit of wastewater types can take advantage of RBC reactor whereas oxidation of ammonia is an essential term in evaluating the RBC framework. Extreme nitrification ratio happens when the BOD load reduces adequately since bacterial rivalry to nitrifies in the preliminary phases within height BOD concentrations. The normally initial BOD 5 is 8-10 g /(m2.d) and for best results, it should intensifier of ammoniac nitrogen not less than 3-5 mg/l in the volume liquid [1,7]. Kulikowska et al. [49] Applying RBC in contaminated wastes or refractory and reached maximum nitrification as 4.8 g.NH4-N.m2d-1 at a loading of 6.6 g.NH4-N.m2d-1, therefore reported that microbial variety declined with time, and proposing more superficial measures of community change are obligatory.

The employment of the RBC unit for denitrification is not very extensively used. Denitrification annotation is the reduction of nitrate to nitrite to dinitrogen gas under oxygen lack situations. Studies succeeded to complete nitrogen removal from landfill leachate and coincided that pre ozone process was necessary to eliminate refractory carbon mixtures[50]. The nitrogen removal rate lessened with incremental rotational speed. RBC is appropriate for autotrophic denitrification as bacteria have small growth. The study [7] dealt with several scientific applications and experiments that have been used in nitrogen removal, and they had changeable effects due to their association with other factors linked to the systems.

4.2 Biological Phosphorus Removal

The process of removing phosphorous from wastewater is one of the points that changeable RBC because it achieves moderate ability in it, however, it is problematic to control the oxidizing and anaerobic conditions sequential evolution of phosphorous. it has successfully eliminated 80-90% of a total load of phosphorus [51].

Phosphorus accumulating organisms in a modified RBC arrangement with an anaerobic sedimentation and carbon addition for its cycle growth, with the following sludge reutilize to the RBC. This solids item improving organic removal rates. Mass transfer constraint stopping interchange of obtainable phosphorus and organic substrates restricting total phosphorus uptake rate which is not present in suspended growth systems [7].

The study [52] Paralleled phosphate reduction with COD and nitrate reduction profiles, the phosphate reduction outline is more intensely described to be virtually consuming the available nutrient. Phosphate-phosphorus is needed in the cellular metabolic rate of organisms and a high phosphate nutrient uptake is a manifestation in this study. a very high phosphate reduction was achievable.

4.3 An integrated of RBC

The rotating biological contactor (RBC) is integrated with other technology to have an optimum wastewater treatment process. A recent study[8] in 2020 carried out by Sharjeel at el. affirmation the principle of RBC with a membrane (RBC-MI) as a new system introduces high quality in biological acting and can avoid related disadvantages as fouling in the membrane by using rotation in RBC reactor as well as enhancing hydrodynamics features which increase membrane permeability compared its traditional situations. At increasing disk rotational speed, The permeability can be extra improved. A predictable power demands of this integrated system on a large scale around 0.18 kWh m 3. It seems a quarter of energy desirable at a full-sized membrane. The purification and biological presentation of RBC-MI make known its financial perspective and open the door for substantial enhancements to the existing wastewater treatment processes. Figure (4.1) shown the trialed operation for RBC with a membrane where the membrane is outside the bioreactor and the membrane is placed inside the RBC bioreactor.

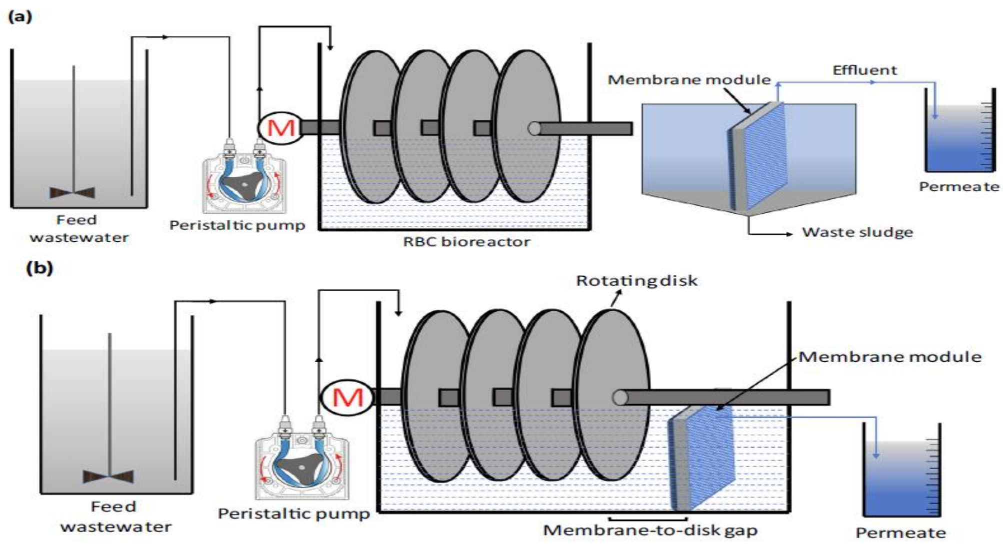

Figure (4.1) presentation of the RBC-ME confirmation; (a) membrane outside the RBC and (b) the membrane is inside RBC [8].

A notable study by Milad Ebrahimi et al. [53] in 2018, inspected the innovative application of a combined system for the treatment of extraordinary strength industrial influent such as synthetic textile, chloral-phenolic, and cheese production. A joint system that uses Anaerobic RBC and MBBR processes. Due to analysis and conducting experiments, it obtains COD removal efficiency of 97.85% and methane gas production of 116.60 L= day. it was determined that using the projected combined system is extremely better compared with a singular Anaerobic RBC. The outcome unique integrated system can afford both extreme removal efficiency and methane production potency. Therefore, this system is endorsed for the treatment of high organic force industrial wastewater steams with consideration of operational parameters.
The study [54] introduces creatively integrated to RBC with catalytic wet hydrogen peroxide oxidation (CWHPO) and utility for the treatment of agriculture and chemical wastewater. A complex model was developed to simulation this integrated system. This modeling for CWHPO and RBC treatment can be of assistance to adjust the CWHPO step to achieve ideal composition of the waste runoff. It reflected very valuable implements to simulate the performance of the treatment under diverse functional situations and even to forecast the theoretic scaling of the methods. Similarly, for large scale aims, parameter as time or biological disc capacity can be assessed as a function of preliminary surroundings of the inlet agriculture and

chemical influent and the anticipated quality features in the last out stream of the treatment cycle.

Another useful application is the treatment of pharmaceutical wastewater. Elorriaga et al. [55] analyze the effectiveness of the RBC unit to eject double pharmaceuticals (carbamazepine and sildenafil) and an individual care product methylparaben in municipal wastewater. These compounds were selected for their exemplification in drainage water and wastewater. High removal efficiencies were found for methylparaben, even though removals less than 20% were attained for carbamazepine and sildenafil citrate. The removal percentages of up to 95% were realized for organic matter through the diverse examinations executed. RBC has been widely used for the removal of nitrogen and phosphorus. However, their design should be adapted and carried out to appraise the removal efficacy of emergent pollutants of complex molecular structure [56].

5. Conclusion

This paper deals with the evaluation of the effectiveness of biological rotating contactor (RBC) as a distinctive tool in wastewater treatment with various applications. Several characteristics and features related to this system have been reviewed, including the various factors related to the media, factors related to the influent flow rate as well as factors related to the configuration and nature of the composition of the RBC system. The wastewater appearance and the biofilm consistency have been discussed to obtain the best performance and more productivity and high quality in the output compared with other devices.

The research included many applications pursued by the rotating biological disks, through its positive points were achieved. The study showed several integrations of RPC devices in treating industrial, chemical, and agricultural wastewater, as well as using them in generating electricity and energy through biogas, in addition to their intersection with other biological methods that led to higher efficiency and reduced cost.

These high specifications, open the door wide open, to increase research, and the development of means and methodologies to reach the best design steps for RBC and future research is available in the development and study of the best among the factors used to reach the ideal state especially, in the integration of RBC with converged technology to achieve an effective and sustainable biological treatment.

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