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SOLVING PROBLEMS FACED DURING BIOLOGICAL KINETIC DETERMINATION

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Abstract: One of the most effective methods used in the biological treatment of a wastewater is the activated sludge process. The importance of the biological kinetic parameters determination is clearly illustrated by the fact that it is usually used in designing such systems. The present study aims to depict the problems faced during the experimental work of determining the bio-kinetics and their causes with an attempt to find proper solutions for them. A completely mixed continuous flow bench scale reactor was operated to determine the biological kinetic for municipal wastewater, during which the generated problems were depicted and solved. It was found that the most common affecting problems were sludge bulking in the final clarifier, followed by rising sludge, filamentous bacteria, settlement of biomass at the bottom of the aeration tank, and finally low biomass activity either immediately after acclimation or after steady state was reached. Solutions were recommended for each problem having continuous monitoring of several parameters at the reactor as their base. Despite the fact that different problems and their solutions have been introduced in this paper, there is no guarantee that all problems are covered. However, one can benefit from what is available.

Keywords: *Biological Kinetic, Activated Sludge, Sludge Bulking, Rising Sludge, biomass.*

حل المشاكل التي تواجه خلال حساب محددات الحركة البايولوجية

الخلاصة: ان قياس المحددات البايولوجية لأي مخلف مائي يعتبر مهم جدا، حيث ان تصميم وحدة المعالجة البايولوجية لهذا المخلف تعتمد على قيم هذه المحددات. يهدف البحث الحالي الى تحديد المشاكل التي تواجه خلال الجانب العملي في حساب المحددات البايولوجية وأسبابها، مع محاولة ايجاد حلول مناسبة لها. تم تشغيل مفاعل مختبري لغرض قياس المحددات البايولوجية لمياه الصرف الصحي وقد تم خلالها تشخيص معوقات العمل وحلولها. وجُد أن أكثر المشاكل تأثيرا على الجانب العملي هو طفو الحمأة في حوض الترسيب النهائي وبعدها تأتي معوقات اخرى متمثلة بالحمأة الصاعدة، البكتيريا الخيطية، ترسبات الكتلة الحية في احواض التهوية، واخيرا خمول الكتلة الحيوية في احواض التهوية. تم التوصية بعدة حلول لهذه المعوقات وقد كانت المراقبة المستمرة للمنظومة اثناء العمل اساس لهذه الحلول.بالرغم من استحداث البحث لعدة معوقات مع مقترحات لحلولها، الّا انه لا يوجد ما يضمن احتواء جميع المشاكل، مع ذلك ممكن الاستفادة مما هو متاح.

1. Introduction

The biological kinetic, for any type of waste, are important parameters in designing the biological treatment system for this waste. Therefore it is of great interest to know basic concepts about them.

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Studying the kinetics of an aerobic biological treatment yields the rate at which microorganisms degrade a particular waste, and by that provide the basic information required for sizing the biological reactor [1].

Determining the bio-kinetic parameters is usually done in a bench scale model reactor dealing with very delicate creatures represented by the microorganisms in the biomass.

Efforts have been expended to determine the biological kinetics of different types of wastewaters around the world [1-8]; however, none of them reported the problems faced during the process. Table 1 illustrated the bio-kinetics found empirically for different types of wastes.

Table1: Typical biological kinetics for different types of wastes

Wastewater type	*k,d^{-1}*	*K_s, mg/l*	*Y, mg/mg*	*K_d, d^{-1}*	*Test basis*	*Reference*
Pulp and Paper mill	5.0	500	0.47	0.19	BOD	[9]
Dairy and Baby milk	0.12	158.76	0.171	0.0421	BOD	[1]
Swine	1.8	167	0.51	0.108	COD	[4]
Domestic	-	25-100 ~ 60	0.4-0.8 ~ 0.6	0.06-0.15 ~0.1	BOD	[10]
	2-10 ~ 5	10-60 ~ 40	0.3-0.6 ~ 0.4	-	COD	
Tannery	3.125	488	0.64	0.035	BOD	[2]
Automobile	0.75	110	1.1	0.28	COD	[5]
Winery	0.28	175	0.26	0.12	COD	[7]
Textile	3.83	1303.56	0.70	0.01	BOD	[3]
	5.20	3407.64	0.25	0.006	COD	
Tobacco	0.39	5.45	0.25	0.005	BOD	[6]

Many issues greatly impact the activated sludge process in actual operation; sludge bulking, for instance, affects 60% of activated sludge plants [11]. Filamentous bacteria, which are floc-bridging type of bacteria, results in poor compaction and settling of sludge [11]. These issues, among others, need to be taken into consideration in more details. The biological kinetics for an activated sludge process treating municipal wastewater had been determined. Many obstacles had been experienced during the process. From that, the idea of this study was created. This study is concerned in illustrating some of the difficulties that could be faced during the experimental work of bio-kinetics determination, giving possible solutions for them.

2. Material and Method

The experimental setup used in this research, the operational procedure, the setup monitoring, and the analytical methods were illustrated below.

2.1. *The Experimental setup*

A completely mixed continuous flow reactor was constructed to determine the biological kinetics. No recycle was adopted in the system duo to the difficulty in controlling the recycling in a bench scale reactor [10]. Figure 1 illustrated a schematic flow diagram of the bench scale biological reactor used in this study while figure 2 represents a picture of the used reactor.

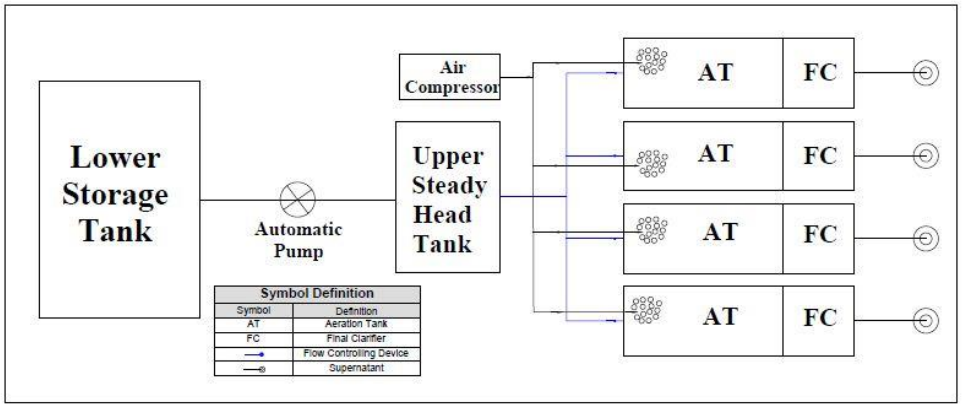


Figure 1: Schematic diagram of the experimental setup

Figure 2: The experimental setup of the biological reactor

The components of the bench scale reactor used were as follows:

1- Lower storage tank.
2- Automatic pump.
3- Upper steady head tank.
4- Four reactors each contain an aeration tank (AT) and a final clarifier (FC).
5- Aeration system.
6- Mixing system.
7- Effluent collecting tank.

2.2. *Operational Procedures*

The reactors in the experimental setup were seeded with activated sludge obtained from the recirculation line of the final clarifier in Al-Rustimiyah wastewater treatment plant. Slow microbial acclimation with wastewater was observed. The reactors were operated initially as batch systems for a period of three days in order to develop the biomass, and then switched to the continuous completely mixed flow system. The desired cell residence times, which were equal to the hydraulic detention times for this case, were adopted by controlling the flow rates of each reactor. Continuous observations were done to detect steady state conditions, denoted by constant BOD_5 values for effluent samples taken at different times, and stably approaching to zero turbidity and suspended solids values for effluent samples. When steady state was reached, samples of in, out, and within the reactors were taken. Different measurements such as BOD, MLSS, MLVSS, and others were tested for each sample and used in determining the biological kinetic.

2.3. *Experimental setup Monitoring*

During an entire experiment, continuous monitoring of DO, pH, and temperature were conducted duo to their great affect on the biological process. Nitrogen, phosphorus, and other parameters were tested.

2.4. *Analytical Methods*

All performed tests were carried out according to the APHA regulations [12].
The DO and temperature were measured by using the WTW DO meter which adopted the standard methods number 4500-O and 2550 of DO and temperature measuring respectively. The pH measure was done by the use of the pH meter (pH 200) Lovibond, that adopted the standard method number 4500-H^+ of pH measuring. The BOD test was done by the Lovibond BOD-system OxiDirect device, assisted by the incubator. This device adopts the standard method number 5210 of BOD measuring. The total volatile solid (TVS) was performed by using the 2540 E. Fixed and volatile solids ignited at 550°C standard method. The total suspended solid (TSS) test was done by using the 2540 D. Total suspended solids dried at 103-105ºC method given in the APHA. The total nitrogen test was done by the WTW photo lab S12 device. This device adopts the standard method number 4500-N-C of TN measuring used in the APHA. The phosphate and phosphorus tests were done by the C200 Multiparameter bench photometer device. This device adopts the 4500-P E. Ascorbic acid method for PO_4^{-3} and P measuring used in the APHA [12].

2.5. *Biological Kinetics Definitions*

The biological kinetic determined from an activated sludge process in an aerobic system are:

The bacterial biomass yield (Y): defined as the ratio of the produced biomass to the consumed substrate (g biomass/g substrate).[10]

Endogenous decay coefficient (K_d): defined as the fraction of MLVSS oxidized per unit time during endogenous respiration process ($time^{-1}$).[13]

Maximum specific substrate utilization rate (k): defined as the maximum substrate utilized per unit mass of microorganism per day.[10]

Half-Velocity constant (K_s): defined as the substrate concentration at one half the maximum specific substrate utilization rate, (mg/l).[10]

3. Results and Discussion

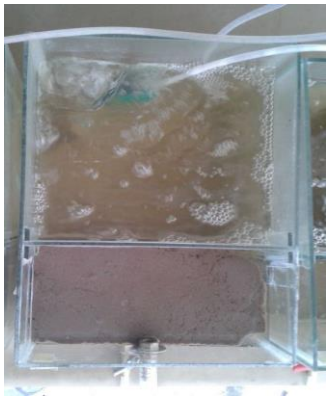
During the experimental work of determining the bio-kinetics of Al-Rustimiyah wastewater treatment plant several difficulties occurred which led to the failure of the experiment and it had to be repeated all over.

The importance of these problems is clearly illustrated by the fact that if no solution is found for these problems, then the whole experiment of bio-kinetic determination would fail.

A detailed discussion of the problems faced, causes, and potential solutions was as follows; noting that the solutions for these problems were applied successfully on the experimental setup.

3.1. *Sludge Bulking at the Final Clarifier*

After reaching the steady state condition, sludge bulking occurring at the final clarifier is possible, as shown in Figures (3;a & b). This may be due to the high rates of continues aeration to more than 3mg/L. When continues aeration is applied to the reactor, high rates of DO occurs at the aeration tank. At high levels of DO, the biomass is over saturated with oxygen. As a consequence, it eventually suffocates. Furthermore, sludge bulking at the final clarifier occurs instead of sludge settling. The easiest solution for this problem is to monitor the aeration tank continuously, and switch off the aeration system whenever reaching 3mg/L of DO concentrations. Note that a mixing system should substitute aeration during its shutdown phase, in order to prevent biomass settling at the aeration tank.



a. Top view

b. Side view

Figure 3: Sludge bulking at final clarifier

3.2. *Settlement of the biomass in the aeration tank*

After reaching the steady state condition, settlement of the biomass at the aeration tank may occur, as shown in Figure (4). This is probably caused by the insufficient mixing in the aeration tank, which shall lead to the lack of suspension of the biomass and eventually its settlement. It has been believed that providing an automatic or manual mixing system that works whenever the aeration system is switched off can solve this problem.

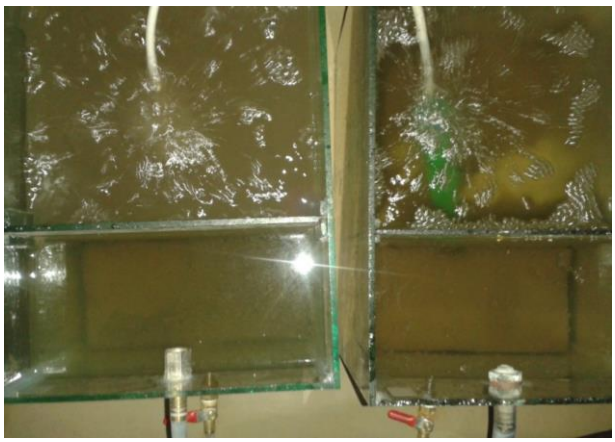


Figure 4. Top view showing the settlement of the biomass in the aeration tank

3.3. *Occurrence of filamentous bacteria at the final clarifier*

After reaching the steady state condition, filamentous bacteria occurring at the final clarifier, as shown in Figure (5), is probably due to low substrate or DO concentrations.
The filamentous bacteria has low half saturation and deoxygenation constants [11] that is why low substrate and DO concentrations favors the filamentous bacteria. Other factors that may affect, at lower levels, the occurrence of this type of bacteria are the presence of sulfide at the wastewater, or wastewater septicity [10].

Possible solutions for this problem are monitoring the DO concentrations in the aeration tank so that it remains at the range of (2-3) mg/l [14], perform the (BOD:N:P) test on the raw wastewater, were it should be (100:5:1)[10]. And if not enough, adding chlorination or hydrogen peroxide to the final clarifier may help. Since the filamentous bacteria have a greater surface area/volume ration than the floc forming bacteria, it should be more susceptible to chlorine and hydrogen peroxide [11].

Figure 5. Top view of the final clarifier showing filamentous bacteria

3.4. *Rising sludge and septic conditions in the final clarifier*

After reaching the steady state condition, another problem that could be presented at the final clarifier is rising sludge and septic conditions, as shown in Figure (6).

This may be attributed to insufficient DO concentrations that caused anaerobic conditions; moreover, leading to the production of nitrogen gas that raises the sludge upwards. This can be detected as small bubbles of gas appearing at the surface of the final clarifier.

At some cases of low DO concentrations, where there are no appropriate environmental circumstances for the denitrified bacteria to occur at the reactor, death of the biomass represented by septic conditions would appear.

The best solution may be found in monitoring the DO concentrations in the aeration tank so that it remains at least 2mg/l. And if not enough, increasing the wasted activated sludge withdrawal from the final clarifier would be helpful.

Figure 6. Side view of the FC showing rising sludge and septic conditions

3.5. *Low activity of the biomass immediately after acclimation*

Low activity of the biomass appearing immediately after biomass acclimation may be a problem. This means that the steady state has not been reached yet.

In general, two major reasons come in mind. First is that the biomass is originally inactive, and second is the biomass suffocation duo to the small volume of the reactor.

The biomass in the experimental setup used to determine the activated sludge bio-kinetic, is either synthetic or taken from the final clarifier of an activated sludge treatment unit. So, for the first cause mentioned above, the biomass may originally be inactive, this can be controlled by performing activity tests on the biomass before starting the experiment, such as viability ratio, total viable count, and most probable number.

For example, the viability ratio should be more than 85% to indicate an active biomass [15]. If the results are undesirable, a reactivation of the biomass can be performed by adding nutrient broth (NB), which is a growth media, to the biomass and continuously shaking, using a shaker, for 18 hours [16]. Or simply another activated sludge may be used.

Now for the second cause, in which the biomass suffocates duo to the small volume of the reactor, this occurs when the biomass concentration is higher than the normal levels which

may lead to a high population of biomass in a small space. Neither food nor air or space would be enough for the biomass; this leads to biomass suffocation and death in the aeration tank. This problem can be eliminated by performing initial experiments with different dilution rates of the biomass, until reaching the most proper biomass volume used for each reactor.

3.6. *Low activity of the biomass after reaching steady state conditions*

Another type of low biomass activity, which may occur after reaching steady state conditions, can be of great effect on the biological process. A lot of possible reasons can cause this problem, such as variance in pH and temperature, low food to microorganism ratios, and low nutrients in substrates.

The suitable pH range for biological treatment is (6.5-8.5) [17]. Higher and lower pH values can affect the biological process. Therefore, continues monitoring of pH during the process is important. For lower pH values in the reactor, the addition of an alkaline such as sodium hydroxide (NaOH) may raise its levels. As for higher pH values, an addition of an acid such as hydrochloric acid (HCl) may help.

The convenient temperature range required for biological treatment by heterotrophs under aerobic conditions lies between (25 to37) ºC [18]. For lower degrees, increasing the surrounding temperature either by providing a high-voltage light near the reactor or a heater can be of great influence. Higher temperatures need to be declined by using an air cooler. Note that the use of an air-conditioner gives a negative impact due to low temperatures obtained.

The problems of low food to microorganisms, and low nutrients in substrates can be controlled by performing the (BOD:N:P) test on the raw wastewater, were it should be (100:5:1) [10]. If not sufficient, the addition of nutrients such as magnesium sulfate, calcium chlorides, and ferric chloride may help. Note that the addition of glucose sugar is not recommended, due to its great influence on the initial BOD_5 value, which in turn affects the whole biological process.

4. Conclusions

An attempt has been made to find the biological kinetics of activated sludge process treating municipal wastewater of Al-Rustimiyah wastewater treatment plant. Many problems had been faced during the process. A summary of these problems, causes and solutions was depicted at Table (2).

In conclusion, even though different problems and their solutions have been introduced in this paper, there is no guarantee that any other problem would not appear. However, one can eliminate the listed problems and if others occurred, then trying to gain new solutions is recommended.

Table 2. Problems faced at the experimental work and their solutions

Problem description	Cause of problem	Solution in brief
Sludge bulking at the final clarifier	High rates of DO in the aeration tank above 3 mg/l	Keeping the DO levels in the aeration tank within 3 mg/l
Settlement of the biomass in the aeration tank	Insufficient mixing in the aeration tank	The addition of automatic or manual mixers to the aeration tank.
Occurrence of filamentous bacteria in the final clarifier	Low substrate and DO concentrations, and insufficient nutrients	Keeping the DO levels in the aeration tank within 3 mg/l and if not enough adding chlorination or hydrogen peroxide to the final clarifier.
Rising sludge and septic conditions in the final clarifier	Insufficient DO concentrations	Keeping the DO levels in the aeration tank within 3 mg/l and if not enough increase the activated sludge withdrawal
Low activity of the biomass immediately after biomass acclimation	Biomass suffocation duo to the small volume of the reactor	Reduce the initial biomass volume used in the experiment
	The biomass is originally inactive	perform activity tests on the biomass before starting the experiment
Low activity of the biomass after reaching steady state conditions	Low pH concentration	The addition of an alkaline
	High pH concentration	The addition of an acid
	Low food to microorganisms	The addition of nutrients
	Low temperature, less than 15ºC	Increasing the surrounding temperature
	High temperature, more than 40ºC	Decreasing the surrounding temperature
	Low nutrients in substrates	perform the (BOD:N:P) test on the raw wastewater

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