

Nitrogen Removal Enhancement in Extended Aeration System



Zakri Ahmed, Aminuddin Mohd Baki, Jurina Jaafar, Zulhafizal Othman, Suzana Ramli

Abstract: Several methods of wastewater treatment systems are implemented but among these methods activated sludge process is demonstrating process in Malaysia. Fortunately, numbers of studies have been conducted to treat and remove either nitrogen or combined phosphorus and nitrogen resulted in enhancement removal of nutrients worldwide. This research aims to study the current operation in Mawar wastewater treatment plant and monitor the reduction of several parameters. The research also examines the new standard limits of effluents. From the result obtained, the monitoring of Mawar wastewater treatment plant indicates that influent concentration of majority of the parameters were in small. Despite that, the removal efficiency of several parameters was not high. That was basically because to the need of proper maintenance activities. Besides, the concentration of measured parameters in the aeration tank inlet were small. Comparison of Mawar wastewater to the typical composition of untreated domestic sewage indicated that the wastewater in Mawar wastewater treatment plant is classified as weak wastewater. The enhancement of nitrogen removal resulted in Mawar wastewater treatment plant led to decrease the removal efficiency of several parameters.

Keywords : Extended Aeration, Malaysia, Nitrogen Removal, Wastewater Treatment

I. INTRODUCTION

During last decades, a huge attention was introduced regarding nutrients removal from wastewater. This emerged concern has advocated legislation makers to set limits for nutrients in wastewater effluent in order to protect the environment and human health as well [1]. The nutrients in aquatic environment mainly are phosphorus and nitrogen [2],[3]. Their main impact is the formation of eutrophication

process and its relating aquatic adverse impacts.

Eutrophication is defined by World Health Organization (2002) as “a complex process which occurs in both fresh and marine waters, where excessive developments of certain types of algae disturb the aquatic ecosystems and becomes a threat for animal and human health” [4]. Eutrophication process has several symptoms including algae blooms that results in algae scums and toxins, massive growth of certain aquatic plants, an increase of water-related diseases frequency, unpleasant odors and unpalatable tasting water, turbid water, depleting of dissolved oxygen and fish kills [5],[6].

Malaysia also is amongst these countries that had enforced regulation to control nutrients dischargers. National Hydraulic Research Institute of Malaysia (2010) has ranked eutrophication which is known as global widespread issue among the most prevalent environmental dilemmas in Malaysia [6]. A considerable effort of the Suruhanjaya Perkhidmatan Air Negara along with the Department of Environment has been performed to revise, evaluate and pollinate the regulation of Malaysian water industry. This attempt has resulted in some upgrades in Malaysia Sewerage Industry Guidelines and relative effluent limits [7]. Accordingly, wastewater treatments plants are required to meet these limits. Basically, these limits are included in future wastewater treatment plants’ design but in term of existing treatment plants these limits could become difficult to meet.

In Malaysia several methods of wastewater treatment systems are implemented but among these methods activated sludge process is demonstrating process in Malaysia [7]. Fortunately, numbers of studies have been conducted to treat and remove either nitrogen or combined phosphorus and nitrogen resulted in enhancement removal of nutrients worldwide. Nitrogen removal efficiency varies from a treatment plant to another due to the differences of wastewater characteristics and environmental factors such as weather conditions. Such studies have not been practiced in Malaysia basically because nutrient concentration in effluent was not concerned. As the changes of the effluent discharge regulation including nutrient concentration which lately enforced, researches that focus solely on nitrogen removal enhancement within extended aeration system form domestic wastewater are needed. This research will eventually relieve the work needed to adjust operation and process in extended aeration system to improve nitrogen removal efficiency. This research aims to study the current operation in Mawar wastewater treatment plant and monitor the reduction of several parameters.

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The research also examines the new standard limits of effluents. That includes the determination of effluents permits that should be practiced in the wastewater treatment plant. The main target of this study is to find the proper technology to configure the current operations to treat nitrogen from wastewater which eventually will help to diminish nutrients' threat on aquatic ecosystems.

II. CURRENT OPERATION IN MAWAR PLANT IN UTM

Mawar wastewater treatment plant is designed to treat wastewater of 8000 population equivalent. The practiced method in the treatment plant is known as extended aeration activated sludge plant. Extended aeration process is considered as a modification of activated sludge process. Extended aeration process is known by having low organic loadings which is usually less than 9.1 kg of biochemical oxygen demand BOD per aeration tank volume of 28.32 cubic meters [7],[8]. It is also characterized by long retention time within the aeration tank varies from 18 hours to 24 hours. These characteristics result in a high content of activated sludge suspended solids in mixed liquor and low and stabilized quantities of biomass due to the digestion of bacteria in the aeration basin. The sludge age or as termed as sludge retention time SRT in extended aeration process is typically more than 20 days [7].

The mechanized Mawar wastewater treatment plant was designed as extended aeration activated sludge system (Universiti Teknologi Mara). The treatment plant was designed to achieve two main goals which are as follow:

- i - Reduction biochemical oxygen demand BOD to permitted level.
- ii - Reducing decomposable organic matter, pathogenic microorganisms and nutrients to levels which could not threat public health.

Mawar wastewater treatment plant consists of primary screen chamber, sump pump, valve chamber, secondary fine screen, grit chamber, grease chamber, aeration tank, distribution tank, secondary clarifier, sludge holding tank, chlorination chamber, covered sand drying beds, sludge storage house and control room that includes blower house and thickener house.

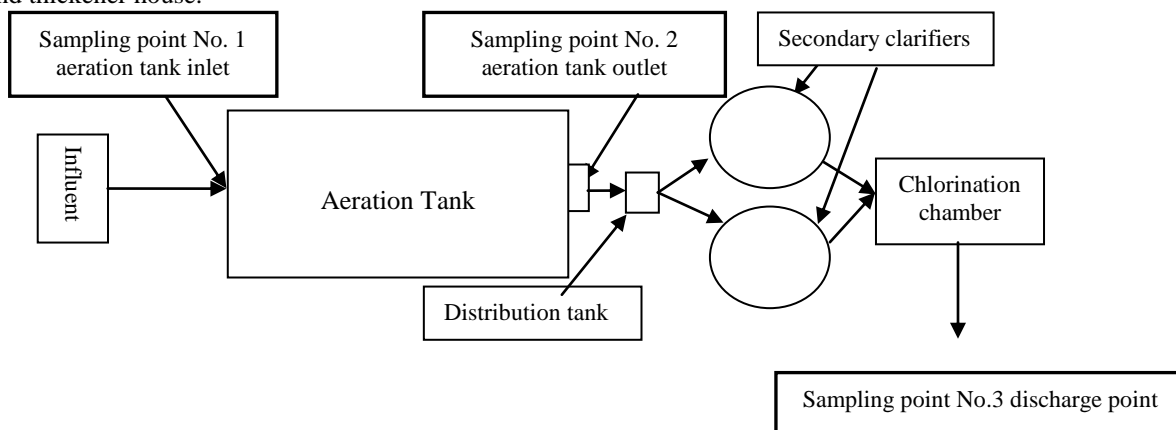


Fig. 1. Schematic Diagrams Shows Sampling Locations.

A. AERATION TANK

Primary sedimentation tank is excluded in Mawar wastewater treatment hence extended aeration time between 18 to 24 hours is needed. This extended aeration enhances the treatment efficiency and provides lesser organic surge susceptibility. However, the system has low food to microorganism ratio F/M. Mixed liquor suspended solids MLSS is maintained through sludge recirculation. That to ensure that organic matters are broke down sufficiently. In term to meet this target air is submersibly injected into the wastewater. That provides adequate dissolved oxygen to allow cell metabolism stabilizing organic matter.

The air blower used for the aeration process is Fu-Tsu blower model number Fu-Tsu SSR- 150. Two units are used. The output of this type of blower is 18.5kw. Capacity of oxygenation of this blower is 1077m³/hour with a speed of 1455 rpm. Blower can be set on manual or automatic starting. When setting the automatic mode, blower is controlled by a 24 hours timer switch. The blower can run during 24 hours as well. In this mode, blowers shift working every 30 minutes. FlexAir fine bubble diffuser model number 9'' FlexAir Disc is used within the aeration tank. The output of this model is 4.80m³/hour/diffuser. There are 105 units of fine bubble diffusers are installed in each aeration tank.

B. MEASUREMENT OF WASTEWATER CONTENTS

The study is used to determine the category of the wastewater treatment plant in accordance to the Suruhanjaya Perkhidmatan Air Negara and relatively identify the effluent limits. Then, wastewater's constituents were selected and their concentrations were quantified as well. These samples were collected from several points in the plant which are aeration tank inlet, aeration tank outlet and at the discharge point. Sampling points for this purpose are illustrated in Fig. 1. Subsequently, the treatment efficiency level for each constituent was assessed. These sampling and analyzing were conducted suing standard methods following standard methods for the examination of water and wastewater and the Code of Federal Regulations [9].

C. DETERMINATION OF THE MODIFIED SYSTEM

The study included approved scientific equations for recalculating and redesigning the wastewater treatment plant under study in attempt to result in enhanced treated effluents' concentrations in comparison with the current values. It involved calculation of the anoxic and aerobic zones for denitrification and nitrification respectively. In addition, several operational factors were modified to create suitable environmental conditions for bacterial activities. These design parameters are required to be provided in the system within extended aeration process by Suruhanjaya Perkhidmatan Air Negara (2009) [7]. In the design parameters for extended aeration it has been mentioned by Suruhanjaya Perkhidmatan Air Negara (2009), extended aeration system must include anoxic zone ahead of the reactor to acquire denitrification process [7]. But many systems can be used as well to enhance nitrogen removal from wastewater by activated sludge systems.

After modification process and by using the standard methods for the examination of water and wastewater and the Code of Federal Regulations, additional samples were collected and analyzed then compared to the previous records [9],[10]. The samples gathered after modification step were collected from the same locations of samples before the modification step and analytical methods used are consistent as well. Consequently, the efficiency level of the treatment was evaluated followed by the determination of compliance with the limits.

D. MODIFICATION OF THE ACTIVATED-SLUDGE SYSTEM

Activated-sludge process can be particularly modified within the different ranges of the parameters processes and they also produce some effluents of the different qualities [11]. The major basis for selecting the required modification of process and is linked to determining the characteristics of wastewater, size of the treatment plant, and treatment objectives [12]. Activated sludge systems include conventional activated sludge, contact stabilization process, extended aeration process, oxidation ditches, sequenced batch reactor [11],[13].

The activated process of sludge has extensively been employed in its modified as well as conventional form throughout the globe and all are able to meet the effluent limits of secondary treatments. There are varieties of modifications that have been done in the conventional system of activated sludge to meet the objectives of specific treatments. One of the modifications that have been done in the traditional activated-sludge process and the variation led to the extended-aeration activated-sludge process.

Activated-sludge plants having extended aeration are specifically designed to give an aeration period of 24 hours for all the low organic loadings and having a biochemical oxygen demand that are in fact less than 9.1 kg per 28.32 m³ of volume of the aeration tank [7],[8]. This system is actually used for reducing the sludge amount that is being wasted for the disposal and can be simply used for the treatment plants with a capacity of 45460.9 liters per day [13]. This is a mixed process that is operated at quite long detention time of hydraulic that is almost 18 to 36 hours and also an extra long SRT that is 20 to 30 days [13].

There are two main advantages of the long SRT that includes a greater stability of process and a low production of the stabilized sludge. Extended-aeration activated-sludge system has greater requirements of oxygen. This system is very stable, simple, and robust for operating and thus making it highly suitable for the smaller communities [8],[13].

This study involved three steps which are to find out the proper techniques to modify Mawar wastewater treatment plant to treat nitrogen content. These three steps are characterization of the wastewater in three points, revise and implementation the modification process and reanalysis the wastewater in the same three points. Measurement of ammonical nitrogen was performed using Nessler method which is referred as method number 8038 in the procedures manual of the spectrophotometer DR 2800. The method that was used to measure nitrate is cadmium reduction method. This method is referred as method 8039 in the fifth edition of procedure manual of DR 5000 spectrophotometer.

III. SELECTION OF MODIFICATION SYSTEM FOR NITROGEN REMOVAL

A. CREATION OF ANOXIC ZONE IN THE AERATION TANK

In term to provide an anoxic zone in the reactor physical work was needed. In fact, this task could not be accomplished without disturbing the current operation of Mawar wastewater treatment. Work to provide anoxic zone in the reactor is done after the approval and support from the head of mechanical department of UiTM. The physical work was done by the contractor of maintenance in UiTM. Providing anoxic zone was done through three major steps including Drying out the aeration tank, Laying down plastic sheets on the diffusers and Stabilizing the plastic sheets by sand pages.

Drying out the reactor called for shutting down the operation in the treatment plant. To dry out the aeration tank, portable submersible pump was installed in each aeration tank and connected to the outlet of the aeration tank.

B. LAYING DOWN PLASTIC SHEETS ON DIFFUSERS

This step is done after the aeration tanks were completely dried. Two plastic sheets with proper dimensions were placed on diffusers in each aeration basin. Each plastic sheet has dimensions of 6.096 as length and 9.144 of width. These plastic sheets were used to prevent air to flow into wastewater through diffusers. Plastic sheets help to force air to flow towards aerobic zone. The plastic sheets used were wide to cover the bottom of the anoxic zone in the aeration tank. Plastic sheets managed to cover all diffusers, distances between air pipes and surrounding edges of the anoxic zone. Almost half of the bottom of each reactor was covered by plastic sheets. Plastic sheets will not last at the bottom by itself or by a function of the gravity; therefore, the third step came into action.

C. STABILIZING THE PLASTIC SHEETS BY SAND PAGES

Plastic sheets will float to the surface of the aeration tank because of the air flows through diffusers. Hence sand pages were used to force the plastic sheets to become stable. Sand pages as well as the water above the plastic sheets afford enough gravity force to hold the plastic sheets at the bottom of the anoxic zone. Fig. 2 illustrate placing down the plastic sheets and complete work after putting down the sand pages. Then number of sand pages were placed in each aeration tank was 105 pages. Sand pages were distributed and placed on every diffuser located in the anoxic zone, on surrounding edges of the plastic sheets and between air pipes.



Fig. 2. Complete works by placing sand pages

IV. RESULT

Samples were collected after the aeration tanks were refilled

Table-I: BOD₅ measurements at Mawar Wastewater Treatment and Removal Efficiency

BOD ₅ measurements before Modification					BOD ₅ measurements after Modification				
Day	Aeration Tank Inlet	Aeration Tank Outlet	Discharge Point	Removal Efficiency %	Day	Aeration Tank Inlet	Aeration Tank Outlet	Discharge Point	Removal Efficiency %
1	81.9	31.2	22.6	72.40	1	62	58.71	46.68	24.71
2	103.5	93.9	70.8	31.59	2	111	104.83	79.17	28.68
3	45.9	27	19.2	58.17	3	81.20	69.30	49.89	38.56
4	83.4	31.50	26.8	67.87	4	48.12	35.64	31.68	34.16
5	53.7	50.10	37.5	30.17	5	64.8	57.39	41.25	36.34
6	39.30	36	26.3	33.08	6	50.6	32.20	31.58	37.59
7	130.2	129	94.3	27.57	7	120	115.78	86.64	27.8
8	42.9	38.10	18	58.04	8	46.92	32.85	33.43	28.75
Average	72.6	38.1	39.4375	47.36	Average	73.08	63.34	50.04	30.07
Highest	130.2	129	94.3	72.4	Highest	120	115.78	86.64	38.56
Lowest	39.3	27	18	27.57	Lowest	46.92	32.2	31.58	24.71

^a. *All values in mg/l except removal efficiency which is in per cent.

At the aeration tank inlet it seems there is not a significant change. Values of BOD₅ at the second point are affected by the modification system. Measured lowest value of BOD₅ at the second collection point increased to be 32.2 mg/l after modification instead of 27 mg/l before modification. The highest values declined from 129 mg/l to 115.78mg/l. That led to raise the overall BOD₅ concentration at the same point from 38.1 mg/l to 63.34 mg/l. The same phenomenon happened at the third collection point. Lowest value increased to be 31.58 mg/l as a replacement for 18 mg/l and the highest value changed to 86.64 mg/l instead of 94.3 mg/l. As a sequence, the overall of BOD₅ measurements up surged from 39.44 mg/l to be 50.04 mg/l.

Due to the changes of BOD₅ values in the second and third collection points, the removal efficiency levels are alternated.

and almost two rounds of the operations were carried out. Samples collected after two days since the reactors were completely filled with wastewater. Samples were collected from the same points of collection points before the modification. The same procedures were practiced in samples analysis and measurements. In better words, sampling locations and analyzing and measurement after the configuration practice are consistent with these before the modification. Reading of pH and temperature are not affected by the modification practice.

Recorded readings were compared to both the standard limits and the previous readings obtained before modification. Removal efficiency of each parameter was compared as well.

A. BIOCHEMICAL OXYGEN DEMAND, BOD₅

BOD₅ concentrations and removal efficiency are tabulated in Table-I. As a result of the modification practice BOD₅ values have experienced some changes in both concentrations at certain points and removal efficiency.

Calculated removal levels before the modification was between 27.57 and 72.4 per cent with mean of 47.36 per cent. After the modification the removal level range was narrowed to be between 24.71 and 38.56 per cent. The overall removal level turned down to be 30.07 per cent instead of 47.36 per cent.

B. REMOVAL EFFICIENCY OF SUSPENDED SOLIDS

Removal efficiency of suspended solids and their concentrations are shown in Table-II. The overall removal SS level is slightly decreased to be 40.62 per cent instead of 46.91 per cent.



The range of the removal level is faintly narrowed to be 17.95 to 70.73 per cent meanwhile it was between 17.05 and 72.36 per cent before the modification. Nevertheless, suspended solids concentrations at the effluent point were below the standard limits. The average of suspended solids concentrations at the discharge point was 53.5 mg/l. The lowest and the highest concentrations at the discharge point are less than the permit which is 100 mg/l.

It has been mentioned by researcher's biological nutrient removal system through nitrification and denitrification processes are usually utilize to remove nutrient and enhance

BOD5 and SS [14],[15]. BOD5 and SS removal decreased because of the modification practice. It could be justified by that, the secondary clarifiers in the treatment plant do not function. Hence, proper separation of the sludge and liquid is not adequately accomplished. Despite the concentration of BOD5 and suspended solids increased after the modification rather than the modification at the aeration tank outlet, further removal could be achieved if the clarifiers were working.

Table-II: Suspended Solids Measurements at Mawar Wastewater Treatment and Removal Efficiency

SS measurements before Modification					SS measurements after Modification				
Day	Aeration Tank Inlet	Aeration Tank Outlet	Discharge Point	Removal Efficiency %	Day	Aeration Tank Inlet	Aeration Tank Outlet	Discharge Point	Removal Efficiency %
1	123	46	34	72.36	1	106	101	48	54.72
2	140	116	50	66.67	2	123	62	36	70.73
3	71	79	58	18.31	3	91	97	52	42.86
4	44	41	36.5	17.05	4	65	72	41	36.92
5	48	39	35	27.08	5	71	76	45	36.62
6	125.5	118	38.5	69.32	6	94	89	63	32.98
7	88	79	52	40.91	7	112	109	76	32.14
8	107	111	39	63.55	8	78	75	67	17.95
Average	93.3125	78.625	42.875	46.91	Average	92.5	85.125	53.5	40.615
Highest	140	118	58	72.36	Highest	123	109	76	70.73
Lowest	44	39	34	17.05	Lowest	65	62	63	17.95

b. *All values in mg/l except removal efficiency which is in per cent.

C. REMOVAL EFFICIENCY OF AMMONIACAL-NITROGEN (NH⁺₃-N)

The absolute permitted discharge value of ammoniacal nitrogen is 20 mg/l. All the measured discharged ammoniacal nitrogen concentration is smaller than the limit. Considering

the removal efficiency, it seems that ammonical nitrogen dose not experience any removal level. That basically because the operation is not designed to remove nutrient. That was supported by Michael (2008) who said that extended aeration system has shown poor nutrient removal ability [8].

Table-III: Concentrations of Ammoniacal Nitrogen and Removal Efficiency at Mawar Wastewater Treatment Plant

NH+3-N measurements before Modification					NH+3-N measurements after Modification				
Day	Aeration Tank Inlet	Aeration Tank Outlet	Discharge Point	Removal Efficiency %	Day	Aeration Tank Inlet	Aeration Tank Outlet	Discharge Point	Removal Efficiency %
1	16.6	16.4	16.4	1.2	1	17.75	13.65	13.45	24.23
2	17.6	17.9	19.9	-	2	17.57	13.8	13.15	25.16
3	16.5	15.4	16.3	1.2	3	16.6	13.90	13.78	16.99
4	13.8	14.8	13.9	-	4	17.34	15.23	14.50	16.38
5	15.8	15.95	16.9	-	5	17.54	14.7	14.50	17.33
6	16.45	16.7	18.15	-	6	14.8	12.5	12.4	16.22
7	16.9	17.65	18.9	-	7	15.7	14.1	14.3	8.92
8	16.2	16.25	17.75	-	8	13.9	12.1	12.1	12.95
Average	16.231	16.381	17.275	1.2	Average	16.4	13.747	13.522	17.272
Highest	17.6	17.9	19.9	1.2	Highest	17.75	15.23	14.5	25.16
Lowest	13.8	14.8	13.9	1.2	Lowest	13.9	12.1	12.1	8.92

c. *All values in mg/l except removal efficiency which is in per cent.

Ammonical Nitrogen is the most influenced parameters due to the implementation of modification process. Readings of ammonical Nitrogen measurement at the aeration tank inlet before and after the modification were relatively the same. As shown in Table-III huge changes were observed at the second collection point. Measurements of ammonical nitrogen at this point indicate that the lowest concentration was 12.1 mg/l instead of 14.8 mg/l. The highest value also decreased from 17.9 to 15.2 mg/l. The average of the whole values declined to 13.75 mg/l meanwhile it was 16.38 mg/l before the modification. The decline of ammonical nitrogen concentrations continued at the discharge point as well.

The modification implementation enhanced ammonical nitrogen removal from the wastewater. Removal efficiency of ammonical nitrogen was between 8.92 and 25.16 per cent. Comparing the concentrations of ammonical nitrogen at the discharge point to the standard limit indicates that all the readings of ammonical nitrogen measurement are lower than the standard limit.

Temperature was perfect to enhance the nutrient removal. Complete nitrification can be accomplished in aerobic condition with temperature 20 °C but along with 2.7 days of sludge age.



Despite this proven fact, the reduction of ammonical nitrogen was around 17.27 per cent. In addition, nitrification process is influenced by the BOD₅/TKN which affects the growth rate of organic consuming organisms and nitrifiers [14]. Measurement of TKN is not performed to check this ratio but using the ratio between TN and BOD₅, the ratio is around 2.7. This is bigger than the BOD₅/TKN ratio because TKN is the sum of ammonical nitrogen and organic nitrogen meanwhile the total Nitrogen TN is the sum of nitrate nitrogen, ammonical nitrogen, organic nitrogen and nitrite [14],[16],[17]. Because of that the organic consuming organisms grow faster than the nitrifier organisms. pH value seems to affect the nitrification rate. As claimed by Qasim (1999), the optimum range which is in the range of 7.2 to 8.6 but in the actual operation pH is between 7.17 and 7.07 [14]. Metcalf and Eddy (2004) specified 7.5 to 8.0 as the best range of pH for nitrification to occur [17]. The last factor that has affected the nitrification rate is the dissolved oxygen. It seems that the dissolved oxygen in the aerobic zone did not reach the perfect amount which is around 4.6 mg/l. That because the operator sets the blower to work every half an hour and automatically switches off during the other half an hour. Besides some amount of oxygen escapes from the aerobic zone to the anoxic zone due to the direction of wastewater flow. The wastewater flows from the aerobic zone which is after the aeration tank inlet towards the anoxic zone which is located ahead of aeration tank outlet.

D. REMOVAL EFFICIENCY OF NITRATE NITROGEN

Nitrate nitrogen effluent limit implemented in Mawar wastewater treatment plant is 50 mg/l. Hence the concentration on nitrate nitrogen influent, the removal efficiency of less than 1.0 mg/l is neglected. The amount of nitrate nitrogen in the aeration tank is low basically because nitrification process which considered as the production mechanism of nitrate in activated sludge systems in not provided. That can be justified by that the lack of dissolved oxygen in the aeration tank which is 2.0 mg/l. With the current operation Mawar wastewater treatment plant perfectly comply with nitrate nitrogen discharge limit.

Nitrate nitrogen concentrations have been influenced by

the modification implementation. At the aeration tank inlet the concentrations before and after the modification were found relatively the same. At the second collection point, nitrate nitrogen concentration increased. Before the modification as shown in Table-IV, the nitrate nitrogen concentration at the reactor outlet was in the range of 0.06 and 0.38 mg/l with average of 0.18 mg/l. These values changed after the modification at the same location. Concentration of nitrate nitrogen was between 1.04 and 2.22 mg/l with mean value of 1.24 mg/l. At the discharge point, concentration of nitrate nitrogen was between 0.64 and 2.5 mg/l. Meanwhile the average value on nitrate nitrogen measurement was 0.95 mg/l.

Nitrate nitrogen removal efficiency before the modification was high. It was fluctuating between 3.7 and 90 per cent with mean value of 56.34 per cent. The removal efficiency after the modification implementation is difficult to be obtained. The mean reason is that the concentration of nitrate nitrogen at the effluent is higher than the concentration at the aeration tank inlet. That basically because nitrate nitrogen is created within the aeration tank. Nonetheless, concentration of the nitrate nitrogen at the discharge point is extremely small comparing to the discharge limit. Discharge limit is 50 gm/l meanwhile concentration of nitrate nitrogen at the effluent oscillated between 0.64 and 2.5 mg/l with the average of 0.95 mg/l.

Denitrification rate is not affected by the temperature or pH. That because is above 20 °C which is proven to high denitrification rate [18]. Besides the anoxic zone is extended which was practiced decreasing the effect of temperature on the denitrification rate [18]. In addition, preferred pH value for denitrification is within the range of 7.0 to 8.0. pH will influence the denitrification ratio if it is in the range between 7.0 to 6.0 [17]. Because of that significant amount of nitrate nitrogen created at the aeration tank was removed in the anoxic zone. The shutdown of clarifier due to the damage is beneficial to the nitrate nitrogen removal at Mawar wastewater treatment plant. The removal of nitrate nitrogen continued to happen even within the clarifiers because it provides anoxic zone as well. This damage was beneficial to the nitrate nitrogen removal even before the modification.

Table-IV: Nitrate Nitrogen Concentrations and Removal Efficiency at Mawar Wastewater Treatment Plant

NH ₃ -N measurements before Modification					NH ₃ -N measurements after Modification				
Day	Aeration Tank Inlet	Aeration Tank Outlet	Discharge Point	Removal Efficiency %	Day	Aeration Tank Inlet	Aeration Tank Outlet	Discharge Point	Removal Efficiency %
1	0.63	0.23	0.23	63.49	1	0.30	2.22	2.5	-
2	0.41	0.38	0.27	34.15	2	0.46	2	1.8	-
3	0.54	0.18	0.52	3.70	3	0.26	1.08	0.9	-
4	0.21	0.12	0.08	61.90	4	0.07	1.5	0.9	-
5	0.23	0.06	0.023	90	5	0.43	1.04	2.1	-
6	0.09	0.18	0.14	-	6	0.09	1.15	0.76	-
7	0.07	0.19	0.1	-	7	0.57	1.05	0.64	-
8	0.46	0.17	0.07	84.78	8	0.40	1.24	0.95	-
Average	0.33	0.1888	0.17913	56.3367	Average	0.3225	1.24	0.95	-



Highest	0.63	0.38	0.52	90	Highest	0.57	2.22	2.5	-
Lowest	0.07	0.06	0.023	3.7	Lowest	0.07	1.04	0.64	-

^d. *All values in mg/l except removal efficiency which is in per cent.

E. CALCULATION OF BOD REMOVAL WITH NITRIFICATION PROCESS

BOD removal with nitrification design was controlled by nitrification rate. The most concerned design parameters in this part are hydraulic and organic loading, sludge retention time, determination of the aeration tank volume, finding out the hydraulic detention time, computing the ratio of food to microorganisms F/M, determination of the nitrogen that can be converted to nitrate, calculating the oxygen demand and air flowrate. The following Table-V shows these parameters and the results of calculations.

Table-V: Results of Calculations of Several Parameters for BOD Removal and Nitrification

Computed Parameters	Result of calculation
Hydraulic Loading/Average Flow	1800 m ³ /d
BOD ₅ Loading Rate	0.24 kg/m ³ .d
Sludge Retention Time	7.14 d
Aeration Tank Volume	557 m ³
Hydraulic Detention Time	7.427 hours
Ratio Food to Microorganisms F/M	0.15 g BOD/g MLVSS.d
Nitrogen Oxidized to Nitrate	22.31 g/m ³
Oxygen Demand	15.63 kg/hour
Air Flowrate	7.92 m ³ /min

F. CALCULATION OF DENITRIFICATION PROCESS

Denitrification process was calculated due the need of nitrate reduction. So, calculation aimed to calculate anoxic zone to convert nitrate-nitrogen to nitrogen gas which eventually will escape into the atmosphere. Many aspects were computed including the food to microorganism ratio F/M, estimation of the nitrate reduction, determination of the anoxic zone volume and finding out the hydraulic detention time. Results of these elements are demonstrated in Table-VI. Since there are not similar parameters in the current operation of Mawar wastewater treatment plant operation to these parameters, these design parameters are not compared to previous values.

Table-VI: Results Calculations of Several Parameters for Anoxic Zone

Computed Parameters	Results of Calculations
Estimation of the Nitrate Reduction	5400 g/d
Determination of the Anoxic Zone Volume	188 m ³
Food to Microorganism Ratio F/M	1.4
Hydraulic Detention Time	2.5 hours

V. CONCLUSION

The following conclusions can be drawn from the experimental works carried out in this reserach.

Monitoring of Mawar wastewater treatment plant indicates that influent concentration of majority of the parameters were in small. Despite that, the removal efficiency of several parameters was not high. That was basically because to the need of proper maintenance activities. Nevertheless,

measured parameters were below the effluent permits.

Concentration of measured parameters in the aeration tank inlet were small. Comparison of Mawar wastewater to the typical composition of untreated domestic sewage indicated that the wastewater in Mawar wastewater treatment plant is classified as weak wastewater.

After Mawar wastewater treatment plant has been upgraded by implementing post- anoxic single sludge system, portion of the nitrogen content removal has been enhanced. The enhancement of nitrogen removal resulted in Mawar wastewater treatment plant led to decrease the removal efficiency of several parameters. Average concentrations of these parameters were found below the regulatory limits but one of them exceeded its limits due the broken clarifiers.

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Micropollutants and Pathogens in Water Research Group which is actively collaborate the research between Faculty of Medicine and Pharmacy.



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