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Optimization of Activated Sludge Process for Enhanced Nitrogen and Phosphorus Removal: Integrating the ASM2d with Floc Model and SRT Control

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Abstract-To reduce energy consumption, and to achieve the desired denitrification, the activated sludge process sometimes needs to operate at low dissolved oxygen concentrations. The ASM2d model describes the activated sludge process during different phases in a sequencing batch reactor. A comprehensive floc model remains lacking despite the widespread study of enhanced biological phosphorus removal. As a result, the integrated system model is developed to understand the impact of floc at low DO concentrations, during biological nitrogen and phosphorus removal. Additionally, optimisation of parameters and effectiveness factors for developing of the ASM2d with floc model could be achieved by controlling sludge retention time (SRT), particularly during the activated sludge process. In a wastewater treatment plant, the dissolved oxygen was controlled at a low concentration, and its dispersion coefficient into the floc is $1.2 \times 10^{-4}\ m^2/day$. This study aims to optimise the activated sludge process, which is critical for efficient wastewater treatment by controlling the SRT and the amount of sludge access. The objective is to predict process behaviour under various operational configurations, based on differing sludge wasting times.

Key words: ASM2d, Floc, SRT, Phosphorus Removal.

I. INTRODUCTION

DO concentrations in the activated sludge process are usually approx. 2 mg/L, to enable organisms to grow at their maximum rate, because half-saturation constant values are intrinsic values. However, this does not take into account diffusion resistance, and DO diffusion within the flocs. Therefore, most of the matters about the concentration in activated sludge systems are perplexing, because the actual concentration of DO in the activated-sludge floc is not represented in the concentrations measured in the bulk liquid.

Despite the availability of all operating conditions, difficulties still exist because the concentration of DO in the bulk is not the same as within the biological floc where oxygen consumption occurs. Thus, to ensure the desired growth process, it is essential to identify the amount of sludge wasted. Controlling the solid retention time (SRT) is one way to achieve this.

Optimising activated sludge access and examining the effect of SRT, in terms of using different times for sludge wastage according to dynamic removal behavior.

The activated sludge process is one of the most extensive biological wastewater treatments, and it has been modified to include different combinations of processes. It has often been instrumental in supporting a considerable expansion in capabilities to remove a variety of elements. Activated sludge models (ASMs) have been successfully used to effect intersections between WWTP plans and modeling controls, and another additional process. ASMs are also responsible for biological processes.

Several factors influence the physiology of sludge factors. Some of these include environmental conditions, operating conditions, and reactor configuration. Regarding these, the activated sludge floc in a bioreactor, normally regarded as the influence of floc, comprises one of the most critical phenomena in the treatment and physiology of a microbial community.

The formation of an activated sludge process requires the establishment of a high concentration of microorganisms (mostly bacteria; but potentially also protozoa and fungi) to eradicate any organic matter from the wastewate. Nitrification and denitrification are the major processes involved in the removal of organic material.

II. ACTIVATED SLUDGE MODEL

While the ASM has successfully effected biological nutrient removal in many wastewater treatment plants, where nitrification and denitrification have occurred at different phases or in aerobic and anoxic tanks respectively, it needs to be enhanced through the incorporation of the floc effect. This will enable denitrification in a single aeration tank in which aerobic and anoxic zones co-exist [1].

In addition, bulk liquid and floc phase reactions occur in the aerator, and metabolic reactions are accompanied by mass transfer within the floc matrix, thereby establishing a concentration gradient inside the floc, which could have a significant effect on system reaction rates [2]. In addition, the microbial flocs that exist in an aerobic reactor are subject to size distribution which can span three to four orders of magnitude [3], affecting both physical and chemical phenomena such as flocculation, substrate transfer, utilisation, and the overall reaction pattern.

The occurrence of both nitrification and denitrification in a sequence batch reactor is termed a simultaneous process. The existence in the reactor, of aerobic and anaerobic zones with low DO concentrations, is contingent on mixing conditions, as well as aeration. Therefore, reduced rates of nitrification and denitrification occur as a result of DO effects. However, the efficiency of nutrient removal can be improved if SRT is sufficient.

Activated Sludge Model no. 2d (ASM2d)

According to Henze et al. (1999), this model is an improved form of the above model and is used principally to explain the biological elimination of excess phosphorus, and nitrogen removal. The links between nitrates and phosphorus in the absence of oxygen are components of this model. ASM2d is a re-modification of ASM2, that involves adding PAOs' denitrifying activity to improve the description of phosphate and nitrate dynamics. PHA is utilised for anoxic poly-P formation and anoxic PAO growth processes. The ASM2 for the growth of PAOs, and poly-P formation in the presence of oxygen, was used in the formulation of these processes. In the absence of oxygen as a terminal electron acceptor, PAOs utilise NO3's reaction with phosphorus [4].

Activated Sludge Floc Process

Activated sludge flocs consist of a combination (see Figure 1) of different bacteria, defunct cells, organic and inorganic components, and extracellular polymeric substances (EPS) [5, 6]. An extensive body of research has focused on modelling the activated sludge process about developing carbonaceous oxidation dynamics, as well as on characterising dissolved oxygen behaviour during the stages of nitrification. Microbial flocs have also been emphasised in many studies [7].

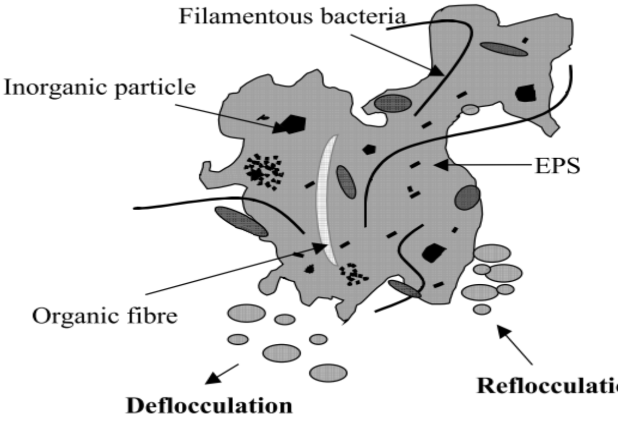

Figure 1: Schematic representation of an activated sludge floc.

In terms of flocculation, the general concept of the aggregation of bacteria in a system of sewage treatment can be said to be essential for biomass separation during liquid waste treatment. Additionally, the best measure is an optical technique involving the appearance of the floc, as well as the clarification of water. At the end of the flocculation, the paddle is disconnected and the floc settlement and condensation capacity are examined. During settling tests, there is sometimes an inaccurate indication of floc behaviour; therefore, this test should be performed using a small amount (1 liter) of liquid for experimental measurement [8].

Moreover, floc sizes differ, which could influence the modelling of the overall reaction [2]. Consequently, it is important to take into account the specifications of the secondary clarifier because of the presence of bulking sludge, with poor settling properties. The floc cannot be compacted effectively, leading to the discharge of floc particles into the clarified effluent [9].

The investigation of the effect of cyclic operation on the allocation and morphology of a floc size at different SRTs has been performed using efficient laboratory-scale SBRs. The results indicated a design for SRT (9-12d) because of transitions in floc properties. This SRT maintains a relatively stable microbial community for effective biomass flocculation [10].

EBPR's most noteworthy drawback pertains to the reversible nature of biological phosphate storage. Organisms break down internal phosphorus content, and then it can be re-released into the environment. The sludge should be handled with extreme caution. It is imperative to limit the sludge retention times (SRT) in the settler, and to provide sufficient oxygen to the aerobic phase and the basin's outlet, to avert the occurrence of anaerobic conditions in the secondary clarifier [11].

As a result of the addition of effectiveness factors to extend ASM2d, the floc model would be built using the kinetics given by the International Association on Water Pollution Research and Control (IAWPRC) task group, to represent the reaction at each point within the floc. The process rate equation is thus modified as shown below:

$$\rho'_4 = \mu_H \cdot \frac{S_{O2}}{K_{HO2} + S_{O2}} \cdot \frac{S_F}{K_F + S_F} \cdot \frac{S_F}{S_F + S_A} \cdot \frac{S_{NH4}}{K_{HNH4} + S_{NH4}} \cdot \frac{S_{PO4}}{K_P + S_{PO4}} \cdot \frac{S_{ALK}}{K_{ALK} + S_{ALK}} . X_H * \rho_F$$

$$\rho'_{11} = q_{PP} \cdot \frac{S_{O2}}{K_{O2} + S_{O2}} \cdot \frac{S_{PO4}}{K_P + S_{PO4}} \cdot \frac{S_{ALK}}{K_{ALK} + S_{ALK}} \cdot \frac{X_{PHA}/X_{PAO}}{K_{PHA} + X_{PHA}/X_{PAO}} \cdot \frac{K_{MAX} - X_{PP}/X_{PAO}}{K_{PP} + K_{MAX} - X_{PP}/X_{PAO}} X_{PAO} * \rho_{PP}$$

$$\rho'_{13} = \mu_{PAO} \cdot \frac{S_{O2}}{K_{O2} + S_{O2}} \cdot \frac{S_{NH4}}{K_{NH4} + S_{NH4}} \cdot \frac{S_{PO4}}{K_P + S_{PO4}} \cdot \frac{S_{ALK}}{K_{ALK} + S_{ALK}} \cdot \frac{X_{PHA}/X_{PAO}}{K_{PHA} + X_{PHA}/X_{PAO}} . X_{PAO} * \rho_{PHA}$$

$$\rho'_{18} = \mu_{AUT} \cdot \frac{S_{O2}}{K_{O2} + S_{O2}} \cdot \frac{S_{NH4}}{K_{NH4} + S_{NH4}} \cdot \frac{S_{PO4}}{K_P + S_{PO4}} \cdot \frac{S_{ALK}}{K_{ALK} + S_{ALK}} . X_{AUT} * \rho_{AUT}$$

Where*:*

$$\rho_F = 0.6264$$
$$\rho_{PP} = 0.7905$$
$$\rho_{PAO} = 0.7392$$
$$\rho_{AUT} = 0.703$$

Effect Of Sludge Retention Time (Srt)

A higher amount of SRT is needed in nitrification than in carbonaceous oxidation, especially if the temperature of the wastewater is low, as this would decelerate the nitrifiers' growth rate. When the nitrifiers' growth rate is slow, a higher SRT is required to assist the nitrification process. To change the SRT the measure of sludge wasted every day should be controlled, and effluent suspended solids (ESS) lost accounted for.

The SRT factor increases the flexibility of operational variations and enables the augmentation of nitrifying bacteria, which is necessary when dealing with peak loadings. As a result, the denitrification process most significant benefit is satisfied with the allocation of the oxygen demand for carbonaceous matter.

To achieve an even better control of SRT, it is imperative to calculate the mixed liquor suspended solids (MLSS) and change the quantity of sludge wasted.

$$\boldsymbol{SRT} = \frac{\boldsymbol{Sludge\ in\ Reactor\ (gVSS)}}{\boldsymbol{Sludge\ waste\ (\frac{g}{day})}} = \frac{\boldsymbol{V_0X}}{\boldsymbol{(Q_WX+Q_EX_E)}}$$

1

Where:

V_0 is the volume of each reactor (*l*).

X is the mixed liquor suspended solid (MLSS) concentration at the end of one cycle (*mg/l*).

Q_W is the amount of sludge wasted per day (*l/day*).

Q_E is the amount of discharged effluent per day from each reactor (*l/day*).

X_E is the effluent suspended solids concentration in treated effluent (*mg/l*).

III. SEQUENCING BATCH REACTOR (SBR)

A sequencing batch reactor (SBR), described simply, is an activated sludge process that facilitates the stages that enable aeration and sludge settlement in one location. The variety of operating stages allows aerobic, anaerobic or anoxic conditions exist, which specifically supports the propagation of desirable microorganisms.

Concerning the economy of airflow, it is better to operate the system under conditions of low DO. However, because the concentration of DO can affect multiple factors, the DO concentration and presence or absence of anoxic conditions are identified as affecting most microorganisms; this, in turn, can impact biomass deposition and efficiency [12]. Consequently, building a controller that can retain the concentration of oxygen at the desired level is an important issue. PID controller has been taken into account for use in the simulated SBR system to retain the desired value of oxygen (1.5-2.0 mg/l).

Figure 2 shows typical sequences with five common steps, which are sequentially designed: fill, react, settle, draw and idle.

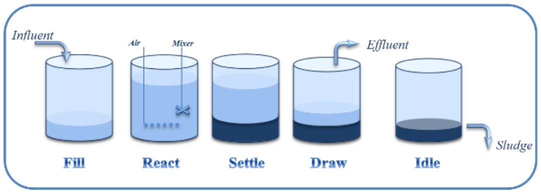

Figure 2: The order of events in the sequencing batch reactor (SBR)

Sludge Wasting In Sbrs

Sludge wasting is an important step in the SBR operation and one that greatly affects performance. Wasting is not included as one of the five basic process steps, because there is no set period within the cycle dedicated to wasting. The amount and frequency of sludge wasting are determined by performance requirements, similar to a conventional continuous-flow system. In an SBR operation, sludge wasting usually occurs during the react phase, so that a uniform discharge of solids (including fine material and large floc particles) occurs. A unique feature of the SBR system is that it removes the need for a return activated sludge (RAS) system.

One hour or less is required to remove any BOD dissolved, because of the batch kinetics of domestic wastewater treatment. This usually leads to a moderately low early concentration of dissolved BOD. The time required for SBR aerobic reactions in nitrification ranges between 1.0 and 3.0 hours. There is no similarity between SRTs, SBR and the process of continuous-flow activated sludge. Similar to SRT, the efficiency of SBR is expected to be higher, because of its batch kinetics. However, biomass is not exposed to aeration for longer periods, thus lowering the effectiveness of the SRT.

The utilisation of substrates, as well as the rate of oxygen demand, reduce with time; this is because the concentration of the substrate changes as time progresses. The design of the aeration system is supposed to reflect the changing rates of oxygen demand.

Reactor operation

The schematic installation of the equipment used in the model experiment is depicted in Figure 5.2. This study was carried out in a SBR reactor, with 30 l, 0.03 m^3volumes, a height diameter of 0.5m and a 0.06m^2 cross area. In terms of reaction input, the plant was operated for 60 days, with three cycles per day; each cycle had seven periods. In addition, the reactor was supplied with wastewater effluent, which had been converted into model vectors (ASM2d). In all simulations, the dissolved oxygen concentration in the bulk was maintained at a constant level of $1.7\ gm^{-3}$ during the aerobic phase. The temperature is $20^{\circ}C$. The initial mixed liquor suspended solids (MLSS) of the activated sludge was 3000gm^{-3}.

After the settling period, about 5 l of supernatant was discharged from the top of the reactor and replaced with 5 l of domestic wastewater during the first and second fills. The amount of substrate withdrawn was 600 ml of excess sludge every cycle, and, this was replaced with 600 ml of domestic wastewater; thereby ensuring a sludge retention time (SRT) of approximately 10 days. This operation enabled a mixed liquor suspended solid (MLSS) concentration of activated sludge of approximately 6000-8000gm^{-3}.

IV. SLUDGE ACCESS OPTIMISATION

The SRT is the time that microorganisms spend on the system. It can also be interpreted as the period available in which microorganisms can reproduce, and the sludge age. Every organism has its own regeneration time, which is dependent on numerous factors. If the SRT exceeds the regeneration time for a specific organism, that organism proliferates. If the reverse is the case, the organism will be washed from the system.

Sludge retention time SRT

Optimisation of the process could be achieved by controlling the SRT, especially during the activated sludge process, which tends to be essential to facilitate wastewater treatment. The SRT determines the rate of growth of microorganisms in the activated sludge process.

In addition, controlling the SRT permits a simple and real-time calculation to adjust the wasting flow rates, to maintain a target SRT and stability in a microbial population. In situations where there is no control, or where the control is poor, the mixed liquor constitutes a group of microorganisms not optimised for the prevailing growth conditions.

SBR control

Sludge recirculation, dissolved oxygen (DO) and sludge wasting are operating parameters that are controllable in different circumstances. The DO concentration is controlled in the aerobic zone with the simulation. Whereas, SRT depends on MLSS in the aerobic zone. Sludge wasting normally happens after the settlement stage, due to the MLSS having been reached to assure a maximum concentration of solids. This wastage can take place every cycle, which is daily or even weekly.

Currently, automation of the DO control has generated immense debate, due to the amount of energy required to integrate automation. Nevertheless, SRT that is controlled via sludge wasting emerges as the most crucial parameter of the design and operation in terms of influencing the performance, as exhibited by the activated sludge systems [9].

In the SBR reactor, the resulting value when dividing the mass of solids during the aeration stage by the mass of the wasted solids (no sludge return) represents the sludge retention time SRT. Solid mass could be determined by multiplying tank volume by mixed liquor concentration TSS under aerobic. Also, the wastage of solid mass could be determined by multiplying the flow of wasted sludge with the mixed liquor concentration TSS of the wasted sludge.

$$\boldsymbol{SRT(day)} = \frac{\boldsymbol{Mass\ of\ solids\ in\ Reactor\ (gTSS)}}{\boldsymbol{Mass\ of\ wasted\ solids\ \ (\frac{gTSS}{day})}}$$

2

It is possible to control the SRT, in the case of granular sludge SBR, through daily sludge discharge. For instance, for a 10-day SRT to be maintained, a tenth of the reactor sludge ought to be discharged daily. Notably, a short SRT tends to favour the development of PAOs. Whereas, maintenance of an SRT exceeding 10 days ought to be done to facilitate complete nitrification [13].

Impact of SRT

Generally, a higher SRT is associated with greater biodiversity. Whereas, the risk of an SRT that is too low lies in that it might not support particular functions. This is especially critical in the case of nitrification, as it is the only pragmatic mechanism for removing ammonia. Additionally, denitrification would not occur if there was no nitrification. Whereas, an SRT that is too high would raise the operating costs while reducing the system's treatment capacity. Achievement of optimum settling would depend on the prevalence and diversity of microorganisms. In the case of SRT that is too low, organisms would predominate, while pin floc would occur in cases where SRT is too high.

V. RESULTS AND DISCUSSION

The impact of access time on the biological removal of phosphorus and nitrogen will be examined, taking into account the time required to access the sludge, which indicates that sludge access will be achieved every cycle (every day and every two days). Concerning evaluation, nutrient removal is evaluated in terms of the percentage at which efficiency is attained. This efficiency regularised the data with the effluent concentration. Tables 1 and 2 present the percentage efficiency of ammonia and phosphor removal at different SRTs, about several sludge access stages.

Table 1: Ammonia removal efficiency

Sludge taken	**Every cycle**			**Every day**			**Every 2 days**		
	1-20	21-40	41-60	1-20	21-40	41-60	1-20	21-40	41-60
EX Data	60.01	94.82	98.00	60.01	94.82	98.00	60.01	94.82	98.00
SRT 11d	59.32	92.57	90.89	83.36	77.17	74.28	85.25	85.87	89.27
SRT 9d	61.77	92.54	96.34	72.56	99.10	97.93	73.59	87.16	83.36
SRT 7d	46.41	72.62	93.76	65.68	86.61	98.05	70.46	64.63	87.63
SRT 5d	24.74	2.04	-2.89	68.26	86.84	40.78	69.69	59.17	44.57

Table 1: Phosphors removal efficiency

Sludge taken	**Every cycle**			**Every day**			**Every 2 days**		
	1-20	21-40	41-60	1-20	21-40	41-60	1-20	21-40	41-60
EX Data	6.01	5.01	78.38	6.01	5.01	78.38	6.01	5.01	78.38
SRT 11d	52.01	52.13	42.60	56.14	60.92	64.80	51.00	71.25	34.52

SRT 9d	35.04	37.64	42.60	33.43	45.09	49.69	52.95	47.41	34.52
SRT 7d	40.75	68.54	66.07	70.77	78.30	66.13	70.56	75.52	39.62
SRT 5d	30.17	9.29	51.34	69.12	81.30	90.98	54.43	69.26	72.14

Sludge access every cycle

In the case of Figures 1 and 2, a comparison of nutrient removal was conducted for different wastewater plants, and the average percentage of ammonia removal (in the hydrogen form) was found to stand at 90.98, 96.34 and 93.76 percent for SRT 11 days, 9 days and 7 days respectively. During the first 20 days, it stood at 59.32, 61.77 and 46.41 percent. These percentages illustrate that SRT affected the N removal.

On the other hand, when SRT is low (5 days) the ammonia conversion process for nitrogen is absent and does not take place during the treatment. This is because the time is not sufficient for the growth of the bacteria which led to an increase in ammonia concentrations. When it comes to the anaerobic and aerobic phosphorous removal process, the release of phosphate S_{PO4} took place in the anaerobic phase. The process of phosphate S_{PO4} release and uptake is a strong determinant of removal efficiency. The percentage in Figure 3 shows that concentrations of P-effluent differed for various SRTs.

The SRTs resulted in phosphorous removal efficiencies in the range of 40.75, 68.54 and 66.07 percent during the first, second and final 20 days at SRT=7d. This indicated that there was an improvement in terms of phosphorous removal. Whereas, there was a slight decrease in efficiencies at SRT=9d.

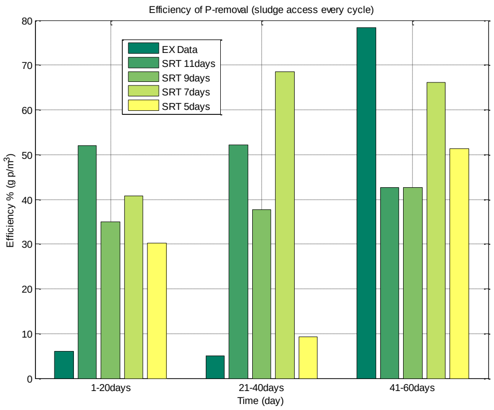

Figure 3: Efficiency of phosphors removal (sludge wasted every cycle)

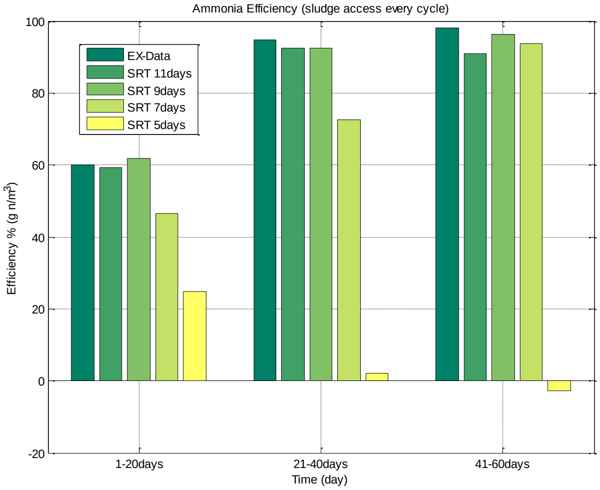

Figure 4: Efficiency of ammonia removal (sludge wasted every cycle)

Figure 5 illustrates the MLSS in instances where there were different sludge levels. It can be noted that the MLSS is low (about $2000\ mg\ TSS/m^3$) at SRT=5d, because the amount of sludge wasted was high. However, the MLSS is $(4000-6500\ mg\ TSS/m^3)$ when the volume of sludge access decreased, as a result of SRT being in the range 7-11d.

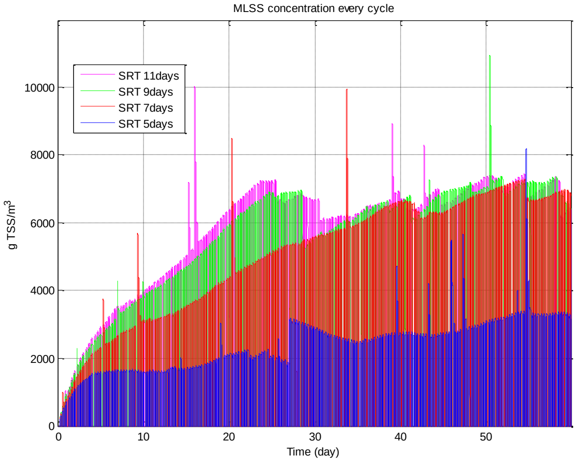

Figure 5: MLSS concentration (sludge wasted every cycle)

Sludge access every day

Figure 6 exhibits an increase in phosphate removal efficiency between day 10 and day 60, resulting in 33.43 and 56.14 percent removal in the initial 20 days, 45.09 and 60.92 percent in the following 20 days, while 49.69 and 64.8 percent removal took place in the final 20 days when increasing SRT from 9d to11d. These phosphate uptakes and the polyphosphate storage are likely to result from PAOs. These results could be caused by the fact that the phosphate is released only in completely anaerobic conditions, while the uptake of phosphate in bulk liquid only occurs in aerobic conditions.

As evident in Figure 5, the efficiency of phosphorous removal stood at 90.98 percent, and the SRT was 5d. However, the efficiency of nitrogen removal fell to 40.78 percent from 86.84 percent for the same amount of sludge access (Figure 6).

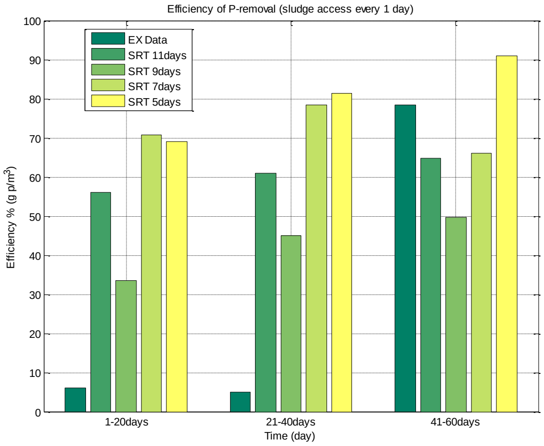

Figure 6: Efficiency of phosphor removal (sludge wasted every day)

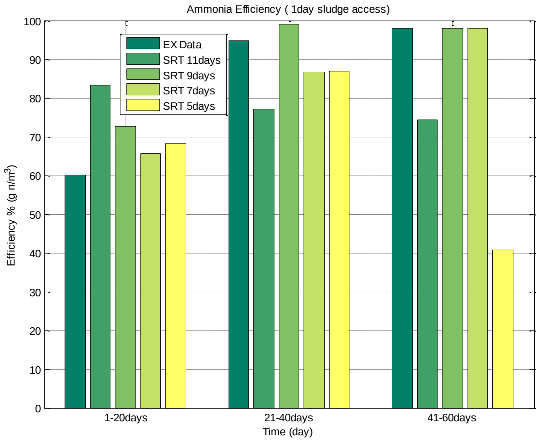

Figure 7: Efficiency of ammonia removal (sludge wasted every day)

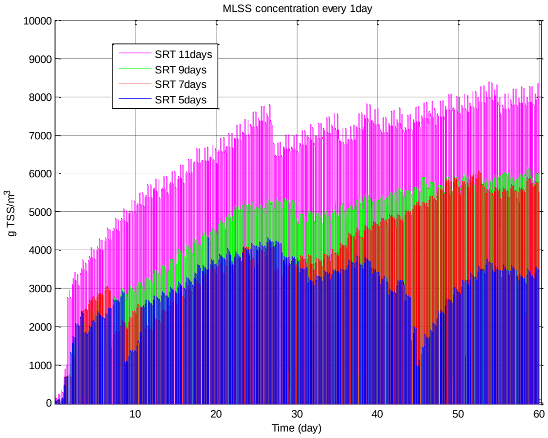

Figure 8: MLSS concentration (sludge wasted every cycle)

Sludge access every 2 days

In the case of Figure 8, SBR is shown to exhibit a low P-removal performance as it decreased as SRT increased (7-11d). However, ammonia concentration efficiency showed a low NH4-N removal performance as it was recorded, decreasing from 69.69 to 44.75 percent at (SRT=5d). It was suggested that the exhibition of such low removal efficiencies, as in the case of NH4-N, could be attributed to the length of sludge access being inadequate to accommodate nitrifiers' growth [13]. Consequently, withdrawing the same volume of sludge as that wasted every 2 days would be inappropriate, unless it has been subjected to SRT control. This is likely to be difficult. Nonetheless, the alternative is that there is a likelihood that there will be a small amount remaining at the end of the various cycles, raising the amount withdrawn at the end of each day.

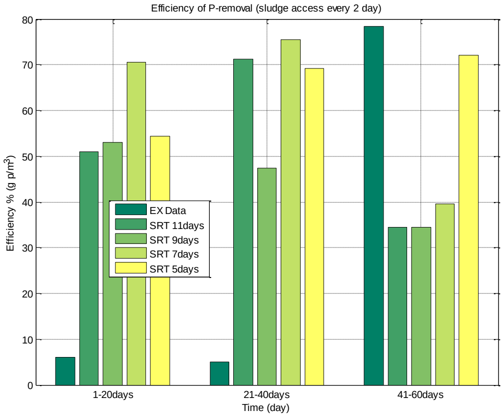

Figure 9: Efficiency of phosphor removal (sludge wasted every day)

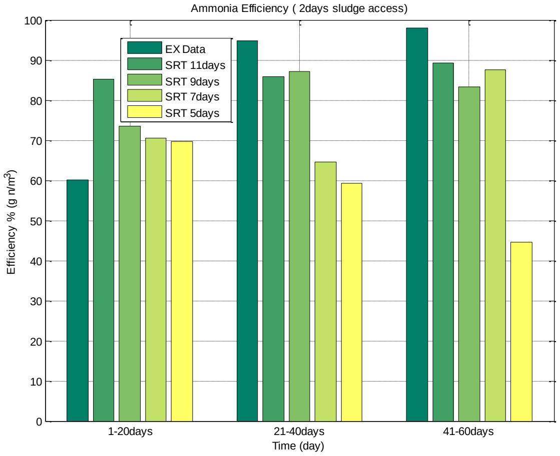

Figure 10: Efficiency of ammonia removal (sludge wasted every day)

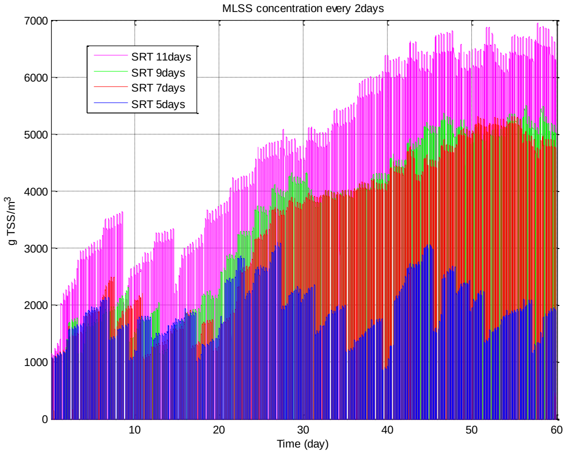

Figure 11: MLSS concentration (sludge wasted every cycle)

Figures 6, 7, 9 and 10 show that it can be deduced that wasting the sludge amount in a 1 day case was beneficial, as it raised the efficiency of P removal compared to the case of 2 days.

To obtain phosphorus-rich biomass from the biofilm system, back-washing of filters must take place when the level of internally stored phosphorus in the bacteria is elevated. Limited net phosphorus removal is achieved due to limited sludge wasting; frequent wasting may disrupt system performance [14].

The role that SRT plays in the determination of the dewatering characteristics of activated sludge was examined at different levels of activated sludge access. It was found that SRT plays a crucial role in determining the sludge dewatering rates.

SRT can be taken as less than 11 days in the case of more reliable and effective systems. It can be concluded that simulations, where SRT is between 7 and 9 days are the only ones meeting the requirement for sludge access each cycle; however, the system was slightly flexible when sludge was taken at the end of the day.

The growth of nitrifiers was controlled at a short SRT and nitrite existed in the SBR effluent. There was an increase in SS concentrations relative to increasing SRTs, while there was a decrease in excess sludge production with increasing endogenous decay with high SRTs. The minimum effluent concentration of soluble microbial products was obtained at an SRT of 5 days.

VI. CONCLUSION

Achieving optimal phosphorous and nitrogen removal from nutrient-rich industrial wastewater biological is possible, by using the activated sludge, operated under alternating anaerobic and aerobic conditions. The floc factors are likely to play a role in facilitating the nitrification, the denitrification, and the phosphorous removal processes as observed.

The comparative behaviours of the biological phosphors removal between the benchmark model ASM2d and the floc model in the SBR reactor revealed the results of floc model are in stronger agreement with the theoretical and experimental data than the ASM2d model.

Essentially, the design and operation of biological systems should not be based on SRT values exceeding the need for the overall treatment of organic N and P removal. As a result, SRT needs to be a manipulating parameter, when it comes to the optimisation of the biological process.

SRT is an important factor in activated sludge optimisation. The selection of SRT is accompanied by numerous consequences associated with sludge production and process performance. The conventional mechanism of SRT control could involve the manual adjustment of the sludge-wasting rate, based on the concentration of the MLSS. However, taking MLSS measurements and analysing the manual sample for MLSS should be undertaken experimentally, to calculate the sludge volume wasted for SRT control.

The results reveal that phosphorous removal efficiency decreased with the rising SRT, because of the reduced rate of biomass yield. Whereas, phosphorous removal efficiency could increase under a longer SRT because the decay in PAOs was lower than the decay for the remainder of the microorganisms.

A long SRT would be necessary to maintain a specific level of nitrifies while ensuring that the nitrification would be effective. Nevertheless, a long SRT has been associated with increased phosphorous removal efficiency, because of the low rate of sludge wastage, and the likelihood of phosphorous being released in the reactor.

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