Effect of Aeration Rates on Removals of Organic Carbon and Nitrogen in Small Onsite Wastewater Treatment System (*Johkasou*)

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Abstract. Onsite application of oxygen supply in domestic wastewater system may be influenced by several factors that can inhibit the oxidation and nitrification processes. In this study, the influence of aeration rate on the *Johkasou* performance was focused using two *Johkasou* facilities serving up to five persons household. In the *Johkasou* A (JO-A) system, we increased the aeration rate from 30 to 63 L.min^{-1} whereas, in the *Johkasou* B (JO-B), it was decreased from 59 to 34 L.min^{-1}. Water and sludge samples were collected from the anaerobic-anoxic-oxic zones before and after adjustment of the aeration rate measured for organic matters and nitrogen parameters. Increasing the aeration rate in JO-A resulted in a high removal of organic matter (82.5%) and nitrogen (60.3%) compared to decreasing of aeration rate in JO-B (52.0% and 33.0%, respectively). Simultaneous nitrification and denitrification (SND) exhibited a maximum percentage when the aeration rate was increased compared to decreasing of aeration rate. These results indicate that application of a high aeration rate increases removal of organic matter and nitrogen and enhances ammonia transformation. It is therefore recommended to apply high aeration rates in Johkasou system.

1 Introduction

Small-scale onsite domestic wastewater treatment systems named *Johkasou* have been widely used in Japan`s rural areas and are still developing the performance. *Johkasou* systems treat for both black and gray waters from household wastewater. The effluent of *Johkasou*s is generally discharged into a local environmental receiving body, which the biochemical oxygen demand (BOD) and total nitrogen (TN) should be less than 20 m/L [1]. *Johkasou* system is considered to be an effective means for wastewater treatment in rural areas, which are designed, located and maintained satisfactorily. *Johkasou* system consists of an anaerobic stage as a primary treatment unit (a primary settling tank) and a secondary anaerobic (anoxic) stage that both are equipped filter bed. And the aerobic (oxic) stage is a biological treatment unit typically like; activated sludge process, aerobic submerged biofilter, fluidized bed reactor, or biofilm filtration reactor. A disinfection chamber is also installed at end of the process to inactivate microorganisms and fecal indicator bacteria in the effluent before disposing to the environment.

During the last decade, biological nitrogen removal (BNR) has been promisingly method used both in domestic and industrial wastewater treatment [2]. A biological system is mostly eliminated the nitrogen compounds through combination processes of nitrification and denitrification. This system consists of two successive steps: 1) autotrophic nitrification in which NH_4^+-N is oxidized to nitrite (NO_2^--N) and then nitrate (NO_3^--N) under aerobic condition; and 2) heterotrophic denitrification in which NO_3^--N is reduced to nitrogen gas (N_2) by heterotrophic denitrifiers under anoxic conditions with organic carbon as the electron donor [3].

Several studies reported the factors that inhibited nitrification-denitrification in biological system. These factors included higher free ammonia [4]–[6], hydraulic retention time (HRT) [7], [8], dissolve oxygen (DO) concentration and inhibitor [9]. However, the efficiency of biological nitrogen removal can be improved by maintaining and monitoring the ORP, pH and DO in the nitrification-denitrification process [10]. Peng *et al.*[11] conducted the real-time aeration control using pH and DO in sequence batch reactor, and found that the end of nitrification could be identified by the binding the point in pH and increased in DO profile.

Recently, studies of BNR process mainly used DO as a limiting factor to achieve the nitrification and

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denitrification [7], [11], [12]. Dissolved oxygen is also economically feasible control the parameters particularly at low concentration that can save the aeration consumption, while in some cases the efficiency of BNR can be achieved at high DO concentration. Therefore, there is no definitive explanation regarding an appropriate DO concentration to achieve complete nitrification. Guo *et al*. [7] conducted the partial nitrification by comparing the high and low DO concentration (2.5 and 0.5 mg/L, respectively) on long-term aeration time. The complete nitrification was reached at both conditions, which corresponded increase nitrite concentration and kept constant or nearly negligible the nitrate concentration. Under limited oxygen condition, Jianglong and Ning [13] reported that significantly higher ammonia oxidation rate was reached when increased the DO concentration from 0.5 to 1.5 mg/L. Another study found that temporal nitrite accumulation was obtained at medium of DO at 1.7 mg/L, however, the excess of DO concentration had no influence on nitrite accumulation, while at low DO concentration decreased the nitrite accumulation and ammonia consumption [14].

The successful of DO concentration in BNR process can also be measured by simultaneous nitrification and denitrification. The efficiency of SND mainly occurs as consequence of DO concentration gradients within microbial flocs of biofilms due to diffusional limitation. This indicates the appropriate application of DO for degrading organic matter and producing less sludge. In batch scale reactor, many researchers pointed that high efficiency of SND was achieved during low DO concentration [7], [15], [16], which remained organic compounds used by denitrifying bacteria. Contrary, Zhu *et al*. [8] noted that the SND could be obtained even at high DO concentration under variances of alkalinity concentration.

The studies on nutrient and organic removal using biological system were mostly conducted in a batch reactor that is easy to control and less complexity in the system. The application of BNR in the real system or in-situ study faces many factors such as air supply clogging, low oxygen availability and out of usage of a blower. These factors may reduce the aeration rate and then decrease organic and nutrient removal in wastewater treatment system. It will result in poor effluent quality discharged to the local water and can deteriorate downstream water environment. Moreover, little research was conducted in *Johkasou* system to study the effect of aeration rate and there is no authentic regulation on setting the aeration rate by third parties. Therefore, the objective of this study was to know the effect of aeration rate in the biological process involved in the removal of organic and nitrogen in *Johkasou* system during onsite research and to find the appropriate aeration rate that can apply in this system.

2. Material and methods

2.1 Description of *Johkasou* system

We studied the effect of aeration rate in two *Johkasou* facilities. The experiments were carried out in two installed *Johkasou* facilities (CE-5, Fuji clean, Japan) used up to five family members (**Fig. 1**). *Johkasou* system is a household-size unit with a capacity of 1-2 m^3 per day. It composes of a primary treatment unit consisting of an anaerobic settling tank as sludge store and a down-flow anaerobic filter packed media as an anoxic process, the aerobic reactor coupled with a fixed filtration bed, and then a final settling tank and a disinfection chamber [1]. The filter packed media in the anaerobic zone and the fixed filtration bed in the oxic zone is made of polystyrene material. A blower was utilized to provide the air for sufficient gas-liquid mixing in aerobic treatment. Adjustable opening valves in the aeration tank were used to control the air supply and recirculate the settled sludge from the bottom of the aeration tank to the anaerobic settling tank. The maintenance of the system is generally conducted once in four months, while the cleaning and sludge dragged are scheduled once a year.
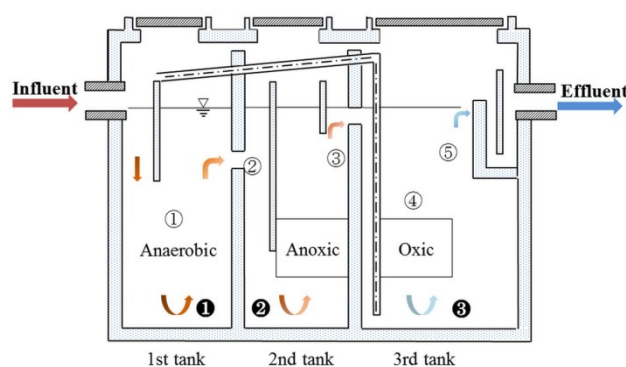

Fig. 1. Structure of *Johkasou* used in the study and sampling points. Open numbers from 1 to 5 are water sampling in each zone; influent in the anaerobic, effluents of anaerobic and anoxic, oxic and settling tank, respectively. Bold numbers from 1 to 3 indicate sludge samplings in each zone.

2.2 Experimental operation and sampling

The two *Johkasou* systems, *Johkasou* A (JO-A) and *Johkasou* B (JO-B), were operated under different aeration supplies. The JO-A was utilized at high aeration rate, which an initial rate was 30 L/min started from October 15th, 2015. After two weeks of operation and collecting sample prior adjustment, the aeration rate was increased to 63 L/min and then maintained till end of the operation (December 17, 2015). We assumed that the steady state of the system in JO-A was achieved within two weeks after increasing aeration and the sample collections were started on this date and continued for bi-weekly sampling. The total operation time of JO-A was 71 days and mean influent loading was 0.58 m^3/d.

The JO-B was operated as low aeration rate with an initial rate of 59 L/min started from September 1st, 2015. After ten days operation and collecting samples prior

Table 1. Initial influent characteristics in both *Johkasou*.

	Influent flow rate	A_r [a] before adjustment	A_r After adjustment	BOD	DOC	TN	TP	NH_4^+-N
	(m³/d)	(L/min)	(L/min)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Increase aeration (JO-A)	0.52 ± 0.08	30	63	258.0 ± 21.7	65.4 ± 24.0	50.2 ± 4.1	5.9 ± 0.4	38.4 ± 2.9
Decrease aeration (JO-B)	0.38 ± 0.06	59	34	225.0 ± 54.5	40.0 ± 12.4	51.8 ± 8.3	5.0 ± 0.9	38.0 ± 8.8

[a] A_r indicates aeration rate

Values are mean ± standard deviation.

adjustment, the aeration rate was decreased to 34 L/min and maintained up to end of the operation (November 5th, 2015). We assumed that the steady state of the system in JO-B was achieved within a month operation after decreasing the aeration and then the samples were collected and continued for bi-weekly samplings here after. The total operation time of JO-B was 63 days and the mean influent loading was 0.38 m³/d.

2.3 Wastewater and sludge characteristics

Each of *Johkasou* system received continuous influent (black and gray waters) from single house. The influent characteristics of both *Johkasou* systems were described in **Table 1**. During the operation, there was no sludge recycled either before or after adjustment of aeration. The mixed-liquor suspended solid (MLSS) and mixed-liquor volatile suspended solid (MLVSS) of sludge were measured and the result is displayed in **Table 2**.

2.4 Sample collection and analytical methods

We collected water samples from several sampling points in order to study the differences of effluent quality for each stage before and after adjustment of aeration rate. Water samples were obtained from the influent of anaerobic zone, effluents from anaerobic, anoxic and oxic zone, and settling zone. From each sampling points, water samples were taken once before adjustment as initial condition and bi-weekly after it. And, we also grabbed sludge samples at the bottom of each zone. The samples of water and sludge phases were transferred into one litter polystyrene plastic bottle and stored in a cooling box before transporting to the laboratory. Then, the samples were analyzed soon on the same day for organic matter and nutrients.

We measured the physico-chemical parameters to identify the basic effluent quality at each zone. The physical parameters such as oxidation reduction potential (ORP), pH, DO, and water temperature (T_w) were measured onsite once a week. The measurements of ORP, pH, DO, and Tw were done using the corresponding portable probe meters (DKK-TOA, Tokyo, Japan). The organic matter and nutrients constituents including biochemical oxygen demand for 5 days at 25ºC (BOD), dissolved organic carbon (DOC), turbidity, suspended solid (SS), volatile suspended solid (VSS), total nitrogen (TN), total phosphorous (TP), ammonia-N

(NH_4^+-N), nitrite-N (NO_2^--N) and nitrate-N (NO_3^--N) in the water samples; and MLSS, MLVSS and sludge volume index (SVI) in the sludge samples were analyzed according to standard methods [17].

2.5 Statistical analyses

Statistical analysis was calculated to find the differences among means and influence of aeration rates on the wastewater quality variables. One-way ANOVA with Post-Hoc Honest tests, Tukey HSD was used to obtain the variance data between the *Johkasou* systems.

3. Results and discussion

3.1 Physical parameters

The mean values of physical parameters at each zone are displayed in **Table 2**. The ORP values showed the difference before and after adjustment of aeration rate for both JO-A and JO-B. At anoxic and oxic zones, the mean of ORP ranged from -110.0 to -250.5 mV before adjustment and from -24.1 to 93.4 mV after adjustment for JO-A, and from 102 to 116 mV before adjustment and from -101.4 to 49.5 mV after adjustment for JO-B. These results implied that the ORP increased by increasing oxygen supply and dropped when the oxygen supply was shortened. The pH in both *Johkasou*s (ranged from 6.7 to 7) was sufficient for nitrification (pH > 6.5) and demonstrated a slight drop during nitrifying aeration phase as according to Canziani et al. [18]. The water temperature was similar before and after adjustment of aeration rate for both JO-A and JO-B, which indicated that seasonal effect was not the main factor reflecting the water temperature.

Difference concentrations in DO were recognized between before and after adjustment of aeration rate. In the anaerobic stage, concentration of DO was recorded at zero and ORP was lower than -250 mV for both *Johkasou*s. In the anoxic zone, significance in DO concentrations was showed after adjustment of aeration rate. It increased from 0.2 to 2.7 mg/L after increasing DO for JO-A and decreased from 5.1 to 0.9 mg/L after decreasing DO for JO-B, which indicated that the limited oxygen supply could be transferred from the oxic zone through upflow system. High DO concentrations in the anoxic zone might be caused the excess oxygen supply in the oxic zone whereas the mean values of ORP were -

Table 2. Parameter indexes measured in this study.

	Before adjustment					After adjustment				
	Inffluent	1st Stage Anaerobic	2nd Stage Anaerobic	Aerobic	Settling	Inffluent	1st Stage Anaerobic	2nd Stage Anaerobic	Aerobic	Settling
Increasing aeration (JO-A)										
ORP (mV)	-250.5 (2)	-	-236 (2)	-110.5 (2)	-250.5 (2)	-249.1 ± 24.0 (8)	-	-24.1 ± 50.3 (8)	93.4 ± 25.1 (8)	44.3 ± 63.6 (8)
pH	6.1 (2)	6.2 (2)	7.3 (2)	7.3 (2)	7.2 (2)	6.2 ± 0.1 (8)	6.2 ± 0.1 (8)	6.7 ± 0.2 (8)	6.7 ± 0.3 (8)	6.6 ± 0.2 (8)
DO (mg/L)	0 (2)	0 (2)	0.2 (2)	1 (2)	0 (2)	0 ± 0.0 (8)	0 ± 0.0 (8)	2.7 ± 0.9 (8)	5 ± 0.9 (8)	1 ± 0.7 (8)
Tw (°C)	24.6 (2)	-	24.6 (2)	-	24.3 (2)	24.0 ± 1.8 (8)	-	21.3 ± 1.8 (8)	-	21.0 ± 2.0 (8)
Turbidity (NTU)	55 (1)	80 (1)	23 (1)	23 (1)	21 (1)	113.3 ± 15.1 (4)	117.8 ± 166.7 (4)	9.1 ± 2.7 (4)	4.5 ± 0.3 (4)	3.9 ± 1.0 (4)
TSS (mg/L)	63 (1)	97 (1)	12 (1)	13 (1)	14 (1)	67.0 ± 12.5 (4)	78.5 ± 21.3 (4)	12.6 ± 4.6 (4)	9.6 ± 3.1 (4)	5.1 ± 34 (4)
VSS (mg/L)	57 (1)	95 (1)	9.4 (1)	11 (1)	13 (1)	58.8 ± 12.8 (4)	70.0 ± 19.1 (4)	11.5 ± 4.7 (4)	8.2 ± 2.4 (4)	4.1 ± 2.2 (4)
MLSS (mg/L)	16,435	–	11,173	4,028	4,000	16,690.0 ± 7322.4	–	9,745.6 ± 725.5	4,337.8 ± 408.3	5,275.6 ± 2,386.4
MLVSS (mg/L)	16,310	–	10,283	3,970	3,928	15,910.0 ± 7087.4	–	8,966.3 ± 831.0	4,174.4 ± 459.2	4,960.0 ± 2,066.1
Deacreasing aeration (JO-B)										
ORP (mV)	-343 (2)	-	104.5 (2)	116 (2)	102 (2)	-265.0 ± 104.3 (8)	-	-101.4 ± 75.5 (8)	49.5 ± 40.1 (8)	- 97.4 ± 147.8 (8)
pH	6.7 (2)	6.7 (2)	6.5 (2)	6.4 (2)	6.5 (2)	6.3 ± 0.3 (8)	6.5 ± 0.2 (8)	7.1 ± 0.2 (8)	7.1 ± 0.2 (8)	7.0 ± 0.2 (8)
DO (mg/L)	0 (2)	0 (2)	5.1 (2)	7 (2)	2.8 (2)	0.0 ± 0.0 (8)	0.0 ± 0.0 (8)	0.9 ± 0.8 (8)	2.3 ± 0.8 (8)	0.1 ± 0.2 (8)
Tw (°C)	26 (2)	-	26.0 (2)	-	26.0 (2)	23.2 ± 1.6 (8)	-	23.3 ± 1.9 (8)	-	22.8 ± 1.6 (8)
Turbidity (NTU)	34 (1)	35 (1)	6.9 (1)	6 (1)	6.9 (1)	63.7 ± 18.9 (3)	66.7 ± 14.6 (3)	13.2 ± 6 .0 (3)	7.2 ± 0.6 (3)	5.7 ± 1.2 (3)
TSS (mg/L)	40 (1)	18 (1)	9.4 (1)	12 (1)	9 (1)	60.3 ± 23.4 (3)	70.0 ± 27.9 (3)	21.0 ± 1.0 (3)	19.0 ± 3.6 (3)	13.0 ± 2.0 (3)
VSS (mg/L)	36 (1)	16 (1)	7.5 (1)	10 (1)	8.5 (1)	55.7 ± 25.7 (3)	63.0 ± 21.7 (3)	18.3 ± 0.6 (3)	15.7 ± 3.5 (3)	10.8 ± 2.9 (3)
MLSS (mg/L)	20,740	–	10,130	5,750	2,685	14,467.5 ± 5203.6	–	8,266.3 ± 2,198.1	5,697.1 ± 715.5	3,603.8 ± 2,174.5
MLVSS (mg/L)	19,970	–	9,705	5,573	2,400	13,442.5 ± 5568.9	–	7,595.0 ± 2,186.7	5,295.0 ± 881.9	3,280.0 ± 2,153.4

Values before adjustment are means/raw data and parentheses indicate number of samples.
Values after adjustment are mean ± standard deviation and parentheses indicate number of samples.

24.5 mV and -101.4 mV for JO-A and JO-B respectively, which these zones indicated as the facultative aerobic state. In the oxic zone, the mean concentrations of DO were 5 and 2.3 mg/L for JO-A and JO-B, respectively, and the mean ORP was +49.5 and +93.4 mV for JO-A and JO-B, respectively, which indicated both *Johkasou* were well supplied with oxygen (**Table 2**).

3.2 Suspended solid and biomass properties

The concentrations of TSS and VSS in water samples are shown in **Table. 2**. Concentration of TSS and VSS before adjustment for JO-A and JO-B showed similar values in the anoxic and oxic zones. After adjustment, however, concentrations of TSS and VSS were nearly two times lower in the JO-A then in the JO-B. The ratio of VSS/TSS in JO-A turned into less than JO-B with a value from 85.0 to 87.5 % and 82.7 to 91%, respectively. These results indicated that increasing of aeration rate could increase conversion of ammonia and other soluble organic into biomass.

Initial concentrations of MLSS and MLVSS in the JO-A and JO-B were operated in different sludge concentrations; whereas, in the oxic zone, concentrations of MLSS and MLVSS pointed a slightly lower at high aeration rate rather than low aeration rate (**Table 2**). These results were found at same circumstance after adjustment of aeration rates. This indicated that high aeration rate could be an important factor to degrade organic carbon and increase the number of biomass. The ratios of MLVSS/MLSS for the whole operating condition were 91.6% and 94.4% respectively in JO-A and JO-B, represented a high proportion of biomass in the sludge.

3.3 Removal of organic carbon and nitrogen by increasing aeration rate in JO-A

Concentrations of organic compound and nutrient in JO-A before and after adjustment of aeration rate are shown in **Fig. 2**. The removals of DOC and BOD were used as representative of a part of total organic matter and biodegradable organic matter, respectively. Removal percentages of BOD and DOC after adjustment of aeration rate were not significantly different.

Increasing DO concentration showed an improvement of organic carbon removal in the *Johkasou* system. When the aeration rate increased from 30 to 63 L/min, the DO concentration lifted from 0.19 to 2.7 mg/L and from 1 to 5 mg/L in the anoxic and the oxic zones, respectively. Before adjustment, at low aeration rate (30 L/min), total removals of BOD and COD were 81.7% and 40%, respectively. However, total removals of organic carbon increased sharply onto 98.1% and 91.1% for BOD and DOC, respectively, when the aeration rate was increased into 63 L/min. Proportions of organic carbon removal were detected mainly occur in the anoxic zone. This indicated that high DO improved organic carbon oxidation in the anoxic zone and remained organic carbon was utilized by autotrophic bacteria in nitrification process in the oxic zone. Effect of increasing DO on improvement of organic removal was also reported by several studies [16], [19]–[22].

Concentrations of TN and NH_4^+-N in JO-A before and after adjustment aeration rate are displayed in the **Fig. 2b**. Before adjustment of aeration rate, at low DO of 0.19 L/min, removals of TN and NH_4^+-N could not be found in both the anoxic and the oxic zones. It reveals that the operation of *Johkasou* at low DO is inappropriate for nitrifier bacteria to produce nitrite and nitrate from oxidized ammonia as shown in **Fig. 4**.
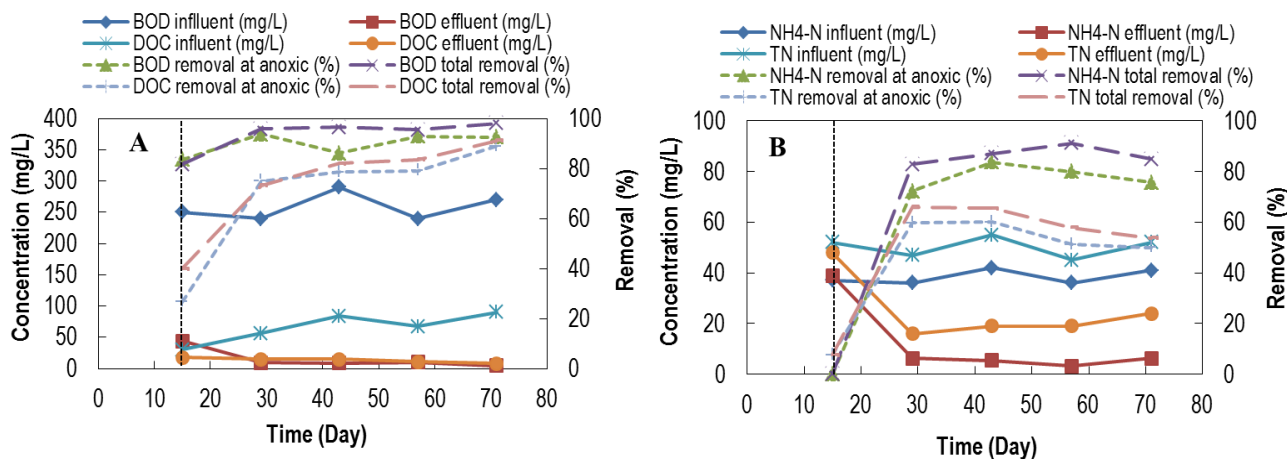
Fig. 2. Concentrations of a) organic carbon and b) nitrogen in JO-A during operation. Concentrations at dash line indicate the operation before adjustment with an aeration rate of 30 L/min and then, the aeration rate was increased to 63 L/min (after adjustment).
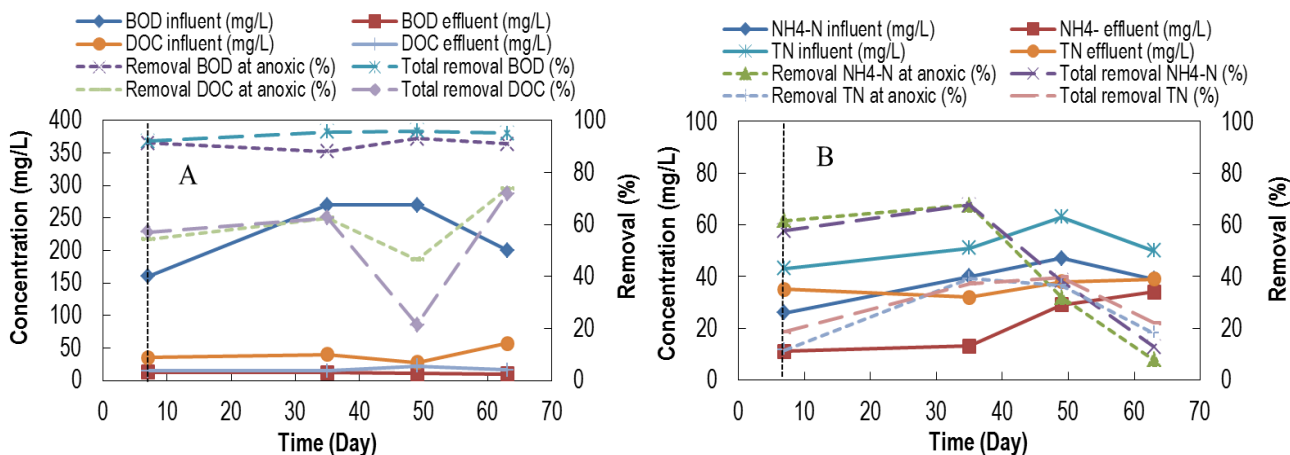

Fig. 3. Concentrations of organic matter and nitrogen in JO-B during operations. Concentrations at dash line indicate the operation condition before adjustment with an aeration rate of 59 L/min and then, the aeration rate was decreased to 34 L/min (after adjustment).

Conversely, TN and NH_4^+-N removals increased sharply when DO was increased to be 2.7 mg/L in the anoxic zone and the removals of these compound ranged from 50 to 60 % and from 72 to 83 %, respectively. The excess DO in the oxic zone could only remove the TN up to 65% while NH_4^+-N removal reached to 91%, respectively. These results indicate that high DO is an appropriate condition for *Johkasou* system to oxidize TN and transform the ammonia into NO_2^--N and NO_3^+-N forms.

3.4 Removal of organic carbon and nitrogen by decreasing aeration rate in JO-B

Concentrations of organic carbon and nitrogen during low aeration condition in the JO-B system are displayed in **Fig. 3**. The removals of BOD and DOC were statistically not difference between before and after adjustment. Before adjustment with a high aeration rate

(59 L/min), DO concentration in the anoxic and oxic zones was in very rich condition on the level of 6.1 mg/L and 7.5 mg/L, respectively. At this condition, BOD and DOC removal could be obtained with mean percentages of 95.5% and 71.9%, respectively, and most removals of these organic carbon occurred in the anoxic zone (91.9% and 62.5%, respectively). The removal of NH_4^+-N was in moderate level around 57%, however, TN removal could not be obtained. These results suggested that excess DO concentration in the oxic zone changed the state of anoxic condition into rich DO that was not sufficient for reducing TN and ammonia.

Contradictory results were obtained when the aeration rate was decreased. When aeration rate decreased from 59 to 34 L/min, DO concentration dropped from 5.1 to 0.9 mg/L and from 7 to 2.3 mg/L both in anoxic and oxic zones, respectively. Decreasing DO concentration leads to slightly declined DOC removal from 73.7% to 71.9% and sharp declined of

NH_4^+-N from 57.7 to 12.8%. However, total removal of TN showed increased trend to 22%. This condition suggests that the organic consumption was not properly achieved during nitrification in which nitrifier growth much slower than heterotrophic bacteria, and caused competition of oxygen consumption between both groups of organisms.

These results indicate that high DO concentration is a favor condition for niftrifier bacteria to oxidize the ammonium and improves the removal of TN and NH_4^+-N. However, decreasing aeration rate caused high dissolved organic carbon concentrations, which inhibited nitrification both in the anoxic and oxic zones and thereby increased the concentration of nitrogen in the effluent. Similar results were reported by [3], [15], [16]. Therefore, it is suggested that *Johkasou* system is recommended to applied continuous oxygen supply at high rate to achieve simultaneously nitrification.

3.5 Effect of aeration rate on simultaneous nitrification and denitrification

Adjustment of aeration rates affected the transformation of ammonia into nitrite-nitrogen and nitrate-nitrogen forms during nitrification process (**Fig. 4**). The amount of oxidized ammonia nitrogen via simultaneous nitrification and denitrification (SND) is calculated from the difference between total consumption of ammonia nitrogen and NH_4^+-N assimilated into heterotrophic biomass (Eq. 1) [15]. While, nitrate accumulation rate (NAR) based on the Eq. 2) [22].

$$\% \text{ SND} = \left(1 - \frac{NO_x^- - N}{NH_4^+ - N_{oxidized}}\right) \times 100 \qquad 1)$$

$$\% \text{ NAR} = \frac{NO_2^- - N}{NO_x^- - N} \times 100 \qquad 2)$$

Where NO_x^--N is the sum of nitrite and nitrate produced at the moment when ammonia was depleted, and $NH_4^+ - N_{oxidized}$ is the amount of ammonia nitrogen oxidized during the aerobic circumstance. NAR during

nitrification stage more than 50% is indicated as nitrification via nitrite.

In the JO-A system, before adjustment of aeration rate, concentrations of ammonia were not significant differences and also NO_x-N formations exposed limited to a negligible amount in each process (**Fig. 4a**). It indicated that insufficient DO level inhibited the nitrifier bacteria to convert ammonia into NO_2^--N and NO_3^-N and caused the SND and NAR could not be measured as well. Contrast when the aeration was raised into 63% L/min, sufficient oxygen supply into the system could enhance nitrification with the NH_4^+-N was depleted and NO_x^--N productions increased. The production of NO_2^--N detected very less because rapid conversion of NO_2^--N into NO_3^--N by Nitrobacter bacteria, which resulted percentages of NAR rose to 74.5 % and 60.9%, in the anoxic and oxic zones respectively. At this condition, the SND exhibited increased values in average 68.9% in the anoxic and 71.8% in the oxic. The maximum of SND value (84.6%) was found at the beginning after increasing DO concentration in the oxic zone and the SND percentage at the last sampling was slowly declining to 64.9% during long term aeration.

Decreasing aeration rate lead to in opposition results in the JO-B system particularly after decreasing aeration rate (**Fig. 4b**). Before adjustment, aeration rate was set upped at high rate around 59 L/min. The oxidized ammonium nitrogen was confirmed by detection of nitrite and nitrate with percentages of SND and NAR in the anoxic zone were 94% and 93.2 %, respectively. At this condition, the nitrification process had been achieved due to appropriate oxygen supply used by nitrifier bacteria, while nitrification effect in the oxic zone not differed with in the anoxic zone.

After adjustment, DO concentration declined linearly with decreasing aeration rate to 34 L/min. This circumstance affected DO changed into very low concentration, increased ammonium concentration and depleted NO_x^--N productions. Particular in day of 50, the sharp dropped of nitrite and nitrate could be detected at the end of experiment with percentages of SND and NAR fell onto zero level. This circumstance resulted low accumulations of nitrite and nitrate due to limitation of oxygen for nitrification bacteria. These results indicate
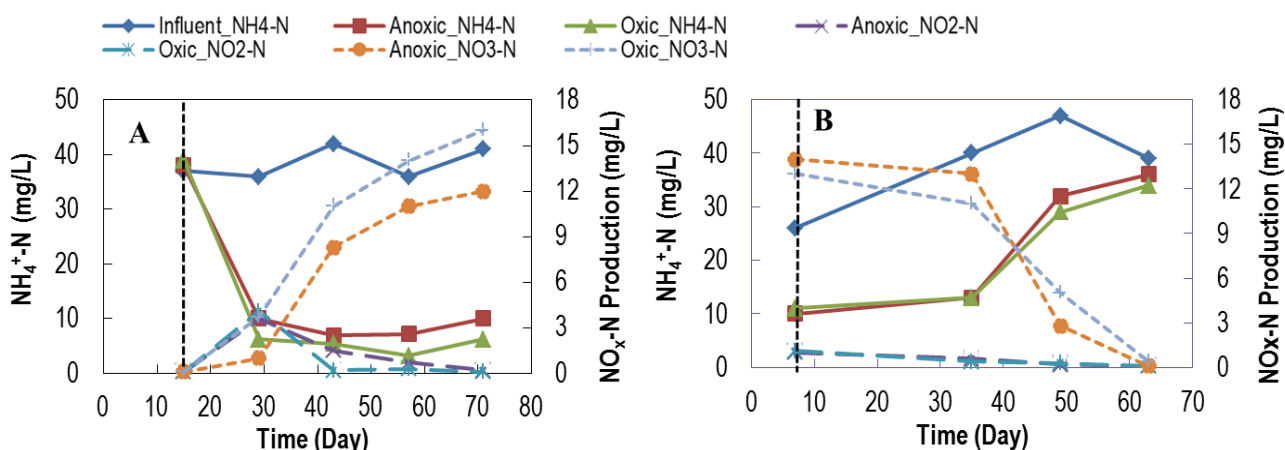

Fig. 4. Oxidized ammonia nitrogen into nitrite and nitrate affected by aeration rates in the a) JO-A and b) JO-B.

that high DO concentration favors conditions for niftrifier bacteria to oxidize the ammonium and improve the removal percentages of TN and NH_4^+-N. However, decreasing aeration rate caused high dissolved organic carbon concentrations, which inhibited nitrification both in the anoxic and oxic zones and thereby increased the concentration of nitrogen in the effluent. Similar results were reported by [3], [22], [23].

Limited DO concentration had no influence on the ammonia and nitrite oxidization, meanwhile the continuous supply of high DO concentration possibly inhabited oxidation of NO_3^--N into Nitrogen by denitrification reaction. This pointed that DO concentration plays an important role for nitrifier bacteria to oxidize the ammonia and the appropriate DO concentration or intermittent aeration supply may has a necessity to retain the oxidization, which can also save the cost of operation. The results in this study were also comparable with report by several researchers. Ruiz *et al.* ([14]) studied the behavior of the nitrification system during consecutive changes in DO values in high ammonia concentration. At a DO of 1.7 mg/L there was a temporal accumulation of nitrite and at DO of 1.4 and 0.7 mg/L accumulation increased with the same ammonia consumption. At a DO of 0.5 mg/L, both nitrite accumulation and ammonia consumption decreased. Similar results were also obtained by Bae *et al.* [24] that the maximum specific oxidation of ammonia (k_a) and nitrite (k_n) were similar under DO = 0.5 mg/L and increased as DO increased.

4. Conclusion

Aeration rate is an important variable in the biological wastewater treatment process and affects removals of organic matter and nitrogen. Effect of aeration rate on performance of two *Johkasous* was studied to know the degree oxidation of organic matter and nitrogen. High removals of BOD, DOC, NH_4^+-N and TN were achieved when the aeration was increased. The percentages of BOD and DOC removals could rich 98% and 91% respectively. And oxidization of ammonia nitrogen into nitrite and nitrate was obtained, which total mean percentages of SND and NAR were 71.8% and 60.9%. Contradictory results were attained when the aeration sharply decreased and followed declining removals of organic matter and nitrogen, and increase NH_4^+-N concentration in the effluent. Therefore, it is suggested that *Johkasou* system is recommended to applied continuous oxygen supply at high rate to achieve simultaneously nitrification.

5. References

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