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Study of Reducing Waste Biosolids in Sequencing Batch Reactor by Ozonation to Waste Biosolids

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One of the problems of biological aerobic systems for example sequencing batch reactor, is production of waste biosolids. If we reduce the volume of this waste biosolids, we would be able to solve the important problems of aerobic processes in all over the world. One of the suitable ways to reducing the waste biosolids is oxidizing the wste biosolids by oxidants such as ozone. Waste biosolids ozonation, by reducing the biomass coefficient (Y), will result in easier sewage biosolids disposal. In this study we used two sequencing batch reactor reactors with 15 L capacity. One of these was the blank. We tested parameters such as COD, MLSS, SVI, residual ozone and yield coefficient (Y). During the solid retention time of 10 days, biomass coefficient (Y) was 0.51 (mg Biomass/mg COD). Then, we started adding ozone with different doses in waste biosolids and we rejected this waste biosolids to the reactor. The results showed that with adding 30 (mg O_3/g MLSS), the kinetic coefficient of Y, reduced from 0.51 to 0.24 (mg Biomass/mg COD) and the volume of waste biosolids reduced about 0.53 %. From the other side, while adding ozone, the soluble COD in the effluent increased. So, the COD removal percentage decreased from 81.7 % in the blank to 56 % in the test reactor.

Key Words: Sequencing batch reactor, Biosolids reduction, Yield kinetic coefficient, Ozone, Oxidation of Biosolids.

INTRODUCTION

One of the aerobic processes in wastewater treatment is sequencing batch reactor (SBR) which has been widely used to treat industrial and municipal wastewater because of its low cost and suitable efficiency in pollutant removal. The process is composed of five stages as filling, reaction, settling, effluent and idle[1]. The biological biosolids waste is as heavy as 1.005, with the solid concentration of totally 0.5 to 1.0 % which is composed of 70 to 90 % of organic materials. The rate of the secondary biosolids production depends on the applied biological degradation and such procedural conditions as biosolids age, temperature and the organic along with hydraulic load rate in the biological unit[2,3].

The waste biosolids generated from the biological treatment process is a secondary solid waste that must be disposed in a safe and cost-effective way. The ultimate disposal of waste biosolids has been one of the most expensive problems faced by wastewater utilities[1-3]. The relatively high production of the biological waste biosolids is considered one of the major drawbacks of the aerobic processes involved in wastewater biological treatment[3]. The treatment of the waste biosolids may account for 25-65 % of the total plant operation cost[4]. If we reduce biosolids production, biosolids-associated problems will be solved *ca.* 40 to 60 % of the investment expenses and more than 50 % of the operation and maintenance expenses of the activated biosolids treatment plants have to do with treating the biosolids coming from the wastewater treatment plants[3,5,6].

The important methods for the reduction of waste biosolids are: endogenous metabolism[5,6], uncoupling metabolism[7-10], predation on bacteria[11,12]. Also oxidation of a part of produced biosolids is done by oxidizing materials such as chlorine and ozone[4,6,13,14].

The addition of ozone to biosolids return line can also affect the reduction of waste biosolids and the improvement as well as control of filamentous bulking[15]. Ozone is a strong chemical oxidant and can reduce waste biosolids. In the ozonation-activated biosolids process, the improved biosolids settleability and less influence on the effluent quality has been observed[16]. It is well- known that ozone has much higher oxidation power than chlorine, releases limited by-products and is non-reactive with ammonia[17]. Ozonation-assisted biosolids reduction process is based on the idea that part of activated biosolids is mineralized to carbon dioxide and water, while part of biosolids is solubilized to biodegradable organics that can be biologically treated. Many research works have been conducted with respect to the ozonation-assisted biosolids reduction process[15,18,19]. A combined activated biosolids process and intermittent ozonation system had been successfully developed.

In this combined system, waste biosolids withdrawn from a continuous activated biosolids system was subject to ozonation and then returned to the aeration tank. Results showed that the waste biosolids production was reduced by 50 % at an ozone dose of 10 mg g^{-1} mixed liquor suspended solids (MLSS) d^{-1} in aeration tank, when the ozone dose was kept as high as 20 mg g^{-1} MLSS d^{-1}, no waste biosolids was produced[21]. Study of Takdastan *et al.*[20] showed that 20 mg ozone per gram of MLSS is able to reduce the biological waste biosolids by 52 %. In the study of Egemen (1999), a similar technical approach was used. Ozone is a strong cell lysis agent. When biosolids is kept contact with ozone in the ozonation unit, most activated biosolids microorganisms would be killed and oxidized to organic substances. There is evidence that more than 50 % of the carbon obtained after ozonation is readily biodegradable[19]. This is the reason that those organic substances produced from the biosolids ozonation can be degraded in the subsequent biological treatment. Results from a 10 month full-scale ozonation-activated biosolids system loaded with 550 kg BOD d^{-1} showed that no waste biosolids was produced and the accumulation of inorganic solids in the aeration tank is negligible, while effluent total organic carbon was slightly higher than under the conventional activated biosolids process[21]. It had been reported that the biosolids settleability in term of biosolids volumetric index was highly improved as compared to control test without ozonation[20]. Apparently, both operation and capital costs of the ozonation- activated biosolids process should be high due to energy required for ozone production. However, economical estimate suggests that the operation costs of the whole process was lower than that of conventional activated biosolids process if the costs of biosolids dewatering and disposal were taken into account[17].

Ozonation-combined activated biosolids process would be a useful technology for reducing waste biosolids production and further improving biosolids settleability. But there are still some problems associated with this technique. Ozone is not a selective oxidant, it can react with other reducing materials and this may lower the oxidation efficiency of activated biosolids, while refractory organic carbon can be released into the effluent after ozonation.

Refractory organic carbon might pose problem to effluent receptor. It was also found that the initial rate of ozone consumption by biosolids was extremely high and reached 30 mg O_3 g^{-1} volatile suspended solids[20] (VSS) min^{-1}. On the other hand, it can be easily understood that the effectiveness of ozonation is strongly dependent upon the physical structure of activated biosolids and system operation conditions. These make the optimization of ozone dosage and dosing mode much more difficult[20].

EXPERIMENTAL

In this research we used the two sequencing batch reactors (SBR) with cylindrical shape tank, type of Plexi glass, inner diameter of 25 cm, 50 cm height and net volume of 20 L and treatment capacity of 10 L per cycle. Fig. 1 demonstrates the layout and schematic diagram of sequence batch reactors (SBR).

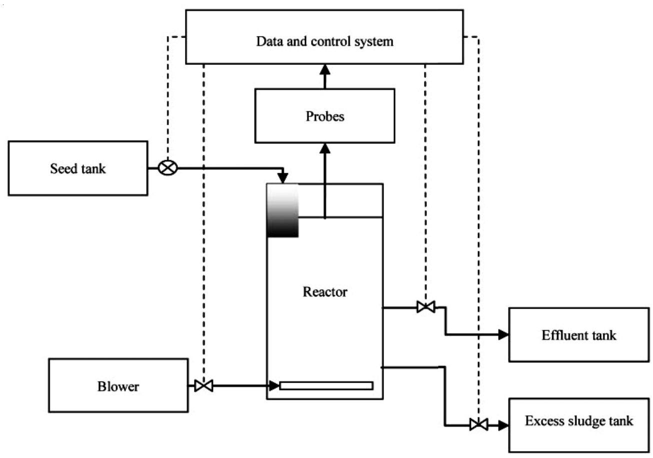

Fig. 1. General schematic view of sequencing batch reactor pilot

The run time of two reactors which selected in the same manner according to the type and characteristics of influent wastewater are shown in Table-1.

TABLE-1
SEQUENCE OF OPERATION TIME IN SEQUENCE BATCH REACTOR

Stage	Time (min)
Fulfilling	2
Aeration	240
Settling	102
Drainage	15
Idle	1

Synthetic wastewater characteristics: To prepare synthetic wastewater mixed 50 mg industrial milk powder and 100 L of urban treated water. The characteristics of operational conditions in the experiments are presented in Table-2.

TABLE-2
SUMMARY OF THE OPERATIONAL CONDITIONS

	Reactor-1 (blank)	Reactor-2 (tested)
Reactor volume (L)	15	15
SRT (day)	10	10
Ozone concentration (g)	Ozone is not added	0 to 0.35
COD (mg/L)	600	600
BOD5 (mg/L)	350	350

Pilot start up: First started the pilot with the seed of recalculated activated biosolids of Choneybeh wastewater treatment plant which was normal and had no problem such as bulking, rising and other problems. The seed added with volume *ca.* 4 L per SBR with volume of 15 L and COD of 600 mg/L. In this step, 2 weak aeration and reaction was happened to establish of flocs. In this period we added food to reactor every day and reaction performed. In next step sequencing batch reactor was started up with 5 cycles, *i.e.* fulfilling, reaction, wastewater drainage, biosolids drainage and idle. The parameters of COD and suspended solids (SS) and pH of wastewater were tested and compared with previous data. After 2 weeks of pilot run, the effluent COD data were close to each other, demonstrating the start up ending. In other words the system reached to steady state and situation was stable in pilot. Then, the parameters of COD and mixed liquor suspended solids (MLSS), biosolids volume index (SVI) and residual ozone and the kinetic coefficient of Y were tested during this study. The tests were performed according to standard methods for the examination of water and wastewater (APHA, 1995).

Variable situation: Due to the changes in the biosolids age and ozone concentration, at least 2 weeks were considered for the system to be adopted with the new situation. After reaching the steady statae we gathered the data. Parameters of COD in the effluent wastewater and suspended solids (SS) in sequencing batch reactor, considered as indexes of situation stability. Different ozone feed was injected to the reactor. According to standard methods for water and wastewater examination, this process was triplicated and the mean of the results was registered (APHA, 1995).

RESULTS AND DISCUSSION

Determination of Y coefficient in 10 days cell retention time in different ozone feed to reactor: In order to determine the synthetic efficiency of Y (the biomass production efficiency), in different cell retention time, we used 4 COD concentrations as to 300, 400, 600, 800 in a 10 days cell retention time. The operation was in the growth stable phase with high efficiency. This reduced the phase effect of logarithmic growth as well as endogenous. The temperature was maintained by the adjustable aquarium heater at 20 to 22 ºC and the dissolved oxygen was kept as much as 1.5 to 2 mg/h.

In order to determine the biosynthetic efficiencies especially biomass production co-efficiency (Y), we used the biomass production change in time unit according to COD change consumed in time unit during the 10 day returned time (maximum removal efficiency of COD). According to Fig. 2, Y = 0.51 mg Biomass/mgCOD during the 10 day cell retention time without the addition of ozone. In higher ozone added the biomass co-efficiency production during yield operation can be calculated by the following relation:

$$dX/dt = Y\ dS/dt$$

where: dX/dt = the increase rate in biomass concentration or MLSS (mg/L); ds/dt = the removal rate of substrate or COD (mg/L).

$$Y = \frac{X_0 - X}{S_0 - S}$$

where S_0, S are respectively the primary and ultimate substrate concentration (mg/L) and X_0, X are respectively the primary and ultimate biomass concentration (mg/L).

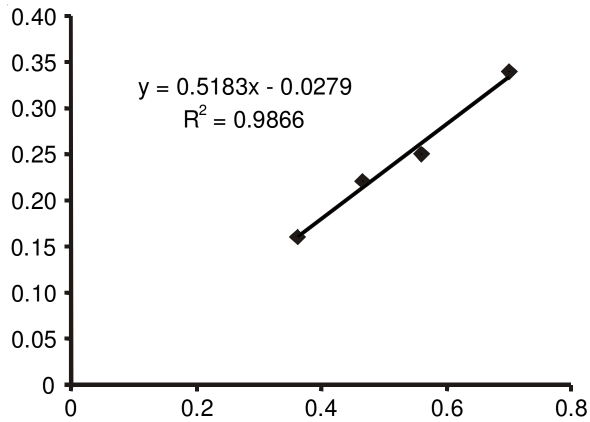

Fig. 2. Determination of Y in SRT = 10 days. Under no-ozone-addition condition

The biosynthetic co-efficiency rate of biomass (Y) is in the different ozone concentration injected into the reactor of Table-2, as the Table-3 shows under 5 and 20 mg ozone per gram MLSS in reactor, the values of biomass production are 0.53 and 0.32 mg biomass/mg COD, respectively.

As can be seen in Table-3, in the state of no- ozone with COD = 600 mg/L, the Yield coefficient equals 0.51 mg biomass/mg COD and the removal of COD is 81.7 %. But by adding ozone to reactor the yield coefficient decreases, in a way that by adding 15 mg ozone per gram of MLSS in reactor, the yield coefficient will be 0.42 mg biomass/mg COD thus reducing the waste biosolids. But its disadvantage is causing slight increase of soluble COD in effluent and the removal of COD reduced *ca.* 63.3 % by adding 35 mg of ozone per gram of MLSS into the reactor resulted in no waste biosolids. Yet the COD removal coefficient was lowered to 47.5 %. In such amount of ozone, many microorganisms in the reactor turned non-viable and died. The cause of such a low coefficient is that ozone plays the role of disinfection and oxidation, hence killing many micro-organisms in the reactor (except for limited number of slime microorganisms which can tolerate).

Effect of different ozone dosage on COD removal: The effect of added different ozone doses to waste biosolids is shown in the Fig. 3. Tests showed that by returning the waste biosolids to the reactor after adding ozone, the biosynthetic co-efficiency rate of biomass (Y) was decreased and waste biosolids was minimized also filamentous balking was

TABLE-3
EFFECT OF ADDED OZONE ON Y, SVI, COD REMOVAL AND RESIDUAL OZONE

Value of added ozone to biosolids (mgO_3/gMLSS)	Y (mgBiomass/mgCOD)	Residual ozone in the end of reaction (mg/L)	COD removal (%)	SVI (mL/g)	Biosolids reduction (%)
0	0.51	0	81.70	101	0
5	0.53	0	80.83	106	3.92 (increase)
10	0.49	0.03	80.70	95	3.9
15	0.42	0.08	63.30	56	17.6
20	0.32	0.57	60.80	43	37.2
26	0.29	1.20	59.00	25	43.1
30	0.24	1.90	56.00	16	52.9
35	0	2.40	47.50	0	100

TABLE-4
LITERATURE DATA FOR REDUCING WASTE BIOSOLIDS PRODUCTION BY OXIDATION

Operation condition	Biosolids reduction (%)	Effluent quality	Ref.
Full scale: 550 kgBOD/d of industrial wastewater, continuous ozonation at 0.05 g O_3/gMLSS	100	Increase of COD	21
Full scale: 450 m^3/d of municipal wastewater, continuous ozonation at 0.02 g O_3/gMLSS	100	Slightly Increase of BOD	19
Lab scale, synthetic waste water, intermittent ozonation at 11 g O_3/g MLSS (aeration tank)d	50	Nearly un affected	15
Pilot plant scale, synthetic waste water, intermittent ozonation to biosolids in SBR at:			
1. 20 mg O_3/gMLSS	52	Slightly Increase of COD	20
2. 25 mg O_3/gMLSS	100		
Pilot plant scale, synthetic waste water, intermittent ozonation to biosolids in SBR at:			
1. 30 mg O_3/gMLSS	52.9	Increase of COD	Present study
2. 35 mg O_3/gMLSS	100		

controlled. But by adding ozone to the system, the slight soluble COD increased in effluent. Fig. 3 shows that by increasing the concentration of ozone, the COD removal coefficient decreases. The COD removal co-efficiency reaches less than 47.5 % in 35 mg ozone dose per gram MLSS in 1 L of return biosolids to the reactor (Fig. 3) but the soluble COD in effluent increases. The soluble COD rate increases in the effluent because ozone kills a lot of heterotrophic microorganisms in the reactor and oxidizes part of the biomass.

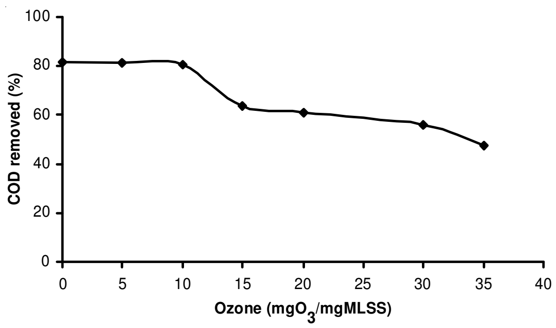

Fig. 3. Effect of ozone doses on COD removal efficiency

Effect of different ozone doses on SVI: By increasing the concentration of ozone dose addition to reactor the SVI decreases (Fig. 4). Fig. 4 also shows that with the 30 mg ozone dose per gram of MLSS in to reactor, SVI reached to around 16 mL/g the other hand having increased the ozone doses, the MLVSS/MLSS ratio decreases, thus light increasing the specific weight of biosolids.

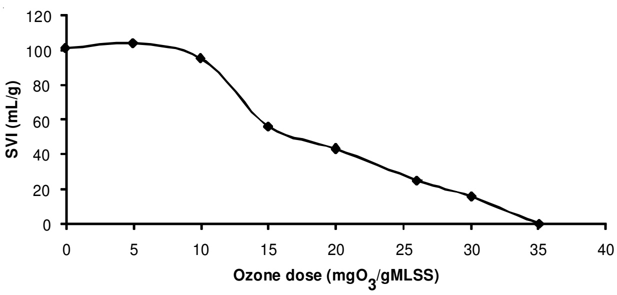

Fig. 4. Effect of ozone does on SVI

Effect of different ozone doses on yield coefficient: Fig. 5 shows the effect of different ozone doses into sequencing batch reactor on yield coefficient (Y). It was found that with the 30 mg O_3/g MLSS ozone in 1 L of biosolids return to the reactor, yield coefficient reduced from 0.51 to 0.24 (mg Biomass/mgCOD). In other words, the biological waste biosolids reduced to 52.9 %. With adding the 35 mg O_3/g MLSS ozone in 1 L of biosolids return to the reactor the biological waste biosolids reduction was 100 %. In ozone dose more than above mentioned amount (35 mg). Organic matter removal coefficient reduced as a result of the inhibitory effect of ozone on microorganisms.

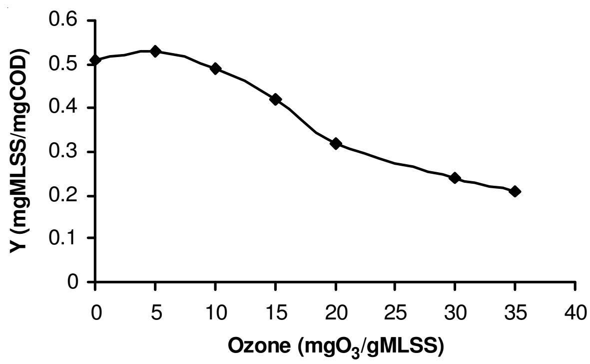

Fig. 5. Effect of ozone does on yield

Conclusion

The use of ozone is one of the waste biological biosolids reduction methods which can reduce waste biological biosolids, considerably. With the high ozone concentration into the reactor, a large number of microorganisms are deactivated or die and some of the biomass is oxidized. However in the 30 mg ozone per gram of MLSS in 1 L of biosolids return to the reactor reduces by 52 %, the amount of soluble COD in the effluent increases. In high concentration of ozone (35 mg ozone per gram of MLSS in 1 L of biosolids return to the reactor) no biological waste biosolids is produced, but the COD removal percentage in the effluent reduces. A comparative data of present study with previous work are given in Table-4.

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