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Investigation of Excess Biological Sludge Reduction in Sequencing Bach Reactor

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The ultimate disposal of excess sludge generated from activated sludge processes is one of the most challenging problems for wastewater treatment utilities. In this research, the two sequence batch reactors (SBR) used with cylindrical shape tank, net volume of 20 L and treatment capacity of 10 L per cycle. After reaching to steady state and stable situation in pilot running, the parameters of COD, MLSS, MLVSS, SVI, SOUR, residual ozone and yielding kinetics tested during 8 months. The results demonstrated that MLSS concentration increase a little after initially breakthrough due to feed ozone. COD removal efficiency reaches to 42 % at 25 mg/L ozone/g MLSS. The MLSS concentration also reduced considerably. In the other hand, Biomass production rate/g COD (Y) in 10 day cell retention time in without ozone dosage stage reach to 0.62 mg produced biomass. But, Y rate decreases by ozone dosage increment to part of sludge which reaches to 20 mg ozone/g MLSS of 1 L circulated sludge. Biomass production rate/g COD (Y) in 10 day cell retention time in without ozone dosage stage reach to 0.62 mg produced biomass. But, Y rate decreases with ozone dosage increment to part of sludge. And, we can reach to standard levels by10 day cell retention time in just feed 4.2 mg ozone/g MLSS to circulated sludge.

Key Words: Activated sludge, Excess sludge, Ozonization, Sludge minimization, Sludge volume index.

INTRODUCTION

The removal of organic materials by biological oxidation is a core technology in wastewater treatment process. New cells (sludge), carbon dioxide, soluble microbial products and water are the end products for this process. Activated sludge process has been applied worldwide in municipal and industrial wastewater treatment practice. Daily production of excess sludge from conventional activated sludge process is around 15-100 L/kg BOD5 removed, in which over 95 % is water[1-3]. It is evident that in general purpose of activated sludge process is for the removal of organic pollutants rather in cultivation of excess sludge[1,3,4].

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One of the aerobic processes in waste water treatment is Sequencing Batch reactor (SBR) which in recent years 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 and effluent and idle[3,5].

In typical secondary municipal sewage treatment, a large amount of excess sludge is produced daily. Handling, treatment and disposal of this solid waste accounts for 50-60 % of the operating cost of a secondary treatment plant[6,7]. In addition, its ultimate disposal by landfill and/or incineration has created environmental challenge since the availability of landfill sites and incineration of solid wastes poses major difficulties in densely populated countries[8].

There is therefore considerable impetus to explore and develop strategies and technologies for reducing excess sludge production in biological wastewater treatment processes[9-12]: endogenous metabolism[7,11], uncoupling metabolism[13-16], increase of DO in reactor[17,18], oxic settling - anaerobic (OSA)[12,19], ultrasonic cell disintegration[12,20], alkaline heat treatment[11,21], predation on bacteria[16,22-25], oxidation of a part of produced sludge is done by such oxidizing materials as chlorine and ozone[7,26-32].

Yasui and Shibata[33] attempted the use of ozone gas to dissolve the excess sludge, thereby leading to 100 % minimization of excess sludge within the process. In their approach, a small amount of return sludge was ozonized and then returned to the aeration tank. They demonstrated that sludge ozonization can make the excess sludge biologically oxidized[33,34]. Other studies[35-37] also showed that sludge ozonization treatment is a potential solution to the excess sludge problem.

With the growing applications of activated sludge processes, huge amount of solids waste, namely the excess sludge is generated daily as the byproduct of the transformation of dissolved and suspended organic pollutants into biomass and evolved gases (CO_2, CH_4, N_2 and SO_2). The treatment and ultimate disposal of excess sludge are expensive, which usually accounts for 30-60 % of the total operational cost in a conventional activated sludge treatment plant[38].

Since sludge degradation in a bioreactor call is much improved after ozonization, minimization of excess sludge production can be achieved recirculation the ozone treated sludge into bioreactor. The sludge ozonization process can be also applied to membrane bioreactor (MBR) system for minimization of excess sludge production. Due to the relatively high biodegradability, organic matter in the ozonated sludge can be effectively used as a carbon source in a biological nutrient removal (BNR) system under low organic loading condition[37].

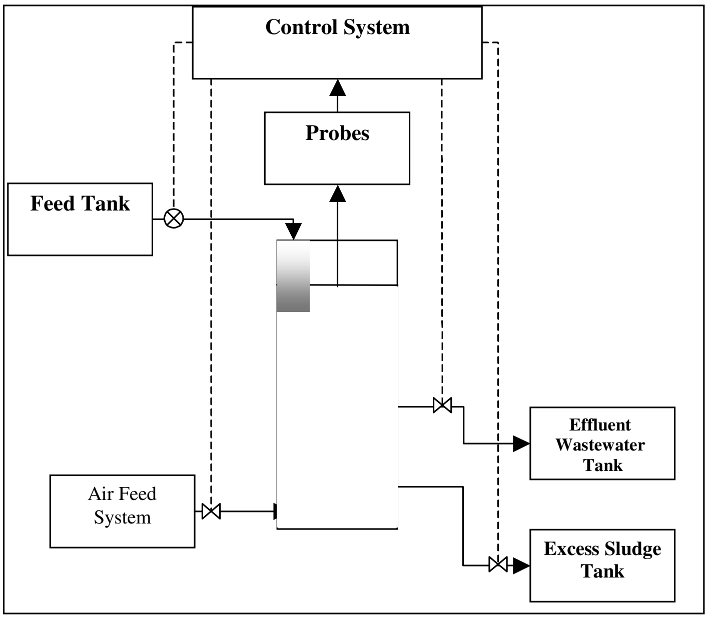
Yasui and Shibata[39] developed a new process for reducing excess sludge production in the activated sludge process. The process consists of a sludge ozonization stage and a biodegradation stage, in which a fraction of recycled sludge passes through the ozonization unit and then the treated sludge is decomposed in the subsequent biological treatment. The ozonization of sludge results in both solubilization (due to disintegration of suspended solids) and mineralization (due to oxidation of soluble organic matter) and the recycling of solubilized sludge into the aeration tank will induce cryptic growth.

Thus, the main objectives of this study are to investigate some parameters on reduce of excess biological sludge in sequencing bach reactor (SBR).

EXPERIMENTAL

In this research, the 2 sequence batch reactors (SBR) used with cylindrical shape tank, type of Plexiglas, inner diameter of 25 cm, 60 cm height and net volume of 20 L and treatment capacity of 10 L per cycle. Pictures 1 and 2 demonstrate the layout and schematic diagram of sequence batch reactors (SBR).

Picture 1. Sequencing bach reactor (SBR) layout



Picture 2. Sequencing bach reactor (SBR) schematic

The programmable logic controller (PLC) is used to operate of system. The run time of both reactors which selected in the same manner according to the type and characteristics of influent wastewater are as below: fulfilling: 3 min, aeration: 4 h, settlement: 105 min and drainage: 12 min. In the pilot run, the fulfilling time of the tank reduced to 70 s.

Synthetic wastewater characteristics: The synthetic wastewater of pilot prepared with mixing of 40 mg industrial dry and 100 L of tab water. The characteristic of wastewater in experiments are as below: COD = 600 mg/L, BOD5 = 420 mg/L, nitrogen (as nitrate): 4.7 mg/L as N, nitrogen (as organic nitrogen): 30 mg/L as N, nitrogen (as TKN): 30.7 mg/L as N, phosphorus = 10.5 mg/L

Pilot start up: First, seed of recalculated activated sludge of Ekbatan wastewater treatment plant used to start up of pilot which had not any problems such as bulking and other problems. And, the seed added with volume about 2 L per SBR with volume of 20 L and COD of 600 mg/L.

Aeration and reaction of 2 weeks performed to establish of flocs. But, in this stage only the reaction performed and food added every day. After this stage, SBR with run 5 cycles of fulfilling, drainage of wastewater and sludge started up. The parameters of COD, suspended solids and pH of wastewater tested and compared with previous data. After 2 weeks of pilot run, effluent COD data were close to each others.

After reaching to steady state and stable situation in pilot running, the parameters of COD, mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), sludge volume index (SVI), specific oxygen uptake rate (SOUR), residual ozone and yielding kinetics tested during 8 months.

The tests performed according to standard methods for the examination of water and wastewater[8].

Variable situation: Two weeks running (equal to 42 cycles of SBR running) considered to compliance with new situation because of changing the sludge age, residual ozone during sludge age changes. Then, the data gathered after stable situations. The suspended solid concentration in SBR and effluent wastewater COD considered as indexes of situation stability. SBR run 3 times by different ozone feed to 1 L of sludge to reduce of excesses sludge production. Finally, the data collected and only the average of data reported.

RESULTS AND DISCUSSION

COD and MLSS change by different added ozone to 1 L of circulated sludge to reactor.

Figs. 1-9 demonstrate COD and MLSS changes by variable ozone concentrations to 1 L circulated sludge to reactor. According to these figures, COD removal efficiency reduced a little by increase of ozone concentration to circulated sludge which is because of disinfection and oxidation by residual ozone in reactor and oxidation of part of biomass. And, only strength microorganisms and spore microorganisms can be alive and live in ozonized wastewater. This phenomena causes that COD reduction efficiency improve relative to added ozone. And, MLSS concentration increase a

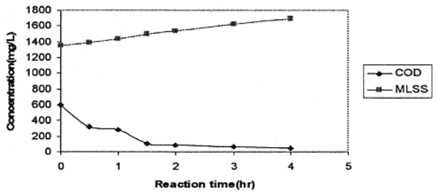


Fig. 1. COD and MLSS changes rate in reactor without ozone feed

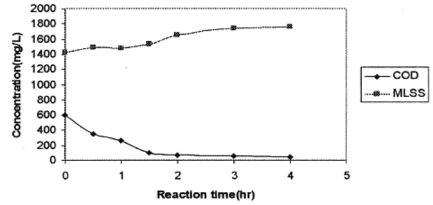


Fig. 2. COD and MLSS changes rate in reactor by feed of 1.66 mg ozone/g MLSS of 1 L circulated sludge in reactor

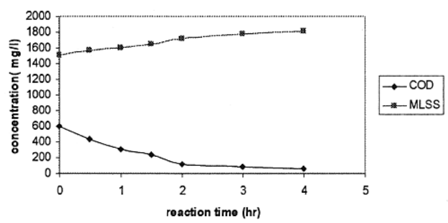


Fig. 3. COD and MLSS changes rate in reactor by feed of 2.5 mg ozone/g MLSS of 1 L circulated sludge in reactor

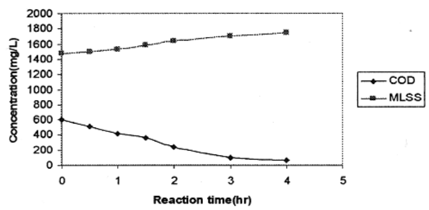


Fig. 4. COD and MLSS changes rate in reactor by feed of 4.2 mg ozone/g MLSS of 1 L circulated sludge in reactor

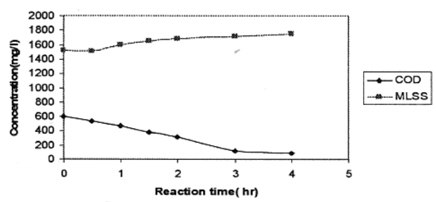


Fig. 5. COD and MLSS changes rate in reactor by feed of 8.0 mg ozone/g MLSS of 1 L circulated sludge in reactor

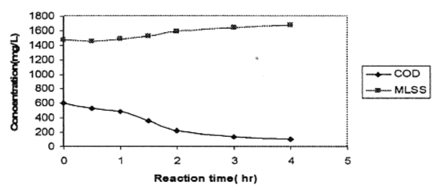


Fig. 6. COD and MLSS changes rate in reactor by feed of 12.5 mg ozone/g MLSS of 1 L circulated sludge in reactor

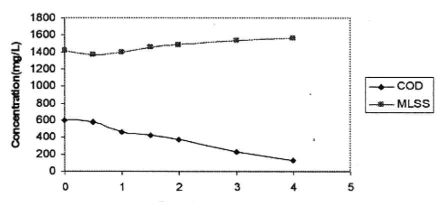


Fig. 7. COD and MLSS changes rate in reactor by feed of 16 mg ozone/g MLSS of 1 L circulated sludge in reactor

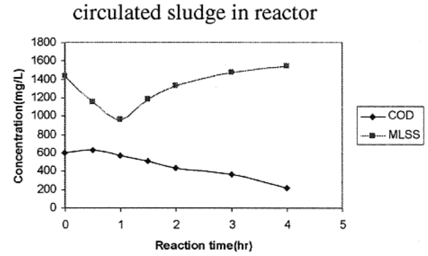


Fig. 8. COD and MLSS changes rate in reactor by feed of 20 mg ozone/g MLSS of 1 L circulated sludge in reactor

little after initially breakthrough due to feed ozone. Fig. 9 shows that COD removal efficiency reaches to 42 % at 25 mg/L ozone/g MLSS. Also, MLSS concentration reduced considerably. So, dissolved COD concentration increases in effluent wastewater by this ozone concentration.

Determination of Y coefficient in 10 days cell retention time in different ozone feed to part of sludge: Biomass production changes *versus* time relative to consumed COD changes used to determination of bio kinetic coefficient specially biomass production (Y). Biomass production in operation (yield operation) derived from this equation:

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

which, dX/dt is the biomass production increment rate or MLSS (mg/L) and dS/dt is the substrate removal rate or COD (mg/L)

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

which, S and S_0 are the substrate concentration or initial and final COD (mg/L). And, X and X_0 are the initial and final concentrations (mg/L).

Biomass production coefficient rate (Y), residual ozone, SOUR SVI and COD removal efficiency in different ozone feed of 1 L sludge listed in Table-1.

TABLE-1
DIFFERENT OZONE DOSAGE EFFECT ON Y, RESIDUAL OZONE, SOUR SVI AND COD REMOVAL EFFICIENCY

Ozone feed to 1 L sludge (mgO_3/g MLSS)	Final residual ozone (mg/L)	SOUR (mgO_2/h/g VSS)	SVI (mL/g)	COD removal efficiency (%)	Y $\left(\frac{\text{mg Biomas}}{\text{mg COD}}\right)$
0.00	0.00	18	90	92	0.62
1.66	0.00	20	92	93	0.61
2.55	0.00	17	88	91	0.56
4.20	0.00	14	83	88	0.50
8.00	0.00	11	62	85	0.46
12.50	0.01	7	44	83	0.41
16.00	0.05	5	35	79	0.33
20.00	0.20	3	20	64	0.48
25.00	0.50	3	0	42	0.00

Effect of different ozone dosage on COD removal: According to Fig. 10, COD removal efficiency decreases due to ozone dosage increment and reach to 42 % in 25 mg ozone/MLSS of 1 L circulate sludge in reactor. Thus, dissolved COD concentration increase in effluent wastewater.

Effect of different ozone dosage on SOUR: According to Fig. 11, some of microbes get inactive and dye due to ozone affect on microorganisms (except spin microorganisms) and microbial activity decreases. So, SOUR, which is index of bacteria breath, decreases. SOUR less than 12 mg oxygen/h g suspended solids is demonstration of poisonous materials existents in reactor. The results showed that dosage 20 mg ozone/g MLSS in 1 L circulated sludge to reactor can reduces SOUR of 18 in stage of no ozone feed to 3 mg O_2/h g VSS.

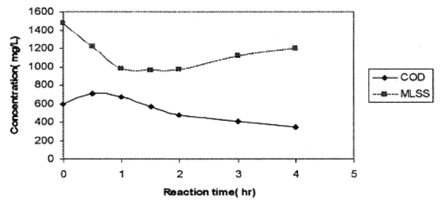


Fig. 9. COD and MLSS changes rate in reactor by feed of 25 mg ozone/g MLSS of 1 L circulated sludge in reactor

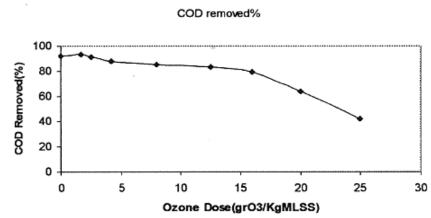


Fig. 10. Ozone feed effect on COD

Effect of different ozone dosage on sludge volume index: Fig. 12 demonstrates that sludge volume index (SVI) reduces due to ozone dosage increment in part of sludge feed which is because of oxidation of part of sludge and reduction of MLVSS/MLSS.

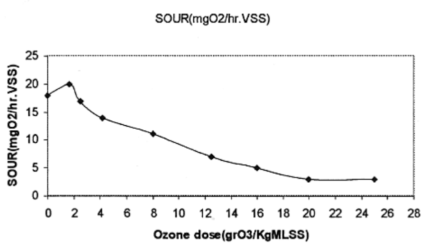


Fig. 11. Effect of different ozone dosage on SOUR

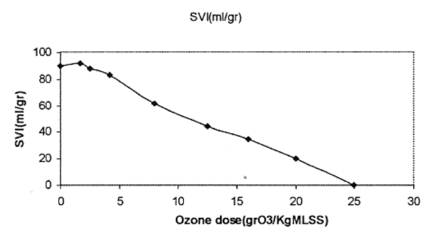


Fig. 12. Effect of ozone dosage on SVI

The figure shows that SVI reach to 20 mg ozone/g MLSS of 1 L circulated sludge. But, sludge doesn't establish in 25 mg ozone/g MLSS of circulated sludge to reactor.

The experiments showed that 20 mg ozone/g MLSS reduces SVI of 90 to 20 mL/g in no ozone dosage.

Different ozone effect on biomass production (Y): Fig. 13 shows that biomass production rate/g COD (Y) in 10 day cell retention time in without ozone dosage reach to 0.62 mg produced biomass. But, Y rate decreases by ozone dosage increment to part of sludge.

Comparison of effluent wastewater COD with disposal and reuse standard of ozonated sludge: The Fig. 14 shows that 10 day cell retention time in just 4.2 mg ozone/g MLSS of circulated sludge can reach to standard levels. But, 20 mg ozone/ g MLSS of 1 L circulated sludge is in compliance with wastewater reuse standard of agricultural uses. The higher dosage than this level can not be in compliance with standard levels.

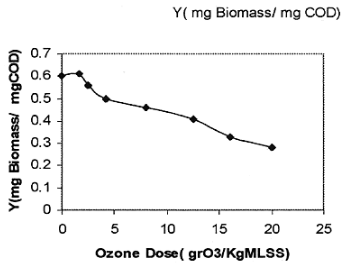


Fig. 13. Effect of ozone dosage on yield coefficient

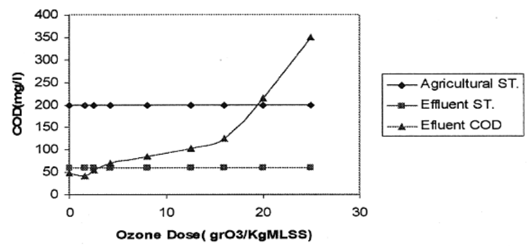


Fig. 14. Comparison of effluent wastewater COD removal by different ozone dosage with Iran wastewater reuse standard for agricultural usage

Conclusion

Ozone is one of the excess biological sludge reduction methods which can reduces excess biological sludge, considerably. The experiment demonstrated that: (i) MLSS concentration increase a little after initially breakthrough due to feed ozone. COD removal efficiency reaches to 42 % at 25 mg/L ozone/g MLSS. The MLSS concentration reduced considerably. (ii) Biomass production rate/g COD (Y) in 10 day cell retention time in without ozone dosage reach to 0.62 mg produced biomass. But, Y rate decreases with ozone dosage increment to part of sludge. (iii) SVI reaches to 20 mg ozone/g MLSS of 1 L circulated sludge. But, sludge doesn't establish in 25 mg/g MLSS of circulated sludge to reactor. (4) Biomass production rate/g COD (Y) in 10 day cell retention time in without ozone dosage reach to 0.62 mg produced biomass. But, Y rate decreases with ozone dosage increment to part of sludge. And, 10 day cell retention time in just 4.2 mg ozone/g MLSS of circulated sludge can reach to standard levels.

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REFERENCES

1. Metcalf and Eddy, Wastewater Engineering: Treatment, Disposal and Reuse, New York, USA, McGraw Hill, p. 680 (2003).
2. M.L. Arora, E.L. Barth and M.B. Umphres, *J. WPCF*, **57**, 867 (1985).
3. G. Bitton, Wastewater Microbiology, New York: Wiley-Liss (2002).
4. USEPA, Wastewater Technology Fact Sheet Sequencing Batch Reactors, United States Environmental Protection Agency, 832-F-99-073 (1999).
5. A. Takdastan, A. Torabian and A.A. Azimi, Excess Sludge Reduction Methods in Anaerobic Wastewater Treatment, National Water and Wastewater Operation Seminar, Water and Wastewater Company of Iran, 20-22 February, Tehran, Iran, pp. 240-234.

6. A. Takdastan and A. Torabian, Investigation of Excess Biological Sludge Reduction in Sequencing Bach Reactor (SBR) by Partial Oxidation of Sludge by Chlorine, 10th Environment Seminar, Water and Wastewater Company of Iran, 20-22 February, Hamedan, Iran, pp 30-34.
7. A. Takdastan and A. Torabian, Investigation of Excess Biological Sludge Reduction in Sequencing Bach Reactor (SBR) by Partial Alternative Oxidation of Sludge by Chlorine, 10th Environment Seminar, Water and Wastewater Company of Iran, 20-22 February, Hamedan, Iran, pp. 374-380.
8. A.P.H.A., A.W.W.A., W.P.C.F., Standard Method for the Examination of Water & Wastewater, A.P.H.A.N.W-Washington D.C., edn. 19 (1983).
9. Y. Liu and J.H. Tay, *Biotech. Adv.*, **19**, 97 (2001).
10. E.W. Low and H.A. Chase, *Water Res.*, **33**, 1119 (1999).
11. Y. Liu, *Chemosphere*, **50**, 1 (2003).
12. A. Canales, A. Pareilleux, J.L. Rols, C. Goma and A. Huyard, *Water Sci. Technol.*, **30**, 96 (1994).
13. Y. Liu, *Water Res.*, **34**, 2025 (2000).
14. Y. Liu and J.H. Tay, *J. Appl. Microbial.*, **88**, 663 (2000).
15. E.W. Low, H.A. Chase, M.G. Milner and T.P. Curtis, *Water Res.*, **34**, 3204 (2000).
16. X. Huang, P. Liang and Y. Qian, *J. Biotechnol.*, **127**, 443 (2007).
17. B. Abbassi, S. Dullstein and N. Rabiger, *Water Res.*, **34**, 139 (2000).
18. R. Wunderlich, J. Barry and D. Greenwood, *Poll. Control Fed.*, **57**, 1012 (1985).
19. Y. Sakai, T. Fukase, H. Yasui and M. Shibata, *Water Sci. Technol.*, **36**, 163 (1997).
20. H. Yasui and M. Shibata, An Innovative Approach to Reduce Excess Sludge Production in the Activated Sludge Process, Vol. 30, pp. 11-20 (1994).
21. M. Rocher, G. Roux, G. Goma, A.P. Begue, L. Louvel and J.L. Rols, *Water Sci. Technol.*, **44**, 437 (2001).
22. P. Liang, X. Huang and Y. Qain, *Chem. Eng. J.*, **28**, 117 (2006).
23. C. Liang, X. Huang, Y. Qian, Y. Wei and G. Ding, *Bioresour. Technol.*, **97**, 854 (2006).
24. U.L. Lee, S. Topfl and V. Heinz, *Food Biotechnol. Process Eng.*,
25. S.H. Yoon, H.S. Kim and S. Lee, *Process Biochem.*, **39**, 1923 (2004).
26. S. Saby, M. Djafer and G.H. Chen, *Water Res.*, **36**, 656 (2002).
27. H. Yasui, K. Nakamura, S. Sakuma, M. Iwasaki and Y. Sakai, *Water Sci. Tech.*, **34**, 395 (1996).
28. T. Kamiya and J. Hirotsuji, *Water Sci. Technol.*, **38**, 145 (1998).
29. G. Chen and S. Saby, *Water Sci. Technol.*, **44**, 203 (2003).
30. M. Rocher, G. Goma, A.P. Begue, L. Louvel and J.L. Rols, *Appl. Microbial. Biotechnol.*, **51**, 883 (1999).
31. A. Canales, A. Pareilleux and J.L. Rols, *Water Sci. Technol.*, **30**, 96 (1994).
32. J.B. Copp and P.L. Dold, *Water Sci. Technol.*, **38**, 285 (1998).
33. H. Yasui and M. Shibata, *Water Sci. Technol.*, **30**, 11 (1994).
34. N.J. Horan, Biological Wastewater Treatment Systems, Chichester: Wiley (1990).
35. S. Saby, M. Djafer and G.-H. Chen, *Water Res.*, **36**, 656 (2002).
36. E. Egemen, J. Corpening and N. Nirmalakhandan, Evaluation of an Ozonization System for Reduced Waste Sludge Generation, Proceedings of the IWA Conference, July 2000, Paris, France (2000).
37. H. Yasui, K. Nakamura, S. Sakuma, M. Iwasaki and Y. Sakai, *Water Sci. Technol.*, **34**, 395 (1996).
38. K.-H. Ahn, I.-T. Yeom, K.-Y. Park, S.-K. Maeng, Y. Lee, K.-G. Song and J.-H. Hwang, *Water Sci. Technol.*, **46**, 121 (2002).
39. H. Yasui and M. Shibata, *Water Sci. Technol.*, **30**, 11 (1994).

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