BIOMEDICAL AND ENVIRONMENTAL SCIENCES **18**, 5-8 (2005)

Effect of Salinity Variations on the Performance of Activated Sludge System[1]

JIAN-LONG WANG[*,#,2], XIN-MIN ZHAN[#], YE-CHENG FENG[#], AND YI QIAN[#]

[*]*Laboratory of Environmental Technology, INET, Tsinghua University, Beijing 100084, China;* [#]*State Key Joint Laboratory of Environment Simulation and Pollution Control, Tsinghua University, Beijing 100084, China*

Objective To investigate the influence of salinity variations on the performance of activated sludge systems, treating domestic wastewater. **Methods** The completely mixed reactor was used and operated in a batch-wise mode. The activated sludge taken from the Gaobeidian Wastewater Treatment Plant was used as a seeding sludge. Total organic carbon (TOC), oxygen uptake rate (OUR) and suspended solids (SS) were used as parameters to characterize the performance of the treatment systems. TOC was measured using a TOC-analyzer (TOC-5000, Japan). The OUR value was measured with a dissolved oxygen meter (YSI model-58). SS was measured gravimetrically. **Results** The TOC removal efficiency and the OUR value of activated sludge were not deteriorated when the NaCl shock concentration was less than 0.5 g/L. However, when the NaCl shock concentrations were up to 10g/L and 20 g/L, the OUR of activated sludge was reduced by 35% and TOC removal efficiency was dropped by 30%, compared with the control experiment without NaCl shock loading. **Conclusion** The effect of NaCl shock loading on the activated sludge wastewater treatment system is dependant upon the NaCl concentrations and the degree of influence can be inferred through the change of substrate utilization rate at different shock NaCl loadings.

Key words: Activated sludge; Saline wastewater; NaCl; Shock loading; TOC; OUR

INTRODUCTION

Sodium chloride (NaCl) and other salts may reach wastewater by several means. Seawater has been used as an alternative water source for toilet flushing in some coastal cities, resulting in a high salt content in the sewage. Also in coastal areas, infiltration of saline water into sewers is associated with subsurface water rise and contributes a high concentration of chloride to wastewater. In addition, certain industrial wastewater contains high inorganic salts because of specific technologies, such as cheese, pickling, canning and dye manufacturing. Saline sewage is also generated and has to be treated on board marine vessels or on offshore installations[1-3]. The activated sludge process is usually used to treat wastewater for its low cost, so it is thought that the shock salt loading may influence the process when saline wastewater enters wastewater treatment systems.

In the wastewater treatment field, there are conflicting reports on the influence of NaCl on the performance of biological treatment processes. It was found that addition of NaCl increased the respiration rate of microorganisms up to a specific salt concentration, thereafter a decrease was observed[4-7]. Some investigators reported the adverse effects of high NaCl concentrations or shocks of NaCl on organic removal efficiency and sludge settleability[8-11]. Other researchers claimed that addition of NaCl to biological treatment systems did not upset the organic removal efficiency, on the other hand, it resulted in a good flocculation of the biomass[12-14].

It seems that the level of NaCl content used and acclimation of the biomass to NaCl content are important factors to explain the observations above. In the light of earlier studies, this study was to determine the effects of shock NaCl loading on the activated sludge process treating domestic sewage. Variation of TOC removal efficiency and the OUR of activated sludge with NaCl shock loadings were determined.

MATERIALS AND METHODS

Experimental Set-up

Two reactors made of Plexiglass (20 cm diameter and 30 cm high) were used. Aeration was performed with an air pump and diffusers. Experiments were

[1]The work was supported by the National Natural Science Foundation of China (Grant No. 29637010; 59978020; 50325824).
[2]Correspondence should be addressed to Dr. Jian-Long WANG, Laboratory of Environmental Technology, INET, Tsinghua University, Beijing 100084, China. Tel: 86-10-62784843. Fax: 86-10-62771150. E-mail: wangjl@tsinghua.edu.cn

Biographical note of the first author: Jian-Long WANG, male, born in 1964, Ph. D., majoring in the field of water pollution control as well as environmental biotechnology.

0895-3988/2005
CN 11-2816/Q

operated in batch-wise. Two point five L domestic wastewater was added in each reactor and inoculated with 0.5 L activated sludge (MLSS=6 g/L). Activated sludge was taken from the Gaobeidian Wastewater Treatment Plant, Beijing, treating municipal wastewater. Domestic wastewater was taken from the campus of Tsinghua University. One reactor was used as the tested reactor and the other was taken as the control reactor so as to provide the baseline of the study.

Experimental Design

All experiments were conducted in batch-wise at room temperature (20℃±5℃). After 2.5 L domestic wastewater and 0.5 L activated sludge with 6 g/L MLSS were added into the two reactors, aeration started to acclimate activated sludge. During the acclimation period, 2.5 L supernatant was withdrawn and 2.5 L fresh domestic wastewater was refilled in the two reactors every 23 hours for one month. After acclimation, 2.5 L supernatant was withdrawn and 2.5 L fresh domestic wastewater was refilled in the two reactors. After operation for one hour, various amounts of NaCl needed to maintain the shock concentration was added into the tested reactor. The examined shock loadings of NaCl were 0.1 g/L, 0.5 g/L, 2 g/L, 5 g/L, 10 g/L, and 20 g/L. At different intervals, samples were taken and TOC, OUR and SS of the control and tested systems were determined.

The analytical method used for SS was outlined in Standard Methods[15]. The TOC was determined using a TOC-analyzer (TOC-5000, Japan). The OUR value was measured with the YSI model-58 dissolved oxygen meter.

RESULTS

Effect of Shock NaCl Loading on TOC Removal Efficiency

The effect of shock NaCl loadings on activated sludge process was evaluated based on TOC removal efficiency and the OUR of activated sludge. TOC removal efficiency was defined as:

TOC removal efficiency (η)=C_t/C_0 (1)

Where: C_t is TOC in wastewater at time t, mg/L. In this study, the zero point of time was defined as 1 hour before the addition of NaCl.

C_0 is TOC in wastewater 1 hour before the addition of shock NaCl loading, mg/L.

TOC_{1-} is TOC in wastewater just before the addition of NaCl and TOC_{1+} is TOC in wastewater just after the addition of NaCl.

The variation of TOC removal efficiency with NaCl concentrations is depicted in Fig. 1. From Fig. 1, it was found that NaCl shock loading had no obvious influence on TOC removal efficiency of the activated sludge system when the shock NaCl concentrations were 0.1 g/L and 0.5 g/L. The TOC removal efficiency was near to that of the control experiment. While the shock loading was 2 g/L, TOC removal efficiency decreased 7% at t=10 hours, compared with the control reactor.

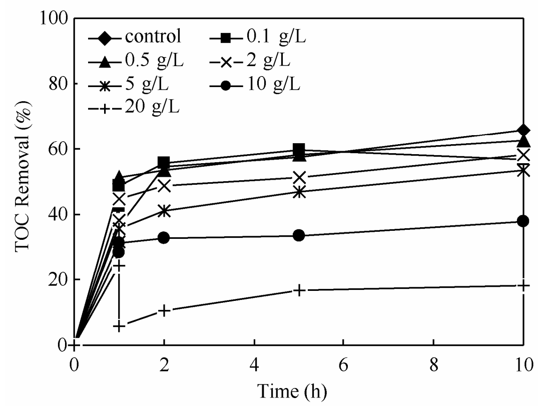

FIG. 1. Variation of TOC removal efficiency at different shock loadings of NaCl.

Effect of Shock NaCl Loading on OUR

Oxygen uptake rate (OUR) is an important parameter to express the microbial activity of activated sludge in the wastewater treatment process. Actually, more attention was paid to the change of OUR of activated sludge when the addition of shock NaCl loading in this study.

A parameter defined as OUR retention was utilized to express the change of activity of activated sludge, shown in Equation (2).

OUR retention=OUR_t/OUR_{1-} (2)

Where: OUR_t is value of OUR of activated sludge at time t;

OUR_{1-} is value of OUR of activated sludge just before the addition of NaCl;

OUR_{1+} is value of OUR of activated sludge just after the addition of NaCl.

The influence of NaCl concentrations on OUR value is shown in Fig. 2. The experimental results indicated that low shock concentrations of NaCl (0.1 g/L and 0.5 g/L) had no significant effect on OUR of the activated sludge, as the impact on TOC removal efficiency. OUR retention of activated sludge was near to that of the control experiment.

Macro-kinetic Analysis

To examine the effect of shock NaCl loading on the activated sludge system, macro kinetic analysis is a useful method. The substrate utilization rate was subjected to the substrate concentration and the amount of active biomass, etc. In this study, in order to elucidate

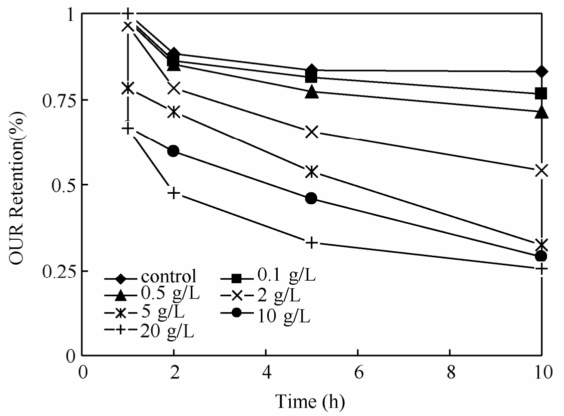

FIG. 2. Variation of OUR retention of the activated sludge at different shock loading of NaCl.

the impact of shock NaCl loading on activated sludge process, a pseudo first-order model was employed to express the substrate utilization rate, shown in Equation (3). This method was based on the following assumption: in such a short time in this study, the amount of active biomass was constant and macro kinetics analysis was for the comparison between the tested reactor and the control reactor.

$$-dS/dt = KS \quad (3)$$

where: $-dS/dt$ is the substrate utilization rate, g/(L h)

K is the substrate utilization rate constant, h^{-1}

S is substrate concentration in the reactor (expressed as TOC), g/L

Integrating equation (3) for the boundary conditions: t=1 to t=t and $S=S_1$ to $S=S_t$, yields the following equation:

$$\ln S_t - \ln S_1 = -K(t-1) \quad (4)$$

Equation (4) shows that there is a linear relationship between $\ln S_t$ and t, and the K is the slope of this line. The straight-line plots of lnS *versus* time were analyzed and the K at various NaCl shock concentrations is summarized in Table 1.

TABLE 1

Substrate Utilization Rate Constant (K) at Various Shock Loadings of NaCl

NaCl Shock Concentrations (g/L)	K (h^{-1})	K_0^*/K
0.1	0.465	1.1
0.5	0.427	1.2
2	0.341	1.5
5	0.135	3.8
10	0.100	5.1
20	0.067	7.6

Note. * K_0 is corresponding to substrate utilization rate in the control reactor and the value was determined to be 0.512 h^{-1}.

DISCUSSION

Fig. 1 shows that TOC removal efficiency decreased sharply at a high shock loading of NaCl, it decreased by 30%, 45%, and 72%, respectively, when NaCl concentrations were 5 g/L, 10 g/L, and 20 g/L, compared with the control reactor. In addition, when the NaCl shock concentration was 20 g/L, it was different from the other cases. In comparison with TOC_{1-}, TOC_{1+} was increased by 25%. The reason may be that high NaCl shock concentrations caused plasmolysis so that cellular constituents were released immediately into wastewater treatment systems. However, when t > 1 h, the TOC removal efficiency of this system increased gradually, the negative impact of shock NaCl loadings could be recovered partly.

Fig. 2 reveals that the activated sludge process could function normally through adjusting its metabolism under these NaCl concentrations. At the moment of NaCl addition, OUR decreased rapidly, especially when the activated sludge was dosed with 2 g/L and 5 g/L of NaCl. The OUR value was decreased by 20% and 22%, respectively. The activity of sludge was inhibited under such conditions and the respiration rate decreased.

From Figs. 1 and 2, we can see that both the TOC removal efficiency and OUR retention were not affected obviously at the shock concentration of 2 g/L. The reason may be that the microbial physiological frame was not destroyed, respiration and anabolism could perform normally, and the activated sludge could recover through acclimatization. The OUR value of the sludge dropped sharply at the point of adding NaCl when the NaCl concentrations were 5 g/L, 10 g/L and 20 g/L, respectively. Fig. 2 demonstrates that the OUR was decreased by 35% and 37% when the NaCl concentrations were 10 g/L and 20 g/L.

Figs.1 and 2 show that the effect of shock NaCl loading on the activated sludge treatment system varied with the NaCl concentrations. The higher the NaCl concentration, the more the TOC removal efficiency decreased because a high NaCl concentration could destroy the normal osmotic pressure and cause the loss of biological activity.

From Table 1, it is easy to infer the impact of shock NaCl loading on the activated sludge system treating domestic wastewater. The sequence of impact is: NaCl=20 g/L > NaCl=10 g/L > NaCl=5 g/L > NaCl=2 g/L > NaCl=0.5 g/L > NaCl=0.1 g/L. That is to say, the higher the shock NaCl loading, the more the notable impact. When the NaCl shock loading was less than 2 g/L, the impact could be ignored, however when the NaCl shock concentration was up to 20 g/L, the impact was so serious that some measures must be taken so as to avoid unrecoverable impairment.

CONCLUSION

Based on the experiment results obtained, the following conclusions can be reached: the effects of salt shock loading on activated sludge vary with the shock concentrations of NaCl. TOC removal efficiency and the OUR of activated sludge are not deteriorated when the shock NaCl loading is less than 0.5 g/L, however, when the NaCl shock concentration is greater than 5 g/L, OUR of the activated sludge can be reduced by more than 35% and TOC removal efficiency decreased by more than 30%. The impact of shock NaCl loading on biological treatment systems can be investigated through the variations of substrate utilization rate at different shock NaCl loadings.

REFERENCES

1. Zhan, X., Wang, J., Wen, X., and Qian, Y. (2000). Influence of Inorganic Salt on Biodegradability of Dyestuffs. *J. Environ. Sci.* **12**, 416-421.
2. Zhan, X., Wang, J., Wen, X., and Qian, Y. (2001). Indirect electrochemical treatment of saline dyestuff wastewater. *Environmental Technology* **22**, 1105-1112.
3. Woolard, C. R. and Irvine, R. L. (1995). Treatment of hypersaline wastewater in the sequencing batch reactor. *Water Res*. **29**, 1159-1168.
4. Mitchell, R. (1974). Introduction to Environmental Microbiology. Prentice-hall, Inc., Englewood.
5. Kargi, F. (2002). Enhanced biological treatment of saline waste-water by using halophilic bacteria. *Biotechnology Letters* **24**, 1569-1572.
6. Woolard, C. R. and Irvine, R. L. (1994). Biological treatment of hypersaline wastewater by a biofilm of halophilic bacteria. *Water Environ. Res*. **66**, 230-235.
7. Kargi, F. and Dincer, A. R. (1999). Salt inhibition of nitrification and denitrification in saline wastewater. *Environ. Technol*. **20**, 1147-1153.
8. Lawton, G. W. and Eggert, E. (1957). Effects of high sodium chloride concentrations on trickling filter slimes. *Sew. Ind. Wastes* **29**, 1228-1237.
9. Stewart, M. J., Ludwig, H. F., and Kearns, W. H. (1962). Effects of varying salinity on extended aeration process. *J. Wat. Poll. Cont. Fed.* **37**, 1167-1177.
10. Burnett, W. E. (1974). The effect of salinity variations on the activated sludge process. *Wat. Sewage Wks.* **121,** 37-55.
11. Witmayer, G., Froula, D., and Shell, G. (1985). Effect of salinity on a rendering-meat packing hide curing wastewater activated sludge process. Proc. 40th Ind. Waste Conf., Purdue Univ., West Lafayertte, Ind., 79-86.
12. Kincannon, D. F. and Gaudy, A. F. Jr. (1968). Response of biological waste treatment system to change in salt concentrations. *Biotechnol. Bioeng.* **10**, 483-496.
13. Tokuz, R. Y. and Eckenfelder, W. W. Jr. (1979). The effect of inorganic salts on the activated sludge process performance. *Wat. Res*. **13**, 99-104.
14. Dan, N. P., Visvanathan, C., and Basu, B. (2003). Comparative evaluation of yeast and bacterial treatment of high salinity wastewater based on biokinetic coefficients. *Bioresource Technology* **87**, 51-56.
15. APHA (1985). Standard Methods for the Examination of Water and Wastewater. 16th ed., Am, Pub. Health Assoc., Washington, D. C.

(*Received January* 10, 2004 *Accepted August* 31, 2004)