



Treatment of mixed (fresh and salt) wastewater

Dr. S .L. Tang and T. H. Lee, Hong Kong

Hong Kong has the geographical advantage of being situated on the coast and therefore it is possible to use dual water supply systems (fresh + sea water systems in two separate distribution networks) for potable and non-potable uses. From the sea water supply system, about three quarters of the population in Hong Kong is supplied with salt water for toilet flushing. The seawater is extracted from the sea directly and pumped by pumping stations located near the shore and supplied to the households. The used toilet flushing water (saline wastewater) is discharged into the sewerage system which conducts the mixed (fresh + salt) wastewater into the STW (sewage treatment works). The salt concentration of the mixed wastewater is between 5,000 mg/l to 6,000 mg/l, about one-fifth of seawater salt concentration, in Hong Kong.

Wastewater treatment system in Hong Kong

The incoming sewage enters at the screw pumping station of the inlet works. It is then pumped to the screening chamber, where coarse solids in the sewage are removed by bar screens. The screened sewage passes to the detritors for the removal of grits before going on to the primary sedimentation tanks for settling suspended solids (see Fig-

ure 1). The settled sewage from the primary sedimentation tanks travels to the aeration tanks for biological treatment. Using fine bubble diffusers, low-pressure air is fed continuously into the aeration tank which provides the oxygen essential for sustaining the life of the microorganisms which assimilate the pollutants in the sewage. Extended aeration systems are used in the biological treatment processes so that the rear part of the long aeration tank is used for nitrification, and then later for denitrification (an anoxic process) with a much reduced air supply in this part of the aeration tank. The treated sewage finally passes to sedimentation tanks in which the activated sludge is settled out. A controlled amount of this settled activated sludge is re-circulated back to the aeration tank. The remaining activated sludge (surplus activated sludge), together with the primary sludge is then conveyed to sludge treatment facilities in the STW. The final effluent from final sedimentation tanks is pumped through the effluent pumping station to the sea outlet for disposal.

Previous laboratory scale research work for the treatment of mixed wastewater

Over twenty years ago, an experiment (believed to be the first experiment of this sort) was carried out by Kessick and

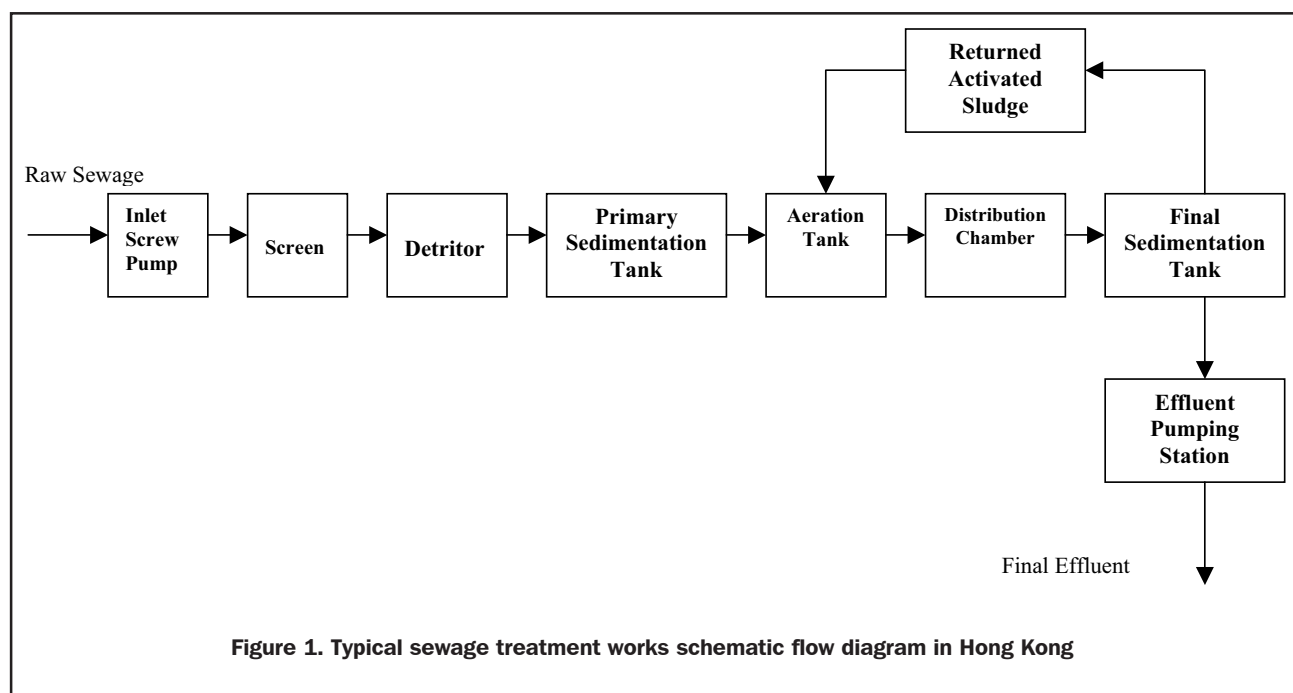


Figure 1. Typical sewage treatment works schematic flow diagram in Hong Kong

Manchen (1976) on the treatment of saline wastewater. In that experiment, with the addition of sea salts (39,100 mg/l) to primarily treated domestic wastewater, TSS (total suspended solids) and VSS (volatile suspended solids) were found to increase by 40% and 11 % respectively. The marked increase of suspended solids was believed to be because of the inhibition of the biodegradation of the suspended fraction in a saline environment. Biodegradation of the soluble fraction, however, was found to be unaffected by sea salts added to the levels expected in a seawater waste system. Hamoda and Al-Attar (1995) carried out a study on the effects of high NaCl concentrations on activated sludge treatments. The findings were that the activated sludge process did not deteriorate as a result of the constant application of NaCl up to 30,000 mg/l, that NaCl did not inhibit biomass growth, that the salt appeared to stimulate the aggregation of microbial cells and improve sludge settling, and that the response of the acclimated activated sludge saline-water system was similar to that of the fresh-water system. It was found that kinetic models developed for the fresh wastewater system could be used successfully. This phenomenon most likely contributed to by the growth of halophilic (i.e. salt-loving) micro-organisms in the system. For nitrification and denitrification, Dincer and Kargi (1999) carried out experiments on the salt inhibition effects of these two processes. It was found that nitrification efficiency dropped markedly (to half or one-third) as salt levels increased, and salt inhibition effects became more significant at salt concentrations above 20,000 mg/l. It was also found that nitrobacter (responsible for converting nitrite to nitrate) was more adversely affected than nitrosomonas (responsible for converting ammonia to nitrite), thus resulting in an accumulation of nitrite in the effluent at high salt concentrations. As to denitrification it was found that when the salt concentration was increased to a level above 10,000 mg/l, the denitrification efficiency dropped. The denitrification rate seemed to be more sensitive to salt inhibition when compared to nitrification. Other researchers, such as Kargi and Uygur (1996, 1997) did experimental works on saline wastewater treatment by aerated percolator unit and rotating bio-disc contactor. The findings of these works are interesting, but because their treatment methods are not directly relevant to this paper, the details of the findings are therefore not discussed here.

Experiences of activated sludge process in Tai Po STW in Hong Kong

BOD and COD removal efficiency

In the aeration tank of an activated sludge system in Tai Po STW, the heterotrophic organisms are responsible for BOD removal under the aerobic process. High BOD removal was found in the effluent and it showed there is no adverse effect on heterotrophic organisms under saline conditions. There is also no significant effect on COD removal found in such

conditions. This was supported by the paper written by Yu, S.M., W.Y. Leung, K.M. Ho, P.F. Greenfield and W.W. Eckenfelder (2000) confirming that COD removal efficiency was not affected in saline conditions in some bench-scale experiments.

Nitrification and denitrification

Experience in Tai Po STW is that the nitrification process has been inhibited in saline wastewater. By the way, from the paper written by Yu et al. (2000), bench-scale investigations of nitrification have been done and it was found that nitrification is greatly impaired with increase in salinity. As the degree of salinity fluctuates throughout the day the variation of Cl⁻ ions in wastewater, due to differing peak hours when people are flushing the toilet, considerably affects the rate of nitrification in the treatment process. The activity of autotrophic organisms responsible for nitrification was determined in several batch tests and was found to be about 1/2 to 1/3 of the degree of activity observed in fresh wastewater. In order to restore the achievement of the original full nitrification for the activated sludge nitrogen removal process, the Tai Po STW in Hong Kong has the sludge age and mixed liquor suspended solids (MLSS) increased in order to compensate for this deficiency. Sludge age was increased from 10 days in fresh wastewater to 15 days in saline wastewater. At the same time, the MLSS is increased from 2,000 mg/l in fresh wastewater concentration to approximately 3,000 mg/l in saline conditions. Given sufficient nitrifying bacteria in the system, there is no need to lengthen the aeration time and the amount of oxygen required. The treatment plant just keeps the same hydraulic retention time, which is about 8-11 hours, and also the same dissolved oxygen level is maintained at around 2 mg/l before and after the introduction of saline wastewater. The denitrification process, unlike BOD/COD removal and nitrification processes (which require a large amount of oxygen), is basically anoxic. The result found in Tai Po STW is that the heterotrophic organisms in saline wastewater perform satisfactorily in the de-nitrification process, even when the wastewater is saline. The presence of dissolved oxygen is measured by redox potential (ORP), which is between +50 mV and -100 mV. This means that the wastewater contains nitrite ions and the anoxic process does occur. It appears that no adverse effect is found on denitrification in saline wastewater in Tai Po STW.

Sulphate concentration and odour problems

The introduction of seawater to wastewater treatment plants not only adversely affects nitrification, but also increases the sulphate concentration of biological processes because sea water contains considerable undesirable sulphur compounds. The increase of sulphate concentration can lead to an increase of H₂S in any down stream anaerobic process such as sludge digestion. In order to reduce the release of H₂S gases during biological treatment processing, a certain amount of ferric chloride (Fe₂Cl₃) is added. However, the added Fe₂Cl₃ can create corrosion problems

in tanks, pipelines and so on. These problems are now being investigated by a study team from the University of Hong Kong.

Besides odour problems, a marked reduction of ortho-phosphate (O-P) content in sewage can be found when sulphate concentration increases. The reduction of soluble phosphate is believed to be a chemical precipitation process associated with the low solubility of most phosphate salts. It is removed as primary sludge in the primary sedimentation process. As a result, the level of O-P content must be monitored carefully in order to ascertain that the ratio of BOD :N:P is 100:5:1 as required by the DSD (Drainage Services Department) of Hong Kong. If the required P, is reduced in saline condition, phosphate acid will be added so that the O-P concentration can be increased to reach the required standard.

Conclusion

The addition of seawater to fresh wastewater, from the experience obtained in Hong Kong, does not significantly affect BOD/COD removal efficiency and denitrification. The former experience (BOD/COD removal) is consistent with previous researchers' findings but the latter (denitrification) is not. The adverse effects found are the inhibition of nitrification, the increase in sulphate concentration and hence the occurrence of odour problems. Salinity in wastewater affects mainly nitrification. An increase of the concentration of the mixed liquor suspended solids (MLSS) from 2,000 mg/l to 3,000 mg/l and the sludge age from 10 days to 15 days can improve nitrification in saline conditions. This can be achieved by reducing the wastage of the returned activated sludge (ie. the settled activated sludge from the final sedimentation tanks) and increasing its circulation back to the aeration tank. Moreover, the high content of sulphate compounds in seawater, which will result in a reduction of the ortho-phosphate (O-P) concentration, will increase the content of H₂S gases. This will cause hazards (eg. odours, etc.) to the treatment plant and the addition of ferric chloride to the wastewater can reduce the production of H₂S. The ferric chloride added, however, creates corrosion problems, the mitigation measures of which are being investigated by a study team from the University of Hong Kong, and the result is not yet available at the time when this paper is written.

Acknowledgement

Thanks are due to Mr. W.Y. Leung of DSD (Drainage Services Department) of The Hong Kong SAR Government. He has kindly help the authors by providing useful information so that the production of this paper becomes possible.

References

- DINCER, A.R. and KARGI, F. (1999). Salt inhibition of nitrification and denitrification in saline waste water. *Environmental Technology*, Vol.20, pp1147-1153.
- HAMODA, M.F. and AL-ATTAR, M.S. (1995). Effects of high sodium chloride concentrations on activated sludge treatment. *Water Science Technology*, Vol.31, No.9, pp.61-72.
- KARGI, F. and UYGUR, A. (1996). Biological treatment of saline wastewater in an aerated percolator unit utilizing halophilic bacteria. *Environmental Technology*, Vol.17, pp.325-330.
- KARGI, F. and UYGUR, A. (1997). Effect of liquid phase aeration on performance of rotating biodisc contactor treating saline wastewater. *Environmental Technology*, Vol.18, pp.623-630.
- KESSICK, M.A. and MANCHEN, K.L. (1976). Salt water domestic waste treatment. *J. WPCF*, Vol.48, No.9, pp.2131-2136.
- TANG, S.L. (2000). Dual water supply in Hong Kong. *Proceedings of the 26th WEDC Conference on Water, Sanitation and Hygiene, Dhaka, Bangladesh, November 2000*, pp.364 – 366.
- YU, S.M., LEUNG, W.Y., HO, K.M., GREENFIELD, P.F. and ECKENFELDER, W.W. (2000). The impact of seawater flushing on biological nitrification-denitrification activated sludge sewage treatment process. *Drainage Services Department, Hong Kong SAR Government, Hong Kong*.

DR. S. L. TANG, Civil and Structural Engineering Department, The Hong Kong Polytechnic University, Hungghom, Kowloon, Hong Kong.

T. H. LEE, Method Engineer, Dragages et Travaux Publics (H. K.) Ltd., 27/F, 625 Kings Road, North Point, Hong Kong.
