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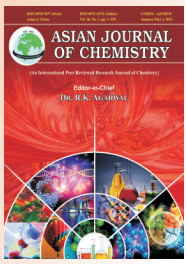

REVIEW

Technology for Small Sewage Treatment: The Chinese Perspective

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On the basis of demographic projections, it is estimated that the quantity of sewage which will be produced in China between 2009 and 2015 will increase from 35.52 billion tons to 56.65 billion tons. Sewage treatment and its management is one of the most critical environmental issues of today. The treatment and disposal of sewage contribute a considerable proportion of the cost. The increasing amount of sewage and more and more legislative regulation of its disposal have stimulated the need for efficient and economical technologies to process sewage. Currently, the predominant method for the disposal of this sewage is biological treatment. The small sewage treatment facilities are cost-effective and getting benefit instantly. Here we review the state of knowledge and technology in small sewage treatment, which makes proposals to the construction of sewage treatment.

Keywords: Sewage treatment, Environmental issues, Technologies.

INTRODUCTION

The term sewage refers to the wastewater produced by a community, which may originate from three different sources: (a) domestic wastewater, generated from bathrooms and toilets and activities such as cooking, washing, *etc*.; (b) industrial wastewater, from industries using the same sewage system for their effluents (treated or not) and (c) rain-water, particularly in the case of sewer systems constructed for both wastewater and storm-water (combined systems)[1-10]. The treatment and disposal of sewage is one of the most critical environmental issues of today. The waste stream of sewage is rapidly growing, generating wastes which require management in compliance with the law[11-16]. China is inhabited by 1.37 billion people with an average population density of 140 persons per square kilometer and has about a territory of 9,600,000 km^2, of which 9,326,410 km^2 is occupied by land. In the year 2008, more than 33 billion tons of sewage was produced. In China, only 372 cities possessed a modern wastewater treatment plant with enhanced nitrogen and phosphorus removal. In these plants, 5.7 million tons of waste was treated per day[17-24]. Table-1 presents the quantities of municipal sewage produced in China in the years 2001-2009 along with the anticipated amount in the future.

According to the Chinese environmental policy and the objectives of the National Wastewater Treatment Plan, the quantity of sewage treated in China is systematically increasing. A measurable effect of this is, first of all, the increasing proportion of the population being served by wastewater treatment, but also the growth of the amount of produced sewage. On the basis of demographic projections, it is estimated that the quantity of sewage which will be produced in China between the years 2009 and 2015 will increase from 35.52 billion tons to 56.65 billion tons[25].

Proper treatment and disposal of sewage avoiding harm to environment is an integral part of wastewater treatment and environmental protection. Municipal sewage has high water content, high load of organic pollutants and high content of pathogens as well as considerable concentration of heavy metals. Generalized processes for sewage handling are biological treatment, chemical treatment and physical treatment. Currently, the predominant method for the disposal of this sewage is biological treatment. In order to achieve a better understanding of the prospective application of biological technology for the small sewage treatment, here a brief review of this promising technology is presented and application of this technology and some results reported from both laboratory and full-scale studies are reviewed. The effects of biological

TABLE-1
AMOUNT OF MUNICIPAL SEWAGE PRODUCED IN CHINA IN THE PERIOD 2001-2009 (MINISTRY OF ENVIRONMENTAL PROTECTION OF PRC, 2006; RONG AND WANG, 2012) (AND THE ANTICIPATED AMOUNT IN THE FUTURE)

Year	Amount of sewage produced, billion tons
2001	22.77
2003	24.76
2005	28.14
2006	29.75
2008	33
2009	35.52
2015	56.65

technology for the small sewage treatment are discussed in detail. Finally, some concluding remarks are given and future directions are also proposed.

Technology employed in sewage processing: Five options are currently available that can be used for the processing of sewage, which contains septic tank, stabilization pond process, land treatment system, activated sludge method and biological membrane.

Septic tank: People began to treat sewage by septic tanks 100 years ago. More than 70 % of suspended solids content and 30 % of BOD_5 can be reduced by septic tanks, but it is still difficult to achieve the requirements of the integrated wastewater discharge standard. Therefore, sewage is able to discharge after it meets the integrated wastewater discharge standard by centralized sewage treatment plants. This caused repeated construction investment and reduced the efficiency of the sewage treatment plant. Currently many cities require new district to prohibit the use of septic tanks[26-29].

Unpowered sewage treatment apparatus is an improved septic tank, which is applied to many southern cities. The apparatus does not need power and it is flexible[30]. But its civil construction cost is high and it can not ensure the water quality in the running process, which has been banned in Japan.

Stabilization pond process: Stabilization pond process was applied to treat the sewage 100 years ago, but it was not widely used until World War II. Stabilization pond was employed to small sewage treatment in the United States and Europe in particular. The United States owned stabilization pond more than 7000 in 1983, 90 % of which was built in the small town with a population of less than 5000. Stabilization pond was included in large key projects of the 7th five-year plan in 1986 and the stabilization pond developed rapidly in China[31].

It can take full advantage of the terrain if sewage is treated by stabilization pond and infrastructure and maintenance costs are low and sewage is able to realize resource recovery. However, it covers a big area and the treatment effect is vulnerable to impacts of climate. Land is much in Northern China, but it is not suitable for application because of cold climate; land resources are precious in Southern China and it is not suitable for application, which makes stabilization pond difficult to spread in China[32-34].

Land treatment system: Wastewater land treatment system contains many forms, which is slow rate land treatment system, rapid infiltration land treatment system, wetland treatment system, subsurface wastewater infiltration system, which is often used together with the oxidation pond. Treatment of sewage by land treatment system is researched deeply in China during the seventh five-year plan period and the user manual of sewage treatment by land treatment system is compiled. Application of land treatment system in China contains sewage slow rate land treatment system in Shenyang, the Changping sewage rapid infiltration land treatment system and municipal sewage land treatment system in Tianjin[35].

Artificial wetland wastewater treatment technology has unique advantages for small sewage treatment and it can take full advantage of the natural conditions; it has a simple structure and running cost is only 10-50 % of the traditional craft[36]. A lot of natural wetlands distribute in China from south to north and these wetlands are handled appropriately to develop artificial wetland technology, which has a broad space.

Investment of wastewater land treatment is less and wastewater can be achieved resource recovery. Wastewater land treatment and utilization can be combined in China vast rural areas and small urban areas.

Activated sludge method: Because water quality and quantity of small sewage water treatment plant changes larger and activated sludge process is particularly sensitive to the shock loading, so too small wastewater treatment plant is not appropriate to use activated sludge treatment process. Only eight use the activated sludge process within 127 small sewage treatment plant (<1000 population equivalent) in Eastern Switzerland[37]. In 1987, the Norwegian Environmental Pollution Control Agency made a survey on the existing small-scale sewage treatment plants and believed that activated sludge process often cause sludge wastage due to shock loading and running is difficult to control. Therefore, biological membrane method was recommended to treat small sewage. If activated sludge process is selected, sludge storage is needed to set up[38-42].

Oxidation ditch and sequencing batch reactor originate from the activated sludge process and it is difficult to control for small sewage, so it has few applications. Hydraulic retention time of extended aeration process is too long and cost of treatment is high. It is not widely used in China due to the restrictions of economic development level.

Biological membrane: Applications of the biofilter on small sewage treatment are not too much. Researches on the biological aerated filter and earthworm biofilter are more[43-46], but practical engineering applications are less.

The rotating biological disc began in Germany and is widely used in western countries. Nearly 50 % small sewage treatment plants that its population scale is less than 1000 in Swiss employ the rotating biological disc technology; 21 small-scale sewage treatment plants of 29 in northwestern England employ rotating biological disc[47]. Rotating biological disc has been applied in China, sewage treatment and reuse project of Jinan Nanjiao hotel utilizes the parallel turntable, which obtains a well-functioning.

Research progress of small sewage treatment

Researches on septic tank: Fu *et al.*[48] apply the improved 3 cell septic tank to treat sewage. The results indicate that suspended solids, COD, chroma and ammonia nitrogen removal by using three different thicknesses filler is from 81.6

to 92.9, 17 to 60.5, 13.5-23.2 and 7.9 to 11.9 %, respectively. Various pollutants removal increases with increasing thickness of the filler. Wang *et al.*[49] investigate the septic tank of a residential area in the typical city o f northwest region-Lanzhou, the change of sewage quality and the removal of pollutants indicators after passing septic tanks is analyzed. The results indicate that after the septic tanks treatment, the concentration of COD_{Cr}, BOD_5, nitrogen, total phosphorus, animal and vegetable oils in domestic wastewater reduced. The average annual removal of them reached to 83.6, 51.1, 64.3, 68.2 and 75.6 %, respectively. And the biodegradation of wastewater is improved obviously. Their results provide technical reference to the problem on setting or canceling the septic tank by comprehensively evaluating the functions and characteristics of septic tanks. Wang *et al.*[50] select a total of 168 normally running. Three-Grille-Model septic tank in 9 cities of Jiangsu is used as objects of the research. Analysis of the samples shows that "Three-Grille-Model" septic tank could reduce COD_{Cr} by 48.51 %, total nitrogen by 6.83 % and total phosphorus by 23.92 %. Generally, its treatment efficiency is lower than of biogas-digesterc. The treated water flowing out of the septic tanks fails to meet the criteria of the national standard for wastewater discharge and its discharge will significantly affect the environment.

Researches on stabilization pond process: Li *et al.*[51] apply constructed wetland/stabilization pond process to treat rural domestic sewage. The results show that the average removal rates of COD, BOD_5, suspended solids, total nitrogen, NH_4^+-N and total phosphorus are 75.1 to 87.3, 75.2 to 94.3, 90.2 to 97.6, 50.2 to 67.8, 65 to 75.3 and 70.6 to 85.9 %, respectively. The effluent quality meets the first class criteria specified in the integrated wastewater discharge standard (GB 8978-1996). This process has characteristics of low investment, good treatment effect, simple operation and low maintenance cost. He[52] studies sewage of development area in Shihezi by hydrolysis acidification stabilization pond process. The findings indicate that the effluent water reaches discharge standards for farmland irrigation water, this process is an economic application sewage treatment process; the best hydraulic retention time of hydrolysis acidification segment is 3 h; COD capacity burden in the 2.09-2.73 kg COD/(m^3 d) at hydrolysis acidification segment, biodegradability of effluent water is higher. The best hydraulic retention time of stabilization pond is 9d; BOD surface burden in the 19.44-55.56 kg/(hm^2 d) at stabilization pond segment, the BOD and COD of effluent can reach farmland irrigation standards. (GB5084-92).

Han[53] apply stabilization pond process to treat rural domestic sewage. Under the optimal parameters, stabilization of the pond process can be use to handle rural domestic sewage. The treatment effect was stable. The effluent quality met the national discharge standard. That was to meet water quality requirements. The average removal rates of COD, total phosphorus and ammonia-nitrogen were, respectively 89.6, 83.2 and 86.0 % in an aerobic pond reactor. The average removal of COD, total phosphorus and ammonia-nitrogen were, respectively 86.9, 78.3 and 77.4 % in a facultative pond reactor. Sludge activity was stable.

Tang *et al.*[54] present the application of a new type stabilization pond process, which is double anaerotanks-oxidation pond-oxidation ditch, treating wastewater of town. It is indicated by the practical operation project that the process has high treatment efficiency and stable water quality of effluent. All indexes of effluent can meet the secondary standard in. Integrated Wastewater Discharge Standard (GB8978-1996). Huang *et al.*[55] apply stabilization pond process to treat the sewage and investigates the removal of nitrogen and phosphorus. The results show that the average removal of total nitrogen, total phosphorus, NO_3^--N and NH_3-N by the whole system are 25.3, 50.6, 38.4 and 35.6 %, respectively. The system improves water quality and contributes to the ecological landscape, which provides a demonstration for other water purification projects. Fig. 1 is the flow chart of domestic sewage treatment process.

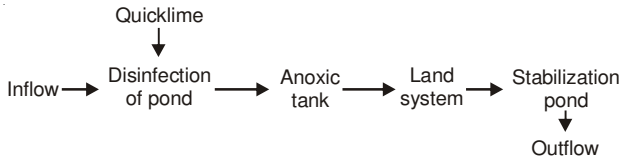

Fig. 1. Flow chart of domestic sewage treatment process

Researches on land treatment system: Zhang *et al.*[56] test a pilot plant of subsurface wastewater infiltration system filled with red clay to treat rural sewage with hydraulic loading of 2 cm/d. The results show that average removal of COD, NH_4^+-N, total phosphorus and total nitrogen being 84.7, 70, 98 and 77.7 %, with average effluent concentrations of COD, NH_4^+-N, total phosphorus and total nitrogen being 11.7, 4.0, 0.04 and 4.7 mg/L, respectively, which met the standard for water reuse issued by the Ministry of Construction of China. Guo *et al.*[57] bring land treatment system to process the rural sewage and investigates the pollutants removal at low temperature. The experimental results indicate that the effect of low temperature on COD removal is less obvious, as the COD removal is 74.66 %; the COD of effluent is less than 40 mg/L, which satisfies the first level B criteria specified in the discharge standard of pollutants for municipal wastewater treatment plant (GB 18918-2002). The low temperature has a notable effect on the removal of total phosphorus and NH_4^+-N and the average removal of total phosphorus and NH_4^+-N are 37.44 and 36.25 %, respectively.

Zheng[58] introduces subsurface wastewater infiltration system to process the rural sewage. The results indicate that suspended solids, COD, ammonia nitrogen, total phosphorus and total nitrogen have good removal effect by infiltration filter system. suspended solids remove is above 92 %, COD removal is above 85 %, total phosphorus removal is 73 %, DP removal is 72 %, total nitrogen removal is 66.6 %, NH_4^+-N removal is 69 %. Wang and Sun[59] introduce artificial fast filtration system to process the rural sewage and discusses the factors of effluent COD removal of wastewater land treatment as an example of artificial rapid infiltration system. The result implies that shortening hydraulic load cycle is able to raise reoxy-genation efficiency and stabilize water quality. Zhang *et al.*[60] design subsurface infiltration system to treat rural domestic wastewater in Dianchi valley. The treatment ability is 30 m^3/d and the design hydraulic loading of the infiltration system is 0.08 m^3/(m^2 d). The COD, total nitrogen and total phosphorus removal

of the system reach 86.7, 85.5 and 96.5 %, respectively. The system offers advantages including lower construction and operation costs, easy maintenance and many economic returns.

Peng *et al.*[61] concisely introduce the history of development, principle and advantage of artificial wetland and studies artificial wetland of Shajing town. The result implies that its respective COD removal is 83 % and total nitrogen is 45 %, the effluent quality can meet the National Sewage Discharge Standards. Cui *et al.*[62] reported the sewage treatment by hybrid constructed wetlands. The results show that the performance of both hybrid constructed wetlands is much better than single type wetlands. The average removal rates of COD, BOD_5 and total phosphorus by the combination of vertical-flow and horizontal flow constructed wetland were 70.52, 69.21 and 55.56 %, respectively. The combination of two vertical-flow wetlands system had high purification efficiency for total phosphorus, of which the average removal rate is 72.62 % and the concentration of effluent is between 0.10 and 0.60 mg/L. The average removal rates are 64.74 % for COD and 60.63 % for BOD_5. It is obvious that the concentrations of COD, BOD_5 and total phosphorus in the effluent could all reach to the first rank of. Urban Sewage Treatment Plant Pollutants Drainage Standards. (GB 18918-2002). Fig. 2 is the flow chart of domestic sewage treatment by land treatment system.

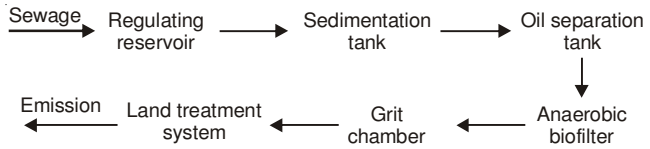

Fig. 2. Flow chart of sewage treatment process

Researches on activated sludge method: Hu *et al.*[63] suggest the high-load activated sludge process that is suitable to treat municipal wastewater in medium and small cities, aiming at high investment and operating cost for secondary municipal wastewater treatment plants. Having no primary sedimentation tank, the high-load activated sludge process has advantages such as high-load, short sludge age, good sludge settleability, no sludge bulking. The high-load activated sludge process removes pollutants in the ways of flocculation, adsorption and precipitation. It removes COD, BOD and suspended solids in high rate. It also can remove nitrogen and phosphorus. The effluent can meet the requirement of. The Standards for Irrigation Water Quality. Zhang *et al.*[64] study the treatment of municipal wastewater by sequencing batch reactor and the regularity and effects of nitrogen and phosphorus removal from municipal wastewater. The results show that the removal rate of BOD_5, COD_{Cr}, NH_3-N and total phosphorus was respectively 85-93, 82-86, 53-87 and 85-99 %.

Zhou and Sun[65] study the sewage treatment to determine the best aeration time, the best pH range of complete mixing activated sludge process. According to the result of the experiment, they can determine the rank of COD of sewage and the concentration of sludge to ensure the effect of treatment. The test results showed that completely mixed activated sludge process of domestic sewage is a very satisfactory method, with advantage of smaller covering area, high removal rate. Furthermore, it can endure more shock load. Finally, technical process of activated sludge process is very simple. Zhang *et al.*[66] test sequencing batch reactor (SBR) process in municipal wastewater treatment. When sludge loading is 0.14-0.26 kg [BOD_5]/(kg [MLSS] d), the indices of effluent from SBR are as follows: BOD_5 = 5.12-13.6 mg/L, COD_{Cr} = 10.7-32.2 mg/L, NH_3-N = 2.83-9.23 mg/L and total phosphorus = 0.1-0.45 mg/L. The result shows that using SBR to treat municipal wastewater with low content carbon and nitrogen is applicable.

Pang *et al.*[67] apply the pilot-scale airlift oxidation ditch to treat the sewage. The result shows that it is possible to achieve a COD effluent concentration < 50 mg/L at the maximum loading rate of 0.88 kg/(m^3·d). The ammonium nitrogen concentration of the effluent could be lower than 5 mg/L with a loading rate less than 0.06 kg/(m^3 d). After the dissolved oxygen in the straight part is maintained between 0.6-1 mg/L, total nitrogen (TN) concentration in the effluent was less than 15 mg/L and kept steadily for over 14 days. The result shows that using pilot-scale airlift oxidation ditch to treat sewage is applicable. Zhang *et al.*[68] introduce the composition, technological principle and operational characteristics of a improved oxidation ditch device for municipal sewage treatment by integration with the technological process of a sewage treatment plant, its operating conditions and treating effect are analyzed; the removal rates of main effluent indexes, such as BOD, COD, suspended solids, NH_3-N and total phosphorus content, reached to 90, 87, 93, 97 and 64 %, respectively, reaching the national discharge standard. Fig. 3 is the flow chart of domestic sewage treatment by activated sludge method.

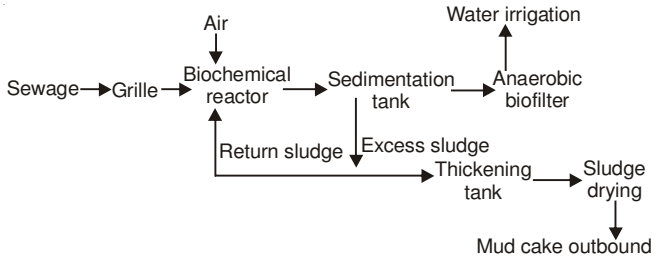

Fig. 3. Flow chart of high-load activated sludge process

Researches on biological membrane: Zhou *et al.*[69] apply the biofilm process to treat such kind of wastewater. The capability of denitrification for low carbon source-high nitrogen concentration wastewater by biofilm process is investigated by changing the reaction conditions such as HRT, C/N *etc.* Under the conditions of the HRT 15 h, C /N of wastewater 5:1 and the influent ratio of the low oxygen level reactor to aerobic reactor 1:1, better nitrogen removals are achieved. As mentioned above, better results of denitrification were obtained in such treatment process and water quality was improved, which may be helpful to the denitrification for the municipal secondary effluent and beneficial to industrial application. Li *et al.*[70] investigate start-up characteristics of biological aerated filter (BAF) and the removal efficiency in treating domestic wastewater with biological aerated filter. The results indicate that the best removal efficiency of COD and NH_3-N is 94.8 and 93.2 %, respectively during the start-up. While in the stable running, under the certain gas-water ratio of 3:1, the average removal efficiency of COD and NH_3-N of biological aerated

filter is 95.9 and 93.7 %, respectively. The degradation rate of COD and NH_3-N increases gradually along with the increasing height of filter bed till it is higher than 120 cm.

Li *et al.*[71] bring the biological aerated filter (BAF) with ceramicite material to domestic wastewater treatment and investigates the effects of HRT, aeration and pH value on the treatment efficiency. The results show that when HRT is 3 to 6 h, the removal of COD and ammonia are 83.7-90 % and 85 %; when ammonia is 0.08-0.32 m^3/h, the removal of COD and ammonia are 83.4-86.8 and 85.2 %; the pH value varying in the range 6.57-8.72, has no effect on the removal of COD and ammonia in the research. The effluent wastewater quality can meet with second degree discharging standards after treatment. Yang *et al.*[72] investigate the effect of the urban wastewater treatment by the biological aerated filter. The result indicates that COD_{Cr} removal rate is 40 %; suspended solids removal rate is 6 %; ammonia nitrogen removal rate is 14 %; total nitrogen removal rate is 11 %; total phosphorus removal rate is 44 %. The removal rate of COD_{Cr}, suspended solids and ammonia nitrogen *etc*. could not reach the discharge standard. The main reasons included that the waterpower didn't stay long enough; the back washing machine is not equipped; the production can't be continued and so on.

Wu *et al.*[73] discuss the removal effects of COD, NH_3-N, total nitrogen and total phosphorus by bio-contact oxidation process under operating modes of continuous influent intermittent aeration and continuous influent continuous aeration at different organic loading levels. The results show that: when the HRT is 5.8 h, the continuous aeration time was 4 h and the aeration pause time was 1.8 h, the water treatment effect under the intermittent aeration mode is equal to that under the continuous aeration mode and the effluent quality meet the specification for level B of grade 1 in discharge standard of pollutants for municipal wastewater treatment plant (GB 18918-2002). The study could provide guidance for the development of energy-saving process. Hu *et al.*[74] apply an intergrated A/O fixed biofilm reactor to treat domestic wastewater and study the effects of different on the performance of the reactor under conditions: with or without reflux ratio. The results show that the effluent can meet to the standard of reuse (GB/T 18920-2002 and GB/T 18921-2002), when the influent was 5 L/h, the gas-water ratio was 20:1. Fig. 4 is the setup chart of sewage treatment by biological membrane.

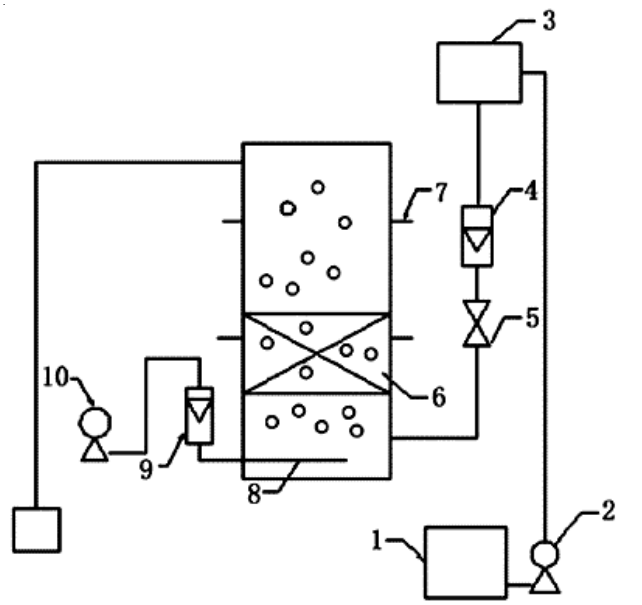

Fig. 4. Setup chart of sewage treatment by biological membrane. 1. Water storage tank 2. Pump 3. High slot 4. Glass rotameter (water) 5. Valve 6. Filter 7. Sampling ports 8. Aeration hose 9. Glass rotameter (gas) 10. Gas pump

Conclusions

• According to the prognosis, the stream of produced sewage in China will grow; it follows foremost from the lifestyle changes of our society, but is also due to the increased percentage of the population connected to the sewerage network.

• Chinese urban wastewater treatment and recycling facilities the Twelfth five-year. Construction planning is the largest with regard to investment and the most expensive from among all the tasks resulting from the implementation of the Chinese government directives in the field of environmental protection. Treatment ability and level will be further improved during the Twelfth five-year plan.

• Undoubted advantage of A/O - MBR combination process, in addition to the disposal of sewage, is that it becomes possible to reduce the waste of energy. Chinese conditions also appear to present a good opportunity to utilize this group of waste-disposal technologies.

• At present, China has increased the strength of environmental legislation. The legislated limits will determine the choices for sewage disposal; the disposal of sewage will have to be replaced in the next few years by other methods. This is strong incentive to develop physicochemical, biochemical and other combination methods of sewage.

REFERENCES

1. L. Seghezzo, G. Zeeman, B.J. van Lier, H.V.M. Hamelers and G. Lettinga, *Bioresour. Technol*., **65**, 175 (1998).
2. J. Gasperi, S. Garnaud, V. Rocher and R. Moilleron, *Sci. Total Environ*., **407**, 263 (2008).
3. M. Ichihara, A. Yamamoto, K. Takakura, N. Kakutani and M. Sudo, *Chemosphere*, **110**, 78 (2014).
4. A.C. Johnson, M.D. Jürgens, A.J. Lawlor, I. Cisowska and R.J. Williams, *Chemosphere*, **112**, 49 (2014).
5. C.Q. Xu, W. Chen and J.L. Hong, *J. Clean. Prod*., **67**, 79 (2014).
6. F. Jiang, L. Zhang, G.L. Peng, S.Y. Liang, J. Qian, L. Wei and G.H. Chen, *Water Res*., **47**, 5773 (2013).
7. N. Kamei-Ishikawa, A. Ito and T. Umita, *J. Hazard. Mater*., **260**, 420 (2013).
8. H. Chen and M.M. Zhang, *Environ. Int*., **55**, 9 (2013).
9. H.W. Leung, T.B. Minh, M.B. Murphy, J.C.W. Lam, M.K. So, M. Martin, P.K.S. Lam and B.J. Richardson, *Environ. Int*., **42**, 1 (2012).
10. O. Bergersen, K.Ø. Hanssen and T. Vasskog, *Bioresour. Technol*., **117**, 325 (2012).
11. S. Werle and R.K. Wilk, *Renew. Energy*, **35**, 1914 (2010).
12. G. Murtaza, A. Ghafoor, M. Qadir, G. Owens, M.A. Aziz, M.H. Zia and Saifullah, *Pedosphere*, **20**, 23 (2010).
13. A.A. Khan, R.Z. Gaur, V.K. Tyagi, A. Khursheed, B. Lew, I. Mehrotra and A.A. Kazmi, *Resour. Conserv. Recycling*, **55**, 1232 (2011).
14. J.L. Wang and J.Z. Wang, *J. Hazard. Mater.*, **143**, 2 (2007).
15. S.I. Borrely, A.C. Cruz, N.L. Del Mastro, M.H.O. Sampa and E.S. Somessari, *Prog. Nucl. Energy*, **33**, 3 (1998).
16. K.M. Smith, G.D. Fowler, S. Pullket and N.J.D. Graham, *Sep. Purif. Technol*., **98**, 240 (2012).
17. S.W. Xu, J.X. Zhang and Q. Fu, *Water Wastewater Eng*., **34**, 7 (2008).
18. B. Du and H.L. Hou, *Environ. Prot. Circular Econ*., **4**, 73 (2011).

19. H.L. Zhang, J. Zhang and J.N. Liu, *Liaoning Urban Rural Environ. Sci. Technol*., **24**, 3 (2004).
20. S. Song, M. Song, L. Zeng, T. Wang, R. Liu, T. Ruan and G. Jiang, *Environ. Pollut*., **186**, 14 (2014).
21. M. Lu, X.J. Wu, D.C. Zeng and Y. Liao, *Environ. Pollut*., **171**, 78 (2012).
22. H. Yan, C.J. Zhang, Q. Zhou, L. Chen and X.Z. Meng, *Chemosphere*, **88**, 1300 (2012).
23. B.B. Liu, Q. Wei, B. Zhang and J. Bi, *Sci. Total Environ*., **447**, 361 (2013).
24. Z.Z. Zhu, Z.L. Wang, J. Li, Y. Li, Z.G. Zhang and P. Zhang, *J. Rare Earths*, **30**, 609 (2012).
25. S.H. Rong and X.C. Wang, *China Rural Water Hydropower*, **2**, 135 (2012).
26. W. Al-Jamal and N. Mahmoud, *Bioresour. Technol*., **100**, 1061 (2009).
27. M. Al-Shayah and N. Mahmoud, *Bioresour. Technol.*, **99**, 7758 (2008).
28. T. Sabry, *J. Hazard. Mater*., **174**, 500 (2010).
29. A.G. Boon, A.J. Vincent and K.G. Boon, *Water Sci. Technol*., **37**, 223 (1998).
30. C. Zhang, B.J. Zhang and G.D. Chen, *Environ. Sci. Technol*., **12**, 21 (1999).
31. M. Huang and X.B. Li, *Technol. Develop. Enterprise*, **23**, 19 (2004).
32. X.L. He, J.F. Li, X.L. He and W.B. Fan, *J. Water Resources Water Eng*., **18**, 75 (2007).
33. H.B. Liu and H.Z. Yang, *J. Tianjin Urban Constr. Institute*, **9**, 19 (2003).
34. Z.H. Guo and Z.P. Xia, *Sci. Info*., **11**, 292 (2007).
35. Z.Q. Jing, X.W. Lv, G.F. Lin and X.W. Sun, *Yunnan Environ. Sci*., **21**, 23 (2002).
36. Y.L. Shen and B.Z. Wang, China Environmental Science Press, Beijing (1999).
37. M. Boller and G. Deplazes, *Water Sci. Technol*., **22**, 1 (1990).
38. H. Ødegaard and R. Storhaug, *Water Sci. Technol*., **22**, 33 (1990).
39. Y. Suzuki and T. Maruyama, *Water Res*., **40**, 1061 (2006).
40. X. Yin, X.P. Lu, P.F. Han and Y.R. Wang, *Ultrasonics*, **44**, 397 (2006).
41. G.M. Zhang, J.G. He, P.Y. Zhang and J. Zhang, *J. Hazard. Mater*., **164**, 1105 (2009).
42. U. Sarkar, D. Dasgupta, T. Bhattacharya, S. Pal and T. Chakroborty, *Desalination*, **252**, 120 (2010).
43. J. Yang and D.F. Shi, *Environ. Poll. Control*, **23**, 107 (2001).
44. P. Zhang, R. Hai, D.K. Zhou, Y.Q. He and Z.Y. Bai, *Chin. J. Chem. Eng*., **19**, 881 (2011).
45. D.W. Gao, Z. Li, J.X. Guan, Y.F. Li and N.Q. Ren, *Chemosphere*, **97**, 130 (2014).
46. G. Farabegoli, A. Chiavola and E. Rolle, *J. Hazard. Mater.*, **171**, 1126 (2009).
47. F.E. Greaves, B. Thorp and R.F. Critchley, *Water Sci. Technol*., **22**, 25 (1990).
48. W.X. Fu, X.J. Qin and Y. Wang, *Water Wastewater Eng*., **35**, 284 (2009).
49. H.Y. Wang, J. Li, Y.E. Wang and H.F. Hao, *J. Lanzhou Jiaotong Univ*., **28**, 118 (2009).
50. Y.H. Wang, Y. Fang and J. Jiao, *J. Ecol. Rural Environ*., **24**, 80 (2008).
51. S. Li, S.D. Shan, L.H. Zeng and Z.H. Su, *China Water Wastewater*, **24**, 67 (2008).
52. X.L. He, *Shihezi Uni. China*, 1 (2008).
53. X. Han, *Harbin Northeast Agric. Univ. China*, 1 (2011).
54. W.Q. Tang, G.M. Zeng, X.M. Li, Z.P. Chen and H.S. Yuan, *J. Hengyang Normal Univ*., **28**, 129 (2006).
55. L. Huang, T. Tang, D.F. Li and Q.H. Cai, *China Water Wastewater*, **24**, 13 (2008).
56. K.F. Zhang, H.W. Rong and C.S. Zhang, *J. Harbin Univ. Commerce*, **18**, 201 (2002). (Natural Sciences Edition).
57. Y.L. Guo, Y.S. Wang, S. Wang and J.G. Du, *Technol. Water Treatment*, **37**, 121 (2011).
58. H. Zhang, *Sci. China Series D*, **48**, 1 (2005).
59. D.C. Wang and L.F. Sun, *Chem. Ind*., **36**, 144 (2009).
60. J. Zhang, X. Huang, H.C. Shi, H.Y. Hu and Y. Qian, *Water Wastewater Eng*., **30**, 34 (2004).
61. C.Y. Peng, G.H. Zhu, G. Yin, Y.G. Yu and S.S. Zeng, *Environ. Sci*., **22**, 43 (2002).
62. L.H. Cui, Q. Lou, X.H. Zhou, S.L. Liu, X.H. Tan, Z. Liu and H.X. Li, *Ecol. Environ. Sci*., **18**, 1688 (2009).
63. C.L. Hu, Q. Fu, D.Y. Wei and R.C. Qiu, *Sichuan Environ.*, **27**, 8 (2008).
64. K.F. Zhang, C.S. Zhang, Q. Fang, X.J. Wu, L.P. Zhou and X.P. Tan, *Ind. Water Wastewater*, **33**, 18 (2002).
65. F.C. Zhou and X.S. Sun, *Technol. Water Treatment*, **35**, 50 (2009).
66. J. Zhang, X. Huang, C.X. Liu, H.C. Shi, H.Y. Hu and Y. Qian, *Environ. Sci*., **23**, 57 (2002).
67. H.T. Pang, H.C. Shi, H.M. Shi and Y.M. Yin, *China Environ. Sci*., **29**, 692 (2009).
68. J.X. Zhang, K.Y. Huang, L. Xing and Y. Wang, *Technol. Water Treatment*, **33**, 82 (2009).
69. K. Zhou, W.F. Sun and S.B. Zhang, *Environ. Sci. Manage*., **36**, 110 (2011).
70. Y.F. Li, Y.X. Sun, Y. Tian and R.T. Gao, *Chinese J. Environ. Eng*., **5**, 575 (2011).
71. J.S. Li, X.J. Wang, F. Gu and J.L. Zuo, *J. Harbin Univ. Commerce*, **26**, 152 (2010). (Natural Sciences Edition).
72. M.H. Yang, J.Q. Yao, J. Zhang and G. Li, *J. Anhui Agric. Sci*., **40**, 6770 (2012).
73. J.Q. Wu, Q. Pan and H. Lu, *Ind. Water Wastewater*, **40**, 50 (2009).
74. T. Hu, S.B. Huang and Z.M. Wei, *Ind. Safety Environ. Prot.*, **37**, 1 (2011).