Regional Difference Survey of Wastewater Treatment Methods in Highway Service Areas of China

Dong Ni\textsuperscript{1,4}, Gang Li\textsuperscript{2}, Gensheng Han\textsuperscript{2}, Zhigang Deng\textsuperscript{3}, Shegang Shao*\textsuperscript{1,4}

\textsuperscript{1}Research institute of Highway, MOT, Beijing, 100088, China
\textsuperscript{2}Jiangxi Provincial Expressway Investment Group Co., Ltd. Nanchang, 330025, China
\textsuperscript{3}Guangdong Road and Bridge Construction Development Co., Ltd. Guangdong, 510635, China
\textsuperscript{4}Key Laboratory of Environmental Protection Technology on Road Traffic, Ministry of Transport, Beijing, PRC, 100088, China

* E-mail: sg.shao@rioh.cn

Abstract. This thesis, based on questionnaire survey, field investigation, sewage sample test etc., studies the relationship between water consumption and discharging volume, type and process of sewage treatment facilities, and statistical analysis of sewage discharge whereabouts in highway service areas. There are 35.5\% and 27.6\% respectively in the service areas of north and south China without sewage treatment facilities installed or operated. The great difference between the highway service areas of north and south China lies on the differences in geographical location, climate and level of economic development. The problem of nearby discharging of sewage and sludge in the service areas, lower recycle rate, unused or damaged sewage treatment equipment seems to be prevalent. On the whole, quite a few sewage treatment facilities and processes in service areas are not capable of managing the sewage in service areas, which has great potential for improvement.

1. Overview

The sewage in highway service area is divided into scattered domestic sewage, and the water quality change and volume are closely related to the traffic volume and functional composition of the service area. The sewage volume generated in highway service areas varies and there is higher content of ammonia nitrogen and COD. Part of highway service areas established earlier can partly achieve the up-to-standard discharge, while there is a big difference in removal rate of pollutant, discharge whereabouts and equipment operation\cite{1-2}. The sewage disposal technologies are evolving with the increasingly strict water environmental protection requirements and pollution emission limits, showing different features in the improvement and operation of interregional processing technology in different geographical conditions\cite{3}. This thesis, based on questionnaire survey, field investigation, sewage sample test etc., investigates the treatment of domestic sewage in highway service areas and analyzes the influence factors. Moreover, the thesis puts forward the change rule of sewage load in highway service areas with different functions in different regions through comparative analysis of merit and demerit of wastewater recycling technology in construction and typical service areas.
2. Questionnaire survey

2.1 Questionnaire establishment
Investigation on the Operation of Sewage Treatment Facilities in Highway Service Areas is formulated based on the features of highway service areas in China and its sewage treatment facilities. Survey items include highway name, service area name, national and provincial expressway network number, milepost number, traffic time, years in service, main service function, number of workers, actual traffic volume corresponding to the main road section, number of vehicles entering the service areas, daily average passenger flow, daily water consumption, discharging volume, etc.

2.2 Questionnaire survey
Field research and correspondence research are combined on the research work of sewage treatment and recycling in highway service areas.

Scope of correspondence research: Questionnaires were sent to 18 provinces, cities and autonomous regions, with a total of 481 questionnaires returned.

On-site investigation: adopting self-driving mode, 15 national highways involved in the field research, including G2 Beijing-Shanghai Expressway, G3 Beijing-Taipei, G4 Beijing-Hong Kong-Macao, G5 Beijing-Kunming, G6 Beijing-Tibet, G25 Changchun-Shenzhen, G30 Lianyungang-Horgos, G35 Jinan-Guangzhou, G40 Shanghai-Xi’an, G42 Shanghai-Chengdu, G45 Daqing-Guangzhou, G55 Erenhot-Guangzhou, G56 Hangzhou-Ruili, G60 Shanghai-Kunming, G85 Kunming-Mohan.

Main contents of field investigation: key research on intake quantity of water, discharging volume, wastewater treatment process, sewage treatment facility system, operating and maintenance fee for sewage treatment facility, wastewater quality, sewage discharge whereabouts, way of sewage recycling, sludge production, sludge whereabouts, sludge treatment and so on.

3. Regional difference of sewage treatment in service areas

3.1 Statistical relation of water consumption and discharging volume in service areas
Average daily water consumption is significantly positively correlated with average daily discharging volume and average daily sewage recycling ($P<0.01$). The average daily number of people going to the toilet and the average daily number of diners are significantly positively correlated with the average daily water consumption ($P<0.01$). The average daily water consumption is negatively correlated with average daily sludge production. The large water consumption and discharging volume in service areas shortens the time of sewage in the sewage treatment facilities\[4-5\], causing some precipitation taken by the discharging before sediment. Therefore, the amount of sludge is reduced when dredge regularly. Discharging directly instead of using sedimentation basin in the part of service areas samples in statistics may be the other reason why the sludge quantity is inversely proportional to the discharging volume.

| Average daily water consumption (t/d) | Average daily discharging volume (t/d) | Average daily number of people going to the toilet (/d) | Average daily number of diners (/d) | Average daily sewage recycling (t/d) |
|--------------------------------------|----------------------------------------|---------------------------------------------|--------------------------------------|-------------------------------------|
| Average daily water consumption (t/d) | 1                                      | .934**                                      | .444**                               | .380**                              | .360**                             |
| Average daily discharging volume (t/d) | 1                                      | .467**                                      | 0.4**                                | -                                   | -                                  |
| Average daily number of people going to the toilet (/d) | 1                                      | 0.497**                                     | -                                    | -                                   | -                                  |
3.2 Comparison of water consumption and discharging volume in service areas of south and north China

When there is a small gap in the number of vehicles entering the service areas ($P=0.492$), the daily water consumption, discharging volume, sewage recycling and daily passenger flow in the service areas of south China are significantly higher than those in the service areas of north China, while sludge production in the service areas of north China is significantly higher than that in the service areas of south China. The COD removal rate has no significant difference between the above two regions.

Water consumption in the service areas of south China is higher than that in the service areas of north China due to the difference of climate and population density between two regions even when there is a small gap in the number of vehicles. Meanwhile, the sludge digestion and decomposition is faster in the south due to the high average temperature[6]. That’s why the average sludge production in the service areas in the south is also lower than that in the service areas in the north.

Table 2. Comparison of water consumption and discharging volume, passenger flow volume and sewage recycling in the service areas of south and north China

| Survey indicators                                | No. | Sample size | Average value | F Test statistics | Sig Test of significance |
|--------------------------------------------------|-----|-------------|---------------|------------------|--------------------------|
| Average daily water consumption (t/d)             | 1   | 318         | 150.08        | 24.831           | 0.000                    |
|                                                  | 2   | 308         | 94.85         |                  |                          |
| Average daily discharging volume (t/d)            | 1   | 291         | 129.69        | 30.944           | 0.000                    |
|                                                  | 2   | 302         | 75.85         |                  |                          |
| Average daily sewage recycling (t/d)              | 1   | 195         | 18.55         | 6.726            | 0.010                    |
|                                                  | 2   | 232         | 5.34          |                  |                          |
| Sludge production (t/d)                          | 1   | 48          | 0.10          | 4.877            | 0.029                    |
|                                                  | 2   | 108         | 0.26          |                  |                          |
| COD removal rate                                  | 1   | 25          | 0.1125        | 0.409            | 0.528                    |
|                                                  | 2   | 5           | 0.3337        |                  |                          |
| Number of vehicles entering the service areas (unit) | 1   | 289         | 1338          | 0.473            | 0.492                    |
|                                                  | 2   | 318         | 1221          |                  |                          |
| Average daily passenger flow volume (/d)          | 1   | 170         | 4489          | 13.400           | 0.000                    |
|                                                  | 2   | 158         | 2540          |                  |                          |
| Capacity of sewage treatment facilities (t/d)     | 1   | 215         | 212.22        | 34.886           | 0.000                    |
|                                                  | 2   | 232         | 105.65        |                  |                          |

1 for the service areas in south China, 2 for the service areas in north China

3.3 Investigation on type of sewage treatment facilities and process in the service areas

There are 35.5% and 27.6% respectively in the service areas of north and south China without sewage treatment facilities installed or operated. Biochemical process is the main method for the dispose of sewage in the service areas of south China, accounting for 19.9%, while in the service areas of north China, a buried integrated treatment unit has been used and contact oxidation method is used for the dispose of sewage, accounting for 23.6%. Other processes are more complex, but notably, constructed
wetlands have been used in some service areas to further purify the sewage and improve the landscape environment in the service areas at the same time, which is promising.

Figure 1. Comparison of wastewater treatment process in the service areas of south and north China

We can see from the above figure that biological oxidation, contact oxidation method, biochemical process and A/O method are the most common processes for the dispose of sewage than any other processes.

3.4 Statistics on sewage discharge whereabouts

Sewage from most service areas in the north and south China has been discharged to the nearest ditch on both sides of the service areas, or nearby surface water and irrigation channels. Only a small proportion of service areas reuse the sewage, mostly in the service areas of south China. There are still some service areas adopting two or more discharging way. In fact, the discharging way of sewage in the service areas is closely related to the geographical location and the characteristics of the surrounding environment of the service areas. Most service areas in the survey through analysis adopt the most convenient way due to geographical location and environment. However, it’s not necessarily the most environmentally friendly way.

Table 3.4-1 Statistics on sewage discharge whereabouts

| Sewage discharge whereabouts | Service areas in south China | Service areas in north China | Proportion of south China | Proportion of north China |
|-----------------------------|------------------------------|-----------------------------|--------------------------|--------------------------|
| Side ditch                  | 141                          | 220                         | 0.401                    | 0.627                    |
| Side ditch, recycling       | 3                            | 2                           | 0.009                    | 0.006                    |
| Side ditch, recycling, agricultural irrigation | 3 | 2 | 0.003 | 0.000 |
| Side ditch, municipal pipe network | 1 | 1 | 0.003 | 0.000 |
| Surface water body          | 56                           | 36                          | 0.159                    | 0.103                    |
| Surface water body, side ditch | 4 | 1 | 0.011 | 0.003 |
| Surface water body, recycling | 2 | 2 | 0.000 | 0.006 |
| Recycling                   | 16                           | 6                           | 0.045                    | 0.017                    |
| Recycling, side ditch       | 1                            | 3                           | 0.003                    | 0.009                    |
| Agricultural irrigation ditches | 49 | 22 | 0.139 | 0.063 |
| Agricultural irrigation ditches, | 2 | 2 | 0.006 | 0.000 |
4. Conclusion

Based on the analysis of water consumption and discharging volume, water supply source, sewage treatment equipment and process, sewage discharge whereabouts and recycling conditions in the service areas of south and north China, the daily water consumption, discharging volume, sewage recycling and daily passenger flow in the service areas of south China are significantly higher than those in the service areas of north China, while sludge production in the service areas of north China is significantly higher than that in the service areas of south China. The COD removal rate has no significant difference between the above two regions.

Suppliers in south China provide a few types of sewage treatment equipment for the service areas in local or nearby provinces and the equipment are less useful for other regions, while suppliers in north China are scattered. There are 35.5% and 27.6% respectively in the service areas of north and south China without sewage treatment facilities installed or operated. Biochemical process is the main method for the dispose of sewage in the service areas of south China, accounting for 19.9%, while in the service areas of north China, a buried integrated treatment unit has been used and contact oxidation method is used for the dispose of sewage, accounting for 23.6%. Stacked drying, the passive method, is mainly used in the service areas of north and south China for the disposal of sewage.

It can be seen from the above analysis that the great difference between the highway service areas of north and south China lies on the differences in geographical location, climate and level of economic development. The problem of nearby discharging of sewage and sludge in the service area, lower recycle rate, unused or damaged sewage treatment equipment seems to be prevalent. On the whole, quite a few sewage treatment facilities and processes in service areas are not capable of managing the sewage in service areas, which has great potential for improvement.

Acknowledgements

Thanks due to the Secretariat of the Technical Committee on Standardization of Traffic Environmental Protection on investigation. This paper was supported by the Science and Technology Project of Jiangxi Provincial Department of Transport (2017C0003-1) and the Science and Technology Project of Guangdong Province Department of Transport (2017-02-002).

References

[1] LIANG Li-ping, ZHANG Lin. Problems and Solutions for Sewage Treatment in Expressway Service Areas in Jiangsu Province[J]. China Water & Wastewater, 2017, Vol33 No.4: 20-21.
[2] SHEN Yi, LIU Huan, SHAO Shegang. Suggestions for improving the Highway Service Area Service Quality Measures[J]. CHINA TRANSPORTATION REVIEW Vol.39, No.01, 10-12.
[3] Li J, Ding L/B, Cai A, et al. Aerobic sludge granulation in a full-scale sequencing batch reactor[J]. BioMed research international, 2014, (2014):3-6.
[4] Willoughby A, Houweling D, Constantine T, et al. Protocols for researching the impact of sludge granulation on BNR processes[J]. Proceedings of the Water Environment Federation, 2016, (9): 5865-5877.
[5] MKH Winkler, JP Bassin, R Kleerebezem, et al. Selective sludge removal to control PAO-GAO competition at high temperatures.
[6] Bin Y. Discussion on Applicable Sewage Treatment Process & Technology for Expressway Service Zone [J]. Technology of Highway and Transport, 2008, 2.