Upgrading project of leachate treatment station in a landfill site in Beijing

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Abstract. The technical route and design for the upgrading the leachate treatment station of a landfill site in Beijing were systematically introduced. By strengthening the advanced treatment and introducing chemical oxidation of the effluent by sodium hypochlorite, the standard of leachate treatment effluent meets the requirements of the Beijing DB11/307-2013 "Table 1" A level emission limits. At the same time, the original system is heated and heat preservation is used to meet the stable operation of the system in winter. It provides engineering design reference for the upgrading of landfill leachate treatment.

1. Introduction
There are 16 landfill sites in Beijing, in which the leachate treatment mainly implements the Standard for Pollution Control on the Landfill Site of Municipal Solid Waste (GB 16889-2008) "Table 2" discharge limits[1]. But since January 2014, Beijing has implemented the "Integrated discharge standard of water pollutants" (DB11/307-2013). It is required that the sewage of landfill discharged into Beijing's Class II and Class III water is subject to the "Table 1" A discharge limits[2]. For landfills with no sewage pipe, it is necessary to carry out the upgrading to meet the new emission standard requirements of Beijing.

Taking the upgrading project of a landfill leachate treatment station in Beijing as an example, this paper introduces the technical route and practical engineering design in the upgrading project, so as to provide engineering design reference for the improvement of leachate treatment.

2. Project Overview
A landfill site in Beijing is located in the mountainous area in the northwest of Beijing. The site is a gully in a wasteland, surrounded by mountains on three sides. and there are no villages or shops within 500m. The garbage generated daily within the service area of the landfill site weighted average of 88.7 tons, and the storage capacity of the treatment site is 640000 cubic metres, which is expected to last 15.8 years.

2.1. Basic situation of the existing leachate treatment works

2.1.1. The design scale is 80m3/d.

2.1.2. Designed Water quality of influent and effluent
After treatment of leachate reaches the "Table 2" discharge standard of the "Standard for Pollution Control on the Landfill Site of Municipal Solid Waste" (GB16889-2008), the effluent is discharged into the drainage ditch on the north side of the station area.

### Table 1. Water quality of influent and effluent

| Parameter | Influent quality | Effluent quality |
|-----------|-----------------|-----------------|
| COD<sub>e</sub> (mg/L) | ≤20000 | 100 |
| BOD<sub>5</sub> (mg/L) | ≤10000 | 30 |
| NH<sub>4</sub>-N (mg/L) | ≤1000 | 25 |
| TN (mg/L) | ≤1500 | 40 |
| SS (mg/L) | ≤1000 | 30 |
| pH | 6~9 | 6~9 |

#### 2.2. Treatment process

The original leachate treatment process is "Pre-treatment + UASB + first-stage A/O + second-stage A/O + external ultrafiltration + reverse osmosis".

The leachate in the collection well is first lifted into the regulating pool. After homogenization, it is pumped up by the pump and filtered into the UASB anaerobic pond. After the anaerobic reactor is used to degrade most of the organic matter, the effluent enters the first-stage A/O pond and the second-stage A/O and the organic matter in the water is removed by the action of microorganisms. At the same time ammonia nitrogen and total nitrogen in landfill leachate were removed by denitrification and nitrification. After treatment, external ultrafiltration membrane and reverse osmosis were applied.

#### 2.3. Constructions of leachate treatment works

### Table 2. List of main constructions

| Name                  | Specifications (length × width × height) | Material               | Number | Remarks       |
|-----------------------|-----------------------------------------|------------------------|--------|---------------|
| 1 Infiltration well   | 4.00m×4.00m×13.42m                       | Steel concrete         | 1      | underground   |
| 2 Regulating pool     | Volume:2000m3                           | Anti-seepage earth pond | 1      | underground   |
| 3 Intermediate pool   | 5.00m×1.50m×3.00m                       | Steel concrete         | 1      | underground   |
| 4 Anaerobic pool      | 5.00m×5.00m×10.00m                      | Steel concrete         | 2      | Semi-underground |
| 5 First-stage A/O pool| 13.80m×10.40m×5.00m                     | Steel concrete         | 1      | Semi-underground |
| 6 Thickening tank     | 5.00m×3.10m×3.30m                       | Steel concrete         | 1      | underground   |
| 7 Sedimentation tank  | 5.40m×5.40m×4.70m                       | Steel concrete         | 1      | Semi-underground |
| 8 second-stage A pool | 4.00m×2.50m×5.00m                       | Steel concrete         | 1      | Semi-underground |
| 9 second-stage O pool | 2.50m×2.20m×5.00m                       | Steel concrete         | 1      | Semi-underground |
| 10 Mud sump           | 3.00m×1.40m×3.10m                       | Steel concrete         | 1      | underground   |
| 11 Filtrate pool      | 3.00m×1.40m×3.10m                       | Steel concrete         | 1      | underground   |
| 12 Mud storage tank   | 3.00m×3.00m×5.80m                       | Steel concrete         | 1      | underground   |
| 13 Membrane treatment workshop | 15.60m×8.10m×4.50m | frame structure       | 1      | Above ground  |

#### 2.4. Sludge treatment and disposal

The excess sludge generated by the leachate treatment process enters the storage tank and is dehydrated by the plate and frame filter press. The filtrate is returned to the first-stage A/O system and the mud cake is sent to the landfill site for landfill.

#### 2.5. Disposal of RO concentrate

The concentrate produced by reverse osmosis (RO) is transported to landfill area by pump truck for recharging.
2.6. Operation condition
The leachate treatment system of the original leachate treatment system has less production and low temperature in winter, and the leachate treatment system in winter does not run or operates intermittently with a small amount of influent every day.

3. Analysis of engineering problems

3.1. Increased emission standards
Since January 2014, Beijing has implemented the "Integrated discharge standard of water pollutants" (DB11/307-2013). The leachate treatment station needs to increase the emission targets and achieve the "Table 1" A emission limit. The comparison between the "Table 2" emission standard of the “Standard for Pollution Control on the Landfill Site of Municipal Solid Waste” (GB16889-2008) is as follows:

| Pollutant or project name | DB11/307-2013 "Table 1" A emission standards | GB 16889-2008 "Table 2" emission standards | Original effluent quality |
|--------------------------|------------------------------------------------|------------------------------------------|-------------------------|
| 1 | pH value/dimensionless | 6.5~8.5 | - | 6.5~7.5 |
| 2 | Water temperature/°C | 35 | - | 20~30 |
| 3 | Chroma | 10 | 40 | - |
| 4 | Suspended matter(SS) | 5 | 30 | ≤ 5 |
| 5 | Five-day biochemical oxygen demand (BOD 5) | 4 | 30 | ≤ 5 |
| 6 | Chemical Oxygen Demand (CODcr) | 20 | 100 | ≤ 15 |
| 7 | Total Organic Carbon(TOC) | 8 | - | - |
| 8 | Ammonia nitrogen | 1.0 | 25 | 1~2 |
| 9 | Total nitrogen | 10 | 40 | 8~15 |
| 10 | Total phosphorus | 0.2 | 3 | - |

According to the comparative analysis of the emission standards, it can be seen that the new standards have extremely strict emission requirements for ammonia nitrogen and total nitrogen. The existing process is "Pre-treatment + UASB + primary A/O + secondary A/O + external ultrafiltration + RO (Reverse Osmosis), which is difficult to meet the DB11/307-2013 “Table 1” A emission limits. Compared with the emission indicators, the original system is mainly ammonia nitrogen and total nitrogen exceeding standard, so it is necessary to strengthen the removal of ammonia nitrogen and total nitrogen from the whole process unit.

3.2. Low temperature in winter affects the normal operation of the system
At present, the original anaerobic system in landfill leachate treatment station has not been installed with heating and insulation, and the heat preservation and aging of pipelines above ground are serious, and the biochemical part of MBR has been exposed to open air. When the leachate treatment system is running in winter, the water temperature is too low, the operating efficiency of biochemical system is low, and the water yield of ultrafiltration and reverse osmosis system is low too. The original system does not run in the winter, which resulted in a large accumulation of landfill leachate. In view of the current situation, to ensure the stable operation of the leachate treatment system in winter, the leachate treatment system needs to be reformed with corresponding heating and insulation.

4. Upgrading technical route and design parameters

4.1. Strengthen the advanced treatment
The original biochemical system is two-stage A/O, and the removal potential for ammonia nitrogen and COD from the biochemical point of view is limited. Therefore, this upgrading is focused on strengthening the advanced treatment.

The original reverse osmosis system's processing capacity is 80t/d, the system recovery rate is only 50%. The equipment is aging, and the COD, ammonia nitrogen and total nitrogen of the effluent can not meet the A emission limits of the "Integrated discharge standard of water pollutants" (DB11/307-2013).

In view of the aging problem of the existing RO equipment, the RO desalination equipment is the most important desalination device in the system. The RO system uses the characteristics of reverse osmosis membrane to remove most of the soluble salts, humic acids, and refractory organic matters in the leachate, and so on[3].

The membrane module used in this project is the membrane module of DOW Company. The total recovery rate of the system is 70%. The reverse osmosis membrane uses polyamide membrane, the first-stage reverse osmosis uses high-pressure resistant seawater desalination membrane, and the second-stage reverse osmosis uses anti-pollution compound. The first-stage reverse osmosis membrane area is 32m², the second-stage level membrane area is 34m², the first-stage reverse osmosis operational pressure can achieve 80bar, the second-stage reverse osmosis is 40bar. Generally speaking, the service life of the first-stage RO is 1 years, and the second-stage reverse osmosis is 2 years. The membrane has the characteristics of high desalination rate, strong pollution resistance and high throughput under low pressure operation conditions. The first-stage RO system treatment unit is 8 inches, 8040RO, using 10 high-pressure anti-fouling membrane DOW reverse osmosis membrane module. The second-stage RO system treatment unit is 8 inches, 8040RO, using 5 high-pressure anti-fouling membrane DOW reverse osmosis membrane module.

4.2. Guarantee measures for effluent stability

Since the project's effluent requirements are very strict, after the upgrading, the COD, BOD, and total nitrogen indexes compliance rates are very high. In particular, the ammonia nitrogen index standard requirement is 1.0mg/L, while the influent design index 1000mg/L. The concentration of leachate influent fluctuates greatly, and the biochemical system is greatly affected by water temperature, climate, and season. Therefore, when fluctuation occurs, the ammonia nitrogen in the effluent may fluctuate, and the effluent cannot be guaranteed to be below 1.0 mg/L. In order to ensure the stable discharge of the overall system, a chemical oxidation unit should be added at the back end of the reverse osmosis project to ensure the qualified ammonia nitrogen effluent.

At present, the commonly used chemical oxidation treatment processes are FENTON, ozone, hypochlorous acid, etc. [4]. Due to the site constraints of this project, the economic, reliability and safety
factors of various chemical oxidation measures are integrated, and sodium hypochlorite oxidation is designed.

The advantage of the chemical oxidation process is that the process is mature and is not affected by changes in temperature and pollutant parameters. The effluent water quality is stable and the system can ensure long-term and short-term water quality. The operation and management are simple and can be started and stopped at any time. The shortcoming is that the investment cost is higher than that of biochemical technology (generally higher than 30%).

The effluent from Maiyuan landfill leachate was treated by biochemical treatment of oxidation ditch-A/O process. The concentration of ammonia nitrogen was 350~450mg/L, and NaClO solution (effective chlorine content 5%) was added. With the increase of NaClO dosage from 50mL/L to 90mL/L, the removal rate of ammonia nitrogen increased with the increase of dosage. The mass concentration of ammonia nitrogen decreased from 390mg/L to 10mg/L[5]. In this project, according to the concentration of ammonia nitrogen in the actual RO effluent, the dosage of NaClO solution (effective chlorine content 5%) was 10mL/L (0~20mL/L adjustable).

4.3. System heating and insulation

4.3.1. System heating. At present, the residence time of raw water in the regulating tank is longer than that of the original leachate treatment station, and the temperature of raw water entering the treatment system is between 2~3℃. The subsequent treatment process has a poor treatment effect under low temperature conditions and is basically unable to operate. If it is necessary to achieve winter stability operation, the raw water needs to be warmed up. The optimal treatment temperature of medium temperature anaerobic system is 30~35℃[6], the optimal treatment temperature of second-stage A/O system is 20~32℃[7], and the optimal treatment temperature of UF/RO membrane system is 25~30℃[8]. Electric heating, steam heating and other methods are usually used. Since there is no steam source in the field at present, the electric heating of the pipeline is designed, the heating power is 180kW, and the heating material is titanium. The heating point is set in the pipeline before the anaerobic tank.

4.3.2. Insulation of biochemical tank. In winter, all open biochemical tanks in the leachate treatment station need to be added with top insulation facilities. Generally, the thermal insulation of the cistern is made of two forms: concrete cover board or sunshade shed, each of which has its own advantages and disadvantages. The investment cost of the concrete cover plate is high and the maintenance is inconvenient. The advantages are long service life, and the advantages of the heat preservation of the sun shading shed are low investment, convenient maintenance, and the disadvantage is that the service life is low, but it can guarantee 5 years of service life. There are many facilities in the project pool. If the concrete cover is closed, the maintenance is not convenient and the cost is high. It is more comprehensive to adopt the method of adding a sun shed for tank top insulation. The sun shading keel used in this project is made of hot dip galvanized material, taking full consideration of natural factors such as wind resistance and hail. The PC plate with a thickness of 10 mm is adopted. In order to ensure safety and ventilation, explosion-proof blower is installed at the top and two sides to ventilate.
4.3.3. Pipe insulation. The insulation layer of the outlayer pipeline of the leachate treatment station is seriously aging and damaged. The insulation is reset. The insulation of the pipeline is as follows: the insulation layer is combined with rock wool pipe and rubber; the reinforcement layer is bound with iron wire, and the wire diameter of the binding iron wire is not less than 14#, Hexagonal wire mesh wrapped, wire mesh specification is 20#; the protective layer is made of double-coated polyester color-coated aluminum foil, crimped, buckled, riveted and installed, and the pipeline is 0.35mm thick.

5. Treatment effect
At present, the leachate treatment system has been operated for a year, and the system has been running steadily. The environmental treatment target requirements have been achieved. The average inflow and effluent water quality are as follows:

|                      | COD$_{cr}$ (mg/L) | BOD$_5$ (mg/L) | NH$_4$-N (mg/L) | TN (mg/L) | SS (mg/L) | pH     |
|----------------------|-------------------|----------------|-----------------|-----------|-----------|--------|
| Influent quality     | ≤5000             | ≤2500          | ≤500            | ≤550      | ≤500      | 6–9    |
| Effluent quality     | ≤5                | ≤2             | ≤0.5            | ≤9        | ≤5        | 7.0–7.6|
6. Conclusions
On the basis of strengthening the advanced leachate treatment measures, this project creatively adopted the sodium hypochlorite to treat the effluent of the system, and implemented the "Integrated discharge standard of water pollutants" (DB11/307-2013) “Table 1” Class A limits, which requires that the ammonia nitrogen in the effluent must below 1 mg/L. In addition, through heating and insulation measures, the stable operation of the original system has been realized in winter, and the accumulation of leachate in the landfill was reduced. The stable operation of this project provides a new transformation idea and technological route for landfill leachate treatment and upgrading.

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