Optimization of Leachate Treatment in Low Temperature by DTRO

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Abstract. The operating conditions of landfill leachate treatment by DTRO (Disk Tube Reverse Osmosis) was long-term monitored in a plateau area of Southwest China, and low-temperature leachate was preheated by the LFG (Landfill Gas) heating system. DTRO operating pressure was observed, then the mechanism analyzed and optimization methods recommended. The results show that the operating pressure reached the highest value of 57.87 bar when the leachate temperature is lower than 14°C. And the pressure dropped from 56.2 bar to 49.5 bar when the leachate was heated by LFG heater from 14°C to 22°C. The system performance can be improved by adjusting the temperature into a proper range. And leachate concentrate treatment by afterheat of the burner is also discussed.

1. Introduction
DTRO is a kind of RO (Reverse Osmosis). It has the advantages compared with other processes, such as unaffected by biodegradability and C/N ratio, stable effluent quality, flexible system operation and fast start-up. It has been widely used for landfill leachate treatment in China, for construction costs have been gradually reduced over past 10 years. According to the operation record of the leachate treatment station, temperature is one of the main factors affecting the performance of DTRO.

The effectiveness and operating conditions of landfill leachate treatment by DTRO system have been published in journal and conference paper [1-7]. However, few studies are available on how to improve the operating performance in low temperature with LFG preheating applications. This paper observes the change of operating efficiency of DTRO with LFG heating system. The causes of the influence are analyzed and the corresponding optimization methods are explored to provide useful information to other landfill leachate treatment projects.

2. Experiment
The landfill leachate treatment station is located in the plateau of Southwest China at an altitude of 1910m. This low latitude area belongs to the subtropical monsoon climate zone. The average annual temperature is 14.8 °C. The average minimum and maximum temperature are 9.7 °C and 21.6 °C, respectively.

The experimental equipment includes LFG pumping well, gas-water separator, dry gas holder, LFG boiler, leachate heating tank, concentrate solution storage tank, DTRO, sprinkler system, igniter, Pressurized ventilator and safety equipment. The system is shown in Figure 1.
The LFG is compressed into the biogas pipeline after being dehydrated, then passed the metering device and flame blocker to reach the flame nozzle, then ignited by the propane igniter. Heating system needs to be adjusted manually in the process. The speed of leachate flow and residence time in the boiler tank should be set to match the ambient temperature, to ensure the leachate is heated to appropriate temperature. Then the heated leachate flows into the DTRO system by its own gravity.

3. **Effect of low temperature on operating pressure of RO**

The detection period lasted 10 months from August 5, 2015 to May 15, 2016. The temperature of the original leachate was 9.7°C to 22.4°C. The leachate was sampled every 5~7 days, and a total of 57 groups of data were recorded. Water production rate of DTRO was set at 71% during the test and the influent pH value was adjusted to 6.5. The relationship between DTRO operating pressure and temperature is shown in Figure 2.
The peak value of DTRO operating pressure appeared between December 15, 2015 and March 5, 2016, with an interval value of 39.81 bar to 57.87 bar. The leachate temperature decreased from 15.2°C to 9.7°C and then slowly rose to 13.7°C. During this period, the transmembrane differential pressure grew rapidly, chemical cleaning times increased, operating pressure fluctuates greatly, and the desalination rate reached the highest value of 97.73%. Thereafter, DTRO operating pressure showed a downward trend.

It is obvious that the operating pressure enters the peak region when the leachate temperature is lower than 14°C. Because of the dynamic viscosity and kinematical viscosity of leachate solution will change when the temperature decrease. The tangential stress between the liquid levels is also relatively increase. The permeability coefficient of the boundary layer of the RO diaphragm surface solution and the rate of diffusion of salt through the membrane is decrease, so that the osmotic pressure is getting higher. The water viscosity increases gradually leads to lower salt permeability and water production flux, thus the operation efficiency of DTRO system is affected. It can be estimated that the water permeability of RO decreases about 2.7% when the influent temperature drops 1°C.

The temperature of leachate should not be lower than 5°C, the percolation rate is already very slow when it is below 8°C. The operator has to consider shutting down the leachate treatment equipment in such low ambient temperature. But the leachate will continue to be produced due to the heat created by internal anaerobic biochemical reaction in landfill, even if the temperature is lower than 0°C. Rains and snow in winter will also create more leachate. The only way to reduce leachate is continuous recirculation by pumping equipment if the capacity of the leachate equalization basin is exceeded. The recirculation can result in a significant increase of operating costs, affecting the stability of the landfill dam and endangering the structure of the landfill. Therefore, it is necessary to improve the operating conditions of DTRO in low temperature climate to ensure the continuous operation of the leachate treatment system.

4. LFG heating performance

4.1. Leachate preheating

LFG is a kind of gas produced by municipal solid waste in anaerobic environment. The organic matter in landfill waste is anaerobically degraded by microorganisms, then this mixed gas is produced after a series of complex biological and chemical reactions. LFG contains methane with a volume ratio of 30% to 55%, which is up to the source and composition of landfill waste. The combustion value of the untreated LFG is estimated to be 19.2~22.5 MJ/m³, which is equivalent to the combustion value of approximately 0.5 m³ of natural gas.

Using LFG burner to heat leachate is stable and sustainable. The exhaust gas can be collected and reused through a vertical perforated pipe in the landfill shaft, and the combustible gas is delivered to the gas collection cabinet. The change of operating pressure by temperature adjustment is shown in Figure 3.
Figure 3. Schematic diagram of pressure changes with temperature

The temperature of leachate raised from 14°C to 22°C and the operating pressure was reduced from 56.2 bar to 49.5 bar. The heating system runs synchronously with the DTRO system, and the amount of leachate entering the heating system keeps balance with the DTRO effluent. And the heating system can be turned off if the ambient temperature is high enough. The DTRO generally produces about 30% leachate concentrate. The burner also can be used to dry the concentrate.

4.2. Leachate concentrate drying by LFG burner

The leachate concentrate is a high aggregate of the main pollutants after the DTRO system completes the concentration and separation, and the pollution level is much higher than the leachate. A large part of its composition is toxic and cannot be used as a nutrient source to participate in biological reactions. The leachate concentrate usually backfills in municipal solid waste directly, or seeping into landfill by artificial sprinkler irrigation. The landfill can be used as a biological filter bed, the microorganisms in the waste degrade the concentrate in the process of leachate self-flowing through the landfill. There was no significant change of the major pollutants discharged from the landfill in a short period. But backfilling will cause short circuit of water flow, increase the moisture content of the landfill layer, and the salt content of the landfill.

Evaporation and solidification are processes of physically separating volatile components from non-volatile components. The liquid of concentrate is heated to boil and the steam is continuously removed. All heavy metals and inorganics, as well as most organics, which are less volatile than water are retain in the concentrate. Only some of the volatile hydrocarbons, volatile organic acids and ammonia will enter the steam and eventually in the condensate. The air in the burner can be heated and sprayed into the leachate concentrate as microbubble, the liquid of concentrate is evaporated by the heat quantity, and the exhaust gas generated during the evaporation process enters the torch for secondary combustion. The pollutants of emissions can also be further reduced by resin absorption. There is research shows that only about 3% of the sediment [8] is left. It means evaporation can achieve complete and harmless disposal. The main disadvantage is main material of the evaporation device must be titanium or higher-level material to meet the requirements of anti-corrosion. It will lead to higher construction costs and operating expenses. The technology is only recommended for cities and towns with enough municipal operating funding.

5. Conclusion

The viscosity of liquid decreases and the diffusion rate of salt gradually increases with the growth of temperature. The conductivity of the effluent water increases, and the change of the operating pressure gradually becomes stable. This shows the operating performance of RO membrane can be greatly
improved when the system runs in a proper temperature range. The LFG preheating system lifts the temperature of leachate above 14 °C in cold environment will effectively improve membrane separation capacity and ensure continuous operation in winter.

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