

Study on the Short-term Treatment Technology of Landfill Leachate

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Abstract. Domestic garbage is mainly treated by sanitary landfill. The main characteristics of landfill leachate produced in the sanitary landfill process are high concentration of COD and BOD, high ammonia nitrogen content, high levels of refractory organics, heavy metal ions, poor biodegradability, unstable water quality, difficult handling and so on. If the treatment is not carried out, the environment will be severely damaged. According to the needs of the project, this paper proposes a set of short-term landfill leachate treatment process, which involves ozone oxidation, internal electrolytic oxidation technology, coagulation precipitation, deep oxidation of the chain reaction, microwave field catalytic oxidation, adsorption and other treatment processes. Eliminating the biochemical process, the entire process flow is relatively short, and the processing efficiency is high. And the use of PLC-based control system to achieve automatic control of landfill leachate treatment. Since the leachate water quality has a wide range of variation, the PID control method based on BP neural network adaptive control strategy is adopted to achieve on-line adjustment of PID control parameters. The final effluent water quality can meet the emission standards.

1. Introduction

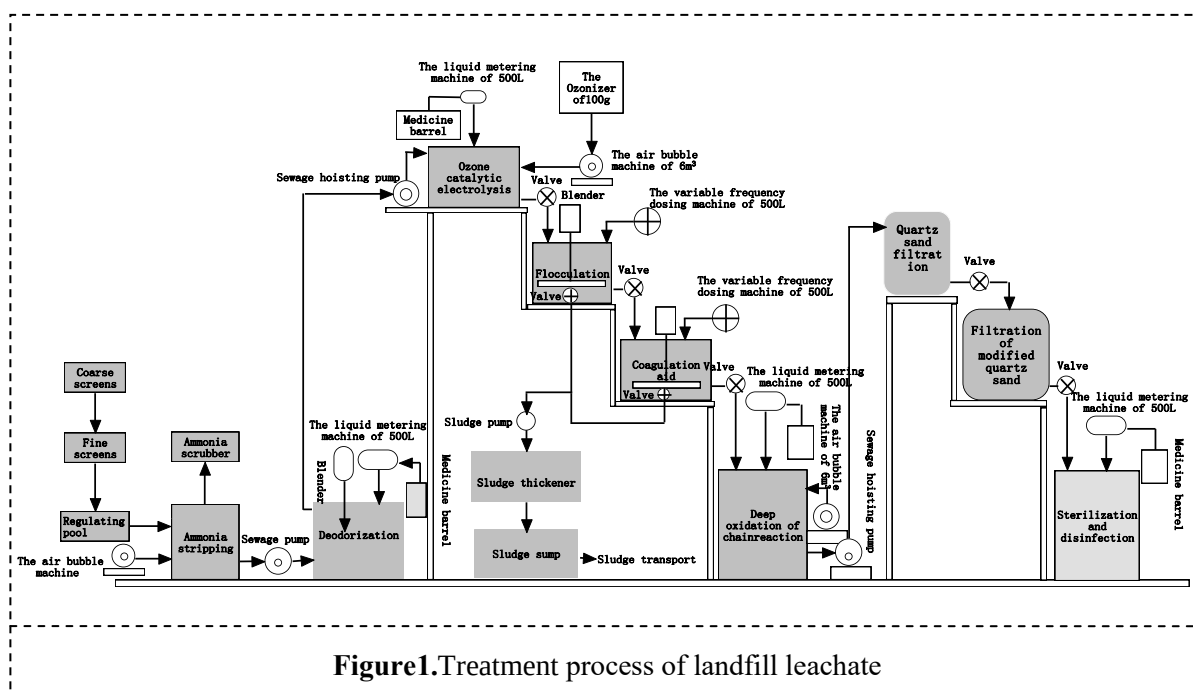
With the increase of the urban population, the expansion of the city scale and the improvement of the residents' living standards in China, the production of urban domestic waste in China has increased dramatically. At present, waste disposal methods include sanitary landfills, waste incineration, and composting. The main reason for adopting the sanitary landfill method in China is that the method is not only low in cost, but also able to handle a large amount of garbage, and it is also relatively simple to manage and has strong adaptability [1].

In the urban landfill process, factors such as atmospheric precipitation, surface runoff, and self-contained water in the garbage will cause the pollutants in the garbage to dissolve out together with the water, thereby forming landfill leachate. Leachate has more than 20 toxic and hazardous pollutants that are preferentially controlled by the environment. Not only is the composition of the leachate complex, but also the water volume and water quality are very volatile. These characteristics make leachate treatment a worldwide issue [2]. Leachate will seriously affect people's health and living environment, and the harmless treatment of leachate is more and more important. Therefore, it is of great significance to study the leachate treatment process [3].



Domestic and foreign landfill leachate treatment methods include physicochemical methods, biological methods, land treatment methods, and some combination processes. Physicochemical treatment has a good effect on the leachate with poor biological treatment effect. The change of water quality and water quality has little effect on it, and the effluent water quality is relatively stable. Physical and chemical reactions generally include coagulation and sedimentation, activated carbon adsorption, chemical oxidation, ion exchange, membrane separation, and catalytic oxidation. Biological methods can be divided into aerobic, anaerobic, and anaerobic-aerobic combination processes. The principle of the land treatment method is to use the natural self-cleaning ability of the earth to treat the organic matters in the leachate through processes such as adsorption, filtration, oxidation, or microbial utilization. Currently, there are few applications. Some studies have used microwave and activated carbon in combination to enhance persulfate treatment of landfill leachate. The results show that the removal rate of COD and ammonia in landfill leachate is 78.2% and 67.2%, and the ratio of BOD_5/COD is increased from 0.17 to 0.38 [4]. The experimental results show that the removal rates of COD, ammonia nitrogen and chromaticity are 88%, 79% and 100%, and BOD_5/COD from 0.07 to 0.34 [5]. Some studies used aluminum sulfate and ferric chloride to treat a stable leachate, and the COD removal rate was over 75% [6]. In some studies, coagulation combined with photo-Fenton's method has been used to treat aged landfill leachate. It was found that the introduction of coagulation in the photo-Fenton combined treatment of landfill leachate compared to the single use of the photo-Fenton process for leachate treatment. The process can increase the COD removal rate from 63% to 89%, and the treated leachate exhibits no toxicity [7]. This dissertation mainly discusses a short-range landfill leachate treatment process. The leachate is mainly treated by physical treatment.

2. Landfill Leachate Treatment Process



The treatment process for the formulated landfill leachate is shown in figure 1. The following describes each process in detail.

2.1. Coarse grid

The coarse grille is placed before the intake pump room. It is used to remove large-size floating and suspended materials and protect the operation of the pump to avoid accidents such as impeller winding and plugging, and ensure that the subsequent processing facilities can operate normally. The

rotary grid decontamination machine is generally composed of rake teeth installed at a certain distance on the slewing chain. Driven by the driving device, the revolving chain drives the rake tooth to rotate in a certain direction. In the water surface, the rake teeth are moved from the bottom to the top to fish out the floaters in the water, rotate to the top and then remove the floaters. The filtering accuracy is 20mm [8].

2.2. *Fine grid*

Fine grids are set behind the coarse grids, because there are various fine linear floats, flake-like floats, such as hair, fabric fines, plastics and rubber fragments in the landfill leachate. With the accumulation of these fibrous substances, the sludge will be entrapped in the fiber mass and the sludge will be lost with the effluent. The drum-type fine grid is used to filter the landfill leachate. The filtration accuracy is 5mm [9].

2.3. *Regulating pool*

The garbage composition of the landfill site is complex, and the pH of the leachate generally fluctuates within the range of 4-9. The pH value will have a greater impact on subsequent treatment processes. In the ammonia stripping process, the most suitable pH value is 10.5 [10]. Alkaline lime water is added to the conditioning tank through the dosing machine, and the pH of the leachate is adjusted to 10.5.

2.4. *Ammonia stripping*

The basic principle of the blow-off method is to use air to blow off under the alkaline condition by utilizing the difference between the actual concentration of the volatile components such as ammonia nitrogen contained in the waste water and the equilibrium concentration under the determined conditions. In order to improve the stripping efficiency, recover the useful gas and prevent the secondary pollution, the packed tower is adopted. The packing tower is constructed by gas-liquid contacting device, and a certain height of filling layer is set in the tower [11]. The lime-treated leachate is showered from the upper part of the tower to the filling to form water droplets. It falls down in the gap between the fillers, and then the air is blown upward from the bottom of the tower with a fan to make ammonia evolve into gas to escape from the water. The ammonia-containing tail gas enters ammonia absorption tower. After the leachate is blown off by ammonia, not only a large amount of free ammonia is removed, but also some phenols, cyanides, sulfides, and other difficult-to-biodegrade volatile substances are removed [10].

2.5. *Deodorant*

The filtered leachate was passed through the deodorant tank, and sodium hypochlorite was added while the mixer was stirring. Simultaneously, sulfuric acid was added to adjust the leachate to acidity. In terms of the properties of various oxidants, sodium hypochlorite has good effect and economic efficiency, so it is widely used. In the solution, sodium hypochlorite is present in the hypochlorous acid situation. The source of odor is mainly hydrogen sulfide, organic sulfur, volatile fatty acids, etc. Sodium hypochlorite has strong oxidizing properties and can kill bacteria and viruses. At the same time, it can remove hydrogen sulfide and so on. so it can deodorization [12].

2.6. *Ozone catalytic electrolysis*

Ozone oxidation technology is often used to remove refractory organics and chromaticity in leachate. Ozone oxidation alone used to treat landfill leachate has problems such as low ozone utilization and long reaction time. Therefore, a new combination of catalytic technology and ozone oxidation is used. On the basis of this, internal electrolytic oxidation method is used to produce oxygen radicals and other active groups to oxidize and degrade the organic matter in the leachate, and at the same time, the flocculation precipitation removes most of the heavy metals [13]. First add iron-carbon filler to the tank, then inject ozone into the tank through the bubble machine, and add potassium monopersulfate inside by using the dosing machine. The sulfate radical ($\text{SO}_4^{\cdot-}$) produced by the activated persulfate can rapidly organic pollutants and mineralize them into CO_2 and inorganic acids. Compared with the traditional advanced oxidation technology, sulfate radicals are highly selective and low requirements

for the external environment [14]. The leachate is electrolyzed using a 1.2V potential difference generated by the iron carbon material filled in the leachate. Numerous micro-battery systems are formed in the reaction tank, and an electric field is formed in the action space. The new ecology [H], Fe^{2+} , hydroxyl radicals, sulfate radicals and other energy generated during the treatment process can undergo redox reactions with many components of the leachate. These oxidation reactions can destroy the chromophoric group or the chromophoric group of the colored substances in the leachate, or even break the chain, to achieve the effect of decolorization. The generated Fe^{2+} is further oxidized to Fe^{3+} , and their hydrates have strong adsorption-flocculation activity. The process can effectively remove the organic matter, heavy metal and chromaticity in the leachate, which can reduce the COD value of water quality and its toxicity.

2.7. Flocculation aid

The flocculant PAC was added by means of a variable liquid metering dosing machine. The aqueous solution of PAC is a hydrolytic product between aluminum chloride and aluminum hydroxide, and has a colloidal charge. Therefore, it has strong adsorption for suspended solids in water [13]. PAC is a kind of polymer inorganic flocculant. Polyaluminumhydrolyzate has polynuclear hydroxyl group containing Al^{3+} complex. These complexes are further hydrolyzed and the hydrolyzed product have the ability to neutralize the black colloid negative charge, compress the electric double layer, and reduce the zeta potential of the colloid [15].

After the PAC flocculant was put into the leachate, the colloids were reduced or eliminated due to the potential, and the stability of the particles was destroyed. The destabilized particles aggregate with each other into larger particles. Flocculation sedimentation not only removes fine suspended particles in leachate, but also remove color, oil, microorganisms, nitrogen, heavy metals and so on. The precipitated sludge enters the sludge thickening tank through the sludge pump.

2.8. Coagulation aid

After 7 minutes of addition of PAC flocculant, polyacrylamide (PAM) was added to the reaction tank via a frequency meter dosing machine. PAM is a macromolecule substance added to regulate or improve flocculation conditions and promote aggregation. It has been widely used in the field of water treatment [14]. The PAM molecular chain contains a certain number of polar groups, which can adsorb solid particles suspended in the waste water to bridge the particles or neutralize the particles to form large flocs. The density and weight of PAM can accelerate the sedimentation of particles in the suspension [16]. The resulting sludge enters the sludge thickening tank through the sludge pump.

2.9. Chain reaction deep oxidation

Sodium persulfate is added to the barrel through the liquid metering dosing machine, and then bubbles of ozone are bubbled into the tank through the bubble machine. The chain-catalyzed multi-oxidation radical mutual catalytic deep-oxidation oxidant is composed of an active radical source, an active activator, a balance stabilizer, and a sustained-action accelerator, etc. It is a strong oxidation technology formed by the integrated excitation of electromagnetic field, microwave and ultraviolet radiation to form S-free radical as the core, hydroxyl radical ($\text{OH}\cdot$), halogen free radical ($\text{Cl}\cdot$), hydrogen peroxide free radical ($\text{HOO}\cdot$) and so on. Microwave activation is a heating method that is different from thermal energy at the molecular level. It selectively heats absorbing materials through microwaves, catalyzes at low temperature, and penetrates quickly. The organic matter in landfill leachate undergoes violent catalytic and physicochemical reactions under the combined action of activated carbon and microwaves, and which is converted into insoluble substances or gases separated from water. Some of the organic pollutants are broken down under the action of microwave catalysis. They are decomposed into small molecules and are combined with activated carbon to form floc. Metal ions directly combine with activated carbon to produce sink flocculant precipitates. Ammonia nitrogen is converted into ammonia gas. When the concentration exceeds the standard, it can be absorbed and removed by a subsequent absorption device. Phosphorus in the leachate is converted to insoluble phosphate precipitates for removal. The treatment process has effective removal rates for

COD, $\text{NH}_3\text{-N}$, animal and vegetable oils, phosphates, LAS , Cr^{6+} , CN^- , Cu^{2+} , Zn^{2+} , Pb , Ni , total chromium and other pollution factors, especially for COD.

2.10. Quartz sand filtration

The purified quartz sand filter material is filled into the reaction tank. When the influent water flows through the filter layer from top to bottom, the suspended matter and the viscous particles in the leachate are removed, so that the turbidity of the leachate is reduced. This process can effectively remove suspended solids, organic compounds, colloidal particles, microorganisms, chlorine, smell and some heavy metal ions and other in leachate [17].

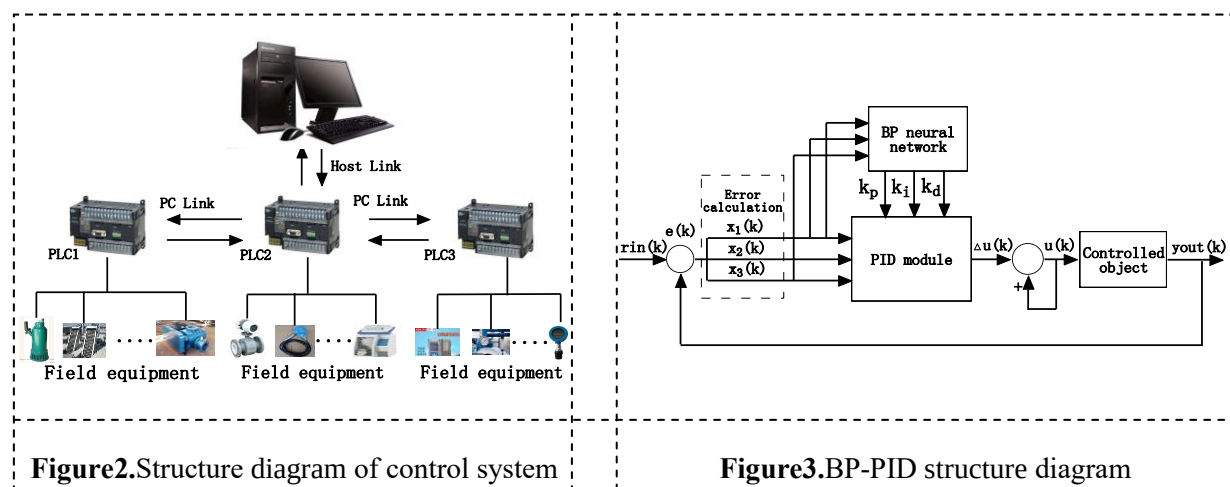
2.11. Modified quartz sand filtration

The reaction tank is filled with refined modified quartz sand filter material, and the graphene is combined with the quartz sand chemically to form a strong coating on the surface of the quartz sand. At the same time, quartz sand and graphene are combined to avoid the uncontrollability of nanomaterials in subsequent processing, and it is easier to recycle and reuse. Graphene forms a dense fiber filter layer that maximizes the use of nanoscale graphene properties and it greatly improves the strength and toughness of composites. Graphene has a large theoretical specific surface area, and graphene evenly penetrates into the gap of the screen substrate, so that the filter fiber component has a large specific surface area and has a lot of microporous structures on it. Therefore, modified quartz sand has stronger adsorption effect than traditional filter materials. The process further filters out leachate suspended solids, organic matter, colloidal particles, microorganisms, chlorine, smell and some heavy metal ions. It has the characteristics of short adsorption time, high adsorption efficiency and long filter screen usage time [17].

2.12. Sterilization and disinfection

Potassium bisulfate is added to the tank by a liquid dosing machine. Potassium bisulfate compound salts are dissolved in water to release reactive oxygen species and high-energy, high-activity small-molecule radicals, neo-atom oxygen, chlorine radicals, hydroxyl radicals ($\text{OH}\cdot$), sulfuric acid radicals ($\text{SO}_4\cdot^-$) and a variety of active ingredients are generated by high energy activator via chain reaction. So it becomes an efficient oxidation disinfectant, killing bacteria, spores, viruses, fungi and other microorganisms. At the same time, lime water was added to the tank to adjust the effluent pH to 7.

3. Control System



According to the landfill leachate treatment process, and then carry out the test operation in the engineering project. In order to realize the automatic operation of landfill leachate treatment, the automation control is carried out by using the host computer and the lower computer programmable

controller (PLC) and the field sensor instrument. The structure diagram of the automatic control system of landfill leachate is shown in figure 2. The leachate treatment plant adopts the SCADA control system. Through industrial communication networks, field devices, control stations, and central control rooms communicate with each other to realize data interaction, form a complete communication network, and implement an automatic control system that integrates monitoring and management[18].

The host computer configuration king realizes the communication with the lower computer PLC through host link. This automatic control system has 3 PLC control stations, collecting data in the reaction pool through various sensors such as: liquid level value, pH value, COD value, turbidity, BOD₅ value, ammonia nitrogen concentration, etc. Each PLC station realizes the data exchange through the PC link agreement. The controller mainly completes the functions such as sending out operation instructions, data collection and real-time processing, and abnormal phenomenon alarm processing. The upper computer adopts kingview to realize data monitoring for each PLC control station, and real-time monitoring of the operation of process equipment of each control station, and controls the execution equipment by adjusting the control parameters of each process.

Because of the components of landfill leachate are complex and the water quality changes greatly, the traditional PID control method has poor control accuracy in the leachate treatment process, and the parameters are difficult to adjust online. Therefore, a PID control method based on adaptive strategy is proposed and designed. The structure diagram of the BP-PID control structure is shown in figure 3. By using the self-learning ability and approximation capability of BP neural network, the PID parameters are adjusted online according to the characteristics of water quality change of leachate. And the controller's control effect and anti-jamming ability are enhanced.

4. Control System

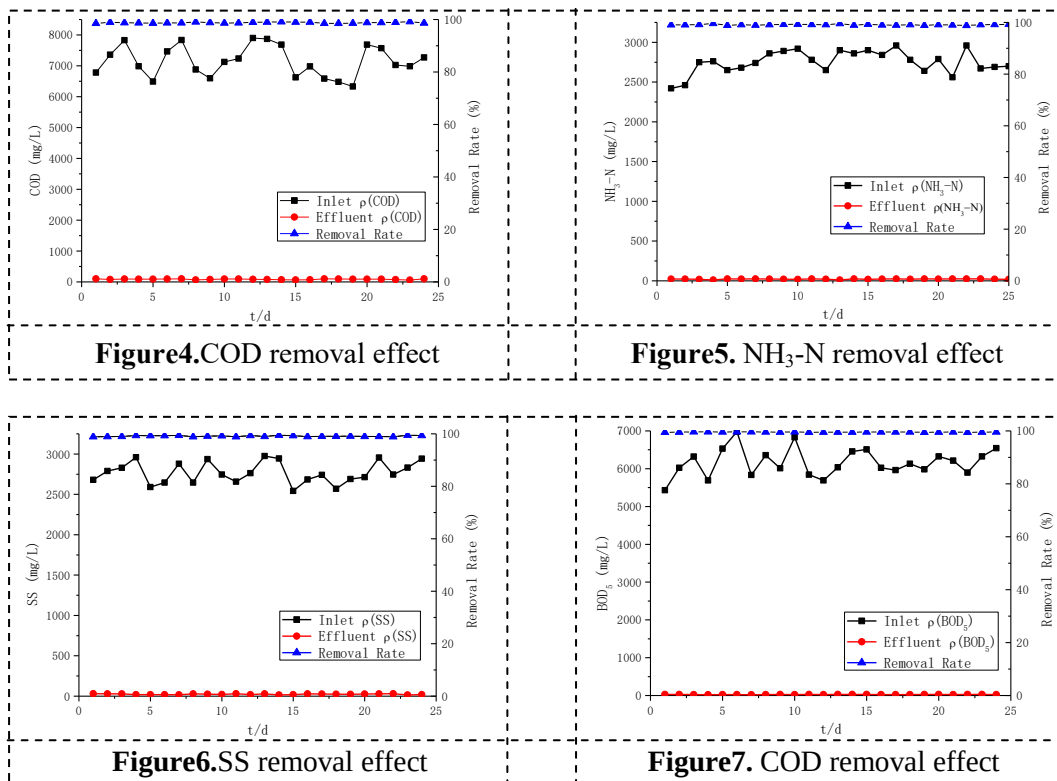
The influent water quality measured by various sensor instruments is shown in table 1 below:

Table 1. Influent pollutant concentration table

Pollutants	Concentration range(mg L ⁻¹)	Pollutants	Concentration range(mg L ⁻¹)	Pollutants	Concentration range (mg L ⁻¹)
COD	6000-8000	Cl ⁻	2000-3000	Pb	0.1-0.3
BOD ₅	5000-7000	SO ₄ ²⁻	400-600	Mn	30-40
TS	4000-6000	Ca ²⁺	3000-4000	Zn	50-70
SS	2500-3000	Fe	1000-1500	TCr	2-3
NH ₃ -N	2000-3000	Mg	500-600	VFA	200-300
P	40-60	Cd	2-3		
PH	5-9	Cu	3-4		

We carry out experimental operation in the project. After a series of physicochemical treatments, the refractory organics in the leachate are effectively oxidized and degraded, and the COD, BOD₅, ammonia nitrogen, suspended solids, chroma, and some heavy metal ions in the leachate are removed. The final effluent quality of leachate reached the first-class emission standards. The main indicators of leachate discharge standards after treatment are: pH6-9, COD≤100mg/L, BOD₅≤30mg/L, SS≤30mg/L, NH₃-N≤25mg/L, TN≤40mg/L, TP≤3mg/L.

We collected the average values of COD, NH₃-N, BOD₅, SS influent concentration and effluent concentration during the daily operation of the landfill leachate treatment system, and monitored a total of 25 days. The experimental results are shown in figure 4, Figure 5, Figure 6, and Figure 7. The removal rate was calculated and then the three parameters were plotted as a graph. As shown in the following four figures, we can see from the figure that the effluent concentration of the four pollutants is relatively low and the removal rate reached 99%.



5. Conclusion

The water quality of landfill leachate is affected by external factors. The size of the landfill, the landfill operation mode, different seasons, and the local meteorological conditions all affect the quality of leachate. Leachate as a special high-concentration intractable wastewater, its investment and operating costs are much higher than the general urban domestic wastewater or industrial wastewater. The main reason is that the concentration of organic matter and ammonia nitrogen in the leachate is extremely high, the biochemical performance is poor, and the proportion of nutrients is unbalanced [2]. In this paper, physicochemical treatment is mainly applied to treat leachate. In general, the main advantages of the physicochemical method are stable treatment effect, assured water quality, and strong anti-hydraulic load capacity, especially with low biodegradability and low BOD₅/COD landfill leachate treatment [2].

This paper has achieved good results in the treatment of landfill leachate by ozone oxidation, internal electrolysis, peroxidation of persulfate, deep oxidation of chain reaction, microwave field catalytic oxidation, coagulation and precipitation, adsorption and other physical and chemical treatment. The process effectively oxidizes and degrades refractory organic matter in the leachate, removes COD, BOD₅, ammonia nitrogen, suspended solids, chroma, and some heavy metal ions in the leachate, and the effluent water quality meets the emission standards. At the same time, the process equipment has less investment, lower cost, short processing flow and high efficiency, and has a good application prospect in the treatment of landfill leachate. Through the application of automatic control system, the stability of the system has been improved, the precise control of the controlled equipment has been realized, the dosage of the medicine can be controlled more accurately, the treatment effect is better, the use of the medicine is reduced, the two pollution of the water quality is avoided and the cost of the sewage treatment is reduced.

However, there are also some defects in the treatment of landfill leachate, such as large amount of catalyst and low efficiency of some catalysts. Therefore, aiming at some problems in the leachate treatment process, we need to deeply study the mechanism of advanced oxidation technology reactions,

strengthen the optimization and combination of advanced oxidation technologies and other treatment processes, and learn from each other to achieve high efficiency, cost-effective, and pollution-free treatment methods. Oxidants are the basis of physicochemical treatment methods. We must research and develop low-cost, more oxidation-efficient oxidants. The research and development of new and complex catalysts and the increase in the number of recycling catalysts will not only contribute to the treatment of landfill leachate, but also have important implications for the realization of their recycling and environmental protection. We also need to develop an efficient and simple reactor to treat landfill leachate, which will provide new ideas and directions for realizing landfill leachate treatment [3].

6. References

- [1] Xiao C H 2017 Study on Leachate Treatment Process of Domestic Waste Landfill Site *Sci. Technol. Innov* 111 112
- [2] Ren H Y, Han L, Kang Y L and Huang W W 2016 Process design and analysis of difficulties for treatment of landfill leachate *China Water Wastewater* 32 56-58
- [3] Liu Z B 2017 Research progress and analysis of treatment technology for landfill leachate *Guangzhou. Chem. Ind* 32 38-41
- [4] LI N, LI X M, YANG Q et al 2014 Landfill leachate treatment by microwave-enhanced persulfate oxidation process using activated carbon as catalyst *China. Env. Sci* 49 1-96
- [5] Amaral-silva N, Rui C M, Castro-silva S et al 2016 Ozonation and peroxozonation on the biodegradability improvement of a landfill leachate *J. Environ. Chem. Eng* 4 527-533
- [6] Tatsi A A, Zouboulis A I and Matis K A 2003 Coagulation-flocculation pretreatment of sanitary landfill leachates *Chemosphere* 53 737-744
- [7] Amor C, De T E, Peres J A et al 2015 Mature landfill leachate treatment by coagulation/flocculation combined with Fenton and solar photo-Fenton processes *J. Hazard. Mater* 286 261-268
- [8] Feng C J, Jiang L L, Liang T and Wu W H 2015 A Review on the Grille Equipment in sewage treatment plant *Env. Eng* 33 941-945
- [9] Zeng S J 2016 Application of new grille decontamination machine in sewage treatment plant *Henan Building. Mat* 5 88-90
- [10] Wang W B, Dong Y and Liu S T 2004 Air stripping to remove ammonia nitrogen in landfill leachate *Techniques Equipment* 551-52
- [11] Aoshiman T, Yang L, An D and Wang T 2014 Progresses in air stripping for treatment of ammonia wastewater *Petrochemical. Techno* 43 1348-49
- [12] Liu Z B 2018 Domestic waste landfill site leachate deodorization process overview *Technology Equipment* 44 86
- [13] Liu Z M, Xu L C, Zhao J F et al 2018 Research progress of advanced oxidation treatment of landfill leachate *Technol. Water. Treat* 44 7-11
- [14] Amr S S A, Zakaria S N F and Aziz H A 2016 Performance of combined ozone and zirconium tetrachloride in stabilized landfill leachate treatment *J. Mater. Cycles Waste* 12 1-7
- [15] Yang E L, Zhou Y X, Wang H L et al 2016 Experiment on the treatment effect of PAC-PAM treating the electroplating wastewater in one industrial park *J. Green. Sci. Technol* 16 141-143
- [16] Zhu L S 2010 Study on the Degradation of Dye stuff Wastewater by the PAC/PAM Flocculation Treatment *Guangdong. Chem. Ind* 37 123-126
- [17] Mo D Q, Xiao W X and Chen B 2007 Adsorption filtration properties of modified quartz sand *J. Guilin. U. Technol* 27 378-381
- [18] Yang W X 2018 Critical review of landfill leachate treatment technologies *Low. Carbon. World* 23 59

Acknowledgments

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