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Countermeasures for Leachate Treatment of Kitchen Waste under the Background of Garbage Classification

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Abstract

The acceleration of urbanization has also caused a high concentration of the population. In the process of domestic waste treatment for urban residents, rapid growth of landfill leachate and environmental pollution problems have emerged. This paper summarizes the characteristics and hazards of kitchen waste leachate, reviews and summarizes the common treatment methods for kitchen waste leachate from three aspects: biological treatment, physicochemical treatment and membrane treatment. It also summarizes the typical treatment process routes of leachate from the perspective of differences in biodegradability, and points out the current difficulties, key points and countermeasures in landfill leachate treatment. In the future, further research on the treatment process of leachate should be carried out from the perspectives of biological enhancement technologies such as biological denitrification, lower-cost chemical methods, innovative integration of membrane separation technologies and exploration of new process routes.

Keywords

Garbage Classification; Landfill Leachate; Water Quantity; Water Quality; Treatment Process.

1. Introduction

With the advancement of social economy and the continuous enhancement of people's living standards, the production of urban solid waste has been increasing year by year, and the issue of garbage disposal has gradually emerged. By the end of 2017, China's urban solid waste collection volume reached 215.4797 million tons [1], and all these wastes were collected, transported, treated, and disposed of in a mixed manner. In order to reduce and recycle the source of domestic waste, waste classification management has become a key topic of concern for the Central Committee of the Communist Party of China and all sectors of society in recent years. In June 2019, the Ministry of Housing and other ministries issued the Notice on Comprehensively Implementing the Classification of Domestic Waste in Cities at the Prefecture Level and Above across the Country, requiring that by 2020, 46 key cities in the country should basically complete the garbage classification and treatment system, and by 2025, cities at the prefecture level and above should basically complete the garbage classification and treatment system.

During the process of garbage classification, the generation of leachate constitutes an important secondary pollution issue. The implementation of garbage classification might facilitate the reduction of leachate. However, in the absence of an effective treatment plan and scientific management, it will conversely result in the expansion of leachate pollution. Hence, it is urgent to study the reduction of leachate during the process of garbage classification. After garbage classification, the water quality of leachate is bound to have a significant impact, and the quantity and quality of leachate in landfill plants and waste incineration plants will also have a considerable influence. Moreover, the leachate of kitchen waste has become a more concerned hotspot, thus it is necessary to enhance the treatment

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process based on the original one or carry out targeted treatment process design. To prevent the improper disposal of landfill leachate into the environment and avoid causing severe harm to the environment and human beings.

2. Sources and Characteristics of Landfill Leachate

After the implementation of waste sorting, food waste will be sent to food waste treatment plants, and other waste, such as contaminated paper, diapers and plastic bags, will be sent to landfills or incinerators. Landfill leachate is a kind of high-concentration organic wastewater produced by compression and biostabilization of kitchen waste and other garbage in the process of landfill or stacking, which is characterized by large chroma, odor, complex organic composition, large concentration change, and high ammonia nitrogen content. Under the existing landfill operation mode, one ton of domestic waste can produce 0.05~0.20 tons of leachate [2]. The output of leachate is affected by many factors, mainly including the composition of landfill waste (affected by local residents' living standards, living habits and garbage classification standards, etc.), seasonal changes and landfill age [3]. Baig S. et al. [4] showed that landfill age had the most significant influence on leachate yield and composition.

3. The Harm of Landfill Leachate

As a kind of organic wastewater with high concentration and high pollution, a large amount of organic matter and inorganic salt in landfill leachate is easy to form a variety of odorous substances under anaerobic or facultative anaerobic conditions, which attracts mosquitoes and flies, and seriously affects the living environment and health of surrounding residents. It is reported that there are 26 kinds of metal ions and more than 100 kinds of organic pollutants that can be detected in the leachate at present. In addition, due to the diversification of types of domestic waste, many new pollutants are constantly detected [5-7]. Therefore, domestic garbage leachate treatment is not up to standard or leakage accidents will not only pollute soil, surface water and even groundwater, and its pollution effect is difficult to eliminate in a short period of time.

Leachate leaks into the soil, and the pollutants carried by it can migrate and transform in the soil through physical, chemical and biological effects, resulting in serious pollution [8]. Xia Lijiang et al. [9] found when analyzing the soil around a landfill that the PH value of the contaminated soil was less than 7, and the heavy metal content was significantly higher than the background value. Qian Liping et al. [10] conducted a study on the Harbin municipal landfill site, which showed that the soil within 100m of the landfill site was polluted by a variety of heavy metals, and the soil microorganisms died under the effects of weathering, rain and high temperature, resulting in the absence of grass [11]. Incidents of leachate pollution of surface water and groundwater also occur from time to time, such as the leachate pollution of rivers in Nepal and the Laf Canal incident in the United States [12-13]. The study of Mikac et al. [14] shows that the pollution of landfill leachate to underground aquifers can penetrate to 60m underground. Zhang Lanying et al. [15] detected the leachate from four landfill sites in Changchun and the groundwater at different distances around them, and found that the groundwater closest to the landfill had the most organic matter content and types. In addition, it is worth noting that a certain amount of organic pollutants can still be detected in groundwater 1000m away from the landfill. These examples all show that leachate can cause pollution of soil, surface water and even groundwater around landfill sites.

4. Kitchen Waste Leachate Treatment Method

4.1 Aerobic Biological Treatment

Aerobic treatment can partially reduce the concentration of biodegradable organic pollutants, and also achieve nitrification of ammonia nitrogen. Aerobic biological process based on suspension growth of biomass, conventional activated sludge process and sequential batch reactor (SBR) have been widely studied and adopted.

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The degradation rate of aerobic organisms in the leachate was affected by many aspects. For example, the use of upper aerated bioreactor could significantly shorten the time required for acidification stage, accelerate the degradation of organic pollutants in the leachate, and both COD and BOD_5 of the aerobic bioreactor were reduced by more than 90% compared with the beginning of the experiment. In addition, prolongation of aeration time can also significantly improve the degradation rate of nitrogen-containing substances in leachate. With the increase of aeration time, the sedimentation ratios of four groups of refuse were 7.1%, 8.6%, 17.1% and 21.4%, respectively, indicating that prolongation of aeration time can help accelerate the sedimentation of refuse and improve the effective storage capacity of landfill.

The amount of leachate recharge has a significant impact on the stabilization process of aerobic landfill. Studies have shown that the leachate produced in landfill columns under aerobic conditions is less, a neutral alkaline environment is easily formed and the temperature is higher, which is conducive to the degradation of COD and ammonia nitrogen, and can accelerate the stabilization process of landfill waste compared with the anaerobic condition. And 20% recharge is the most suitable for landfill waste settlement and pollutant degradation.

Studies on aerobic process show that aerobic granular sludge (GSBR) has a better effect than suspended activated sludge (ASBR). At a high influent concentration of total ammonia nitrogen (498 mg/L), GSBR achieved a total ammonia nitrogen removal rate of 99%, and ensured nitrification efficiency (56±12%) without nitrite accumulation,COD removal rate ranged from 67% to 87%, and phosphorus removal rate was about 49%.

4.2 Anaerobic Biological Treatment

Compared with aerobic process, anaerobic digestion treatment of leachate can not only degrade a large amount of organic matter, but also produce biogas energy for recycling and saving energy, while producing little sludge, but the reaction rate is low. The conventional nitrification-denitrification process is often used to treat young landfill leachate. For mid-life landfill leachate, the nitrifying - endogenous denitrification process is preferred because it can make full use of the organic matter in the original wastewater. For aged leachate, the anaerobic ammoX process is suitable because it effectively removes nitrogen and does not require the addition of external carbon sources. Under the conditions of volume load of 8 ~ 10 $kg/(m^3 \cdot d)$, rising flow rate of 0.3 m/h, and hydraulic residence time of 4 ~ 5 days, the VSS rises to 63 kg/m^3,VSS/TSS value reaches 0.80, and COD removal rate is above 90%. The gas production is 4000 m^3/d, and the pH in the anaerobic tank is balanced . When the COD removal amount is 10.1 $kg/(m^3 \cdot d)$, the gas production rate reaches the maximum of 3.58 $m^3/(m^3 \cdot d)$. When the volume load is 10.9 $kg/(m^3 \cdot d)$, the maximum gas production rate is 3.0 $m^3/(m^3 \cdot d)$. 80.6% of influent COD produces biogas, and the remaining 19.4% is discharged with effluent and utilized by microorganisms. Compared with other processes, the two-stage upflow anaerobic sludge layer (UASB) system can achieve deep removal of total nitrogen (TN). Ammonia nitrogen is oxidized to nitrate in a sequencing batch reactor (SBR), and the effluent enters the UASB, and the organic matter in the landfill leachate is used to remove total nitrogen. The removal rates of COD, NH^{4+}-N and NH^{4+}-N by this method are all over 95%.

4.3 Membrane Treatment

Membrane treatment technology has a very good treatment effect on sewage treatment technology, and the treatment of landfill leachate is no exception. Its separation and selective permeability can well treat COD, ammonia nitrogen, total nitrogen, etc., in landfill leachate, and it also has a certain treatment effect on chroma and salinity. However, the economic investment in processing is greater, and the problem of membrane pollution is the main shortcoming that restrains the application of this technology. Among them, reverse osmosis technology is the most widely used membrane treatment technology, which has a good effect on the treatment of medium molecular weight organic matter, which can reach more than 80%, and the problem of membrane pollution is also an inevitable problem of reverse osmosis technology, but it can improve the effluent quality as a follow-up treatment technology of biochemical treatment, and can also alleviate the problem of membrane pollution.

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5. Leachate Treatment Process of Kitchen Waste

5.1 New AB Process

Anaerobic fermentation technology is widely used in kitchen waste treatment plants. Whether it is dry anaerobic or wet anaerobic, the ammonia nitrogen content in the biogas slurry is higher. With the continuous development and progress of anaerobic fermentation technology, the biogas production rate is greatly increased, which brings about the problem that the COD concentration in the biogas slurry is further decreased and the carbon nitrogen ratio is seriously unbalanced. The content of organic matter in the food waste liquid of the food waste treatment plant is very high, but because it contains impurities such as oils, suspended solids and fibers, it can not be used as a carbon source, which makes the biogas liquid treatment more difficult and the operating cost is much higher than that of other sewage treatment.

On the basis of pretreatment of biogas slurry, the new AB+ deamination combined process is adopted to treat biogas slurry, which can significantly remove COD, SS and ammonia nitrogen and other pollutants, and also effectively remove heavy metals , fats and PAM in the biogas slurry It creates favorable conditions for subsequent biochemical treatment, improves the overall treatment efficiency, stably runs the system, saves the amount of carbon source added, and reduces operating costs. The typical process flow of biogas slurry treatment in the kitchen waste treatment plant is shown As follows.

Percolate→Preconditioning→Bioadsorption→Denitrification→MBR→Advanced treatment→Effluent.

5.2 MBR+NF+RO Process

The biogas slurry separated by solid and liquid enters the regulating tank of the system and is pumped to the MBR system through the lifting pump. After biological nitrification, denitrification and other functions, COD_{Cr}, BOD_5, $NH^{3-}N$, total N and other pollutants in the sewage are removed, and finally the pollutants are further removed by NF+RO membrane to reach the discharge standard. The effluent is used as supplementary water for the cooling tower of the incineration plant.

The biogas slurry treated by this system comes from kitchen waste anaerobic and has a higher $NH^{3-}N$ content. Compared with the general two-stage NF process, one of the stages is adjusted to RO process, which has a better removal rate of $NH^{3-}N$ in a weakly acidic environment and can ensure the stable effluent standard.

In this system, both NF unit and RO unit produce concentrated liquid. Before the concentrated liquid of RO is returned to NF, the outgoing concentrated liquid of the whole system is only produced from NF, and the water production rate of NF is higher than that of RO. This method can effectively reduce the amount of concentrated liquid produced in the whole system, thus reducing the processing cost of concentrated liquid.

The discharge standard of this system is relatively strict, the effluent is used for the cooling and circulating water replenishment of the adjacent incineration plant, and the discharge standard has higher requirements for Cl^-, which is different from the general wastewater discharge standard, and NF has almost no interception effect on the monovalent anion, so the addition of RO is an important guarantee for the discharge standard.

Compared with two-stage NF, NF+RO can improve the removal rate of $NH^{3-}N$ and is more suitable for biogas slurry treatment of kitchen waste. The discharge standard of project effluent requires Cl^-, and the content of Cl^- in biogas slurry of kitchen waste is high. RO can make up for the absence of monovalent anion retention by NF. Using NF as the concentrate production unit of the entire system can reduce the concentrate production of the system and further reduce the operating cost.

5.3 Pre-deammonia Process

With the development of waste classification, many cities in China will build new food waste treatment plants. After anaerobic fermentation of food waste, the ammonia nitrogen content in biogas slurry is relatively high (the measured value of the built project is as high as 4000 mg /L or more). In order to achieve high gas yield, the COD concentration in the effluent biogas slurry is relatively low. The C/N ratio required for efficient biological nitrogen removal cannot be met, and the addition of carbon sources will cause the direct increase in operating costs. In this case, the pre-deammonification process will be increasingly valued. The pre-deamination process includes membrane deamination, ammonia purge and stripping deamination. The C/N ratio of leachate in aging landfills is seriously out of order, the content of organic matter in newly filled garbage after waste classification is low, and the fresh leachate generated cannot make up for the lack of carbon source. For the transformation of leachate treatment process in aging landfills, pre-deammonia process is also needed.

5.4 Short-range Nitrification, Denitrification and Anaerobic Ammonia Oxidation Processes

Waste classification makes the field of leachate treatment in urgent need of nitrogen removal process with low or no carbon sources. For the biogas of anaerobic biogas residue after dehydration of high ammonia nitrogen, short-range nitrification and denitrification or anaerobic ammoxidation process can be used to remove most of ammonia nitrogen and total nitrogen, which can reduce the subsequent biochemical treatment load, greatly reduce the operating cost and improve the treatment effect.

6. Summary

Due to the complex composition of leachate of urban kitchen waste, although there are many current treatment methods, the only disadvantage is that they can not meet the requirements of effluent. The treatment process of domestic kitchen waste leachate is to remove solid suspended substances and oils in the leachate by physical and chemical treatment, and then remove pollutants in the leachate by biological treatment until the organic pollutants reach the emission target. If it cannot meet the discharge standards, it can be treated by physical and chemical processes such as coagulation and precipitation to meet the principle of "pretreatment - main treatment - post-treatment" to complete the treatment of leachate.

In the leachate treatment operation of kitchen waste, the relevant inspection personnel should first detect the substances in the leachate, and then adopt the corresponding treatment process after obtaining the detection result. In the future food waste leachate treatment operation, we hope to develop a new treatment technology that is more in line with the current situation. Although the traditional treatment technology can meet the standard requirements, the overall treatment process is more complex, the cost of treatment facilities is high, and the occupation range is wide, which does not meet the current social development needs. Therefore, there is still room for improvement and innovation in many processing technologies.

In summary, because the water quality of food waste leachate is more complex and the treatment difficulty coefficient is larger, compared with simple physical and chemical treatment methods and biological treatment methods, it is unable to meet the current treatment requirements. Therefore, the combined treatment of COD, ammonia nitrogen, TP, TN impurities has a more significant effect. Therefore, in the future development process, the relevant departments should pay attention to the research and development of leachate treatment technology of domestic kitchen waste, promote the development of emerging technologies, and make efforts to protect the environment.

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