Study on Microbial Treatment Technology of Coal Gasification Coking Wastewater Based on Fractal Concept

Wenxiu Li, Lingkun Rong, Fengjun Jia*

School of Mining and Coal, Inner Mongolia University of Science & Technology, Baotou, 014014, China

*Corresponding author

Keywords: Fractal; Underground Coal Gasification; Wastewater; Coking; Microbial Treatment

Abstract: Microbial treatment technology is to immobilize free microorganisms on carriers by chemical or physical means to improve microbial density and maintain their activity. According to the pore structure of particles and the phenomena of pore opening, enlargement and convergence accompanied by gasification process, the percolation and fragmentation phenomena in gasification process are described. By applying the concept of fractal theory to the study of coal char gasification, the initial population is firstly subjected to fractalization, mimicry and other operations and then evolutionary calculation, so that the generated building has the characteristics of fractal self-similarity. The variation law of pore structure parameters in coal char gasification process accords with a certain fractal relationship. Studies have shown that microbial treatment technology may be an effective method to deal with underground underground gasification and organic pollution of groundwater. In the future, it is necessary to strengthen the breeding and domestication of strains, create conditions for the cultivation of microorganisms, and combine the sewage treatment equipment and other processes to achieve good treatment results.

1. Introduction

The development advantages of coal chemical industry in China are determined by the characteristics of energy resources such as rich coal, poor oil and less gas. Since the 21st century, the international crude oil price has been rising continuously, and the dependence of China's oil on foreign countries has been rising continuously, reaching 58.1% in 2013. Therefore, the development of advanced coal gasification and liquefaction technology to produce coal-based liquid/gas fuels and chemical products is an important way to ensure energy security in China [1]. Coking wastewater is produced in the process of coking and gas making. It has a large amount of wastewater discharge and complex water quality components. Besides inorganic pollutants such as ammonia, cyanide and thiocyanate, it also contains heterocyclic and polycyclic aromatic compounds such as phenol, oil, naphthalene, pyridine, quinoline and anthracene [2]. Polycyclic aromatic hydrocarbons are not only difficult to biodegrade, but also often carcinogenic. Therefore, the massive discharge of coking wastewater not only causes serious pollution to the environment, but also directly threatens human health. The coal char gasification process is accompanied by the fracture phenomenon of solid phase particles [3]. Kerstien and iNksa calculated the kinetics of gasification particle fragmentation from the experimental results and pointed out that in the kinetic reaction zone, when the porosity reaches a critical value, the fracture occurs inside the whole particle. In the diffusion reaction zone, the fracture starts at the periphery and continues to advance to the central domain. However, the underground gasification of coal may enter the rock pores and the gasification residue remains underground, which may cause pollution to the groundwater [4]. It is considered to be the most serious potential environmental risk associated with underground coal gasification, and even affects the promotion and application of underground coal gasification [5].

The purpose of microbial treatment technology is to improve the capacity of wastewater treatment system by adding superior strains screened from nature or efficient strains produced by genomic combination technology to the system. A method for removing one or more harmful substances [6]. In microscopy, fractal concept is used to describe the morphology of internal voids

  DOI: 10.25236/ibmc.2019.010

in coal char particles, that is to say, all kinds of local voids are fractal voids. Macroscopically, the eBthe network is used to model the pore space topology of particles. This method will provide a real natural framework to describe the pore structure of particles and the pore opening, enlargement and convergence phenomenon accompanied by gasification process [7]. Underground coal gasification is a process of converting coal into gaseous fuel or raw materials directly underground. Its essence is also coal gasification. Underground coal gasification can reduce pollutant emissions such as SO2, CO2, dust and fly ash, and reduce emissions of coal gangue, mine water and waste gas during well construction and coal production. It is known as “green” mining technology [8]. In addition, the new standard also clarifies the monitoring location and the base unit displacement of the unit, thus avoiding the inconsistency in the implementation standards caused by different monitoring positions and different displacements. In addition, the quality of coking wastewater used for coal washing, quenching and blast furnace slag is also clearly defined. However, in the past, due to the lack of standards in this area, some production plants will even directly treat coking wastewater without any treatment. Used for quenching [9]. The concept of fractal theory is applied to coal char gasification research. The chemical reaction and material transportation process in the coal char gasification process have nonlinear dynamic characteristics. It can be considered that the pore structure of coal char is a fractal body, and its gasification process is the growth process of pore fractals. This paper studies the microbial treatment technology of coal gasification coking wastewater with fractal concept [10].

2. Materials and Methods

The main pollutants in coal coking wastewater are phenol, ammonia, cyanide, hydrogen sulfide and hydrocarbon. The organic pollutants such as alcohol, acid, ketone, aldehyde and ester are contained in the wastewater from coal gasification to ammonia, alcohol and hydrocarbon. COD and ammonia nitrogen in coal chemical wastewater are generally about 5000 mg/L and 200-500 mg/L respectively. Phenolic compounds in coking wastewater account for 83% of organic compounds, and phenolic compounds in surface gasification wastewater account for 70%-75% of total COD. Phenols and polycyclic aromatic hydrocarbons in wastewater are among the blacklists for priority control of water pollutants in China. With rich pore structure, the coal char gasification process is a gas-solid reaction affected by the specific surface area and pore structure of the coal char. The traditional solid particle reaction model usually simplifies the particles into non-porous or regular pore spheres. It is impossible to investigate the influence of structural differences. As the geometric characteristic parameters of the particles, the fractal dimension reflects the complexity of the particle structure.

Biofluidized bed technology has a good prospect in the treatment of phenolic wastewater. Biofluidized bed is a kind of granular material, such as sand, coke and activated carbon. The flow of water from bottom to top makes the carrier fluidized and grows and adheres to biofilm on the surface of the carrier. The particle size of the carrier is generally 1.0-2.0 mm. Bio-fluidized bed (BFB) has the dual advantages of high efficiency formed by contact of fully mixed activated sludge process and the ability of biofilm process to withstand the impact of load change. According to different sewage quality, microorganisms are screened and domesticated, and a variety of microorganisms are selected to form bacterial flora, forming a decomposition chain and planting it in the sewage treatment tank. Through the metabolism and domestication of microorganisms, harmful substances in wastewater can be transformed or decomposed. The biological treatment technology of coking wastewater is shown in Table 1. The fractal channel hole is different from the smooth cylindrical hole, and its surface is one with an adsorption dimension. With the fractal surface of S, the passage holes can be straight or curved. For the reaction and diffusion phenomena occurring in the pore space, when the gas molecules enter the fractal hole, due to the irregularity of the surface of the hole. That is, there is a self-similar structure similar to a fjord on the inner surface of the hole, so that not every point on the surface of the hole is equally accessible.

Table 1 Biological treatment technology of coking wastewater

	Handle	Degradation rate
Bioaugmentation Technology	2.34±1.75	0.65
Immobilized Microorganism Technology	3.34±0.62	0.67

Underground coal gasification technology is a process of controlled combustion of underground coal, which produces combustible gas through thermal and chemical action of coal. The utility model has the advantages of good safety, less pollution, small investment, low cost, high efficiency and quick effect. However, it may be due to the geological conditions, hydrological conditions, gasification technology and high temperature in the Air-Burning zone of overburden caving zone and fault zone. As a result, gas emission or groundwater influx cause pollution, in which the types of organic pollutants are similar to those of organic pollutants in surface coal gasification wastewater. The carrier is fluidized and microorganisms grow and adhere to the carrier. The unit volume biofluidized bed reactor has high microbial concentration, strong shock load resistance, high mass transfer efficiency, good treatment effect and small area. It can handle refractory organic wastewater. Figure 1 shows the dynamic relationship between the particle conversion rate and the gasification reaction rate during gasification. It can be seen from the figure that there is a maximum gasification reaction rate at a certain stage. When the adsorption dimension decreases, the maximum reaction rate decreases and the delay arrives. At the same time, the calculation results show that when the reaction proceeds to a certain stage, the particles begin to undergo percolation and breakage. When the fractal dimension increases, the fracture occurs in advance.

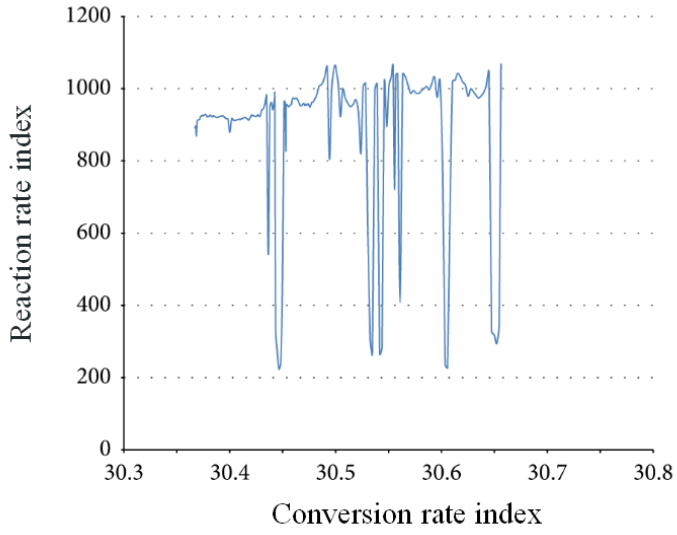

Fig.1. Dynamic Curve of Particle Conversion Rate and Gasification Reaction Rate in Gasification Process

3. Result Analysis and Discussion

The change of specific surface area and pore structure is complex during coal char gasification. With the increase of coal char gasification conversion rate, the pore structure of particles changes continuously. It is very important to introduce a parameter to describe the process correctly. The variation of pore structure parameters of coal char gasification process conforms to a certain fractal relationship. The removal rate of organic pollutants can reach more than 85% by aerobic treatment. Anaerobic treatment is the decomposition of organic matter into small molecules by anaerobic microorganisms under anaerobic conditions. Quinoline, hydrazine, pyridine, biphenyl, etc. in coal chemical wastewater are difficult to be used by microorganisms under aerobic conditions. The anaerobic treatment can be used to remove refractory organic matter. The pilot process of microbial technology for coking wastewater treatment is shown in Figure 2. In order to model the gasification

process of coal char particles, the pore pore spatial topology must also be described to obtain parameters such as porosity, specific surface area and transmission characteristics in the particle space.

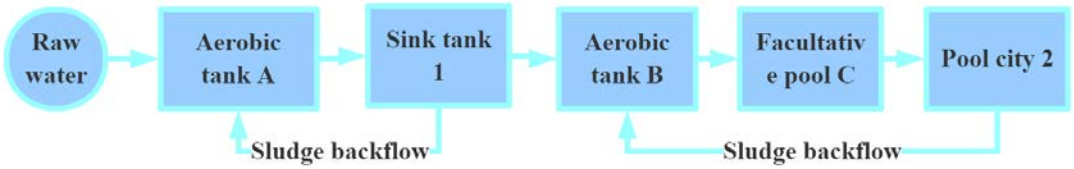

Fig.2. Pilot Process of Coking Wastewater Treatment by Microbial Technology

Underground coal gasification technology is a process of controlled combustion of underground coal. It produces combustible gas through thermal and chemical action of coal. It has the advantages of good safety, less pollution, low investment, low cost, high efficiency and quick effect. However, the coal seam geological conditions, hydrological conditions, gasification technology and high temperature in the burning-out area may cause the overburden caving zone and fault zone, which may cause gas emission or groundwater influx to cause pollution. The fixed-treated bacteria had a wider range of pH and temperature tolerance than the bacteria in the suspension phase, and the degradation rate of phenol was still 94% after 52 days of storage at 2 °C after immobilization. The degradation rate of the suspension phase bacteria began to decrease after 10 days, and the phenol could hardly be degraded after 50 days. The bending of the fractal hole and the concavity and convexity of the inner surface have a great influence on the gasification reaction and diffusion process of the coal char, and the fractal dimension provides an objective tool for comparing the degree of two fractal irregularities. The fractal dimension arc of coal char particles not only measures the ability of the particles to fill the space, but also reflects the characteristics of the pore structure of the particles.

In order to overcome the shortcomings of easy loss of suspended sludge, poor ability to withstand water quality and water quantity impact load, and unsTable operation, we take coking wastewater as the research object and adopt A-A/O process. The coking wastewater was treated by adding spherical packing in the aerobic section to form a composite reactor. The three-dimensional network is used to simulate the pore structure of coal char particles, in which the key represents the axis of the pore in the medium and the seat represents the junction of the pore and the pore in the medium. The non-branching channel connecting the adjacent two nodes is defined as a channel hole. The channel holes defined in this way may be open at both ends, or semi-open (i.e., one end is closed to the dead end), or both ends are closed to the dead end. The pore volume is mainly composed of medium and large pores, which indicates that the fractal characteristics of coal char are closely related to the pore structure. Only those coal chars whose pore volume is composed of small and medium pores conform to the fractal law. After the microorganisms were domesticated by phenol, the degradation rates were 97% and 95.0% at room temperature, hydraulic retention time 22 h, influent phenol and COD concentrations of 420 mg/L and 1270 mg/L, respectively. And the treatment efficiency is increased by 2 times and 8 times, respectively, compared with the conventional full-mix activated sludge device.

4. Conclusion

In this paper, the microbial treatment technology of coal gasification coking wastewater based on fractal concept was studied. Because the gasification reaction of coal char occurs on the inner surface of the particle hole, when the fractal dimension is high, the larger specific surface area can be obtained with less volume. Therefore, the gasification reaction efficiency will be improved. It shows that the reaction rate is faster in the initial stage of gasification process, and the time of percolation and fragmentation of particles is earlier. Underground coal gasification is an ideal low-carbon energy technology. This process may cause organic pollution to groundwater. The types and properties of organic pollutants are similar to those in surface gasification and coking

wastewater. According to the current development and application of microbial treatment technology for coal chemical wastewater, microbial treatment technology will still be the main method for the treatment of coal chemical wastewater. It should continue to strengthen research: 1) the high-quality dominant strain cultivation structure and its commercialization of refractory organic matter in wastewater Apply highly efficient bacteria. 2) Develop new technologies, processes, equipment, and develop anaerobic biological treatment technologies to reduce energy consumption. The concentration of pollutants in coal chemical wastewater is high, toxic and harmful, and may inhibit the activity of microorganisms. The combination of processes has become a development trend.

Acknowledgement

Inner Mongolia Autonomous Region Applied Technology Research and Development Fund (0406031601); the Natural Science Foundation of Inner Mongolia Autonomous Region (2018LH05029)

References

[1] Bing X U, Baolin X, Lunjian C, et al. Physicochemical Properties of UCG Residual Cokes From Neimeng Lignite and Its Purification of Coking Wastewater[J]. Journal of Engineering Thermophysics, 2017, 38(1):197-202.

[2] Ma Q, Qu Y, Shen W, et al. Bacterial community compositions of coking wastewater treatment plants in steel industry revealed by Illumina high-throughput sequencing[J]. Bioresource Technology, 2015, 179:436-443.

[3] Contrasting microbial community composition and function perspective in sections of a full-scale coking wastewater treatment system[J]. Applied Microbiology and Biotechnology, 2016, 100(2):949-960.

[4] Nannan W, Qiang Z, Han X, et al. Adsorptive treatment of coking wastewater using raw coal fly ash: Adsorption kinetic, thermodynamics and regeneration by Fenton process[J]. Chemosphere, 2018, 210:624-632.

[5] Zhang C, Lin H, Chen J, et al. Advanced treatment of biologically pretreated coking wastewater by a bipolar three-dimensional electrode reactor[J]. Environmental Technology, 2013, 34(16):2371-2376.

[6] Man Y, Peng L J, Zhou H R, et al. Integrated process of coke-oven gas tri-reforming and coal gasification to methanol with high carbon utilization efficiency[J]. Industrial & Engineering Chemistry Research, 2015, 38(9):775-780.

[7] Wiatowski M, Kapusta K, ?wi?drowski, J, et al. Technological aspects of underground coal gasification in the Experimental “Barbara” Mine[J]. Fuel, 2015, 159:454-462.

[8] Wang J, Wang Z, Xin L, et al. Temperature field distribution and parametric study in underground coal gasification stope[J]. International Journal of Thermal Sciences, 2017, 111:66-77.

[9] Vadillo V, Sánchez-Oneto, Jezabel, Portela, Juan Ramón, et al. Problems in Supercritical Water Oxidation Process and Proposed Solutions[J]. Industrial & Engineering Chemistry Research, 2013, 52(23):7617-7629.

[10] Diez M A, Borrego A G. Evaluation of CO2-reactivity patterns in cokes from coal and woody biomass blends[J]. Fuel, 2013, 113:59-68.