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Advances in Biopurification Technology of VOCs

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Biopurification Technology of volatile organic compounds (VOCs) has the advantages of mild reaction conditions, low operating costs, less pollution. The paper reviews the current study on the packing characteristics, and long-running biofilm blockage, and kinetic model, and microorganism domestication and cultivation of high efficient degradation bacteria, and safety evaluation in the research of domestic and foreign scholars. Through the above analysis, the paper puts forward the existing problems using biological purification technology and future development trends. The aim is to improve the removal ability of the equipment unit volume and resistance to impact load capacity, and to prolong the service life of equipment, in order to drive the biological treatment technology in the practical application and industrialization.

Key words: Biopurification Technology, Biofilm, VOCs, Microorganism.

VOCs(Volatile Organic compounds, referred to as the VOCs) are a kind of gaseous organic pollutants, mainly refers to the organic compounds whose saturated vapor pressure are about above 70Pa at room temperature, and boiling point less than 260°C at atmospheric pressure[1] .VOCs has great variety ,wide distribution and high toxicity ; with wide pollution area, large air flow, and low concentration. In addition, some VOCs also has three consistency (carcinogenic, teratogenic, mutagenic), toxicity, stench[2].

Purification methods of VOCs waste gas include conventional physical and chemical methods, such as the burning method, active carbon adsorption, absorption, condensation method, etc. In some cases, the conventional processing technology can effectively control the volatilization of organic matter, but economic or technical defects often exist. For example, high investment operation cost, the inconvenient operation management, and problems such as secondary pollution[3], limit the further use of conventional control technology in the field. Therefore, to solve the problem, environmentalists around the world are seeking high efficiency, low energy consumption, no-pollution alternative technologies. The studied methods include corona method[4-5], membrane separation and photocatalytic method[6], the low temperature plasma method[7] and biological method[8], etc.

Compared with the traditional method, biological method has the advantages of simple process, convenient operation, stable running, good treatment effect, low cost and less energy consumption, etc.[9]. Biological method is developed in allusion to VOCs waste gas purification treatment. VOCs waste gas has no recovery value, low industrial concentration, serious environmental pollution, and good biodegradability. Biological method has certain economical efficiency in purifying VOCs. It is a way to rising over the past 20 years. Some successfully running instances have been carried out in Europe .

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Service Life and Stability of Biological Processing Equipment

The stability of processing performance directly determines the service life of equipment and quality of the process. Scholars at home and abroad are carrying out study on the packing characteristics, long-running biofilm blockage, and kinetic model, to enhance the removal ability of per unit volume equipment, equipment's ability to resist impact load, thus to prolong the service life of equipment.

Packing characteristics

Wei Zaishan *et al*. studied different packings, and compared purification performance of the seven packings[10]. Qiang ning *et al*. studied performance of silk screen, fibre adhesion activated carbon, polyethylene polyhedral ball, slag and other media as biological carrier material in gas biological trickling filter, by comprising their dynamic conditions biofilm and static degradation curve[11-12]. Ma GuangDa *et al*. carried out two different ceramsite as packing in biological trickling bed to purify low concentration of xylene gas and obtained favorable purification effect, which suggests ceramsite is an ideal packing in treatment of xylene waste gas by biological method[13]. Sorial tested the performance of the two kinds of synthetic packing with drip tower, one is a kind of Monolithic Channelized Medium (MCM), the other is a Pelletized Ceramic Medium (PCM), and finally come to the conclusion that PCM is a better packing.

Theoretical model

Ottengraf put forward gas-liquid biofilm model by and modifying and based on the adsorption theory. The model divide biological filter bed purification process into three kinds of states :the first order reaction, the zero order reaction under diffusion control and under the control of reaction conditions[14]. Shareefdeen established Shareefdeen model to avoid choices between the zero order reaction and the first order reaction. The numerical integration method was adopted, a large number of parameters were used in the model, some determined by experiments, and some were calculated in advance. Shareefdeen and Saltzis established biofilm formed packing surface debris distributed biomathematics model[15, 16]. Devinny and Hodge described the effect entry pollutants concentration change has on biodegradation[17]. Deshusses model first describes the biofilm diffusion process under transient circumstances[18]. Hekmat made the following assumptions: microorganism evenly distributed in biological trickling bed; The constant surface area and thickness of the biofilm; The well-mixed of the liquid; Constant oxygen partial pressure of the gas; Gas-liquid equilibrium follows Henry Law; No axial diffusion, etc. Then he established model based on the assumptions to calculate the different pollutant concentration in the gas and liquid[19] . Baltzist introduced inhibiting degradation kinetics and biofilm process of oxygen in the model, the model can calculate VOCs and oxygen concentration in the phases of gas, drop of filtrate and biofilm[20]. Sun further considered the axial diffusion and inactivation of degradation enzyme, material balance of gas and liquid phases, carried out the VOC and oxygen double substrate monod degradation dynamics and established the corresponding mathematical model[21]. Alonsot established the axial dynamic model of the VOCs change. The model takes biofilm thickness change of different height , change of the specific surface area caused by the biomass accumulation into account, and estimate the parameters of the steady state conditions in the model, such as maximum utilization rate of substrate, Monod constants, etc ,through the experimental data[22]. Okkerse *et al*., dynamic filter bed model can be used to predict biomass block rate of drops filter bed and can estimate the adaptation time required filter bed to changes of the concentration[23]. Sun Peishi described the biological purification process of exhaust gas according to the theory of gas adsorption and biochemical reaction kinetics principle and put forward the theory of adsorption – biofilm[24].

Biofilm Blockage

In order to maintain the long-term stability operation of the equipment, measures need to be taken to prevent the microbial plugging packing. Foreign scholars put forward many different ideas, Cox and *et al*. carried out NaClO cleaning method and obtained stable biological trickling filter beds with constant biomass concentration[25]. Weber *et al*. also tried to wash the trickling filter beds with a certain concentration of NaOH solution; satisfactory results were achieved. But the chemical method can lead to inactivation of

microorganism, recovery of biofilm activity studies are needed[26]. Smith *et al*. used water to backwash packing, effectively removed extra biofilm, filter tower capacity can be recovered in a relatively short period of time, but it requires the backwash water to flow at high speed, and packing is suspended, which has a certain application restriction[27].

Processing Equipment

At present, the commonly used equipment is biological trickling filter tower. The operating modes are upstream or downstream of gas and liquid contact. There exists a uneven distribution problem of carbon and nitrogen source that carbon source is adequate at the bottom , and nitrogen source is adequate on the top paragraphs. The increase or decrease of carbon and nitrogen source will affect the growth of micrbbial bacteria, thus affect the removal efficiency. There exists optimal balance of carbon, nitrogen source supply in the filter tower, the increase of carbon source will accelerate domestication and breeding of target microorganism, thus improving the removal ability .After balance, it will have a cons tant biomass and stability removal capability in a certain period of time; And the lack of carbon source and excessive increase of nitrogen source lead to the production of a large number of non-target organisms, which scramble for nutrition with target microorganisms, thus affect the removal efficiency, directly results in the decrease of effective degradation area, processing ability, and bulky equipment, limits its practical application in industrial production.

Microorganism Domestication and Cultivation of High Efficient Degradation Bacteria

Microorganism is the motive force of removal VOCs, choosing high efficient degradation bacteria can improve the degradation rate of per unit packing, which has important practical significance to decrease of equipment volume and reduce the energy consumption. In the biological treatment system of waste gas, microorganism is the key part. Only by understanding and mastering the basic physiological characteristic of microorganism, and cultivating high efficient degradation bacteria, produced the advantage, can we achieve optimal purification effects.

Lu Jun, *et al*. using toluene, ethylbenzene, o-xylene, m-xylene, p-xylene, 1,3,5 - three toluene as the substrate, under aerobic conditions, domesticated ,screened and isolated 25 strains of microorganism which can grow with the above 6 kinds of compounds as the only carbon source and energy, and carried out the preliminary appraisal[28]. Liu Qiang *et al*.selected one xylene degrading bacteria plant through the shaking table experiment, and inoculated the bacteria in biological trickling filter bed to study the purification effect of xylene gas[29]. Zheng Lianying *et al*. domesticated and screened high efficient degradation bacteria to degrade low concentration of benzene and toluene and as the only carbon source, named *Pseudmonas* sp. ZD5[30]. Kenneth and Douglas used Pseudomonas putida F1 as advantage strain to observe the degradation of toluene, benzene and phenol[31]. Garcia *et al*.separated and screened Scedosporium apiospermum TB1 as advantage strains in dealing with toluene from biological filter which has consecutively processed toluene for more than 6 months[32]. Wang liping *et al*. studied bacterial species domestication of purification of benzene, toluene and xylene gas biological in trickling filter, and created the “inducer - target pollutants” domestication pattern of obligate degrading bacteria and double substrates, with toluene as the inducer, carried out the toluene-benzene, toluene-xylene “double substrates domestication, and inoculated benzene-obligate degrading bacteria on ¦ 40 mm x 500 mm biological trickling filter to conduct the experiment process of purifying benzene[33].

Dominant species domestication, screening, the cultivation of the mixed bacteria were all carried out in one or more material as the target pollutants by sludge domesticated or pure culture method, the difference is only the source of the sludge and domestication ways, dominant species name is only done through simple traditional bacteria identification methods, the degradation capacity of strain is reflected by the removal effects of the treatment processing device. The removing ability of processing device is largely restricted d by reduction of bacteria enzyme activity, and capacity degradation after many bacteria transfer storage problems. The research to form a set of relatively complete source library is lacked, confined to the domestication of environmental microbiology. Research needed carrying out to find key enzymes of common characteristics when different strains degradated volatile organic

pollutants. Restructure the enzymes to build efficient genetic engineering bacteria.

Safety Evaluation of Biological Treatment Technology

Any arising of a new technology, people will require a thorough research and inspection on the safety. Biological treatment technology, as a rapid development technology, also has security issues. biosecurity is as follows: within a certain time and space, alien species are brought in due to natural or human activities, thus contributing to the change and damage of other species and ecosystem; Changes caused by men exert severe impact and threats to environment and biodiversity; And cause harm to human health, environment and social life in scientific research, development, production and application. Biological technology, from the research, development, production to the practical application, the whole process of the biological exists safety problem. The emergence of genetic engineering technology, make human's ability of operation the organism stronger. Genes transfer between animals, plants and microbes, and even artificial synthesize genes can be transferred into organisms to express, creating many unprecedented new traits, new products, and even new species. Thus it is likely to produce consequences beyond human's foresee ability under the level of current science and technology, that is ,harm human health, destruct ecological balance and pollute the natural environment.

Biological safety evaluation only aims at biotechnology activity itself and its products (mainly genetic engineering activities and products of genetic operations) at home and abroad, involving medicine and food industry.

Biological safety control measures refers to the relevant preventive measures to prevent genetic engineering products from causing potential risk to human health and ecological environment, in research and development, commercialization production, storage and transportation and usage. Biological treatment technology involves gas, liquid and solid(biology) phase. The purpose is to purify the poisonous and harmful substances causing environmental pollution. The impact on the environment and human health of emissions of after-purifyinggases, liquids, waste materials containing microbial bacteria have no related safety evaluation reports, documents and patent research.

Conclusion and Prospect

Biopurification technology of volatile organic compounds (VOCs)can overcome many shortcomings of traditional methods and has great application. However, through the above analysis, it is not hard to find that, to fully realize the effectiveness and marketability of biopurification technology, following breakthrough needs making:

1. Increase the removal capacity of unit volume packing, strengthen the gas-liquid mass transfer and biodegradation ability, so as to make full use of effective space of the equipment.
2. Combine with packings, application technology, biological film ,processing capacity and applications considering gas-liquid distribution, guarantee the stable and long operating life of equipment, overcome biofilm blockage, so as to develop a strong stability, long service life biopurification equipment.
3. Optimization design the existing process parameters, simplify operation, realize automatic Control and reduce the operation cost.
4. Aiming at different kinds of VOCs, establish engineering bacteria source library of high efficient degradation capable by using modern molecular biology methods to obtain efficient and stable production strains, shorten the start-up time of VOCs waste biopurification, and improve processing efficiency.
5. Complete the safety assessment of VOCs biopurification technology, ascertain the impact on the environment and human health of microbial bacteria such as gas, liquid and waste gas packing after biological treatment.

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