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Research on microbial community changes and proliferation in the long-term operation of high temperature and biological filtration tower

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ABSTRACT

With the development of economy, living standard of citizens have been improved, the purification treatment of air pollution becomes more and more important. The volatile organic pollutants, VOCs, have great harm to human health and the environment. Biological filtration tower as typical processing tools have lots advantages like simple operation, low cost of operation and the little secondary pollution etc. In the practical application, the stability of long-term operation has problem, and it serious impact on the disposal effect and operation cost. Microbial proliferation excess in the tower lead to the filler layer congestion. It is a major cause of filtration column unstable operation. Therefore, in this article, through the research on the formation of regularity proliferation and jams of microbial in filtration tower. Established the multiplication rule model to simulate the changing process of microorganism concentration under different environmental conditions. Inspected the influence of toluene removal performance, packing layer drop pressure and void fraction, carbon balance and biomass growth after dosing ozone concentration and eluent NaOH in biological filtration tower.

KEYWORDS

Biological filtration tower; VOCs; Control of biomass accumulation; NaOH elution; Ozone.

INTRODUCTION

The key problems in application of actual production in long stability running of Bio-filtration tower is the removal ability of main pollutant declined and device pressure drop increased. It cause the device can not removal pollutant efficiency. The main reason of unstable running is instability packing structure carrier and microbial excessive accumulation on filler surface. Blockage of the problem may be due to the increase of running time generate thicker biofilm loss on filler surface. Most biological membrane will gather between the filling carriers[1]. Biological filter tower removal rate variation of hydraulic conditions in a reactor is particularly sensitive, when congestion occurs in the reactor, the removal rate will significantly decrease[2]. The study showed that, ozone and NaOH eluent has certain control effect of biomass proliferation in biological filtration tower[3]. In order to investigate the feasibility of the long run performance of the biomass accumulation and bio filter improvement in control of biological filtration process. This paper research on adding different concentrations of ozone and NaOH eluent continuously into biological filtration tower which solve the toluene problem, investigate its effective of toluene removal performance in biological filtration tower, pressure drop and void ratio of filler layer, biomass accumulation and carbon balance.

MATERIALS AND METHODS

Test apparatus

Biological filtration tower made of organic glass, diameter 12cm, height 50cm, cross-sectional area 0.0113m^2. The tower is filled with 250g expanded perlite, the filler layer is 2.6L, the effective volume of 2.6L, two ends are provided with gas sampling port and a pressure port, packing sampling port and spraying mouth. Toluene gas can get through capillary gas distribution system which make the toluene liquid in compressed air. Producing a certain concentration ozone gas through the ozone generator. Ozone gas with toluene gas successively pass into the corresponding.

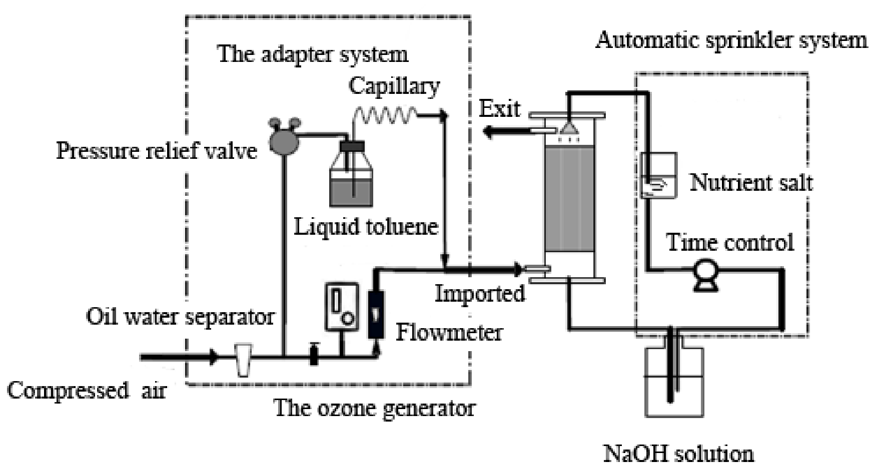

Figure 1 : Detailed device configuration diagram

Biological filtration tower. Using electromagnetic metering pump intermittent spraying nutrient solution to the middle of biological filtration tower, spray time controlled by time relay. This experiment measure a variety of gas distribution method for gaseous VOCs biological treatment has the controllability and stability, decided using capillary gas distribution system. The system is simple, easy maintenance, convenient operation, low investment, economic and practical.

System running environment

Making 200mL sludge of a Tianjin wastewater treatment plant injected into biological filtration tower packing. Then inletting continuously a certain concentration of toluene gas. Starting the capillary gas distribution system. four sets of biological filtration tower continuous operation 100 days. The first 50 days the inlet toluene concentration consistent without access to the ozone in all sets of filter tower After 50 days change the inlet toluene concentration in 4 filter towers and continuous access to the ozone. Using intermittent spray to supplement nutrient and moisture into layer of packing. In order to ensure the normal growth of microorganisms in biological filtration tower, main nutrient elements in the spray solution according to C:N:P=200:10:1 dosage[4], at the same time adding the necessary trace elements.

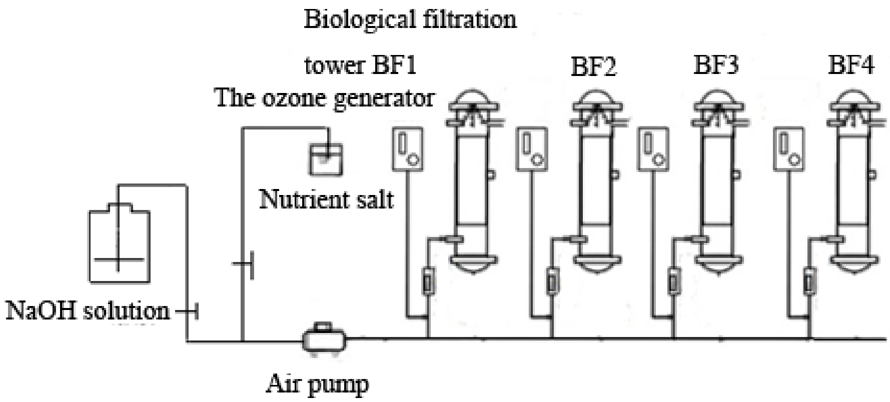

Figure 2 : Schematic diagram

TABLE 1 : Operating conditions of biological filtration tower

Project	Operating parameters
Inlet toluene concentration/ $(mg \cdot m^{-1})$	1500~2000
Inlet flow $(m^3 \cdot h^{-1})$	0.1~0.15
Empty bed residence time (EBRT)/s	62.4~93.6
Ozone concentration	BF1:0;BF2:40~60;
$(50 \sim 68)/(mg \cdot m^{-3})$	BF3:100~120;BF4:180~220
Spray way	spray 1min every 6 hours
Spraying quantity/ $(mL \cdot \min^{-1})$	120
The main components of the spray liquid/ $(g \cdot L^{-1})$	$NaNO_3:10; NaHPO_4,0.7; O_3,0.52$

THE ESTABLISHMENT OF MICROBIAL COMMUNITY VALUE-ADDED MODEL

The microbial concentration in the packing layer is X_0, g/m3; The activity microorganisms which can degrade toluene (referred to as the active microbial)concentration is X_1, g/m3; Microorganisms and dead microbial residues does not have the toluene degradation activity (referred to as inert microbial)concentration is X_2, g/m^3;There relationship is:

$$\mathbf{X_0 = X_1 + X_2} \tag{1}$$

The activity microbial concentration X_1 list the material balance equation[5]. Along with the time change rate is equal to the activity microorganism synthesis rate minus its loss rate.[6]:

$$\mathbf{\frac{dX_1}{dt} + bX_1 = A(-\mu)} \tag{2}$$

A is yield coefficient of microbial degradation toluene to synthetic bacteria, dimensionless; $-\mu$ is toluene removal rate in filter tower, g/m^{3}h; b is the loss coefficient of active microorganisms, 1/h; t is time,h. Inert microbial concentration X_2 Rate of change with time is the rate of active microbial transfer into inert microbial, as :

$$\frac{dX_2}{dt} - \lambda b X_1 = 0 \qquad (3)$$

λ is the amount of transformation in loss of active microbial biomass proportional coefficient that activity microbes transfer into inert microbial conversion ratio coefficient of loss of active microbial biomass[7]. By that type 2 and 3, When the operation in the early stage X_1 is small, Increased microbial mainly is active microorganism; While running for a period of time X_1 increased. he rate of increase of activity microorganism decreased, And the increase rate of inert microbial increase gradually, increase the main microorganisms is inert microbial. Assumptions A, b, λ are constants, And the operation conditions are the same $-\mu$ constant in a certain period of time, then
can be obtained:

$$X_1 = (X_1' - \frac{A(-\mu)}{b})e^{-bt} + \frac{A(-\mu)}{b} \qquad (4)$$

$$X_2 = \lambda(\frac{A(-\mu)}{b} - X_1')e^{-bt} + \lambda A(-\mu)t + \lambda X_1' + X_2' - \lambda\frac{A(-\mu)}{b} \qquad (5)$$

X_1' is the time when t=0 initial microbial concentration, X_2' is the time when t=0 initial inert microbial concentration. In formula 4, the absolute value of the first term on the right site t increases gradually tends to0, So the activity microbial concentration increases with prolonging the running time gradually tends to a stable value $\frac{A\mu}{b}$. Similarly, After a long running time inert microbial concentrations along with the operation time tends to increase linearly, the increase rate is $\lambda A(-\mu)$. We know that by combined type 1 :

$$X_0 = (X_1' - \frac{A(-\mu)}{b})(1-\lambda)e^{-bt} + \lambda A(-\mu)t + \lambda X_1' + X_2' + (1-\lambda)\frac{A(-\mu)}{b} \qquad (6)$$

After In a long time running the total microbial concentration in filtering tower along with the operation time is close to linear increase[8], increase rate is $\lambda A(-\mu)$. The parameters is in TABLE 2.

TABLE 2 : Component content of trace elements

Trace components	CaCl2.2H2O	FeSO4.(NH4)2SO4.6H2O	ZnSO4.7H2O	CoCl2.6H2O
Concentration（mg/l）	2.55	5.1	0.45	3.6
Trace components	MnSO4.H2O	CuCl2.2H2O	Na2Mo4.2H2O	Yeast extract
Concentration（mg/l）	2.1	0.3	0.45	1.5

CONCLUSION OF DATA ANALYSIS

Changes of microbial analysis

In the early operation, rapid increase in microbial activity, inert microbial increased speed is small, main microbial in biological membranes is activity microorganisms which is able to degrade toluene. With the extension of the running time, the active microbial concentration basically stable (No.1 and No. two) or decreased because of the inlet toluene concentration decreased significantly (three and four). The inert microbial concentrations continue to increase, so the activity of microbial biofilms in decline. This shows that although the total amount of microbes increased continuously during operation, the toluene degrading activity of microorganisms is not always increased[9]. The unit weight of biological membrane demonstrate metabolic activity may decreases result of it.

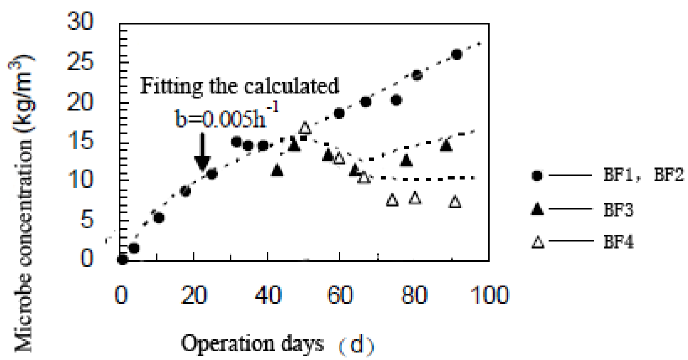

Figure 3 : Microbial concentration data map

The toluene removal capacity

During operation toluene removal rate of filter tower showed a certain fluctuation with time changes. This is caused by the inlet toluene concentration constant fluctuation. In addition to No.1 and No.2 filter tower, the toluene removal rate still maintain in 90% above,but there is still a downward trend during 50~100d. The toluene removal rate of 4 sets filtration tower in the other stages did not show significant variation. This is because, after change the inlet toluene concentration in the 50th day, microbial concentration of No.1 and No.2 filtration tower higher than No.3 and No.4. Because the accumulation of microorganisms causing filler surface area of No.1 and No.2 filtration tower decreased during 50~100d, while the other filter tower packing layer surface area decreased not obviously.

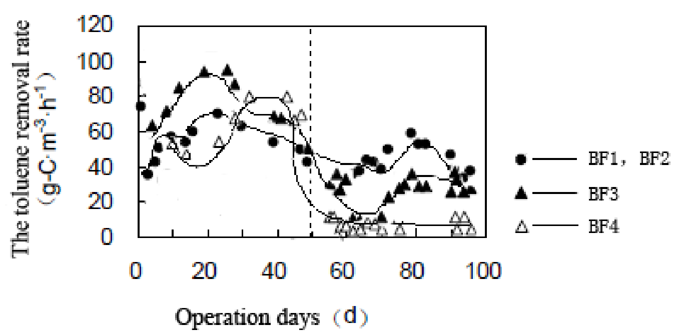

Figure 4 : The toluene removal efficiency data map

Packing pressure drop change analysis

Packing pressure drop in filtering tower increases with prolonging the running time. This is because during the operation biomass accumulation and the packing porosity and equivalent diameter decreased in filter towers. After the continuous operation of 50D, packing pressure drop of biological filtration tower without ozone has increased significantly, about 30mmH2O. In the operation of the 60d,packing pressure drop of biological filtration tower (No.2 and No.3) which inlet concentration of ozone were 40-80mg/m3 and 100-150mg/m3 rises. At this time, packing pressure drop in biological filtration tower which microbe concentration is about 15kg/m3, while the inlet concentration of ozone in is about 180-240mg/m3 (No. four) remained below 5mmH2O. During the operation of 50D to 100D, speed and size of packing pressure drop in No.1 and No.2 filter tower were higher than that of No.3 and No.4. This is because the change of inlet toluene concentration after 50D filtration tower accumulated more biomass.

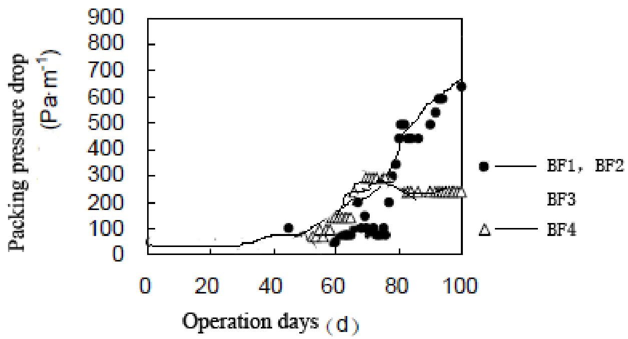

Figure 5 : Pressure drop data analysis chart

This paper established biological filtration tower microbial growth model can be used to simulate the changes of microbial concentration in biological filtration tower in different operating conditions. The results of microbial proliferation experiment showed that the concentration of inert microbial in filler layer increases with time, the active microbial accounted for amount of microorganism is declining[10]. Addition of ozone and chemical washing can significantly improve the toluene mineralization rate and increase its elution amount. But increasing toluene mineralization rate is the main way that ozone can control the rapid accumulation of biomass. The filler layer structure change caused by microbial proliferation induced will affect the performance of filtration tower. As bigger as microbe concentration void ratio and specific surface area of packing layer is smaller. The specific surface area lower of packing layer will reduce the filtration tower VOCs removal capacity. But reducing packing voidage will increase the packing pressure drop. As the filter tower adopted by our study, maintain the maximum concentration of filler layer stable pressure drop is about 15kg/m3.

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