Study on the Factors Influencing the Degradation of Cellulose Acetate Filter Rod

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Abstract. Cellulose acetate filter rod is the most mature and widely used filter material for cigarette development, but it is difficult for cellulose acetate to degrade in natural conditions. Orthogonal experiment is applied to simulate the degradation environment of different filter rod soil burial method by using temperature, humidity, pH value and degradation time in this paper. The results showed that the cellulose acetate filter rod with uncoated wrapping paper could reach the maximum degradation rate of 33.78% in the orthogonal design experiment when the temperature was 40 ℃, the relative humidity was 20%, the pH value of soil was 6.0, and the degradation time was 28 days; the cellulose acetate filter rod with uncoated wrapping paper could reach the maximum degradation rate of 33.78% in the orthogonal design experiment when the temperature was 40 ℃, the relative humidity was 20%, the pH value of soil was 5.0, and the degradation time was 28 days, and the highest degradation rate of n-ca filter rod was 35.56%.

1. Introduction

Acetate cellulose is a kind of cellulose derivative which is prepared by the reaction of cellulose with acetic anhydride under the catalysis of sulfuric acid[1-3]. The acetate fiber used for cigarette filter material is diacetate fiber. On average, about 2.5 hydroxyl groups in each cellulose glucose unit are esterified. To a certain extent, acetate cellulose can selectively adsorb harmful substances in cigarettes. It can intercept tar and harmful chemicals in cigarette without changing the taste of cigarette[4,5]. Compared with other filter media, acetate cellulose provides more appropriate taste and price. It has the advantages of good performance, easy processing and high production efficiency[6-8]. However, due to the acetylation of hydroxyl groups in cellulose molecular chain, the properties of cellulose acetate are stable and the decomposition speed is slow. In addition, due to the mutual adhesion of acetate fiber through plasticizer during the molding process of filter rod and the wrapping of paper in the cigarette process, the degradation of acetate fiber in filter tip is more difficult.

2. Experimental

2.1. Preparation of samples

The cellulose acetate filter rod was cut into a small section with a section diameter of 7 mm and a length of 30 mm, and the samples of filter rod (C-CA filter rod) with wrapping paper on the surface and filter
rod (N-CA filter rod) without wrapping paper on the surface were treated respectively, and then dried in a vacuum drying oven at 25 °C for 24h for future use.

2.2. Preparation of soil
Take soil samples from the places with more leaves in the garden, shovel off the soil layer about 2cm on the surface, and take the soil from the depth of 2-5cm. The soil samples were spread flat and dried at about 30 °C, and the impurities such as stones were removed by 18 mesh standard screen. Then use the grinder to crush the dried soil sample and mix it evenly.

2.3. Preparation of buffer solution with different pH value
Prepare buffer solutions of pH 5.0, pH 6.0, pH 7.0 and pH 8.0 respectively.

2.4. Selection of degradation environmental factors
In this paper, temperature, relative humidity, pH value and degradation time are selected as the main factors to be investigated, and orthogonal experimental design is carried out. The table of factors determined is shown in Table 1.

| Factors | Temperature (°C) | Relative Humidity (RH) | pH  | Degradation time (d) |
|---------|-----------------|------------------------|-----|----------------------|
| ①       | 10 °C           | 10%                    | 5.0 | 7                    |
| ②       | 20 °C           | 20%                    | 6.0 | 14                   |
| ③       | 30 °C           | 40%                    | 7.0 | 21                   |
| ④       | 40 °C           | 60%                    | 8.0 | 28                   |

L16 (4⁴) orthogonal table was selected for the experiment.

2.5. Determination of biodegradation rate of filter rod by indoor soil burying method
The influence of different environmental conditions on the degradation rate of cellulose acetate filter rod was studied by the method of indoor soil burying. The specific experimental steps are as follows: weigh 3g dried C-CA filter rod and N-CA filter rod respectively, mix them with 450g garden soil fully and evenly, and then put them into beaker. Three parallel samples are set for each group of experiments, and blank samples (i.e. only garden soil) are set as control. Determine the volume and pH value of the added buffer according to the different levels of relative humidity and pH value designed. According to the different levels of degradation time, the filter rod samples were regularly taken out from the beaker, and the surface sludge gently washed with 75% alcohol solution, as shown in Fig.2. The cleaned sample was dried with filter paper, dried at 50°C to constant weight, and the quality was recorded. The biodegradation rate is determined according to the mass loss of the filter rod sample, and the calculation formula of the biodegradation rate is as follows, DR% = (m0 - m1) / m0 × 100%. (m0 is the sample mass before the biodegradation experiment, g; m1 is the sample mass after the biodegradation experiment, g)

According to the calculated value of biodegradation rate, the results of orthogonal experiment were analyzed, and the important order of each factor and the best degradation conditions were determined.

3. Degradation rate of filter Rod
Accurately the mass of C-CA &N-CA filter rod which has been degraded by indoor soil burial method was weighed, and calculate the biodegradation rate was calculated, as shown in Table 2 and Fig.1.

| Sample | C1     | C2     | C3     | C-Average | 1     | 2     | 3     | N-Average |
|--------|--------|--------|--------|-----------|-------|-------|-------|-----------|
| 1      | 14.67  | 15.67  | 17.33  | 15.89     | 15.00 | 20.30 | 15.70 | 17.00     |
| 2      | 22.33  | 21.67  | 18.67  | 20.89     | 9.33  | 15.00 | 13.00 | 12.44     |
| 3      | 21.33  | 21.33  | 19.67  | 20.78     | 15.70 | 19.70 | 19.30 | 18.22     |
| 4      | 25.67  | 30.00  | 24.67  | 26.78     | 22.70 | 16.70 | 21.30 | 20.22     |
| 5      | 30.00  | 30.00  | 22.33  | 27.44     | 24.70 | 23.00 | 27.00 | 24.89     |
Fig. 1 Some C-CA filter rod samples after soil burial degradation
Fig. 2 Some N-CA filter rod samples after soil burial degradation
Table 3 Range analysis of C-CA & N-CA filter rod orthogonal experiment

| Level | Temperature (℃) | Relative Humidity (%) | pH | Degradation time (d) |
|-------|-----------------|-----------------------|----|---------------------|
| K1    | 21.08           | 25.19                 | 24.75 | 22.33               |
| K2    | 25.42           | 26.50                 | 26.86 | 24.42               |
| K3    | 27.03           | 25.36                 | 25.11 | 25.42               |
| K4    | 28.83           | 25.31                 | 25.64 | 30.19               |
| RC    | 7.75            | 1.306                 | 2.111 | 7.861               |
| K5    | 17.00           | 20.80                 | 23.40 | 18.19               |
| K6    | 21.70           | 22.90                 | 22.10 | 17.03               |
| K7    | 21.30           | 22.80                 | 21.50 | 21.58               |
| K8    | 24.90           | 18.40                 | 18.00 | 28.08               |
| RN    | 7.97            | 4.53                  | 5.42  | 11.06               |

From the range analysis data listed in Table 3, it can be seen that for C-CA and N-CA filter rods, the range values of the four factors are in the same order: D > A > C > B. The optimal combination of degradation conditions of C-CA and N-CA filter rods are A4B2C4D and A4B2C1D4, respectively. that is, the cellulose acetate filter rod without coated wrapping paper can reach the maximum degradation rate in the orthogonal design experiment when the temperature is 40 ℃, the relative humidity is 20%, the soil pH value is 6.0, and the degradation time is 28 days, while for filter rod with coated wrapping paper, the optimum condition is as follows, the temperature is 40 ℃, the relative humidity is 20%, the soil pH value is 5.0, and the degradation time is 28 days, and the highest degradation rate of n-ca filter rod was 35.56%.

It can be seen from the results in Table 5 that the relative humidity and pH value of soil are the secondary factors affecting the degradation rate of filter rod. When the relative humidity of soil is 40%, the average degradation rate of C-CA filter rod reaches the maximum, but with the continuous increase of the relative humidity of soil, the degradation rate of C-CA filter rod slightly decreases, which may be because the excessive soil humidity will reduce the relative content of oxygen in the soil, thus inhibiting the growth and activity of aerobic bacteria which can decompose cellulose.

The pH value of soil also affects the degradation rate of cellulose acetate filter rod. For C-CA filter rod, when the soil is weakly acidic (pH value is 6.0), the average value of degradation rate reaches the maximum, and when the soil pH value is further reduced (pH value is 5.0), the average value of degradation rate is the lowest, which may be due to the strong acid soil environment may inhibit the growth and activity of cellulose decomposing bacteria in the paper; however, when the soil is weakly alkaline (pH value is 8.0). For N-CA filter rod, the degradation rate decreases with the increase of pH value from 6.0 to 8.0, which indicates that cellulose acetate has poor acid resistance stability. With the increase of soil acidity, it can accelerate the decomposition and increase the degradation rate.

4. Conclusion
(1) Cellulose acetate filter rod with coated paper can reach the maximum degradation rate in orthogonal design experiment after the temperature is 40 ℃, the relative humidity is 20%, and the degradation time is 28 days, with the highest degradation rate of 33.78%; cellulose acetate filter rod without coated paper can reach the positive rate after the temperature is 40 ℃, the relative humidity is 20%, the soil pH value is 5.0, and the degradation time is 28 days, and the highest degradation rate was 35.56%.
(2) Temperature and degradation time are the two most important factors affecting the degradation rate of N-CA filter rod. With the increase of temperature, the degradation rate of the filter rod increases gradually, which may be due to the fact that the activity of cellulose secreted by the bacteria
decomposing the filter rod in the soil is the highest at nearly 40 °C. The degradation rate decreased with the increase of pH value. With the increase of soil acidity, the decomposition and the degradation rate accelerate.

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