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ANALYSIS OF THE START-UP OF NATURAL BIO-FILM COLONIZATION OF CONSTRUCTED RAPID INFILTRATION SYSTEM

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ABSTRACT

Abstract: this paper studied the start-up of natural bio-film colonization under the conditions where wet-to-dry ratio was 1:6, hydraulic load was 0.8m^3/m^2·d, and water temperature was 10^{0}C-15^{0}C, it took 25d in total to become mature, after the success of bio-film colonization, the removal rate of COD and NH4$^+$-N can be stabilized at 80%, and the removal rate of NH4$^+$-N can reach 90% above. The microorganism was divided into the following stages during bio-film colonization:1. Reversible adhesion of cell on the surface of the carrier, 2.Irreversible adhesion of cell on the surface of the carrier, 3.Division of cell adhering to the surface of the carrier and formation of microcolony adhering to the surface of the carrier, 4.Growth of microcolony adhering to the surface of the carrier to be mature bio-film with three-dimensional structure. The process of natural bio-film colonization can be judged comprehensively according to removal rate of NH4$^+$-N and COD, effluent pH as well as color of microbial film.

Keywords: Constructed Rapid Infiltration System, start-up of natural bio-film colonization, removal rate,COD

INTRODUCTION

Constructed Rapid Infiltration System (CRI system) is a new wastewater treatment system developed from Rapid Infiltration (RI system), which works on the basis of purification of wastewater using interaction between infiltration media and microorganisms in the CRI system through a series of physical, chemical and biological actions. It is especially suitable for wastewater treatment in small towns and farmer concentrated residential areas[1]. It has the advantages of low cost, low energy consumption, easy to operate, good effluent quality, etc. However, the total removal rate of nitrogen is not up to standard. Study suggested that the pollutant removal in the CRI system mainly relied on the biological mechanism, supplemented by non-biological mechanism[2]. So the quality of bio-film in the CRI system determined the level of pollutant removal capacity in the CRI system. The bio-film colonization methods mainly adopted at present include: natural bio-film colonization method[3], artificial inoculation bio-film colonization method [4]and compound bio-film colonization method[5]. This paper adopted the natural bio-film colonization method for the CRI system, analyzed the change in COD, ammonia nitrogen and other index during bio-film colonization as well as correlation with bio-film colonization process, thus providing theoretical basis for natural bio-film colonization method of the CRI system.

EXPERIMENTAL DEVICES AND MATERIALS

EXPERIMENTAL DEVICES

The experimental devices are as shown in the figure, the column adopted organic glass column with diameter D of 150mm, column height h was 1500 mm, where the supporting layer adopted cobblestone with height of 100 mm, filtering material height H was 1000 mm, consisting of 10% marble sand + 5% zeolite sand + 85% river sand.

The artificial rapid process was adopted, wastewater was fed from the top and flew downward, where the inlet layer height h1 was 300 mm, the first flow layer height h2 was 100 mm, and a sampling port was set every 200 mm, Fig. 1 shows the experimental devices.

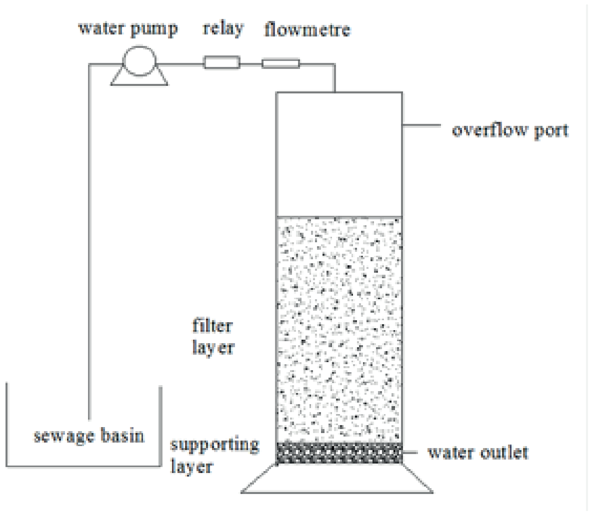

Fig. 1. Experimental Devices

EXPERIMENTAL WATER QUALITY

Experimental raw water adopted the configured wastewater, making up of glucose, soluble starch, sodium acetate, ammonium chloride, peptone, beef extract, ammonium sulfate, potassium dihydrogen phosphate, sodium bicarbonate and tap water, Table 1 shows the experimental water quality, and experimental methods for all water quality adopted the national standard methods.

Tab. 1. Experimental water quality

	COD /mg·L^{-1}	NH^{+}_{4}-N /mg·L^{-1}	NO_2-N /mg·L^{-1}	NO_3-N /mg·L^{-1}	TN /mg·L^{-1}	pH
Mean	206.1	46.8	1.3	12.4	86.3	6.73

EXPERIMENTAL METHODS

NH4+-H: Nessler's reagent pHotometric method
COD: Potassium dichromate method
pH: Glass electrode method

EXPERIMENTAL STARTING METHODS

This experiment adopted the natural bio-film colonization, which was started under the conditions where wet-to-dry (the ratio between water distribution and drying time of CRI[6]) ratio was 1:6, hydraulic load was 0.8m^3/m^2·d, and water temperature was 10^{0}C-15^{0}C.

Around one week after the start-up of natural bio-film colonization, dotted yellow green bio-film that was visible to the naked eyes appeared, and white filamentous film appeared at the outlet pipe orifice.

Around two weeks after the start-up of natural bio-film colonization, the area of the dotted yellow green bio-film that was visible to the naked eyes increased, and color deepened, and the white filamentous film at the outlet pipe orifice changed to black brown.

Around 25 days after the start-up of natural bio-film colonization, the color of filler surface became green-black, and the water quality index showed stable removal effect of COD and ammonia nitrogen, indicating successful natural bio-film colonization.

ANALYSIS OF EXPERIMENTAL RESULTS

REMOVAL EFFECT OF COD DURING NATURAL BIO-FILM COLONIZATION

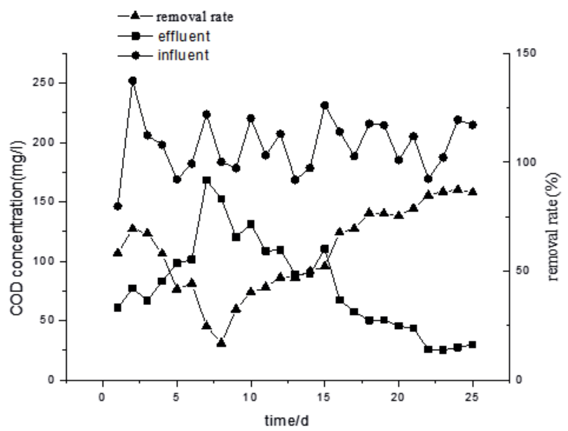

Fig. 2. Removal Effect of COD During Natural Bio-film colonization

It can be seen from Fig. 2, the removal effect of COD during natural bio-film colonization was not stable, around one week before the start-up of natural bio-film colonization, the removal effect of COD decreased gradually, and reached its minimum level at 8d, adsorption rate was only 16.9%.

Then it reached stability gradually at 80% above from low to high.

This was because that around one week before the start-up of natural bio-film colonization, microbial film had not been formed, so the removal of COD in the CRI system mainly relied on the pHysical functions like interception and adsorption, study [7] has found that the theoretical maximum adsorption capacity of pollutants in wastewater by river sand at room temperature is 1893.706 mg·kg^{-1}.

The adsorption capacity of pollutants by filtering material decreased gradually with the decreasing of adsorption point position of filtering material, so the removal rate of COD decreased gradually, however, after one week, the bio-film of the CRI system gradually formed, which decomposed organic matters in pollutants adsorbed, and slowly released the adsorption point position of filtering material, allowing gradual increasing of adsorption capacity of organic matters by filtering material, by adsorbing organic matters during the flooding period and decomposing organic matters and releasing adsorption point position and synthetising its own material during the drying period allowed constant development and maturation of bio-film in the CRI system while increasing the removal effect of COD and stabilized it gradually.

REMOVAL EFFECT OF $NH4^+$-N DURING NATURAL BIO-FILM COLONIZATION

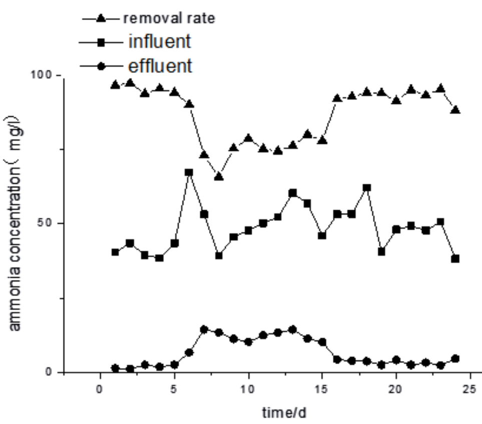

Fig. 3. Removal Effect of $NH4^+$-N during Natural Bio-film Colonization

It can be seen from Fig.3, the removal rule of ammonia nitrogen at earlier stage of natural bio-film colonization basically coincided with that of COD, the removal rate of ammonia nitrogen at earlier stage of natural bio-film colonization was reduced on some degree when the saturation of adsorption point position of filtering material was reached by interception and adsorption by filtering material, however, the minimum removal rate of ammonia nitrogen reached up to 65%, and the average removal rate of ammonia nitrogen reached up to 86.8% during natural bio-film colonization.

This was because that the infiltration media may have more than one adsorption point position for ammonia nitrogen[8], in addition, the infiltration media were negatively charged, while $NH4^+$-N was positively charged, so it was easy to be intercepted and adsorbed by filtering material[9].

Meanwhile, the filtering material contained 5% of zeolite sand, which had good adsorption effect for ammonia nitrogen[10].

With the formation of bio-film, the removal of ammonia nitrogen mainly relied on the absorption and transformation of ammonia nitrogen by nitrifying bacteria.

The growth condition suitable for most nitrifying bacteria was: temperature 25-30^{0}C, pH 7.5-8.0.

Since this experiment was started at early March, the bio-film began to gradually form around the second week, and the temperature cannot reach the optimum temperature for nitrifying bacteria in mid-March, so the nitrifying bacteria grew slowly, during which the removal rate of ammonia nitrogen basically maintained around 75%, which reached around 90% with the rise of climate temperature and became stable with the maturity of bio-film.

CHANGE IN PH DURING NATURAL BIO-FILM COLONIZATION

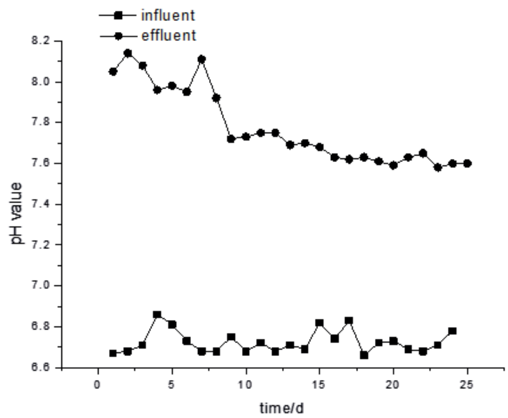

Fig. 4. Change in pH during Natural Bio-film Colonization

It can be seen from Fig.4 that the influent pH basically maintained around 6.7 and the effluent pH basically maintained around 8.1 in the first week, and then pH began to gradually decrease and became stable, and finally basically became stable at around 7.5.

This was because that the adding of 10% marble sand in the CRI system provided a certain alkalinity for the CRI system, at earlier stage of natural bio-film colonization, there were few microorganisms in the CRI system, wastewater entered the CRI system, and ran from top to bottom and contacted with marble sand, which allowed increasing of effluent pH in the CRI system.

However, around the second week, the microorganisms in the CRI system began to grow slowly, whose nitrification required consumption of alkalinity, theoretical alkali consumption of was 7.07g/g($CaCO3/NH4^+$-N)[11], thus allowing gradual decreasing of effluent pH, and the alkali consumption reached stable with the formation of bio-film, so the effluent pH gradually became stable.

CONCLUSION

1 The natural bio-film colonization of the CRI system under the conditions where the wet-to-dry rate was 1:6, water temperature was 10^{0}C-15^{0}C, and hydraulic load was 0.8m^3/m^2·d can succeed at about 25d.

2 The success of natural bio-film colonization of the CRI system can be judged comprehensively according to pH, removal rate of COD and removal rate of ammonia nitrogen as well as color of microbial film.

After the success of natural bio-film colonization of the CRI system, the removal rate of COD can maintain stable at 80%, and the removal rate of $NH4^+$-N can reach 90% above.

3 The forming process of bio-film can be divided into the following stages: 1.Reversible adhesion of cell on the surface of the carrier, 2. Irreversible adhesion of cell on the surface of the carrier, 3. Division of cell adhering to the surface of the carrier and formation of microcolony adhering to the surface of the carrier, 4. Growth of microcolony adhering to the surface of the carrier to be mature bio-film with three-dimensional structure, 5. Shedding of part of cells from the bio-film[12-13].

According to the analysis of removal rate of COD and ammonia nitrogen as well as change in pH during natural bio-film colonization, it can be simply judged that the bio-film of the CRI system was in the first two stages of bio-film formation around the first week, the third stage of bio-film formation from the second week to around the third week, and basically the fourth stage of bio-film formation around the fourth week.

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