Micro-polluted source water treatment at low temperature by activated carbon filter biologically enhanced with heterotrophic nitrifying bacteria

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Abstract

Acinetobacter sp. Y7 and Y16, which have heterotrophic nitrification abilities at low temperature. We sought to confirm whether use of *Acinetobacter* strains Y7 and Y16 was practical for removing ammonium (NH_4^+-N) from micro-polluted source water at low temperature. To test this, continuous ammonium treatment was conducted in order to evaluate the performance of a pilot-scale two-stage biologically-enhanced activated carbon (BEAC) filter, inoculated with Y7 + Y16 mixed bacteria, in removing ammonium. The filters had been running for 120 days. During the operation, the removal efficiency of NH_4^+-N and dissolved organic carbon (DOC) were determined. The Nitrogen conversion, biomass and microbial activity in the filter were investigated. It was observed that 15.5±6.0 %, 31.3±13.1 %, and 70.0±29.4 % of NH_4^+-N were removed using the BEAC filters at 0.9±0.2 ℃, 5.9±3.3 ℃, and 13.2±2.2 ℃, respectively. There was no accumulation of NO_2^--N in the BEAC filters. About 65% of the removed NH_4^+-N was converted to NO_3^--N. When the bed volumn (BV) reached 14.7 m^3/kg-carbon, the removal efficiency of DOC was 40.6 %. The biomass in the first stage BEAC (BEAC-I) filter and the second stage BEAC (BEAC-II) filter at 0.9±0.2 ℃ were both 0.5×10^9 CFU/g-carbon, and had a 2-5 folds increase with the rise of temperature. The microbial activity in BEAC-I and BEAC-II filter increased with the rise of temperature. The results indicated that high ammonium removal efficiency of BEAC filter was due to high biomass and microbial activity. This study provides new insight into the use of biofilters to achieve biological removal of ammonium at low temperature.

Keywords

Ammonium; heterotrophic nitrifying bacteria; low temperature; micro-polluted source water; biologically-enhanced activated carbon

INTRODUCTION

Excessive amounts of NH_4^+-N in micro-polluted source water is associated with potential hazards. Increasing concentrations of NH_4^+-N has resulted in the need for stringent, restrictive legislation regarding NH_4^+-N levels in drinking water. During winter, the excessive NH_4^+-N problem is worse than it is in other seasons. Low temperature is the limiting factor in NH_4^+-N removal when using conventional biological approaches (Huang, 2013). NH_4^+-N removal by heterotrophic nitrifying bacteria is preferable due to the faster growth rates and strong adaptability to low temperature (Zhang, 2011a). *Acinetobacter* sp. strain Y7 and Y16 were isolated from the Songhua River in winter, which have the ability to simultaneously perform heterotrophic nitrification and aerobic denitrification at 2 ℃. In this study, we inoculated strains Y7 and Y16 onto the surface of granular activated carbon (GAC) to develop a pilot-scale BEAC filter. The purpose was to confirm whether it is practical to use Y7 and Y16 in NH_4^+-N removal from drinking water at low temperatures.

MATERIAL AND METHODS

The device contains two tandem BEAC filters. Filters were both 2110 mm in height and 500 mm in internal diameter, and operated in down-flow mode. The filters were filled with 250 mm grit sands as the gravel layer, and 750 mm GAC as a carrier for the bacteria. After conventional treatment (coagulation-sedimentation-filtration), water from Songhua river enters the BEAC process. Operational conditions and influent quality of the BEAC filters is shown in Table 1.

Table 1. Operational conditions and influent quality of the BEAC process.

Periods	Days	Water Temperature ℃	Empty bed contact time min	Influent NH_4^+ mg/L	Influent DOC mg/L
a	1-70	0.9±0.2		1.23±0.38	4.7±2.0
b	71-88	5.9±3.3	24	0.60±0.15	3.7±0.7
c	89-120	13.2±2.2		1.13±0.16*	4.9±0.5

* NH_4^+ concentrations in the influent in period c were adjusted to 1 mg/L with ammonium chloride.

RESULTS AND DISCUSSION

The NH_4^+ and DOC removal efficiency, biomass, and microbial activity are shown in Table 2.

Ammonium removal performance

NH_4^+-N removal rates at 0.9±0.2 ℃ and 5.9±3.3 ℃ were comparative and considerable. NH_4^+-N removal rate at 13.2±2.2 ℃ had a about 4-fold increase. Higher biomass and microbial activity in BEAC filters might result in higher NH_4^+-N removal efficiency.

Nitrogen conversion

There was no accumulation of NO_2^--N in the BEAC filter. About 65% of the removed NH_4^+-N was converted to NO_3^--N in period a. NO_3^--N was accumulated in this study because NH_4^+-N oxidation would be faster than NO_3^--N reduction for heterotrophic nitrifying bacteria at low temperatures.

Table 2. The NH_4^+ and DOC removal efficiency, biomass, and microbial activity of BEAC filters.

Periods	Removal rate (NH_4^+) (mg/L/h)	Removal ratio (NH_4^+) (%)	Removal ratio (DOC) (%)	Biomass (CFU/g-carbon)	Dehydrogenase activity (mg/L/g-carbon)
a	0.50±0.25	15.5±6.0	89.5±10.4	0.5×10^9 (BEAC-I) 0.5×10^9 (BEAC-II)	2.1(BEAC-I) 2.0(BEAC-II)
b	0.44±0.14	31.3±13.1	42.4±15.0	1.8×10^9 (BEAC-I) 1.2×10^9 (BEAC-II)	8.1(BEAC-I) 6.5 (BEAC-II)
c	1.95±0.84	70.0±29.4	48.0±11.1	2.6×10^9 (BEAC-I) 2.1×10^9 (BEAC-II)	25.4 (BEAC-I) 20.0 (BEAC-II)

CONCLUTIONS

Low temperature limited the growth and activity of bacteria, which affected removal efficiency and nitrification ratios. However, BEAC with strains Y7 and Y16 had significant NH_4^+-N and DOC removal efficiency in treating micro-polluted source water at low temperatures.

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