Bioresource Technology 222 (2016) 139–147

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Performance and microbial community of a sequencing batch biofilm reactor treating synthetic mariculture wastewater under long-term exposure to norfloxacin

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HIGHLIGHTS

- NFX affected on the COD and nitrogen removal from mariculture wastewater.
- NFX inhibited the microbial activities of nitrifier and denitrifying bacteria.
- NFX promoted the EPS secretion and affected the chemical composition of EPS.
- NFX affected the relative abundance of nitrifier and denitrifying bacteria.

ARTICLE INFO

Article history:
Received 21 July 2016
Received in revised form 26 September 2016
Accepted 28 September 2016
Available online 30 September 2016

Keywords:
Norfloxacin
SBBR
Mariculture
Microbial activity
Microbial diversity

ABSTRACT

The performance and microbial community of a sequencing batch biofilm reactor (SBBR) treating synthetic mariculture wastewater were evaluated under long-term exposure to norfloxacin (NFX) due to the overuse of antibiotics during the mariculture. The COD and NH_4^+-N removals had no distinct change at 0–6 mg L^{-1} NFX and were inhibited at 6–35 mg L^{-1} NFX. The specific oxygen uptake rate (SOUR), specific ammonium oxidation rate (SAOR), specific nitrite oxidation rate (SNOR) and specific nitrate reduction rate (SNRR) of the biofilm kept a decreasing tendency with the increase of NFX concentration from 0 to 35 mg L^{-1}. The presence of NFX promoted the microorganisms to secrete more extracellular polymeric substances (EPS) and affected the chemical compositions of EPS. The microbial richness and diversity showed some obvious variations at different NFX concentrations. The present results demonstrated that NFX inhibited the SBBR performance and should decrease the NFX dosage in the mariculture.

1. Introduction

Mariculture is the farming of marine organisms for food and other products such as pharmaceuticals, food additives and jewelry. Mariculture has been a rapidly developing industry in recent years due to the increase of global population and seafood demand. Mariculture wastewater is rich in suspended solids, organic matter, NH_4^+-N, NO_2^--N and NO_3^--N, which mainly originate from the unused feed and the excreta of mariculture organisms. If untreated mariculture wastewater is directly discharged into the neighboring sea field, it will result in the damage of the surrounding estuarine ecosystem. Physical treatment processes, including filtration, sedimentation and foam separation, are often applied to remove suspended solids from mariculture wastewater. Biological treatment methods are used to remove organic matter and nitrogen compounds after physical treatment processes (Fontenot et al., 2007; Schreier et al., 2010).

Infectious diseases can reduce the production of mariculture organisms and also affect the rapid development of mariculture industry. In order to avoid the spread of infectious diseases, antibiotics are used to kill pathogenic bacteria in mariculture facilities.

Abbreviations: SBBR, sequencing batch biofilm reactor; SBR, sequencing batch reactor; NFX, norfloxacin; SOUR, specific oxygen uptake rate; SAOR, specific ammonia oxidation rate; SNOR, specific nitrite oxidation rate; SNRR, specific nitrate reduction rate; EPS, extracellular polymeric substances; LB-EPS, loosely bound EPS; TB-EPS, tightly bound EPS; MLSS, mixed liquor suspended solids; MLVSS, mixed liquor volatile suspended solids; PN, protein; PS, polysaccharide; Ex/Em, excitation/emission; OTU, operational taxonomic units.

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http://dx.doi.org/10.1016/j.biortech.2016.09.114
0960-8524/

However, the overuse of antibiotics during the process of mariculture leads to their residue into mariculture wastewater. The antibiotics in mariculture wastewater will induce the biological toxicity to marine organisms in neighboring sea field (Seoane et al., 2014; Zheng et al., 2012). Previous researches reported that the antibiotics (e. g. ciprofloxacin, ofloxacin, and sulfamethoxazole) could affect the pollutant removal of the bioreactors treating different kinds of wastewater (Amorim et al., 2014; Collado et al., 2013).

Norfloxacin (NFX) is extensively used to prevent the spread of infectious diseases in mariculture facilities. NFX exhibits the superior ability against the gram-positive and gram-negative organisms by inhibiting the activity of DNA gyrase (He et al., 2012). The normal NFX content in the feed of adult shrimp was reported to be in the range of 0.5 and 6 g kg^{-1} feed (Van Doorslaer et al., 2014). Actually, NFX is often overused during the process of mariculture and then results in higher NFX content in the feed and mariculture wastewater. Sequencing batch biofilm reactor (SBBR) is a biological process based on the sequencing batch reactor (SBR) and utilizes microorganisms (attached to different carriers) to treat wastewater. SBBR has been widely applied in different wastewater biological treatments due to its flexible operation, greater biomass concentration, land and energy savings, lower sensitivity to toxicity and greater volumetric loads (Jin et al., 2012). The presence of NFX in mariculture wastewater might affect the COD and nitrogen removals of SBBR. The SBBR performance is closely related to the microbial diversity and richness in the biofilm. The effects of NFX on the diversity and dynamics of microbial community in the SBBR is an uncertain and evolving issue. The knowledge of microbial ecology in the SBBR becomes relevant for the control of COD and nitrogen removals at different NFX concentrations. Additionally, the presence of NFX in the mariculture wastewater might impact on the microorganisms in the bioflim to secret the extracellular polymeric substances (EPS) due to the self-protection strategy of the microorganisms against the toxicity of NFX. EPS consist of loosely bound EPS (LB-EPS) and tightly bound EPS (TB-EPS), which are closely related to the flocculability, dewatering ability and stability of the biofilm. However, little information is obtained concerning the long-term effects of NFX on the performance and microbial community of SBBR in the treatment of mariculture wastewater.

The aims of the present research consisted of evaluating the performance and microbial activity of SBBR treating mariculture wastewater under the long-term exposure to NFX and analyzing the effect of NFX on the production and chemical composition of EPS. As high-throughput sequencing can provides enough sequencing depth to characterize the complex microbial community, and it has been used to investigate the microbial diversity of the environment samples, which may help to elucidate the potential mechanisms involved the effect of NFX on the SBBR performance. Therefore, the effects of NFX on the microbial diversity and richness of SBBR treating synthetic mariculture wastewater were also analyzed through high-throughput sequencing at the phyla, class and genus levels.

2. Materials and methods

2.1. SBBR and synthetic mariculture wastewater

A SBBR with 14 cm inner diameter and 55 cm total height was employed in the present research, which was filled with the fibrous carriers. In order to prevent light into the SBBR, the outer of SBBR

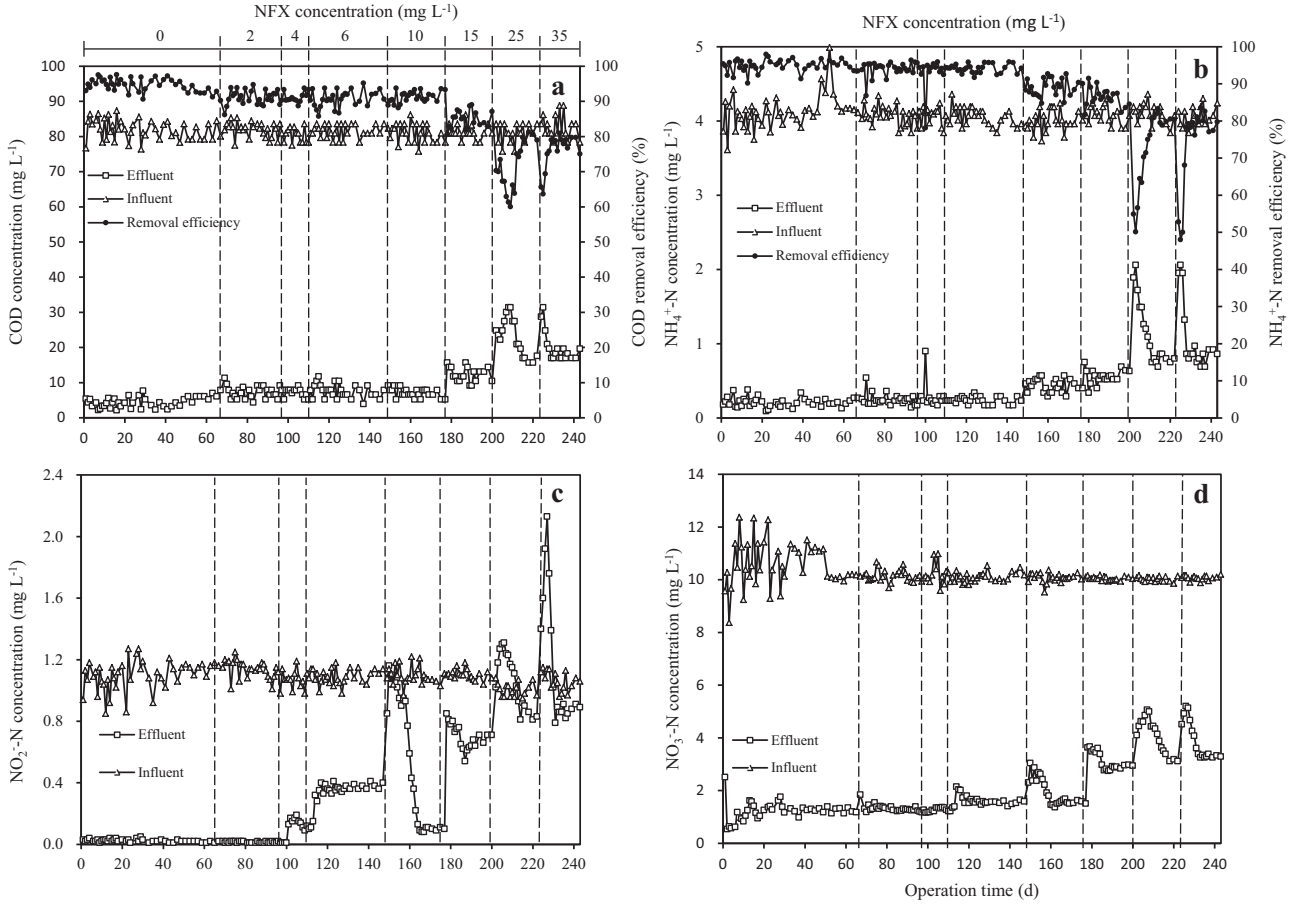

Fig. 1. Effects of NFX on the SBBR performance. (a) COD, (b) NH_4^+-N, (c) NO_2^--N, (d) NO_3^--N