



Review

Overview of strategies for enhanced treatment of municipal/domestic wastewater at low temperature



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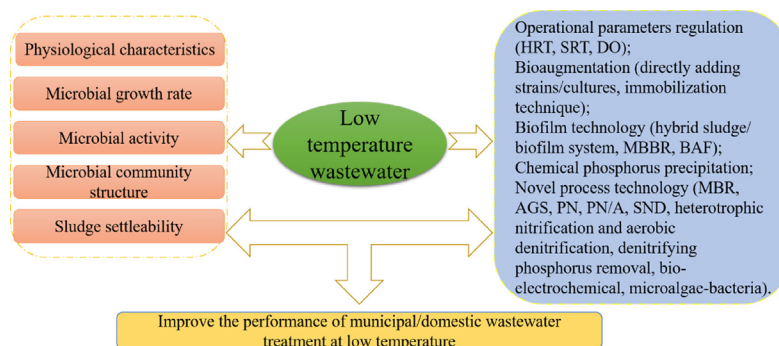
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HIGHLIGHTS

- Enhanced treatment of low temperature wastewater is necessary to meet stricter standards.
- Mechanisms of the effects of low temperature on wastewater treatment are discussed.
- Strategies for enhanced treatment of municipal wastewater at low temperature are systematically summarized.
- Novel process/technology configurations provide attractive alternatives for performance intensifications at low temperature

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:

Received 25 March 2018

Received in revised form 5 June 2018

Accepted 8 June 2018

Available online xxxx

Editor: Jay Gan

Keywords:

Low temperature

Municipal/domestic wastewater

Enhanced treatment

Operational strategies

ABSTRACT

Biological wastewater treatment has been widely applied to municipal/domestic wastewater treatment systems. However, low temperature significantly decreases process performance. Furthermore, increasingly stringent effluent discharge standards are causing wastewater treatment facilities to have to improve and maintain contaminants removal under low temperature. Hence, this review aims to summarize strategies for enhanced treatment of municipal/domestic wastewater at low temperature. First, mechanisms of the effects of low temperature on wastewater treatment, including physiological characteristics, microbial growth rate, microbial activity, microbial community structure and sludge settleability, are analyzed. Strategies for performance intensifications at low temperature, mainly operational parameters regulation, bioaugmentation, biofilm technology, chemical phosphorus precipitation and application of novel process technologies, are then reviewed. Finally, future directions to address low temperature wastewater are highlighted. A special emphasis is given to the application of novel process/technology configurations to enhance process performance at low temperature in practical engineering.

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1. Introduction

Biological wastewater treatment has been widely applied to municipal/domestic wastewater treatment processes because of its low operation costs, high removal efficiency and lower management requirements (Zhou et al., 2016). During the process, organic matter and nutrients (nitrogen and phosphorus) from various wastewater sources are degraded and utilized through microbial metabolism. Temperature is one of the most important environmental factors influencing microbial functions in biological wastewater treatment processes. Indeed, temperature can affect biochemical reactions in many ways, such as reaction rates, reaction pathways, microorganism yields and death rates (Huang et al., 2015). However, because of differences in geographic area (higher latitude or hilly regions) and seasonal changes (entering into winter/spring), wastewater temperature can decrease to 8 °C–15 °C, even below 5 °C, which is common for wastewater treatment systems located in a temperate climate. In Canada, wastewater temperatures in lagoon treatment systems decrease to as low as 4 °C during winter operation (Delatolla et al., 2009), and the temperature at the end of lagoon pond may drop to 1 °C (Hoang et al., 2014b). In view of cold regions, low temperatures are defined as “1 °C–15 °C”, occurring in areas including but not limited to most of Canada, North America, northern Europe (Norway, Denmark and Sweden, etc.), Russia and northern China (Wittgren and Mæhlum, 1997). Low temperature severely inhibits microbial activity, substrate utilization rate and cell growth (Pietikäinen et al., 2005), leading to deteriorated process performance. As we all know, low temperature can significantly decrease wastewater removal efficiency, despite differences in reactor configurations. Therefore, it is still a challenge to maintain and improve process performance of biological wastewater treatment under low temperature conditions.

In recent years, with the sustainable development of global economy and increasing environmental protection consciousness of government and citizens, the discharge standards of pollutants for wastewater treatment have increasingly improved to alleviate water body pollution and protect water environment (Jin et al., 2014). For instance, most municipal wastewater treatment plants (WWTPs) in China have been required to retrofit existing facilities or upgrade process configurations to meet the Class 1A of GB 18918-2002 (national standard). Besides the Class 1A requirement, Beijing, Tianjin and Anhui have issued their own effluent discharge standards (DB 11890-2012, DB 12/599-2015 and DB 34/2710-2016, respectively), which are more stringent than the national standard. In the United States (US), Environmental Protection Agency (EPA) has implemented national secondary treatment standards for discharges from municipal wastewater treatment facilities.

However, most WWTPs need to meet regional discharge standards that are stricter than the secondary standards of US. Furthermore, EPA's National Pollutant Discharge Elimination System permits establish different discharge limits and conditions for municipal wastewater treatment facilities. Therefore, regional WWTPs must upgrade current facilities to meet the requirements of new EPA permits. In the European Union (EU), European Commission issued the Urban Wastewater Treatment Directive (91/271/EEC) and the Water Framework Directive to regulate discharge of urban wastewater. These requirements have raised the need to retrofit existing WWTPs to meet stricter discharge limits. Beside these directives, the EU members also established new, strict effluent discharge standards based on the function and sensitivity of receiving water bodies. In Canada, the government has recently implemented the Wastewater Systems Effluent Regulations that is the first national effluent quality standards. Wastewater systems that do not meet these standards must upgrade. These high effluent standards require effective removal of organic matter and nutrient from wastewater treatment systems. Overall, the increasingly stringent discharge guidelines have placed great pressure on municipal WWTPs operators to remove excess contaminants from wastewater at low temperature. Accordingly, how to sustain and enhance pollutants removal of existing facilities at low temperature is an urgent issue for academic and engineering fields.

Given the effects of low temperature on biological wastewater treatment and more stringent effluent discharge standards of WWTPs, it is necessary to improve wastewater treatment efficiency and maintain operational stability under low temperature. Furthermore, innovative approaches and technologies have been introduced to improve wastewater treatment performance. Unfortunately, there has been few papers summarizing existing strategies to enhance wastewater treatment performance at low temperature. Therefore, the main objective of this paper is to discuss mechanisms of the effects of low temperature on wastewater treatment, summarize methods and strategies to enhance the performance of municipal/domestic wastewater treatment under low temperature and provide future directions to address low temperature wastewater. This review will provide guidance to municipal/domestic WWTPs operators and designers to select appropriate strategies for performance intensification at low temperature.

2. Mechanisms of the effects of low temperature on wastewater treatment

As mentioned above, temperature is very important to biological wastewater treatment processes. Most microorganisms in this process are temperature dependent, with optimum temperatures of 20 °C–35

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