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論　文　の　要　旨
Abstract of thesis

Aerobic granular sludge (AGS) has been proven to be a promising biotechnology in wastewater treatment since it possesses incomparable advantages over conventional activated sludge systems, such as excellent settleability, strong and dense microbial structure, and withstand to higher pollutants loading and toxicants. Previous works were conducted in sequencing batch reactors (SBRs) which are regarded as the most successful ones. While from an engineer's viewpoint, continuous-flow reactors are more advantageous for large-scale application. This research for the first time investigated various operation conditions to optimize the design and performance of algal-bacterial AGS in wastewater treatment by using continuous-flow reactors. Kinetic models were also developed to better understand the processes involved in organics and nutrients removal using this novel symbiosis system, followed by mechanisms exploration on the stability of algal-bacterial AGS under the tested conditions.

The thesis is divided into 5 chapters. The author introduced the recent achievements of AGS systems and its problems related during operation in Chapter 1, especially the occurrence of algae growth which may have effect on the reactor performance. In this chapter the author also addressed the necessity of the development of mathematical models which can be very useful for realization of successful large-scale application of general AGS or algal-bacterial AGS systems. In Chapter 2 the author investigated the stability of algal-bacterial AGS in two different reactor configurations (single and two series reactors) for approximately 120 days of operation which was divided into two stages. During the Stage I operation (days 0 – 60), both systems were fed with the same influent containing same concentrations of organics and nutrients. During the subsequent 60 days (Stage II) when the

influent concentrations of organics and nutrients to the single reactor was elevated to two-fold of the stage I, its total nitrogen (TN) removal increased from 29% to 80%. The two reactor systems well maintained their granular stability, and all granules became algal-bacterial ones after 120 days' operation. In addition, the mechanisms regarding the formation and enhanced stability of the new algal-bacterial granules in continuous-flow reactors were proposed. Then the author introduced a novel approach to develop kinetic models by using cycle test data and study the performance of different AGS systems in Chapter 3. The developed mathematical model was tested by using the same reactor system (continuous-flow reactor) under different aeration strategies and a different reactor system (SBR) under different seed sludge, reactor dimension, and influent compositions. Results show that the proposed model was successfully applied to predict the reactor performance with good accuracy ($R^2 > 0.98$ and relative error < 10%) for both tested reactor systems. Furthermore, the model was implemented in decision making on aeration strategy for optimum organics and nutrients removal along with energy requirement. In Chapter 4 the author investigated the potential capability of algae co-existence in AGS systems that could realize low energy consumption for wastewater treatment by algal-bacterial AGS with effluent re-circulation instead of aeration. The results suggest that the algal-bacterial AGS possesses better overall performance and stability. In addition, after being switched from no aeration to intermittent aeration, the algal-bacterial AGS could quickly adapt to the change in operation conditions, which was obviously indicated by its recovered removals of dissolved organic carbon (DOC) from 40% to 100%, total nitrogen (TN) from 61% to 98%, and total phosphorus (TP) from 14% to 64% along with improved sludge settleability and stability. Finally, the author summarized the major conclusions of the thesis, and proposed the future research directions in Chapter 5.

審　査　の　要　旨
Abstract of assessment result

This research explored various operation strategies and optimized the design and performance of algal-bacterial aerobic granular sludge (AGS) in wastewater treatment by using continuous-flow reactors which have great potential for large-scale application. Kinetic models were also developed by using a novel approach (from cycle test experiments) to evaluate the effect of different aeration strategies on organics and nutrients removal and energy consumption. Moreover, the mechanisms involved in the stability of algal-bacterial AGS under the tested conditions were also proposed and analyzed. Results indicate that the series reactor system exhibits superior performance on total nitrogen (TN) removal (76%), and the single continuous-flow reactor could achieve better denitrification with TN removal increased up to 80% when double increased strength influent was fed. The kinetic model developed by using cycle test experiments could well predict the organics and nutrients removal from different types of AGS systems under different aeration strategies. Results from this study are expected to provide basic experimental data and scientific reference for the development of the novel algal-bacterial AGS, especially in continuous-flow reactors to realize high-efficacy and low-cost operation of large-scale wastewater treatment plants.

The final examination committee conducted a meeting as a final examination on 17 January, 2018. The applicant provided an overview of the dissertation, addressed questions and comments raised during Q&A session. All the committee members reached a final decision that the applicant has passed the final examination. Therefore, the final examination committee approved that the applicant is qualified to be awarded the degree of Doctor of Philosophy in Environmental Studies.