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論　文　の　要　旨
Abstract of thesis

Sewage sludge is one of the main byproducts inevitably generated from biological wastewater treatment units. The commonly applied technologies for sewage sludge disposal include anaerobic/aerobic digestion, incineration, and landfilling, in which sludge dewatering functions as an essential pre-/post-treatment for sludge volume reduction, transportation facilitation, and calorific value increase as well. Due to its highly complicated composition and charged surface, the sludge can only be dewatered to 80 - 90% by mechanical dewatering under no effective preconditioning condition. The existing conditioning methods include physical, chemical, and biological processes, and only those with lower investment/operational costs and high efficacy could have the highest fitness and feasibility in practice. Therefore, the conditioner-based physicochemical technology, i.e., the dosing of efficient and cost-effective substances such as coagulant, flocculant, filtration aid, or their combinations, has always been the most common choice. In this study, the author for the first time attempted the combined use of polydimethyldiallylammonium chloride (PDDA) and tannic acid (TA) to co-condition the sewage sludge, and comprehensively investigated the dewatering efficacy and mechanisms involved. The impact of dosing order of the two chemicals was further explored to optimize the conditioning process and achieve a better understanding of the dewatering process.

This dissertation is divided into 5 chapters.

In Chapter 1, the author gave a literature review on the research background. The author firstly reviewed the disposal methods for sewage sludge, discussed the importance of sludge dewatering on its posttreatment and the influencing factors in addition to the chemicals widely used for sludge conditioning. Finally, the research objectives and thesis structure were addressed.

In Chapter 2, the author investigated the co-conditioning and dewatering performance of the combined use of PDDA and TA on sewage sludge, which was found to effectively improve the

dewaterability of sewage sludge, achieving reductions in Capillary Suction Time (CST) and Specific Resistance to Filtration (SRF) by 82.10% and 94.06%, respectively when compared to the raw sludge; and the moisture content of sludge cake decreased significantly to 55.83%. The optimal dosage was determined as 2% of PDDA and 2% of TA, with little negative effect observed on water reuse and sludge disposal, which is also very competitive in the economic aspect when taking both chemicals and disposal costs into consideration.

In Chapter 3, the author further explored the mechanisms involved in this highly efficient co-conditioning process through the analysis of physicochemical properties, variations of extracellular polymeric substances (EPS) and its compositions, and rheological behavior. Results showed that PDDA and TA could remarkably strengthen the inter-particle force of sludge particles. The Pearson analysis revealed a positive correlation between moisture and protein contents in tightly bound EPS (Rp =0.908, p < 0.05), indicating that the proteins in tightly bound EPS may dominantly govern the sludge dewaterability. Being similar to the change of moisture content, all the rheological parameters reflected a common three-stage pattern characterized by a significant rise (TA < 2%), a partial decline (TA = 2 ~ 3%), and final fluctuation (TA = 3 ~ 5%), deeply influencing the sludge dewatering process.

In Chapter 4, the author examined the impact of dosing mode of PDDA+TA or TA+PDDA on sludge dewaterability. Compared with the conventional PDDA+TA dosing mode, the TA+PDDA mode resulted in better sludge filterability and dewaterability, further reducing SRF and CST by 90.60% and 65.08%, respectively with moisture content varied from 57.71% to 53.46%. As for the structure-activity relationship, the TA+PDDA conditioned sludge was also featured with a lower absolute value of zeta potential, higher apparent viscosity, enhanced compressibility, and significantly improved solid-like rheological property. Therefore, the TA+PDDA mode is beneficial for the sufficient reaction of proteins precipitation by adding TA first and then PDDA that plays a crucial role in charge neutralization and flocculation, achieving more compact flocs or particle clusters consequently.

In Chapter 5, the author summarized the major findings and proposed future research perspectives.

審　査　の　要　旨

Abstract of assessment result

Sludge conditioning is a crucial step towards efficient pretreatment and then deep dewatering, achieving the low-cost posttreatment and disposal of sewage sludge. In this study, the author proposed and examined the combined use of polydimethyldiallylammonium chloride (PDDA) and tannic acid (TA) for sludge co-conditioning in addition to the dewatering efficacy and mechanisms involved. Results revealed that the combined use of 2%PDDA and 2%TA could effectively improve the dewaterability of sewage sludge, with 82% and 94% reduction in capillary suction time (CST) and specific resistance to filtration (SRF) when compared to the raw sludge, which resulted in the significant decrease in sludge moisture content to 56%. Besides, compared to the conventional dosing order of PDDA+TA, the TA+PDDA dosing mode is more beneficial for sludge dewatering. The experimental data on the variations of extracellular polymeric substances (EPS) content, rheological and physicochemical properties suggested that the proteins precipitation by TA addition together with PDDA's crucial capability of charge neutralization and flocculation could greatly strengthen the intermolecular force, thus improving the dewaterability of the conditioned sludge. Results from this study are expected to provide new concepts and useful information for the practical application of combined use of organic conditioners in sludge conditioning and dewatering. This study also fills in the knowledge gap in the research domain of dewatering process and sludge disposal, which is meaningful for the large-scale application of the proposed conditioning method in wastewater treatment plants.

The final examination committee conducted a meeting as a final examination on 19th July, 2022. The applicant provided an overview of the dissertation and addressed questions/comments raised during the 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.