Role of sulfate reducing bacteria and its control in the anaerobicoxic activated sludge

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学 位 論 文 要 旨

ABSTRACT

This dissertation deals with the role and control of the sulfate reducing bacteria (SRB), some aspects of its interactions with phosphate releasing and filamentous sulfur bacteria. The study was carried out using municipal wastewater sludge and laboratory cultivated anaerobic-oxic and oxic unit systems. There was a positive correlation among the sulfate reducing rates, maximum released phosphates and the sulfide oxidizing rates implying the formation of a sulfur cycle in the sludge. Other growth factors indicated that anaerobic stress was favourable for SRB growth, and less sensitive to temperature changes than denitrification bacteria but more than phosphate releasing bacteria. Control of SRB and filamentous bulking with iron compounds was investigated. Iron compounds were effective in reducing bulking and also suppressing SRB growth.

CHAPTER 1: Introduction

Microbial interactions in activated sludge is very important because of the various kinds of organisms that degrade organic material and thrive in the activated sludge. The ecological study of the activated sludge process is of basic importance for determining which microorganisms have a significant role in this process. The role of the sulfate reducing bacteria is important because of its enducement of filamentous bulking due to the provision of sulfide. Therefore a clear understanding of the role and control of the sulfate reducign bacteria in the

activated sludge is necessary.

CHAPTER 2: Interactions of sulfate reducing bacteria, poly-p accumulating and filamentous bacteria in the anaerobic – oxic sludge

Under anaerobic conditions sulfate reduction and phosphate release occurred simultaneously. Inhibition of sulfate reduction caused a slight decrease in phosphate release. Moreover for the sludge with high sulfate reductions, high phosphate released concentrations were also observed. It was therefore concluded that the poly-p bacteria utilizes acetate produced by SRB respiration. There was a tendency for higher sulfate reducing rates to be associated with higher numbers of SRB in the sludge and longer filaments. The SRB in this sludge degraded 3 moles of sulfate per 4 moles of acetate produced. The SRB in the sludge utilized the propionate produced from the breakdown of peptone and other propionate sources in the sludge.

CHAPTER 3: Study of some growth factors of sulfate reducing bacteria in the anaerobic oxic activated sludge.

Some growth factors related to the sulfate reducing bacteria and its interactions with other processes in the activated sludge was studied. The results showed increase in MLSS caused an increase in the sulfate reducing rates for the real plant sludge but decreased for the laboratory unit systems. Increase in sulfate concentrations did not have an effect on the sulfate reducing rates. The results from the anaerobic stress experiments showed that the growth of SRB and Type 021N was dependent on the aeration flow rate and the anaerobic stress was identified as one reason for Type 021N bulking. Inoculation of enriched SRB and Type 021N did not have any effect on their growth. Two sulfate loading rates on activated sludge bulking was studied in long term experiments with a continuous laboratory scale anaerobic-oxic system and short term batch tests to study phosphate release, sulfate reduction and total organic carbon (TOC) removal. A low sulfate loading caused the sludge to have good settling properties while a higher loading caused an increase in filament length and deterioration in settling properties.

The relations and effect of temperature among the sulfate reducing bacteria and other microbial processes were studied at 4, 20, 30 and 37°C using sludge from an anaerobic-oxic plant. Phosphate accumulated sludge tended to decrease sulfate reduction and the number of SRB, sulfide oxidizing rate and filament length tended to increase with sulfate reduction rate. Denitrification completely suppressed SRB and PAB activity over the temperature range while nitrate was present. Results from the application of the Arrhenius equation indicated that the

denitrification was the most sensitive to temperature changes, with a mean Q_{10} value of 2.4, followed by sulfate reduction (1.84) and phosphate release (1.35).

Chapter 4: Effect of iron coagulant on control of filamentous bulking

The effect of iron coagulant on control of filamentous bulking and phosphate removal was investigated using the laboraotory scale activted sludge process. The results showed that sulfate reduction was correlated to the activated slduge bulking. When $FeCl_2$ was added to the aeration tank, most of phosphate was removed. sulfate reduction and filamentous bulking were also suppressed. The addition of $FeCl_2$ was also effective in suppressing phosphate release and sulfide production from the wasted sludge. Interactions among sulfur oxidation reduciton and iron oxidation redution were examined in batch exeriments. When $FeCl_2$ was added, feric reducing bacteria out competed the sulfate reducing bacteria and the sulfate, oxidizing bacteria iron oxidizng bacteria grew predominantly.

Chapter 5: Simultaneous sulfur and iron oxidation-reduction in anaerobic oxic activated sludge

Simultaneous sulfur and iron oxidation were examined. Batch experiments were carried out using artificial wastewater. Sulfate reduction rates tended to increase with sulfide oxidation rates for both wastewater treatment and laboratory scale sludge. Under oxic conditions, both sulfide and iron oxidation occurred simultaneously and iron was responsible for lowering sulfide oxidation rates. In anaerobic conditions, sulfate and iron reduction occurred simultaneously with sulfate inhibition by anthroquinone. Phosphate release tended to increase with iron reduction. The results from the electron flow and activity calculations suggested that sulfate reducing bacteria utilized substrate electrons than iron reducing bacteria.

Chapter 6: Concluding Remarks

The results from this dissertation shows that the sulfate reducing bacteria is important in the microbial processes in the activated sludge and its interaction with other bacteria in the activated sludge is important. The use of iron compounds is also important in controlling sulfate reducing bacteria growth and preventing filamentous bulking.

学位論文審査結果の要旨

本論文に対し，８月５日に第１回論文審査委員会を開催し，論文内容について詳細な検討を行うとともに，８月９日の口頭発表の後，第２回の審査委員会を開催し，協議の結果，以下のように判定した。

活性汚泥法は，浮遊懸濁型の混合微生物集団を用いた下排水処理方法であり，その中には様々な微生物が生育し相互作用を及ぼしている。しかし，硫酸塩還元細菌の活性汚泥中での挙動や役割については不明な点が多い。本論文では，まず，活性汚泥中での硫酸塩還元細菌の影響について検討を行っている。その結果，実処理場，室内実験に限らず，硫酸塩還元細菌の活性が高まると硫黄酸化細菌の活性が高まり，硫黄酸化能のある糸状性細菌Type021Nの現存量の増大により，活性汚泥の沈降性が悪化して運転管理上重要な問題を引き起こすことを明らかにした。さらに，りん除去をになうpoly-P蓄積細菌と硫酸塩還元細菌の相互作用を検討し，単純な基質を用いた室内実験では基質の競合が起こるが，都市下水のような複雑な有機物を処理する場合は，硫酸塩還元の活性化により酢酸の供給が促進され，りん除去が活性化することを指摘した。これは，嫌気好気活性汚泥法による生物学的りん除去のために，重要な知見を与えるものである。次に，硫酸塩還元細菌の増殖因子について検討した結果，嫌気ストレスによる硫黄サイクルの開始が重要であることを指摘するとともに，硫酸塩還元細菌の温度依存性が高いことを明らかにした。最後に，硫酸塩還元の抑制方法として鉄系凝集剤の添加を提案し，室内実験により鉄系凝集剤添加が硫酸塩還元とバルキングの抑制，およびりんの凝集除去に効果的であることを明らかにした。さらに，その抑制機構が，鉄還元細菌との相互作用によるものであることを示した。

以上のように，本論文では活性汚泥中の微生物動態と工学的な制御方法の両者の観点から，有用な知見が得られており，博士(工学)の学位に値するものと判断した。