

温度和污泥浓度对短程内源反硝化脱氮的影响

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摘要:采用 SBR 反应器,以亚硝酸盐(NO_2^-)作电子受体,对温度和污泥浓度对短程内源反硝化脱氮的影响进行了研究。结果表明,在 15~30 范围内,随着温度的升高,短程内源反硝化速率逐渐增高,温度每升高 10,反硝化速率增加 3 倍。温度一定时,污泥浓度增加,短程内源反硝化速率也相应增加,当 MLSS 从 4000mg/L 变化到 12000mg/L 时,反硝化速率从开始的 0.0259gN/(gVSS·d)增加到了 0.0378gN/(gVSS·d),即增大了近 1.5 倍,即采用较高污泥浓度可以大大节省反应时间。

关键词:生物脱氮; 内源反硝化; 温度; 污泥浓度

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氮污染是引起水体富营养化的主要因素之一,污水中氮的去除越来越受到人们关注。生物脱氮是污水脱氮处理中应用得最为普遍的方法,生物脱氮包括硝化和反硝化两个过程。作为常规硝化过程产物的硝酸盐(NO_3^-)和亚硝酸盐(NO_2^-),如果去除不彻底而排入水体,则会给环境带来危害^[1-2]。硝酸盐及亚硝酸盐的去除可通过反硝化来完成。生物反硝化需要有机碳源作为电子供体,用于产能和细胞合成。可用碳源一般有三类:外加碳源、原污水碳源和内源碳源。利用原水碳源的前置反硝化工艺一般总氮去除率不高,如果要进一步提高脱氮效率,则需外加碳源。而采用内源脱氮既可以节省外加碳源,又可以减少剩余污泥产量和污泥处置费用,有些工艺也正是利用内源反硝化来加强其脱氮或除磷效率的^[3-4],然而国内外此类研究的详细报道却不多见,对于短程内源反硝化(以亚硝酸盐为电子受体)的研究就更少。本文主要对内源反硝化脱氮过程中不同温度及其污泥浓度(MLSS)对反硝化速率的影响进行了研究,以期探索内源脱氮合适的环境条件和合理的运行参数。

1 材料与方法

1.1 试验用泥

试验所用活性污泥取自北京市某污水处理厂,测得该活性污泥上清液各项指标如表 1 所示。

表 1 试验用污泥及其上清液指标 (mg/L)

| pH | COD | $\text{NH}_4^+ - \text{N}$ | $\text{NO}_2^- - \text{N}$ | $\text{NO}_3^- - \text{N}$ | TP | VSS/MLSS |
|---------|-------|----------------------------|----------------------------|----------------------------|-----|----------|
| 7.3~7.6 | 30~40 | 0~3 | 0~1 | 0~5 | 1~3 | 70%~76% |

1.2 试验装置

本试验采用总容积为 8L 的玻璃 SBR 反应器,有

效容积 7L。反应器中设有搅拌器,保持泥水混合均匀;温控仪和加热器用于调控水温。运行方式为:瞬时投加亚硝酸盐并搅拌。定时检测混合液的 MLSS、 $\text{NH}_4^+ - \text{N}$ 、 $\text{NO}_3^- - \text{N}$ 和 $\text{NO}_2^- - \text{N}$ 等参数,在线监测 ORP、pH 和水温。见图 1。

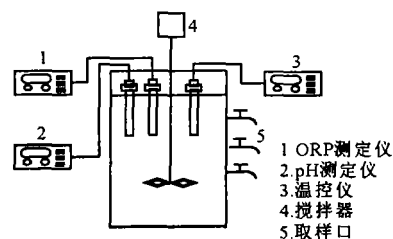


图1 SBR反应器系统示意图

2 结果与分析

2.1 温度对短程内源反硝化速率的影响

MLSS 维持在 6500mg/L 左右,起始亚硝酸盐氮($\text{NO}_2^- - \text{N}$)浓度均为 40mg/L,采用 4 个温度水平进行短程内源反硝化试验,即:17、20、25 和 30。

图 2 为 25 时以 $\text{NO}_2^- - \text{N}$ 作电子受体时一个具有代表性的周期内氮的转化。从图中可以看出,随着反硝化反应的进行, $\text{NO}_2^- - \text{N}$ 浓度逐渐降低,并在 6h 后达到最低。反应起始 $\text{NH}_4^+ - \text{N}$ 浓度较低,然后逐渐增加,这是由于微生物的死亡、分解而导致混合液中氨氮浓度上升,并使得反应后期总氮(TN)浓度变化有略微升高趋势。该周期内 TN 最大去除率(第 9h)为 83%。

图 3 为 4 个温度水平下短程内源反硝化过程中 $\text{NO}_2^- - \text{N}$ 浓度的变化,显然,在试验范围内,随着温度的升高,反硝化速率相应加快,当温度从 20 增加到 30 时,内源反硝化速率由 0.018gN/(mgVSS·d)升高到 0.057gN/(mgVSS·d),即增大了 3 倍多,反硝化 40mg/L 的亚硝态氮,时间从 6h 缩短到 4h。因此,在 30 以内,采用较高的温度可以大大加快内源

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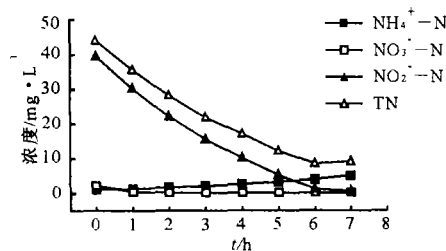


图2 短程内源反硝化一个周期内氮的转化

反硝化的反应速率。

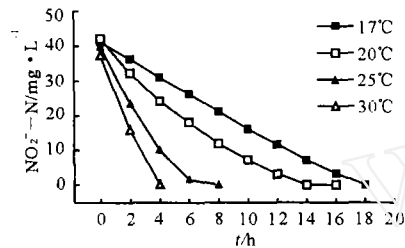


图3 不同温度下的NO₂⁻-N变化

温度不仅影响细菌的比增长速率,而且会影响细菌的活性。在 5~30℃,随着温度的升高,反硝化反应速率也逐渐增加。温度过高,蛋白质的变性会降低细菌的活性,反硝化速率则会降低。当温度低于 4℃,细菌的生命活动几乎停止。本试验的温度范围在 15~30℃ 之间,图 4 对不同温度下的短程内源反硝化速率进行了总结,并回归出实验条件下短程内源反硝化速率和温度之间的关系式: $r_{DN} = 0.0017e^{(0.1173T)}$ 。

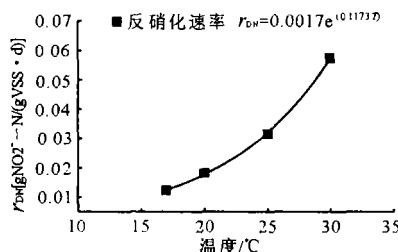


图4 温度对内源反硝化速率的影响

2.2 污泥浓度对反硝化速率的影响

温度均控制在 25℃,起始 NO₂⁻-N 浓度均为 40mg/L,在不同 MLSS 下进行短程内源反硝化试验,这里采用 5 个 MLSS 水平,分别为: 4000mg/L、6000mg/L、8000mg/L、10000mg/L 和 12000mg/L。

图 5 是在不同污泥浓度下短程内源反硝化过程中 NO₂⁻-N 的变化情况,显然,高污泥浓度下 NO₂⁻-N 浓度降低的速率比低污泥浓度下要快。MLSS 为 4000mg/L 时,完全还原 40mgNO₂⁻-N/L 需要 11h;而在 12000mg/L 的 MLSS 下,只需 3h。因此,采用短程内源反硝化进行脱氮时,应该选择较高的污泥浓度。

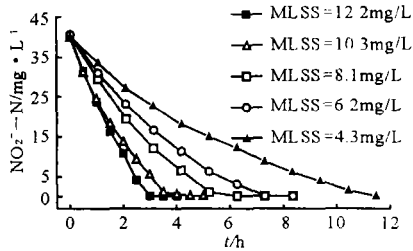


图5 不同时间MLSS下的NO₂⁻-N变化

表 2 总结了本试验中不同污泥浓度 (MLSS) 下的反硝化速率 r_{DN} 值。可以看出,随着污泥浓度的增加, r_{DN} 值也逐渐增大。根据反硝化反应动力学可知^[5],影响反硝化菌反硝化速率有两种底物,即硝态氮 ($NO_x^- - N = NO_3^- - N + NO_2^- - N$) 和碳源有机物。由于各反应器内起始 $NO_2^- - N$ 浓度相同,因此,这里决定反硝化速率的主要有两个因素:反硝化菌数量和有机碳源。MLSS 较高时,相应的反硝化菌数量就较多,重要的是,反硝化菌可利用的有机碳源的量也相应增多。这是因为随着 MLSS 的增高,微生物量也就增加,根据细菌死亡-再生 (death-regeneration) 理论^[6],微生物衰减时会产生二次基质,这些二次基质可供微生物生长使用。微生物量的增加,必然引起内源代谢物质的增多,因此,反硝化反应所需要另一底物—有机碳源浓度也随之增大,这两个因素协同作用,最终导致了反硝化速率的加快。因此,在起始亚硝酸盐浓度相同的条件下,随着 MLSS 的增高,短程内源反硝化速率也逐渐增加,当 MLSS 从 4000mg/L 变化到 12000mg/L 时, r_{DN} 值从 0.0259gN/(gVSS·d) 增加到了 0.0378gN/(gVSS·d),即 r_{DN} 值增大了近 1.5 倍。

表 2 不同 MLSS 下的短程内源反硝化速率

| MLSS mg/L | 起始 NO ₂ ⁻ 浓度 mg/L | 反硝化速率 gN/(gVSS·d) | 标准 误差 |
|--------------|--|----------------------|----------|
| 4000 | 40 | 0.0259 | 0.0014 |
| 6000 | 40 | 0.0291 | 0.0015 |
| 8000 | 40 | 0.0313 | 0.0015 |
| 10000 | 40 | 0.0341 | 0.0013 |
| 12000 | 40 | 0.0378 | 0.0018 |

3 结论

- (1) 采用短程内源反硝化脱氮,在节省 100 %外加碳源条件下,总氮去除率可达 80 %以上。
- (2) 污泥浓度一定时,在 15~30℃ 内,随着温度的升高,短程内源反硝化速率加快,温度每升高 10℃,反应速率增大 3 倍,试验条件下短程内源反硝化速率和温度的关系式为: $r_{DN} = 0.0017e^{(0.1173T)}$ 。

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影响已趋平稳态势,考虑到垃圾场处于瓯江边,长年受流动水的影响,污染浓度可能会有所减少,否则污染更为严重,同时,垃圾场污染向江水和地下水的渗透也是不可避免的。本调查还对土壤中水分以及挥发酚的含量进行了测量,结果也高于土壤的本底含量,对土壤环境存在一定的影响。

3 讨论与展望

我国大部分城市的垃圾填埋场院和部分工业固体废物填埋场,都采用当地天然黏土或人工改性土作为防渗衬层,其最大的优点就是经济成本低。但事实证明^[6-8],几乎所有的黏土衬层都不可避免地有一部分垃圾渗滤液经过一段时间的腐蚀而穿透,由此造成地下水和环境的污染。尤其是城市垃圾在进入填埋场之前,绝大部分都没经过早期脱水处理,加上填埋场封顶防渗措施缺乏或排水不畅,在全年雨水充足的亚热带地区,渗滤液必然大量产生,导致天然防渗衬层的填埋场对周边环境,尤其是对地下水起到的污染隔离作用非常有限,严格地说,黏土型防渗层只能延缓渗滤液的渗漏,并不能绝对安全地阻止污染的迁移。就目前而言^[9-10],对防渗衬层或屏障材料的研究和设计,主要考虑如何防止污染因对流而渗透,因浓度梯度而扩散,起到隔离的作用。在考虑到垃圾经过多年的填埋,会自动降解或衰减,保持稳定后,便可成为名符其实的垃圾安全处置地。但从调查的情况看,杨府山垃圾填埋场在勘探深度内,由淤泥及淤泥夹砂二个工程地质层组成,渗透系数与黏土的接近, $<10^{-7}$ cm/sec,不到20年的时间内,污染质已穿透天然屏障,对周围500m土壤造成了不容忽视的污染。

今后屏障材料和发展方向不仅是防渗,还要考虑对可能穿透的污染进行有效处理、净化和降解。新型的屏障隔离材料,结合物理化学方法和生物技术,提出了两种基本不同类型的增强屏障的概念:一种是

所谓的矿化增强屏障,具有低渗透率,由吸附、沉淀和可能的其他化学反应延缓有机和无机的污染;另一种是生物增强型屏障,不但具有低渗透率,而且有能力促使和提高已经渗透的有机污染进行生物降解,也有能力象第一种类型一样,延缓有机和无机污染。增强型屏障是对现有屏障的改进,是目前研究的热门课题。

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(3) 随着污泥浓度的增高, 短程内源反硝化速率逐渐增加。因此, 在采用内源反硝化进行脱氮时, 应该选择较高的污泥浓度, 以缩短反应时间。

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cyte; Comet assay

**Air Environment Assessment of
Artificial System by Genetic Algorithms**

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Abstract ID:1003-6504(2005)04-0083-03-EA

Abstract: Cognition function of brain was simulated by artificial nerve network by changing threshold limit value of linking point. BP network model based on genetic algorithms was used to assess air quality in some area with national air quality criteria as inputting samples of the network. The results were in conformity with comprehensive index method.

Key words: genetic algorithms; artificial system; BP network; environment assessment; comprehensive index method

**Effects of Temperature and MLSS on
Endogenous Denitrification Via Nitrite**

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Abstract ID:1003-6504(2005)04-0085-03-EA

Abstract: Laboratory experiments were conducted to study the effects of temperatures and MLSS on endogenous denitrification via nitrite with SBR reactor operating in denitrification mode. Results showed the endogenous denitrification rate via nitrite increased as temperature became higher among experimental temperature range. When temperature increased 10°C, the endogenous denitrification rate raised to 3 times. On the other hand, MLSS has a positive effect on endogenous denitrification rate. When mixed liquor suspended solids (MLSS) changed from 4g/L to 12g/L, the endogenous denitrification rate increased from 0.0259gN/(gVSS_d) to 0.0378 gN/(gVSS_d), which indicates reaction time is saved by adopting higher MLSS.

Key words: biological nitrogen removal; endogenous denitrification; temperature; mixed liquor suspended solids (MLSS)

**Study on Optimal Design of
Dredged Spoils Solidification**

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Abstract ID:1003-6504(2005)04-0087-03-EA

Abstract: Multiobjective optimization model for solidification is established based on mechanical characters as restriction condition and secondary pollution and cost as optimization goal. The contradiction between mechanical characters, secondary pollution and cost by optimal design can be solved, which will lay a base to establish systemic solidification theory. Dredged spoils solidification in Dayawan was optimal designed by the model.

Key words: dredged spoils; solidification; mechanical character; secondary pollution; multiobjective optimization

Study on Electrolysis Treatment of Zymogenic Wastewater

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Abstract ID:1003-6504(2005)04-0090-02-EA

Abstract: Based on the experiment of electrolytic oxidation of non-biodegradable organic pollutants after biologic process in a zymogenic plant, the impact of factors such as flocculation agent, NaCl concentration, electric current intensity and pH on removal of COD and color were studied, and their mechanism were analysed as well.

Key words: electrolysis; zymogenic wastewater

Study on Performance of Zeolites Modified Clay-liners

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Abstract ID:1003-6504(2005)04-0092-03-EA

Abstract: Different percentage of zeolites was used to modify natural clay to study permeability, contaminants-removal ability and feasibility of leachate leaking control of zeolites modified clay-liners. Experiment results indicated that the permeability of liner is proportional to percentage of zeolites. If the ratio of zeolites and clay is proper, the permeability of liner can be less than current standard of 1×10^{-7} cm/s, and the pollutants-removal ability is enhanced. Therefore, it is feasible that zeolites modified natural clay can be used as material of landfill liners.

Key words: zeolites; liner; modify; natural clay

**Study on Disposal Technology of Residual Sludge
in Municipal Wastewater Treatment**

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Abstract ID:1003-6504(2005)04-0095-02-EA

Abstract: This paper briefly analysed the present status of wastewater treatment, production of residual sludge and disposal technology. The feasibility of making protein foam extinguishing agent by residual sludge recycling was also introduced.

Key words: municipal wastewater; residual sludge; protein foam extinguishing agent

**Study on Adhesive Produced with Waste
Foamed Polystyrene Plastics**

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Abstract: A kind of low cost adhesive was produced with petroleum cracking by-product as major solvent and waste foamed polystyrene plastics (FPS) as raw material. The prescription choice of adhesive preparation was studied, and the properties were tested.

Key words: solvent; foamed polystyrene plastics; adhesive

**Pilot Scale Study on MBR Process in Removal of
COD from Pharmaceutical Manufacturing Wastewater**

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