污水处理过程中聚糖菌的富集培养

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摘　要:研究了通过磷限制条件来达到聚糖菌的选择与富集,同时在驯化过程中还观察到,在第一阶段培养过程中,对除磷效果乙酸比丙酸更加有效。

关键词:聚糖菌;　聚磷菌;　强化生物除磷
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强化生物除磷(EBPR)工艺是目前广泛接受和认可的经济有效的生物除磷工艺,该工艺要求厌氧段和好氧段交替运行,以富集聚磷菌(PAOs)。在厌氧阶段,PAOs吸收挥发性脂肪酸(VFAs)并以聚β羟基烷酸(PHA)的形式贮存于胞内。该过程所需的还原力来自糖原酵解,能量主要来自胞内聚磷的水解,结果导致磷的厌氧释放。在随后的好氧阶段,PAOs氧化分解胞内储藏的PHA,过量地吸收正磷酸盐,同时完成细胞生长以及糖原的合成。最终通过剩余污泥的排放达到系统除磷的目的。

但是不少文献曾报道,即使在有利于EBPR系统运行的条件下,也会发生系统除磷效果较差或完全没有除磷的现象[1-4]。近来的研究表明,导致上述现象产生的原因是由于系统中存在的聚糖菌(GAOs)占优势造成的。GAOs能在厌氧阶段吸收污水中的VFAs并合成PHA,但不释放磷;在好氧阶段分解PHA,合成糖原而不聚集磷。由于在强化生物除磷系统中厌氧区VFAs的数量有限,若GAOs在厌氧区利用的VFAs百分比增加,则供PAOs可利用的VFAs数量将会减少,从而导致整个系统除磷效率下降。因而如何有效控制GAOs,确立不利于GAOs的生长环境,但同时又不影响PAOs的生长和对碳源的利用,使PAOs在与GAOs的竞争中取得优势地位,从而提高EBPR系统运行的稳定性和磷的处理效率,已成为众多研究者感兴趣的课题。

Liu等人曾通过实验发现通过控制进水中的磷浓度与基质浓度(P/C)之比可达到GAOs的富集培养[5]:在P/C为20/100时,此时系统可到达完全的磷去除,污泥中的磷含量达8%,镜检发现此时的微生物细胞多成杆状或棒状,并且含有磷的内含物;而在P/C之比为2/100时,此时的污泥中的磷含量<2%,系统的除磷功能丧失,镜检所观测到的微生物细胞多成四分体排列,且不含有磷的内含物。同时随着P/C比例的下降,磷释放速率与乙酸吸收率(Pi/AC)、糖原消耗速率/乙酸吸收率(Gly/AC)分别成下降和上升的趋势;PHA中的聚羟基丁酸(PHB)的含量也由85%~90%降低到67%。上述现象表明在高P/C时,活性污泥中富含PAOs,而当P/C降到2/100时,则GAOs占主导地位。Filipe等也曾通过限制进水磷浓度获得了富集生长的GAOs[6-7]。本论文研究了在乙酸、丙酸的混合废水中,通过控制进水磷浓度,以期达到GAOs的选择与富集。

1　实验材料及方法

1.1　实验装置

试验采用5套相同的序批式反应器(SBR)(编号分别为1#、2#、3#、4#、5#)。每个反应器的总容积为4.5L,有效工作容积为3.5L;每个反应器每天连续运行3个周期,每个周期为8h,包括一个厌氧阶段(120min)一个好氧阶段(180min曝气),在该周期的剩余时间则进行沉淀、排水和进水。各反应器均通过时间控制器进行自动控制,具体运行时间见表1。

表1　SBR反应器运行时间表

周期	一	二	三
进水	8:00~8:10	16:00~16:10	0:00~0:10
厌氧+搅拌	8:00~10:00	16:00~18:00	0:00~2:00
好氧+搅拌	10:00~13:00	18:00~21:00	2:00~5:00
沉淀	13:00~15:30	21:00~23:30	5:00~7:30
排水	15:30~16:00	23:30~24:00	7:30~8:00

另外,每套SBR反应器每周期的进水流量为275mL/min,进水时间控制在10min以内;每周期在好氧结束前10min进行排泥,以维持系统的污泥泥龄(SRT)在10天左右;好氧阶段溶解氧维持在4.2~4.5mg/L之间。

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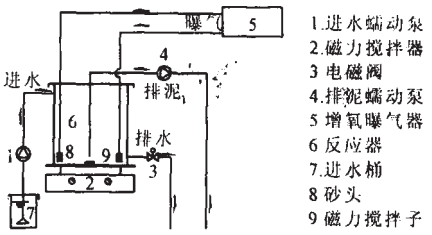

图1 SBR反应器工作示意图

1.2 实验用水

本实验采用人工配制的模拟污水。每个反应器内磷溶液,浓缩液和营养液的浓度均相同(见表2);各反应器的总基质浓度也相同,但其乙酸与丙酸的碳摩尔比不同,具体见表3。

表2 反应器中各溶液的浓度

溶液	药剂	浓度(mg/L)
浓缩液	蛋白胨	61.0
	酵母膏	10
	NH_4Cl	21
	$MgSO_4·7H_2O$	45
	$MgCl_2·6H_2O$	80
	$CaCl_2·2H_2O$	21
	ATU	0.25
磷溶液	KH_2PO_4	55.32~4.61*
	K_2HPO_4	41.49~3.46*
营养液	$FeCl_3·6H_2O$	0.45
	H_3BO_4	0.045
	$CuSO_4·5H_2O$	0.009
	KI	0.3542
	$MnCl_2·4H_2O$	0036
	$Na_2MoO_4·2H_2O$	0.018
	$ZnSO_4·7H_2O$	0.036
	$CaCl_2·6H_2O$	0.045
	EDTA	3.0

* 进水磷溶液浓度由于驯化分别经过了三个阶段,但是每个阶段各反应器均保持一致。

表3 各反应器进水中丙酸/乙酸的碳摩尔比

反应器编号	SBR1	SBR2	SBR3	SBR4	SBR5
乙酸/丙酸(mol-C/mol-C)	10∶1	2∶1	1∶1	1∶2	1∶10

1.3 分析方法

所有的检测分析均重复两遍。乙酸、丙酸的测定采用HP5890-Ⅱ型气相色谱仪。糖原的测定采用蒽酮法[8]。PHA的测定采用Comeau等的方法[9]。总磷及溶解性磷:钼锑抗分光光度法;MLSS、MLVSS采用滤纸重量法[10];pH:pH计(ECSCON公司);溶解氧:溶解氧仪(OXi330i,WTW公司)。

1.4 GAO的富集培养

接种污泥取自上海长桥水质净化厂(该厂采用除磷脱氮的A^2O工艺),并均分5个SBR反应器中。GAOs的富集培养经历采用三阶段方式:第一阶段,进水磷浓度为20mg/L,COD为260mg/L,使P/C>1∶100,以便观察系统中确实富含PAOs;第二阶段,反应器中的进水磷浓度为10mg/L,COD为260mg/L,此阶段为一过度段,通过逐步降磷使微生物具有一个逐渐适应的过程;第三阶段,进水磷浓度为1.3mg/L,COD为216.7mg/L,此阶段进水中的P/C<1∶100,所加入的磷含量,仅希望用于满足微生物的生长需要(如合成核酸等)。每阶段均控制进水后的pH为6.8。

2 结果与讨论

第一阶段驯化的第5天,各反应器中的活性污泥厌氧末磷释放量就出现明显增多现象。第23天,经检测各反应器的厌氧末磷释放量分别在85~106mg-P/L之间,磷的除去效率最高的可达99%,同时各反应器中活性污泥中的P/MLSS值由起始的5.2%上升到9%左右(见图2)。该现象充分表明在厌氧/好氧交替运行的环境下已经具备较强的厌氧释磷和好氧吸磷能力。另外在此阶段,还观察到随着丙酸/乙酸比例的增加,厌氧末磷释放量减少(见表4),并且厌氧磷释放量/好氧磷吸收量的比值也是1#反应器最大(1.19mgP/mgP)而5#反应器最低(1.144mgP/mgP),这似乎说明在磷浓度为20mg/L的第一阶段驯化过程中,丙酸含量的增加可能导致系统内PAOs富集量的降低,从而使PAOs在系统内的竞争优势有所削弱。这一现象与有关文献的报道相符[11]。也即是短期的驯化过程中,在EBPR系统中乙酸比丙酸对除磷效率更加有效。

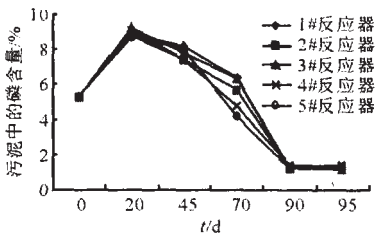

图2 驯化期间1#~5#反应器底泥磷含量随时间变化图

表4 驯化第一阶段中各反应器中磷的代谢情况

磷代谢量	SBR1	SBR2	SBR3	SBR4	SBR5
厌氧磷释放量(mg-ΔP/g-MLVSS)	59	54	50	49	43
好氧磷吸收量(mg-ΔP/g-MLVSS)	71	64	57.5	56	47
磷吸收量/释放量(mg-P/mg-P)	1.20	1.18	1.15	1.14	1.10

经25天后驯化,开始进入第二阶段驯化培养,此时将进水中的磷含量降低,使反应器中的起始厌氧磷浓度为10mg/L,大约经过两周,各反应器的厌氧末释磷量普遍降低到51~70mg-P/L,活性污泥中P/MLSS之值分别在7.4%~10.4%之间,较第一阶段下降约2%,但是仍具有较高的含磷量。各反应器的的厌氧磷释放和好氧磷吸收并没有呈现如第一阶段的显著变化规律。但是单位活性生物量的厌氧磷释放和好氧磷吸收均较第一阶段普遍下降(见表5),同时MLSS中的糖原含量普遍增加(见图3),这也意味着在活性污泥中PAOs所占的比例在逐步减少,而GAOs含量在逐步增多。

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表 5　驯化第 43 天各反应器中磷的代谢情况

磷代谢量	SBR1	SBR2	SBR3	SBR4	SBR5
厌氧磷释放量(mg-ΔP/g-MLVSS)	28.68	25.00	36.23	32.00	26.68
好氧磷吸收量(mg-ΔP/g-MLVSS)	33.87	29.90	41.90	37.48	32.43
磷吸收量/释放量(mg-P/mg-P)	1.18	1.196	1.157	1.171	1.216

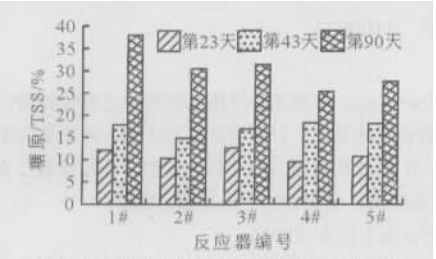

图3 驯化期间糖原含量变化对照图

在驯化的第 50 天,开始进入第三阶段,此时将进水中的磷含量与 COD 同时降低,使反应器厌氧始的磷浓度为 1.3mg/L,COD 为 216.7mg/L。大约经过 40d,各反应器的厌氧末磷释放量在 0.5~0.2mg/L 左右,而好氧末只有 5# 反应器出现了磷的完全吸收现象,同时污泥中的 P/MLSS 值普遍在 1.4%~1.6%之间,各反应器活性污泥中的糖原/TSS 值在 26%~31%之间,比初始值增加了 2 倍多(见图 4),这表明有更多的糖原参加了代谢,因为活性污泥在以聚磷菌为主导菌属时,其吸收有机酸时,糖原主要是起着提供还原力的作用;而在以聚糖菌为主导菌属时,其吸收有机酸时,糖原不但是起着提供还原力的作用,而且还起着提供能量的作用,因而需要更多的糖原。在随后的试验中各反应器的糖原、PHA、有机酸的代谢规律均与有关文献所描叙的典型聚糖菌的代谢特征相吻合:厌氧阶段吸收有机酸,分解糖原并合成 PHA,但几乎不释放磷;好氧阶段分解 PHA 合成糖原而不聚集磷。这充分表明在活性污泥中聚糖菌已成优势主导微生物。

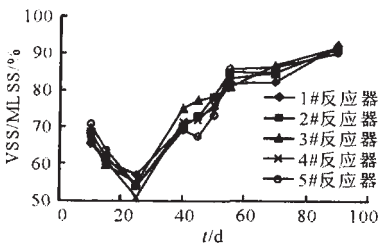

图4 驯化期间VSS/MLSS含量变化图

另外,通过驯化期间 VSS/MLSS 随时间变化图,也可再次表明:系统活性污泥中的主导菌属已由开始的聚磷菌转化为聚糖菌。因为在总的 TSS 含量中包含有净微生物量、体内聚合物(糖原、PHA 以及聚磷)及其它各种无机物等。随着 PAOs 向 GAOs 的转化过程中,聚磷的含量不断降低而聚塘的含量不断增加,在没有向系统添加另外物质的情况下,势必会使 VSS/MLSS 的比值增大。图 3 也清楚表明了该变化过程。

3　结论

(1)在强化生物除磷系统中存在着聚糖菌,通过磷限制条件的逐步驯化可达到聚糖菌的选择与富集。

(2)在聚糖菌的驯化培养过程中,微生物胞内的糖原含量呈明显增加趋势,同时 VSS/MLSS 也显著增加。

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Enrichment Culture of Glycogen-accumulating Organisms in Wastewater Treatment Process

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Abstract ID: 1003-6504(2006)06-0001-03-EA

Abstract: The selection and dominance of glycogen-accumulating organisms(GAOs) were investigated in laboratory-scale sequencing batch reactors. Results indicated that the enrichment of GAOs could be improved by reducing influent phosphate concentration. It was found acetate is more effective to remove phosphorus than propionate in the first phase cultivation.

Key words: glycogen-accumulating organisms(GAOs); phosphorus-accumulating organisms (PAOs); enforced biological phosphorus removal (EBPR)

Studies of Lignocellulose Degradation by Streptomyces badius

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Abstract ID: 1003-6504(2006)06-0004-03-EA

Abstract: Acid-precipitable polymeric lignin(APPL) degradation by Streptomyces badius under the condition of liquid state fermentation as well as decrease of lignin, cellulose and hemi-cellulose is studied. Results show that nitrogen nutrient-yeast extract can obviously stimulate growth of peroxidase and APPL while nitrogen-nutrien-ammonium chloride and carbon nutrient-glucose inhibit growth of them.

Key words: environmental engineering; Streptomyces badius; lignin; peroxidase; acid-precipitable polymeric lignin (APPL)

Characteristics of Distribution of Heavy Metals and Mineral Matter in Sediments of Bohai Bay in Tianjin's Sea Area

HAI Re-ti, XIE Tao, QI Feng-xia
(Beijing University of Chemical Engineering, Beijing 100029)

Abstract ID: 1003-6504(2006)06-0006-04-EA

Abstract: A study of distribution of heavy metals and mineral matter in sediments of Bohai Bay in Tianjin's sea area is described, and based on this the correlation analysis is made; the collective distribution trend of the elements is analyzed, which indicates the evident correlation of these heavy metals in this sea area, reflecting their concomitant geochemical character. As to mineral matter, it has been found that amphibole and dolomite constitute the major mineral in Bohai Bay.

Key words: Bohai Bay; heavy metals; distribution characteristics; correlation analysis

Preparation of Carbon-based Electrodes and Their Application to Electro-Fenton Degradation of 4-Chlorophenol

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(Environmental Science Research Institute, Huazhong University of Science and Technology, Wuhan 430074)

Abstract ID: 1003-6504(2006)06-0009-03-EA

Abstract: The carbon-based electrodes developed in the laboratory include two composite electrodes: graphite-PTFE and activated carbon-PTFE. Based on electro-Fenton principle, wastewater containing 4-chlorophenol was treated using those electrodes and better performance was showed with the one of activated carbon-PTFE.

Key words: carbon-based composite electrode; electro-Fenton; 4-chlorophenol

Study on Residue of Famoxadone in Citrus and Soil

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Abstract ID:1003-6504(2006)06-0011-03-EA

Abstract: Residue of famoxadone in citrus and soil was determined using gas chromatography with electron capture detector(GC-ECD). The study indicated that the final residue of famoxadone in citrus and citrus pulp could be less than the recommended maximum residue limit when it was applied less than four times at a certain dosage and interval.

Key words: pesticide residue; famoxadone; citrus; soil; degradation

Dynamic Adsorption of Toluene on Viscose Rayon-based Activated Carbon Fibre

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Abstract ID:1003-6504(2006)06-0013-03-EA

Abstract: Dynamic equilibrium adsorption capacity of viscose rayon-based activated carbon fibre(ACF) for toluene was studied on a bench-scale installation in terms of influences of temperature, flow velocity, humidity and concentration of toluene.

Key words: activated carbon fibre (ACF); dynamic adsorption; toluene; adsorption isotherm

Photocatalytic Degradation of Acid Red B by Nanometer TiO_2

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