

# 应用淹没式膜生物反应器处理含磷污水

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**摘 要:** 为了提高废水的回收利用率, 考察了应用淹没式膜生物反应器处理含磷污水的工艺流程及效果. 在生物除磷流程中, 设置厌氧段, 除磷率可达 63 % 以上, 与不设厌氧段相比, 提高了 32 %; 在生物除磷的同时进行化学除磷, 将  $Al_2(SO_4)_3$  加入反应器中, 保持污泥活性, 平均除磷率可达 82 %. 结果表明, 该反应器可以有效地去除含磷污染物, 应用中设置厌氧段, 同时进行化学除磷, 可进一步提高该反应器的除磷效果.

**关 键 词:** 除磷; 含磷污水; 膜分离; 生物处理; 反应器

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## 0 引言

磷(P)含量是衡量水体是否受污染的一个重要指标. 淡水湖泊的水华、海水中的赤潮等都根源于 N 与 P 的污染. 水体中 P 的来源是多方面的, 主要是由人类生活污水、工业废水及农田废水引起的. 目前, 处理含 P 污水主要采用生物法或化学法. 根据现代生物除 P 机理<sup>[1]</sup>, 生物除 P 须使微生物处于厌氧、好氧的交替状态, 将过量摄取 P 的污泥及时排出系统. 生物除 P 法主要包括 Phostip, A/O,  $A^2/O$  及氧化沟等工艺, 共同特征是设置厌氧区<sup>[2]</sup>, 控制污水中的溶解氧量, 使聚 P 菌(贮 P 菌)吸收基质产生选择性增殖, 最后通过排除含 P 污泥来实现除 P. 化学方法主要是投加各种药剂, 通过化学反应形成不溶性磷酸盐沉淀物, 然后经固液分离将 P 从污水中除去. 膜生物反应器是根据膜分离技术与生物处理技术设计的废水生物处理工艺装置<sup>[2,3]</sup>, 它具有去除有机污染物效率高、出水水质好、流程简单、结构紧凑等优点, 在废水回用与资源化领域具有极为广阔的应用前景. 笔者研究了膜生物反应器的除 P 效能.

## 1 试验

### 1.1 膜组件

选用的膜件为国产聚丙烯中空纤维膜, 膜孔孔径为  $0.2 \mu m$ ; 膜件长度为  $0.35 m$ , 膜面积为  $1 m^2$ ; 好氧反应器容积  $14.2 L$ ; 厌氧反应器容积为  $5 L$ .

### 1.2 装置及流程

淹没式膜生物反应器除 P 试验装置见图 1.

无厌氧段工艺流程: 配水箱中配制的废水经稳压水箱, 从膜生物反应器下部进入, 在微气泡曝气搅动下, 经过组合填料, 被真空抽吸至膜组件过滤后出水.

有厌氧段工艺流程: 配水箱中配制的废水经稳压水箱再经过厌氧段, 从膜生物反应器下部进入, 在微气泡曝气搅动下, 经过组合填料, 被真空抽吸至膜组件过滤后出水; 部分回流污泥经泵回流到厌氧段; 从空压机来的空气经过

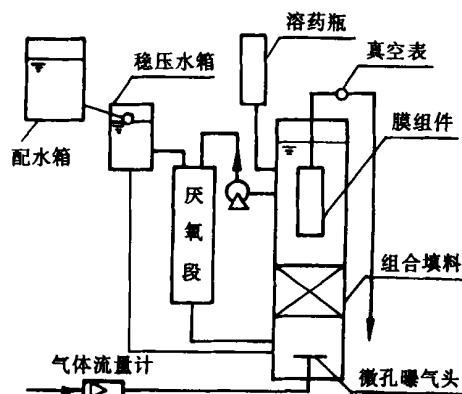


图 1 淹没式膜生物反应器除磷试验装置

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气体流量计计量后经微孔曝气头进入反应器。

化学除 P:流程与无厌氧段工艺流程基本相同,所用药剂从溶药瓶进入反应器。

### 1.3 含 P 污水的配制

试验用的含 P 污水是用直链淀粉、复合肥、 $\text{NH}_4\text{Cl}$ 、 $\text{KH}_2\text{PO}_4$ 、 $\text{Na}_2\text{HPO}_4$  配制而成的。经仪器法测定,配水 pH 值为 6.58~7.53;经回流法测定 (COD<sub>Cr</sub>) 为 150.24~200.46 mg/L,光度法测定 ( $\text{NH}_3\text{-N}$ ) 为 9.45~19.98 mg/L, (P) 为 2.16~7.21 mg/L。

### 1.4 选择参数

通过改变底物浓度、污泥龄及溶解氧等条件,可控制膜生物反应器中污泥的质量浓度<sup>[4]</sup>,本试验中,通过定期排泥,将污泥质量浓度控制在 3.5~4.0 g/L;过大的曝气强度将导致反应器内剧烈水力搅动,而强大的剪切力将不利于生物膜的附着<sup>[5]</sup>,因此,本试验中控制溶解氧质量浓度在 4~6 mg/L;总的水力停留时间为 5 h;出水流量稳定在 64 mL/min,通过调整负压水头高度而实现。

### 1.5 调试运行

通过测定对 COD<sub>Cr</sub> 及  $\text{NH}_3\text{-N}$  的去除率,调试运行膜生物反应器。首先在厌氧段加入培养好的厌氧污泥,注入配好的原水,进出水口密封;在好氧段反应器中加入活性污泥菌种,注入原水、曝气,培养活性污泥,进行 15 d 连续流的调试。稳定运行后,启用厌氧段反应器再连续培养 15 d。连续测定污染物去除率,结果表明,进水中 (COD<sub>Cr</sub>) 在 150~200 mg/L 之间,而出水多在 28 mg/L 以下,去除率达到 85%以上;出水 ( $\text{NH}_3\text{-N}$ ) 仅为 0.3~0.8 mg/L,氨氮的去除可达 96%以上;对 COD<sub>Cr</sub> 及  $\text{NH}_3\text{-N}$  的去除效果达到了较好的水平。这主要是由于复合式膜生物反应器中的膜组件可以阻留污染物,使污染物的停留时间延长,而较高浓度的污泥对 COD<sub>Cr</sub> 的降解可以取得非常好的效果<sup>[4]</sup>;膜组件对硝化细菌具有同样的截留作用,同时填料为硝化菌提供了十分良好的依附介质,合理的曝气量和底物浓度,均使反应器中硝化菌大量增值,因此,硝化效果好。

## 2 结果与分析

### 2.1 生物除 P 效果

比较了有、无厌氧段时膜生物反应器的除 P 效果,见表 1。从表 1 可看出,在有厌氧段时,膜生物反应器对 P 的去除率可达 63%以上,最高值可达 71.2%;在无厌氧段时,除 P 率最高达到 31.7%。在进水 (P) 相差不大的情况下,两者的去除率有显著的差别。造成这种差别的主要原因在于设置厌氧段后,在好氧段聚 P 菌可过量聚 P,而在厌氧段释 P,通过排除厌氧段的剩余污泥达到的除 P 效果要好于排除好氧段污泥所达到的效果。

### 2.2 化学除 P 效果

由于生物除 P 去除率可达 63%以上,出水中的 (P) 仍然较高,所以在生物除 P 过程中同时进行化学除 P。目前,化学除 P 使用的是沉淀法。利用可溶的 Fe 盐、Al 盐等与溶解的磷酸根结合生成较难溶的磷酸盐,达到去除的目的。由于 Fe 盐易引起对聚丙烯膜组件的污染,故试验中选用  $\text{Al}_2(\text{SO}_4)_3$  作为除 P 剂。称取一定量的  $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ ,溶解后加入溶药瓶。在反应器中加入配制好的含 P 污水,停止出水,充分曝气,从溶药瓶加入  $\text{Al}_2(\text{SO}_4)_3$  溶液,继续曝气 30 min,停止曝气,恢复出水。分析时,分别取上清液经滤纸过滤后的滤液和膜出水测定含 P 的质量浓度,结果见表 2。从表 2 可见,当进水 (P) 为 5 mg/L 时,无论是膜出水还是上清液出水中除 P 率都较高,分别为 88%,80%;而当进水 (P) 为 10 mg/L 时,膜出水的除 P 率要好于上清液,表明膜对金属磷酸盐化学沉淀物有一定的截留作用;而当进水 (P) 为 20 mg/L 时,药剂量相对不足,导致除 P 率下降;反应器的平均除 P 率可达 82%。在反应过程中发现在负压值没有改变的情况下,出水流量仍能维持在 64 mL/min,表明 Al 盐不易引起膜表面的污染。(下转第 55 页)

表 1 有、无厌氧段的除 P 效果

处理过程	(P)/(mg L <sup>-1</sup> )		除 P 率/%
	进水	出水	
无厌氧段	2.03	1.50	17.0
	2.10	1.70	26.1
	3.05	2.75	9.8
	5.58	3.81	31.7
	7.17	5.56	22.5
	7.21	5.45	24.4
有厌氧段	3.56	1.39	63.2
	5.45	1.67	69.4
	7.56	2.18	71.2
	7.45	2.21	70.3

获得在交互过程中实验变化的动态显示效果. 学生可以通过输入不同数据观察曲线的变化情况 ,还可以直接观察实体的变化过程 ,可以从任意角度浏览整个虚拟实验室环境 ,也可以通过选择、移动、操纵、比例缩放等以不同的角度观察仪器结构 ,详细了解仪器的组成.

2.4 虚拟实验室的集成与发布

先将创建的虚拟环境场景、虚拟仪器、控制界面的总体布局在 VRT 内部集成 ,然后在网上与其他媒体素材合成 ,形成一个有丰富控制结构和友好界面的虚拟实验环境. 通过 Viscape 插件与 Java JavaScript , VBScript 的外部接口把虚拟实验室放在网络服务器上 ,可以实现远程教学. 只要实验者安装 Internet 浏览器和 Viscape 插件 ,即可通过 Internet 对虚拟实验室进行远程浏览和交互操作.

2.5 安全策略

本系统采用的是通过数字证书进行安全认证的安全策略. 先将 Java 编译生成的 class 文件打成 jar 包 ,然后生成密钥 ,利用密钥对生成的 jar 包签名 ,利用 keytool 产生认证的证书文件 ,客户端在访问服务器时 ,证书会随同 Applet 一同下载到客户端. 客户端在运行 Applet 的时候 ,系统会生成安全警告提示 ,只有在信任该证书的情况下 ,才可以继续进行实验内容.

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表 2 化学除 P 效果

取 样	(P)/ (mg L <sup>-1</sup> )	除 P 率/ %	取 样	(P)/ (mg L <sup>-1</sup> )	除 P 率/ %	取 样	(P)/ (mg L <sup>-1</sup> )	除 P 率/ %
进水	5.0	-	进水	10.0	-	进水	20.0	-
上清液	1.0	80	上清液	3.3	67	上清液	5.1	75
膜出水	0.6	88	膜出水	1.2	88	膜出水	4.6	77

3 结论

- (1)在淹没式膜生物反应器工艺流程中设置厌氧段 ,除 P 率可以达到 63 %以上 ,而不设厌氧段时的除 P 率最高仅为 31.7 % ;
- (2)化学除 P 中使用 Al 盐不易引起膜污染 ,金属 P 酸盐沉淀物很难透过超滤膜 ;反应器的平均除 P 率可达到 82 % ;
- (3)采用膜生物反应器处理含 P 污水时 ,应在工艺流程中设置厌氧段 ,同时进行化学除 P ,可提高该反应器的除 P 效果.

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in Duanxi of Bei - 1 Area in Daqing oil field is identified and the depositional environment and depositional feature of Sa - 0 member are studied, the physical property parameters of this reservoir are determined. Then the reserves in place and recoverable reserves of this reservoir are calculated. Finally, taking into account the result of production test, exploitation feasibility of Sa - 0 reservoir is evaluated. The result shows that S<sub>02</sub> unit of Sa - 0 reservoir in Duanxi of Bei - 1 Area is the main reservoir containing oil and is the main reservoir for production. The reserves in place of Sa - 0 reservoir is  $265 \times 10^4$  t, its recoverable reserves is  $111.09 \times 10^4$  t. Sa - 0 reservoir in Duanxi of Bei - 1 Area has a production capacity to a certain extent, and has a nice potential of development.

**Key words:** Sa - 0 formation; depositional feature; reserves; exploitation feasibility

**Conditions and kinetic of *n* - Pentane isomerization reaction/ 2003, 27(2) :31 ~ 33**

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**Abstract:** Performance of *n* - pentane isocatalyst at variety conditions were investigated. A mathematical orthogonal experimental method was used to obtain an optimum reaction conditions: reaction temperature is 275 °C, reaction pressure 1.5 MPa, space velocity  $1.3 \text{ h}^{-1}$  and H<sub>2</sub>/*n* - pentane molar ratio 2.0. At the conditions *n* - Pentane conversion is 69.88 %, isopentane yield 67.68 %, isopentane selectivity 96.85 % and liquid product yield 97.80 %. A first-order reversible kinetic model of pentane isomerization reaction was set up. The apparent active energies in the forward and reverse reactions are 74.65 kJ/mol and 81.32 kJ/mol respectively, and the rate constants are  $2.82359 \times 10^6$  and  $5.26425 \times 10^6$  respectively. The result showed that pentane isomerization reaction with catalyst could be described by this model.

**Key Words:** *n* - pentane; isomerization; mordenite; platinum; zirconium; kinetic model

**Catalytic synthesis of N,N - Dimethylaminoethyl methacrylate with tetrabutyl titanate/ 2003, 27(2) :34 ~ 36**  
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**Abstract:** N,N - Dimethylaminoethyl methacrylate were synthesized by ester exchange using methyl methacrylate and N,N - dimethylethanolamine as feed stock, tetrabutyl titanate as catalyst, *p* - methoxyphenol as inhibitor. The effect of reaction conditions such as the molar ratio of methyl methacrylate to N,N - dimethylethanolamine, the amount of catalyst and inhibitor, reaction temperature and reaction time on reaction result were studied. The optimum conditions are: the molar ratio of methyl methacrylate to N,N - dimethylethanolamine is 4.0, the amount of tetrabutyl titanate 1.0 % (the percentage of the total amount of the reaction system), the amount of *p* - methoxyphenol 0.40 % (the percentage of the total amount of the reaction system), the reaction temperature 100 ~ 120 °C, reaction time 8 h, under these conditions the yield of N,N - dimethylaminoethyl methacrylate is over 90 %.

**Key words:** N,N - dimethylaminoethyl methacrylate; tetrabutyl titanate; ester exchange; catalyst; synthesis

**Research and development of descaling agent for a scale with high silicon content in ASP flooding system/ 2003, 27(2) :37 ~ 39**

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**Abstract:** The analysis of the composition of the scale caused by ASP flooding reveals up to 50 % of silica, 20 % of oil and 10 % of carbonate in the composition of scale in the ASP flooding system. According to the results, a descaling agent was prepared as the follow: 0.5 % ~ 1.0 % surface active agent, 0.5 % penetrating and dispersing agent and 0.5 % corrosion moderator with HCL and HF 15 % of the total acidity. The experimental results show that the agent can descale 90 % of the scale and the corrosion delaying rate is over 95 %.

**Key word:** ASP flooding; descaling agent; descaling rate; corrosion-moderated rate

**Application of submerged membrane bioreactor to removal of phosphorus in wastewater treatment/ 2003, 27**

(2) :40 ~ 41

CHI Jun , WANG Bao-zhen , JING Guo-lin

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**Abstract :** In the paper , to improve the reclamation rate of wastewater , the process and efficiency of submerged membrane bioreactor for removing phosphorus in wastewater were studied. Anaerobic process was adopted in the biological process , and the phosphorus removal rate ( PRR) could be over 63 % . Compared with the process without an anaerobic one , 32 % of improvement of PRR could be gained.  $\text{Al}_2(\text{SO}_4)_3$  was added in the reactor for removing the phosphorus in a chemical way at the same time with the biological process , and the average phosphorus removal rate could reach 82 % . However , the activity of the active sludge should be maintained in all the process. The result of this research showed that the submerged membrane bioreactor is effective in removing phosphorus. The anaerobic process and the chemical process , which were adopted in the process , could greatly enhance the phosphorus removal rate of the reactor.

**Key words :** phosphorus removal ; phosphorus in wastewater ; membrane separation ; biological process ; reactor

**Simultaneous stabilization of linear systems via genetic algorithms/** 2003 ,27(2) :42 ~ 44

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**Abstract :** In this paper , the simultaneous stabilization problem of linear systems is transformed into solving problems of a set of nonlinear inequalities by using a sufficient criterion of polynomial stability. Then a genetic algorithm program is constructed for solving the inequalities , for finding a feasible set of control parameters which simultaneously stabilize a finite set of plants. Examples demonstrate the effectiveness of this algorithm.

**Key words :** multi-plant systems ; simultaneous stabilization ; inequalities ; genetic algorithms

**A kind of improved digital filtering method/** 2003 ,27(2) :45 ~ 46

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**Abstract :** In order that real time data collection system appears , full scale with certain frequency , this paper puts forward a kind of new digital filtering method , which uses the principle of data redundancy to eliminate disturbance of falsehood data , it can be applied to the cases of known disturbance character. Practical application showed its effectiveness.

**Key words :** data processing ; digital filtering ; redundancy

**Virtual instrument and its application/** 2003 ,27(2) :47 ~ 51

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( 1. Economy and Management College, Daqing Petroleum Institute, Daqing, Heilongjiang 163318, China; 2. Personnel Resource Center of Daqing Petroleum Administration, Daqing, Heilongjiang 163453, China )

**Abstract :** Based on the latest computer technique to realize and expand the traditional instrumental function , this paper introduces the basic concept , characteristics , hardware system and software development platform of VI , expatiates the instrumental function , discusses the instrumental application , as well as the problems and their solutions in applying the VI , clarifies the developing prospect of VI in applying virtual realistic technique.