# 淮河(蚌埠段)饮用水源水生物接触氧化预处理生产性试验*

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摘要 为了探索饮用水生物预处理的可行性,进行了国内第一家生产规模饮用水生物接触氧化预处理装置试验. 试验表明: 在水气比 1∶1、滤速 3.6–6.0m/h 时,生物预处理对水源水中有机物(OC)和氨氮的去除效率分别为 13.6%–20.5%和 70%–90%;影响生物预处理运行效果的主要因素是溶解氧和温度.

关键词 饮用水,生物预处理,有机物,氨氮.

小试及中试的饮用水生物预处理试验在国内已有报道,但生产规模的生物预处理技术在饮用水处理中的应用研究鲜见报道. 笔者选择淮河中游典型城市——蚌埠市,进行国内第一座生产规模的生产接触氧化预处理试验,以探索生物预处理改善饮用水水质的可行性和生物预处理在实际应用中运行管理特点,为生物预处理的推广应用及淮河流域其他城市改善饮用水水质提供参考.

## 1 试验装置与方法

### 1.1 试验装置

生物陶粒滤池共 4 池,设计单池处理能力为 $2500m^3/d$,实际运行时最大处理能力为 $3750m^3/d$,其中# 1、# 4 为下向流,# 2、# 3 为上向流.

### 1.2 试验方法

试验从 1993 年 10 月底开始启动与挂膜,# 1池采用自然接种挂膜方式,# 2、# 3、# 4 池采用接种挂膜方式,在挂膜成功后(即生物滤池对 OC 去除效率达 15%左右)进行其它试验.

### 1.3 水质分析项目与方法

OC: 常规方法测定; TOC: 日本岛津-500TOC 仪测定; DOC: 水样经孔径为 0.45$\mu$m 滤膜过滤后测 TOC; BDOC: 可生物降解性有机碳,水样经孔径为 0.45$\mu$m 滤膜过滤后加少许生物陶粒,在 20±5℃下培养 14d,测培养前后的 TOC 值,其差即为 BDOC; $UV_{254}$: 254nm 波长下紫外吸光度,北京分析仪器厂 WFZ800-D3A 型紫外分光光度计测定; DO: 英国 JENWAY 公司的 9071 型 DO 仪; 生物量测定: 取一定量陶粒,用蒸馏水冲净后在恒温箱中以 105±1℃干燥至恒温,然后在马福炉里以 550℃灼烧 30min,称灼烧前后减重即为生物量; 其它水质指标以常规方法测定.

## 2 试验结果与讨论

### 2.1 有机物去除效果

#### 2.1.1 OC 去除效果

由于水中有机物种类复杂,含量较低,目前普遍采用综合性替代参数(Surrogate Parameter)表示. 本试验采用 OC、TOC、DOC 等指标,其中以 OC 作为日常监测指标. 在试验期间(1993-11–1995-05)生物滤池进出水 OC 月平均值及平均去除率如图 1 所示. 在整个运行期间,滤速为 3.6–6.0m/h,水温为 1.5–30℃,进水 OC 值变化较大,出水 OC 值也随进水 OC 值变化而变化,生物陶粒滤池对 OC 的去除率月平均值为 13.6%–20.5%(充分曝气),5.48%–9.75%(间隙曝光),5.83%–12.46%(未曝气),去除率变化范围较大,但在曝气充分时对有机物(OC)去除效果较稳定.

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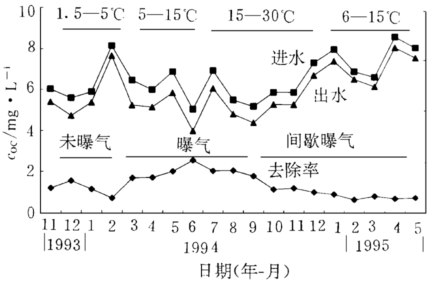


图1 生物陶粒滤池对OC去除效果

试验中间断测定生物陶粒滤池对TOC的去除效果(取样时间: 1994-03- 1994-10), 滤速4.8m/h(即接触时间为25min), 水气比1∶1, 水温6.5- 17℃条件下, 当进水浓度为4.2- 12.7mg/L时, 生物陶粒滤池出水浓度为3.2- 8.7mg/L, 去除率为18.46%- 35.59%, 平均去除率为29.46%. 由于水源水中TOC量与饮用水最终氯化消毒所形成的消毒副产物量有一定的相关性, 因此TOC量的减少意味着饮用水中消毒副产物量的减少, 饮用水水质的提高.

### 2.1.2 影响去除效果的因素

(1) 原水水质 为了研究原水中可生物降解有机物占有机物总量的比例以及可生物降解有机物降解比例, 对生物滤池进出水的TOC、DOC、BDOC进行了分析, 结果见表1.

表1 生物陶粒滤池对可生物降解有机物的去除效果

| 项 目 | 水温 /℃ | TOC /mg·L⁻¹ | DOC /mg·L⁻¹ | BDOC /mg·L⁻¹ |
|---|---|---|---|---|
| 原 水 | 17.0 | 6.5 | 5.3 | 2.3 |
| 生物滤池总出水 | 17.0 | 5.3 | 3.6 | 0.6 |
| 去除率/% | | 18.46 | 32.08 | 73.91 |

由表1可以看出, 原水中溶解性有机碳(DOC)占总有机碳比率(DOC/TOC)为81.54%, DOC中可生物降解成分比例(BDOC/DOC)为43.79%, 还有56%的溶解性有机碳是不能被生物降解的, 比例较高. 经过生物预处理后, DOC/TOC则变为67.92%, 比原水下降. 原因在于生物预处理中, 生物降解去除的主要是溶解性有机物, 生物预处理出水中BDOC值已经降到0.6mg/L, 占DOC比例为16.67%, 此时绝大部分有机物(占83.33%)均不能被微生物所降解, 生物预处理对BDOC去除率达73.91%, 对DOC及TOC去除率分别为32.08%, 18.46%. 因此, 即使生物预处理对TOC的去除率在20%左右时, 其生物可降解成分已去除了73.91%, 生物预处理已充分发挥了去除有机物的作用, 只是原水中可生物降解的有机物比例并不高, 影响了生物预处理对有机物去除效率的进一步提高.

(2) 曝气情况 生物陶粒池生产性装置内布气管为穿孔管, 在试验初期(1993-01- 1994-02), 由于各种原因一直未能正常曝气. 图1表明: 正常曝气时, 生物滤池对有机物(OC)去除效果比较稳定, 要好于曝气不正常阶段.

## 2.2 氨氮去除效果

试验中生物陶粒滤池对氨氮去除效果如图2所示, 图2中原水、出水氨氮值及去除率均为平均值. 图2表明: 生物滤池对原水中氨氮去除率曝气时达70% - 90%, 不曝气或曝气不正常时在50%- 70%之间. 由于氨氮含量过高易引起水处理系统内部及配水管网中细菌特别是硝化自养菌生长, 引起管网腐蚀, 而常规处理工艺又不能有效去除氨氮, 因此, 生物预处理对氨氮的良好去除效果引起了广泛注意.

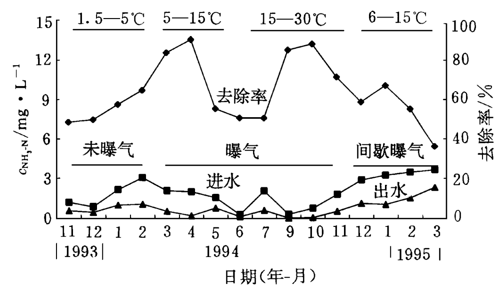


图2 生物预处理对氨氮的去除效果

## 2.3 其它指标

试验中测定了生物滤池对原水中$UV_{254}$的去除效果, 结果表明: 在水温7- 31℃, 水气比为1∶1, 滤速为4.8- 6m/h(即接触时间25- 20min)条件下, 进水$UV_{254}$为0.133/cm - 0.569/cm时, 出水为0.096- 0.42/cm, 去除效率为17.43%- 40.22%, 平均去除效率为29.22%. 由于$UV_{254}$与三卤甲烷(THMs)前体物的生成能力(THMFP)有很好的相关性[1],

因此,也说明了生物预处理对三卤甲烷前体物有很好的去除作用,这对整个工艺降低氯耗,减少 THMs 的生成量有十分重要的意义.

试验表明:进水浊度在 18- 120NTU 时,生物预处理出水浊度为 14- 101NTU,去除率为 19.2%- 63%,平均为 37.9%;当进水色度为 35- 120 度时,出水色度为 20- 120 度,去除率为 11.1%- 41.6%,平均为 21.55%.

试验还表明生物预处理可以降低水源水中胶粒的 Zeta 电位值,减少后续传统工艺混凝投药量*.

**2.4** 影响生物预处理运行效果的因素

(1) 温度　温度变化对微生物代谢活性有一定的影响,温度越低,微生物活性越小.试验表明:温度变化对有机物去除效果影响较大,对氨氮的去除效果则影响不大(见图 1、图 2),其原因在于:有机物的去除主要依靠异养细菌,在适宜的温度范围内温度每升高 10℃,酶促反应速度将升高 1- 2 倍,因而微生物代谢速率可相应提高,在饮用水生物预处理中,经检测生物反应器内细菌主要是贫营养菌,其中优势菌种以假单胞菌属(*Pseudomonas*)占决定地位,假单胞菌属中有几种适合在 4℃以下范围内生长的菌种,这可能就是反应器对有机物的去除效果尽管随温度变化而受影响但在低温(3- 5℃)条件下仍保持一定去除效果的原因;而氨氮的去除则主要靠自养细菌,化能自养硝化细菌中,亚硝化杆菌(*Nitrosomonas*)和亚硝化球菌(*Nitrosococcus*)均适合在 2- 40℃范围内生长,硝化杆菌(*Nitrobacter*)也适合在 5- 40℃条件下生长[2],因此对温度有一定的适应性.同时根据 McCarty 等人研究[3],维持生物膜的稳态运行时,温度越低,出水氨氮浓度越低,温度上升后,出水氨氮浓度随之上升,因此,在低温条件下,反应器也能达到对氨氮较高的去除效率.

(2) 溶解氧　微生物对有机物的分解和使氨氮转化为 $NO_3^-$ 的过程中均需要氧的参与.试验表明:保持出水中溶解氨 2.0- 4.0mg/L,可保证生物陶粒反应器对有机物和氨氮有较好的去除效果.

(3) 水力负荷　在试验期间,水力负荷由 3.6$m^3/(m^2 \cdot h)$ 变化到 6.0$m^3/(m^2 \cdot h)$(即 HRT 由 33min 减少到 20min)时生物陶粒滤池对有机物(OC)及氨氮的去除效果基本没有影响,但以生物氧化过程分析,有机物被微生物氧化成 $CO_2$ 和 $H_2O$ 以及一些中间产物和氨氮被氧化成 $NO_3^+$ 都需要一定的时间,所以停留时间不能过低.另外,过滤速度因停留时间降低而增大,使水力冲刷增强,导致生物膜脱落增多,长期运行将影响处理效率,一般认为稳态膜中生物氧化所需时间不少于 10min.试验中因陶粒孔隙率为 50%,因此,当空床停留时间为 20min 时,实际接触时间只有 10min.根据实际运行效果,推荐采用空床停留时间 20- 30min[即水力负荷 4- 6$m^3/(m^2 \cdot h)$]作为设计参数.

## 3 结论

通过国内首次生产规模的饮用水生物陶粒预处理试验,表明生物预处理在水气比 1∶1、空床滤速 3.6- 6.0m/h 时对水源水中有机物和氨氮的去除率分别为 13.6%- 20.5%和 70%- 90%,对改善饮用水水质,减少形成氯化消毒副产物,减少给水管网腐蚀均有一定作用.影响生物陶粒预处理反应器对有机物和氨氮的去除效果的主要因素是溶解氧和温度,要保证稳定运行效果,须保持反应器出水溶解氧 2- 4mg/L;反应器设计水力负荷推荐为 4- 6$m^3/(m^3 \cdot h)$.

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* 刘文君,淮河蚌埠段水源水饮用水生物预处理生产性试验,硕士论文,清华大学,1995

dexes controlled in producing.

**Key words**: dye intermediates, J-acid, wasteliquor, extraction, resource recovery.

**Study On Full-scale Test of Biological Contact Oxidation Pretreatment in Drinking Water Treatment from Huaihe River Source Water (Bengbu Reach)**. Liu Wenjiun, He Beiping et al.(Dept. of Environ. Eng., Tsinghua University, Beijing 100084), Lu jianhong et al. (Bengbu Water Company, Bengbu, 233000): *Chin. J. Environ. Sci.*, **18**(1), 1997, pp. 20- 22

In this study, the test of full-scale biological contact oxidation pretreatment in drinking water treatment was discussed, which is first in domestic. The results demonstrated that biological pretreat process can remove organic compounds and ammonia of source water by 13.6%- 20.5% and 70%- 90% respectively when the ratio of water to air is 1∶1; the key factor to affect the biological pretreat process performance is dissolved oxygen and temperature.

**Key words**: drinking water, biological pretreatment, pilot scale test, Huaihe River.

**Degradation of Black Liquor Lignin Produced from Kraft Pulping Process of Pine by White-Rot Fungi**. Lin Lu, Yang Gao et al. (State Key Laboratory of Pulp and Paper Engineering, South China University of Technology, Guangzhou, 510641): *Chin. J. Environ. Sci.*, **18**(1), 1997, pp. 23- 25

Black liquor lignin is the main pollutant in the black liquor produced from kraft pulping process of paper-making raw materials. In this paper, effect of white-rot fungi on degradation of black liquor lignin produced from pine kraft cook was studied. Results showed that white-rot fungus could degrade more than 74.5% of black liquor lignin in the medium after 10 days of culture, the main part of black liquor lignin degraded was in the range of 1500- 3000kD of molecular weight. Culture factors such as cabon and nitrogen source, pH value in the medium and temperature exerted during the culture had an important role respectively on the effect of degrading black liquor lignin by white-rot fungus.

**Key words**: white-rot fungus, black liquor from kraft pulping process, sulfonate lignin, biodegradation.

**Pilot Scale Petrochemical Wastewater Treatment Using Inner Loop Fluidized Bed Bioreactor**. Zou Ping, Wang Chengwen and Qie Yi(Dept. of Environ. Eng., Tsinghua University, Beijing 100084): *Chin. J. Environ. Sci.*, **18**(1), 1997, pp. 26- 29

A Pilot scale experiment on petrochemical wastewater treatment using inner loop fluidised bed bioreactor and floatation process was conducted. The effluent COD from the process is about 200 and 100 mg/L when influent COD is 800 and 500mg/L, respectively. The loading rate of the bioreactor can be achieved above 15kgCOD/($m^3$.d).

**Key words**: inner loop fluidised bed bioreactor, petrochemical wastewater, floatation process.

**Investigation of the Landfill Gas Composition and Its Yield in South China**. L.Y. Chan and S.C. Lee (Dept. of Civil and Structural Engineering, The Hong Kong Polytechnic University, Hong Kong), Y. Qin(Institute of Environmental Science, Zhongshan University, Guangzhou, 510275): *Chin. J. Environ, Sci.*, **18**(1), 1997, pp. 30- 34

Five landfill gas monitoring wells were installed and the composition of landfill gases were monitored in Wufengshan landfill in Foshan, south China. For the wells located in the late landfilled region, $CH_4$ and $CO_2$ concentrations of landfill gases are high and stable. For the wells located in the early landfilled region, $CH_4$ and $CO_2$ concentrations of landfill gases are low and variable. In the last field measurement, the gases in the well located in early landfilled region has lost the characters or landfill gas. It's implication is that the biological decomposition process of the refuse underground has completed or the anaerobic environment has been destroyed. It just lasted for about 4 years and is much shorter than the expected time of 10 - 20 years. The differences of landfill gas between Foshan Wufengshan landfill and Hong Kong Shuen Wan landfill were compared and discussed. The yield of landfill gas in Wufengshan landfill was estimated according to the original carbon component of the refuse.

**Key words**: landfill, waste gas, biological decomposition, monitoring well, $CH_4$, $CO_2$, gas yield, Foshan.

**Photolysis of α-Naphthaleneacetic Acid in Aqueous Solution**. Zufei Zhou, Weichuan Jiang and Weiping Liu (Dept. of Chemistry, Zhejiang University, Hangzhou 310027): *Chin. J. Environ. Sci.*, **18**(1), 1997, pp. 35- 37

Photolysis of α-naphthaleneacetic acid(NAA) has been investigated at 25℃ in aqueous solutions by irradiation at different wavelengths. The shorter wavelength of 254nm is considerably more effective in promoting degradation than wavelength of 365nm. The primary degradation of NAA follows a pseudo-first-order kinetics. The photolysis half-life and rate constant were determined to be 60min and $1.15 \times 10^{-2} min^{-1}$ respectively. The optimum photolysis rate has been observed using $TiO_2$ powder as photocatalyst. Several reaction intermediates were identified using GC/MS technique. The photolysis of NAA involves decarboxylation and oxidation on aromatic ring. On the basis of the analytical data, a mechanism of the process has been proposed.

**Key words**: photolysis, α-naphthaleneacetic acid, ultraviolet light.

**$Mn^{2+}$-Oxidizing Bacteria and the $Mn^{2+}$-Removing Activity of the Filter Sand Used in Water Plants**. Bao Zhirong et al (Dept. Molecular Biology, Jilin Univ,