厌氧附着膜膨胀床工艺活性污泥特性的研究*

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摘要 对厌氧附着膜膨胀床(AAFEB)反应器中活性污泥的特性进行了研究. 结果表明, 载体上生物膜的形成和发展经历吸附、局部挂膜和完全挂膜 3 个阶段, 在此过程中, 微生物种群演变由以球菌占优势, 逐步过渡到丝状菌占优势, 厌氧污泥的活性随之提高. 酸化状态下的活性污泥表面有许多链球菌和大量的胞外多聚物, 污泥活性较低.

关键词 厌氧附着膜膨胀床反应器, 厌氧活性污泥, 生物膜.

厌氧附着膜膨胀床(Anaerobic Attached microbial Film Expanded Bed, AAFEB)反应器是 Jewell 于 70 年代中期研制的厌氧消化工艺, 已成功地用于处理不同类型和浓度的有机废水[1-5]. 在这种反应器内, 厌氧微生物被固定在载体上, 形成具有生物膜结构的活性污泥, 为 AAFEB 反应器高效稳定地运行创造了重要的条件. 研究厌氧活性污泥的特性, 有助于探明该工艺运行的微生物学机制, 为进一步研究推广高效 AAFEB 反应器提供理论依据.

1 材料与方法

1.1 试验装置

供试 AAFEB 反应器用有机玻璃制成, 容积为 1.7L. 内充填烟囱灰作载体, 其粒径< 1mm. 反应器纵向设有 2 个取样口, 彼此相距 25cm. 床层膨胀率控制在 10% – 20%. 装置与工艺流程见图 1.

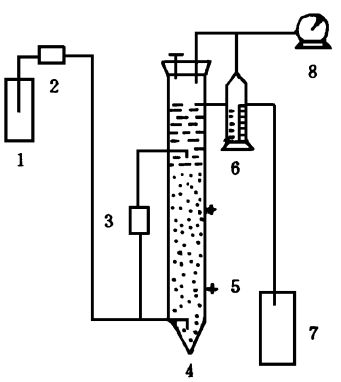

图 1 AAFEB 反应器装置和工艺流程

1. 进水贮瓶 2. 进水蠕动泵 3. 回流蠕动泵 4. AAFEB 反应器 5. 污泥取样口 6. 气液固三相分离器 7. 出水贮瓶 8. 湿式气体流量计

1.2 供试废水

为了稳定进水样的性质, 采用模拟废水(成分见表 1). 进水 COD 浓度控制在 5000mg/L 左右, 水温 28℃左右.

表 1 模拟废水的成分

组 成	蔗糖	酵母膏	NH_4Cl	KH_2PO_4	$K_2HPO_4 \cdot 3H_2O$	$NaHCO_3$
含量/$g \cdot L^{-1}$	27.5	0.3	7.3	2.5	1.3	33.0

1.3 分析项目与方法

最大比产甲烷速率: 间歇试验方法[6]. 最大比产酸速率: 采用间歇试验法培养污泥, 用 3, 5–二硝基水杨酸比色法测定葡萄糖浓度, 以单位污泥单位时间内去除的葡萄糖量(g/gVSS · d)表示污泥的最大比产酸速率. 脱氢酶活性: TTC(2, 3, 5–氯化三苯基四氮唑)法[7]. 生物膜厚度: 用测微尺测定厌氧颗粒污泥的生物膜厚度, 每次取样 50 粒, 计算均值. 微生物相观察: 采用 Olympus 相差显微镜、荧光显微镜、JEM–1200EX 型透射电镜和 EM–ASID10 型扫描电镜. 其它常规测定: 参照《环境监测标准分析方法》[8]和《沼气发酵常规分析》[9].

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2　结果与讨论

2.1　生物膜的形成和发展

在AAFEB反应器内,充填供微生物附着生长的烟囱灰载体,用扫描电镜观察发现其表面有许多微孔、裂缝和凹陷(图2).

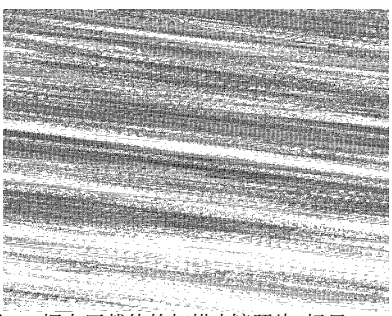

图2　烟囱灰载体的扫描电镜照片(标尺: 6μm)

载体上生物膜的形成和发展大致经历3个阶段:

(1) 吸附　接种污泥中的一些微生物絮体被吸附至载体表面. 取样镜检发现,载体表面的某些部位有微生物絮体附着,但结合比较疏松. 该阶段持续15d.

(2) 局部挂膜　附着于载体微孔、裂缝、凹陷部位的微生物利用基质生长繁殖,在局部首先形成新生生物膜. 这一阶段也需15d.

(3) 完全挂膜　新生生物膜不断发展,并覆盖整个载体表面. 此阶段需30d.

反应器运行50d完成起动,起动过程中反应器的主要效能变化如图3. 经过60d培育,载体上形成厚度为20μm的生物膜. 随着微生物在载体上的继续增殖,生物膜逐渐增厚,生物膜厚度随时间的变化曲线如图4所示.

2.2　厌氧活性污泥的微生物组成

用于起动反应器的接种污泥中存在着球菌、杆菌、丝状菌、螺旋菌和原生动物等,以球菌占优势. 运行至32d时,杆菌和球菌的数量均等,丝状菌数量明显增加,至第60d,丝状菌成为优势菌,它们相互缠绕形成网状结构,其它形状的细菌镶嵌于此结构中(图5),在荧光显微镜下可见许多细菌能发射出较强的荧光,说明活性污泥中含有许多产甲烷细菌,这种十分活

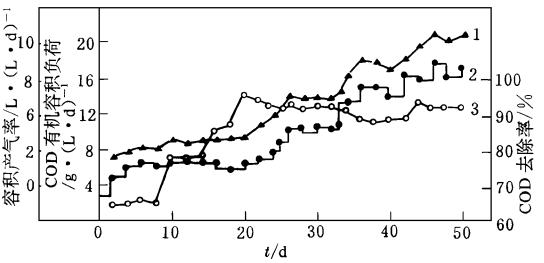

图3　起动过程中容积产气率、容积COD有机负荷、COD去除率的变化

1. 容积产气率　2. 容积COD有机负荷　3. COD去除率

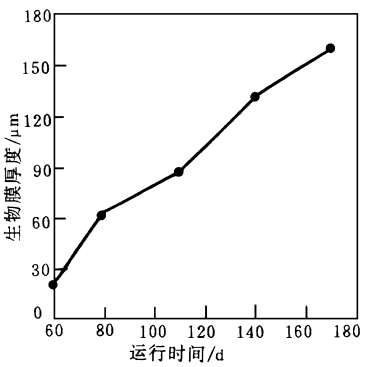

图4　生物膜厚度的变化曲线

跃的丝状菌类似于索氏甲烷丝菌(*Methanothrix soehngenii*).

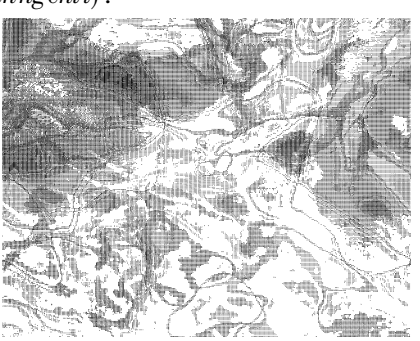

图5　稳态运行期间活性污泥表面的扫描电镜照片(标尺: 0.6μm)

2.3　厌氧污泥的活性分析

污泥活性指标的最大比产酸速率、最大比产甲烷速率和脱氢酶活性的变化曲线见图6,污泥活性呈逐渐提高趋势,观测表明反应器运行效能也相应提高,处于正常稳态运行的状况.

2.4　酸化状态下活性污泥的性状变化

本试验中,AAFEB反应器在稳态运行期间,平均容积COD有机负荷为16.13

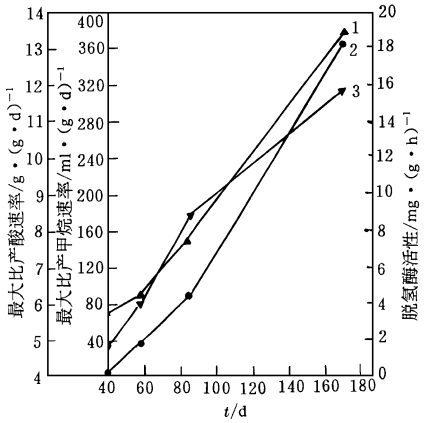

图 6 厌氧污泥活性的变化曲线

1. 最大比产甲烷速率 2. 最大比产酸速率 3. 脱氢酶活性

g/(L · d), COD 去除率为 90.06%, 容积产气率为 7.56L/(L · d), 沼气的甲烷含量稳定在 60%– 70% 之间. 连续稳态运行 120d 后, 给以冲击负荷, 使之超负荷运行, 造成反应器酸化(表 2).

表 **2** 反应器酸化的相应运行参数

运行时间 /d	进水 COD 浓度 /mg · L–1	容积 COD 有机负荷 /g · (L · d)–1	COD 去除率 /%	容积产气率 /L · (L · d)–1
171	4987.28	40.11	47.41	9.32
173	5015.87	38.28	50.22	9.61
175	5100.31	38.94	50.73	9.47
177	4907.31	20.33	63.81	6.35
179	5002.73	18.22	63.92	5.71
181	4878.98	16.35	65.14	5.32
185	4991.71	15.29	65.22	5.08
190	5003.52	16.71	64.81	5.13

采用光学显微镜和电子显微镜观察, 可以看到酸化状态的活性污泥表面发酵性细菌过度生长, 出现许多链球菌(图 7). 而在正常运行状态下的活性污泥表面很少见到这种链球菌. 链球菌的大量出现, 使污泥的活性降低, 经测定, 最大比产酸速率由 13.20g/(gVSS · d) 下降至 8.14g/(gVSS · d), 最大比产甲烷速率由 360.42ml/(gVSS · d) 降为 168.37ml/(gVSS · d), 脱氢酶活性由 15.72mg/(gVSS · h) 降至 8.20mg/(gVSS · h).

通过镜检比较正常状态和酸化状态的活性污泥性状, 还可以发现, 正常的活性污泥比较密实, 而且类似细纤维状的胞外多聚物较少; 酸化状态的活性污泥膜结构疏松, 同时胞外多聚物急剧增加, 交织成犹似一张巨网. 胞外多聚物粘性较大, 对有机酸在生物膜中的传质过程产生阻碍, 这也是导致有机酸积累, 反应器处于不正常状态的原因之一*.

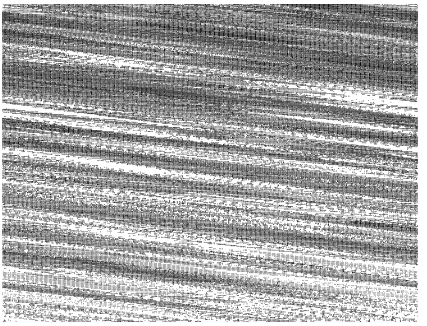

图 7 酸化状态下活性污泥表面的扫描电镜照片(标尺: 0.6μm)

3 结论

(1) 微生物优先选择载体上的微孔、裂缝和凹陷部位附着和生长繁殖, 在局部形成生物膜.

(2) 随着载体上生物膜的形成和发展, 类似于索氏甲烷丝菌的细菌逐步取得优势, 与此相应, 表征污泥活性的最大比产酸速率、最大比产甲烷速率和脱氢酶活性逐渐提高. 厌氧活性污泥形成过程是一个微生物种群演变的过程.

(3) 酸化状态的活性污泥表面, 发酵细菌的组成发生变化, 可观察到很多链球菌, 并出现大量的胞外多聚物, 污泥活性降低, 影响反应器正常运行.

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The Mn^{2+} removing activity of the filter sand from 2 Chinese Water Plants was analyzed to determine the role of the bacteria in the Mn^{2+} removing Procession. Enumeration of bacteria on PYCM medium showed that there were 10^5-10^6 bacteria per g wet sand and about 40%-50% of the colonies had the ability to oxidize Mn^{2+}. By the in situ enrichment of the bacteria, sterilization and the $HgCl_2$ inhibition of the mature sand, it was found that bacteria were indispensable to the maintenance of the activity of the sand. When the bacterial activity was inhibited, the activity of the sand was reduced to20% of the original one. The remaining activity might be due to the chemical catalysis. Bacteria were the major source of the Mn^{2+} removing activity of the filters.

Key words: groundwater, Mn^{2+}, bacteria, chemical factors, filter sand.

A Study on the Characteristics of the Activated Sludge for Anaerobic Attached Microbial Film Expanded Bed Process. Zhang Jianli and Li Lijian (Dept. of Food Science, Laiyang Agricultural College, Laiyang 265200), Feng Xiaoshan (Dept. of Environ Science, Zhejiang Agricultural University, Hangzhou 310029): *Chin. J. Environ. Sci.*, **18**(1), 1997, pp. 42-44

The characteristics of activated sludge in the anaerobic attached microbial film expanded bed (AAFEB) reactor were studied. The results showed that there were three consecutive phases in the course of biofilm formation and development, namely, adsorbtion phase, partly coating phase and fully coating phase. In this process, the predominant microorganisms were changed gradually from coccus to filamentous organisms, which caused anaerobic sludge activity increasing. Under the acidification condition, there were a lot of streptococcus and extracellular polymer on the surface of activated sludge, and the sludge activity was low.

Key words: anaerobic attached microbial film expanded bed reactor, anaerobic activated sludge, biofilm.

Catalytic Properties of Two Kind of Catalysts in Toluene Combustion Reaction. Li Shiyao, Li Shulian et al. (Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian 116023): *Chin. J. Environ. Sci.*, **18**(1), 1997, pp. 45-47

Toluene organic exhausts were regarded as index reaction in evaluating the catalytic performance of honeycomb ceramic monolith catalysts consisting of noble metals and non-noble metals respectively by means of a continuous system with a fixed bed of catalysts. The effect of toluene concentration and oxygen content in the exhaust, space velocity, linear velocity on toluene reaction, and the thermal stability of catalysts were investigated. It is found that the activity of noble metal catalyst is superior than that of non-noble metal catalyst under different conditions. The light-off temperature of toluene exhaust on non-noble metal catalyst is by 50℃ higher than that on noble metal catalyst after catalysts calcine at 600℃ for 3h. Meanwhile, after catalysts calcine at 900℃ for 3h, the light-off temperature of toluene exhaust on noble metal catalyst increases only by 3℃ as compared with the calcination of 600℃ for 3h. But under same condition, the light-off temperature of toluene exhaust on non-noble metal catalyst increases by 87℃.

Key words: combustion reaction of toluene exhaust, honeycomb ceramic monolith catalyst, thermal stability, light-off temperature.

Photochemical Disinfection of Wastewater. Kong Lingren, Chen Xi et al. (Dept. of Environ. Sci. and Eng., Nanjing University, 210093): *Chin. J. Environ. Sci.*, **18**(1), 1997, pp. 48-50

A new method of photochemical disinfection for wastewater from Nanjng city was investigated. By aerating and using methylene blue(MB) as photosinsitizer, the wastewater samples were disinfected under sunlight and a medium pressure mercury lamp separately. The results were as follows: (1) The disinfection of wastewater were remarkably affected by the light sources, light intensity, irradiaded time, MB concentration and dissolved oxygen; (2) The bacteria which were disinfected by UV could be partially photoreactivated under sunlight; (3) The disinfection rate could reach 100% and the bacteria photoreactivation were not appeared when 1 liter of the sample containing 3.1×10^6 bacteria and 2 mg MB were irradiaded by a 300W medium pressure mercury lamp for 4 min; (4) The residual MB in the samples could be removed by bentonite clay. The disinfection mechanisms of UV and photosensitization, the bacteria photoreactivetion and the effects for affecting disinfection were discussed.

Key words: photochemistry, photosinsitization, UV irradiation, disinfection.

Summary of Studies on the Ecology of Lake Donghu. Liu Jiankang and Huang Xiangfei (Institute of Hydrobiology, Chinese Academy of sciences, Wuhan 430072): *Chin. J. Enwiron. Sci.*, **18**(1), 1997, pp. 51-53

Taking the Donghu (in Wuhan), a representative lake of the middle and lower basins of Chang Jiang River as a base, the present project has conducted stationary monitoring and systematic researches on the ecology of Lake Donghu for more than 30 years. Achievements of the studies include the estimation of the budgets for the main nutrients nitrogen and phosphorus of the lake, as well as their distribution and accumulation in