

治理技术

常温中试升流式厌氧污泥层反应器 污泥颗粒化过程研究*

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摘要 应用 6.7m^3 的中试升流式厌氧污泥层反应器,以双层沉淀池污泥为接种污泥,处理啤酒废水(COD 浓度在 2400mg/L 左右),采取适宜的技术措施,在 20°C 左右的常温条件下成功地实现了污泥颗粒化,反应器容积负荷达 $10\text{--}13\text{kg COD}/\text{m}^3 \cdot \text{d}$, COD 去除率大于 85% 。

关键词: 外流式厌氧污泥层反应器,污泥颗粒化,啤酒废水。

升流式厌氧污泥层反应器(UASB)的污泥颗粒化是污泥形态的一种特殊变化,可使该工艺的处理能力得到大幅度提高。但现有的很多 UASB 反应器并非都能在运行中实现这一转化。有关颗粒污泥的形成机理、培养条件等,仍处于研究阶段,尚无成熟的结论。此外,国内外有关该工艺的研究和应用多限于中温(或高温)条件,对于常温条件(20°C 左右)所做的工作要少得多^[1]。常温下污泥的颗粒化至今还未见获得成功的报道,容积负荷的水平也较低,一般为 $3\text{--}5\text{kg COD}/\text{m}^3 \cdot \text{d}$ 。本研究以啤酒废水为处理基质,在中试规模装置上,就污泥颗粒化及反应器的处理效果、负荷潜力等问题进行了系统的试验和探讨。

一、试验方法与材料

1. 试验流程和设备

图 1 为本研究的试验流程,其中 UASB 反应器总容积为 6.7m^3 ,底部有三个均匀进水口。

2. 处理水质

取自北京啤酒厂下水井,一般 COD 浓度为 $2000\text{--}3000\text{mg/L}$, BOD_5 为 $900\text{--}1700$

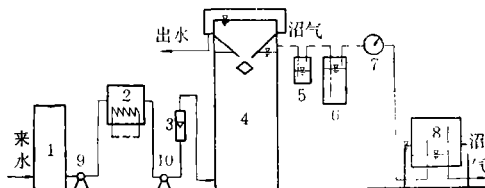


图 1 UASB 反应器中试流程图

1. 配水箱 2. 热交换器 3. 污水流量计 4. UASB 反应器 5. 沼气脱水罐 6. 水封罐 7. 气体流量计 8. 沼气柜 9. 水泵

mg/L , 水温 $15\text{--}26^\circ\text{C}$, pH $5.0\text{--}6.5$ 。

3. 接种污泥

取自北京某城市污水处理厂双层沉淀池的污泥,微观结构松散、呈絮状, $\text{VS}/\text{TS} = 0.46$,总接种污泥量为 81.2kg VS 。

二、试验过程及结果

本试验共持续运行 320 余天,依负荷水平和污泥形态的变化大致分为初期启动、颗粒污泥培养和高负荷三个运行阶段,图 2 是主要测试项目逐周的变化情况。

1. 初期启动阶段

* 本研究已于 1989 年 7 月通过了国家环保局主持的成果鉴定(属国家七·五攻关课题)。参加试验工作的还有蒋青、陈守义、李静、田秉波等。

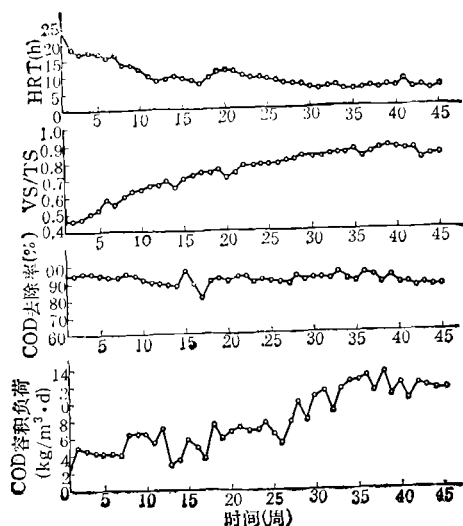


图2 主要测试项目周统计值

首先为近两周的间歇培养,随后转为连续进水运行。水温在 20—25℃,容积负荷由 2.5kg COD/m³·d 逐步提高到 4—5kg COD/m³·d, COD 去除率大于 90%,其间出水感官趋于良好,携泥量不断减少。

该阶段污泥的微观形态明显变化,结构变得紧密,呈菌胶团化趋势,6 周后几乎全部转变为以丝状菌为主的厌氧菌胶团。至第 7 周时,在显微镜下已可观察到粒径 0.1mm 左右,边缘圆滑的初期小颗粒污泥。

2. 颗粒污泥培养阶段

该阶段自第 8 周至第 21 周,进水温度一般为 19—21℃,为加速培养颗粒污泥,在保证 COD 去除率大于 85% 的前提下,尽可能维持较高的负荷水平,处理水量不断增大,容积负荷达 5.5—7.1kg COD/m³·d,污泥负荷相应为 0.32—0.45kg COD/kg VS·d。

污泥性状的变化主要表现为颗粒的长大和颗粒污泥相对量的增加。由于脱气和沉淀性能上的优势,颗粒污泥首先相对集中于反应器底部,之后逐渐向上扩充,至第 17 周,距底 1.6m 处可检测到颗粒污泥层的界面,到第 21 周时,反应区主体大部分污泥已转化为颗粒状(间有少量絮状污泥),污泥总量增至

206kg VS。此外 VS/TS 也由 0.46 增至 0.78,说明污泥中活性微生物的成分也获得了相应的增加。

3. 高负荷运行阶段

该阶段反应器仍维持常温运行,一般在 20—23℃,冬季最低为 15℃,夏季最高为 26℃。第 28 周以后,反应器运行技术参数基本保持 HRT 5—8h,容积负荷 8—15kg COD/m³·d(一般为 10—13kg COD/m³·d),其间 COD 去除率大于 85%,出水 SS 小于 200mg/L,反应器容积产气率在 3.7m³/m³·d 左右。如此,一直持续到第 45 周试验结束。

本研究在第 21、22、23 和 27 周有意做了 4 周的低温试验,反应器温度降至 15—19℃,结果容积负荷仍可达 6.5—8kg COD/m³·d, COD 去除率大于 85%,无污泥流失和其他恶化迹象。由此可见,常温 UASB 反应器受温度不利变化的影响较之中(高)温的处理装置要小得多,Grin, R. R. 等人的试验也曾证实过这一点^[2]。

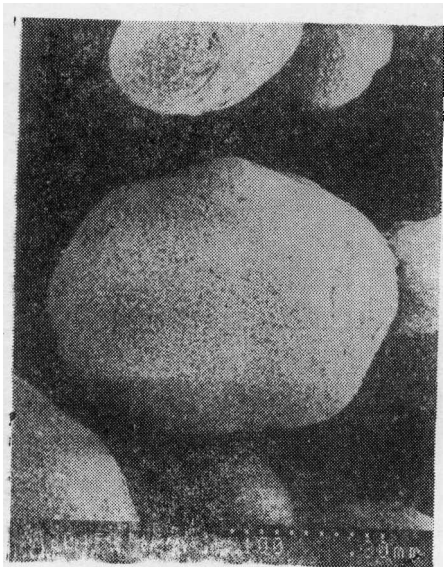
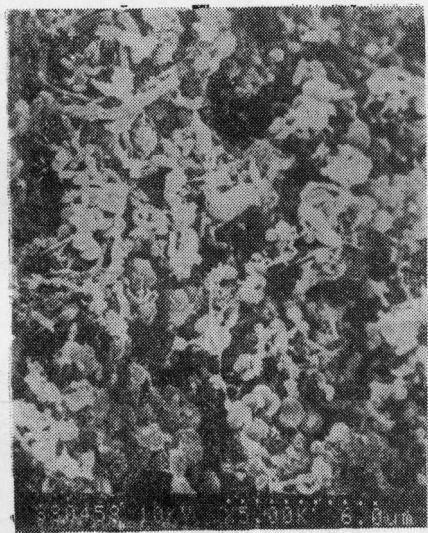
三、分析与讨论

1. 颗粒污泥特性

本试验在常温下培养出的颗粒污泥,颜色墨黑,多为球状或椭圆状,粒径 0.3—1.5 mm,表面圆滑,具有一定的机械强度,湿比重 1.04,含水率 90%,VS/TS = 0.84。

在光学显微镜下,可看到颗粒表面有一层透明的黄色胶状物质,偶有较长的菌丝伸出,且泥水中有活跃活跃的纤毛虫。

利用扫描电镜观测,在低倍镜下,颗粒表面凹凸不平,酷似一比表面巨大的多孔不规则球状体(见图 3)。有些学者测定,其有效系数可大于 0.85^[3]。在高倍镜下,可明显看出各种不同形态的细菌(见图 4),反映出颗粒污泥菌种组成的多样性和微观结构的复杂性。这些细菌中,可识别的有丝状菌、球菌、八叠球菌和短杆菌等,其中以球菌和八叠球菌为优势菌种。

图3 颗粒污泥外观($\times 100$)图4 颗粒污泥表面群($\times 500$)

利用切片在透射电镜下进行观察发现:颗粒表面和浅层的菌群长势良好,而中心附近残留细胞壁较多,活菌相对稀少,形成一种近似于中空的结构。据此推断,对有机物降解起重要作用的部位应在颗粒表面和浅层,在一定范围内,其粒径的大小对处理效果不会有什么影响,故不必苛求。

2. 颗粒污泥培养措施浅探

(1) 较高的污泥负荷和水力负荷

颗粒污泥的形成首先是厌氧细菌群不断

繁殖、积累的结果。较高的污泥负荷保证了细菌可获得充足的营养基质,故对颗粒污泥的形成和发展具有决定性的促进作用。适当高的水力负荷将产生污泥的水力筛分,辅之以沼气的扰动,可使形成的颗粒相对地沉积于反应器底部,优先获得基质养分而得到迅速增长,因而是污泥颗粒化积极的外因条件。本试验在颗粒污泥培养阶段,污泥负荷为 $0.32\text{—}0.45\text{kg COD/kgVS}\cdot\text{d}$,水力负荷为 $0.4\text{—}0.6\text{m}^3/\text{m}^2\cdot\text{h}$,结果证明是适宜的。

(2) 适量的碱度

就厌氧生物处理而言,要求适当高的碱度是正常的,产甲烷菌类的最适宜 pH 在 $6.8\text{—}7.2$,一定的碱度既能维持所需的 pH 值,又可保证足够的平衡缓冲能力。McCarty 曾建议反应器的碱度应保持在 $2000\text{—}5000\text{mg/L}$ (以 CaCO_3 计)。依本试验情况看,未必需要那么高,然而进水碱度维持在 800mg/L (以 CaCO_3 计)以上,对于颗粒污泥的培养和反应器高负荷下的良好运行是必要的。

(3) 稳定的运行

以往的经验对此点强调得非常不够。颗粒污泥是各类细菌尤其是厌氧菌的活性聚集体,因而断断续续的运行,负荷、温度、碱度、pH 值等的频繁变化,毒害物的偶然冲击等种种不稳定因素都会影响细菌的良好生长和繁殖,最终制约污泥颗粒化的实现。在启动和颗粒污泥培养阶段,对此及其相应的操作调节尤应给予充分重视。

四、结 论

(1) 采用容积为 6.7m^3 的中试 UASB 反应器处理啤酒废水(COD 平均浓度约为 2400mg/L),在常温条件下(20°C 左右),在5个月内成功地实现了污泥颗粒化。该反应器容积负荷可达 $10\text{—}13\text{kg COD/m}^3\cdot\text{d}$,COD 去除率大于 85% 。

(2) 较高的污泥负荷和水力负荷、适宜的碱度及稳定的运行有利于污泥的颗粒化。

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reactors at temperature from 9—20°C, Seminar/Workshop on Anaerobic Sewage Treatment, pp 27—28, University of Massachusetts, Amherst, U. S. A., 1985.

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(收稿日期: 1989 年 11 月 28 日)

干法煤粉磁选脱硫的试验研究

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摘要 本工作首次在国内完成了干法煤粉磁选脱硫的试验,探讨了脱硫机理,简述了磁法脱硫的工艺及高梯度磁分离器(HGMS)装置。试验结果表明:最佳梯度磁场强度为 0.65—0.75T,最佳煤粉颗粒度在 100 目—120 目,脱硫率最高达 70% 左右,费用估计为 7.5 元/t 煤左右。

关键词: 干法煤粉磁选脱硫;磁场强度;煤粉颗粒度。

我国煤产量的四分之一(约 2.5 亿吨煤)用于电厂发电,每年向大气中排放的 SO_2 数量惊人。目前已有许多锅炉烟气脱硫方法有干法、湿法、炉内喷钙等等。然而这些工艺方法多属于烟气污染的尾端治理,设备庞大,投资高,建造周期长,很难实现综合利用。能否在煤进入锅炉燃烧之前进行脱硫处理,即炉前处理,干煤粉磁法脱硫即能达到这个目的。因此进入 80 年代之后磁法脱硫已成为先进国家环保与动力部门重点科研课题之一,为此我们受江苏省环保局的委托,从 1987 年到 1988 年在国内首次开展了干法煤粉磁选脱硫的试验研究,并于 1989 年 4 月通过了省级鉴定,当前我们正积极配合电厂做原型实用试验。

一、干法煤粉磁选脱硫的机理 和试验装置

煤是一种成分复杂的有机与无机的混合物,其中 C, O, H, H_2O 为主要成分,此外,烟煤中都含有一定量的硫铁矿成分,恰是

这些物质在煤燃烧过程中分解出硫并与空气中的氧化合生成 SO_2 。如果能把锅炉燃用的煤粉中含有的硫铁矿物质去掉,就可大大减少煤粉燃烧产生的 SO_2 。

纯煤主要是 C 元素,它是逆磁性物质,而煤粉中含有的硫铁矿物质却是顺磁性物质,因此可用梯度磁场产生的磁力把它从煤粉里分离出来。所谓梯度磁场是指在磁场中单位距离内磁场强度变化,它是非均匀的。我们采用在磁场空间填充高导磁率的不锈钢毛,从而使磁场中磁力线仅密集于钢毛表面,引起磁场内磁力线各处稀疏不均,进而形成一个梯度磁场。梯度磁场的强弱与材质的磁化强度、形状、直径、填充率有关。硫铁矿物质在磁场内所受的磁力 F_m 可用下式表示:

$$F_m = X \cdot V \cdot H \frac{dH}{dX} \quad (1)$$

式中, X 为硫铁矿颗粒物的磁化率, V 为颗粒物体积, H 为磁场强度, $\frac{dH}{dX}$ 为磁场梯度。从上式可以清楚地看出,要想把硫铁矿物质从

Economic Principles of Management for Controlling Total Amount of Pollutants Discharged to Water.

Zhang Tianzhu (Department of Environmental Engineering, Tsinghua University, Beijing): *Chin. J. Environ. Sci.*, 11(6), 1990, pp. 2—6.

Through analyzing the externality concept and developing the optimal/second optimal management models for pollutants discharged to water vs. environmental quality, this paper discusses two economic principles of the management system on controlling total amount of pollutants, the meanings and the relation of two managerial goals, i.e. equity and efficiency. Equity as a goal is a requirement for reasonably running the national economical management system which is an external constraint of total amount control for water pollutants discharged.

Key Words: economic principles of management, total amount of pollutants, water.

Separation and Speciation of Selenium in the East Lake Water, Wuhan.

Lu Xiaohua, Du Wentao, Shi Wenzhao (Huazhong University of Science and Technology, Wuhan): *Chin. J. Environ. Sci.*, 11(6), 1990, pp. 7—10.

Trace selenium in natural water of the East Lake was separated into suspended particle and soluble, colloid and non-colloid, ionic and non-ionic species by means of 0.45 μm filter membrane, activated carbon and anion exchange resin. Then the water samples were determined. The results showed that soluble ionic selenium was the dominant species, which amounted to about 70 per cent of total selenium in water, and four-valence selenium was prevailing.

Key Words: selenium, speciation analysis, natural water.

Study on Absorption of ^{134}Cs in Wheat.

Chen Chuanqun, Xu Yinliang, Sun Zhiming (Institute of Nuclear Agronomy, Zhejiang Agricultural University, Hanzhou): *Chin. J. Environ. Sci.*, 11(6), 1990, pp. 10—14.

The roots of wheat can absorb ^{134}Cs from irrigating water. The specific activity of ^{134}Cs in the roots is the highest, in grains the lowest, and that in bran is higher than in flour. Absorption capacity of ^{134}Cs by wheat varies with different kinds of soil. The order of absorption capacity is as follows: farinose clay > clay loam \geq sandy loam. In addition, the absorption capacity of ^{134}Cs in soils is different in soil texture, pH and organic matter; absorption amount of it varies with irrigating time,

the closer to maturity stage, the more amount of ^{134}Cs in wheat. Its migration in soil is very slow because there is 90.4% of ^{134}Cs concentrated in surface soil (0—3 cm). The ratio of ^{134}Cs in wheat and in soil is 2.1% to 97.9%.

Key Words: cesium-134, wheat, soil, irrigating water.

Identification of 1-Hydroxypyrene and Its Excretion in Dog Urine after Pyrene Injection

Zhao Zhenhua, Quan Wenyi, Tian Deha. (Beijing Municipal Research Institute of Environmental Protection *Chin. J. Environ. Sci.*, 11(6), 1990, pp. 14—17

With High Performance Liquid Chromatograph and fluorospectrometry, 1-hydroxypyrene is identified as a major metabolite of pyrene in the dog urine after intramuscular injection of pyrene. As three successive doses of 1, 2 and 5 $\mu\text{mol/kg}$ wt pyrene were injected into the dogs, 1-hydroxypyrene in urinary excretion reached to peak levels within 24—48 hours. The amounts of excreted 1-hydroxypyrene were accounted for about 0.05% of the injected pyrene.

Key Words: identification of 1-hydroxypyrene, pyrene, dog urine.

The Enrichment of Cadmium and Its Leaching Loss in Soils of Beijing Area with a View to the Relationship between Zn and Cd.

Xu Qian (Beijing Municipal Environmental Monitoring Center). *Chin. J. Environ. Sci.*, 11(6), 1990, pp. 17—21

In this article, the author intends to discuss the variations of enrichment and leaching loss in surface soils of Beijing area and the causes of these variations with a view to the relation of Zn/Cd values in soils. The range of Zn/Cd is so wide that it can reflect the difference in relative enrichment and leaching loss of Cd in soils. The relative enrichment of Cd in moisture soil is apparent in plain area, while the relative leaching loss of Cd in drab soil is obvious in the plain in front of the mountains. The reasons why the variations exist have been explored in this article.

Key Words: enrichment of Cd in soil, relation of Zn and Cd, Beijing area.

A Study on the Process of Sludge Granulation in A Pilot Upflow Anaerobic Sludge Blanket Reactor at Ambient Temperature.

Li Xiaoyan, Hu Jicui, Xing Yongjie (Department of Environmental Engineering, Tsinghua University, Beijing): *Chin. J. Environ. Sci.*, 11(6), 1990, pp. —

In this study a pilot upflow anaerobic sludge blanket reactor of capacity of 6.7 m^3 was used at ambient temperature (about 20°C) to treat brewery wastewater (the influent COD concentration was about 2400 mg/L).

Seed sludge was obtained from an Imhoff tank. By controlling the operation conditions granular sludge was well formed. A volumetric COD loading up to $10\text{--}13\text{ kg/m}^3\cdot\text{d}$ was achieved with more than 85% removal of COD.

Key Words: upflow anaerobic sludge blanket reactor, ambient digestion, sludge granulation, brewery wastewater.

An Experimental Study on Desulfurization of Pulverized Coal Firing by Magnetic Separation.

Wu Shibing, Zhang Hengjian, Zhang Sijing (Xuzhou Municipal Institute of Environmental Protection, Jiangsu Province): *Chin. J. Environ. Sci.*, 11(6), 1990, pp. 25—28

Desulfurization of pulverized coal firing by magnetic separation is one of important methods that remove SO_2 from firing coal. The key technology of desulfurization is to apply appropriately a high-gradient magnetic separator. The authors first completed the experiments in China during 1987—1989. The paper introduces briefly the technological process and results.

Key Words: desulfurization, pulverized coal firing, magnetic separation.

Investigation of Organic Pollutants in the Songhuajiang River Basin.

Xu Zhiyi, Gao Yifei, Cao Shuying, He Zunshi, Jia Yiqun (Changchun Institute of Applied Chemistry, Academia Sinica): *Chin. J. Environ. Sci.*, 11(6), 1990, pp. 29—31.

The organic pollutants in the Songhuajiang River basin have been analyzed with GC, GC/MS, HPLC and TIC methods, water samples were treated in situ for GC/MS and HPLC and treated in the laboratories for GC and TIC. The samples were collected in winter and summer. 152 organic compounds were detected out. Among them, 19% were PAHs, 14% were chlorocompounds, 13% aromatic compounds and 54% others. Most of the organic compounds polluting some sections of the River have been found from the analytical results.

Key Words: organic pollutants, the Songhuajiang River basin.

Determination of Chemical Oxygen Demand without Using Mercury Salts.

Han Xiangkui, Yao Xiuqin, Liu Ying (Jilin College

of Architectural and Civil Engineering, Jilin): *Chin. J. Environ. Sci.*, 11(6), 1990, pp. 32—34

This method is based on the principle that potassium dichromate and chlorine (Cl_2) can be quantitatively determined. An absorber was used to absorb Cl_2 that was the product of what dichromate oxidated. Then iodimetry was used to determined the residual chlorine, of which the equivalent numbers were subtracted from the equivalent numbers of the dichromate consumed. Thus the interference of chloride was eliminated. The result showed that the method was of higher accuracy and precision and reproducibility of results covered a wide range of chloride concentrations.

Key Words: Chemical Oxygen Demand, determination, without mercury salts.

Conservation of Soil Resources in the Scenic Regions of the Huanshan Mountain, Jiuhuashan Mountain and the Tianzhushan Mountain.

Chen Conghong (The Agriculture-Animal Husbandry-Fishery Department of Anhui Province, Hefei): *Chin. J. Environ. Sci.*, 11(6), 1990, pp. 35—40.

The author has made a survey of soil resources in the three famous scenic mountains, and found that soil resources are getting deteriorative there, facing a potential crisis. Its anthropocentric causes are mainly due to soil erosion aggravated by over-cultivation, construction of highway and tourist facilities as well as excessive numbers of tourists so that soil and the environment in the landscape regions burden with heavy pressure. The article presents some measurements to preserve the landscape soil, such as speeding up greening barren hills, moderate utilization of landscape resources, development of soil amelioration in the regions, development of local special products, strengthening eco-environmental protection around the regions etc.

Key Words: conservation, soil erosion, scenic mountain.

Aluminum in Acidic Soils and Its Phytotoxicity.

Tian Rensheng, Liu Houtian (Chinese Research academy of Environmental Sciences, Beijing): *Chin. J. Environ. Sci.*, 11(6), 1990, pp. 41—46.

Made in this paper is a general review on following topics: (1) factors of soil acidification and process of aluminum activation; (2) the symptoms of Al-injured plants, the resistance of plants to aluminum and the relationship between aluminum speciation and phytotoxicity; (3) the external factors affecting aluminum toxicity expression, such as P, Ca and organic matter; and (4) some mechanism of Al phytotoxicity relating to biomembrane,