

UASB 反应器快速启动的试验研究

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摘要 在中温条件下投加颗粒活性炭可加快 UASB 反应器颗粒化进程。通过对比试验, 表明投加和不投加活性炭的反应器处理石化厂废水污泥颗粒化时间分别为 39 d 和 62 d。投加活性炭反应器的颗粒污泥粒径也较大, 最大 COD 去除率在 86% 以上。并且投加活性炭反应器的有机负荷为不投加的 2 倍, 运行效果更稳定。

关键词 UASB 反应, 颗粒活性炭, 颗粒污泥, 颗粒化, 启动。

从目前 UASB 反应器的实际使用情况来看, 形成颗粒污泥所需的启动时间常需数月, 有时甚至更长, 技术条件或措施要求也较高^[1], 影响着反应器的顺利运行。本试验研究提供了投加颗粒活性炭加快 UASB 反应器颗粒化进程、缩短启动时间的新方法, 并对这种方法的机理进行了初步的讨论。

1 试验设备和材料

1.1 试验设备

同时制作 2 个相同的有机玻璃 UASB 反应器, 容积均为 10.4 L, 反应器内径 110 mm, 反应器总高度 1250 mm。将反应器安装在人工制成的恒温箱内, 用电接点温度计、晶体管继电器和热源构成自动温度控制系统, 温度控制

在 $35 \pm 1^\circ\text{C}$ 。试验系统见图 1。

1.2 试验用废水

试验用废水采用石油化工厂氯醇法生产环氧乙烷过程中产生的皂化废水, COD 为 8 000—100 000 mg/L, SS 大于 30 000 mg/L, pH 大于 13, 水中主要的有机物为氯醇、乙二醇、二氯乙烷和少量的酚、氰等。此外水中 Ca^{2+} 为 8 000—10 000 mg/L, Cl^- 为 3 000—5 000 mg/L。

皂化废水 pH 高、有机物高、悬浮物高, 属于高浓度工业废水。在废水进入反应器之前进行预处理, 降低 SS 和 Ca^{2+} 的含量, 经过预处理 $\text{SS} < 300 \text{ mg/L}$, $\text{Ca}^{2+} < 1500 \text{ mg/L}$, pH 调整至中性。

1.3 接种污泥

采用西安污水处理厂中温消化池污泥作为种泥, 将取来的消化污泥静沉, 再用筛网过滤去除大块杂质, 此时测得接种污泥的 MLSS 为 60.34 g/L, MLVSS 为 12.71 g/L。

1.4 颗粒活性炭

量取 300 ml 的颗粒活性炭(北京市医药公司分装), 粒径 0.43—0.50 mm, 用蒸馏水冲洗干净, 105℃ 烘干待用。

2 试验方法

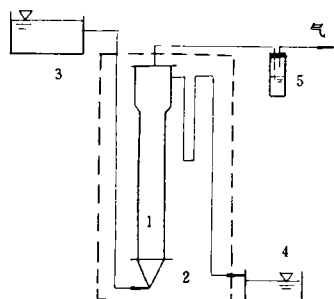


图1 试验系统示意图

1. UASB反应器 2. 恒温箱

3. 进水箱 4. 出水箱 5. 水封瓶

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向 A、B 2 个反应器中各加入消化污泥 5.2 L。为进行对照比较, 2 个 UASB 反应器在相同环境条件下运行。

首先将皂化废水配成 20% 浓度比例, 并加入葡萄糖和适量的 N、P 及微量元素, 然后把废水分别通入 2 个反应器中, 持续 2 周进行驯化培养, 水量由 1 L/d 增加到 2 L/d, COD 维持在 3000 mg/L 左右, 出水 100% 回流。

上述过程完成后, 向反应器 A 中加入活性炭 300 ml。反应器 A、B 便开始正式运行, 进水改由浓度不同的皂化废水和适量微量元素配成, 不再加入葡萄糖。反应器 A 的第一周运行方式采用出水回流。这主要出于 2 点考虑, 一是在继续驯化污泥的同时, 增加活性炭与微生物充分接触的机会, 产生对微生物最大的吸附。二是由于活性炭的比重较小, 为防止运行初期活性炭过多地流失, 将含有较多活性炭颗粒的出水回流。反应器 B 的这一周仍是适应驯化期。进水 COD 2 个反应器均控制在 2000—4000 mg/L, 进水量每日 2 L。从第二周开始 2 个反应器按同一操作流程运行。进水量和有机负荷的提高以 COD 去除率大于 80%、出水挥发酸(VFA) 小于 500 mg/L (以乙酸计) 为依据。进水 COD 浓度按 20%、50%、70% 和 100% 的原皂化废水比例进行投加。

3 试验结果和分析

3.1 反应器 A

经过 3 个多月的连续运行, 反应器 A 的有机负荷、产气量、COD 去除率和挥发酸(VFA) 变化情况见图 2。

试验运行过程中, 有机负荷逐步提高, 当出水 COD 和 VFA 未能达到前面的标准时, 则适当降低进水负荷, 待恢复之后再继续提高有机负荷。反应器 A 在整个试验阶段出水 COD 总体来说比较稳定, 去除率基本维持在 80%。在运行中, 前 80 d, 有机负荷的提高对出水水质影响较大。随着负荷增大, 出水 COD 有明显升高, 但降低负荷后出水 COD 随即下降。在试验的第 87 d 将 COD 有机负荷由 2.81 kg/(m³·d)

提高到 4.02 kg/(m³·d), 出水 COD 值反而没有升高, COD 去除率增加, 这说明系统在这时基本稳定, 对一定的冲击负荷具有承受能力。在 4 kg/(m³·d) 连续运行 20 d 左右, COD 去除率平均在 86%, 出水 VFA 为 410 mg/L (以乙酸计), 低于通常厌氧系统正常工作要求的 VAF 小于 1000 mg/L 的指标。为进一步考察反应器 A 的极限负荷, 试验后期以 1.5 kg/(m³·d) 的幅度提高 COD 有机负荷(此时进水不稀释, 进水 COD 平均为 8130 mg/L), 在负荷为 5.5 kg/(m³·d) 时, COD 平均去除率达 70%, 稳定 10 d 后其值没有上升, 而出水 VFA 升高到 1138 mg/L。厌氧系统运行状况恶化。因此反应器 A 有效处理皂化废水的 COD 有机负荷应为 4.0 kg/(m³·d) 左右。

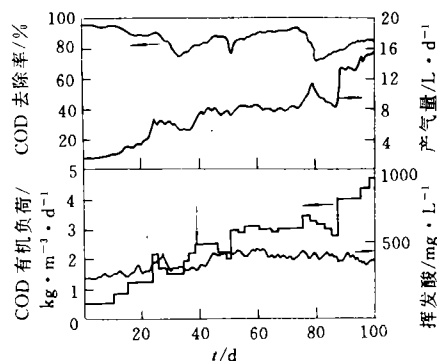


图 2 反应器 A 的运行结果

反应器 A 启动速度比较快, 从反应器运行开始对反应器污泥进行连续观察。在第 21 d 底部有颗粒状污泥出现, 但数量不多, 第 23 d 提高 COD 负荷至 2.3 kg/(m³·d), 进水量为 5.85 L/d, 到第 39 d 发现反应器底部已全部被颗粒污泥充满(见图 2 中箭头处), 而且反应器内污泥层和悬浮层有明显的分界面, 取出污泥观察, 最大颗粒污泥粒径在 3 mm 左右, 颜色发黑, 与食品工业废水中产生的厌氧污泥(灰黑色)有所不同, 同时发现有些颗粒中包含着活性炭, 用 40 号标准筛将打碎的颗粒污泥筛滤, 初期所截留的活性炭数量较多, 随着试验的进行, 被标准筛截留的活性炭越来越少, 具体比例关系见图 3。

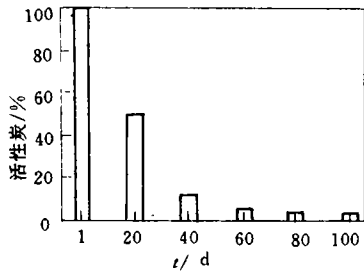


图 3 颗粒污泥中活性炭所占比例相对数的变化

3.2 反应器 B

反应器 B 的几何尺寸及试验开始投加的接种污泥量、进水量和浓度等均与反应器 A 相同,但负荷提高的幅度明显低于反应器 A。这主要是由于系统中的挥发酸浓度变化很大,常常超过提高负荷时 VFA 低于 500 mg/L 的要求,而且 COD 去除率也常小于 80%。这也说明反应器 B 的运行稳定性差。此外系统运行的最高负荷比反应器 A 低, COD 负荷高于 2.0 kg/(m³·d)左右时, COD 去除率和出水挥发酸便出现恶化现象,这从图 4 中第 75 d 到 85 d 的运行情况中可以看出。

从反应器 B 运行开始对其中的污泥进行观察,发现在第 56 d 时反应器底部出现细小颗粒状污泥,在第 62 d 颗粒污泥大量出现(见图 4 中箭头处),最大粒径不超过 2mm。如以颗粒污泥大量出现作为启动成功的主要标志,反应器 B

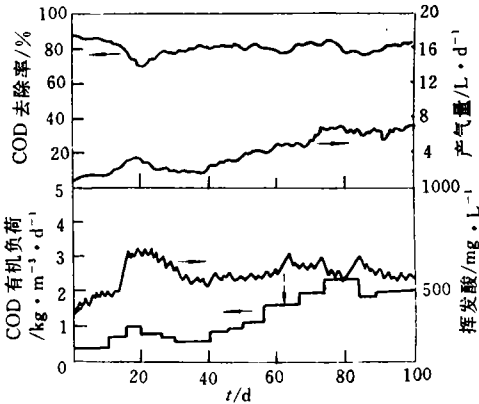


图 4 反应器 B 的运行结果

所需的时间是反应器 A 的 1.6 倍。

在试验后期,为再详细地考察反应器 B 处理皂化废水的最佳有机负荷,以 0.5 kg/(m³·d)的幅度增加 COD 负荷,出水水质随之改变,待 COD 负荷增加到 4.0 kg/(m³·d)时, COD 去除率仅 50%, VFA(出水)达 2140 mg/L, pH 下降至 5.7。因此对不加活性炭的反应器,试验发现皂化废水的最大 COD 有机负荷为 2.0 kg/(m³·d),此时废水未进行稀释,系统的水力停留时间约为 4 d, COD 去除率为 85%。

3.3 污泥性质的比较

从 2 个反应器运行开始到运行的第 100 d,反应器的污泥活性有了很大提高,见表 1。

表 1 不同反应器中的污泥特性

项 目		时间(d)				
		1	2	50	70	100
反应器 A	VSS ²⁾	6.77	6.92	7.13	7.41	7.51
	VSS/MLSS	0.21	0.24	0.37	0.40	0.48
	V _{max} ¹⁾	0.32	0.47	0.51	0.60	0.66
反应器 B	VSS ²⁾	6.67	6.87	7.02	7.25	7.27
	VSS/MLSS	0.20	0.22	0.29	0.38	0.45
	V _{max} ¹⁾	0.32	0.41	0.45	0.53	0.60

¹⁾ V_{max}: 最大比基质去除率 COD/VSS[g/(g·d)],以葡萄糖为基质 ²⁾ VSS: 单位为 g/L

4 结论

通过对比试验发现投加活性炭的反应器所需启动时间仅为不投加活性炭的 62%,最大稳定运行负荷为不投加活性炭的反应器的 2 倍,相应水力停留时间缩短 50%, COD 最终去除率

相差不大,均为 80%左右。另外,投加活性炭的反应器运行稳定性也优于不投加活性炭的反应器。

参 考 文 献

1 Lettinga G et al. . Wat. Sci. & Tech., 1991, 24(8): 729

tration increased; and the toxicity (EC_{50} , 96 h.) of rare-earth elements on *Chlorella pyrenoides* was in sequence as: $Nd > Ce > Pr > La$ > mixture of them, but little difference.

Key words: rare-earth element, *Chlorella pyrenoides*, effect on growth and reproduction.

Study on in-Bed Desulfurization within Fluidized Bed Coal Gasifier. Bu Xuepeng et al. (Beijing Research Institute of Coal Chemistry, Central Coal Mining Research Institute, Beijing 100013); *Chin. J. Environ. Sci.*, 17(2), 1996, pp. 39–41

The data obtained from the tests indicated that both limestone and dolomite can be used effectively for capturing sulfur during the gasification of high sulfur coals. Desulfurization efficiencies can be improved with increasing the Ca/S molar ratio, the efficiencies were maximum when the ratio was 3, or by increasing total sulfur in raw coals. The effect of operating pressure on desulfurization efficiency is determined by temperature and partial pressure of carbon dioxide. The desulfurization rate was range of 50%–85% under different conditions.

Key words: fluidized bed gasification, in-bed desulfurization, desulfurization sorbent.

Mass Transfer-Reaction Process Mechanism of Wet Flue Gas Desulfurization with Lime. Wu Zhongbiao and Tan Tian'en (Dept. of Chem. Eng., Zhejiang University, Hangzhou 310027); *Chin. J. Environ. Sci.*, 17(2), 1996, pp. 42–44

By studying experimentally wet flue gas desulfurization with lime as absorbent and rotating-stream-tray scrubber as absorber, the mass transfer and reaction process on $Ca(OH)_2$ slurry absorbing SO_2 is analyzed. Furthermore, the process mechanism is proposed. According to the mechanism, the total reaction rate is controlled by SO_2 diffusion in gas phase and $Ca(OH)_2$ dissolution and diffusion in liquid phase. The reaction process can be divided into three stages, the stage controlled by gas phase resistance, by gas phase and liquid phase resistance, and by liquid phase resistance. The process mechanism has been verified by the experiment. These results will help to optimize the design and operation of the industrial installation of wet flue gas desulfurization with lime.

Key words: flue gas desulfurization, mechanism, mass transfer-reaction process, lime, wet.

Effects of Three Sorts of Anaerobic Promoter on Anaerobic Digestion of the Waste Liquor from Ammonium Sulfite Pulping of Straws. Zhang Renquan (Dept. of Resource and Environ. Sci., Hefei Univ. of Technol., Hefei 230009); *Chin. J. Environ. Sci.*, 17(2), 1996, pp. 45–46

The effects of activated carbon, ferrous sulphate and bentonite on anaerobic digestion of the waste liquor from ammonium sulfite pulping of straws have been analysed on the basis of the experimental results of anaerobic batch assays with the waste liquor. The results indicate that, with a dose of 2.5 g/L, each sort of the anaerobic promoter can substantially promote anaerobic digestion of the waste liquor, which can increase 30 day total gas production of the anaerobic system by 16.1%, 13.9% and 26.1% respectively compared with the control. The ac-

tion mechanisms of the three sorts of anaerobic promoter have been discussed preliminarily.

Key words: anaerobic promoter, waste liquor from ammonium sulfite pulping of straws, anaerobic digestion, action mechanisms.

Using Hydra Reaggregations Evaluating the Safety of Two Kinds of Food Additives. Cheng Qinyao et al. (Dept. of Biology, Anhui University, Hefei 230039); *Chin. J. Environ. Sci.*, 17(2), 1996, pp. 47–48

This paper studied the safety of two kinds of food additives using *Hydra* reaggregations. The results showed that both sodium benzoate and sodium nitrite inhibited the growth of reaggregations. The minimum effective concentrations were 34.7×10^{-4} mol/L and 2.9×10^{-3} mol/L respectively. In addition, the negative correlation existed between the depolymerization time of the reaggregations and the concentration of food additives. Therefore, *Hydra* reaggregations technique will be a rapid screening method for predicting the potential toxicity of food additives.

Key words: *Hydra* reaggregation, food additive, evaluation safety, rapid screening.

A Study on Long-wave Pulsed Electromagnetic Fields Around A Long Range Navigation Station. Yao Gengdong et al. (School of Public Health, Zhejiang Medical University, Hangzhou 310031); *Chin. J. Environ. Sci.*, 17(2), 1996, pp. 49–50

A measurement and a theoretical calculation of long-wave pulsed electromagnetic fields (PEMF) around the antenna of the first long range navigation station in China were conducted. The results showed that the electric field intensities were 0.5–3.6 V/m (RMS) corresponding to peak values of 38.5–276.9 V/m in the PEMF generating room; in the residential area which is 850–1100 m away from the antenna, the electric fields were 0.7–3.9 V/m corresponding to peak values of 53.9–300.3 V/m; the PEMF decreased in environment with the distance away from the antenna and when the distance is over 1200 m from it, the fields tended towards minimum.

Key words: pulse, long-wave, environment, electric field intensity.

Determination of Hydraulic Load Cycle in Rapid Infiltration Treatment System of Waste Water. Wu Yongfeng et al. (Dept. of Environ. Sci., China University of Geosciences, Beijing, 100083); *Chin. J. Environ. Sci.*, 17(2), 1996, pp. 51–53

Hydraulic load cycle is the most important operation parameter in rapid infiltration treatment system of waste water. The decrease curve and recovery curve of infiltration rate in flooding and drying periods are obtained from the in situ test with the area of 80 m² and flooded with brewery waste water. The curves can be expressed with exponential and logarithmic equations respectively. A quantitative method is proposed to determine the hydraulic load cycle with maximum hydraulic load. The calculated result is 1.78 days flooding and 2.77 days drying, very similar with the test results.

Key words: rapid infiltration, hydraulic load, hydraulic load cycle, infiltration rate.

A New Way to Accelerate the Start-up of UASB Reac-

tor. Zhou Lu et al. (Dept. of Environ. Eng., Tsinghua Univ., Beijing 100084); *Chin. J. Environ. Sci.*, **17**(2), 1996, pp. 54–56

This paper indicated a new way to speed up granulation in UASB reactor by adding GAC. The results of experiment on UASB reactor with and without GAC treating effluence from petrochemical plant showed that the time of sludge granulation in the reactors with and without GAC were 39 days and 63 days respectively. The sludge pellet in the reactor with GAC had larger diameter than one in the reactor without GAC, and maximum COD removal rate was above 86%. Organic load of reactor with GAC was 2 times larger than the reactor without GAC. The reactor with GAC became more steady in process.

Key words: UASB reactor, granular active carbon, sludge pellet, granulation.

A Study on New Purification of High Concentration Sulphur Dyeing Sewage. Sun Jianhui et al. (Research Institute of Environ. Sci., Henan Normal Univ., Xinxiang 453002); *Chin. J. Environ. Sci.*, **17**(2), 1996, pp. 57–59

The combined technology of coagulative precipitation-iron chippings filtering-alkaline separation was used to purify the high concentration sulphur dyeing sewage. The results in the mode of production showed that the removal rates of sulphide, COD, BOD₅ and colority were 97.0%, 87.4%, 85.7% and 98.9% respectively. Every pollution index is up to the National Water Emission Standard. This technology system has the advantage in run stable, operation and management easy, engineering invest low, and treatment cost cheap.

Key words: coagulative precipitation, iron chippings filtering, alkaline separation, sulphur dyeing sewage.

Ecological Restoration of Coal Mining field in Loess Plain. Xue Ling et al. (Inner Mongolia Environmental Research Institute, Huhhot 010010); *Chin. J. Environ. Sci.*, **17**(2), 1996, pp. 60–63

This paper reports the results of an ecological restoration project in the Zhunger open-cut coal mining field in Inner Mongolia. The design, technique and effectiveness of the project are described. The results showed that the key points for ecological restoration in the Loess Plain condition include: selection of suitable plant species, proper soil treatments plus necessary construction work, adapt suitable ecological planting patterns based on site conditions. More than sixty plant species and eight ecological planting patterns were evaluated. Over 70% plant coverage and high yields of the crops (compared with the same crops in the nearby area) were obtained. A good ecological and economical return was achieved from the project.

Key words: ecological restoration, demonstrative project, Zhunger, open-cut coal mine in inner mongolia, land reclaim.

Determination of Atmospheric Methyl Bromide by Photoionization Detector. Zhong Jinxian and Liu Ye (Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085); *Chin. J. Environ. Sci.*, **17**(2), 1996, pp. 64–65

Atmospheric CH₃Br was trapped by Tenax adsorbent and was determined by gas chromatography with photoionization detector. The CH₃Br concentrations in indoor and

outdoor are 24×10^{-12} (V/V) and 77.4×10^{-12} (V/V). The standard deviation and detection limit for the method are 0.0521, 10 pg respectively. The level of CH₃Br pollutions is 10^{-11} (V/V).

Key words: methyl bromide, GC, photoionization detector.

Indirect Spectrophotometric Determination of Trace Cyanide by Means of the Colour Reaction of Silver with Cation in Presence of Triton X-100. Gong Churu et al. (Dept. of Chemistry, Hubei Normal University, Huangshi 435002); *Chin. J. Environ. Sci.*, **17**(2), 1996, pp. 66–67

Silver gives a colour reaction with Cation in the presence of Triton X-100, and suppression of the colour competitive complex ion of the silver can be used for the indirect spectrophotometric determination of trace cyanide. Cyanide in waste water can be separated by distillation from other ions that also interfere, and then determined. The determination range of this method is 0–10 µg/25 ml. The recoveries of standard cyanide added to waste water samples are in the range of 91.0–100%, and its relative standard deviation is less than 9%.

Key words: cyanide, cation, indirect spectrophotometry.

The Liquid-Solid Extraction of Methomyl in Environmental Water and Gas Chromatographic Analysis. Chen Yanjun et al. (Dept. of Chemistry, Jining Medical College, 272113); *Chin. J. Environ. Sci.*, **17**(2), 1996, pp. 68–70

A solid-phase extraction procedure of methomyl from environmental water with active carbon cartridge for gas chromatographic analysis is presented. The detection limit and the minimum detectable concentration of methomyl in water were 0.2 ng and 0.2 µg/L, respectively. The average recoveries of methomyl as added to water were in the range of 95.8–100.7%. The relative standard deviations were lower than 5%.

Key words: methomyl, solid-phase extraction, active carbon, gas chromatography.

Determination of Trace Levels of Nitrophenols in Water by Polyvinylpyrrolidone Modified Carbon Paste Electrode. Wang Kaixiong et al. (Dept. of Environ. Protection, Zhejiang Agricultural University, Hangzhou 310029); *Chin. J. Environ. Sci.*, **17**(2), 1996, pp. 71–73

In this paper, a method to determine simultaneously p-nitrophenol and 2,4-dinitrophenol in water by differential pulse voltammetry (DPV) with a carbon paste electrode modified with 10% (W/W) polyvinylpyrrolidone (PVPr) was described. The electrode showed a strong response to the nitrophenols, and the sensitivity and selectivity were much higher than ordinary carbon paste electrode. The nitrophenols were preconcentrated in 0.1 mg/L KCl solution during open circuit period, then the preconcentrated nitrophenols at the electrode were determined in phosphate buffer solution (pH7.0). The oxidation peak potentials were +0.88 V and +1.23 V (VS Ag-AgCl) respectively and two current peaks were completely separated. The detection limits were 0.50 µg/L (p-nitrophenol) and 1.80 µg/L (2,4-dinitrophenol). This method had been applied to the determination of nitrophenols in pol-