

同轴流光电晕放电消除硫化氢试验研究

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摘要 利用脉冲流光电晕放电消除臭气硫化氢 H_2S 。对负脉冲供电、正脉冲供电和直流供电情况下, H_2S 消除效率及能量利用率进行了比较。结果表明脉冲流光电晕放电消除 H_2S 是有效的。在负脉冲流光电晕放电过程中, H_2S 消除效率可达 88%, 能量利用率为 $6.74g/(kW \cdot h)$ 。与负脉冲供电相同工作条件下, 正脉冲流光电晕放电过程 H_2S 消除效率为 45%, 能量利用率为 $2.27g/(kW \cdot h)$ 。

关键词 脉冲流光电晕放电, H_2S , 消除率, 能量利用率, 废气处理。

Hughes et al^[1]采用扩散电晕放电氧化及分解 H_2S , Mizuno^[2]利用脉冲电晕放电处理烟气中的 SO_2 , 但都存在能量效率过低等问题。在非均匀电极结构中采用脉冲流光电晕放电将会提高反应效率及能量利用率, 流光将会在整个气体反应室内传播, 电离分子产生高能电子, 脉冲流光电晕放电过程中的电子平均能量高于 6eV, 可产生大量的活性粒子(O 、 OH 、 H_2O 等)。这些活性粒子与 H_2S 反应形成微小颗粒^[3], 可利用电收尘器或布袋等收集。笔者借鉴处理 SO_2 的经验, 采用同轴脉冲流光电晕放电技术处理臭气硫化氢, 该处理技术利用了脉冲电晕放电的优点, 同时避免了非反应区。

1 实验装置

H_2S 处理系统由图 1 所示。 H_2S 和水蒸气在室温条件下引入均化室, 与空气充分混合后进入同轴流光电晕放电反应室。按照实际 H_2S 排放源条件, H_2S 的浓度调整范围为 10×10^{-6} — 125×10^{-6} , 相对湿度调整范围为 25%—75%, 空气流量为 5.66×10^{-2} — $1.41Nm^3/min$ 。采用 621 型金膜 H_2S 分析仪测试 H_2S 浓度, 用 100/5 型风速仪测试空气流量, 利用 112 型湿温仪测试相对湿度及温度。

图 2 给出同轴流光电晕反应室结构。它包括针-圆筒结构电极系统及绝缘子。圆筒型接地电极壁厚 0.25cm、长 2.6m、外径为 11.25cm。针状

电极由钢棒上固定铝钉构成, 铝钉尖部曲率半径

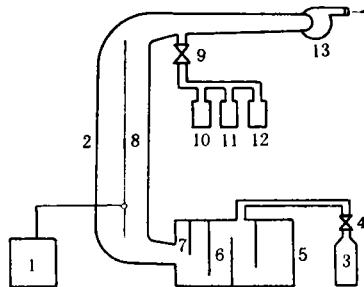


图 1 H_2S 处理系统

1. 供电装置 2. 反应器 3. H_2S 储罐 4. 总阀 5. 空气
6. 均化室 7. 温湿计 8. 电极 9. 取样阀 10. 臭氧
测试仪 11. SO_2 测试仪 12. H_2S 测试仪 13. 引风机

半径小于 0.1mm, 铝钉尖部与圆筒壁间距为 3.75cm。反应室有效横截面积为 $82cm^2$ 。脉冲供电装置由电压控制器, 高压变压器, 高压分压器及旋转火花间隙开关构成^[4]。脉冲峰值电压在 0—50kV 内可调, 重复频率在 0—100Hz 内调整, 脉冲宽度不依赖于重复频率。脉冲电压叠加在直流电压上, 直流电压等于或稍低于起晕电压。

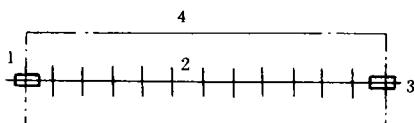


图 2 反应室

1. 绝缘子 2. 放电电极 3. 高压输入 4. 铝筒

2 实验结果及讨论

在实验中对 H_2S 消除效率与供电电压、频率、极性、电源输出功率、直流偏压之间关系进行了探索。

2.1 直流电晕放电

H_2S 消除效率与电压关系在表 1 中给出。在 $+15kV$ 情况下(稍低于火花电压), H_2S 消除效率为 42%, 负电晕放电, 在 $-20kV$ 情况下(稍低于火花电压), H_2S 消除效率为 48.5%。

表 1 H_2S 消除效率与电压关系¹⁾

极性	电压 (kV)	电流 (mA)	H_2S 浓度(10^{-6})		效率 (%)
			出口	入口	
正	10	0.25	1.2	0.9	25
	15	5.16	1.2	0.7	32
负	10	1.6	7.36	6.5	17
	15	5.4	7.36	5.4	27
负	16	6.5	7.36	4.6	37.5
	18	12	7.36	3.94	46.5
负	20	16	7.36	3.82	48.5

1) 室温 23℃ 相对湿度 30% 气体流量 $8.5 \times 10^{-2} \text{Nm}^3/\text{min}$

2.2 脉冲流光电晕放电

典型的实验结果由表 2 中给出。具有直流偏压的负脉冲电压(脉宽为 200ns FWHM)加在针-圆筒型电极系统, H_2S 的消除效率为 88.1%。在直流偏压的正脉冲电压下, H_2S 消除效率为 45%。在实验过程中有白色粉状物形成, 并沉积在放电电极及接地圆筒上。

表 2 脉冲流光电晕放电 H_2S 消除效率¹⁾

极性	电压 (kV)	电流 (mA)	H_2S 浓度(10^{-6})		效率 (%)
			入口	出口	
负脉冲	40	7.4	50.3	6.0	88.1
正脉冲	15	28	4.63	2.56	45

1) 室温 23℃ 相对湿度 30% 频率 40Hz

气体流量 $5.66 \times 10^{-2} \text{Nm}^3/\text{min}$

2.3 消除效率与供电功率关系

H_2S 反应室的供电功率是供电电压与电晕电流的乘积, 供电功率的提高将提高反应室中活性粒子浓度, 从而提高 H_2S 的消除效率。 H_2S 消除效率与供电电压关系的典型实验结果见图 3。消除效率基本随供电电压直线上升。

供电功率随脉冲电压重复频率升高而提高(图 4)。在相同供电电压情况下, 频率升高, 平均电晕电流随之增大。 H_2S 消除效率与频率之间关系在表 3 中给出。结果表明, 在同等条件下, 频率升高, 将获得较高的 H_2S 消除效率。

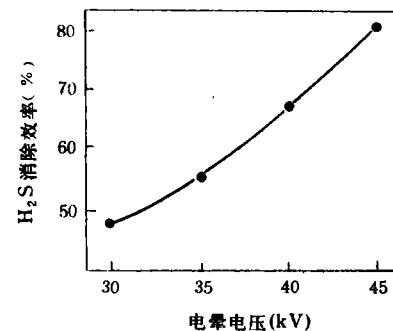


图 3 电晕电压对 H_2S 消除效率的影响

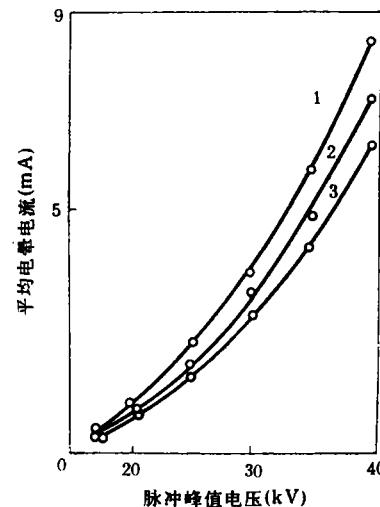


图 4 无直流偏压情况下不同频率负脉冲电压的 V-I 特性

1. 80Hz 2. 40Hz 3. 20Hz

表 3 H_2S 消除效率与频率关系¹⁾

频率 (Hz)	电流 (mA)	H_2S 浓度(10^{-6})		效率 (%)
		入口	出口	
20	4.3	72.3	34	53
40	7.4	139.7	50.3	63.5
80	8.0	294	88.7	70

1) 电压 40kV 气体流量 $8.5 \times 10^{-2} \text{Nm}^3/\text{min}$

2.4 电压极性及偏压对 H_2S 消除效率的影响

脉冲电压的极性及偏压对 H_2S 的消除效率也有很大的影响, 典型实验结果在表 4 中给出。

同样是负脉冲供电,有直流偏压消除效率为 88.1%,无直流偏压效率为 63%。结果表明在脉冲间歇期加直流偏压,加速驱逐空间离子,对下一次脉冲产生流光电晕放电创造了良好条件。

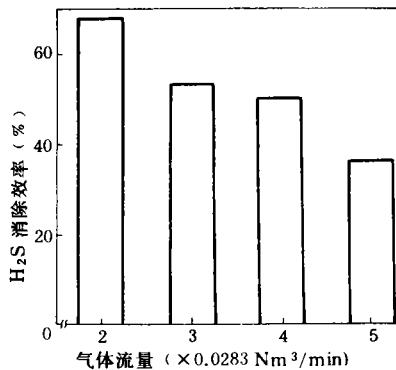
表 4 电压极性及偏压对 H₂S 消除效率影响¹⁾

序号	电压极性及波形	电压 (kV)	电流 (mA)	H ₂ S 浓度(10 ⁻⁶)		效率 (%)	能量利用率 [g/(kW·h)]
				入口	出口		
1	有直流偏压的负脉冲	40	7.4	50.3	6.0	88.1	6.74
2	有直流偏压的正脉冲	15	2.8	4.63	2.56	45	2.27
3	负脉冲	42	3.5	10.8	4.03	63	2.07
4	正脉冲	24	1.6	29.4	16.9	43	1.47

1) 频率 40Hz, 气体流量 $5.66 \times 10^{-2} \text{Nm}^3/\text{min}$

2.5 带留时间的影响

H₂S 消除效率与反应时间直接相关, 典型实验结果见图 5, 表明气体流量提高, H₂S 的消除效率将下降。

图 5 H₂S 消除效率与气体流量关系

脉冲频率 20Hz 脉冲宽度 400ns 脉冲电压 -40kV 电晕电流 1.3mA 气体温度 23°C 相对湿度 30% H₂S 入口浓度 10×10^{-6}

2.6 能量的比较

直流电晕放电消耗能量计算采用:

$$P_{DC} = V_{DC} \times I_{DC}$$

这里 V_{DC} 是直流电压, I_{DC} 是电晕电流。

脉冲流光电晕放电消耗能量采用:

$$P_P = V_P \times I_{AC}$$

这里 V_P 是脉冲峰值电压, I_{AC} 是平均脉冲电晕电流, 由机械电流表获得。H₂S 消耗能量利用率为: $gH_2S/(kW \cdot h) = [H_2S(10^{-6})I_n - H_2S(10^{-6})Out] \times 1.39g/m^3 \times \frac{1}{10^{-6}}$

$$\begin{aligned} & \times Q(2.83 \times 10^{-2} \text{Nm}^3/\text{min}) \times 0.27 \text{m}^3/\text{min} \\ & \times 2.83 \times 10^{-2} \text{Nm}^3/\text{min} \times \frac{60 \text{min}}{\text{h}} \times \frac{1}{P(W)} \times \frac{1000 \text{W}}{\text{kW}} \\ & = 22.516[H_2S(10^{-6})I_n - H_2S(10^{-6})Out] \\ & \quad \times Q(2.83 \times 10^{-2} \text{Nm}^3/\text{min}) \times \frac{1}{P(W)} \end{aligned}$$

这里 Q 为气体流量, $P(W)$ 为供电功率。能量利用率的实验结果在表 4 中给出。结果表明, 直流供电能量利用率低于脉冲供电, 无直流偏压的脉冲供电能量利用率低于有直流偏压的脉冲供电, 正脉冲低于负脉冲。

按实际 H₂S 排放浓度 13.9—174g/m³ 计, 表 4 中最高能量利用率 6.74g/(kW·h), 那么处理 1m³ 含 H₂S 烟气所需能量为 2—25.8 kW·h, 我国北方电价 0.4 元/(kW·h), 所需费用为 0.8—10.3 元, 说明采用脉冲高压处理 H₂S 能量利用率有待提高。

3 结论

脉冲流光电晕放电处理 H₂S 是有效的; 采用窄脉冲供电可获得较高的能量效率; 负极性脉冲流光放电比正极性获得更好的 H₂S 消除效率; 能量利用效率有待进一步提高。

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Abstracts

Chinese Journal of Environmental Science

Immobilized-Microbial-Cell A/O Process. Wang Lei . (Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085), Yu Yuxin (Dept. of Environ. Eng., Tsinghua Univ. , Beijing 100084); *Chin. J. Environ. Sci.*, **16** (1), 1995, pp. 29—31

Immobilized-microbial-cell (IMC) technology, a new technique for biological wastewater treatment, was used to treat a spent tetracycline liquor. The experimental results showed that the removals of both COD and tetracycline were 96% at a COD loading of 2. 07 kg/(m³ • d). As compared with a conventional A/O process, there was an increase of COD loading by 16. 3% and of gas production by 4. 57 times. The IMC technology was found to have some further advantages, including a more stable operation and allowing a higher pollutant loading and less sludge generation.

Key words: anaerobic-aerobic process, tetracycline, immobilized microbial cell.

Flux of N₂O Emission from the Fields in a Wheat and Maize Rotation System. Zeng Jianghai et al. (Institute of Agricultural Modernization, Chinese Academy of Sciences, Shijiazhuang 050021), Song Wenzhi et al. (Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085); *Chin. J. Environ. Sci.*, **16**(1), 1995, pp. 32—35

Nitrous oxide fluxes from the fields in a wheat and maize rotation system were studied in the North China Plain from September 25, 1992 to September 21, 1993. The total emission of N₂O was also estimated according to the fluxes of nitrous oxide measured in a year period. The fluxes of N₂O are 10. 6—24. 2 μg N/(m² • h) with the correspondingly annual emission of 0. 93—2. 11 kg N/(hm² • a). The N₂O emissions from urea-fertilized and organic-fertilized plots account for about 0. 54% and 0. 70% of the amount of applied fertilizers, respectively.

Key words: N₂O, flux, emission, environmental factor.

Study on the Removal of Odor Gas H₂S by a Coaxial Streamer Corona. Liu Linmao et al. (Dept. of Environ. Sci., Northeast Normal Univ. , Chuang Chun 130024); *Chin. J. Environ. Sci.*, **16** (1), 1995, pp. 36—38

The pulsed streamer corona have been used to remove odor (H₂S). The H₂S removal efficiency and power utilization efficiency were compared in the cases of negatively pulsed voltage, positively pulsed voltage and DC voltage. The results show that the

pulsed streamer corona is effective to remove H₂S. The negatively pulsed streamer corona was found to have a H₂S removal efficiency of 88% and a power utilization efficiency of 6. 74g/(kw • h). In the same operating condition with negatively pulsed streamer corona, the positively streamer corona was found to have a H₂S removal efficiency of 45% and a power utilization efficiency of 2. 27g/(kw • h). **Key words:** coaxial streamer corona, H₂S, removal efficiency, power utilization efficiency.

Study on the Cultivation of Granular Sludge in a UASB reactor with a Foaming Porous Calcium Alginate Colloid. Xu Dandong and Xiao Hong (Dept. of Environ. Eng., Lanzhou Railway Institute, Lanzhou 730070); *Chin. J. Environ. Sci.*, **16**(1), 1995, pp. 39—41

Based on the experiment, this paper describes the effects of foaming porous calcium alginate colloids, as the nucleus of biological granula and the promoter of granular sludge, on the acceleration of operation at the beginning of upflow in an anaerobic sludge bed reactor. It also indicates the process of producing calcium alginate colloids. In the reactor, sludge was cultivated immediately after the microorganisms were introduced, then the produced colloids were taken to mix with the microorganisms. After a continuous 20 day operation, the measurements showed that the content of CH₄ decreased to 70% and the removal rate of TOC reached 70% when calcium alginate colloids, as the nucleus of granula, were replaced by microorganisms with the sedimentation of biological granula at a rate of 300mm/min and a number of about 700 particles/ml. A satisfactory result was obtained by giving a granular sludge, of high activities and better sedimentation performance.

Key words: granular sludge, UASB reactor, alginic acid, anaerobic treatment.

Hydrogen production from soybean wastewater by Immobilized Photosynthetic Bacteria. Liu Shuangjiang et al. (Institute of Microbiology, Chinese Academy of Sciences, Beijing 100080); *Chin. J. Environ. Sci.*, **16**(1), 1995, pp. 42—44

This paper presents the results of hydrogen production from soybean wastewater by immobilized photosynthetic bacteria (IPSB). The results showed that the IPSB in sodium alginate could produce hydrogen from a wide range of the concentrations of soybean wastewater. When the concentrations of wastewater ranged from 7560 to 12600 mgCOD/L, the IPSB could maintain stable hydrogen production for 260 hours, with an average gas production rate