火山凝灰岩厌氧过滤塔废水处理系统的控制和稳定性研究

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摘要　本研究选用三种不同性质的填料柱，以三种不同性质和不同浓度的废水进行对比试验，观察处理后的出水．结果表明：火山凝灰岩是一种优良的填料．由于火山岩孔隙多表面积大，接种菌种极易吸附在其粗糙的表面上，迅速生长繁殖，形成有效的生物过滤膜．该系统运转第14天，废水中 TOC 去除率达95%．

引　言

厌氧过滤塔法（Anaerobic Filtration Process）是一种生物过滤技术．接种和繁殖的厌氧菌在过滤塔中形成生物过滤层，当食品厂废水从塔底泵入，流经生物过滤层时，填料层中的细菌便把废水中的有机物分解成甲烷和二氧化碳．生成的气体从塔顶导入甲烷收集罐作为能源．

厌氧过滤塔填料的种类、性质和规格以及接种污泥的性质对系统的稳定性起决定作用．本试验选用三种不同填料在相同条件下进行对比试验．结果表明，火山凝灰岩是一种优良的填料．在系统运转第十四天，废水中总有机碳（TOC）的去除率达到95%．在系统条件控制良好的情况下，即使废水的性质和浓度在相当宽的范围内变化，处理效果仍然十分稳定．这种生物过滤系统比较适合于处理水果和蔬菜罐头厂的废水．

试验方法与设备

1. 厌氧过滤塔及其处理系统

表1为四组厌氧过滤塔的技术参数．选用的填料有石英石、泡沫塑料和日本的火山凝灰岩三种．其中火山凝灰岩（以下简称火山岩）是火山爆发时喷射出来的岩浆和灰砂等物质凝结成的岩石颗粒．由于火山爆发时的高温燃烧和随后的冷却凝结，使岩石颗粒孔隙多，质地比较疏松，表面积大．接种污泥中的厌氧菌（主要是甲烷球菌）很容易吸附在多孔火山岩的表面和空隙内的粗糙表面上．厌氧菌从泵进的废水中吸取营养，迅速生长繁殖，起生物降解作用．

表1　厌氧过滤塔的技术参数

过滤塔编号	1	2	3	4
有效截面积（cm^2）	10×10	10×10	3.2×3.2	3.2×3.2
装填高度（cm）	50	50	30	30
装填体积（cm^3）	5000	5000	307.2	307.2
总体积（cm^3）	6720	6720	889	889
有效体积（cm^3）	3820	3620	180	145
过滤塔填料名称	火山岩＋泡沫塑料	火山岩	火山岩	石英石
标准筛号	15，11	15，11	8，5	8，5
筛孔尺寸（mm）	15.9，11.1	15.9，11.1	7.93，4.76	7.93，4.76
泡沫塑料（mm^3）	10×10×10	—	—	—

1号和2号过滤塔的火山岩颗粒粒径约

为 12—16mm. 3 号和 4 号过滤塔的火山岩颗粒和石英石颗粒分别用 8 号和 5 号标准筛筛选. 泡沫塑料为边长 10mm 的正方体.

图 1 是厌氧过滤塔废水处理系统流程图. 其中, 1 号过滤塔填料分五层, 第一、三、五层为火山岩颗粒, 第二、四层为泡沫塑料层. 火山岩与泡沫塑料的体积比为 3 比 2. 2 号和 3 号过滤塔填料全部用火山岩颗粒, 4 号塔全部用石英石粒. 塔内温度为 20℃或 37℃. 表 2 为四组处理系统的供料技术参数.

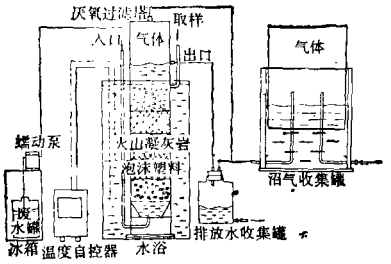

图 1 厌氧过滤塔废水处理系统流程图

表 2 系统供料条件和技术参数

过滤塔编号		1	2	3	4
控制温度(℃)		37	37	20	20
物料流量 (L/d)		2.6	2.6	0.37	0.37
滞留时间 (h)		35.5	33.4	11.7	9.4
菌种污泥量与总体积之比(%)		4.8	4.8	11	11
供料条件	人造废水 TOC 浓度 (ppm)	果胶废水 1000	果胶废水 1000	淀粉废水 1000	淀粉废水 1000
	工厂废水 TOC 浓度 (ppm)	柑桔废水 2530	果胶废水 2000	— —	— —
	高浓度废水 TOC 浓度 (ppm)	果胶废水 5000	果胶废水 4000	— —	— —

2. 菌种污泥

厌氧过滤塔接种的菌种污泥是在发酵罐中经 20 天培养后含有大量细菌的污泥. 含菌污泥按表 2 规定的百分比分别由塔的底部接种到四个过滤塔中. 静置 24 小时, 让厌氧菌吸附在填料上. 然后起动蠕动泵, 进行连续培养. 表 3 为菌种污泥的性质.

表 3 菌种污泥的特性

污泥沉淀物*	16%
上层清液	84%
PTN**	703ppm
SS	8.92g/l

* 菌种污泥在离心机中以 10000 r/min 速度离心分离 10min.

** 颗粒沉淀物中的总氮含量.

3. 实验用废水

本试验使用了三种废水, 即果胶废水(人工配制), 熟淀粉废液(人工配制), 罐头厂加工糖水桔子废水. 表 4 为三种废水水质.

表 4 三种废水的成分

项目 \ 废水种类	果胶废水	熟淀粉废水	桔子废水
果胶 (g)	2.56	—	—
可溶性淀粉 (g)	—	2.25	—
总氮 (ppm)	—	—	38
磷 (ppm)	—	—	6.05
NaCl(%)	—	—	0.225
干酵母提取物 (g)	0.025	0.022	—
$NaHCO_3$(g)	4	4	—
NH_4Cl(g)	0.192	0.192	—
K_2HPO_4(g)	0.058	0.058	—
自来水 (ml)	1000	1000	—
pH	8.0	8.3	7.3
C:N:P	100:5:1	100:5:1	100:5:1
TOC(ppm)	1000	1000	2530

试验结果和讨论

1. 填料性质和过滤塔温度对处理效率的影响

试验结果见表 5 和表 6. 从表 5 可见, 两组过滤塔系统在运转 14 天后, 废水中的

TOC 去除率分别达到 94.5% 和 95.7%. 在 20 天后达到稳定状态，TOC 去除率超过 97.5%. 说明两组填料都较理想.

表 5　火山岩与火山岩-塑料混合填料的比较

过滤塔编号	1	2
填料	火山岩-泡沫塑料	火山岩
废水	含果胶废水	含果胶废水
进水 TOC (ppm)	1000	1000
TOC 负荷 (kg TOC/m³/d)	0.39	0.39
起动时间 (d)	14	14
出水 TOC (ppm)	55	43
TOC 去除率(%)	94.5	95.7
到达稳定值时间 (d)	20	20
出水 TOC (ppm)	15	22
TOC 去除率(%)	98.5	97.8
出水 POC (ppm)	61	41
沼气产量 (L/d)	2.1	2.1
甲烷含量(%)	58	59
CO_2 含量(%)	42	41
运行总天数 (d)	50	50

表 6　火山岩与石英填料的比较

过滤塔编号	3	4
填料	火山岩	石英
废水	含熟淀粉废水	含熟淀粉废水
进水 TOC (ppm)	1000	1000
运转总天数 (d)	50	50
出水 TOC (ppm)	165	524
TOC 去除率(%)	83.5	47.6
沼气产量 (L)	9.8	8.1

表 6 列出在 20℃ 条件下，火山岩与石英颗粒过滤填料的比较结果. 在厌氧过滤塔系统运转 50 天后，3 号塔的 TOC 去除率已达 83.5%，4 号塔的 TOC 去除率仅达到 47.6%，可见石英填料的效率只有火山凝灰岩填料效率的一半左右. 石英颗粒作填料，由于表面过于光滑，细菌在填料上的吸附性差，所以厌氧过滤塔经很长时间才趋向稳定. 图 2 为四组厌氧过滤塔的 TOC 变化曲线. 从图 2 可以看出，即使在 20℃ 较低温度条件下，火山凝灰岩的效果也相当好.

2. 进水 TOC 浓度对处理效率的影响

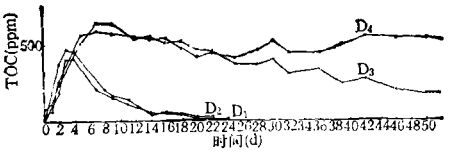

图 2　TOC 变化曲线

D_1 火山凝灰岩+泡沫塑料 (3:2, V/V) 37℃;
D_2 火山凝灰岩 37℃; D_3 火山凝灰岩 20℃;
D_4 石英石 20℃.

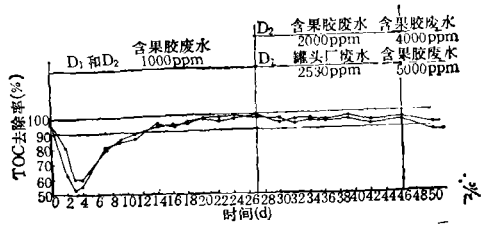

图 3　各种浓度废水的 TOC 去除率

在厌氧过滤塔系统运转稳定以后，改变进水的种类和浓度. 1 号和 2 号塔的废水浓度从开始的 1000ppm，分别增加到 2000ppm，2530ppm，4000ppm 和 5000ppm，两个塔的废水种类和浓度详见图 3. 结果表明，废水浓度从 1000ppm增加到 2000，2530 和 4000ppm 时，TOC 去除率（系统效率）分别从 97.1% 降到 96.1%，94.8% 和 92%，而当废水浓度提高到 5000ppm 时，TOC 去除率降到 86.9%.

试验结果还证明，过滤塔的负荷与 TOC 去除率之间存在着线性关系，即在过滤塔一定容积范围内，负荷与 TOC 去除率之间是一直线关系. 见表 7 和图 4. 此结果为厌氧过滤塔的实际设计工作提供了重要的技术依据.

表 7　负荷与 TOC 去除率的关系

TOC (ppm)	1000	2000	2530	4000	5000
负荷(kgTOC/m³/d)	0.39	0.78	0.98	1.55	1.95
平均TOC去除率(%)	97.1	96.1	94.8	92	86.9

3. 罐头厂酸碱废水对系统效率的影响

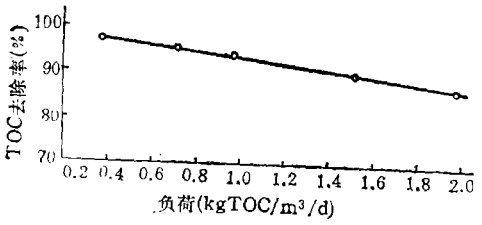

图 4　负荷与 TOC 去除率的线性关系

罐头厂在加工水果蔬菜罐头时，去皮等原料处理和预煮过程中常使用大量酸或碱液，为了研究厌氧过滤塔系统对罐头厂废水处理的实用性，从罐头厂取来酸碱废水．废水先在中和罐中和，调整 pH 至 7.3．然后把这种废水连续泵入 1 号厌氧过滤塔系统．为了对照，2号过滤塔在其他条件与 1 号塔基本相同的情况下，泵入浓度为 2000ppm TOC 的含果胶废水．罐头厂废水的 TOC 浓度为 2530ppm．试验条件和结果见表 8．从表 8 可以看出，两组系统在连续运转 19 天时，1 号塔的 TOC 去除率达到 94.8%（平均），作为对照用的 2 号塔的 TOC去除率达到96.1%（平均），效率相当接近．另一方面每升罐头厂废水可产沼气 3 升，气体中的甲烷含量为 61%．而对照组每升废水产沼气 2.8 升，气体中的甲烷含量 56%，罐头厂废水比对照组好．

表 8　罐头厂废水与对照组的比较

过滤塔编号	1	2
废水	罐头厂废水	对照组人造废水
TOC (ppm)	2530	2000(含果胶)
TOC负荷(kg TOC/m³/d)	0.98	0.78
过滤塔运转时间 (d)	19	19
处理废水量 (L)	37.6	38
TOC 去除率(%)	94.8	96.1
沼气总量 (L)	114.4	106.4
沼气产量 (L/L 废水)	3.0	2.8
甲烷(%)	61	56
CO_2(%)	39	44
POC(ppm)	17.1	9.3

试验结果表明，火山凝灰岩为填料的厌氧过滤塔废水处理系统很适合于罐头食品厂以生产水果、蔬菜为主的排放废水的处理．

结　论

1. 火山凝灰岩是一种不规则的近似椭圆形的颗粒．由于火山凝灰岩孔隙多，质地疏松，接种细菌很容易吸附在其粗糙的表面和孔隙中，迅速生长繁殖，形成生物过滤膜．实验证明，以火山凝灰岩为填料的厌氧过滤塔废水处理系统起动快，运行稳定，成本低，效率高．

2. 试验结果证明，火山凝灰岩厌氧过滤塔系统在起动和运行稳定以后，即使废水的浓度和性质在相当宽的范围内变化，对系统的处理效率的影响却很小．也就是说，该系统对工厂废水的性质和浓度的变化有非常好的适应性．

3. 火山凝灰岩厌氧过滤塔废水处理系统适用于水果蔬菜罐头食品厂的废水处理．果蔬食品加工厂的废水中不仅含有大量的有机物质，而且废水的浓度和性质往往随着水果蔬菜的加工季节的变化而发生较大的变化．这方面正好符合火山凝灰岩厌氧过滤塔废水处理系统的特点．

此项研究得到田中先生的合作及帮助，谨表谢意．

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that the activity changes of SOD in a half of the samples was lower in the polluted area than in the control area. The factors that result in the activity changes of SOD have been discussed. (See pp. 22—26)

Preservation of Water Sample Containing Se (IV) and Se(VI)

Wu Dunhu (Department of Applied Chemistry, Dalian Railway College): Zhang Jingyan and Liu Xiufang (Changchun Training School of Metallurgical Geology)

A new polarographic method has been used to study the effects of preserving conditions, such as materials of container, pH, temperature, and addition of fulvic acid, on the losses of Se(IV) and Se(VI) at the initial levels of 0.05—0.10 ppb in water samples during preservation. It has been found that, when the water samples were preserved at low temperature and added with fulvic acid under the acidic condition, quartz containers were the most suitable to be used for the purpose, and glass containers were the most unsuitable to do so while polythene ones were between them. The use of polythene bottles passivated with nitric acid for preserving the natural water, adjusting pH to 1.0 with HNO_3, has led to the levels of Se(IV) and Se(VI) almost without change for one month. (See pp. 26—30)

A study on Concentrations of Microorganisms in the Atmosphere of Beijing and Tianjin areas

Hu Qingxuan et al. (Institute of Biotechnology, Acadamy of Military Medical Sciences, Beijing 100071)

Concentrations of airbone bacterial and fungous particales in three sites in the Beijing and Tianjin areas were determined by a six-stage Andersen sampler modelled in our laboratory. Results showed that the average concentrations of bacteria in air were 3.02 CFU/L a year for Xidan, Beijing, 2.56 CFU/L for Fengtai Beijing, and 1.38 CFU/L for the seaside in Tanggu, Tianjin, and that the average concentration of fungi in air of Fengtai was 1.20 CFU/L a year. With respect to the temporal distribution of concentration of bacteria in air, there were two peaks, at 7:00 a. m. and 10:00 p. m., and two valleys, at 1:00 p. m. and 1:00 a. m.. There had been similar pattern for the concentrations of bacteria which were collected on each stages inside the Andersen sampler. (See pp. 30—35)

Effects of Low Level of SO_2 on Growth of Apple Tree Long-term Exposured to It

Jiang Fang (Shenyang Institute of Environmental Science)

The experiments have ben conducted on the 11-yearold *Guoguang* apple trees during a growing period by exposing to low levels of SO_2 in 4 top-open field chambers with one chamber for each tree. The levels of SO_2 in each chamber were 0, 0.10, 0.18 and 0.28 mg/m^3, respectively. By the determination and analyses of the photosynthesis rate, area of leaf, unit weight of leaf and length of branches in one year old, it has been found that the exposure to 0.10 mg/m^3 of SO_2 had no significant effect on the indicators studied, the exposure to 0.18 mg/m^3 had a slight effect, and the exposure to 0.28 mg/m^3 had a significant effect. (See pp. 35—38)

Controlling the Source of PCBs Pollution at a Transformer Substation

Jiang Ke and Chen Ronli (Research Center for Eco-Environmental Sciences, Academia Sinica, Beijing)

Some transformer substations are potential sources of PCBs pollution in China. PCBs will be released to the environment when the old power capacitors using PCBs as soaker are demaged. This paper deals with the harness of a typical source of PCBs pollution at Qin'an Transformer Substation. A set of GC/ECD and GC/MS methods have been used for accurate and rapid measurement of total PCBs. The assessment of soil and air quality in a typical substation at Qin'an has been completed. The practical options for PCBs pollution control have been designed based on the local conditions. The follow-up monitoring in one year after completing the harness shows that the pollution has been substantially controlled and the risk of PCBs contamination to human health has been minimized at the substation. (See pp. 43—46)

Decolorization of Dyeing Wastewater Using Purple Nonsulfur Photosynthetic Bacteria

Wu Guoqing et al. (Taiyuan University of Technology, shanxi Province)

The purple nonsulfur photosynthetic bacteria have been separated from the activated sludge in an aeration tank at Shanxi Textile Mill. The bacteria were used to decolor 14 kinds of dyeing wastewater, of which under anaerobic conditions 12 kinds of dyes were mostly decolored. The efficiency of decolorization was higher than 75%. The influence of temperature, pH, etc. on the decolourization and the decolourizing mechanism have also been studied. (See pp. 46—50)

Research on the Stability and Control of Pelelith Anaerobic Filtration Process

Zhang Lifen (Research Institute of Food and Fermentation Industry, Ministry of Light Industry)

The anaerobic filtration (AF) is the process in which organic matter is broken down under anaerobic condition to methane and carbon dioxide. In the process, bacteria attach themselves quickly upon filter media and

(continued on p. 77)

(14)式中E (0) 及 E(m) 是 $k=0, m$时的E(k) 值. k为谐波波数, $k=0,1,2\cdots m$. 本实验中 $m=20$; 式中 $\rho(1)$ 是 $\tau=1$ 秒时的自相关系数. 将(12)及(14)代入(13)式即可算出 RE(k) 值. 对每一车流状态均可求算出 20 个RE(k)值, 其结果表示在图(2)中.

四、主要结论

1. 在180 辆/h 至 1224 辆/h 离散分布的8 种车流密度下, 我国城市交通噪声自相关分析表明: 采样数据的相关半径在 4 秒左右;采样间隔时间 $\Delta t=1$ 秒的采样数据,相邻数据的相关系数均在 0.86 以上, 为明显相关. 这不符合独立采样的要求; 在快速采样的情况下, 必需的样本时间长度应在 800 秒以上;当 $\Delta t<4$ 秒时, 采样数N应保证在 $800/\Delta t$ 以上.

2. 城市交通噪声功率谱的谐波波数一般不大于 10, 具有"红噪声" 特点. 所以, 城市交通噪声实际上是红噪声调幅的宽频带噪声. 5 秒采样周期满足采样定理的要求.

3. 对城市交通噪声若选择过小的采样时间间隔 Δt, 则可能导致在相关半径内采样数据个数的增加. 而数据之间自相关的增强将导致统计量 (等效声级 Leq) 随机误差的增大, 其增大量为独立采样时的 0.7—0.9 倍.

4. 交通噪声级的随机起伏, 经显著水平为 0.05 的周期性检验,表明在谐波波数 $k=3$—6 范围内, 即对应周期为 33 秒—17 秒范围内常表现出周期现象.

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absorb nutrient from the surrounding flow of influent. The stability of anaerobic filter depends on seed sludge, filter media and the condition of digester. Three kinds of the filter media and various wastewaters were used in this study. The result indicated that the pelelith filter can remove about 95% of TOC in wastewater only 14 days after it was set up. It is evident that if the AF process was controlled in a good condition, it will start up and get stability qpickly. (See pp. 51—54)

Determination of Uranium in Environmental Samples Using Laser-Fluorecence

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A method for determining trace uranium in natural water, soil and plant samples is reported by using laser induced fluorecence. Fluorescence of uranium is produced due to excitation by a small nitrogen laser, and the method is simple in operation and rapid in measurement. Natural water, including seawater, riverwater, lakewater, groundwater etc. can be measured directly without preconcentration, solid and plant samples must be transformed into solution and then be measured. Concentration of uranium is determined in the range from 0.05 to 20 ppb with the detection limit of uranium in 0.05 ppb and the accuracy of ± 15%. (See pp. 58—61)