凤眼莲在炼油废水中的生长及其净化作用

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摘要 报道凤眼莲(*Eichhornia crassipes* Solms)在炼油废水中的生长状况，并对以COD为综合指标的污染物浓度之间的关系作了定量研究。结果表明：用凤眼莲生态工程处理炼油废水实施运行最佳控制条件为65 mg/L<[COD]<131 mg/L，临界有效点为[COD]=262.6 mg/L。

关键词 凤眼莲，炼油废水，净化。

凤眼莲是一种生长快，产量高，净化污水能力强的漂浮性水生植物[1-4]。以它为主在炼油废水氧化塘上建设生态工程，对废水可作进一步处理。然而大面积的应用前，需对凤眼莲在炼油废水中的适应能力，最佳适应条件进行系统科学的试验研究。旨在为工程实施和管理提供可靠依据。

1 材料与方法

1.1 凤眼莲种苗

来自江苏省植物所自然水塘，然后移至南京某炼油厂自来水池暂养半个月，使其正常生长繁殖。选择根系发达，大小均称，健壮无损的凤眼莲植株作为试验材料。试验前先用自来水冲洗植株2次，晾干后备用。

1.2 试验方法

试验采用实验室内连续培养法，即利用该厂已经隔油、浮选、曝气处理的炼油废水加自来水配制成若干浓度等级作为培养液，连续观察培养一个半月，并测定废水中有机物综合指标(以COD为代表)及凤眼莲生物量(鲜重)。试验在半径12 cm，表面积0.045 m^2，容积为8 L的瓷缸中进行。生物量资料采用4点法及Logistic方法拟合求解凤眼莲在炼油废水中的生长参数即内禀增长率(r)和种群容纳量(K)，并通过统计学方法建立内禀增长率(r)和废水COD浓度(用重铬酸钾法通过COD测定仪测量)以及种群容纳量(K)与COD的定量数学模型[2,5]。由于实验过程中炼油废水COD经常变动，因此计算过程中采用生长阶段的平均COD浓度为污染物指标。K、r的计算公式如下：

$$K=\frac{W_{02}W_{t1}W_{t2}+W_{01}W_{02}W_{t1}-W_{01}W_{t1}W_{t2}-W_{01}W_{02}W_{t2}}{W_{02}W_{t1}-W_{01}W_{t2}}$$

$$r=\frac{LN(W_t(K-W_0))-LN(W_0(K-W_t))}{t}$$

其中，W_{01}，W_{02}分别表示样方1及样方2在试验开始时的凤眼莲生物量(kg/m^2)；W_{t1}、W_{t2}则分别表示样方1和样方2在培养7 d后的凤眼莲生物量(kg/m^2)。

K、r值不随凤眼莲密度而变，但随外界环境因子而变，因此K、r为种群在一定生态条件下的固有特性。

2 试验结果

2.1 炼油废水对凤眼莲的毒性及伤害

2.1.1 炼油废水对凤眼莲的急性毒性

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试验结果见表 1。

表 1 表明，随着接触时间的增加，受伤叶片数越来越多，而且引起伤害的浓度范围也越来越低，因此炼油废水对凤眼莲具有明显的急性伤害作用。

2.1.2 炼油废水对凤眼莲的长期毒性作用

试验及调查结果见表 2、表 3。

表 2 表 3 表明，炼油废水污染物(COD)浓

表 1　炼油废水中短期培养凤眼莲叶片受伤情况[1)]

体积稀释比(污水：自来水)		8：0	6：2	4：4	2：6	1：7	0.8：7.2
接触 1d	平均 COD(mg/L)	545	408.7	272.5	136.2	68.1	54.5
	受伤叶数	3	0	0	0	0	0
接触 2d	平均 COD(mg/L)	443	332.2	221.5	110.7	55.4	44.3
	受伤叶数	5	1	0	0	0	0
接触 3d	平均 COD(mg/L)	580.7	435.5	290.3	145.2	72.6	58.1
	受伤叶数	8	2	1	2	2	0

1) 伤害症状为叶缘卷曲枯萎→发黄脱落

表 2　炼油废水对凤莲生长的长期影响

体积稀释比(污水：自来水)	8：0	6：2	4：4	2：6	1：7	0.8：7.2
平均 COD(mg/L)	525.1	393.8	262.6	131.3	65.6	52.5
24 d 后凤眼莲每株重量(g，鲜重)	42.9	64.3	57.1	93.7	62.5	75.0
34 d 后凤眼莲每株重量(g，鲜重)	35.7	57.1	60.7	106.2	75.0	90.0

表 3　炼油废水对凤眼莲根系的长期影响

体积稀释比(污水：自来水)	8：0	6：2	4：4	2：6	1：7	0.8：7.2
平均 COD(mg/L)	525.1	393.8	262.6	131.3	65.6	52.5
老根长(cm)	15		17	20	22	22.5
34 d 后新根长(cm)	3.7	4.0	6.3	12.5	12.5	14.6
34 d 后新根长/株高	0.26	0.33	0.36	0.81	0.93	1.04

度越高，新根的长度也越短，其占植株比也越小，个体重量也越轻，而且在 34 d 的培养中炼油废水平均 COD＞390 mg/L 时，凤眼莲植株越来越小(34 d 后植株个体较 24 d 时的个体小)，种群将逐渐衰亡，而当炼油废水平均 COD＜260 mg/L 时，经一定时间的驯化培养，凤眼莲植株个体大小可以逐渐提高(34 d 后个体重较 24 d 时的个体为重)。由此可见，长期生活于较高浓度炼油废水中的凤眼莲，其根系的生长及伸长被抑制，从而使凤眼莲根系分解有毒物质和吸收营养物质的能力减弱，植株个体也将趋小，种群逐渐消亡，不可能起到持续、稳定的净化作用，即随着时间的推移，净化作用也将逐渐消失。因此，控制凤眼莲生态氧化塘废水进水浓度是该生态工程成功的重要关键。

2.2 凤眼莲在炼油废水中内禀增长率(r)及种群容纳量(K)的测算

结果及与炼油废水 COD 浓度的定量关系测计结果见表 4。

表 4 表明，随着炼油废水 COD 浓度的升高，凤眼莲的 K、r 值均出现先上升后下降的极大值曲线，其原因估计是由于 COD 浓度高时毒性强，浓度低时营养状况较差的综合结果，因此影响 K，r 值的环境因子(这里主要是废水浓度)

表 4　炼油废水中凤眼莲的生长参数 K、r 值测计结果

体积稀释比(污水：自来水)	8：0	6：2	4：4	2：6	1：7	0.8：7.2
平均 COD(mg/L)	525.1	393.8	262.6	131.3	65.6	52.5
K(kg/m^2)	7.0[1)]	10.5	10.67	15.78	29.78	22.67
第一阶段 r_1(t=0－24 d)	0.069	0.111	0.064	0.030	0.022	0.030
第二阶段 r_2(t=24－34 d)	－0.166	－0.129	0.044	0.028	0.026	0.030

1) 估算值

在这里是一个最佳生长条件控制问题。

K，r 随炼油废水 COD 浓度变化曲线见图 1 和图 2。

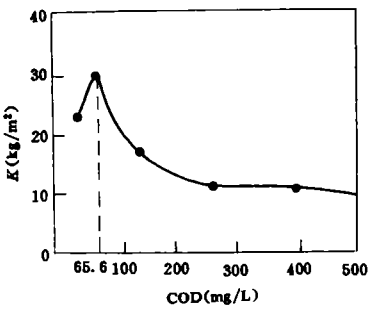

图 1 凤眼莲种群容纳量(K)与炼油废水 COD 关系

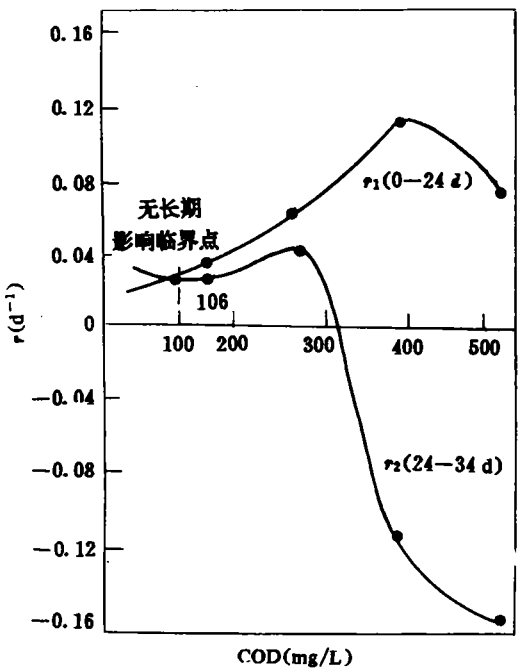

图 2 凤眼莲在第二个生长期内禀增长率(r)与炼油废水 COD 之关系

从图 1 和图 2 可确定几个毒性临界点：

(1) 当炼油废水 COD＞262.6 mg/L 时，将引起凤眼莲长期严重伤害，影响凤眼莲的长期生长，种群将逐渐消亡；当炼油废水 COD＜131.3 mg/L 时，炼油废水对凤眼莲基本上已无长期毒性作用，凤眼莲在经历一定时间的驯化后种群仍能得到一定的恢复。

(2) 炼油废水对凤眼莲无长期毒性临界点，COD 浓度的确定：当第二阶段 r_2＞第一阶段 r_1 时可以认为炼油废水对凤眼莲的长期毒性作用基本上消除。从图 2 可见，该临界点只可能出现在 COD＜300 mg/L 的区域内，据此对在 COD＜300 mg/L 的区域对 r-COD 关系作相关数学模型，经计算得：

$$r_1 = 0.019 \exp(0.0044[\mathrm{COD}])$$
$$([\mathrm{COD}] = 52.5 - 262.6\ \mathrm{mg/L})$$
$$r_2 = 0.024 \exp(0.0022[\mathrm{COD}])$$
$$([\mathrm{COD}] = 52.5 - 262.6\ \mathrm{mg/L})$$

当 $r_1 = r_2$ 时求解得：

$$[\mathrm{COD}] = 106.2(\mathrm{mg/L})$$

即 106.2 mg/L 为凤眼莲无长期毒性作用临界 COD。

3 结论

(1) 凤眼莲在炼油废水中生长时，炼油废水对其有明显的急性伤害及慢性长期毒性影响。

(2) 凤眼莲炼油废水中的 r，K 值随 COD 浓度的变化而变化，当 COD＜131 mg/L 时长期影响基本消除；当 COD＞263 mg/L 时，炼油废水对凤眼莲有严重长期毒性作用，经数值计算获得无长期影响临界 COD 浓度为 106.2 mg/L。

(3) 由于凤眼莲对炼油废水的耐受性有限，仅在 COD＜131 mg/L 时才能不受长期影响，而该值已达国家工业企业排放标准 GB8978-88 (150 mg/L)，所以凤眼莲生态工程处理炼油废水仅适合于出水要求更高的深度处理系统中，当然，若炼油废水 COD 控制在 260 mg/L 以下，尽管会对凤眼莲有一定慢性伤害，且种群量较小，但种群尚能有限地恢复而不致于衰亡，并起一定的净化作用，因此在这样的废水中仍能有限地生长并起到一定的净化作用。

(4) 凤眼莲生态工程处理炼油废水实施运行时最佳控制条件为 65 mg/L ＜[COD]＜131 mg/L，临界有效点为[COD]＝262.6 mg/L。

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protection. In addition, the environmental drag were used to explain the model's meaning as well as to discuss the measurement of the environmental drag.

Key words: social rate of return, private rate of return, elasticity of elasticity, environmental discount rate, environmental investment, environmenal improvement, environmental drag.

The Growth and Purification Function of *Eichhornia crassipes* Solms in Oil-refinery Wastewater. Tang Shuyu et al. (Institute of Botany, Jiangsu Province and Chinese Academy of Sciences, Nanjing 210014): *Chin. J. Environ. Sci.*, **17**(1), 1996, pp. 44—46

The growth of *Eichhornia crassipes* Solms in oil-refinery wastewater has been described in this paper. An influence of COD, a comprehensive index of the pollultant concentration in the wastewater, on the growth of *Eichhornia crassipes* Solms was quantitatively studied. It was found that an optimum working condition for treating oil-refinery wastewater by *Eichhornia crassipes* Solms eco-engineering is established as follows: 65 mg/L<[COD]<131 mg/L; and 262. 6 mg/L of COD at effective critical point.

Key words: *Eichhornia crassipes*, oil-refinery wastewater, purification.

Study on Method of Sister Chromatid Exchange in *Vicia faba* to Detect Environment Mutagen. Kong Zhiming et al. (Dept. of Environ. Sci. and Eng., Nanjing University, Nanjing 210093): *Chin. J. Environ. Sci.*, **17**(1), 1996, pp. 47—49

The experimental conditions of the Brdu-Feulgen method of SCE in *Vicia faba* root which include the content of Brdu, labelling time of Brdu, the impacts on SCE of the content of hydrochloric acid and time and temperatrue for hydrolysis were studied and discussed in this paper. The best experiment conditions and procedure, which overcome the short-comings of FPG method that is complicated in procedure and, hence, difficult to be popularized, were obtained. In addition, such method was compared with other genotoxicology method in order to probe into the possibility of utilizing such technology to detect environment mutagen.

Key words: *Vicia faba*, SCE, Brdu-Feulgen method.

A Pulse-feed Upflow Anaerobic Sludge Blanket Reactor. Su Yumin et al. (Dep. of Environ. Eng., Taiyuan Univeristy of Technology, Taiyuan 030024): *Chin. J. Environ. Sci.*, **17**(1), 1996, pp. 50—53

The key parts of Upflow Anaerobic Sludge Blanket Ractor are gas-solids separator and feed system. The goals of this research, in which a conventional continuous feed system was replaced by an intermittent pulse-feed one, are to provide gently hydraulic mixing, to promote hydraulic selection, and to improve the contact between substrate and microorganisms. Pulse-feed method can raise the orgainc load rate as high as 27. 5 gCOD/(L. d), reduce HRT to nearly 3 hrs, and quickly develop granulated sludge in 47 days. It can not cause shock load and intermediates accumulation, as every pulse only releases a small amount of wastewater (1/56 reactor volume), which can not raise the substrate concentration in whole reactor. The pulse-feed also can not cause sever wash-out of sludge, because pulse-feed mi-xing can effectively separate sludge flocs and entrapped gas bubbles, and hence improve sludge settleability. The advantages of enrichment of *methanosarcina* species in the process of granulation are also discussed. At high load rate, *methanosarcina* species do appear in clumps on the granules.

Key words: anaerobic digestion, UASB, pulse-feed, mixing, granulation, *methanosarcina* species.

Study on Biological Pretreatment Method-bio-ceramic Reactor Treating Micro-pollution Source Water at Low Temperature and Low Turbidity. Hu Jiangyong et al. (Dept. of Environ. Eng., Tsinghua Univ., Beijing 100084): *Chin. J. Environ. Sci.*, **17**(1), 1996, pp. 54—56

One of biological pretreatment methods-bio-ceramic reactor (BCR) was used to treat a typical source water with micro-pollution at low temperature and low turbidity. By means of in-situ experiments with the bio-ceramic reactor, it was found that: the organic matter (OC or COD), ammonia, SS in the source water could be removed about 20%—30%, 60%—70% and 80%, respectively. Removl efficiency could be reduced at low temperature. Low turbidity and high concentration of organics in the source water would be benifical to BCR. In general, BCR would be a powerful way to purificate this kind of source water.

Key words: micro-pollution, source water, low temperature, low turbidity, organics, bio-ceramic pretreatment process.

Studies on the Leaching and Species of Aluminum in Soil. Huang Yanchu and Qu Changling (Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085): *Chin. J. Environ. Sci.*, **17**(1), 1996, pp. 57—59

The leaching and chemical forms of aluminum in soil by sequential fraction procedure were studied. Solutions used sequentially to extract Al are inorder of 1 mol/L KCl, 1 mol/L NH_4Ac, 1 mol/L HCl and 0. 5 mol/L NaOH. The spectrophotometric determination of leaching Al was performed with Eriochrom Cyamine RC. It has been found that the type of soil and the amounts of organic materials and total Al in soil have a siginificant effect on the amount of leaching Al. A certain amount of exchangeable Al can be leached from acid soil with 1 mol/L KCl extractant, however, it can not be leached from alkaline soil. The leaching Al extracted with 0. 5 mol/L NaOH is correlated at a high level of siginficance with the total Al in soil.

Key words: soil, leaching aluminum, chemical form.

Efficiency of Fluidized Biofilm Method for Treating Phenolic Wastewater. Yin Jun et al. (Jilin Architechtural and Civil Eng. Institute, Changchun 130021): *Chin. J. Environ. Sci.*, **17**(1), 1996, pp. 60—62

A dynamic experiment was conducted to examine the efficiency of the fluidized biofilm method with home-made carrier for treating phenolic wastewater. The experimental results have shown that COD and phenol were removed on an average over 80% and 90%—100%, respectively, while COD volumetric loading is 4. 0 kg/(m^3·d), and the final concentrations of COD and phenol in the effluent can meet Chinese Standard of Wastewater dischange permission. The biofilm can adhere quickly to the home-made carrier and the thickness of biofilm is suitable