大气污染植被控制模型及应用

——以湖南省益阳市为例*

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摘要 以野外监测数据为基础，应用模糊综合评判方法掌握大气污染物的变化规律，然后采用熏气试验测定植被对污染物的净化速率，建立大气污染物的植被控制模型，并以此提出了益阳市大气主要污染物的植被负荷及绿化设计.

关键词: 大气环境质量;植被控制模型;模糊综合评价;绿化设计.

通过对益阳市大气环境状况一年的监测，应用模糊数学进行分析与综合评价，掌握了该市大气环境污染变化规律. 在野外调查、室内熏气试验的基础上筛选出高效净化树种，获得了植物对 SO_2 的净化速率(α). 据此建立了益阳市大气主要污染物——SO_2 的植被控制模型.

$$f = 2.2200 \times 10^{-4}(\bar{c}_i - \bar{c})\alpha^{-1} \cdot h$$

式中，$\bar{c}_i$ 为大气污染物实际监测浓度 (mg/m³)，$\bar{c}$ 为执行允许的标准浓度，α 为植物对 SO_2 的净化速率 (g/100g 鲜叶重)，h 为城区大气混合层污染物浓度达到 $\bar{c}_i$ 时的最大高度. 然后，在模型指导下，对该市的绿化树种、绿化格局进行了设计. 同时根据模型提出了该市 SO_2 大气浓度的警戒值及植被的负荷值，从而为大气污染物的排放管理、城市园林绿化目标提供了科学的、定量的依据.

一、益阳市环境概况

益阳市位于湘中偏北、资水下游，洞庭湖之滨；约处东经 112°30′、北纬 28°26′，属于中亚热地区，全市城区面积 10.27km²，城区人口 15 万.

该市现状绿化较差，人均公共绿地仅有 0.37m²，覆盖率不到 9.00%. 主要绿化树种比较简单，法国梧桐 (*Platanus acerifolia Willd*)、香樟 (*Cinnamonmum camphora* (*L.*) *Presl*) 构成骨干树种. 此外女贞 (*Ligus lucidum Ait*)、泡桐 (*Paulownia fortunei Hemsl*)、七厘香 (*Euongmus japonica L.*)、夹竹桃 (*Nerium indicum Mill*)、小叶黄杨 (*Buxus harlandii Hance*) 雪松 (*Cedrus deodara G. Don*)、小叶冬青 (*Ilex micrococca Maxim*) 也有一定的栽培.

该市大气污染主要分布在两处：龙山巷工区是污染最为严重的地区，位于市西南，地区氮肥厂、市化肥厂是该区的污染大户，主要是 SO_2、NO_x 污染；另一处是大海塘——三里桥工业区，位于市东南，主要是化工和纺织行业排出的 SO_2、烟尘污染. 除此之外桥北大码头商业区、桥南汽车南站交通密集区的 NO_x、降尘污染也比较严重.

二、益阳市大气环境质量的模糊评价

(一) 步骤

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1. 评价因子的选择

根据以前监测数据和污染普查结果，认定对大气环境质量影响较大的几个主要因子是：SO_2、NO_x、TSP、降尘。因此，我们选取这四项作为评价因子。

2. 监测点的布设

根据区域功能特点和环境质量基本一致的原则划分 10 个小区，每个小区取具有代表性的地点设立监测观察点。

3. 监测方法及结果

根据国家环保局颁发的标准对上述 10 个点的 4 项指标进行了一年的监测分析，共获得数据 3200 个。

（二）结果分析

1. 构造小区的模糊矩阵

设：$\{U_i \ i = 1、2、3、4\}$ 为污染因子集 ⇒ {SO_2、NO_2、TSP、降尘}

又设：$\{V_i \ \ i = 1、2、3、4\}$ 为环境质量评语集 ⇒ {一级、二级、三级、四级}

又设：$\underset{\sim}{R_j}(j = 1、2、3\cdots\cdots10)$ 为污染因子集与环境质量评语集构成的 4×4 的模糊矩阵：$\underset{\sim}{R_j} = (U_i)^{-1} \cdot (V_i)$

再设 $\underset{\sim}{A}$ 为权重模糊矩阵

则 $\underset{\sim}{B_j} = \underset{\sim}{A} \circ \underset{\sim}{R_j}$

2. 各小区环境质量综合评价结果

$$\underset{\sim}{R_1} = \begin{pmatrix} 0.19 & 0.28 & 0.10 & 0.44 \\ 0.38 & 0.50 & 0.11 & 0.12 \\ 0.15 & 0.10 & 0.20 & 0.55 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$\underset{\sim}{R_2} = \begin{pmatrix} 0.55 & 0.22 & 0.13 & 0.10 \\ 0.63 & 0.23 & 0.05 & 0.08 \\ 0.20 & 0.05 & 0.15 & 0.16 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$\underset{\sim}{R_3} = \begin{pmatrix} 0.72 & 0.16 & 0.07 & 0.05 \\ 0.83 & 0.15 & 0.02 & 0 \\ 0.24 & 0.14 & 0.10 & 0.53 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$\underset{\sim}{R_4} = \begin{pmatrix} 0.55 & 0.27 & 0.14 & 0.65 \\ 0.44 & 0.43 & 0.13 & 0.01 \\ 0.20 & 0.11 & 0.15 & 0.47 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$\underset{\sim}{R_5} = \begin{pmatrix} 0.40 & 0.22 & 0.13 & 0.25 \\ 0.48 & 0.30 & 0.10 & 0.12 \\ 0.20 & 0.11 & 0.10 & 0.59 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$\underset{\sim}{R_6} = \begin{pmatrix} 0.77 & 0.17 & 0.02 & 0.05 \\ 0.78 & 0.20 & 0.02 & 0 \\ 0.45 & 0.28 & 0.15 & 0.13 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$\underset{\sim}{R_7} = \begin{pmatrix} 0.39 & 0.30 & 0.11 & 0.20 \\ 0.59 & 0.30 & 0.08 & 0.64 \\ 0.45 & 0.28 & 0.15 & 0.13 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$\underset{\sim}{R_8} = \begin{pmatrix} 0.54 & 0.30 & 0.06 & 0.11 \\ 0.30 & 0.30 & 0.21 & 0.19 \\ 0.30 & 0.80 & 0.15 & 0.75 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

$$\underset{\sim}{R_9} = \begin{pmatrix} 0.64 & 0.25 & 0.03 & 0.09 \\ 0.78 & 0.13 & 0.09 & 0 \\ 0.20 & 0.17 & 0.12 & 0.51 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$\underset{\sim}{R_{10}} = \begin{pmatrix} 0.75 & 0.14 & 0.05 & 0.06 \\ 0.70 & 0.19 & 0.04 & 0.01 \\ 0.45 & 0.28 & 0.15 & 0.13 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

$$\underset{\sim}{B_1} = (0.19 \ 0.28 \ 0.20 \ 0.35)$$

$$\underset{\sim}{B_2} = (0.35 \ 0.22 \ 0.15 \ 0.30)$$

$$\underset{\sim}{B_3} = (0.35 \ 0.15 \ 0.10 \ 0.30)$$

$$\underset{\sim}{B_4} = (0.35 \ 0.27 \ 0.18 \ 0.30)$$

$$\underset{\sim}{B_5} = (0.35 \ 0.22 \ 0.13 \ 0.03)$$

$$\underset{\sim}{B_6} = (0.35 \ 0.28 \ 0.20 \ 0.15)$$

$$\underset{\sim}{B_7} = (0.35 \ 0.30 \ 0.15 \ 0.20)$$

$$\underset{\sim}{B_8} = (0.30 \ 0.20 \ 0.20 \ 0.30)$$

$\underset{\sim}{B_9}$ = (0.35 0.25 0.12 0.30)

$\underset{\sim}{B_{10}}$ = (0.35 0.28 0.20 0.13)

在综合考虑 4 个污染因子的情况下对各小区的大气环境质量评价，(S_i: 小区编号)以 S_1、S_6、S_2、S_3、S_4、S_5、S_9、S_7、S_8、S_{10} 的顺序，环境质量逐渐转好.

3. 小区环境质量模糊聚类分析

取各小区污染因子的日均浓度，采用绝对减数方法建立模糊关系矩阵 $\underset{\sim}{R}$，利用传递闭包方法作变换，然后取一定水平进行聚类，结果如下：

$$\underset{\sim}{R^4} \circ \underset{\sim}{R^4} = \underset{\sim}{R^8} = \begin{bmatrix} 1 & 0.93 & 0.73 & 0.70 & 0.69 & 0.94 & 0.73 & 0.73 & 0.91 & 0.73 \\ 0.93 & 1 & 0.73 & 0.70 & 0.67 & 0.93 & 0.73 & 0.73 & 0.91 & 0.73 \\ 0.73 & 0.73 & 1 & 0.70 & 0.67 & 0.73 & 0.98 & 0.93 & 0.73 & 0.98 \\ 0.70 & 0.70 & 0.70 & 1 & 0.67 & 0.70 & 0.70 & 0.70 & 0.70 & 0.70 \\ 0.67 & 0.69 & 0.67 & 0.67 & 1 & 0.67 & 0.67 & 0.67 & 0.67 & 0.61 \\ 0.94 & 0.93 & 0.73 & 0.70 & 0.67 & 1 & 0.73 & 0.73 & 0.91 & 0.73 \\ 0.73 & 0.73 & 0.98 & 0.70 & 0.67 & 0.73 & 1 & 0.93 & 0.73 & 0.99 \\ 0.73 & 0.73 & 0.93 & 0.70 & 0.67 & 0.73 & 0.93 & 1 & 0.73 & 0.93 \\ 0.91 & 0.91 & 0.73 & 0.70 & 0.67 & 0.91 & 0.73 & 0.73 & 1 & 0.73 \\ 0.73 & 0.73 & 0.98 & 0.70 & 0.67 & 0.73 & 0.99 & 0.93 & 0.73 & 1 \end{bmatrix}$$

取 $0.91 \leqslant \lambda \leqslant 1$ 可知：

{1}、{2}、{10}、{3、4、5}、{6、7、8、9}

三、大气污染物植被控制模型

(一) 树种筛选

从上面的分析可知影响益阳市大气环境质量的主要因素是 SO_2，因此，我们根据因地制宜，适地适树原则选用绿化用的主要乔灌木进行 SO_2 熏气试验，测定其对 SO_2 的吸收率，观察其抗污染能力，为建立 SO_2 植被控制模型提供依据.

1. 熏气方法

用动态闭项式人工熏气箱输入人为生成的 SO_2 气体，分三个时间 (2、4、8h)、三种浓度(安全浓度、可恢复浓度、致死浓度)对植物进行熏气试验. 灌木树种采用三年生盆栽苗，乔木树种采用非离体健康枝条，在光合时间进行熏气.

2. 熏气结果

植物熏气结束后，立即采叶分析 SO_2 含量，熏气前后 SO_2 含量差的绝对值除熏气时间得吸收率. 表 1 为所筛选树种的熏气结果.

(二) 模型的建立

对城市来说植被系统无疑是污染物的一个重要"库". 植被群落和污染物种类不同，该"库"的容量大小亦不同. 熏气筛选高效防污净化树种，同时优化栽植比例形成合理立体格局无疑能使污染物的"植被库"得以扩大. "植被库"的大小最终反映在群体质量和城区覆盖率上. 建立益阳市大气环境执行浓度与覆盖率之间的关系称为植被控制模型. 其建模假设：城区大气环境超标的排放量全部为植被吸收.

1. 植被群体吸收率的确定 通过试验：测得单个树种的吸收率，根据绿化结构的要求各树种的混种比例系数为 β，则：

$$\alpha = \sum_{i=1}^{k} \beta_i \cdot \alpha_i \qquad (1)$$

式中 α 为植被群体吸收率，β_i 为结构比例系数，α_i 为各树种吸收净化率，k 为树木种类数.

2. 植被群体单位面积上鲜叶重量

$$g = A \cdot f \qquad (2)$$

式中 g 为一定面积上鲜叶重量 (t/km^2)，f 为覆盖率，A 为常数，反映群体的结构与质量特

表 1　主要绿化树种 SO_2 吸收率

树种* \ 吸收率	吸收率(g/100g 鲜叶重·单位光合时间)		安全浓度 (mg/m³)
	最大吸收率	最小吸收率	
法国梧桐	0.5250×10^{-2}	4.000×10^{-3}	0.5490
海桐	5.900×10^{-2}	4.500×10^{-3}	0.6825
山胡椒	4.400×10^{-2}	5.250×10^{-3}	0.9450
泡桐	2.750×10^{-2}	5.260×10^{-3}	0.6990
女贞	2.850×10^{-2}	2.550×10^{-3}	0.9450
香樟	1.750×10^{-2}	5.550×10^{-3}	0.5490
雪松	1.300×10^{-2}	5.000×10^{-4}	0.4200
柏树	4.000×10^{-3}	1.500×10^{-3}	0.9540
油茶	5.500×10^{-3}	2.750×10^{-3}	0.5490
七厘香	1.200×10^{-2}	4.250×10^{-3}	0.9450
夹竹桃	1.180×10^{-2}	2.000×10^{-3}	0.9550
小叶黄杨	2.050×10^{-2}	3.750×10^{-3}	0.5490

* 树种的拉丁学名如下(第一次出现者): 油茶 (*Camella oleifera Abel*), 柏树 (*Cupressus orientalis France*). 海桐 (*Pittosporum tobira Ait*)、山胡椒 (*Osmanthus fragrans Lawy*).

征，即某一类型的植被在一定的郁闭状态下单位面积上的鲜叶重量大致相同。

3. 模型的建立

根据前面的假设，我们有下列关系式：

$$g\cdot S\cdot\alpha=10^{-1}\cdot s\cdot h(\bar{c}_i-\bar{c})$$

将(1)、(2)式代入上式并统一单位整理后：

$$f=10^{-1}h\cdot(A\cdot\alpha)^{-1}\cdot(\bar{c}_i-\bar{c})\qquad(3)$$

(3)即为我们所要求得的控制模型。

(三) 模型应用

1. 益阳市绿化总体目标的确定

在以上所选的十二种植物等比例（不是个体数，而是构成群体后的鲜叶重量）造林绿化市区，待3—5年以后(2)式中 A 可达 $4.5045\times10^{2}(t/km^2)$（根据实际测定而得），(1) 式中 $\alpha=3.4880\times10^{-3}$(表 1 中最小吸收率的平均值，为了保险起见，取最小吸收率)，h 为 100m（根据市环保局的监测数据），$\bar{c}_i$ 为 0.1345 mg/m³（市环保局监测数据）、$\bar{c}$ 为 0.05mg/m³（国家颁发的一级大气环境质量允许的 SO_2 浓度)，将以上各值代入(3)式得 $f=54\%$。这就说明在目前的污染状况下，按照前述的绿化原则和标准，到达 54% 的覆盖率则大气环境质量可望恢复到一级水平。

2. 城区各片的绿化树种与 α 值标准

3. 植被的 SO_2 负荷

(1) 大气浓度的警戒值由(3)式变换得：$c_i=10\cdot h^{-1}\cdot f\cdot A\cdot\alpha+\bar{c}$。这里 $\bar{c}_i$ 就是 SO_2 浓度的允许值，也即警戒值，如浓度超过此值，将使大气环境质量不符合国家标准，且会造成植物大量死亡。

(2) SO_2 排放阈值 (δ) $\delta=A\cdot f\cdot s\cdot\alpha\cdot t$

式中 t 为光合作用时间，s 为市区面积。其它字母意义同上。该公式告诉我们如果只考虑污染物的植物净化作用（当然实际情况往往还有许多其它作用)，那么益阳市 SO_2 年排放量计算如下：

$$\delta=A\cdot f\cdot s\cdot\alpha\cdot t(s{:}10\times10^{6}(m^2),$$
$$t=12\times365(h))=450.45\times0.540$$
$$\times10\times10^{6}\times3.488\times10^{-5}\times365$$
$$\times12=371.61(t/a).$$

4. 重点污染区的绿化设计

根据前面的分析结果可知，益阳市的重点污染区 1 号龙山巷工业区是最为严重的污染区，地、市两个氮肥厂是主要污染源，两厂距离较近，位置相似，可以类似处理。两厂直接影响邻近几个小区的环境质量，因此，解决了该区的污染问题不仅消除了益阳市的排污大户，为解决好其它地区提供方便，更提供了解决污染问题的植物方法示范。

该区的绿化要求 α 值在表2中已经给出，由于浓度较高，所以绿化质量要求相当高，不仅要选择抗污强的树种，而且要多层建立绿化带，从水平与空间两个角度使林带结构复杂化，同时要提高郁闭度使 A 值加大。下面就造林位置作设计。

根据高斯公式计算两厂烟囱扩散地面最大浓度出现的距离：

$$X_{max}=\left(\frac{H_e}{\gamma_2}\right)^{\frac{1}{\theta_1}}\cdot\left(1+\frac{\theta_2}{\theta_1}\right)^{-\frac{1}{2\theta_1}}$$

表 2 各小区绿化设计(单位同前所述)

污染区名称	$\bar{c}_i$	$\bar{c}$	要求 α^*	建议树种	植被 α^*
1 龙山巷区	0.445	0.150	1.213×10^{-2}	提高A值	/
2 豆腐店区	0.307	0.150	6.453×10^{-3}	泡桐、法桐、樟树	4.937×10^{-3}
3 农药厂区	0.175	0.150	1.028×10^{-3}	法桐、樟树、雪松	3.350×10^{-3}
4 南汽站区	0.151	0.150	4.151×10^{-3}	法桐、泡桐、樟树	4.937×10^{-3}
5 大码头区	0.109	0.050	2.425×10^{-3}	法桐、七厘香、樟树 泡桐、女贞	3.912×10^{-3}
6 市三中区	0.127	0.050	3.165×10^{-3}	樟树、雪松、夹竹桃 泡桐、女贞	3.172×10^{-3}
7 地党校区	0.115	0.05	2.672×10^{-3}	雪松、泡桐、女贞、小 叶黄杨、七厘香	3.262×10^{-3}
8 广播局区	0.218	0.05	6.904×10^{-3}	法桐、泡桐、雪松、女 贞、樟树	3.572×10^{-3}
9 工具厂区对照区	0.198 0.045	0.15 0.05	1.973×10^{-3} 清洁	油茶、山胡椒、法桐 /	4.00×10^{-3} /

* 要求 α 表示满足 $\bar{c}$ 标准所要求的植被群体应具备多大的吸收率；植被 α 表示用建议树种进行绿化时植物群体的吸收率.

上式中，X_{max} 为最大浓度出现的距离，H_e 为烟囱抬升高度和实际高度之和，经计算为 64.44m，θ_1、θ_2、r_2 为有关气象参数，在不同的大气稳定度下可以查表而得. 根据以上公式的计算结果和益阳市25年统计的风频玫瑰图寻得风频最大的方向后，在厂区北向 751.76m 处厂区北向 1134.10m 处营造绿化屏障(重点)为最佳位置.

四、小 结

全文就益阳市的大气环境质量，改善环境质量的植物措施进行了评价和探索. 用模糊综合评判方法对环境质量进行评价，把城市绿化与环境保护结合起来且模型化，数量化进行了偿试和摸索，但这些工作及其结果都是初步的，有待进一步提高、检验和发展.

参 考 文 献

[1] 朱忠保，林业科学，19(2)，54(1983).
[2] 贺仲雄，模糊数学，第四章，天津科学出版社，1984年.
[3] 李宗恺等，空气污染气象学原理与应用，第四章，气象出版社，1985 年.
[4] 浓铎等，空气污染与控制，107 页，中国环境科学技术出版社，1985 年.

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Influence of Traffic Noise on Teaching and the Teachers and Students' Health. Wang Shaohan, Cai Lina (Beijing Medical University); Yan Hui (Sanitation and Antiepidemic Station of Haidian District, Beijing); Han Yuntao (Kunming Medical College, Yunan Province): *Chin. J. Environ. Sci.*, **11**(4), 1990, pp. 2—7

This paper deals with a study on health standard of noise in the classrooms. Among the primary and middle schools in Beijing, Tianjin and Kunming, twenty two campuses were selected for monitoring noise. The campuses were devided into three groups according to the noise levels they suffered from traffic noise. Group A, composed of 8 campuses, was quiet (L_{10} less than 50dB); group B, 8 campuses, noisier (61 dB); group; C, 6 campuses, nodsiest (71 dB). The teachers' voice would get louder with noise level getting higher in the classrooms. The incidence of symptoms in the teachers' vocal cords and the studenrs' psychological reactions were investigated as indices. The differences between group A and groups B and C were obvious or very obvious in accordance with statistical examination. The results demonstrated that traffic noise had affected teaching activities and people's health of groups B and C. So it is suggested that 50 dB as L_{10} of noise in the classrooms be appropriate to formulation of the health standard of noise in the classroom.

Key Words: traffic noise, health standard, classroom.

Removal of Volatile Halohydrocarbons in Sewage by Rapid Infiltration of Land Treatment. Xu Meizhen(Beijing Municipal Institute of Environmental Protection Sciences): *Chin. J. Environ. Sci.*, **11**(4), 1990, pp.7—11

This paper focuses on the efficiency of removing volatile haloid organic compounds from sewage with the method of land infiltration, which was compared with six usual treatment techniques. The results showed that land infiltration method was more effective.

Key Words: rapid infiltration, land treatment, sewage, volatile halohydrocarbons.

Application of Environmental Effective Coefficient Matrix Method to the Research of the Optimal Pollution-Control Strategy for Urban Energy. Fang Dong, Wang Yaqiu (Institute of Nuclear Energy, Tsinghua University): *Chin. J. Environ. Sci.*, **11**(4), 1990, pp.11—18

This paper presents a method to explain the interaction between energy and the environment in investigating into the optimal pollution-control strategy in cities. The method is called environmental coefficient matrix method. Its definition and generation of the matrix are formulated in detail. In a cese study, the method has been used in the comprehensive assessment of energy on environmental impact in Harbin, a large city in Northeast China. It focuses on control strategy of air pollution caused by energy conversion and energy comsumption. The result illustrates the method available.

Key Words: optimal pollution-control stragy, energy and environment, coefficient matrix.

Study on Chemical Stability of Heavy Metals in the Xiangjiang River. Luan Zhaokun, Tang Hongxiao (Research Center for Eco-Environmental Sciences, Academia Sinica, Beijing); *Chin. J. Environ. Sci.*, **11**(4), 1990, pp.18--25

In order to evaluate the chemical stability of heavy metals in the polluted river, a series of static and dynamic simulated experiments under different conditions has been performed with the sediment samples collected at S_1—S_5 sections in the Xiangjiang River. The content of metals and their releasing rates from sediments were obtained in the model experiment, and then the process of chemical transformation and transfer between sediment and water were discussed. The results showed that heavy metals in the River revealed higher chemical stability and their releasing contents in the polluted sediments were very limited.

Key Words: simulated experiments, heavy metals, chemical stability.

A Model Designed for Vegetation Controlling Air Pollution in Yiyang City. Wen Jianping (Research Center for Eco-Environmental Sciences, Academia Sinica, Beijing): *Chin. J. Environ. Sci.*, **11**(4), 1990, pp.26—30

According to the results of monitoring air pollution factors for one year in Yiyang City, Hunan Province, the variations of atmospheric environment were clarified by means of fuzzy mathematics. Meanwhile the artificial fumigation tests were carried out to select the higher tolerant plants and to measure the pollutant-absorption rate. In consideration of these factors, a vegetation controlling model for air pollution was put forward.

$f = 2.22 \times 10^{-4}(\bar{C}_i - \bar{C}) \cdot \alpha^{-1} \cdot h$ f——plant cover ratio; α^{-1}——SO_2-plant absorption rate; h——height of air mixing layer; $\bar{C}_i$——real concentration; $\bar{C}$——

standard concentration.

Directed by the model, the plant species and afforestation pattern were designed, and the capacity of plants for SO_2 and the amount of SO_2 released in Yiyang were established.

Key Words: model, vegetation, control, air pollution.

The Avoidance of Eel Larvae (*Anguilla japonica* Tem. et Schl.) in the Solution Containing Copper Ions. Zhn Jiang (Institute of Zoology, Academia Sinica, Beijing): *Chin. J. Environ. Sci.*, **11**(4), 1990, pp.31—34

Theavoidance of ell larvae (*Anguilla japonica*) in the solution containing copper sulfate (as Cu^{2+}) has been studied in a flowing water system under the laboratory conditions: water temperature 16.5 C, pH 7.43, water hardness ($CaCO_3$ and others contained) 220 mg/L and saturation of DO 62—68%. The larvae used for the experiment were collected from the Minjiang River, Fujian Province. Their lengths ranged 46—69.5 mm, and their weights 174—227 mg. The experiment illustrated that the ell larvae was highly sensitive to copper, because the avoidance action was obserbed at the level of 0.001 ppm of copper ions. However, below the level of 0.001 ppm, the avoidance was not so obvious, but the larvae all avoided the test solution as its concentrations increased to 0.064 ppm. The results indicated that the concentrations of avoidance against copper was much lower than that of MATC derived from acute toxicity test.

Key Words: avoidance, eel larvae, (*Anguilla japonica*). copper.

Estimation of Fishery Losses Caused by Water Pollution in a Country of Jiangsu Province. Ge Jigi (Department of Agricultural Economics, Nanjing Agricultural University): *Chin. J Environ. Sci.*, **11**(4), 1990, pp. 34—37

Based on the fundamental principles of environmental economics, the fishery losses caused by water pollution in the area can be calculated in three parts: loss of resources, loss of accidents and expense of protection from pollution impact. The calculative methods of the said every items of losses and a case study are also presented, according to the author.

Key Words: fishery losses, water pollution.

Improvement of Removing Rate of Nitrate in Drinking Water with the CARIX Process. Gong Wenli (Institute of Nuclear Energy Technology, Tsinghua University): *Chin. J. Environ. Sci.*, **11**(4), 1990, pp.38—41

The paper describes treatment of drinking water using CARIX ion exchange process. The combined application of a weakacid ion exchanger in the free acid from and an anion exchanger in the bicarbonate from provides a combined removal of nitrate, sulfate and hardness from drinking water. Carbon dioxide is used for the simultaneous regeneration of both resins. In order to improve the regeneration efficiency of nitrate, the application of additives like $CaCO_3$ or MgO has been studied. The dosage of different quantities of MgO has been investigated with respect to an optimization. MgO should be added at the concentrations above 0.4%. Eurthermore, the usual mixed bed was compared with a compound bed, consisting of several short single beds. Under the raw water conditions of the test, over 50 BV of water could be treated, whereas regeneration required about 5 BV of water.

Key Words: CARIX process, nitrate, drinking water.

Research on the Starting Conditions of An Anaerobic Digester. Xu Chunlan, Yan Dacheng, Wu Chibo (Department of Environmental Engineering, Huangshi University, Hubei Province): *Chin. J. Environ. Sci.*, **11**(4), 1990, pp. 42—48

The primary intent of this research is to explore optimal starting conditions of an anaerobic digester. Anaerobic treatment of wastewater has many advantages, but it takes a long time for the digester to start running, so that the equipment cannnot bring into full play. The authors investigated starting conditions of anaerobic treatment in a acitric acid factory, found that the conditions were optimized by using orthonal design. The experimental results were applied to the industrial equipment for treating wastewater and got a satisfactory benefit.

Key Words: starting conditions, anaerobic digester.

Automatic and Continuous Determination of Aromatic Compounds in the Ambient Air Using Capillary Column Gas Chromatograph. Wulan Sendan, Tong Qing, Liu Yansen (Inner Mongolia Monitoring Center for Environmental Protection, Huhehot): *Chin. J. Environ. Sci.*, **11**(4), 1990, pp.49—53

An automatic and continuous analysing device of aro-