

## 调查与评价

# 用计算机模糊综合评价环境质量

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**提要** 本文从通用线性隶属函数出发,建立了环境质量综合评价的模糊数学模型,并进行程序设计,在 IBM PC 计算机上成功地实现了武汉市大气环境质量的模糊综合评价。

自六十年代以来,国内外对环境质量综合评价进行了大量的研究工作,为环境管理,环境规划和决策提供了依据。然而,经典环境质量评价的缺陷在于它采用了精确数学的模型,公理化地认为环境可以抽象为用精确数学语言和逻辑来描述的理想系统。事实上,环境是一个多因素、多层次的复杂动态系统,污染与否、质量优劣等等都不可能存在经纬分明的界限。为更客观地反映环境的本来面目,引入模糊集合论思想,应用模糊评价方法已成为必要和必然。

用计算机来实现模糊环境质量综合评价,不仅可以快速、准确、方便地处理大量信息,而且能直观生动地绘出环境质量图或环境质量变迁图。通过输入不同的模糊算子,比较评价结果,还可以帮助我们进一步认识环境系统内部的决定性、随机性和模糊性。

### 一、数学模型

设:

$U = \{u_1, u_2, \dots, u_m\}$  为环境参数集合;

$V = \{v_1, v_2, \dots, v_n\}$  为评语集合;

$A = (a_1, a_2, \dots, a_m)_{1 \times m}$  为权重矩阵。

$m$  为选择的环境参数个数,  $n$  为评语等级数。

对单要素进行评判,得单要素评判矩阵:

$R = (r_{ij})_{m \times n}$   $r_{ij}$  表示从第  $i$  个参数着眼,对被

评为  $V_j$  级的隶属度。

综合评判得综合评判矩阵:

$$B = A \circ R = (b_j)_{1 \times n}$$

1.  $A$  的获得:

$$a_i = \frac{\frac{c_i}{\bar{s}_i}}{\sum_{i=1}^m \frac{c_i}{\bar{s}_i}}, \quad \sum_{i=1}^m a_i = 1.$$

$\bar{s}_i$  为第  $i$  项参数的平均质量标准,  $c_i$  为监测浓度。

### 2. $R$ 的计算

本文按照国家标准(《大气环境质量标准》(GB 3095-82)、《地面水环境质量标准》(GB3838-83)、《海水水质标准》(GB3097-82)) 将环境质量分为三级(即  $n = 3$ ),各级之间的界线用下述线性关系描述:

$$r_{i1} = \begin{cases} 1, & c_i < s_{i1} \\ \frac{c_i - s_{i2}}{s_{i1} - s_{i2}}, & s_{i1} \leq c_i \leq s_{i2} \\ 0, & c_i > s_{i2} \end{cases}$$

$$r_{i2} = \begin{cases} 0, & c_i < s_{i1} \\ \frac{c_i - s_{i1}}{s_{i2} - s_{i1}}, & s_{i1} \leq c_i \leq s_{i2} \\ \frac{c_i - s_{i3}}{s_{i2} - s_{i3}}, & s_{i2} < c_i < s_{i3} \end{cases}$$

$$r_{i3} = \begin{cases} 0, & c_i \leq s_{i2} \\ \frac{c_i - s_{i2}}{s_{i3} - s_{i2}}, & s_{i2} < c_i \leq s_{i3} \\ \left[ \frac{c_i}{s_{i3}} \right], & c_i > s_{i3} \end{cases}$$

$s_{i1}$ 、 $s_{i2}$ 、 $s_{i3}$  分别为  $i$  项参数的一级、二级、三级质量标准。

### 3. $B$ 的获得

$B = A \circ R$ , “ $\circ$ ” 的运算可选用不同的算子:

①. Zadeh 算子

$$b_j = \bigvee_{i=1}^m (a_i \wedge r_{ij})$$

“ $\wedge$ ”、“ $\vee$ ”的算法是:

$$c \wedge d = \min(c, d)$$

$$c \vee d = \max(c, d)$$

②.  $\odot \oplus$  算子

$$b_j = \bigodot_{i=1}^m (a_i \oplus r_{ij})$$

“ $\odot$ ”、“ $\oplus$ ”的算法是:

$$c \oplus d = \min(c + d, 1)$$

$$c \odot d = \max(c + d - 1, 0)$$

Zadeh 算子的清晰域、“与或”度均为 0, 是一对最“模糊”的算子;  $\odot \oplus$  算子的清晰域、“与或”度均为 0.5, 介于最模糊与最清晰算子之间。这两个算法具有较强的代表性。

4. 结果表示——环境质量图和环境质量变迁图

设有  $N$  个监测点位, 在  $B-N$  图上描出每个点位对应的三个质量级别的隶属度 (已归一化处理), 将属于同一级别的点连在一起, 就得到环境质量图 (图 1)。若横坐标以时间  $t$  表示, 得到的是环境质量变迁图 (图 2)。

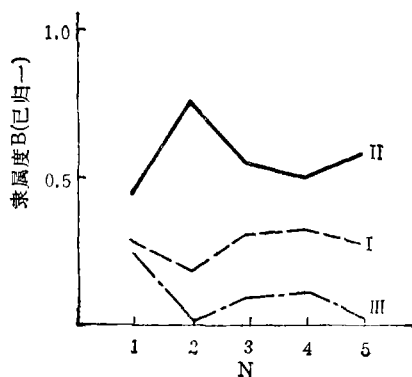


图1 环境质量图

## 二、程序设计

### (一) 程序说明:

1. 本程序适用于大气、地面水、海水水质评价。由于模型的通用性广泛, 只需增加新的数据库就可对土壤、地下水等环境单元进行综合评价。

2. 本程序既可进行横向多点位的环境质量现状评价, 又可进行纵向的环境质量变迁评价, 了解环

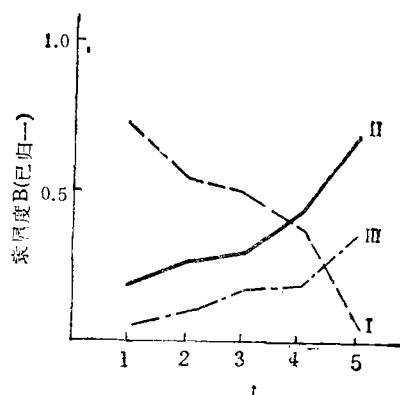


图2 环境质量变迁图

境质量的过去、现状, 并借此预测、预报未来的变化趋势。

3. 本程序提供多种算子, 更加减少了监测信息的损失度, 提高结果的准确性, 为决策提供多方面依据。

4. 本程序给出多种菜单、询问、提示, 沟通人机对话, 减少出错机会。

(二) 程序框图见图 3。

## 三、应用研究

湖北省武汉市幅员辽阔, 人口众多, 工业发达, 大气环境复杂。本文采用武汉市环境监测中心的监测资料 (表 1), 应用模糊方法, 在 IBM PC 机上对武汉市大气质量状况进行评价。

表 1 武汉市大气环境监测值\* ( $\text{mg}/\text{m}^3$ )

| 编号 | 点位名称   | SO <sub>2</sub> | NO <sub>x</sub> | T.S.P |
|----|--------|-----------------|-----------------|-------|
| 1  | 武汉机修厂  | 0.075           | 0.046           | 0.362 |
| 2  | 航空路口   | 0.107           | 0.124           | 0.661 |
| 3  | 江汉区市委办 | 0.166           | 0.105           | 0.537 |
| 4  | 翠微房管所  | 0.063           | 0.059           | 0.392 |
| 5  | 洪山监测站  | 0.037           | 0.026           | 0.194 |
| 6  | 武汉戏剧学校 | 0.061           | 0.040           | 0.420 |
| 7  | 一六一医院  | 0.032           | 0.027           | 0.314 |
| 8  | 省观象站   | 0.012           | 0.021           | 0.171 |

\* 数据引自《环境科学与技术》, 1988(2)。

这里,  $U = \{\text{SO}_2, \text{NO}_x, \text{T.S.P}\}$ ,  $V = \{\text{I, II, III}\}$ ,  $N = 8$ 。选用 Zadeh 算子。

输入监测浓度, 调出  $\text{SO}_2, \text{NO}_x, \text{T.S.P}$  的分

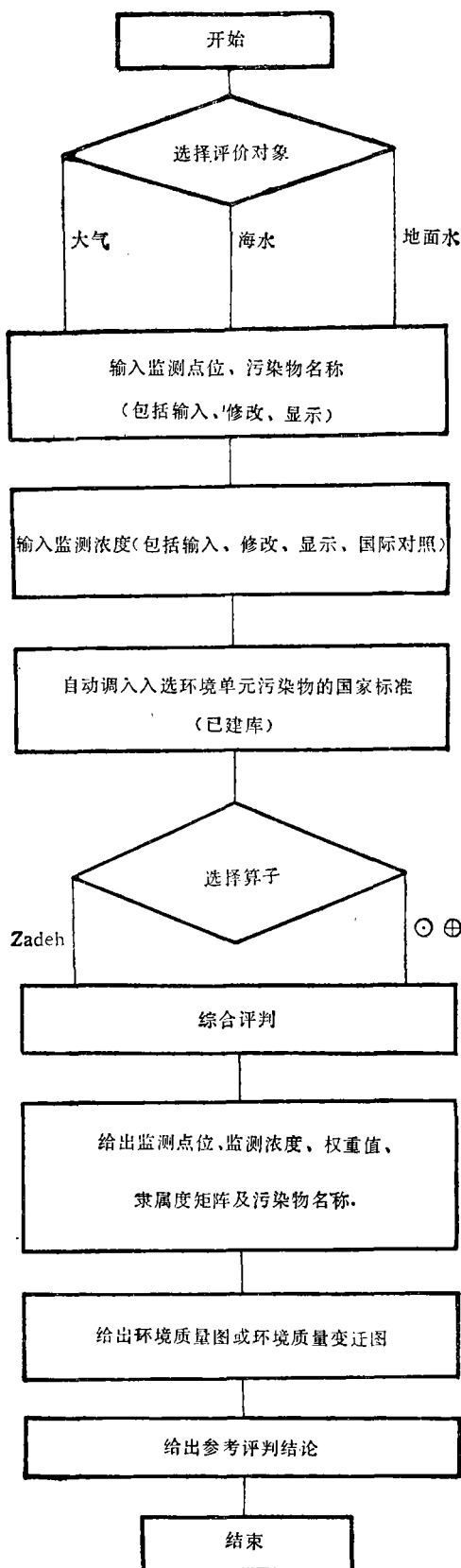


图3 程序框图

级标准(表2),进行综合评价,结果见表3、表4和图4。

表2 大气环境质量分级标准 ( $\text{mg}/\text{m}^3$ )

| 环境参数<br>质量级别 | SO <sub>2</sub> | NO <sub>x</sub> | T.S.P |
|--------------|-----------------|-----------------|-------|
| I            | 0.05            | 0.05            | 0.15  |
| II           | 0.15            | 0.10            | 0.30  |
| III          | 0.25            | 0.15            | 0.45  |

表3 权重值表(评价结果之一)

| 环境参数<br>点位代号 | SO <sub>2</sub> | NO <sub>x</sub> | T.S.P |
|--------------|-----------------|-----------------|-------|
| 1            | 0.230           | 0.212           | 0.558 |
| 2            | 0.172           | 0.298           | 0.530 |
| 3            | 0.280           | 0.266           | 0.454 |
| 4            | 0.181           | 0.255           | 0.564 |
| 5            | 0.214           | 0.225           | 0.561 |
| 6            | 0.185           | 0.181           | 0.634 |
| 7            | 0.139           | 0.176           | 0.685 |
| 8            | 0.093           | 0.244           | 0.663 |

表4 隶属度表(评价结果之二)

| 点位<br>代号 | B                     | 归一化后的 B            |
|----------|-----------------------|--------------------|
| 1        | (0.230, 0.558, 0.413) | (0.19, 0.47, 0.34) |
| 2        | (0.172, 0.298, 0.530) | (0.17, 0.30, 0.53) |
| 3        | (0.000, 0.280, 0.454) | (0.00, 0.38, 0.62) |
| 4        | (0.255, 0.290, 0.564) | (0.23, 0.26, 0.51) |
| 5        | (0.561, 0.290, 0.000) | (0.66, 0.34, 0.00) |
| 6        | (0.185, 0.200, 0.634) | (0.18, 0.20, 0.62) |
| 7        | (0.176, 0.685, 0.090) | (0.19, 0.72, 0.09) |
| 8        | (0.663, 0.140, 0.000) | (0.83, 0.17, 0.00) |

从环境质量图上可看出,武汉市大气环境质量的总体水平是 II 级。地处闹市区和人群密集区的航空路口(点位2)、江汉区市委办(点位3)、翠微房管所(点位4)和武汉戏校(点位6)的大气质量已下降到 III 级。洪山监测站(点位5)和位于郊区的省

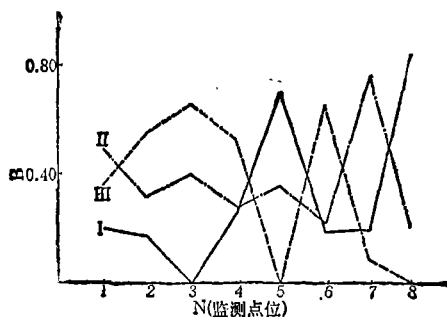


图 4 环境质量图(评价结果之三)

观象站(点位 8)大气质量较好,属于 I 级。

整个评价过程简便、快速,以质量图提交的结果不仅直观、生动,而且基本上与实际情况相符。

致谢: 本文写作过程中始终得到了北京大学地理系陈静生先生的鼓励和支持, 武汉大学环境科学系领导、老师也给予了大力协助, 在此一并致谢!

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(收稿日期: 1989 年 1 月 4 日)

## 燃煤电厂储灰场还田的放射性影响评估

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**摘要** 邯郸区域燃煤电厂储灰场的粉煤灰中放射性核素含量, 除  $^{40}\text{K}$  外均高于当地土壤中的放射性核素含量, 但不影响储灰场还田。实测与化验证实, 粉煤灰上种植的小麦、玉米、水稻中的放射性核素含量和非粉煤灰上种植的无差异; 在储灰场上劳动的农民年接受外辐射附加剂量仅为国家规定的附加剂量限值的百分之一。

邯郸的马头电厂、一五〇电厂、邯郸电厂属华北电力网的燃煤电厂、总装机容量 116 万千瓦。燃煤电厂的粉煤灰既占土地又污染环境, 这些电厂新老储灰场占地已达 5000 多亩, 还要继续增加, 且灰轻而疏松、扬尘污染环境相当严重。为解决这些问题, 我们研究了储灰场还田的方法, 在粉煤灰上开始进行种植荆条、玉米、小麦、水稻等试验。种植收获荆条亩产 2000kg、玉米亩产 350kg、小麦亩产 325.5kg、水稻亩产 275kg, 抑制了扬尘, 减轻了污染。试验证明储灰场还田, 它不仅可以获得良好的环境效益, 还

可以获得一定的经济效益。

考虑到粉煤灰因浓集放射性核素致使灰中天然放射性核素含量较高这一事实, 在储灰场还田中, 放射性的影响如何? 我们进行了研究和评估。

### 一、粉煤灰中天然放射性核素含量

粉煤灰中天然放射性核素主要有  $^{238}\text{U}$ 、 $^{232}\text{Th}$ 、 $^{226}\text{Ra}$  和  $^{40}\text{K}$ , 我们对分别采集的这三座电厂储灰场的灰样, 用 FH-1906 低本底  $\gamma$  谱仪进行了核素分析, 结果见表 1。

表 1 粉煤灰、土壤、煤中放射性核素含量

| 地 点        | 放射性核素含量 (Bq/kg)  |                   |                   |                  |
|------------|------------------|-------------------|-------------------|------------------|
|            | $^{238}\text{U}$ | $^{232}\text{Th}$ | $^{226}\text{Ra}$ | $^{40}\text{K}$  |
| 马头电厂灰场     | 163.7            | 139.4             | 160.1             | 258.6            |
| 150 电厂灰场   | 188.4            | 155.7             | 184.2             | 245.0            |
| 邯郸电厂灰场     | 119.7            | 124.9             | 117.0             | 264.3            |
| 邯郸地区土壤     | $33.4 \pm 10.2$  | $42.1 \pm 5.6$    | $27.2 \pm 3.6$    | $550.0 \pm 46.2$ |
| 马头电厂灰场附近土壤 | 49.9             | 42.5              | 28                | 492.0            |
| 邯郸地区煤      | 78.6             | 70                | 76.9              | 128              |

in general survey of technical chemicals and investigation of potential pollution sources.

**Determination of  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$ , Ca and K in Milk by Radiochemical and Chemical Method.** Sha Lianmao, Wang Zhihui, Wang Fenghua (China Institute for Radiation Protection, Taiyuan): *Chin. J. Environ. Sci.*, **11**(2), 1990, pp. 51

A method for determining low-level radioactive nuclides in milk for intercomparison by WHO-IRC is presented in this paper. The results show that the values of  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$ , Ca concentration appear to be agreement with IRC reference values. Some problems concerning the effect on analytical accuracy have been discussed as well.

**A Survey of  $^{239+240}\text{Pu}$  and  $^{238}\text{Pu}$  in Main Foodstuff of China.** Han Shouling et al. (Liaoning Provincial Institute of Labour Hygiene, Shenyang): *Chin. J. Environ. Sci.*, **11**(2), 1990, pp. 55

Radioactive plutonium isotopes in 16 samples of the main foodstuff collected from nine provinces and autonomous regions of China have been determined by means of radiochemical separation, electrodeposition and alpha-spectrum measurements. The results show that specific radioactivities of both  $^{239+240}\text{Pu}$  and  $^{238}\text{Pu}$  in the foodstuff vary from  $1 \times 10^{-4}$  Bq/kg to  $1 \times 10^{-3}$  Bq/kg, the concentrations of  $^{238}\text{Pu}$  in foodstuff are less than  $^{239+240}\text{Pu}$ . However, by way of exception, the specific radioactivities of  $^{239+240}\text{Pu}$  and  $^{238}\text{Pu}$  in tea samples are  $7.41 \times 10^{-3}$  Bq/kg and  $1.33 \times 10^{-3}$  Bq/kg respectively.

**Advances of Quantitative Structure Activity Relationship (QSAR) in Environmental Chemistry and Its Methodology.** Bai Naibin (Research Center for Eco-Environmental Sciences, Academia Sinica, Beijing): *Chin. J. Environ. Sci.*, **11**(2), 1990, pp. 62

QSAR is a useful means in safety assessment of chemicals. This article describes its application background, fundamental principles, evolution, conception model, mathematical model and algorithm, from which the author and his assistants have developed a software package of applied quantum chemistry with a purpose of producing the molecular structure descriptors. In the software a chemical substance toxicity database has been carried out so as to acquire lots and lots of biological activity data of chemicals, and in order to set up the relationship between molecular structure and its biological activity, a pattern recognition software has been applied. Finally, the perspective of QSAR research in environmental chemistry has

been discussed in this article.

**Microbial Degradation of Pesticides.** Zheng Zhong (Zhejiang Agricultural University, Hangzhou): *Chin. J. Environ. Sci.*, **11**(2), 1990, pp. 68

A general description on microbial degradation of pesticides is given in this review. The subject covers following aspects: isolation of the microbe-degraders, biodegradation pathway of some pesticides, and characteristics of microbial metabolism and involved enzymes. The practical approaches to biological detoxification of pesticides have also been discussed.

**On the Environmental Characteristics and Changes in Northwestern Arid Area of China.** Ma Ruijun (Department of Geography, Northwest Normal University, Lanzhou): *Chin. J. Environ. Sci.*, **11**(2), 1990, pp. 76

With a comparative approach, the author discusses theoretically the arid causes in the northwestern area of China from the viewpoints of its formation course, space structure, heat and moisture conjunction, natural factors and human activities on the environment as well.

**Fuzzy Comprehensive Assessment of Environmental Quality by Computer Performance.** Liu Hui, Wang Feiyue (Wuhan University): *Chin. J. Environ. Sci.*, **11**(2), 1990, pp. 81

This paper presents a fuzzy mathematical model designed for comprehensive assessment of environmental quality by means of IBM PC computer. The model has been applied successfully to the atmospheric environmental assessment in Wuhan.

**Radioactive Impact Assessment of Returning the Coal-Ash Storage Sites of the Power Stations into Farmland.** Wang Bing (Society of Environmental Protection of Handan Prefecture, Hebei Province): *Chin. J. Environ. Sci.*, **11**(2), 1990, pp. 84

The radionuclide contents of coal ash from the power stations in Handan Area are higher than that in the local soil except  $^{40}\text{K}$ . However, this situation doesn't affect the sites to be reformed into farmland. The results of detection show that radionuclide contents in wheat, maize and rice which were planted on the farmland are not different from those planted on ordinary ones, and the additional radiation dosage received annually by the peasants working in the coal-ash storage sites is only 1% of the limit stipulated by Chinese authorities concerned.