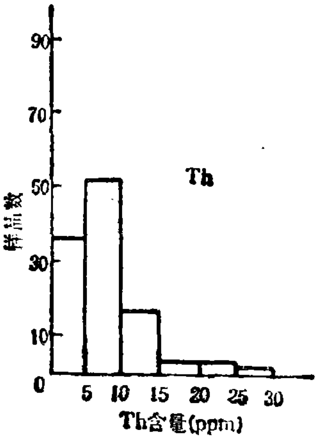


图5　中国 110 个煤矿中钍元素的频数分布

国外一些学者曾对原煤预处理脱除有害元素进行了研究[5]. 结果表明，煤中某些微量元素能够有选择地富集于不同比重的原煤中，如果煤碳在燃烧以前，用不同比重液对它进行浮选，去掉比重大于 1.6（指矿物质的比重，煤中一些有害元素如砷、镉等一般与无机矿物伴生在一起）的那一部分，则有害元素的浓度可减少 50%以上，从而减少对环境的污染。

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# 区域水质监测最优布点数的研究

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**摘要**　本文讨论区域水质测点数的优化问题，在文献［3］推证的最优布点方法—分功能区策略布点法的基础上，用数理统计学的抽样技术对每个功能水体的最优测点数的分配进行研究．利用所得到的理论模式和历史数据进行计算，从而确定了厦门地区水质监测的最优测点数．

关于环境监测优化布点的研究在我国正在深入发展[1,2]，但是关于水质监测优化布点数的研究还很少有过报道．文献［3］曾经推证过环境监测最优布点方法—按功能区策略布点法，可是对于最优布点数如何确定没有深入探讨．本项研究目的在于选择最少的监测点数而又能客观地反映水环境质量．区域水环境的地表水往往包含几种不同功能的水体（如海洋、河流、湖泊、水库、沼泽等）．它们在水质上往往表现出一定程度的差异．本文首先从理论上对各功能水体的最优测点数的分配进行研究，然后将研究结果应用于厦门地区水质测点数的优化研究，结果表明本文所提出的方法简单实用，具有较大的应用前景．

## 一、最优布点数及其分配模式的研究

设区域中的地表水（总体）含有 $k$ 种不同功能的水体．水质监测一般是从第 $i$ 种功能水体（$i=1, 2, \cdots, k$）小总体中抽取容量为 $n_i$ 的样本进行监测．区域水质监测最优布点数的研究就是要确定各功能水体的测点数及其容量 $\{n_1, n_2, \cdots, n_k\}$ 应取多少才能正确地反映区域水环境的质量．这一问题在数理统计学中就是样本容量的最优分配问题．

在一般情形下，样本容量的最优配置就

是在总费用固定的条件下使方差达到最小或者在固定精度(给定方差)要求下使总费用最小的各功能水体测点容量的分配. 费用函数的形式一般可以表述为

$$f = f_0 + \left[\sum_{i=1}^{k}(a_i n_i + b_i)\right]^{\frac{1}{\alpha}} \qquad (1)$$

费用 $f$ 表示为一部分固定的监测费用 $f_0$ 及一部分与各功能水体测点数的监测样本 $n_i$ 有关的费用之和. 如果不考虑监测费用，只对监测样本作出限定，即要求

$$n = n_1 + n_2 + \cdots + n_k \qquad (2)$$

$n$ 为已知数. 这时 (2) 式就是 (1) 式的一种特殊情形，即 $\alpha = 1$, $f = n$, $f_0 = 0$, $a_i = 1$, $b_i = 0$，这种特殊情形其实就是最优布点方法—分功能区策略布点法[3].

当监测对象为某一水质参数，总体就是研究区域内所有点 $N$ 的水质参数的测定值，记为 $x_0$，样本为由此总体中布设一定样点的某一水质参数的测定值.

设布设样点总的测点数为 $N$，各测点某一水质参数的测定值分别记为 $y_1$, $y_2$, $\cdots$, $y_N$. 研究区域中含有 $k$ 种不同功能的水体，其中第 $i$ 种水体中各测点的某一水质参数测定值为 $y_{i1}, y_{i2}, \cdots, y_{iN}$，其数学期望和方差分别为 $m_i$ 和 $\sigma_i^2$. 这就是水质监测所要求的目标，它们可以从部分子样进行估算. 设从第 $i$ 种水体 $N_i$ 个测点中取出 $n_i$ 个测点的样本 $x_{i1}, x_{i2}, \cdots, x_{in_i}$，它们是独立同分布的随机变量. 记第 $i$ 种水体样本的平均值为

$$\bar{x}_i = \frac{1}{n_i}\sum_{j=1}^{n_i} x_{ij}$$

由于总体分成 $k$ 种水体，所以整个总体的样本平均值为

$$\bar{X} = \frac{1}{N}\sum_{i=1}^{k} N_i \bar{x}_i = \frac{1}{N_i}\sum_{i=1}^{k}\frac{N_i}{n_i}\sum_{j=1}^{n_i} x_{ij}$$

显然，$\bar{x}_i$ 的方差 $\sigma^2_{\bar{x}_i}$ 为

$$\begin{aligned}\sigma^2_{\bar{x}_i} &= E[(\bar{x}_i - Ex_i)^2] \\ &= E(\bar{x}_i^2) - (E\bar{x}_i)^2 \\ &= E(\bar{x}_i^2) - m_i\end{aligned}$$

$$\begin{aligned}E(\bar{x}_i^2) &= E\left[\frac{1}{n_i^2}\left(\sum_{j=1}^{n_i} x_{ij}\right)^2\right] \\ &= \frac{1}{n_i^2}\left[E\left(\sum_{j=1}^{n_i} x_{ij}^2\right) + E\sum_{j=1}^{n_i}\sum_{\substack{l=1\\ l\neq j}}^{n_i} x_{ij}x_{il}\right] \\ &= \frac{1}{n_i^2}\sum_{j=1}^{n_i} E(x_{ij}^2) + \frac{1}{n_i^2}\sum_{j=1}^{n_i}\sum_{\substack{l=1\\ l\neq j}}^{n_i} Ex_{ij}x_{il}\end{aligned}$$

由于

$$E(x_{ij}^2) = \sum_{t=1}^{N_i} y_{it}^2 P(x_{ij} = y_{it}) = \frac{1}{N_i}\sum_{t=1}^{N_i} y_{it}^2 = \sigma_i^2 + m_i^2 \quad 对\ j = 1, 2, \cdots, n_i$$

及

$$\begin{aligned}E(x_{ij}x_{il}) &= \sum_{\substack{s,t=1\\ (s\neq t)}}^{N_i} y_{is}y_{it}P(x_{ij} = y_{is}, x_{ik} = y_{il}) \\ &= \frac{1}{N_i(N_i - 1)}\left\{\left(\sum_{s=1}^{N_i} y_{is}\right)^2 - \sum_{s=1}^{N_i} y_{is}\right\} \\ &= \frac{1}{N_i(N_i - 1)}\{(n_i m_j)^2 - N_i(\sigma_i^2 + m_i^2)\} \\ &= m_i^2 - \frac{\sigma_i^2}{N_i - 1}\end{aligned}$$

对于　$j, l = 1, 2, \cdots, n_i$, $j \neq l$

所以

$$\begin{aligned}\sigma^2_{\bar{x}_i} &= \frac{1}{n_i}(\sigma_i^2 + m_i^2) + \frac{1}{n_i^2}n_i(n_i - 1) \times\left(m_i^2 - \frac{\sigma_i^2}{N_i - 1}\right) - m_i^2 \\ &= \left(\frac{1}{n_i} - \frac{n_i - 1}{N_i - 1}\frac{1}{n_i}\right)\sigma_i^2 \\ &= \frac{N_i - n_i}{N_i - 1}\frac{\sigma_i^2}{n_i}\end{aligned} \qquad (3)$$

注意到 $\bar{x}_i$ 是第 $i$ 种功能水体样本的平均值，第 $i$ 功能水体与第 $j$ 功能水体样本的平均值

$\bar{x}_i$ 与 $\bar{x}_j$ 看成随机变量函数是相互独立的，因此

$$\sigma_{\bar{x}}^2 = D(\bar{x}) = D\left(\frac{1}{N}\sum_{i=1}^{k} N_i \bar{x}_i\right)$$

$$= \frac{1}{N^2}\sum_{i=1}^{k} D(N_i \bar{x}_i)$$

$$= \frac{1}{N^2}\sum_{i=1}^{k} N_i^2 D(\bar{x}_i)$$

$$= \frac{1}{N^2}\sum_{i=1}^{k} N_i^2 \frac{N_i - n_i}{N_i - 1}\frac{\sigma_i^2}{n_i} \qquad (4)$$

我们的目的是适当选取 $\{n_1, n_2, \cdots, n_k\}$ 使得抽样方差 $\sigma_{\bar{x}}^2$ 最小，当固定费用取 (1) 式的形式，则有

$$n_i = N_i\sigma_i\sqrt{\frac{N_i}{a_i(N_i - 1)}}\,\frac{(f - f_0)^a - \sum_{i=1}^{k} b_i}{\sum_{i=1}^{k} N_i\sigma_i\sqrt{\frac{a_i n_i}{N_i - 1}}}$$

事实上，由 (1) 式

$$n_k = \frac{1}{a_k}\left[(f - f_0)^a - \sum_{i=1}^{k} b_i - \sum_{i=1}^{k-1} a_i n_i\right]$$

代入 (3) 式得

$$\sigma_{\bar{x}}^2 = \frac{1}{N^2}\sum_{i=1}^{k-1} N_i^2 \frac{N_i - n_i}{N_i - 1} + \frac{N_k^2}{N^2}\frac{N_k - n_k}{N_k - 1}\frac{\sigma_k^2}{n_k}$$

$$= \frac{1}{N^2}\left[\sum_{i=1}^{k} \frac{N_i}{N_i - 1}\left(\frac{N_i}{n_i} - 1\right)\sigma_i^2\right] + \frac{N_k^2\sigma_k^2}{N^2(N_k - 1)} \times \left[\{N_k a_k\}\Big/\left\{(f - f_0)^a - \sum_{i=1}^{k} b_i - \sum_{i=1}^{k-1} a_i n_i\right\} - 1\right]$$

由多元函数的极值原理可得最优样本容量分配方案为

$$n_i = N_i\sigma_i\sqrt{\frac{N_i}{a_i(N_i - 1)}}\,\frac{(f - f_0)^a - \sum_{i=1}^{k} b_i}{\sum_{i=1}^{k} N_i\sigma_i\sqrt{\frac{a_i N_i}{N_i - 1}}}$$

$$= \frac{N_i S_i}{\sqrt{a_i}}\,\frac{(f - f_0)^a - \sum_{i=1}^{k} b_i}{\sum_{i=1}^{k} N_i S_i\sqrt{a_i}} \qquad (i = 1, 2, \cdots, k) \qquad (5)$$

式中 $S_i$ 为标准差.

在 $n$ 为已知数，即 $n = n_1 + n_2 + \cdots + n_k$ 时

$$n_i = \frac{nN_i\sigma_i\sqrt{\frac{N_i}{N_i - 1}}}{\sum_{i=1}^{k} N_i\sigma_i\sqrt{\frac{N_i}{N_i - 1}}} = \frac{nN_i S_i}{\sum_{i=1}^{k} N_i S_i} \qquad (6)$$

当 $N_i$ 比较大时，$\sqrt{\frac{N_i}{N_i - 1}} \simeq 1$。(5) 式也可化为：

$$n_i = \frac{nN_i\sigma_i}{\sum_{i=1}^{k} N_i\sigma_i} \qquad (7)$$

最优布点数 $n$ 是采样误差的函数。由不等式 $\frac{|\bar{x} - m_i|}{\sigma_{\bar{x}}} < t_a$ 可以估计误差[4]。$t_a$ 为双侧百分位点，

绝对误差：

$$\Delta = \sigma_{\bar{x}} t_a \qquad (8)$$

相对误差：

$$d = \frac{\Delta}{\bar{X}} = \frac{\sigma_{\bar{x}} t_a}{\bar{x}} \qquad (9)$$

把 (4) 式化为

$$\sigma_{\bar{x}} = \sum_{i=1}^{k} \frac{N_i^2}{N^2}\left(\frac{1}{n_i} - \frac{1}{N_i}\right)S_i^2 = \frac{\left(\sum_{i=1}^{k} W_i S_i\right)^2}{n} - \frac{\sum_{i=1}^{k} W_i S_i^2}{N}$$

式中 $W_i = \frac{N_i}{N}$ 为权重，当 $N$ 较大时

$$\sigma_{\bar{x}} = \left(\sum_{i=1}^{k} W_i S_i\right)^2 \Big/ n$$

代入 (9) 式就可得到最优测点数

$$n \geq \frac{\left(\frac{t_a}{d}\right)^2 \left(\sum_{i=1}^{k} W_i S_i\right)^2}{\bar{X}^2} \qquad (10)$$

## 二、应用实例

厦门地区的地表水环境主要由坂头水库、北溪引水渠、筼筜湖、杏林湾水库、九龙江干流河口、九龙江入海口、厦门西港、宝珠屿海域、厦门湾、厦门港海域等 10 个水系组成. 按 GB 3838-88《地面水环境质量标准》中关于水域功能分类的定义，厦门地区地面水水域可分为 4 类. 坂头水库和北溪引水渠属于第 II 类功能水域(即集中式生活饮用水水源一级保护区)，九龙江干流河口、九龙江入海口和杏林湾水库属于第 III 类功能水域(即集中式生活饮用水水源二级保护区和一般鱼类保护区)，筼筜湖属于第 IV 类功能水域(即一般景观要求水域)，而厦门岛周围海域属于 GB 3097-82《海水水质标准》中的第二类水质要求区域.

厦门市环境监测站在这 4 种功能水体中共布设 26 个测点(断面)进行 28 个水质参数的监测. 如果按照不同的水质参数进行各类功能水体最优测点数的研究，可能产生不同的结果. 因此我们对 1987 年各测点 (断面) 监测的水质参数，根据该测点(断面)所属的功能水域标准，计算其污染指数 $P_i = \frac{C_i}{S_i}$，再求出各测点(断面)的平均污染指数 $\bar{P}$，就可以进行厦门地区地表水环境最优布点数的计算.

表 1 为厦门地区 4 类功能水域的有关参数. 当置信度取为 90%，相对误差为 0.1 时，$t_a = 1.64$，把表 1 的有关参数代入 (10) 式进行计算可得

**表 1　厦门地区各类水域有关参数**

| 水域类别 | II | III | IV | 海二 |
|---|---|---|---|---|
| 监测面积 $N_i$(km²) | 6 | 95 | 2 | 75 |
| 权重 $W_i = \frac{N_i}{\Sigma N_i}$ | 0.0337 | 0.5337 | 0.0112 | 0.4213 |
| 平均污染指数 $x_i = \bar{P}_i$ | 0.1692 | 0.1772 | 1.0582 | 0.4038 |
| 均值 $\bar{X} = \Sigma W_i x_i$ | 0.2819 | | | |
| 标准差 $S_i$ | 0.0644 | 0.0591 | 0.5682 | 0.0628 |
| 加权标准差 $W_i S_i$ | 0.00217 | 0.03153 | 0.00636 | 0.02647 |
| $\Sigma W_i S_i$ | 0.06653 | | | |

$$n = \frac{\left(\frac{t_a}{d}\right)^2 \left(\sum_{i=1}^{k} W_i S_i\right)^2}{\bar{X}^2} = \left(\frac{1.64}{0.1}\right)^2 \left(\frac{0.06653}{0.2819}\right)^2 = 15$$

再按 (6) 式计算各类水域测点数的分配为

$$n_1 = \frac{nW_iS_i}{\sum_{i=1}^{k} W_i S_i} = \frac{15 \times 0.00217}{0.06653} \approx 1$$

$$n_2 = 7, \quad n_3 = 1, \quad n_4 = 6$$

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## Study on Oxidation and Hydrolysis of Cyanides in Wastewater

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The aim of this work is to explore oxidation and hydrolysis of cyanides in wastwater under the condition of normal atmospheric reflux. Taking potassium cyanide as an example, the test has separated oxidation of the cyanidae from hydrolysis, and proved that both of oxidation and hydrolysis unler the said condition will identify themselves with the first-order reaction kinectics, thus determined the constant of reaction rate under different pH values. The theoretical analysis and practical experiment has also proved that reaction rate of oxidation and hydrolysis of cyanides in the presence of a certain amount of ferrous ions pcan be increased by controlling adequate pH in the solution or by adjusting the concentration of ferous ions at the primary pH of the wastewater. So a new approach to raising treatment efficiency of cyanide-bearing wastewater in coal gasification is provided. (See pp. 2—5)

## Metal Elements in Various Geochemical Phases of Suspended Particulate Matter and Estuarine Chemical Processes

*Li Feiyong* and *Chen Jinsi*(South China Sea Institute of Oceanology, Academia Sinica, Guangzhou)

Using a sequential extraction procedurr, the metal elements were partitioned in different geochemical phases of suspended particulate matter collected from 7 represendive sampling locations in the estuary of the Zhujiang River(the Pearl River), and their contents were determined. There were 6 phases divided: ion-exchange and adsorption, carbonates, easy of reducing, reducibleness, organic matter and sulfides, and residual. Ten metals(Al, Fe, Mn, Ti, Cu, Co, Pb, Zn, Cr and Ni) in the estuarine chemical processes have been investigated. The results successfully reflect distribution, behavior, removal and variation of various phase elements of the suspended matter in the complicated estuary. (See pp. 5—13)

## Behaviour of A $^{14}C$-alkaloid Compound in A Simulative Aquatic Ecosystem

*Dai Shugui, Wang Juxian* and *Rao Xin*(Department of Environmental Science, Nankai University, Tianjin)

The pathway of transportation and transformation of an alkaloid compound in a simulative aquatic ecosystem have been studied by using $^{14}C$-labelled technique. The change of concentration with time and accumulation of the compound both in aquatic organisms and in sediment were investigated. Experimental result shows that there is more than 85 percent of the $^{14}C$-residue in sediment within 20 days, which indicates that the compound can transport into the sediment quickly. It is also found that light and microbe may signpificantly affect transformation of the compound. (See pp. 13—16)

## On the Validation of Gaussian Plume Model for Elavated Releases over a Terrain of Major Roughness

*Hu Erbang* and *Li Jikai*(Research Institute of Radiation Protection, Ministry of Nuclear Industry, Taiyuan)

Based on correlation analysis and index of agreement *d* and used the information of 19 atmospheric dispersion experiments with releases at 160 m height at Karlsruhe Nuclear Research Center, the axial normalized diffusion factors $X_p$ and $X_o$ predicted and observed have been statistically compared so as to examine the validation of the Gaussion Plume Model for elevated releases over a terrain of major roughness. This paper presents 4 stability classifications and 2 diffusion parameter systems. The result shows that the prediction performance of *d* is better than correlation coefficient *r*. (See pp. 16—23)

## Content Distribution of As, Se, Cr, U and Th Elements in Chinese Coal Samples

*Chen Bingru, Yang Shaojin, Qian Qinfang* and *Yang Yinnan* (Institute of High Energy Physics, Academia Sinica, Beijing)

Accumulation of As, Se, Cr, U, Th etc elements in the environment is interrelated to emission of coal burning as these elements existing in coal are abundant and Coal consumes in bulk. So coal burning is considered as one of pollution sources in the area where some harmful trace elements entered into tphe environment. It is obvious that in order to study the relationship between coal burning and environmental pollution, it is necessery for us to thoroughly investigate trace elements in coal. This paper reports As. Se, Cr, U, Th contents in coal samples from 110 coal mines in 24 provinces and cites of China, determined by using instrumental neutron activation anlysis. The content ranges of As, Se, Cr, U, Th in coal mines in China are given. The relationship between these elements and the environment has been discussed. (See pp. 23—26)

## Optimal Numbers of the Stations for Monitoring Regional Water Quality

*Zhuang Shijian* and *Ye Lina*(Xiamen Municipal Research Institute of Environmental Protection, Fujian Province )

This paper deals with optimization of the stations for monitoring regional water quality. The sampling techniques statistically are used for studying the distribution of optimal monitoring stations in every functional water body. Based on the theoretical model research and historical data, the results of the study have been applied

to determine the optimal numbers of stations for monitoring water quality in Xiamen region, Fujian Province. (See pp. 26—30)

**Radiative Levels of Indoor Environment in Xia'n City**

*Qiang Yonggang et al.* (Shaanxi Provincial Station of Sanitation and Epidemic Prevention, Xi'an)

This paper presents that the radiative levels of indoor environment in Xi'an City were investigated with a high sensitivity thermoluminescent dosimeter—LiF(Mg, Cu, P).

The radiative doses absorbed by local residents were also evaluated. The results show that average γ-radiation dose in air absorbed by the residents seems to be $9.10\times 10^{-8}Gy\cdot h^{-1}$ and the contributive component of cosmic ray to be $2.82\times 10^{-8}Gy\cdot h^{-1}$. The annual effective dose equivalent and collective effective dose equivalent have been determined to be 374 μSv and $1.36\times 10^{3}$ Man. Sv. (See pp. 30—34)

**Study on Treatment and Utilization of Industrial Wastewater in Dexin Copper Mine**

*Ni Dong* (Beijing Central Engineering and Research Institute for Non-ferrous Metallurgical Industry, Beijing)

Dexin Copper Mine is one of the largest mines in the world. The industrial wastewater discharged from the mine is more than $300000M^3$/day. The acidic water from the mine in brown colour contains a lot of heavy metal ions, such as ferric ion and copper ion etc. The pH of acidic water is 2 or 3 while the pH of the tailing slurry and sulfur-bearing basic water discharged from the concentrator is 10 to 13. As it contains comparatively high sulphur ions, this water threatens the environment around the lower reaches of the river and causes big loss of resources.

Since $Fe^{3+}$ in mine acidic water is ten times higher than ropper ion, the addition of lime can remove $Fe^{3+}$ in the first stage and sulphur-bearing wastewater is added to form sulphide settlings and recover copper in the second stage. In the third stage, the process with addition of basic wastewater for neutralization is adopted and through multitypes of tests, the water can be discharged out or recycled for use. At the same time, copper ion in water can be effectively recovered, thus environmental and economic benefits are achieved. (See pp. 34—39)

**Ambient Two-Phase UASB Process for Treatment of Brewery Wastewater**

*Yan Yuegen, Liu Jingsong* and *Hu Jicui*(Department of Environmental Engineering, Tsinghua University, Beijing)

Perfor mance of ambient (25°C) two-phase UASB process treating malting wastewater (diluted to 2000 mgCOD/L has been investigated. It is shown that this process has a high treatability with organic loading rate of 18 $kgCOD/m^3\cdot d$, HRT of 2.7 h and soluble COD removal of 86% on a methane phase base. A systematic research is also done on the performance of acid- and methane-phase reactors and property of granules. (See pp. 39—43)

**Rapid Method for Spectrophotometric Determination of Sulphate in Surface Water Using Ion-Exchange Separation and the Sulphate and Chlorophosphonazo III (CPA III)-$Ba^{2+}$ Complex Reaction**

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A rapid spectrophotometric method for determination of $SO_4^{2-}$ in surface water is reported. It is based on the reaction of CPA III-$Ba^{2+}$ complex with $SO_4^{2-}$ in acidic medium in the presence of ethanol. Beer's law is obeyed up to 120μg of $SO_4^{2-}$ in final solution. The molar absorptivity is $6.3\times 10^{3}$ liters · $mol^{-1}\cdot cm^{-1}$ at 500 nm, and the coefficient of variation varies from 1.85 to 3.10%. The absorbance remains stable for at least 24h and the interfering ions in separated by strongly acidic cation-exchange resin. (See pp. 51—53)

**Study on the Microbial Membrane Electrode for BOD Determination**

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The electrodes of four different microbial membranes have been prepared for determining BOD in wastewater. The linear response range of the electrodes is 10—60 mg/L for BOD certified reference materials. The time for reaching equilibrium is between 4 minutes (for low limit concentration) to 7 minutes(for high limit concentration). The electrodes has sustained the initial sensitivity over 20 days. Compared with the standard method for five days, the microbial electrodes prepared for determination of BOD have obtained good results. (See pp. 53—57)

**Multi-Target Optimization of Environment-Economic System**

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Target programming as a kind of multi-target optimization technique has been found to be increasingly utilized. Taking Shanghai Taopu Chemical Industry District as a case study, the authors present three alternative schemes for reducing discharge of pollutants: (1) reduction by 5%; (2) reduction by 10%; (3) discharge in conformity with norm. Then, they set up a model of target programming for the environment-economic system of this industrial district and performed multi-target optimization simulation for the system by means of a computer. The results of optimization provide concrete approaches to rational adjustment of trade structure, which will better coordinate the two principal factors of the system, i. e. environmenr and economy so as to redress the existing random state of environment-economic system of the district. The system has its integral and comprehensive functions. The optimization schemes not only

(Continued on p. 83)