监测与分析

城市植物叶片含硫量与大气 SO_2 污染关系及其在污染状况评价中的应用*

江　静　蓉　　徐　亦　钢
（国家环保局南京环境科学研究所，南京 210042）
石　磊　许建华　　叶家和　唐后珉
（南京市环境监测中心站，南京）　　（南京化学工业公司环境监测站，南京）

摘要　本文通过对南京市区 29 个采样点的采样和分析（市区 14 个点代表一般城市的环境状况、大厂区 15 个点代表重污染区的环境状况），确认法桐和女贞两种树木叶片含 S 量与大气中 SO_2 浓度密切相关。在一般污染状况下，线性回归方程即可很好地用于测算大气 SO_2 浓度，并评价污染等级；但在较重污染和严重污染的情况下，指数回归方程可以很好地测算大气 SO_2 浓度，并评价污染等级。

关键词　植物叶片，大气 SO_2 污染，环境质量评价，南京.

空气污染能引起植物的多种反应，植物对环境污染的这种指示作用，在国内外的环境监测与评价工作中得到了日益广泛的应用．为了进一步探讨在城市生态环境中生长的植物叶片与空气中的污染物浓度之间的对应关系，笔者于 1989 年在南京市进行了用叶片含硫量监测大气硫污染的工作．

一、研究方法

（一）布点和采样

根据不同的功能区在南京市共设立 29 个采样点，其中市区 14 个，大厂区 15 个．

SO_2 采样：按照国家环保局颁布的《环境监测技术规范》采样，4—9月份采大气SO_2．

挂片 SO_3：为了对照，各监测点分别在 7—9月份挂片，测大气硫酸盐化速率．

叶片采样：分别在 7、9 月份采法桐和女贞叶片，测其含硫量．采集树叶的位置是在气体采样点附近（约 50m 范围），按不同方位选择有代表性的树 3—5 株，采样树的树龄、生长发育状况及所采叶片的着生部位尽可能一致．采样的部位是在树冠的中部外围，沿四个不同方向采集无病、无虫害的正常叶片．

（二）大气 SO_2 浓度和树叶片中硫的测定

1. 大气中 SO_2 浓度测定

大气中 SO_2 浓度的测定，采用“四氯汞钾溶液吸收-盐酸副玫瑰苯胺比色法”和碱片法[1]．

2. 叶片含硫量的测定

叶片采回后，立即洗净、晾干，并放在 40—60℃鼓风干燥箱中烘干，粉碎过 60 目筛，放于玻璃瓶中备用．

叶片中含硫量的测定采用硫酸钡比浊法[2]．

二、结果与讨论

（一）大气 SO_2 与两种树叶片含硫量的关系

监测结果经回归分析得出了大气 SO_2 浓度与法桐叶片含硫量，挂片 SO_3 与法桐、女贞叶片含 S 量之间的关系（见表 1）．显著性检验结果表明相关性极显著．

* 本研究为国家环保局三项经费课题．
收稿日期：1991 年 4 月 7 日

表 1 大气 SO_2 挂片 SO_3 与两种树木叶片含硫量的关系

预测变量 y	功能分区	监测变量 x		回归方程	相关系数 r	样本数 N	置信度 α
大气 SO_2 (mg/m³)	南京市区	含硫量 (%)	法桐	$y = 0.172x - 0.026$ (1)	0.742	27	0.01
挂片 SO_3 (mg/100cm²·d)	南京市区		法桐	$y = 0.944x - 0.066$ (2)	0.746	27	0.01
挂片 SO_3 (mg/100cm²·d)	南京大厂区		法桐	$y=0.0398\exp(5.559x)$(3)	0.651	22	0.01
挂片 SO_3 (mg/100cm²·d)	南京大厂区		女贞	$y=0.0776\exp(6.056x)$(4)	0.733	23	0.01

由表 1 可知，大气污染程度与两种植物叶片含污量之间的关系并非简单线性关系，以挂片 SO_3 与法桐叶片含 S 量的关系为例，南京市区与南京大厂区的回归方程有明显的差异. 市区挂片 SO_3 均小于 0.6mg/100cm²·d，它与法桐叶片含 S 量之间呈线性关系，回归方程(表 1 中式(2))高度显著；而大厂区污染较为严重，挂片 SO_3 可达 4mg/100cm²·d，随着大气污染程度的急剧增大，叶片的含污量只略有增加，因此指数曲线能够更好地反映两者的关系(见图 1). 其回归方程(表 1 中式(3))也是高度显著的.

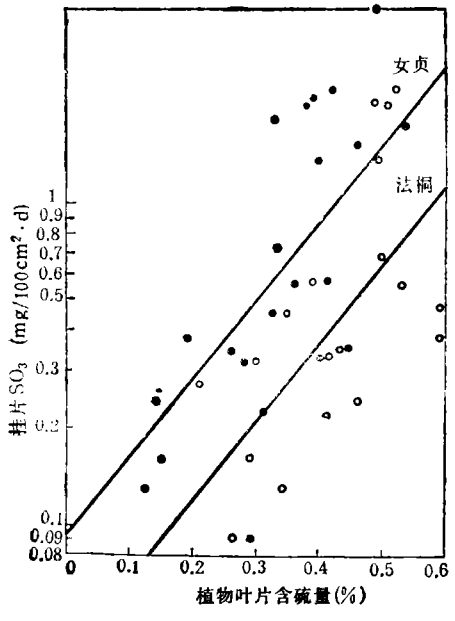

图 1 挂片 SO_3 与叶片含硫量的关系

由表 1 和图 1 还可以看到大气 SO_2 与女贞叶片含硫量的关系与法桐相似. 在整个观测值范围内，法桐叶片的含硫量平均大致高于女贞 0.15%. 这在某种意义上说明法桐和女贞两个树种对大气 SO_2 污染反应敏感程度大致相同.

(二) 预测方法和误差分析

由于两种植物叶片含污量与大气的污染程度密切相关，因此有可能通过分析含污量来测算大气的污染状况.

1. 大气 SO_2 浓度的测算及其误差

对于非重污染地区，可以利用表 1 中的回归方程(1)来测算 SO_2 的平均浓度. 它的测算误差与两次生物分析值误差大体相当. 不同方法测算 SO_2 浓度的误差比较见表 2，用两次平均值预测的误差有所减少，但变化不大，两者的测算精度大体接近，标准误差为 0.008—0.011mg/m³.

表 2 不同方法测算 SO_2 浓度的误差比较

SO_2 浓度测算方法	误差类型 (mg/m³)		
	极大误差	绝对平均误差	标准误差
7 月份法桐样品值	0.039	0.018	0.011
9 月份法桐样品值	0.033	0.010	0.009
两次平均值	0.027	0.014	0.008

2. 硫酸盐化速率的测算及误差比较

硫酸盐化速率即挂片 SO_3 与植物叶片含硫量的关系具有明显的地区性特征. 南京市区(代表轻污染区)和大厂区 (代表中度以上污染区)，所用的测算方程各不相同. 用表 1 中回归方程(2)测算轻污染状况下的 SO_3 值与实测值的标准误差为 0.07mg/100cm³·d，较为理想；用方程(3)和(4)测算重污染状况下的 SO_3 值与实测值的标准误差分别为 0.46 和 0.62mg/100cm²·d，尽管显著性程度很高，但误差较大，不理想. 为此，对原始数据重新

进行分析，发现在重污染(大气污染综合指数 $PI > 9$)情况下，即 $SO_3 > 0.70mg/100cm^2 \cdot d$ ($PI \geq 0.70/0.075 = 9.2$)时，植物叶片含S量与 SO_3 不具有线性关系。

对于 $SO_3 < 0.7mg/100\,cm^2 \cdot d$ 的数据重建回归方程，得到 SO_3 对法桐和女贞叶片含S量方程：

$$y_{法桐} = 0.93x - 0.04 \quad (5)$$

$$y_{女贞} = 0.72x + 0.12 \quad (6)$$

这两个回归方程的置信度分别为 $\alpha = 0.01$ 和 0.05，可作为硫酸盐化速率即挂片 SO_3 的测算方程，它们的适用范围是法桐含硫量小于0.47%和女贞含硫量小于0.28%，即轻度污染和中度污染范围。若叶片含硫量超过这个范围，即可直接判定为较重污染或严重污染。

(三) 污染状况评价

根据南京市历年来试订的南京大气污染程度分级标准[1]及叶片含硫量的评价标准[3](表 3)，用不同方法对南京市各监测点作污染状况评价，结果列于表 4、5。

由表 4 的结果可以看出，对南京市区大气S污染的评价，按理化监测的 SO_2 浓度和挂片 SO_3 浓度的评价结果与用生物监测测算值评价的结果相比，除背景值点以外，其余13个点，有5个点完全一致，8个点也相近。而用两个不同的理化指标(SO_2 和 SO_3)进行评价，13个点中也只有7个点一致，另6个点相差一个等级。这说明用生物监测的结果进行污染状况评价有一定可靠性。本试验中，

表 3　南京大气污染分级标准和叶片含污量分级标准

级　别	I 清　洁	II 轻污染	III 中度污染	IV 较重污染	V 严重污染
大气污染综合指数(PI)	≤1.5	≤4	≤9	≤23	>23
叶片污染综合指数(PI)	≤1.20	.21—2.00	2.01—3.00	>3.00	

表 4　南京市区各监测点 S 污染状况评价

编号	测　点	污染指数 (IPC)					污　染　等　级				
		大气 SO_2		挂片 SO_3		叶片	大气 SO_2		挂片 SO_3		叶片
		实测	计算	实测	计算		实测	计算	实测	计算	
1	中山陵	1		1		1	I		I		I
2	白鹭洲	3.6	3.6	3.8	5.5	2.1	II	II	II	III	III
3	七一四厂	1.6	3.3	3.2	5.3	2.0	II	II	II	III	II
4	中华门	3.8	4.1	6.7	6.6	2.4	II	III	III	III	III
5	安德门	2.0	2.3	5.8	3.7	1.5	II	II	III	II	II
6	光华门	3.8	3.3	6.1	5.3	2.1	II	II	III	III	III
7	瑞金新村	2.9	2.6	4.7	4.1	1.6	II	II	III	III	II
8	山西路	4.9	3.6	6.5	5.7	1.7	III	II	III	III	II
9	玄武湖	2.7	2.3	3.1	3.7	1.5	II	II	II	III	II
10	古　楼	4.0	4.4	6.8	6.2	2.3	II	III	III	III	III
11	教育学院	4.1	3.4	5.5	5.5	2.1	III	II	III	III	III
12	新街口	5.0	4.2	7.2	6.6	2.4	III	III	III	III	III
13	中山码头	1.9	3.0	5.2	4.9	1.9	II	II	III	III	II
14	制革厂	4.9	4.1	7.1	6.6	2.4	III	III	III	III	III

1) 南京市环境质量报告书(1981—1985)。

表 5 南京大厂区各监测点 S 污染状况评价

编号	测点	污染指数 (IPC)					污染等级				
		挂片 SO_3			叶片		挂片 SO_3			叶片	
		实测	法桐	女贞	法桐	女贞	实测	法桐	女贞	法桐	女贞
1	化机厂	5.0	>9	3.6	2.3	2.2	III	≥IV	II	III	III
2	运输公司	17.4	>9	>9	1.9	4.6	IV	≥IV	≥IV	II	≥IV
3	氮肥(像旁)	7.3	4.2	>9	1.5	4.7	III	III	≥IV	II	≥IV
4	图书馆	3.2	5.1	3.2	1.8	1.6	II	III	II	II	II
5	南化一小	9.3	>9	>9	2.0	3.8	III	≥IV	≥IV	II	≥IV
6	太子山公园	4.6	4.7	>9	1.7	5.0	III	III	≥IV	II	≥IV
7	煤球场	1.7	3.7	2.9	1.3	1.4	II	II	II	II	II
8	南化三小	5.8	3.8	>9	1.4	3.7	III	II	≥IV	II	≥IV
9	监测站	2.0	3.0	3.2	1.1	1.7	II	II	II	I	II
10	化校	1.3	3.2	—	1.2	—	I	II	—	I	—
11	催化剂厂	2.8	4.5	>9	1.6	3.6	II	III	≥IV	II	≥IV
12	磷肥厂	22.1	—	>9	—	6.1	IV	—	≥IV	—	≥IV
13	氮肥厂	19.5	—	>9	—	5.2	IV	—	≥IV	—	≥IV
14	六街区	3.5	2.1	2.8	0.8	1	II	II	II	I	I
15	潘营	6.1	>9	—	2.3	—	III	≥IV	—	III	—

大气 SO_2 测值是 4—9 月份的平均值，而生物监测的时段，二次采样所反映的是从叶片开展的 4 月到 7 月和 4 月到 9 月，这中间存在相当大的差距，这是误差的部分原因。

由表 5 的评价结果可以看出，对南京大厂区空气 S 污染评价，15 个监测点中有 6 个点生物监测与挂片法一致，有 5 个点基本一致，有 3 个点相差一个污染等级，只有一个点相差两个污染等级。

通过上面的比较可以认为，利用植物叶片含硫量的监测可以较为准确地评价南京地区大气硫污染状况。

三、初步结论

1. 法桐和女贞叶片的含硫量与大气中 SO_2 浓度密切相关，因此，可以通过叶片含污量分析监测大气环境的污染程度。所建立的回归方程 (1) 可以很好地推算南京市区大气 SO_2 的浓度；方程(2)可以测算南京市区挂片 SO_3 浓度；方程(3)和(4)可以测算大厂区挂片 SO_3 浓度。

2. 根据回归方程的测算值进行评价，结果是可信的。它优于直接用叶片含污量的污染指数所做的评价。从表 4、5 可知，直接用叶片污染指数评价的结果与理化参数的污染指数评价的结果有一定的系统偏差。这可能有两个原因：一是两系统的标准不一致；二是叶片污染指数计算时所用的背景数的误差影响。后者可能是主要的，前者尚难定论，笔者认为表 3 中的两类标准大致是吻合的。

参考文献

[1] 城乡建设环境保护部环境保护局环境监测分析方法编写组，环境监测分析方法，第 186—193、201—205 页，城乡建设环境保护部环境保护局，北京，1983.
[2] 潘如圭，环境污染与防治，(5)，28(1982).
[3] 李正方等，中国环境科学，(2)，29(1982).

(上接第 70 页)

[9] 邓宝山，环境科学学报，3(2)，113(1983)
[10] 中国科学院南京土壤所，中国土壤，科学出版社，北京，1978年
[11] 何群，土壤学报，21(4)，401(1984)

Abstracts

Chinese Journal of Environmental Science

PSAM-A New Decolorizing Flocculant for Dyeing Wastewater. Gao Baoyu, Liu Baodong, Wang Shuren (Center of Environmental Science, Shandong University, Jinan): Chin. J. Environ.Sci. 13(1), 1992, PP.

A new type of decolorizing flocculant, polysilicic acid containing metal ions (PSAM) was prepared. The properties and effectiveness of PSAM for wastewater treatment were studied and compared with those of PAC. Factors, affecting decoloration and flocculation were examined. Experimental results show that pH value has great influence on the flocculating and decolorizing effect of PSAM. PSAM gives good effect in turbidity removal at *pH 5.5—10.5*. The best decolorizing effect of PSAM was observed at pH 6—8 and 13. Compared with PAC, PSAM gives not only good flocculation effect but also good result in color removal.

Key words: polysilicic acid containing metal ions, inorganic polymer decolorizing flocculant, decoloration, flocculation.

Catalysts and Process for the Elimination of Organic Nitrogen Pollutants. Yuan Xianxin, Luo Mengfei, Chen Min, Ma Luoya, Jin Songshou (Dept. of Chemistry, Hangzhou University, Hangzhou): Chin. J. Environ. Sci., 13(1), 1992, pp.

Deep oxidation of volatile organic nitrogen pollutants such as N-dimethylformamide (DMF) and butylamine could be achieved under the catalysis of PCN-1 and PCN-2. The activtiy of the two catalysts were studied. Experiment results show that the effect of a double bed composed of PCN-1 and PCN-2 is better than any single catalyst bed for purifying DMF or the mixed vapors of DMF with toluene or methylethylacetone. The vapors could be completly oxidized and basically no NO_x came out at working temperature ranging from 240 to 300°C. The purified stream was esentially odourless and colourless This technology proved to be suitable for the purification of exhaust gas in the process of producing PU synthetic leather.

Key words: organic nitrogen compounds, purification of organic nitrogen vapour,double catalyst bed.

An Approach to Regional Comprehensive Environmental Risk Assessment in an Oilfield. Yang Xiaosong, Wang Huadong, Ning Datong (Institute of Environmental Sciences, Beijing Normal University): Chin. J. Environ. Sci.,13(1), 1992,PP.

The major interest of Environmental Risk Assessment (ERA) lies in the uncertainty of accidental occurance in the environment. This paper aims at making trial approach on comprehensive ERA in a regional limits. The authors advanced some relevant concept, procedure and method of regional ERA. Furthermore, the Panjin Oil Field was taken as an example for regional integrated study on ERA, and encouraging results have been acquired.

Key words: regional environment, environmental risk assessment; risk management.

A Study on the Reasons of the Low Flourine Content in Groundwater in Southeast China. Chen Jingsheng, Yin song, Zhang Chaosheng (Department of Urban and Environmental Sciences, Peking University): Chin. J. Environ. Sci., 13(1), 1992, PP.

Total flourine content and water extractable flourine content in zonal soils developed on granite from northeast China, north China, middle China and south-east China were compared, and the adsorption capacity for flourine anion of these soils were studied. The total flourine content in soils decreases from north to south, with the lowest in lateritic soil and laterite, and the water extractable flourine content varies in the same way. Adsorption experiment results show that in the eastern part of China, adsorption capacity of soils for flourine anion increases successively from brown soil, yellow soil to red soil and laterite. Considering from the viewpoint of geochemistry, the reason for low flourine content in water resources in south-east China lies on: (1) the heavy leaching of flourine during the process of the weathering of granite into soils. (2) the high hydroxyl content of the soils in southeast China resulting in high exchange capacities for flourine anion.

Key words: flouring in soil, flourine anion, soil adsorption capacity.

Relationship between Sulfur Content in Plants and Atmospheric SO_2 Concentration in Nanjing City and Its Application in Assessment of Air Pollution. Jiang Jinrong, Xu Yigang (Nanjing Institute of Environmental Science, NEPA), Shi Lei, Xu Jianhua (Nanjing Municipal Environmental Monitoring Station), Ye Jiahe, Tang Houdai (Environmental Monitoring Station of Nanjing Chemical Industry Company): Chin. J. Environ. Sci., 13(1), 1992, PP.

Plane tree (Platanus orientalis) and glossy priver were chosen to monitor SO_2 pollution in 29 sites selected from 14 locations in general air polluted areas and 15 locations in heavy industrial polluted areas in Nanjing city. The leaves of the plants and air samples in the sites were collected and analyzed for sulfur. Analytical results show that sulfur contents in the leaves of plants were closely related to SO_2 concentrations in the air. It is concluded that under general air pollution, linear regression function can be used to properly estimate SO_2 concentrations in the air and to assess air pollution level. However under conditions of serious or very serious air pollution, exponential regression function can be used in the proper estimation of SO_2 concentrations in the air and assessment of air pollution level.

Abstracts

Key words: SO_2 pollution, air pollution, sulphur content in plants, assessment of air pollution, plant indicator.

Study on Optimal Station Setting forM onitoring of Atmospheric Environment in Anyang Urban Area. Fu Jinsheng, Liu Ansheng, Chen Yafen. (Anyang Environment Protection Monitoring Station, Anyang): Chin. J. Environ. Sci., 13 (1), 1992, PP.

A model of optimal station setting for the monitoring of atmospheric pollution was developed based on the trait of local environment, the weblike check monitoring and the analysis of historical environmental data. The number of optimal stations was decided by variable factor method of sampling theory. The locations of the optimal stations were decided by correlation analysis method. The outputs of the model can depict the environmental trait of middle cities in plain areas.

Key words: atmospheric pollution monitoring, optimization of monitoring, model of optimal setting stations, number of optimal stations,situations of optimal stations.

Rapid Determination of COD_{Mn} in Environmental Water Samples Using Microwave-Heating Digestion Method. Gao Xiangyang (Henan Agricultural University, Zhengzhou), Guan Di (Southwest Jiaotong University, Chengdu): Chin. J. Environ. Sci. 13(1), 1992, PP.

A new microwave-heating digestion method was developed for the rapid determination of COD of water samples taken from Xiliu lake, Yellow river as well as a standard water sample (CW82: Environmental Monitoring Station of China). Water samples were dispelled in a closed-vessel with potassium permanganate under the action of microwave and as many as 14 samples could be treated each time. High Cl^- content (up to 1000 mg/L) did not interfere with the determination. The detection range of COD was found between 0.26 mg/L and 15.0mg/L, relative standard deviation less than 4.0%(n=5 or 6), recovery ranging from 97.0% to 105.6%, and relative error 0.3% for the determination of CW82 standard water sample. Compared to the classical method, this method proved to be simple, rapid, accurate and suitable for the determination of COD_{Mn} of lightly polluted water.

Key words: microwave-heating digestion, COD_{Mn} determination.

Sediment-Water Exchange Capacity of Total Phosphorus in Taihu Lake Calculated by Mass Budget Model. Huang Shaoji (Department of Environmental Protection, Suzhou Institute of Urban Construction & Environmental Protection, Suzhou), Zhao Haizhou, Fang Manping (Jiaozuo Municipal Pollution Management Station, Henan Province): Chin. J. Environ. Sci. 13(1), 1992, PP.

Sediment is a source or sink of micropollutants. Mass budget model is used to calculate the total phosphorus mobilization monthly in 1980 from the sediment in Taihu Lake. The mobilization is found to obviously affect the total concentration change in water body.

Kew words: mass budget model, taihu lake, sediment, phosphorus.

Introduction to Risk Assessment and Risk Management. Zhao Zhenhua (Beijing Municipal Research Institute of Environmental Protection): Chin. J. Environ. Sci., 13(1), 1992. PP.

In this paper, a brief introduction is given to the concept, main content, procedure and interface of risk assessment and risk management. Risk assessment is gaining increasing importance to the regulatory decision—making bodies in the process of formulatign policies intending to minimize health risks resulting from exposure to hazardous substances. Recent trends of risk assessment of environmental hazards are also reviewed.

Key words: risk assessment, risk management, hazardous chemical.

Statistics of Directional Data in Environmental Meteorology. Zhuang Shijian (Xiamen Municipal Research Institute of Environmental Protection): Chin. J. Environ. Sci., 13(1), 1992, PP.

There are many problems in environmental meteorology in which only angles are concerned. Directional data have specific features resulting in the apparent differences between statistics of directional data and general mathematical statistics. In this paper, statistics of directional data is applied to the ennvironmental science. By means of direct-viewing wind rose, wind direction data is naturally expressed. The concept and calculation of average wind direction is introduced, and the reasonable calculation of wind direction standard deviation is also illuminated. As an example, the wind directions in xiamen was studied.

Key words: wind direction data, statistics of directional data.