研究简报

植物叶片超氧化物歧化酶与二氧化硫大气污染关系的研究

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摘要 本文报道了在自然条件下，二氧化硫污染区与对照区四种抗污染性较强的植物叶片中，超氧化物歧化酶(SOD)的活性变化情况. 结果表明,污染环境中，有一半实验材料的 SOD 活性低于对照;讨论了影响 SOD 活性的因素.

二氧化硫等大气污染物进入植物体内后,会引起植株一系列的变化，并造成伤害. 二氧化硫气体的毒害可分为亚硫酸盐对植物的直接与间接伤害[1]. 对此已做过许多研究并提出过相应的机制. 六十年代末，Fridovich, I. 发现了超氧物歧化酶 (Superoxide Dismutase, SOD) 以后，SOD 在防御衰老、抗干旱、抗污染等方面参与的机制与保护性功能愈来愈引起人们的兴趣[1,2,3]. 在通常情况下，需氧生物在还原 O_2 为 H_2O 的过程中,会产生 O_2^-、$HO\cdot$、$^1O_2$、H_2O_2. 这些反应活性高的中间产物对有机体具有毒害作用. 但是,作为生物体系的保护性酶系统的 SOD 可通过催化 O_2^- 的歧化作用，将 O_2^- 转化为 O_2 与 H_2O_2; 过氧化物酶和过氧化氢酶再将 H_2O_2 转化为 H_2O 与 O_2. 因此，SOD 成为 O_2^- 的清除剂. Tanaka, K. 等人 (1980) 采用人工二氧化硫气体熏蒸方法，发现白杨树叶片经低浓度 SO_2 熏蒸后，叶片的 SOD 活性增加,对 SO_2 忍耐性提高[4]. Agrawal, M. 等人 (1987) 也得出相似的结果[5]. 不过，在自然条件下，SO_2 污染植物叶片中的 SOD 活性变化情况尚未见报道. 本文着重讨论这方面的问题.

一、实验材料与方法

(一) 材料

以受 SO_2 污染的广州氮肥厂硫酸车间附近的四种树样，即高山榕 (*Ficus altissma.* Bl.)、印度榕 (*Ficus elastica* Roxb)、黄槿 (*Hibiscus tiliaceus* Linn)、蒲桃 (*Syzygium jambos* (L.) Alston) 的叶片为材料. 采集时间为 1988 年 5 月中旬.

高山榕位于污染源 (SO_2 排放烟囱) 东 150m 以内，印度榕位于污染源西 200 m 以内,黄槿位于污染源东、南、西各 200 m 以内,蒲桃位于污染源东 200 m、南 150 m 以内. 广州氮肥厂 1988 年 5 月份厂区内空气中 SO_2 的浓度平均为 0.151 mg/m³ (该月最高浓度为 0.623 mg/m³)，风向：东风或北风.

非污染区样品采自华南植物园内，当时园内空气中 SO_2 浓度平均为 0.02 mg/m³.

(二) 酶液制备

将采自不同区不同树种的成熟叶片用自来水冲洗干净后用 70% 酒精消毒. 擦干表面水分,去叶柄和叶脉. 剪碎称重 (4g). 放入预冷的研钵内，加入 1 ml 100 × 3 nmol·dm^{-3} EDTA 和 19 ml 0.05 mol·dm^{-3} pH 7.8

磷酸缓冲液作为研磨介质，加少许石英砂进行研磨．四层纱布过滤入 25 ml 容量瓶内，并用 0.05mol·dm^{-3} pH 7.8 磷酸缓冲液定容．匀浆在 15000 ×g 冷冻离心 20 分钟，上清液即为 SOD 粗提取液．

（三）酶的活性测定

根据王爱国等（1983）的方法[6]．3ml 反应混合液中含有 1.3 μmol·dm^{-3} 核黄素；13 m mol·dm^{-3} 蛋氨酸；63 μmol·dm^{-3} 氯代硝基四唑蓝（NBT）；0.05 mol·dm^{-3} pH 7.8 磷酸缓冲液；酶液 0—35 μl；用重蒸水补充到 3 ml，其中核黄素最后加入，摇匀．置于 82 μmol·m^{-2}·s^{-1} 荧光下光照 15 分钟．体系产生的 O_2^- 还原 NBT 形成蓝色甲臜，在 560 nm 下测其光密度．以置于暗中相同时间的不加酶的反应液为空白．SOD 作为 O_2^- 的清除剂抑制此反应．酶的活性单位采用抑制 NBT 光化还原 50% 的酶用量作为一个活性单位．

二、结　果

NBT在82 μmol·m^{-2}·s^{-1}荧光下照光 5—20分钟，其光化还原直线上升．40 分钟后趋

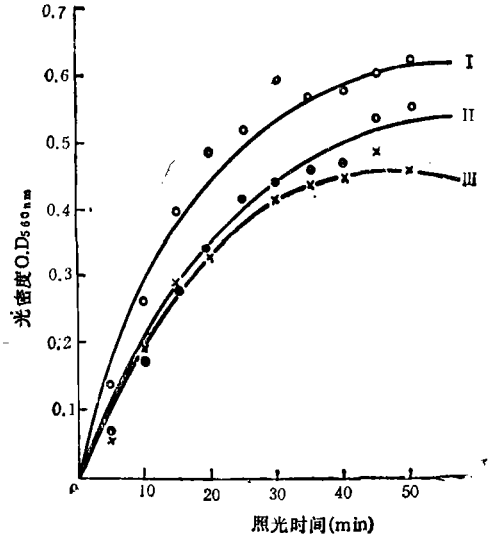

图 1a　高山榕 SOD 对 NBT 光化还原速率的影响
I 无酶液，II 含对照样品酶液 10 μl
III 含污染样品酶液 10 μl

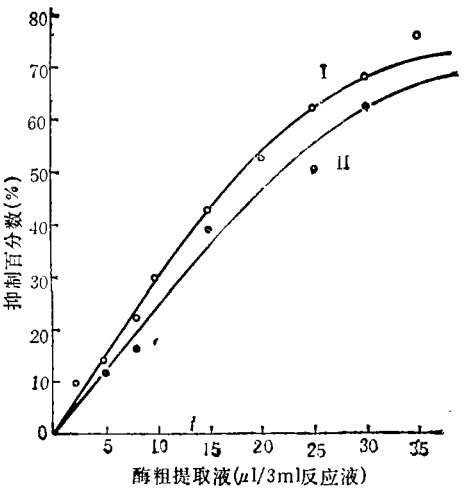

图 1b　高山榕 SOD 对 NBT 光化还原的抑制百分率
I 污染　II 对照

于稳定．SOD 对 NBT 光化还原有明显效应（图 1a，2a，3a，4a），抑制百分数基本随酶量增加呈抛物线上升（图 1b，2b，3b，4b）．高山榕和印度榕叶片被 SO_2 污染后，其 SOD 活性高于对照，黄槿和蒲桃叶片被 SO_2 污染后，其 SOD 活性低于对照（见表 1）．

表 1　SO_2 污染四种树木叶片中 SOD 活性变化幅度

树种	SOD 活性 mol/活性单位/ml 提取液		SO_2 污染区与对照区 SOD 活性的相差
	污染区	对照区	
高山榕	55	45	+10
印度榕	108	85	+23
黄　槿	70	85	−15
蒲　桃	175	208	−33

注：+ 活性增加；− 活性下降．

人们认为 SO_2 进入植物体内会转变成 SO_3^{2-}、HSO_3^-、SO_4^{2-}，同时产生活性氧 O_2^-、HO·、$^1O_2$ 以及 H_2O_2 等[1]．还证实了超氧化物游离基在 0.01—0.1 μmol·dm^{-3} 时就会引起植物伤害，致使 CO_2 固定被抑制，光合作用速率降低[1]．杨礼锐等人*证实了富集 SO_2

* 第五次全国植物与环境保护学术讨论会论文集46—49页．

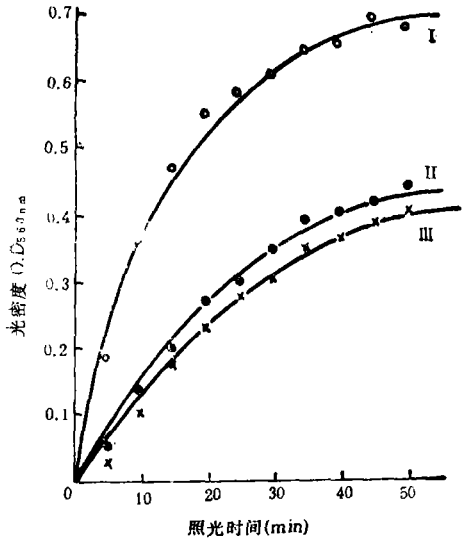

图 2a　印度榕 SOD 对 NBT 光化还原的影响
I 无酶液，II 含对照样品酶液 10 μl
III 含污染样品酶液 10 μl.

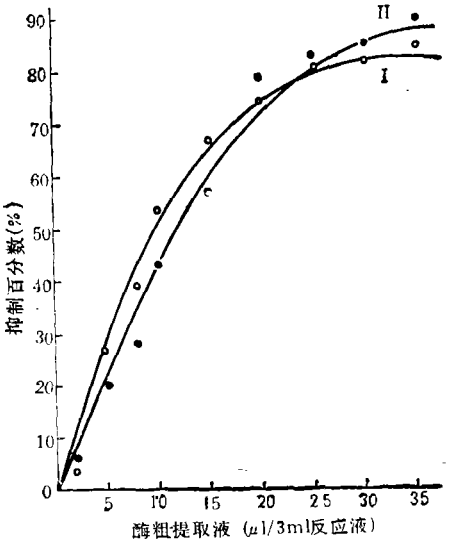

图 2b　印度榕 SOD 对 NBT 光化还原的抑制百分率
照光时间 15 分钟
I 污染　II 对照

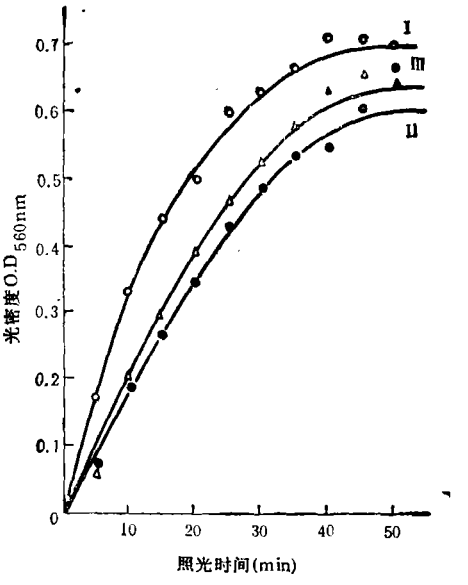

图 3a　黄槿 SOD 对 NBT 光化还原的影响
I 无酶液，II 含对照样品酶液 10 μl
III 含污染样品酶液 10 μl.

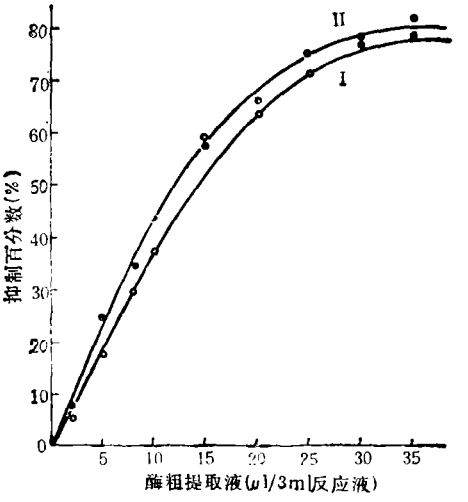

图 3b　黄槿 SOD 对 NBT 光化还原的抑制百分率
照光时间 15 分钟
I 污染，II 对照

越多的叶片，其叶绿素含量下降越多．由此供给植物生长的光合产物减少，植株生长速率下降．污染的空气对植株的毒害作用促使人们研究消除它毒性有关酶的特性．Tanaka 等人（1980）利用人工熏蒸白杨叶片的研究表明，叶片被污染后，叶片中 SOD 的活性高于对照，说明白杨叶片对 SO_2 污染具有抗性．他们认为 SOD 活性的增加，可能是由于 O_2^- 激发叶片中酶合成增加所致．我们的测定结果表明，印度榕与高山榕叶片中 SOD 的活性，在被污染后也是增加的，而且在采集样品时，污染区这两种植株茁壮生长，未见到

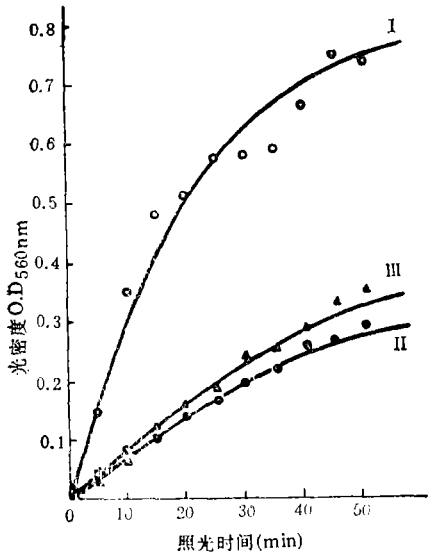

图 4a　蒲桃 SOD 对 NBT 光化还原的影响
I 无酶液，II 含对照样品酶液 10 μl，
III 含污染样品酶液 10 μl

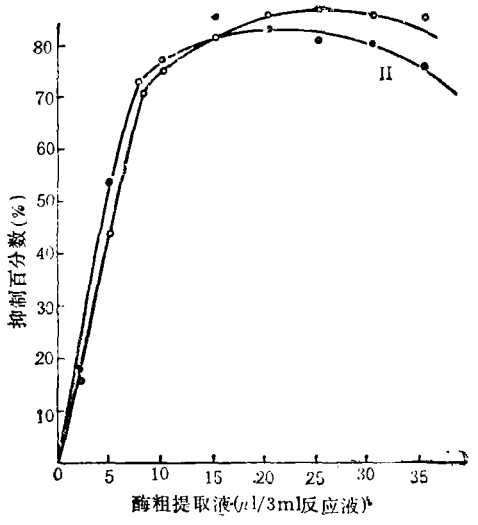

图 4b　蒲桃 SOD对 NBT 光化还原的抑制百分率
照光时间 15 分钟
I 污染，II 对照

有 SO_2 伤害的症状，尤其是印度榕的生长旺盛，叶片无任何斑渍．表观与测定都与 Tanaka 等人的结论相一致．

Tanaka 等人 (1980) 认为大气污染物对植株的伤害程度与植物的品种、营养条件、年龄、周围气体状况与光照强度条件有关．黄槿与蒲桃叶片受 SO_2 污染后，SOD 低于对照可能与上述几个方面有关．Tanaka 等人 (1980) 实验发现，二乙基二硫代氨基甲酸 (DDTC) 处理菠菜叶片会引起 SOD 失活，因而叶绿体中的 O_2^- 浓度增加，增强了 SO_2 熏蒸对叶绿素的破坏，从而降低了对 SO_2 毒素的忍耐力．我们采样时看到蒲桃叶尖端枯干，黄槿叶片有水渍斑并变黄，受害较重．

郁梦德 (1980) 实验证实了，对 SO_2 的抗性，在四个树种中其顺序是印度榕、高山榕、黄槿、蒲桃[7]．我们的实验从另一个侧面证实了，印度榕与高山榕之所以具有高的抗 SO_2 毒害，可能与它们叶片中 SOD 的高活性有关，而黄槿与蒲桃叶片中的 SOD 活性不高，从而表现出不同程度的伤害．当然决定抗性强弱的因素是由它们的遗传特性所决定；而另一方面，也可能由于地点不同（离污染源东、西、南、北不同，距离不等，污染程度相异），SO_2 浓度不同所致．

Tanaka 等人 (1980) 提出，除 SOD 外，O_2^- 还可通过与叶绿体中几种组分相互作用而得到清除．如细胞色素 f、质体蓝素、铁氧还蛋白、抗坏血酸、还原型谷胱甘肽和 Mn^{2+} 等．Nakano 等 (1981) 提出叶绿体中可能存在如下两个电子传递模式：

① 光系统 I $\longrightarrow O_2^- \longrightarrow H_2O_2$

② 光系统 I $\longrightarrow$ 铁氧还蛋白 $\longrightarrow$ NADP $\rightarrow$ 谷胱甘肽 $\rightarrow$ 抗坏血酸 $\rightarrow H_2O_2$

模式②中，抗坏血酸可作为 H_2O_2 的电子供体[8]．Tanaka 等 (1982) 用 2.0 ppm SO_2 熏蒸菠菜 100 分钟，发现菠菜叶片中与清除活性氧有关的酶，即抗坏血酸过氧化物酶、谷胱甘肽还原酶、过氧化氢酶的活性丧失．可见这些酶对 SO_2 熏蒸是敏感的．实验同时指出，此时菠菜叶片中的 SOD 活性稍有下降[1]．因此我们设想，从机理上看，是否黄槿与蒲桃受 SO_2 污染后，电子传递到NADP

或抗坏血酸时由于谷胱甘肽还原酶或过氧化氢酶的失活或部分失活，造成 H_2O_2 的积累；另外，亚硫酸盐的积累也会导致 H_2O_2 的积累[1]. H_2O_2 的积累会促使 $O_2^- \longrightarrow H_2O_2$ 受抑制，从而促使 SOD 活性降低.

SO_2 对植物的毒害，部分是由于超氧化物游离基的缘故. SOD 参与防御 SO_2 毒害的机制已为人们所接受. 黄槿与蒲桃叶片中，究竟是什么物质引起它们的 SOD 部分失活，留待以后研究.

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水样的保存——Se(IV) 和 Se(VI) 吸附特性的研究

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摘要 本文使用新极谱法研究不同材质器皿、温度、pH、富里酸浓度条件下，水样中 0.05—0.10 ppb Se(IV) 和 Se(VI) 的贮存损失. 实验结果确定，低温、酸性、加入富里酸的石英器皿贮存硒的效果最好，玻璃器皿最差，聚乙烯居中. 采用硝酸钝化过的聚乙烯瓶贮存天然水，加硝酸调节 pH 为 1.0 时，Se(IV) 和 Se(VI)保存一个月浓度基本不变.

硒是生命元素已为人们所注目[1]. 有关学者研究指出大骨节病、克山病、心脏病和某些癌症产生于水、土、粮中硒较低的生态环境[2]. 因此对饮水中硒的测定是非常重要的. 文献指出我国西北地区水中硒的含量小于 0.5 μg/l，东北地区小于 0.1 μg/l[3,4]. 水样采集后因器壁吸附、络合、沉淀等物理化学作用影响水中硒的真实含量. 因而为了选择水样硒的保存方法，故对不同材质器皿、水样不同预处理条件下硒的损失研究是很有必要的. 由于硒的分析方法灵敏度所限，在国内外尚未见到低于 0.10 ppb Se(IV) 和 Se(VI) 不同价态硒的水样保存条件的研究报道. 本文采用滴汞电极 1.5 次微分新极谱法测定痕量的 Se(IV) 和 Se(VI)，检测下限为 0.01 ppb，回收率 96—103%[5]，研究 0.05—0.10 Se(IV) 和 Se(VI) 分别在石英、聚乙烯、玻璃瓶中，于不同 pH 值、温度、富里酸的条件下贮存过程中的损失.

实 验 部 分

一、仪器和试剂

XJP-821 型新极谱仪 三电极系统，滴汞电极为工作电极，银电极为参比电极，铂电

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Abstracts

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Study on the Flocculation Mechanism of Polycrylamide

Wang Qi, He Qiang and Jiang Zhanpeng (Department of Environmental Engineering, Qinghua University)

This paper deals with the shape condition of polyacrylamide at the optimum flocculation state using Mean Square Root End-to-End Distance as the shape paramenter of polyacrylamide in aqueous solution. It shows that Mean Square Root End-to-End Distance can be used as the floceulation control factor. When using polyacrylamide to treat water and the bigger the Mean Square Root End-to-End Distance is, the better the results of flocculation of polyacrylamide. Various factors affect the shape of polyacrylamide in aquious solution while in the determined ionscondition Mean Square Root End-to-End Distance can be limited. Hydrolysis test reveals that optimum solubility of polyacrylamide is 54%. It is found that at the range of 0 to 1 mg/L of polyacrylamide the effect of flocculation can come up to optimum and the optimum concentration of polyacrylamide is 0.4 mg/L. In addtion, the shape of polyacrylamide in aqueous solution has been observed by electromicroscope with a satisfied result. (See pp. 2—6)

The Model Prediction of Atmospheric Pollution and Its Comparison with the Observed Data in the Area of Gujiao Mine

Hu Erbang et al. (Institute for Radiation Protection, Taiyuan)

The Gaussian plumemodel or volume puff model under changing weather conditions (for a point source) cee perated with ATDL (for an area source) has been used to predict the following quantities of atmospheric pollutants (SO_2, dust etc.) at several sites of interest in the area of Gujiao coal Mine: annual average concentration, typical average day concentration, and maximum hour concentration, the predicted values are statistically compared with measured ones based on the correlation coefficient r and the index of agreement d. The results show that the models adopted are applicable while the performance of the volume puff model is obviously better than the Gaussian plume model. (See. pp. 7—14)

A Study on Purifying Capacity of Water Hyacinth in Pb-and Cd-Polluted Water

Zhang Zhijie et al. (Dept. of Environmental Engineering, Xi'an Institute of Metallurgy and Construction Engineering)

Under laboratory-conditions, the absorption of Eichhornia crassipes to Pb-and Cd-polluted water and its purificatory function were studied. The results show that water hyacinth has significant accumulation and purifyiny function. In different concentrations of Pb and Cd-containing wastewater about 62—89% of Pb and Cd were dispelled by hyacinth in 7-10 days. The absorbed Pb and Cd in hyacinth was much more in roots and stems than in leaves. It was found that the Pb and Cd levels accumulated in plant roots and stems were 84—93%. Moreover, the absorption of Pb by hyacinth was much more than that of Cd. The above data show that water hyacinth is a good purifier for Pb and Cd-polluted water. (See pp. 14—17)

A Study of the Wave Sound in the Environmental Noise in the Seaside Sanatorium Quarter of Qingdao

Chen Ziming and Xie Fengming (Department of Physics, Qingdao University of Oceanography); Zhang Ning (Qingdao Sanatorium)

In this paper it is assumed that environmental noise in a seaside sanatorium quarter is composed of wave sound and the background environmental noise when wave sound is absent ($L=L_0+L'$). To analyse the effect of wave sound on human beings, an experimental method is presented. The stress is on the studies of the relation between sound from various waves (bores, wind-generated waves, swell) and topography, the relation between the intensity and frequency spectrum of wave sound and people's feeling during the windowopen period (from May to September). The results show that over 98% patients give a favourable or neutral comment on ordinary waves, and the rate of occurence of wave noise interfering sleep is below 2%. Hence we conclude that ordinary wave sound should not be regarded as noise and we make some suggestions concerning the evaluation criterion of the environment noise in seaside sanatorium quarters, which are of practical significance for the environment noise pre-evaluation and the siting of new sanatorium buiding in Qingdao and other seaside cities. (See pp. 17—21)

Studies on the Relationship between Superoxide Dismutase of Plant Leaves and Air Pollution of Sulfur Dioxide

Yang Lirui et al. (Department of Biology, South China Agricultural University, Guangzhou)

The present paper deals with the activity changes of superoxide dismutase (SOD) in leaves of 4 species of trees more resistant to sulphur dixide pollution, determined in polluted and control areas. It has been found

that the activity changes of SOD in a half of the samples was lower in the polluted area than in the control area. The factors that result in the activity changes of SOD have been discussed. (See pp. 22—26)

Preservation of Water Sample Containing Se (IV) and Se(VI)

Wu Dunhu (Department of Applied Chemistry, Dalian Railway College): Zhang Jingyan and Liu Xiufang (Changchun Training School of Metallurgical Geology)

A new polarographic method has been used to study the effects of preserving conditions, such as materials of container, pH, temperature, and addition of fulvic acid, on the losses of Se(IV) and Se(VI) at the initial levels of 0.05—0.10 ppb in water samples during preservation. It has been found that, when the water samples were preserved at low temperature and added with fulvic acid under the acidic condition, quartz containers were the most suitable to be used for the purpose, and glass containers were the most unsuitable to do so while polythene ones were between them. The use of polythene bottles passivated with nitric acid for preserving the natural water, adjusting pH to 1.0 with HNO_3, has led to the levels of Se(IV) and Se(VI) almost without change for one month. (See pp. 26—30)

A study on Concentrations of Microorganisms in the Atmosphere of Beijing and Tianjin areas

Hu Qingxuan et al. (Institute of Biotechnology, Acadamy of Military Medical Sciences, Beijing 100071)

Concentrations of airbone bacterial and fungous particales in three sites in the Beijing and Tianjin areas were determined by a six-stage Andersen sampler modelled in our laboratory. Results showed that the average concentrations of bacteria in air were 3.02 CFU/L a year for Xidan, Beijing, 2.56 CFU/L for Fengtai Beijing, and 1.38 CFU/L for the seaside in Tanggu, Tianjin, and that the average concentration of fungi in air of Fengtai was 1.20 CFU/L a year. With respect to the temporal distribution of concentration of bacteria in air, there were two peaks, at 7:00 a. m. and 10:00 p. m., and two valleys, at 1:00 p. m. and 1:00 a. m.. There had been similar pattern for the concentrations of bacteria which were collected on each stages inside the Andersen sampler. (See pp. 30—35)

Effects of Low Level of SO_2 on Growth of Apple Tree Long-term Exposured to It

Jiang Fang (Shenyang Institute of Environmental Science)

The experiments have ben conducted on the 11-yearold *Guoguang* apple trees during a growing period by exposing to low levels of SO_2 in 4 top-open field chambers with one chamber for each tree. The levels of SO_2 in each chamber were 0, 0.10, 0.18 and 0.28 mg/m^3, respectively. By the determination and analyses of the photosynthesis rate, area of leaf, unit weight of leaf and length of branches in one year old, it has been found that the exposure to 0.10 mg/m^3 of SO_2 had no significant effect on the indicators studied, the exposure to 0.18 mg/m^3 had a slight effect, and the exposure to 0.28 mg/m^3 had a significant effect. (See pp. 35—38)

Controlling the Source of PCBs Pollution at a Transformer Substation

Jiang Ke and Chen Ronli (Research Center for Eco-Environmental Sciences, Academia Sinica, Beijing)

Some transformer substations are potential sources of PCBs pollution in China. PCBs will be released to the environment when the old power capacitors using PCBs as soaker are demaged. This paper deals with the harness of a typical source of PCBs pollution at Qin'an Transformer Substation. A set of GC/ECD and GC/MS methods have been used for accurate and rapid measurement of total PCBs. The assessment of soil and air quality in a typical substation at Qin'an has been completed. The practical options for PCBs pollution control have been designed based on the local conditions. The follow-up monitoring in one year after completing the harness shows that the pollution has been substantially controlled and the risk of PCBs contamination to human health has been minimized at the substation. (See pp. 43—46)

Decolorization of Dyeing Wastewater Using Purple Nonsulfur Photosynthetic Bacteria

Wu Guoqing et al. (Taiyuan University of Technology, shanxi Province)

The purple nonsulfur photosynthetic bacteria have been separated from the activated sludge in an aeration tank at Shanxi Textile Mill. The bacteria were used to decolor 14 kinds of dyeing wastewater, of which under anaerobic conditions 12 kinds of dyes were mostly decolored. The efficiency of decolorization was higher than 75%. The influence of temperature, pH, etc. on the decolourization and the decolourizing mechanism have also been studied. (See pp. 46—50)

Research on the Stability and Control of Pelelith Anaerobic Filtration Process

Zhang Lifen (Research Institute of Food and Fermentation Industry, Ministry of Light Industry)

The anaerobic filtration (AF) is the process in which organic matter is broken down under anaerobic condition to methane and carbon dioxide. In the process, bacteria attach themselves quickly upon filter media and

(continued on p. 77)