CO 污染对木本植物的影响*

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CO是一种无色、无臭、无味的气体，是一种重要的大气污染物质．它主要来自交通运输，燃料不完全燃烧和生产过程排放的废气．

目前大工业城市空气中CO浓度对植物的影响如何，尤其是对木本植物的影响国内外有关的报道尚不多．本文就CO对木本植物伤害症状以及对光合作用的影响进行初步探讨，为环境质量生物学评价提供资料．

一、试验材料与方法

1.熏气模拟试验

试验材料分为离体枝条和盆栽幼树．

离体枝条为沈阳市常见的62种绿化树种．当天把枝条剪下，马上插入装有Hoagland培养液的小口瓶中，然后移入动态熏气箱中进行熏气试验，观察叶片伤害程度．盆栽试验树种有：花曲柳（*Fraxinus chinensis* Roxb.），山桃（*Prunus davidiana* (Carr.) Franch.），臭椿（*Ailanthus altissima* Swingle），桂香柳（*Elaeagnus angustifolia* L.），紫丁香（*Syringa oblata* Lindl.），苗龄2—3年生，于春天栽植在直径25cm，高20cm的盆钵中．幼树生长正常，于7月末移入动态熏气箱进行熏气试验．

熏气条件：熏气箱气体交换3次/min，光照10klx，箱内温度控制在24—25℃，CO纯度99.9%．

熏气浓度和时间：离体枝条熏气浓度30ppm和200ppm，时间为8h和16h。盆栽幼树熏气浓度分别为15ppm，40ppm，100ppm和350ppm，时间16h（即每天8h，连续暴露2天）．

浓度检测：红外分光光度仪，波长2112nm。

2.光合作用测定

树种为2年生盆栽花曲柳和山桃．

方法：首先把1—2片连体叶片放入叶室，在光照强度30klx，流量80—100L/h，叶室温度控制在23—24℃条件下，用佛山仪器厂生产的台式CO_2红外分析仪连续测定其在清洁空气（未加入CO）中光合作用速率，使其趋于稳定状态，作为起始值．然后，在环境条件不变的情况下，通入配置好的已知浓度为100ppm（体积比）的混合空气进行CO熏气，并连续测定CO_2吸收量的变化．用下列公式计算净光合作用速率：

$$P_n = \frac{\Delta CO_2 \cdot F \cdot D}{A}$$

式中，Pn为净光合作用速率（$mg \cdot CO_2/dm^2 \cdot h$）；$\Delta CO_2$为$CO_2$吸收值（ppm）；$F$为气体流量（L/h）；$D$为测定时叶室温度下单位体积$CO_2$重量（mg/L）；$A$为叶面积（$dm^2$）．

二、结果与讨论

（一）CO对木本植物伤害的影响

针对沈阳地区常见的62种绿化树木离体枝条和5种盆栽幼树进行不同剂量的CO熏气试验，观察树木叶片受害状况，结果如表1．

* 姚建华、林继惠同志参加光合作用测定，张丽珊、朱岩同志参加浓度监测，特此致谢．

表 1　木本植物对 CO 污染的反应

试验浓度 (ppm)	试验材料	树　种	症　状
15—40	3 年生盆栽幼树	臭椿、山桃、花曲柳，桂香柳，紫丁香	暴露 8h 树木叶片均未出现可见急性伤害症状
100—350	3 年生盆栽幼树	臭椿、山桃、花田曲，桂香柳，紫丁香	暴露 16h，4天后桂香柳下部枝条叶片变黄脱落，占 8.4—18.4%．其余树种均未出现急性伤害症状．
30	离体枝条	加杨、旱柳、油松，桧柏等 62 种树木	分别暴露 8h 和 16h，树木叶片均未出现急性伤害症状．
200	离体枝条	加杨、旱柳、油松、桧柏等 62 种树木	分别暴露 8h 和 16h，树木叶片均未出现急性伤害症状

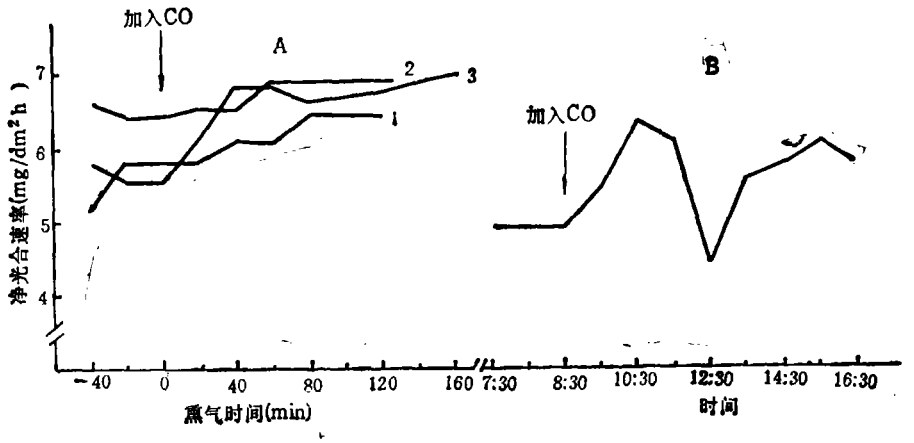

图 1　花曲柳净光合速率与熏气时间相互关系 1、2、3 分别表示 3 株花曲柳光合速率曲线

在环境控制条件下，进行不同浓度和暴露时间的 CO 熏气，其结果可以从表 1 看出，木本植物对 CO 的反应不是很敏感的．在高浓度长时间暴露情况下，仅观察到桂香柳下部枝条有 8% 和 18% 的叶片黄化脱落，而其它树木，无论是盆栽幼树还是中龄树木离体枝条的叶片，在实验浓度范围内均未出现可见的急性伤害症状．美国环保局资料同样表明[3]，植物暴露在 100 ppm CO 中 1—3 星期，不会引起植物的急性伤害．植物产生急性伤害程度，除了与气态污染物浓度和暴露时间以及树木生物学特性有关之外，同时也与气态污染物被植物相对吸收速度及其在水中的溶解度有关．据有关资料认为 CO 不能被植物有效吸收[2,3]．　在相同环境条件下处理等面积苜蓿覆盖对一些很重要的空气污染物的相对吸收速度及其溶解度顺序为 $HF > SO_2 > NO_2 > O_3 > NO > CO$，CO 溶解度为 0.02 $cm^3/cm^3 \cdot H_2O$，在 1pphm 下的吸收速率 0.0L/min · m^2．因此，可以看出，CO 被植物吸收的速度很慢或完全不被植物所吸收，因而也就不易使植物产生急性伤害．

（二）CO 对光合作用的影响

光合作用是植物的重要代谢过程，同时也是确定植物生长和生物量的重要指标．在上述熏气试验的基础上，以花曲柳和山桃为材料，探讨 CO 污染与树木光合作用相互关系，测定净光合作用速率的变化．

1．对花曲柳光合作用的影响

我们将 3 年生盆栽花曲柳暴露在 100

ppm CO 污染物中 2h，连续测定 3 株花曲柳光合作用速率的变化。如图 1 中所示，可以看出，3 株花曲柳的光合作用速率都比加入 CO 熏气之前有明显上升的趋势。尤其是当叶室加入 CO 之后的 40—60min，光合作用速率急趋上升，比加入 CO 前光合作用速率提高 6—25%。以后上升速度变缓，或趋于相对稳定状态。光合作用速率(P_n)与熏气时间(t)成指数相关。其回归方程分别为：① $P_t/P_0 = 5.75\exp(0.001t)$ $(r = 0.929)$，② $P_t/P_0 = 6.46\exp(0.0006t)$ $(r = 0.828)$，③ $P_t/P_0 = 6.38\exp(0.0005t)$ $(r = 0.706)$。其中，P_t 为 t 时间的净光合作用速率，P_0 为未加入 CO 熏气时的净光合作用速率，t 为 CO 熏气时间。

图 1 中 B 同样是暴露在 100ppm CO 污染物中 8h，连续测定光合速率日变化情况。试验从上午 7 时 30 分开始，8 时 30 分往叶室加入 CO 进行熏气，16 时 30 分结束。从试验结果可以看出，当叶室加入 CO 之后，前 2h 光合速率从熏气前 4.91mg/dm²·h 急趋上升为 6.33mg/dm²·h，比加入 CO 前提高 28.9%。此后光合速率逐渐下降，中午下降为 4.38mg/dm²·h，比加入 CO 前下降 11%。下午光合速率又逐渐上升，比加入 CO 前提高 17—23%。因此，花曲柳在 CO 污染物作用下，光合进程日变化形成双峰曲线。一个高峰在上午，一个高峰在下午。中午前后光合速率下降，出现抑制现象。

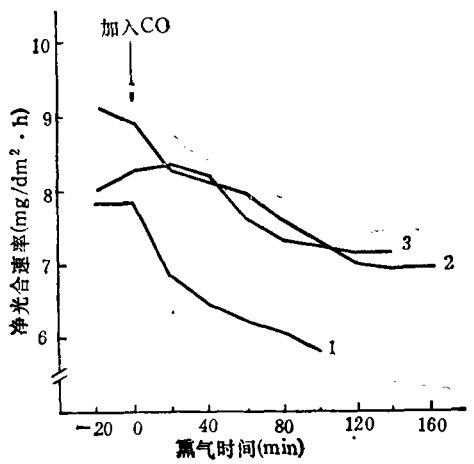

图 2　山桃净光合速率与重气时间关系曲线

注：1、2、3 分别表示 3 株山桃净光合速率曲线

2. 对山桃光合作用的影响

把 2—3 年生盆栽山桃暴露于 100ppm CO 污染物中 100—160min，分别连续测定 3 株山桃幼树 CO_2 交换情况。观察到其光合速率都比加入 CO 之前有所下降。从图 2 可以看出，其中山桃当叶室加入 CO 之后 20min，光合速率略有上升，但不明显。只比加入 CO 前上升 0.8%。40min 后光合速率便开始急趋下降，80min 后光合作用速率比加入 CO 前下降 12%。其余 2 株山桃当加入 CO 之后，光合作用速率立即开始急趋下降，40min 后光合作用速率比加入 CO 前分别下降为 17% 和 10%，以后下降速度变缓，或趋于相对稳定状态。试验结束时，光合作用速率分别下降了 25%，22% 和 14%。说明山桃在试验浓度条件下，其光合作用速率明显地受到抑制。光合作用速率与熏气时间形成负指数相关，其回归方程分别为 ① $P_t/P_0 = 7.04\exp(1.9 \times 10^{-4}t)$ $(r = -0.994)$，② $P_t/P_0 = 8.54\exp(1.4 \times 10^{-4}t)$，$(r = -0.973)$ ③ $P_t/P_0 = 8.62\exp(1.7 \times 10^{-4}t)$，$(r = -0.970)$。

三、小　结

1. 根据熏气试验结果可以看出，目前城市空气中 CO 浓度，不会引起对植物产生直接的损害。木本植物暴露在 350ppm 以下的 CO 污染物中 8—16h，未发现可见的急性伤害症状。

2. CO 对木本植物光合作用的影响，因树种不同而有较大差异。CO 对花曲柳的光合作用速率有促进作用，而对山桃光合作用速率则有抑制作用。因此，可以根据树种光合作用指标确定木本植物对 CO 污染物的抗性。

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接近，因而仅将 TN 去除率作为唯一考察指标填入正交表 Lg(3⁴) 的右侧，计算得表 5.

用直观分析结果，容积比 (1:R) 列以 III/3 最大，应取 1:3；回流比 (r) 列 III/3 最大，应取 5.5；水力停留时间 (HRT) 列 I/3 最大，应取 24h，故试验条件以 A_2、B_3、C_1 为最佳.

应当注意，各因素的水平试验结果差值并不太大，如 A(1:R) 的最大差值为 12.6，B(r) 为 18.4，只有 C(HRT) 为 31.2. 可以判断，HRT 这个因素是高度显著的，即对运转起决定性作用，而其它二因素水平间的差值是否由于水平变化引起的或是因试验误差带来的，尚需作方差分析才能确定.

2. 方差分析

经计算(从略)得方差分析表 (见表 6).

表 6 正交试验结果的方差分析

方差名称	S	f	V	F	显著性
A	98.9	2	49.3	4.65	*
B	171.0	2	85.5	8.07	**
C	492.3	2	246.2	23.23	***
误	212.1	20	10.6		

$F_{0.01}(2,20) = 5.85$ $F_{0.05}(2,20) = 3.49$

3. 工程平均估算

因子 C 高度显著，B 显著，A 较显著，分别选定其对 TN 去除率最有利的水平. 综合得出最优工程条件是 A_2、B_3、C_1.

$$\mu'_{A_2B_3C_1} = \mu + a_2 + b_3 + C_1 = 11.1$$

原数据的平均工程是:

$$\mu_{A_2B_3C_1} = 75 + 11.1 = 86.1$$

经计算 $\delta_{0.05} = 3.1$

应该有 95% 的把握说，按这个条件处理该腈纶废水，TN 去除率的真值为 86.1−3.1 到 86.1 + 3.1 之间，即高于 83%.

五、小 结

(一) 三个工艺影响因素中，以因素 C 即水力停留时间 (HRT) 为影响 TN 去除率的最主要因素. 在同一容积比 (1:R) 和回流比 (r) 条件下，HRT 越长，TN 去除率也越高. 然而，要获得 HRT 与 TN 去除率之间的结论关系，毕竟数据还不多，有待研究.

(二) 在其它条件相同的情况下，对于 TN 去除率来讲，因素 A 即容积比 (1:R) 中的 1:3.8 与 1:3 效果相差无几，说明 1:R 数值增大，TN 去除率将没有显著提高，因此容积比选用 1:3.8 或 1:3 均能满足试验要求.

(三) 在一定条件下，回流比 (r) 大，其 TN 去除效果好. 但从三水平的极差来看，相差并不大，因此如果对 TN 去除率要求不高，而又考虑节省动力消耗，那么也可以选择较小的回流比进行运转.

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A Study on Residual Dynamic of the Acaricide Peropal in Apples

Wang Ke'ou (Research Center for Eco-Environmental Sciences, Academia Sinica, Beijing)

In this paper, residual levels and degradation rates of the acaricide Peropal, tri(cyclohexyl)-(1,2,4-triazol-lyl) tin, in apples have been studied. 250—500 ppm solutions of tested acaricide were sprayed to the test trees at Beijing and Dalian orchards for 1—4 times. After 14 days of the last spray, residues in the apples were at 0.05—0.16 ppm. The half-life was about 14 days in the apples, about 20 days in soil under the fruit trees respectively.

Wethod for gas-chromatographic determination of Peropal and its major degradated product (tricyclohexyhydroxytin) has been established. The procedures are: first to convert the residues into their bromides, then to follow reaction with Grignard reagents quantitatively, last to determine the yielded tricyclohexyl-methyltin with GC-FPD. (See pp. 2—6).

Start-Up of Upflow Sludge Blanket Reactor and Sludge Granulation under Two-Phase Anaerobic Digestion

Yan Yuegen and Qian Yi (Department of Environmental Engineering, Tsinghua University, Beijing)

Start-up of sludge blanket reactor and granulation of sludge are investigated, with highly active and poorly settleable sludge as seed and glucose as substrate, under two-phase mesophlic anaerobic digestion (the acid phase is an upflow reactor of 4.7l without three phase separator within it and methane phase is a typical tower-shaped UASB reactor of 12.3l). Requirements for the cultivation of granules are presented. And physicochemical properties of the cultivated granules are analysed systematically. It is shown that the granules are well settleable and highly methanogenic, with settling velocity of 97.1% of granules $>2mm/s$ and methanogenic activity of 811.2 ml CH_4 STP/gVSS.d and 2.73 g COD/gVSS.d. The reactor can retain large amounts of granules with its concentration of 56g VSS/L, resulting in a high treatability, up to 80kg COD/m^3.d with soluble COD removal of 75—80%. (See pp. 6—11.

Acclimatization and Application of the Granular Sludge in an Upflow-Anaerobic-Sludge-Blanket (UASB) Reactor

Chen Jian and Lun Shiyi (Fermentation Engineering Department, Institute of Light Industry, Wuxi, Jiangsu Province)

In this paper, the acclimating techniques, the nutritional conditions and the environmental factors about the First Start-up granular sludge in an Upflow Anaerobic Sludge Blanket reactor have been studied. The Secondary Start-up process has been discussed, too. The results show that the anaerobic sludge can be granulated within 65 days in the laboratory by controlling the sludge loading, when it is seeded with conventional digested sludge and cultivated in synthetic waste water. The granulation process will be shortened for 17 days if 6.2% matured granular sludge is added to the seed. In addition, it only takes 10 days for the granular sludge cultivated in synthetic wastewater to be adapted to treat industrial wastewater while increasing its concentration. (See pp. 11—15).

Control over the Process of Steady Anaerobic Digestion

Zhang Ahongcheng (Tian Research Institute of Environmental Protection, Tianjin)

Steady performance of anaerobic digestion of sludge has been made under moderate temperature at one stage, in which detention time was shortened to 15—20 days. However 15 days are available with a view of economic efficiency. 9% dry solid of sludge can be taken when polyelectrolyte ZAT is added into sludge and then dewatered machanically. Volatile acid satisfactorily indicates the velocity and extent of acidation and of producing methane. The pH value in digestion process depends mainly on buffer of NH_4HCO_3-NH_4Ac, and 3000 ppm NH_3-N will not poison methanogenic bacteria. If 0.02g $CaCO_3$/g OS is added to feed sludge, detention time will be shortened and inhibition of volatile acid is avoidable. Control over the process will keep the rate of producing gas constant, and availability of the digester will increase three times. (See pp. 16—20).

The Characteristics of Water Quality in the Suzhouhe River, Shanghai

Zheng Yingming and Gao Jianqun (Institute of Environmental Hydrology, Nanjing College of Water Conservancy, Nanjing)

The Suzhouhe River that flows across Shanghai urban districts, is a badly polluted river and is affected by tides. This paper introduces the natural circumstances of hydrology, meteorology, tides and sediments of the river, and water quality monitoring system as well. Water quality features including oxygen-balance factors, nutrients, physiochemical parameters toxicants, time of black foul smell etc. have been described and analysed. On this basis the paper stresses the effect of tides on water quality and the ultimate oxygen demand in the river. (See pp 20—26)

Effect of Carbon Monoxide Pollution on Woody Plants

Zhang Youbiao, Huang Huiyi and Zhang Chuenxing and Wany Yuying (Institute of Applied Ecology, Academia Sinica, Shengyáng)

The experimantal results show that under the conditions of carbon monoxide below 200 ppm within 16 hours of chambering time, there is no obvious injury on leaves of woody plants. But the ratio of photosynthesis is varied from different biocharacters of woody plants. When 100 ppm CO pollution, the relation of ratio of photosynthesis and the chambering time is exponential function, and $P_t/P_o = 5.75 \exp(0.001t)$ to *Fraxinus chinensis* and $P_t/P_o = 7.04 \exp(1.9\ 10t)$ to *Puruns davidiana*. (See pp. 27—29)

Injuries to Tree Leaves by Simulated Acid Rain and Resistant Nature of the Trees

Zhang Jiawu, Feng Zongwei et al. (Institute of Applied Ecology, Academia Sinica, Shenyang)

The paper gives a general description of the effects of simulated acid rain on tree leaves. The experiments have been done in Hunan Experimental Station of Forest Ecology. After the simulated acid rain were sprayed upon tree leaves, there appeared some symptoms: discoloration of greens, tissue necrosis, dewatering and early withering. And injurious extents on leaves were fundamentally due to the rain acidity, duration of spraying and conditions of sunlight and temperature. However, because of different tissue structures of the tree leaves, their resistant capacity were varied. (See pp. 30—33)

Toxicity of Floatation Agent S-808 of Phosphatic Ore and Mineral Wastewater to Fishes and Embryos

Zhang Fuying and Yin Yiwa (Institute of Hydrobiology, Academia Sinica, Wuhan)

Toxic test determining larvae of grass carp and guppy for 96-hour LC_{50} was 18 mg/L and 35 mg/L respectively, 10-day LC_{50} of grass carp embryo was 3.69 mg/L. For fish embryos in 1 mg/L, there appeared deformation. Deformation percentage and concentration were of positive correlation. In fish toxic test, deformed index was more sensitive than dead index. The toxic test showed that, according to classfication standard, S-808 was a "poisonous grade" of fish toxicity. S-808 in floating process was treated with physiochemical method and toxicity of dressing mineral wastewater decreased, so the value of LC_{50} in the test could not be determined, and there didn't appear deformation of fishes. (See pp. 34—37)

Tests on the Residues of 5% *Bestox* in Cotton Fields

Zhou Hou'an et al. (Institute of Zoology, Academia Sinica, Beijing)

Experiments on the residual kinetics of *Bestox* emulsion (5%) were carried out in the cotton fields. The results showed that the half-life of *Bostox* emulsion (5%) was 23 to 25 days in soil, and 3 to 5 days on leaves. The residues were not observed in cotton seeds even by using dosages 1.5 to 2.0 times of the conventional ones. *Bestox* is low toxic to mammals and there is no systemic action. The results can give a reliable basis for rationalizing the use of *Bestox* in the cotton field and limting MRL value in cotton seeds. (See pp. 38—41)

Ascertainment of Main Factors for Biological Denitrification System Using Orthogonal Test

Du Shelin et al. (Institute of Environmental Pretection, Shanghai Petrochemical Complex, Shanghai)

Hydraulic retention time (HRT), ratio of the volume of anaerobic tank to the volume of aerobic tank (I: R) and reflux ratio (r) have been established as three main factors in a biological denitrification system by using mathematically the orthogonal test method of Lg (3^4). Thus, in such a system for the treatment of a combined wastewater containing nitriles and sodium thiocyanate in high concentration, it was determined that HRT, I: R and r are 24 hours, 1:3 and 5.5 respectively, and they would be more favourable process parameters. In addition, an analysis of the whole system is made in this paper. (See pp. 42—46)

Removal of Mercury from Wastewater with Maize-Starch Dregs

Liu Manying and Kang Weijun (Hobei Medical College, Shijiazhuang, Hobei Province)

This paper deals with removal of mercury from wastewater by using maize-starch dregs. The experimental result shows that the rate of removal is 99.9%, and Saturated capacity is 45 mg/g. The method seems to be a cheap and efficient one for treating mercury-contained liquids. (See pp. 47—48)

Method for Determination of Twelve Phthalate Esters in Natural Water

Kang Junxing (Research Center for Eco-Environmental Sciences, Academia Sinica, Beijing) *Hing-biu Lee* (National Water Research Institute, Canada Center for Inland Waters)

An Analytical method was developed and validated, which permits determination parts per billion levels of twelve phthalate esters in natural water. Water sample was extracted with methylene chloride, and the extract was cleaned up by using silica gel liquid chromatographic column prior to determination of the phthalate esters by capillary column ECD-GC, (See pp. 49—54)

Spectrophotometric Determination of Trace Beryllium in Water and Wastewater after Adsorption concentration by Activated Carbon

Qiu Xingchu, Cheng Jun and Zhu Yingquan Ganzhou Institute of Environmental Science, Ganzhou, Jiangxi Province)

In this paper the optimum conditions of colour reaction of Be-CAS-CPC and adsorption concentration by activated carbon has been studied. In the buffer solution of urotropine pH 5.0. The adsorption maximum of the complex is near 605 nm. Beer's law is obeyed for 0-0.70 g *Be*/25ml (2cm cell) ranges. It is applied to determine the trace Be in Water by spectrophotometric method, which is simple exact and rapid. (See pp. 55—58)