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EDITORIAL

RISK COMMUNICATION

There is no doubt that the scientific community faces a risk communication problem. Numerous studies indicate that the public often misunderstands the significance of an action because it misconstrues the value of a risk.

A major school, led by a group of scientists including Vincent Covello of Columbia University, had attempted to systematically evaluate the problem. This group separated the message, the messenger, the channel (or medium for communication) and the audience. Subsequently, various aspects of risk communication were studied using this scheme. Other groups advocated an interactive method of communication. One of this groups suggested that the scientific community must try harder. All of these contributions are based on empirical evidence and provide the foundation for identifying the problem and directing efforts to their solution. However, they do not address the causes of risk communication problems.

Evidence is mounting that there are at least three major causes of failure to communicate even most simple risk assessment results to the public as follows:

1) There is ample evidence that the public education even in most developed countries has failed to teach critical thinking. In most countries of the world, the scientific literacy is nonexistent and even in developed countries with a few exceptions the scientific literacy is marginal. For example, in a recent study conducted in the U.S., the authors found that a large fraction of the public could not define or understand simple scientific terms such as atom, cell, cell nucleus, chemical compound and metabolism. Interestingly, problems associated with scientific literacy are not limited to the general public. Often most educated individuals, once outside of their area of scientific field, follow the pattern of the general public.

2) The public appears to have significant problems in dealing with probabilities. People gamble in gambling casinos despite the fact that they are aware (or should be aware) that their probability of breaking even is less than one and usually at about 0.6 to 0.7. People buy lottery tickets although the odds are against them. The data is convincing that once the top prize increases, the number of sold lottery tickets increases regardless of the odds. Conversely, the public appears to be unable to appreciate the difference between a lifetime risk of 10^{-2} and 10^{-10}, the latter being essentially zero.

3) There appears to be a strong constituency against application risk assessment. This constituency tends to rely upon the lack of scientific literacy and the lack of appreciation for probability to enhance its goals. Much of the media has chosen to follow this constituency because it believes that the goals of this constituency is noble and thus, the goal justifies the means.

The scientific community particularly the environmental scientific community, has a obligation to provide the public with the best available scientific information. It has also the obligation to assure that this information is not misinterpreted. However, the scientific community has no particular wisdom to decide on societal goals. Therefore, the obligation is limited to the interpretation of scientific information and must exclude societal goals, such as a level of acceptable risk.

The scientific community must enhance the scientific literacy, particularly, critical thinking. It must improve the education on probability and its assessment. The organized scientific community must clearly and unambiguously fight those who attempt to mislead the public. The most recent history teaches us that goals do not justify means, and truthfulness is the proper choice of action.

A. Alan Moghissi

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SAMPLING RATE EVALUATION FOR NO_2 BADGE: (II) IN PERSONAL MONITORING

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The sampling rate of the nitrogen dioxide (NO_2) badge used for personal monitoring was evaluated by comparing measurements of the badge when placed inside and outside a portable wind tunnel, which produced a constant wind velocity. The badge measurement at wind velocity of 0.5 m/s was used as a secondary standard. Nitrogen dioxide concentrations in personal monitoring for 8 h in daytime were slightly overestimated by the personal badge at an established sampling rate or overall mass transfer coefficient Kog = 0.10 cm/s. However, the measurements of the badge for 24 h, including a nonactive sleeping period, were almost identical to the secondary standard. The personal monitoring badge can accurately determine the 24-h personal exposure level with Kog of 0.10 cm/s.

INTRODUCTION

The objective of this study was to validate the proposed sampling rate of the NO_2 badge, Kog of 0.10 cm/s, in personal monitoring. Personal exposure monitors can estimate personal exposure to air pollution more accurately than can fixed station monitors (Cortese et al. 1976; Dockery et al. 1981). Estimations from fixed station monitors do not accurately represent personal exposures because of wide spatial and temporal variations of air pollutants and because of the diversity of human activities. There are two different approaches for estimating personal exposures to air pollutants: the direct approach and the indirect approach (Ott 1982). The direct approach uses a personal exposure monitor to directly measure the exposure, while the indirect approach calculates personal exposure from activity patterns and concentrations in many microenvironments. The indirect approach cannot avoid uncertainty due to grouping of the many microenvironments. However, the direct approach requires an appropriate personal exposure monitor.

Since a passive sampler can measure personal exposures without disturbing daily human activities, it is an appropriate direct-approach personal exposure monitor. An appropriate sampling rate is required for quantitative measurements by the passive sampler. The sampling rate of the passive sampler depends upon molecular diffusion which is a function of

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*To whom correspondence should be addressed.

collection medium capacity and environmental factors such as wind velocity, temperature, and humidity (Yanagisawa 1989). The effects of environmental factors on the sampling rate should be experimentally determined in the evaluation of the passive sampler (Brown et al. 1984). The sampling rate must be validated in a laboratory experiment as well as in a field study, because of inconsistent environmental conditions during the sampling period.

A nitrogen dioxide (NO_2) passive badge used in this study was developed to measure NO_2 personal exposures using an absorbent sheet containing a triethanolamine solution (Yanagisawa et al. 1980, 1982). The sampling rate of the NO_2 badge (or overall mass transfer coefficient), Kog of 0.14 cm/s, was derived under experimental conditions at wind velocity of 2.0 m/s and relative humidity of 60%, which were based on typical Japanese outdoor environmental conditions (Yanagisawa et al. 1982).

The wind velocity effect on the sampling rate of the NO_2 badges was experimentally determined using a wind tunnel and a turntable, since the wind velocity effect cannot be expressed by a mathematical equation (Yanagisawa et al. 1986; Lee et al. 1992). The relationship was expressed by a statistically determined equation containing the effects of wind velocity and relative humidity (Lee et al. 1992). The relationship between the sampling rate and the surface wind velocity was not linear. The sampling rate was highly dependent on wind velocities in a range of zero to about 0.3 m/s, while it was slightly increased with wind velocities higher than 0.3 m/s.

The relationship between the wind velocity and the sampling rate cannot be used for personal monitoring without knowing the surface wind velocity around subjects. It is almost impossible to measure the wind velocity on the surface of the badge during personal monitoring. Since the badge with the sampling rate at a fixed wind velocity can accurately measure NO_2 concentrations, this measurement is used as a secondary standard for the personal monitoring badge.

EXPERIMENTAL METHODS

A portable wind tunnel (I.D. = 4.0 cm; length = 30 cm) was used to maintain the wind velocity on the surface of the badge at 0.5 m/s during personal monitoring. Figure 1 shows a schematic diagram of the portable wind tunnel. The back space of the badge inside the portable wind tunnel was tightly blocked by two pieces of styrofoam. The cross-sectional area of the open space above the badge was 2 cm^2. With the flow rate of 6 L/min, the surface wind velocity of the badge inside the wind tunnel was calculated to be 0.5 m/s. The flow rate of 6 L/min was established by use of two personal pumps (Gilan Hi-flow Sampler, Model HFS 513A), which were calibrated before and after the experiments. Wind velocity on the surface of the badge cannot be measured by an anemometer due to the small space in the wind tunnel. The sampling rate of the NO_2 badge placed inside the tunnel was evaluated in the laboratory prior to field measurements. The measurements of the NO_2 badges inside the portable wind tunnel were compared to those of the chemiluminescent analyzer (Thermo Electric, Model 14 B/E), the inlet of which was placed close to the portable wind tunnel. The badge inside the portable wind tunnel and the chemiluminescent analyzer were simultaneously exposed to room air in the laboratory for 8 h.

The sampling rate of the NO_2 badge was evaluated in personal exposures of 10 participants, ages 25 to 44 years old, 4 females and 6 males. Personal exposure levels of the 10 participants as measured by the personal monitoring were compared with the secondary standards, i.e., the measurements of the badges with fixed wind velocity. In the field measurement, participants wore two personal NO_2 badges and a portable wind tunnel in which a badge was placed for 8 h. The two personal NO_2 badges were placed on the opposite side of the chest from the portable wind tunnel, so that the surface wind velocity of the personal badge was not affected by the operation of the wind tunnel. Activities during the sampling period were recorded. In addition to personal exposure in indoor environments, one male subject stayed outdoors while wearing the badge and portable wind tunnel to validate the sampling rate in personal monitoring with outdoor activity.

Personal exposure measurements for 24 h, including an active daytime period and a nonactive sleeping time, were compared with the measurements of a chemiluminescent analyzer and NO_2 badges placed indoors for 24 h. The chemiluminescent analyzer and two indoor badges were collocated in the living rooms of the three occupied residential houses. Two personal badges were worn by the subject whenever the subject was in the living room. When the subject left the living room, the personal NO_2 badges were placed near the chemiluminescent analyzer and the indoor NO_2 badges. The period of the personal monitoring was recorded by the subject. The experiment was repeated three times by the same subject in each residential house. One of three participants was female.

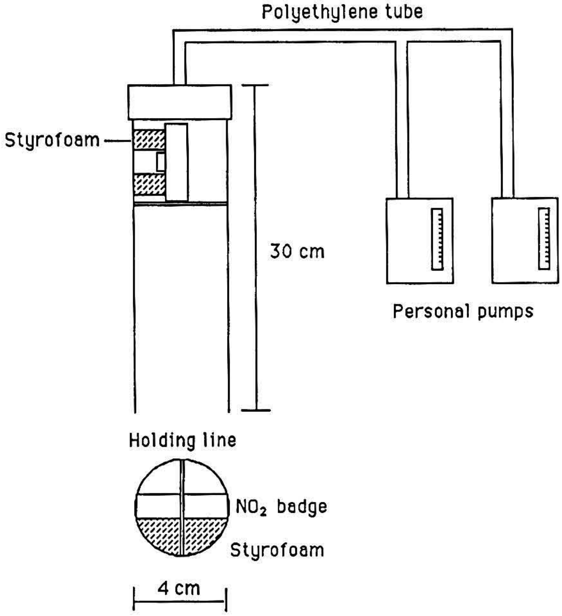

Fig. 1. Schematic diagram of a portable wind tunnel.

RESULTS AND DISCUSSION

Two portable wind tunnels were used to introduce a wind velocity of 0.5 m/s on the surface of the NO_2 badge. The measurement of the NO_2 badge with a fixed wind velocity in the portable wind tunnel was validated in the laboratory, using a chemiluminescent analyzer. The Kog of the badge inside the wind tunnel with the wind velocity of 0.5 m/s was calculated from the following equation:

$$\mathrm{Kog} = 10^9\, M \cdot R \cdot T / A \cdot \tau \cdot f \qquad (1)$$

where,

Kog = overall mass transfer coefficient (cm/s)
M = amount of absorbed NO_2 by badge (M)
R = gas constant
T = gas temperature (°K)
A = cross-sectional area (cm^2)
τ = exposure time (s)
f = NO_2 concentration (nL/L).

The measurement of the chemiluminescent analyzer was used for NO_2 concentration (f) in the equation. When the amount of absorbed NO_2 by the badge placed in the wind tunnel was applied to Eq. (1), Kog of the NO_2 badge placed inside the two units of tunnels were calculated to be 0.124 and 0.126 cm/s at a relative humidity of 40%.

The effects of wind velocity and relative humidity were experimentally and statistically determined and expressed as the following equation (Lee et al. 1992):

$$\mathrm{Kog} = \frac{2.495}{21.543 - 0.078 \times \mathrm{Rh} + 1/(V_w + 0.06)} \qquad (2)$$

where,

Rh = relative humidity (%)
V_w = wind velocity (m/s).

The Kog of 0.123 cm/s is computed from the equation at the wind velocity of 0.5 m/s and the relative humidity of 40%. The computed Kog was comparable to the experimental values of the badges inside the portable wind tunnels, Kog of 0.124 and 0.126 cm/s.

The chemiluminescent analyzer cannot directly measure personal exposure to NO_2, due to its huge size. Therefore, the measurement of the chemiluminescent analyzer cannot be used as a standard for the measurement of personal monitoring. Measurement of the badge with a fixed wind velocity can be used as a secondary standard, if the sampling rate is appropriate. When a fixed wind velocity was provided on the surface of the NO_2 badge, the badge measure-

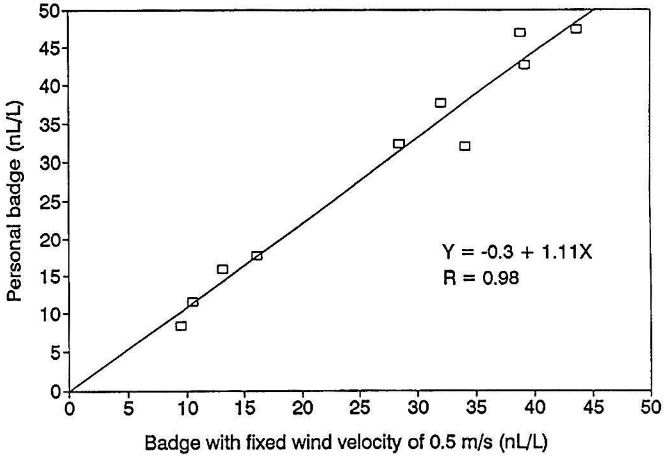

Fig. 2. Relationship between personal badge with Kog of 0.10 cm/s and secondary standard, badge with fixed wind velocity of 0.5 m/s.

ment was accurate as a secondary standard. Wind velocity during personal monitoring can be achieved by use of a personal pump and a portable wind tunnel. The flow rate of 6 L/min in the wind tunnel was achieved by two personal pumps with flow rate of 3 L/min each. The flow rate was half of the maximum performance of the pump. Since the personal pump usually lasts for 8 h, the personal exposures by NO_2 badges inside and outside of the portable wind tunnel were measured for 8 h.

Personal exposures of 10 participants were measured by the personal badges and the badge inside the portable wind tunnel. The participants were asked to stay indoors to control the environmental factors due to distinctly different indoor and outdoor environmental conditions. Four participants stayed in their residential houses and the other six stayed in their working environments. Personal exposures to NO_2 of the ten participants averaged 29 nL/L with the standard deviation of 14 nL/L. Personal NO_2 exposures by the badges with Kog of 0.10 cm/s were 1.1 times the secondary standard, the measurements of the badges inside the portable wind tunnel, as shown in Fig. 2. The slope and intercept of a linear regression line are 1.11 and -0.3, respectively. The correlation coefficient is 0.98. The newly established Kog of 0.10 cm/s causes the slight overestimation in the personal monitoring. The Kog of 0.10 cm/s was based on the wind velocity of 0.10 m/s (Lee et al. 1992). The overestimation suggests that the average surface wind velocity on the badge during the personal monitoring may be slightly higher than 0.10 m/s.

The sampling rate of the personal badge was evaluated when a subject stayed in an outdoor environment. Personal exposure in outdoor activities for 7 h was measured by the personal badge and the badge inside the portable wind tunnel. Nitrogen dioxide concentrations measured by a personal badge and a badge inside the wind tunnel were equal to 9.9 nL/L. The sampling rate of the badge is likely valid in personal monitoring during outdoor activities.

The 24-h personal exposures included inactive time, such as sleeping. The personal monitoring badge was usually placed in a bedroom during sleeping and bathing (Chan et al. 1990). Therefore, the Kog of 0.10 cm/s was evaluated in the 24-h measurement including daytime personal monitoring and nighttime indoor measurement. Two personal badges were worn by the subjects whenever they stayed in the living room and were otherwise placed near the chemiluminescent analyzer in the living room. The measurements of the NO_2 badges including active personal monitoring were not different from the chemiluminescent analyzer, as shown in Fig. 3. Slope and intercept of a linear regression were 0.93 and 1.6, respectively, with a correlation coefficient of 0.98. Average wearing time of the badge was 7.4 ± 1.7 h. Kog of 0.10 cm/s is appropriate for the measurements of the badges for 24 h including the active 7 h and inactive sleeping time.

Measurement of the personal monitoring badge using Kog of 0.10 cm/s was slightly overestimated when the subjects stayed in indoor environments. The sampling time for personal monitoring is generally

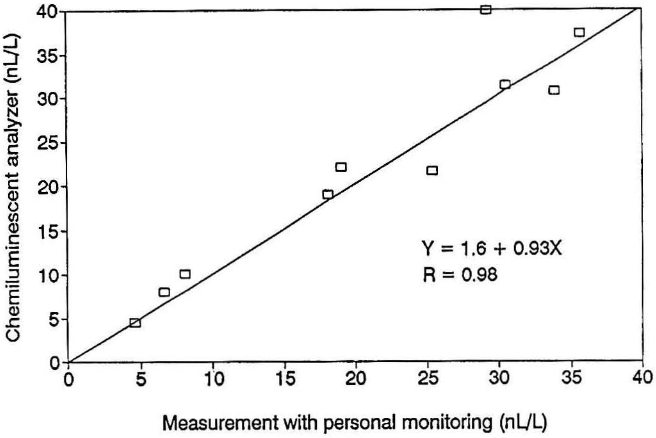

Fig. 3. Relationship between chemiluminescent analyzer and NO_2 measurement for 24 h including active personal monitoring.

24 h, including sleeping time when the samplers were placed in the indoor environment. Kog of 0.10 cm/s provided the accurate measurement, when the badges were placed in the indoor environment. When the badge measures 24-h personal exposure, the overestimation in the personal monitoring is likely diluted by the indoor placement during sleeping. Therefore, the overestimation in personal exposure for 24 h may be lower than the overestimation of 11%. The slight overestimation is not enough to separate the sampling rate based on sampling techniques, since one sampling rate for one sampler is practical.

CONCLUSION

The Kog of 0.10 cm/s was evaluated in personal monitoring. Personal exposure measured by the personal monitoring badge was compared with the measurements with a fixed wind velocity produced with a portable wind tunnel. The measurement of the NO_2 badge for active 8 h was slightly overestimated by Kog of 0.10 cm/s. However, the 24-h measurement, including active 7 h of personal monitoring and indoor measurement, was accurately estimated by the badge using the Kog of 0.10 cm/s. The personal exposure to NO_2 can be accurately determined by the personal badge with the established sampling rate.

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INDOOR AIR QUALITY AND ENVIRONMENTAL TOBACCO SMOKE: CONCENTRATION AND EXPOSURE

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Environmental tobacco smoke (ETS) is often cited as a key factor in indoor air quality (IAQ) and public health. However, there are few studies which attempt to actually calculate the impact ETS has on IAQ or the doses of ETS one may receive from possible exposure in a variety of different settings. This paper reviews the data on indoor air published since 1980 and estimates the portion of various constituents which are produced by ETS. It can be observed that, in most instances, ETS has only a minor impact on IAQ. Retained doses of ETS particles are calculated for various exposure scenarios using respirable particle concentrations associated with ETS, time activity patterns, respiration rates and retention rates. Total doses range from 3-40 mg/y. This dose level does not seem to support the summary relative risk of 1.35 that has been claimed from meta-analyses of epidemiologic studies of spousal smoke exposure and lung cancer.

INTRODUCTION

Interest in indoor air quality (IAQ) is steadily increasing. The factors which affect IAQ and the health effects reportedly associated with it are the subject of intense debate. One of the IAQ issues which generates the most interest and emotion is environmental tobacco smoke (ETS) exposure and its reported health effects. ETS exposure has been claimed to be associated with health effects as diverse as childhood respiratory disease, lung cancer, and cardiovascular disease (Repace and Lowrey 1985; U.S. Surgeon General 1986; National Research Council 1986; Wells 1988; Glantz and Parmley 1991; USEPA 1990).

ETS is a complex mixture of many substances, the concentrations of which will vary with time, room ventilation, and proximity to the source. Since not all of its components are removed from the environment at the same rate, the concentrations of ETS components also vary in relation to each other over time. Because of this, it is difficult to accurately determine exposure to ETS and, further, whether the health claims are realistic in terms of this exposure.

Sterling et al. (1982) performed a comprehensive review of components of ETS measured in different environments and under different smoking conditions. Since that review was completed, there have been many changes in both indoor environments and analytical methodology. Because of this, a new review of the literature pertaining to indoor air quality and environmental tobacco smoke is appropriate.

This study assesses the literature on indoor air quality and ETS published since 1980. Using the data collected, it also attempts to determine what levels of substances measured indoors may result from the presence of ETS and calculates some of the doses which may be expected from exposure to ETS.

INDOOR AIR AND ETS REVIEW

Methods

The literature search was restricted to work which took place in the U.S. and Canada and was published after 1980. There is important IAQ data being generated in European and other countries. However, potential differences in building age, ventilation types, room sizes and other factors may prevent data from other countries from being comparable to the U.S./Canadian data. This study limited the literature to the countries where the data were believed to be more homogeneous and essentially reviewed the literature published since the Sterling et al. (1982) review.

The following indoor air components were chosen for evaluation: respirable particulates (RSP); carbon monoxide; nicotine; nitrogen dioxide; formaldehyde; benzene; polycyclic aromatic hydrocarbons (PAH); and nitrosamines.

When it was obvious that structures and sampling protocol for data acquired in countries outside North America were similar, it was included with the USA/Canada data. In instances where relatively little information was available or the data from all countries were similar, information from other countries also was used.

The information was recorded in the following categories:

1. Homes—includes single family dwellings and apartments.
2. Offices, workplaces, and public facilities—includes offices, work sites, schools, universities, hospitals, retail stores, museums, libraries, clinics, grocery stores, laundromats, and public transportation stations.
3. Restaurants
4. Bars/taverns—includes betting shops, billiard parlors, bars, and taverns.
5. Public transportation—trains, buses, subway, and autos.

The data were selected from the literature using the following criteria:

If no mean was given, generally, the data were not reported in this document unless there were individual values given to make it possible to calculate a mean. If there were 10 or more samples and a median was given, the data were reported. Both arithmetic and geometric means are reported. If an arithmetic mean was given, it was used in any subsequent calculations.

If only one value was given (i.e., one sample) the data were not used because one sample at one point in time is not as representative of conditions as several samples at different points of time or for longer duration.

For respirable particulates, if the data were reported as total particulate matter (TPM), the data were not used. If the sample was PM 5.0 or less, the data were reported.

The data were recorded with a preference for gravimetric data on RSPs. When gravimetric, light scattering, and piezobalance data were all present, the gravimetric data were used. If data from only one of these three methods were present, these data were used.

This paper focuses upon the scientific literature pertaining to the quantification of indoor air quality. Hence, the papers reviewed are those that have measured levels of substances in indoor air. Odor may play a part in the acceptability of indoor air to occupants or visitors to any particular environment, but the evaluation of odor in offices is as yet somewhat subjective and poorly quantified. ETS clearly may influence odor perception in some situations, and the existing scientific literature on this matter has been reviewed. Because of both the scarcity of data on this issue and the subjectivity of the data that do exist, odor has not been considered as a quantified element in the data tabulated in this report.

Results

The results of the literature review on indoor air components are in Tables 1-8. Each table is a summary of one of the components reviewed. Units of measurement in the tables are reported the same as authors presented them in their studies. Conversion factors for ppm (parts per million) and ppb (parts per billion) to $\mu g/m^3$ are given where appropriate. Tables 9, 10, and 11 summarize the data for RSPs, CO, and nicotine. Nitrogen dioxide, formaldehyde, benzene, PAH, and nitrosamine data are summarized in the discussions.

DOSIMETRIC CALCULATIONS

Methods

The particle fraction of ETS is the portion on which the majority of the health claims concentrate. An estimate of the dose of ETS particles that persons

Table 1. Respirable particles (RSPs) measured under realistic conditions.

Author & Date	Country	Building Type	Occupancy	Ventilation	Sampling	Concentrations
Carson & Erikson (1988)	Canada	Offices (31)	≥ 2 people w/min. 1 smoker	Not Given	PASS Unit PM3.5 9 hr samples (8-5)	UVPM ($\mu g/m^3$) A. Mean 44 G. Mean 24 Range 6 - 426
Conner, et al. (1986)	USA	Homes (10) Restaurants (10)	Not Given	Not Given	Gravimetric & UVPM Personal Pump, 120-180 min. samples.	RSP ($\mu g/m^3$) / UVPM ($\mu g/m^3$) Homes, Range 17 - 86 / 1 - 8 Homes, A. Mean 58 / 4.2 Rest., Range 18 - 306 / 15 - 223 Rest., A. Mean 169 / 106
Conner, et al. (1989)	USA	Offices (10) Planes (5)	Not Given	Not Given	Gravimetric PM3.5 PASS Unit, 1-5 hr samples	RSP ($\mu g/m^3$) / UVPM ($\mu g/m^3$) Offices, Range 167 - 1088 / nd - 147 Offices, A. Mean 448 / 65 Planes, Range (Smoking Section) 33 - 119 / 20 - 106 Planes, A. Mean (Smoking Section) 72.6 / 66.6 Planes, Range (Non Smoking Sect.) 3 - 98 / 12 - 30 Planes, A. Mean (Non Smoking Sect.) 22 / 18.6
Coultas, et al. (1990a)	USA	Workplace(15)	Not Given	Not Given	Gravimetric Personal Monitors 6.5 hours, PM2.5	Males / Samples / Avg. RSP ($\mu g/m^3$) Hospital 2 66.15 Offices 2 56.7 Barber Shop 2 80.25 Restaurant 1 145.8 Retail Store 1 85.2 Females / Avg. RSP ($\mu g/m^3$) Hospital 3 35.33 Offices 3 70.37 Public Trans. 1 4.0
Coultas,et al. (1990b)	USA	Homes (10)	Not Given	Not Given	Gravimetric PM2.5 10 samples/home	RSP Means - 32.4 - 76.9 $\mu g/m^3$
Cousins & Collett (1989)	Canada	Schools (3) Portables (6)	Not Given	Not Given	Light Scattering PM5.0	RSP ($\mu g/m^3$) Old School / Ren. School / New School / Port. Class. Indoor 16 (11-22) / 13 (10-20) / 14 (10-17) / 17 (15-20) Outdoor 23 / 15 / 18 / 18
Crouse & Carson (1989)	USA	Offices(32) & Restaurants (36)	Not Given	Not Given	Gravimetric PM3.5	Geo. Mean / Range ($\mu g/m^3$) Offices RSP 61 / 11 - 279 UVPM 47 / 11 - 84 Restaurants RSP 111 / 16 - 366 UVPM 31 / 10 - 194
Crouse, et al. (1988)	USA	Restaurants (37)	Not Given	Not Given	Gravimetric PM3.5 1 Hour Sample	Geo. Mean / Arith. Mean / Range ($\mu g/m^3$) RSP 62 ± 2.2 / 80.8 / 16 - 221 UVPM 26.1 ± 1.9 / 34.1 / 15 - 168

Table 1. Continued.

Daisey, et al. (1989)	USA	Homes (7)	Not Given	0.13–0.89 ACH	Gravimetric w/ Cyclone, 48 hr samples	House # / Indoor / Outdoor (+ = Woodburning) 102 + 37.5 24 - 30.4 13.8 106 + 33.3 30.9 - 57.7 7.2 108 + 36.6 38.4 - 27.6 27 203 + 19.7 32.4 - 20.3 4.5 204 + 35.4 10.5 - 27.3 9.6 208 + 47.6 19.9 - 29.9 - 300 + 60.1 - - 35.6 - Mean - Woodsmoke 32.7
Eudy, et al. (1987)	USA	Restaurant	Not Given	Not Given	Gravimetric PM3.5 4 hr samples, 12 samples/48 hr run	RSP 5 - 48 hour sample runs Range 0 - 105 $\mu g/m^3$ A. Mean 29.3 $\mu g/m^3$
First, (1983)	USA	Public Places	Various	Not Given	Piezobalance	Site / Avg. Conc. ($\mu g/m^3$) Chamber1 300 - 1 cig. smoked Chamber2 290 - 1 cig. smoked School cafeteria1 20 - no smokers School cafeteria2 40 - 2-3 smokers Tavern1 400 - 1-5 smokers Tavern2 660 - 2-3 smokers Tavern3 570 - mostly 1 smoker Bus Terminal 110 - 50-100 people, 1-5 smokers Bus Terminal (outside) 70 Fast Food Restaurant 150 - 1-3 smokers during sampling Sm. Sitdown Rest.1 250 - 15 diners, 4 smokers Sm. Sitdown Rest.2 260 - 23 diners, 1 smoker
Georghiou, et al. (1989)	Canada	Ice Arena	Varied	Not Given	PM10 Indoor Sampling Impactor, 2.5 hr samples 10 games	Range ($\mu g/m^3$) / A. Mean ($\mu g/m^3$) Smoking Allowed 17 - 680 440.75 (n=4) Smoking Restricted 187 - 426 302.57 (n=7)
Grimsrud, et al. (1990)	USA	Office Buildings (40)	Not Given	Not Given	Gravimetric PM3.0 3-20 sampling sites/ building	Concentration ($\mu g/m^3$) Arithmetic Mean 30.0 Geometric Mean 24.0 Range 5 - 86
Hedge, et al. (1990)	USA	Office Buildings (2)	Not Given	Not Given	Piezobalance, Gravimetric PM2.5, UVPM	Area / Method / Data ($\mu g/m^3$) AM PM Building (NS) Piezobalance 20 10 Office (Restricted S) Piezobalance 40 40 Smoking Area w/filter Piezobalance 110 140 Building (NS) Gravimetric N/A N/A Office (Restricted S) Gravimetric 200 300 Smoking Area w/filter Gravimetric 350 400 Building (NS) UVPM 0 0 Office (Restricted S) UVPM 9.0 7.0 Smoking Area w/filter UVPM 120 185

Table 1. Continued.

Hollowell and Miksch 1981	USA	Office (1)	Not Given	Not Given	12 Hours	"Particles" - - - 31 µg/m^3 Avg.
Hosein, et al. (1985)	Canada	Homes	Not Given	Not Given	Gravimetric (RSP) 24 hr. samples	RSP (µg/m^3, Geometric Mean) AC No AC Smoke (n=11) 80.5 (n=25) 70.11 No Smoke (n=4) 34.3 (n=11) 32.5 Carpet No Carpet Smoke (n=28) 76.6 (n=8) 70.2 No Smoke (n=9) 38.7 (n=7) 53.7 Hot Water Forced Air Smoke 84.8 57.1 No Smoke 66.7 37.7
IT Corp. (1987)	USA	Restaurants (36) Offices (38)	Varied	Not Given	Gravimetric PM3.5 PASS Unit 1 Hour Samples	RSP (µg/m^3) UVPM (µg/m^3) Offices Range nd-375 nd-108 Offices A. Mean 114 28.3 Restaurants Range nd-417 nd-127 Restaurants A. Mean 120 33.2
Leaderer, et al. (1990)	USA	Homes (394)	Not Given	Not Given	Gravimetric PM2.5	Source n Suffolk n Onondaga (µg/m^3) None 30 17.3 45 14.1 W 15 18.1 16 19.1 W = Woodstove K 7 22 4 21.2 K = Kerosene S 61 49.3 80 36.5 S = Smokers KW 4 19.7 SW 29 38 31 33.9 SK 23 61.4 4 35.3 SKW 6 30.3 4 28.5 Outdoor 19 16.9 36 15.8
Lofroth, et al. (1989)	USA	Tavern (1)	5 - 25 180 m^3 Smoking Allowed	Not Given	Gravimetric TSP & Piezobalance	First Study (3 hr) Second Study (4 hr) Indoor Outdoor Indoor Outdoor TSP 470 nd 390 nd Piezobalance 420 < 50 320 40
McCarthy, et al. (1987)	USA	Homes (68S, 13NS)	Not Given	Not Given	Gravimetric (RSP) Personal & Area Samples (24 hr)	Mean Median Range (All: µg/m^3) Personal (NS) 29.4 27.2 21.6-39.8 Personal (S) 56.2 52.6 18.0-116.3 Home (NS) 30.9 25.6 16.6-77.1 Home (S) 54.6 55.6 --- Personal Samples on Children (8-11 yr old)
Miesner, et al. (1988)	USA	Public Places, Offices (19)	Varied	Varied	Gravimetric PM2.5 3-16 Hours	Mean RSP (µg/m^3) NS Areas (n=33) 14 Smoking Areas (N=7) 34.5 Trans. Facility (n=4) 64 (Subways or Bus)

Table 1. Continued.

Miesner, et al. (1989)	USA	Public Bldgs (21)	Not Given	Not Given	Gravimetric PM2.5	Samples / Range ($\mu g/m^3$) / A. Mean ($\mu g/m^3$) 4 Library (NS) 5.8 - 12.8 9.08 4 High School (NS) 12.5 - 109.4 41.9 2 Museum 1 (NS) 6.5 - 11.0 8.75 2 Museum 2 (NS) nd - 12.9 6.45 4 Hospital (NS) 14.5 - 23.3 17.35 2 Hospital (S) 20.1 - 52.5 36.3 4 Clinic (NS) nd - 17.3 9.3 1 Clinic (S) 119.1 119.1 2 Groc. Store (NS) 11.9 - 14.0 12.95 1 Laundromat1 (NS) 17.2 17.2 1 Laundromat2 (NS) 24.3 24.3 2 Bar/Rest.1 (S) 36.3 - 107.3 71.8 2 Bar/Rest.2 (S) 133.1 - 140.9 137 3 Bar 3 (S) 30 - 78.3 59 2 Subway St.1 (NS) 91.7 - 157.3 124.5 2 Subway St.2 (NS) 55.1 - 66.5 60.8 1 Bus Station (NS) 43.3 43.3 2 Office Bdg1 (S) 16.2 - 18.6 17.4 1 Office Bdg2 (NS) 15.8 15.8 2 Office Bdg3 (NS) 17.3 - 18.2 17.75 3 Office Bdg4 (S) 26 - 80 44.73 2 Office Bdg4 (NS) 15 - 15.2 15.1 1 Office Bdg5 (S) 520.8 520.8 4 Office Bdg5 (NS) 11.1 - 20 14.83 2 University (S) 114 - 196 155 2 University (NS) 5.6 - 44.3 24.95
Millar (1988)	Canada	Office Buildings (2)	Not Given	Not Given	Piezobalance Pre and 1yr Post smoking ban	Floor / Building A / Floor / Building B 7th Pre 30 $\mu g/m^3$ 3rd Pre 35 $\mu g/m^3$ 9th Pre 28 15th Pre 47 7th Post 22 3rd Post 18 9th Post 22 15th Post 25
Ogden and Maiolo (1989)	USA	Homes (2) Auto (1) Dep't Store (1) Billiard Parlor (1)	Not Given	Not Given	Gravimetric PM3.5 Personal Pumps 2-8 hr samples	Sample Duration / No. of Cigs. / Conc. ($\mu g/m^3$) RSP / Solanesol Billiard Parlor 2 hr 34[a] 355 12.8 Home 4 hr 6[b] 187 6.4 Home 4 hr 6[b] 212 6.6 Dep't Store 4 hr 0 55 ND Automobile 8 hr 0 18 ND [a]Actual Count, 30 cigs., 4 cigars. [b]Kitchen only.
Oldaker, et al. (1990)	USA & Canada	Restaurants & Offices, 4 cities	Min. 2/off. w/ 1 smoker	Not Given	Gravimetric PM3.5 PASS Unit, Sampled during lunch & dinner hours.	Offices ($\mu g/m^3$) / Restaurants ($\mu g/m^3$) RSP Range (n=131) 0 - 1,088 (n=83) 0 - 685 RSP Mean 126 126 UVPM Range (n=125) 0 - 287 (n=82) 0 - 184 UVPM Mean 27 36
Oldaker, et al. (1988)	USA	Offices & Restaurants	Not Given	Not Given	Gravimetric PM3.5	RSP ($\mu g/m^3$) / UVPM ($\mu g/m^3$) Offices (n=45) GM 95 (n=43) 24 AM 107 33 Range 7-258 2-170 Restaurant (n=47) GM 175 (n=49) 47 AM 199 61 Range 57-658 7-163

Table 1. Continued.

<table>
<tr><td>Ozkaynak, et al. (1990)</td><td>USA</td><td>Homes (9)</td><td>18 participants</td><td>0.2 -0.8 ACH</td><td>Gravimetric PM2.5
Stationary &
Personal Samples</td><td>
<table>
<tr><th></th><th>N</th><th>Average</th><th>St. Deviation</th><th>Range - $\mu g/m^3$</th></tr>
<tr><td>Indoors</td><td>230</td><td>37.31</td><td>24.27</td><td>6.97-168.82</td></tr>
<tr><td>Personal</td><td>52</td><td>75.09</td><td>46.82</td><td>19.90-240.56</td></tr>
<tr><td>Outdoor</td><td>101</td><td>42.72</td><td>23.97</td><td>8.98-116.87</td></tr>
</table>
</td></tr>
<tr><td>Proctor (1989)</td><td>UK</td><td>Offices (10)
Train Comp.(20)</td><td>app. 75%</td><td>Mechanical</td><td>Gravimetric PM3.5
PASS Unit, 1 Hr Samples</td><td>
<table>
<tr><th>($\mu g/m^3$)</th><th>RSP Range</th><th>RSP Mean</th><th>UVPM Range</th><th>UVPM Mean</th></tr>
<tr><td>Offices(S)</td><td>33-260</td><td>103</td><td>.5-75</td><td>23</td></tr>
<tr><td>Office(NS)</td><td>29-240</td><td>90</td><td>1-17</td><td>8</td></tr>
<tr><td>Trains (S)</td><td>70.8-325</td><td>216</td><td>13-110</td><td>59.8</td></tr>
<tr><td>Trains (NS)</td><td>63.3-450</td><td>186</td><td>9-105</td><td>33</td></tr>
</table>
</td></tr>
<tr><td>Proctor, et al. (1989b)</td><td>UK</td><td>Office (1)</td><td>26 m^2/ person</td><td>Not Given</td><td>Gravimetric PM3.5
10 sites sampled
5 times each</td><td>
<table>
<tr><th></th><th>RSP ($\mu g/m^3$)</th><th>UVPM ($\mu g/m^3$)</th></tr>
<tr><td>S Mean -</td><td>103</td><td>23</td></tr>
<tr><td>Median -</td><td>91</td><td>24</td></tr>
<tr><td>NS Mean -</td><td>90</td><td>8</td></tr>
<tr><td>Median -</td><td>71</td><td>8.8</td></tr>
</table>
</td></tr>
<tr><td>Quackenboss, et al. (1989a)</td><td>USA</td><td>Homes (98)</td><td>Not Given</td><td>Not Given</td><td>Gravimetric PM10 & PM2.5</td><td>
<table>
<tr><th>Smoking</th><th>Evap. Cool.</th><th>n</th><th>PM2.5 ($\mu g/m^3$)</th><th>n</th><th>PM10 ($\mu g/m^3$)</th></tr>
<tr><td></td><td>Yes</td><td>20</td><td>8.8</td><td>20</td><td>21.0</td></tr>
<tr><td>No</td><td>No</td><td>25</td><td>20.3</td><td>23</td><td>38.4</td></tr>
<tr><td></td><td>Total</td><td>45</td><td>15.2</td><td>43</td><td>30.3</td></tr>
<tr><td></td><td>Yes</td><td>10</td><td>19.3</td><td>10</td><td>33.9</td></tr>
<tr><td>1-20/day</td><td>No</td><td>16</td><td>32.3</td><td>17</td><td>53.4</td></tr>
<tr><td></td><td>Total</td><td>26</td><td>27.3</td><td>27</td><td>46.2</td></tr>
<tr><td></td><td>Yes</td><td>8</td><td>36.2</td><td>9</td><td>47.4</td></tr>
<tr><td>>20/day</td><td>No</td><td>9</td><td>82.7</td><td>9</td><td>102.5</td></tr>
<tr><td></td><td>Total</td><td>17</td><td>60.8</td><td>18</td><td>75.0</td></tr>
</table>
</td></tr>
<tr><td>Quackenboss, et al. (1991)</td><td>USA</td><td>Homes (200)</td><td>Not Given</td><td>Not Given</td><td>Gravimetric PM2.5
2 weeks of sampling</td><td>
<table>
<tr><th></th><th colspan="2">Smokers at Home</th><th colspan="2">No Smokers at Home</th></tr>
<tr><th>Season[a]</th><th>N</th><th>Median $\mu g/m^3$</th><th>N</th><th>Median $\mu g/m^3$</th></tr>
<tr><td>Summer</td><td>49</td><td>20.5</td><td>50</td><td>8.9</td></tr>
<tr><td>Spring/Fall</td><td>39</td><td>20.1</td><td>37</td><td>10.6</td></tr>
<tr><td>Winter</td><td>24</td><td>35.7</td><td>26</td><td>13.4</td></tr>
</table>
[a]Seasons: Summer = May - September
Spring/Fall = March, April, October, November
Winter = December - February
</td></tr>
<tr><td>Santanam, et al. (1990)</td><td>USA</td><td>Homes (280)
70S, 70NS
each city</td><td>Not Given</td><td>Not Given</td><td>Gravimetric PM2.5
1 week samples</td><td>
<table>
<tr><th colspan="4">Steubenville (RSP $\mu g/m^3$)</th></tr>
<tr><th colspan="2">Winter</th><th colspan="2">Summer</th></tr>
<tr><th>S Homes</th><th>NS Homes</th><th>S Homes</th><th>NS Homes</th></tr>
<tr><td>43.57</td><td>19.54</td><td>49.85</td><td>29.5</td></tr>
<tr><th colspan="4">Portage (RSP $\mu g/m^3$)</th></tr>
<tr><th colspan="2">Winter</th><th colspan="2">Summer</th></tr>
<tr><th>S Homes</th><th>NS Homes</th><th>S Homes</th><th>NS Homes</th></tr>
<tr><td>34.6</td><td>14.8</td><td>24.9</td><td>13.9</td></tr>
</table>
</td></tr>
<tr><td>Sheldon, et al. (1988a)</td><td>USA</td><td>Home for
Elderly (2)</td><td>Not Given</td><td>Not Given</td><td>Dichotomous Impactors
< 2.5μm</td><td>
<table>
<tr><th colspan="3">RSP <2.5μm ($\mu g/m^3$) Mean of 3 - 24 Hour Samples</th></tr>
<tr><th></th><th>Home #2</th><th>Home #1</th></tr>
<tr><td>Apartment (S)</td><td>89</td><td>39</td></tr>
<tr><td>Commons Area</td><td>16 (smoking observed)</td><td>30 (smoking lounge)</td></tr>
<tr><td>Apartment (NS)</td><td>9</td><td>9</td></tr>
<tr><td>Outdoors</td><td>4 (1 24 hr sample)</td><td>10</td></tr>
</table>
</td></tr>
</table>

Table 1. Continued.

Spengler, et al. (1985)	USA	Homes Offices Workplace (Non-office)	Not Given	Not Given	Gravimetric PM2.5	Building Type / Smoking ($\mu g/m^3$) / Non-smoking ($\mu g/m^3$) Homes N = 80 186 A. Mean 74 28 Offices N = 31 80 A. Mean 67 24 Workplace N = 9 6 (Non-office) A. Mean 50 23
Spengler, et al. (1987)	USA (6 cities)	Homes App. 300	Not Given	Not Given	Particle Sampler PM2.5 Week Long Samples	Range of Means - Homes Non Smoking 15 - 35 $\mu g/m^3$ Smoking 35 - 75 $\mu g/m^3$ Homes w/smokers $30 \mu g/m^3$ > Homes w/o smokers (Mean)
Sterling & Mueller (1988)	Canada	Office Building (2)	Not Given	Mechanical/ Re-circulated Air Pass. Vent/No Re-circulation	Light Scattering, Digital Dust Counter < 5 μm	# Samples / RSP ($\mu g/m^3$) Cafeteria (S) 6 102.5 Cafeteria (NS) 6 64.5 Offices (NS) 8 6.0 Offices (NS) 2 7.0
Sterling, et al. (1988)	USA & Canada	Offices	Not Given	Not Given	?	"Particles" ND - 2.7 mg/m^3 (0.04 median) 85 samples
Thomas, et al. (1989)	USA	Industrial Cafeteria	30 ± 9 560 m^3	8.8 ACH 2900 cfm OA, 2500 cfm RA	Gravimetric PM3.5 2 hrs/day for 14 Days (Lunchtime)	Lunchtime ($\mu g/m^3$) / Background ($\mu g/m^3$) RSP 60 ± 50 10 ± 10 UVPM 54 ± 33 < 1 (Avg. Smoking Rate During Sampling was 26 ± 6 cig/hr)
Turner, et al. (1991)	USA	Offices (585)	126.5 ft^2/ person	Not Given	Piezobalance	N / RSP ($\mu g/m^3$) means Smokers 331 46.37 Non smokers 254 20.11 Total 585 34.97
Weschler and Shields (1989)	USA	Phone Switching Office (1)	Not Given	Not Given	Gravimetric PM2.5 1 week samples	Week / Indoors ($\mu g/m^3$) / Outdoors ($\mu g/m^3$) Apr. 7-14 0.85 7.41 Apr. 14-21 1.22 10.33 Apr. 21-28 3.05 17.85 Apr. 28 - May 5 0.67 7.80 May 5-12 3.50 16.62 May 12-19 4.12 17.59 May 19-26 2.41 12.40 May 26 - June 2 3.12 20.24
Yocom, (1982)	USA	School, Homes (1) (2)	Not Given	(See Results)	Resp. Part. Matter PM2.5	RPM @ Elementary School ($\mu g/m^3$) Vent. (m^3/h/person) / Indoors / Outdoors 10.8 19.0 26.3 9.1 11.7 15.3 2.5 15.5 26.3 RPM in Home Pre & Post Energy Efficient Retrofit Pre: Indoor / Outdoor; Post: Indoor / Outdoor Home 1, S 31 10 36 11 Home 1, NS 9 14 8 13 Home 2, NS 12 9 10 10

Table 2. Carbon monoxide (ppm) measured under realistic conditions (Conversion factor: 1ppm = 1.15 mg/m³).

Author & Date	Country	Building Type	Occupancy	Ventilation	Sampling	Concentrations/Comments
Carson & Ericson (1988)	Canada	Offices (31)	≥2 people w/min. 1 smoker	Not Given	Electrochemical Detector in PASS Unit, 1 sample/ minute	Indoor / Outdoor (ppm) A. Mean 1.9 / 1.9 G. Mean 1.3 / 1.2 Min. <.1 / <.1 Max. 8.7 / 5.8 No. of Offices 28 / 21
Cousins & Collett (1989)	Canada	Schools (3)	Not Given	Not Given	Electrochemical Analyzer	CO (ppm): Old School / Renovated School / New School / Portables A. Mean 1.3 / 1.1 / 0.9 / 0.9 Range 1.0-1.8 / 0.7-1.5 / 0.7-1.1 / 0.8-1.0 Outdoor 2.1 / 11.5 / 1.1 / 1.1
Crouse, et al. (1989)	USA	Offices (30) Restaurants (30)	Not Given	Not Given	PASS Unit, Electrochemical Detector	N / Range (ppm) / A. Mean (ppm) Offices-Outdoors 29 / 0.2-7.2 / 2.8 Offices-Indoors 29 / 0.6-7.1 / 2.5 Restaurants-Outdoors 31 / 0.2-9.2 / 3.4 Restaurants-Indoors 31 / 0.4-12 / 5.0
Crouse, et al. (1988)	USA	Restaurants (36)	Not Given	Not Given	PASS Unit	N / Range / G. Mean / A. Mean / St. Deviation CO (ppm) 36 / 0.9 - 6.3 / 2.4 / 2.6 / 1.5
Eudy, et al. (1987)	USA	Restaurant	Not Given	Not Given	Electrochemical Analyzer, Sample every 10 mins. during 48 hr runs	CO (5) 48 Hour Sampling Runs Range 0 - 16 ppm A. Mean 4 ppm
First (1983)	USA	Public Places	Various	Not Given	Ecolyzer	Site / Avg. Conc. (ppm) Chamber1 2.0 - 1 cig. smoked Chamber2 1.5 - 1 cig. smoked School cafeteria1 1.0 - no smokers School cafeteria2 0.5 - 2-3 smokers Tavern1 8.0 - 1-5 smokers Tavern2 8.0 - 2-3 smokers Tavern3 7.0 - mostly 1 smoker Bus Terminal 3.5 - 50-100 people, 1-5 smokers Bus Terminal (outside) 2.0-2.5 Fast Food Restaurant 5.0 - 1-3 smokers during sampling Sm. Sitdown Rest.1 6.0 - 15 diners, 4 smokers Sm. Sitdown Rest.2 6.5 - 23 diners, 1 smoker
Flachsbart, et al. (1987)	USA	Car (8) Bus (4) Train (3)	Not Given	Not Given	Electrochemical Detector No Smoking	N[a] / Range of Means (ppm) / A. Mean of means (ppm) Automobile 213 / 8.8 - 22.3 / 11.6 Bus 35 / 3.7 - 10.2 / 6.0 Train 8 / 2.0 - 5.2 / 2.88 [a]N=number of trips
Hedge, et al. (1990)	USA	Office Building (2)	Not Given	Not Given	Direct Reading Interscan 4000 Hourly Samples	A. Mean (ppm): AM / PM Smoking Prohibited 0.0 / 0.0 Smoking Restricted (Office) 2.5 / 1.7 Smoking Restricted (Office with des. smoking area w/LACS[a]) 2.8 / 2.6 [a]Local Air Cleaning System

Table 2. Continued.

IT Corp. (1987)	USA	Offices (38) Restaurants (36)	Varied	Not Given	Electrochemical Detector, sampled each min. for 60 min.	Offices Restaurants Range (ppm) 0.5 - 6 0.4 - 9 A. Mean (ppm) 1.9 3.1
Lofroth, et al. (1989)	USA	Tavern	5-25 people 180 m^3	Not Given	Electrochemical Detector	First Study (3hr) Second Study (4hr) Indoor 4.4 mg/m^3 4.8 mg/m^3 Outdoor < 1 mg/m^3 1-2 mg/m^3
Mumford, et al. (1990)	USA	Mobile Homes	Not Given	0.5 ACH	SPE CO Detectors	N^a Kerosene Heat On N Kerosene Heat Off A. Mean 30 7.4 ppm 37 1.5 ppm Maximum 30 11.5 ppm 37 1.5 ppm [a]N=Number of sampling days or number of samples analyzed.
Proctor, (1989)	UK	Offices (10) Train Comp.(20) (10S, 10NS)	Not Given app. 75%	Mechanical Not Given	Electrochemical Detector, 1 sample/minute	(ppm) CO Range CO A. Mean (ppm) Offices(S) 0.5 - 5 1.4 Office(NS) 0.7 - 4 1.2 Trains (S) 1 - 2.2 1.6 Trains (NS) 0.5 - 2.9 1.3
Proctor, et al. (1989a)	UK	Betting Shops (6)	Not Given	Not Given	Electrochemical Detector	N Range (ppm) A. Mean Indoor Smoking 11 3.6-9.4 5.1 Indoor N-Smoking 2 2.8-3.4 3.1 Outdoor 16 2.8-9.0 4.4
Proctor, et al. (1989b)	UK	Office Building (1)	26 m^2/person	Not Given	Electrochemical Detector, five 1 hr continuous samples	Smoking Mean - 1.4 ppm Median - 1.1 ppm Non smoking Mean - 1.2 ppm Median - 1 ppm
Sterling & Mueller (1988)	Canada	Office Buildings (2)	.73-1.8/10m^2	1)Mechanical Air Recirc. 2)Natural, No Recirc.	Electrochemical Analyzer, 3-4 min. samples, 6/location	Building(s) A. Mean (ppm) Smoking Cafeteria 1&2 3.9 Non Smoking Cafeteria 1&2 2.6 Non Smoking Offices 1 1.8 Non Smoking Offices 2 1.35
Sterling, (1988)	Canada	Office Building	.79/10m^2	Forced Air; recirculation Min. 20 cfm/ person fresh air	Electrochemical Analyzer, 3-4 min. samples, 3/location	A. Mean (ppm) Smoking Prohibited 2.1 Smoking Permitted 2.5 Designated Smoking 4.2
Sterling, et al. (1988)	North Am.	Offices	Not Given	Not Given	Not Given	N Range Median (ppm) CO (ppm) 241 ND - 245 2.65
Thomas, et al. (1989)	USA	Industrial Cafeteria	30±9 people 560 m^3	8.8 ACH 5,400 CFM	Electrochemical Sensor, 120 samples/day for 12 days	Average Concentration (ppm) Lunchtime 0.9 ± 0.4 Background 0.6 ± 0.2
Turner, et al. (1991)	USA	Offices (585)	126.5 ft^2/ person	Not Given	Electrochemical Detector, 10 readings/hour.	N CO (ppm) A. Mean Smoking 331 3.40 Non Smoking 254 3.13 Total 585 3.29
Yuill & Comeau (1989)	Canada	Homes (76)	Not Given	0.29 ACH (0.0-1.35)	CO instrument	N A. Mean (ppm) Range (ppm) Living Room 76 0.7 0.0 - 4.0 Basement 69 0.7 0.0 - 4.0 Bedroom 73 0.4 0.0 - 3.0

Table 3. Nicotine measured under realistic conditions.

Author & Date	Country	Building Type	Occupancy	Ventilation	Sampling	Concentrations/Comments
Chuang, et al. (1988)	USA	Homes (8)	Not Given	Not Given	Pump w/XAD-4 Sorbent 2 - 8 hr samples in living room	Home # 1NS 2S 3S 4S 5S 6S 7NS 8NS S NS Nicotine 0.17 15 1.7 29 45 4.1 0.02 0.06 19 0.08 (μg/m^3)
Coultas, et al. (1990a)	USA	Workplace (15)	Not Given	Not Given	Personal Pump w/ Sodium bisulfate filter, 6.5 hr samples	Males n A. Mean (μg/m^3) Hospital 2 28 Offices 2 4.85 Barber Shop 2 8.85 Restaurant 1 45 Retail Store 1 6.9 Females Hospital 3 22.7 Offices 3 33.97 Public Trans. 1 0.0
Coultas, et al. (1990b)	USA	Homes (10)	Not Given	Not Given	Pump w/Sodium Bisulfate filter, 10 samples/home	Mean Range 0.6 - 6.9 μg/m^3 (100 samples)
Crouse, et al. (1988)	USA	Restaurants (37)	Not Given	Not Given	PASS Unit w/XAD-4 Sorbent, 1 hr sample	n Range (μg/m^3) A. Mean (μg/m^3) G. Mean (μg/m^3) Restaurants 37 1.6 - 34.7 8.6 5.3 ± 2.4
Crouse & Carson (1989)	USA	Offices (32) Restaurants (36)	Not Given	Not Given	PASS Unit w/XAD-4 Sorbent	Offices (μg/m^3) Restaurants (μg/m^3) G. Mean 3.8 4.1 Range 1.2 - 24.3 1.0 - 36
Crouse & Oldaker (1990)	USA	Restaurants (21)	Not Given	Not Given	PASS Unit & Personal Pump w/XAD-4 Sorbent Min. 1 hr sample for four months.	PASS Unit Personal Pump Mean (μg/m^3) 6.3 4.3 Median 4.2 2.9 Range 0.3 - 24.8 0.3 - 24
Eudy, et al. (1987)	USA	Restaurant	Not Given	Not Given	Pump w/XAD-4 Sorbent (12) 4 hr samples during (5) 48 hr sample runs.	Nicotine (μg/m^3) Range 0.29 - 11.5 A.Mean 2.1
First (1983)	USA	Public Places	Various	Not Given	Pump w/Potassium bisulfate filter	Site Avg. Conc. (μg/m^3) Chamber1 13.9 - 1 cig. smoked Chamber2 13.9 - 1 cig. smoked School cafeteria1 5.5 - no smokers School cafeteria2 2.7 - 2-3 smokers Tavern1 6.3 - 1-5 smokers Tavern2 9.4 - 2-3 smokers Tavern3 15.9 - mostly 1 smoker Bus Terminal ---- - 50-100 people, 1-5 smokers Fast Food Restaurant 30.0 - 1-3 smokers during sampling Sm. Sitdown Rest.1 12.0 - 15 diners, 4 smokers Sm. Sitdown Rest.2 16.3 - 23 diners, 1 smoker
Henderson, et al. (1989)	USA	Homes 15 w/Smokers 12 w/o Smokers	Not Given	Not Given	Pump w/Sodium Bisulfate Filter 5pm-7am @ 2 days	Average Concentration (μg/m^3) Smoking Homes 3.74 Non smoking Homes 0.34

Table 3. Continued.

IT Corp. (1987)	USA	Offices (38) Restaurants (36)	Not Given	Not Given	Pump w/XAD-4 Sorbent 1 Hr. Samples	Offices ($\mu g/m^3$) — Restaurants ($\mu g/m^3$) Range: nd - 30 — nd - 12 A. Mean: 6 — 4 (Offices & Restaurants sampled had no smoking restrictions)
Jenkins, et al. (1988)	USA	Restaurants (36)	Not Given	Not Given	Personal Pump w/ Tenax Sorbent. 1 hr samples	Nicotine ($\mu g/m^3$) Range: 0.5 - 37.2 A. Mean: 5.78
Lofroth, et al. (1989)	USA	Tavern	5 - 25 $180m^3$	Not Given	Pump w/ filter 3 & 4 hr Samples	1st Study (3hr): 71 $\mu g/m^3$ 2nd Study (4hr): 60 $\mu g/m^3$
McCarthy, et al. (1987)	USA	Homes (81) 68S, 13NS	Not Given	Not Given	Pump w/ Sodium bisufate filter, Personal & Area Samples	Mean — Median — Range ($\mu g/m^3$) Personal (NS): 0.3 — 0.2 — 0.0 - 1.0 Personal (S): 2.5 — 1.9 — 0.1 - 12.0 Home (NS): 0.1 — 0.0 — 0.0 - 1.6 (Personal samples done on children 8-11 yrs old)
Miesner, et al. (1989)	USA	Public Buildings (11)	Not Given	Not Given	Pump w/Sodium bisulfate filter	n — A. Mean ($\mu g/m^3$) Bar (S): 3 — 3.7 Bar/Rest.1 (S): 2 — 7.55 Bar/Rest.2 (S): 2 — 7.85 Subway St. (NS): 1 — 1.0 Hospital (S): 1 — 1.6 Clinic: 1 — 17.1 (Des. Smoking Area in NS Building) Office Bldg1 (S): 1 — 0.6 Office Bldg2 (NS): 1 — 2.0 (Smoking room directly below) Office Bldg3 (NS): 1 — 0.4 Office Bldg4 (S): 2 — 3.15 Office Bldg5: 1 — 26.5 (Des. Smoking Area in NS Building)
Oldaker, et al. (1988)	USA	Offices (46) Restaurants (49)	Not Given	Not Given	Pass Unit w/XAD-4 Sorbent	Offices ($\mu g/m^3$) — Restaurants ($\mu g/m^3$) G. Mean: 3.3 — 4.5 A. Mean: 4.3 — 6.2 Range: 1.0 - 16.3 — 0.7 - 15.6
Oldaker, et al. (1990)	USA & Canada	Offices & Restaurants (4 Cities)	Min. 2 people/office 1 smoker	Not Given	PASS Unit w/XAD-4 Sorbent Tube.	Offices ($\mu g/m^3$) — Restaurants ($\mu g/m^3$) Range: (n=156) 0 - 69.7 — (n=170) 0 - 23.8 Mean: 4.8 — 5.1
Proctor (1989)	UK	Offices (10) Train Compartments (20)	Varied 75%	Mechanical Not Given	PASS Unit w/XAD-4 Sorbent, 1 hr samples.	Offices (S) — Offices (NS) — Train (S) — Train (NS) Range: 0.6 - 26 — 0.1 - 2.1 — 0.6 - 49.3 — 0.5 - 21.2 ($\mu g/m^3$) A. Mean: 6 — 0.6 — 15.3 — 4.5
Proctor, et al. (1989a)	UK	Betting Shops (6)	Not Given	Not Given	PASS w/Tenax Sorbent	n — Range ($\mu g/m^3$) — A. Mean ($\mu g/m^3$) Smoking: 11 — 3 - 57 — 19.36 Non Smoking: 2 — 0.4 - 2 — 1.2 Outdoor: 3 — 0.3 -0 .4 — 0.33
Proctor, et al. (1989b)	UK	Office (1)	265 ft^2/ person	Not Given	Pump w/XAD-4 Sorbent	Mean ($\mu g/m^3$) — Median ($\mu g/m^3$) Smoking: 6 — 3.1 Non Smoking: 0.6 — 0.6

Table 3. Continued.

Schenker, et al. (1987)	USA	RR Workers Office, Repair Shop, Outdoors	Not Given	Not Given	Personal Pumps w/Sodium Bisulfate Filter (2 Days)	Mean Concentration ($\mu g/m^3$) Office (n=12) 10.2 ± 2.2 Repair (n=13) 5.8 ± 3.4 Outdoor (n=73) 0.4 ± 0.1
Sterling et al. (1988)	USA & Canada	Offices (32)	Not Given	Not Given	Not Given	Range ND - 43.7 $\mu g/m^3$ Median - ND
Sterling & Mueller (1988)	Canada	Office (1) N-Smoking	.79/10m^2	Forced Air; Recirculation from (S) area	Personal Pump w/XAD-4 Sorbent, 2-8 hr Samples	Range ($\mu g/m^3$) nd - 1
Thomas, et al. (1989)	USA	Industrial Cafeteria	30 ± 9 560 m^3	8.8 ACH 2900 cfm OA 2500 cfm RA	Pump w/XAD-4 Sorbent 2 hr. samples for 14 days (11:30-1:30)	Lunchtime Background Avg. Conc. ($\mu g/m^3$) 5.1 ± 1.6 0.14 ± 0.03 (Average smoking rate during sampling was 26±6 cig/hr)
Turner, et al. (1991)	USA	Offices (585)	126 ft^2/ person	Not Given	Personal Pump w/XAD-4 Sorbent, 1 hour samples.	Nicotine- A. Mean ($\mu g/m^3$) Smoking 6.6 Non Smoking 0.17 Total 3.84
Vaughan & Hammond (1990)	USA	Office	Not Given	Not Given	Passive (M-F) & Active (W) on sodium bisulfate filters.	A.Mean Pre Smoking Policy ($\mu g/m^3$) Post Smoking Policy NS desks (n=13) 2.45 0.3 Snack Bar (n=3) 11.3 85.4 (Designated Smoking) Cafeteria (n=6) 4.5 5.3 S Desks (n=6) 10.7 ----

Table 4. Nitrogen dioxide measured under realistic conditions (ppm = 1 900 μg/m³; ppb = 1.9 μg/m³).

<table>
<tr><th>Author & Date</th><th>Country</th><th>Building Type</th><th>Occupancy</th><th>Ventilation</th><th>Sampling</th><th>Concentrations/Comments</th></tr>
<tr><td>Berwick, et al. (1989)</td><td>USA</td><td>Homes (72)</td><td>Not Given</td><td>Not Given</td><td>Passive tubes, 3 locations/house, 2 week samples</td><td>NO_2, μg/m³
<table>
<tr><th></th><th colspan="2">1+2</th><th colspan="2">1 only</th><th colspan="2">2 only</th><th colspan="2">None</th></tr>
<tr><th>Room</th><th>N</th><th>NO_2</th><th>N</th><th>NO_2</th><th>N</th><th>NO_2</th><th>N</th><th>NO_2</th></tr>
<tr><td>Kitchen</td><td>6</td><td>98.50</td><td>49</td><td>41.07</td><td>13</td><td>40.92</td><td>4</td><td>6.40</td></tr>
<tr><td>Living Room</td><td>6</td><td>76.00</td><td>49</td><td>43.40</td><td>13</td><td>24.85</td><td>4</td><td>6.23</td></tr>
<tr><td>Bedroom</td><td>6</td><td>104.75</td><td>49</td><td>38.33</td><td>13</td><td>28.54</td><td>4</td><td>5.19</td></tr>
<tr><td>House Ave.</td><td>6</td><td>90.08</td><td>49</td><td>40.93</td><td>13</td><td>31.43</td><td>4</td><td>5.94</td></tr>
</table>
1 = Kerosene heater 2 = Gas stove</td></tr>
<tr><td>Brauer, et al. (1990)</td><td>USA</td><td>Homes (11)</td><td>Not Given</td><td>Not Given</td><td>Passive samplers Triethanolomine Colorimetric 24 hr. indoor, 48 hr. outdoor</td><td>NO_2, ppb
<table>
<tr><th></th><th>N</th><th>Mean</th><th>Min.</th><th>Max.</th></tr>
<tr><td>Indoor</td><td>30</td><td>17</td><td>7</td><td>36</td></tr>
<tr><td>Outdoor</td><td>30</td><td>15</td><td>5</td><td>26</td></tr>
</table></td></tr>
<tr><td>Dumont, (1986)</td><td>Canada</td><td>Homes (46)</td><td>Not Given</td><td>Varied</td><td>Passive samples, 1 week, 1 sample/house</td><td>
<table>
<tr><th>NO_2</th><th>N</th><th>A. Mean (ppb)</th></tr>
<tr><td>Wood stove, smoke</td><td>9</td><td>5.6</td></tr>
<tr><td>Wood stove, no smoke</td><td>21</td><td>5.1</td></tr>
<tr><td>No wood stove, smoke</td><td>4</td><td>5.3</td></tr>
<tr><td>No wood stove, no smoke</td><td>12</td><td>3.5</td></tr>
</table></td></tr>
<tr><td>Good, et al. (1982)</td><td>USA</td><td>Homes (90)</td><td colspan="2">
<table>
<tr><th>Summer</th><th>S home</th><th>NS home</th></tr>
<tr><td>Avg. No. Smokers</td><td>2.2</td><td>2.7</td></tr>
<tr><td>Avg. No. NSmokers</td><td>1.3</td><td>0.3</td></tr>
<tr><th>Winter</th><th>S home</th><th>NS home</th></tr>
<tr><td>Avg. No. Smokers</td><td>2.0</td><td>2.7</td></tr>
<tr><td>Avg. No. NSmokers</td><td>1.4</td><td>0.2</td></tr>
</table>
vent. rates not given</td><td>Palmes personal sampler, 7 day, kitchen, betroom, living room.</td><td>NO_2, means, μg/m³
<table>
<tr><th>Stove</th><th># of</th><th></th><th colspan="2">Kitchen</th><th colspan="2">Living Room</th><th colspan="2">Bedroom</th></tr>
<tr><th></th><th>Cig.</th><th>N</th><th>Sum.</th><th>Win.</th><th>Sum.</th><th>Win.</th><th>Sum.</th><th>Win.</th></tr>
<tr><td>Elec.</td><td>> 20</td><td></td><td>15.6</td><td>21.3</td><td>16.5</td><td>23.5</td><td>14.0</td><td>21.3</td></tr>
<tr><td>Gas</td><td>> 20</td><td>8</td><td>76.3</td><td>156.6</td><td>66.9</td><td>112.2</td><td>48.4</td><td>96.4</td></tr>
<tr><td>Elec.</td><td>≤ 20</td><td></td><td>11.8</td><td>20.3</td><td>12.4</td><td>19.6</td><td>10.7</td><td>17.5</td></tr>
<tr><td>Gas</td><td>≤ 20</td><td>3</td><td>87.0</td><td>219.6</td><td>47.1</td><td>117.4</td><td>38.7</td><td>97.8</td></tr>
</table>
<table>
<tr><th></th><th></th><th></th><th colspan="4">NO_2, μg/m³</th></tr>
<tr><th>Room</th><th>Season</th><th>Smoke</th><th>N</th><th>Mean</th><th>Max</th><th>Min</th></tr>
<tr><td>Living Room</td><td>Summer</td><td>NS</td><td>54</td><td>12.4</td><td>86.5</td><td>-2.5</td></tr>
<tr><td></td><td></td><td>S</td><td>38</td><td>16.5</td><td>40.8</td><td>-0.4</td></tr>
<tr><td></td><td>Winter</td><td>NS</td><td>49</td><td>17.5</td><td>36.6</td><td>5.7</td></tr>
<tr><td></td><td></td><td>S</td><td>38</td><td>21.3</td><td>49.6</td><td>-1.6</td></tr>
<tr><td>Bedroom</td><td>Summer</td><td>NS</td><td>54</td><td>10.7</td><td>66.9</td><td>-2.7</td></tr>
<tr><td></td><td></td><td>S</td><td>38</td><td>14.0</td><td>42.7</td><td>-0.6</td></tr>
<tr><td></td><td>Winter</td><td>NS</td><td>50</td><td>20.3</td><td>57.1</td><td>5.3</td></tr>
<tr><td></td><td></td><td>S</td><td>38</td><td>21.3</td><td>54.3</td><td>1.4</td></tr>
<tr><td>Kitchen</td><td>Summer</td><td>NS</td><td>54</td><td>11.8</td><td>72.0</td><td>-3.4</td></tr>
<tr><td></td><td></td><td>S</td><td>38</td><td>15.6</td><td>44.7</td><td>0.5</td></tr>
<tr><td></td><td>Winter</td><td>NS</td><td>49</td><td>19.6</td><td>44.5</td><td>5.7</td></tr>
<tr><td></td><td></td><td>S</td><td>38</td><td>23.5</td><td>65.6</td><td>1.4</td></tr>
<tr><td>Outside</td><td>Summer</td><td>NS</td><td>54</td><td>21.3</td><td>70.5</td><td>1.1</td></tr>
<tr><td></td><td></td><td>S</td><td>38</td><td>22.6</td><td>54.5</td><td>6.3</td></tr>
<tr><td></td><td>Winter</td><td>NS</td><td>48</td><td>52.3</td><td>99.9</td><td>18.7</td></tr>
<tr><td></td><td></td><td>S</td><td>35</td><td>50.0</td><td>91.3</td><td>8.9</td></tr>
</table></td></tr>
<tr><td>Hollowell and Miksch (1981)</td><td>USA</td><td>Office (1)</td><td>Not Given</td><td>Not Given</td><td>One week</td><td>NO_2 - 60 μg/m³, 30 ppb</td></tr>
</table>

Table 4. Continued.

Hosein, et al. (1985)	Canada	Homes (52)	Not Given	Not Given	NaOH impinger	NO_2 µg/m^3, Geometric means Air Cond.: N, NO2 / No Air Cond.: N, NO2 Gas Stove 4 175.1 7 182.1 Elec. Stove 12 70.9 29 81.8 No Gas Summer: N, NO2 / Winter: N, NO2 Smoke 29 76.1 29 82.6 No Smoke 12 74.5 12 75.7
Marbury, et al. (1988)	USA	Homes (144)	Not Given	Not Given	Passive sample tubes 2, 2 week samples, 3 samples/home	NO_2, means and range, ppb Gas stove 1, 2 / Elec. stove 1, 2 Outside 19.1 (5.2-26.7) N=36; 20.3 (6.9-31.6) N=38; 14.1 (5.1-24.3) N=38; 19.6 (5.1-30.1) N=28 Activity Room 41.3 (8.4-168.7) N=81; 39.3 (7.0-135.9) N=74; 7.8 (2.0-20.9) N=59; 7.0 (1.3-22.7) N=53 Bedroom 33.1 (4.4-167.1) N=82; 30.9 (4.0-140.4) N=75; 7.0 (1.6-32.5) N=60; 6.2 (1.1-22.4) N=56 1 = 1st cycle of samples 2 = 2nd cycle of samples
Morey and Jenkins (1989)	USA	Offices (7) (problems reported)	Not Given	Not Given	Triethanolamine tube 50-200 ml/min., colorimetric	NO_2, ppm Bldg. Outdoor, roof Indoor E <0.07 <0.06-0.10 E ---- 0.2-0.3 F 0.04 0.20 G 0.05 0.09-0.10 H 0.10 <0.07-0.09 I 0.10 0.03-0.16 J <0.02 <0.02-0.20 K <0.02-0.05 <0.03-0.60 K 0.03-0.08 0.04-0.70
Moschandreas, et al. (1990)	USA	Homes (18) w/gas furnaces	Not Given	Not Given	Portable Chemi-luminescence det., 4 samples ≤ 15 min.	NO_2 Appliance Room (ppb): Mean, Range / Control Room (ppb): Mean, Range 29 3 - 33 32 7 - 40 Furnace Off 40 3 - 58 42 4 - 54 Furnace On

Table 4. Continued.

<table>
<tr><td>Petreas, et al. (1988)</td><td>USA</td><td>Mobil Homes (312)</td><td>Not Given</td><td>Not Given</td><td>Palmes tubes, 3 sites/house, one week samples</td><td>
<table>
<tr><th colspan="6">NO_2, ppb</th></tr>
<tr><th></th><th></th><th>Room</th><th>N</th><th>A. Mean</th><th>G. Mean</th></tr>
<tr><td>Summer,</td><td>all</td><td>Kitchen</td><td>311</td><td>20.73</td><td>16.92</td></tr>
<tr><td></td><td></td><td>Bedroom</td><td>312</td><td>14.64</td><td>11.71</td></tr>
<tr><td></td><td></td><td>Outdoor</td><td>30</td><td>11.64</td><td>8.95</td></tr>
<tr><td></td><td>gas</td><td>Kitchen</td><td>263</td><td>22.89</td><td>20.25</td></tr>
<tr><td></td><td></td><td>Bedroom</td><td>265</td><td>15.99</td><td>13.51</td></tr>
<tr><td></td><td></td><td>Outdoor</td><td>25</td><td>11.20</td><td>8.39</td></tr>
<tr><td></td><td>elec.</td><td>Kitchen</td><td>47</td><td>8.98</td><td>6.18</td></tr>
<tr><td></td><td></td><td>Bedroom</td><td>46</td><td>7.77</td><td>5.14</td></tr>
<tr><td></td><td></td><td>Outdoor</td><td>5</td><td>13.78</td><td>12.33</td></tr>
<tr><td>Winter,</td><td>all</td><td>Kitchen</td><td>254</td><td>26.56</td><td>21.09</td></tr>
<tr><td></td><td></td><td>Bedroom</td><td>254</td><td>18.67</td><td>15.10</td></tr>
<tr><td></td><td></td><td>Outdoor</td><td>27</td><td>22.61</td><td>19.16</td></tr>
<tr><td></td><td>gas</td><td>Kitchen</td><td>230</td><td>28.68</td><td>24.33</td></tr>
<tr><td></td><td></td><td>Bedroom</td><td>230</td><td>19.98</td><td>16.77</td></tr>
<tr><td></td><td></td><td>Outdoor</td><td>23</td><td>22.41</td><td>18.77</td></tr>
<tr><td></td><td>elec.</td><td>Kitchen</td><td>23</td><td>6.29</td><td>5.36</td></tr>
<tr><td></td><td></td><td>Bedroom</td><td>23</td><td>6.07</td><td>5.48</td></tr>
<tr><td></td><td></td><td>Outdoor</td><td>4</td><td>23.74</td><td>21.52</td></tr>
<tr><td colspan="6">gas = gas stove elec. = electric stove</td></tr>
<tr><td>Summer</td><td>Kitchen</td><td>LA</td><td>61</td><td>36.92</td><td>24.26</td></tr>
<tr><td></td><td></td><td>Non-LA</td><td>250</td><td>19.26</td><td>15.66</td></tr>
<tr><td></td><td>Bedroom</td><td>LA</td><td>60</td><td>22.31</td><td>19.44</td></tr>
<tr><td></td><td></td><td>Non-LA</td><td>252</td><td>12.97</td><td>10.27</td></tr>
<tr><td>Winter</td><td>Kitchen</td><td>LA</td><td>46</td><td>34.75</td><td>30.52</td></tr>
<tr><td></td><td></td><td>Non-LA</td><td>208</td><td>24.76</td><td>19.55</td></tr>
<tr><td></td><td>Bedroom</td><td>LA</td><td>48</td><td>25.74</td><td>21.26</td></tr>
<tr><td></td><td></td><td>Non-LA</td><td>206</td><td>17.03</td><td>13.98</td></tr>
<tr><td colspan="6">LA = Los Angeles basin Non-LA = Not in LA</td></tr>
</table>
</td></tr>
<tr><td>Spengler, et al. (1987)</td><td>USA</td><td>Homes</td><td>Not Given</td><td>Not Given</td><td>Palmes Passive Sampler</td><td>
<table>
<tr><th>NO_2</th><th colspan="3">Gas Home (ppb)</th><th colspan="3">Electric Home (ppb)</th></tr>
<tr><th></th><th>N</th><th>Mean</th><th>SD</th><th>N</th><th>Mean</th><th>SD</th></tr>
<tr><td>Fall</td><td>160</td><td>27.6</td><td>10</td><td>68</td><td>11.8</td><td>2.5</td></tr>
<tr><td>Summer</td><td>142</td><td>25.2</td><td>6.6</td><td>68</td><td>14.4</td><td>2.5</td></tr>
<tr><td>Winter</td><td>166</td><td>24.3</td><td>5.4</td><td>70</td><td>17.1</td><td>3.5</td></tr>
</table>
</td></tr>
<tr><td>Sterling, et al. (1988)</td><td>USA & Canada</td><td>Offices</td><td>Not Given</td><td>Not Given</td><td>Not Given</td><td>
<table>
<tr><th></th><th>N</th><th>Median</th><th>Min.</th><th>Max.</th></tr>
<tr><td>NO_2</td><td>49</td><td>ND</td><td>ND</td><td>0.1 ppm</td></tr>
<tr><td>NO_x</td><td>40</td><td>ND</td><td>ND</td><td>26.3 ppm</td></tr>
</table>
</td></tr>
<tr><td>Yocom, (1982)</td><td>USA</td><td>Homes (9)</td><td>Not Given</td><td>Not Given</td><td>Palmes tubes, 4 week
Mean values ($\mu g/m^3$)</td><td>
<table>
<tr><th>NO_2</th><th></th><th>Gas stove (5)</th><th>Elec. Stove (4)</th></tr>
<tr><td>Fixed,</td><td>Outside</td><td>17.1 $\mu g/m^3$</td><td>16.9 $\mu g/m^3$</td></tr>
<tr><td></td><td>Kitchen</td><td>59.2</td><td>15.7</td></tr>
<tr><td></td><td>Bedroom</td><td>37.3</td><td>14.5</td></tr>
<tr><td>Personal,</td><td>Husband</td><td>36.3</td><td>19.8</td></tr>
<tr><td></td><td>Wife</td><td>40.8</td><td>16.7</td></tr>
<tr><td></td><td>Child</td><td>45.2</td><td>8.7</td></tr>
</table>
</td></tr>
</table>

Table 5. Formaldehyde measured under realistic conditions (ppm = 1 230 $\mu g/m^3$).

Author & Date	Country	Building Type	Occupancy	Ventilation	Sampling	Concentrations/Comments
Dumont, (1986)	Canada	Homes (46)	Not Given	0.21 ach, ave.	Passive badges 2 samples/house 1 week/sample	Formaldehyde (ppm) Mean / Median / Range 0.097 / 0.091 / 0.03-0.24
Girman, et al. (1989)	USA	Office Building (52,000 sq. ft.)	Not Given	Mechanical	Midget Impingers chromotropic acid analysis, Formaldehyde	Pre-Bake Out ($\mu g/m^3$) / Post-Bake Out ($\mu g/m^3$) 1st Floor: 51 / 65 2nd Floor: 32 / 38 Plenum: 34 / 38 Outdoor: BD / BD
Grot, et al. (1991)	USA	Office (1)	230 ft^2/Person	Not Given	Sodium bisulfite impregnated filter	Formaldehyde 0.02-0.06 ppm
Hedge, et al. (1990)	USA	Office Buildings (2)	Not Given	Not Given	EPA Method TO-11 3 hr samples	Mean Formaldehyde (ppm): AM / PM SP: 0.023 / 0.019 SR (Office): 0.008 / 0.012 SR (Smoking): 0.018 / 0.023 SP=Smoking Prohibited SR=Smoking Restricted
Hollowell and Miksch (1981)	USA	Home (1) Office (1)	Not Given	0.4 ach	Not Given	Formaldehyde in new home Unoccupied, no furniture: 80± 9% $\mu g/m^3$ Unoccupied, with furniture: 223± 7% $\mu g/m^3$ Occupied, day: 261±10% $\mu g/m^3$ Occupied, night: 140±31% $\mu g/m^3$ Outside: <20 Aldehydes in an office building ($\mu g/m^3$) Formaldehyde: 49 Formaldehyde from various indoor environments Location / Range (ppm) / Mean (ppm) Mobile homes (2), Pa.: 0.1-0.8 / 0.36 Mobile homes w/ complaints (Wash.): 0-1.77 / 0.1-0.44 Mobile homes w/ complaints (Minn.): 0-3.0 / 0.4 Mobile homes w/ complaints (Wisc.): 0.023-4.2 / 0.88
Lofroth, et al. (1989)	USA	Tavern	5-25 people 180 m^3	Not Given	Pump w/sorbent 3 & 4 hr samples HPLC Analysis	1st Study 3 Hr / 2nd Study 4 Hr ($\mu g/m^3$) Formaldehyde: 104 / 89

Table 5. Continued.

Proskiw, et al. (1989)	Canada	Homes (20)	Not Given	see results	Passive dosimeter One week	House type / Formaldehyde (ppm): N, Mean, Median / Vent. rate (ach): N, Mean, Median R-2000 Mar 86: 6, 0.061, 0.060 / 6, 0.28, 0.26 Aug 86: 16, 0.058, 0.057 / -, ----, ---- Oct 86: 16, 0.080, 0.072 / 16, 0.30, 0.29 Feb 87: 16, 0.064, 0.061 / 16, 0.43, 0.45 Total: 54, 0.064, 0.061 / 37, 0.35, 0.36 Conventional Mar 86: 4, 0.078, 0.077 / 4, 0.16, 0.44 Aug 86: 4, 0.067, 0.065 / -, ----, ---- Oct 86: 3, 0.090, 0.086 / 4, 0.15, 0.17 Feb 87: 4, 0.067, 0.060 / 4, 0.20, 0.18 Total: 15, 0.074, 0.066 / 12, 0.17, 0.17 Smoking homes: 0.065, 0.063 Nonsmoking homes: 0.068, 0.063
Quackenboss, et al. (1989b)	USA	Homes (151)	Not Given	Not Given	Passive Samplers Sodium bisulfite One week, 3 sites/house	Building type, Evap. Cooler, Mean $\mu g/m^3$, N Single fam.: Yes 27 50; No 37 52; Total 32 102 Mobile/trailer: Yes 36 6; No 68 10; Total 49 10 Apt./Condo.: Yes 25 5; No 51 24; Total 47 29 All types: Yes 27 62; No 43 83
Sterling, et al. (1988)	USA & Canada	Offices (259)	Not Given	Not Given	Not Given	Formaldehyde ND - 1.9 ppm; 0.01, median
Stock (1987)	USA	Homes (41)	Not Given	Not Given	Passive badges one week samples two samples/home	Formaldehyde (ppm) Area, N, Mean, Range Clear Lake: 27, 0.07, 0.03-0.15 Sunnyside: 14, 0.10, 0.06-0.18 Smoking (cig/day), N, Mean <1: 26, 0.07 1-4: 4, 0.13 5-10: 6, 0.07 ≥ 20: 7, 0.07
Yocom (1982)	USA	Homes (2)	Not Given	Not Given	Not Given	House / Formaldehyde ($\mu g/m^3$): Range, Average, Outdoor ISUERH: 34-75, 42, <9 ERHM: 54-182, 120, <12
Yuill & Comeau (1989)	Canada	Homes (50)	Not Given	0.29, Mean ach 0.00-1.35	Passive bubbler colorimetric 2 hour samples	Formaldehyde (ppm) Room, N, Ave., Max., Min. Living room: 50, 0.090, 0.261, 0.000 Basement: 45, 0.088, 0.235, 0.000 Bedroom: 49, 0.092, 0.285, 0.000

Table 6. Benzene measured under realistic conditions (ppb = 3.2 $\mu g/m^3$).

Author & Date	Country	Building Type	Occupancy	Ventilation	Sampling	Concentrations/Comments
Bayer & Black (1987)	USA	Offices	Not Given	Mechanical	Personal Pump w/Tenax, 4 hr samples(3S,3NS)	Smoking Non Smoking Benzene 2.0ppb 1.2ppb
Chan, et al. (1990)	Canada	Homes (12)	Not Given	Not Given	Tenax/Charcoal 2 outdoor, 4 indoor samples each, 90 min. samples, 5-50 liters/ sample	Frequency, Range, and Avg. ($\mu g/m^3$) Outdoors/Indoors 12 Homes Ambient Air (Nov/Dec): F Range Avg. / Indoor Air: F Range Avg. Benzene 12 1-11 7.3 12 5-59 14.8 Frequency, Range, and Avg. ($\mu g/m^3$) Outdoor/Indoors 6 Homes Ambient Air (Feb/Mar): F Range Avg. / Indoor Air: F Range Avg. Benzene 6 2-8 6.0 6 7-15 10.6
Girman, et al. (1989)	USA	Office Building (52,000 ft^2)	Not Given	Mechanical	Pump w/Tenax Sorbent, GC/MS	Concentrations ($\mu g/m^3$) Pre-Bake-Out: 1st Fl. 2nd Fl. Plenum Roof / Post-Bake-Out: 1st Fl. 2nd Fl. Plenum Roof Benzene 2.8 3 3 1 0.8 1.5 BD BD (BD = Below Detection)
Lewis (1991)	USA	Homes (10)	Not Given	.2-.8 ACH	SS Canister 12 hr samples, GC/MS	Avg. Indoor Conc. from OUTdoor Sources and Indoor Souces (ppbC) Compound R05 R08 R11 R14 R17 R20 R26 R29 ALL Benzene OUT 11 17 20 11 14 15 30 13 15 IN 2 -1 2 1 0 1 -1 2 1
Lofroth, et al. (1989)	USA	Tavern	5 - 25 people 180 m^3	Not Given	Stainless steel canister, GC/MS	First Study (3hr): Indoor Outdoor / Second Study (4hr): Indoor Outdoor ($\mu g/m^3$) Benzene 27 6 21 8
Pleil, et al. (1986)	USA	Homes (26)	Not Given	Not Given	Summa Cannisters GC/FID,ECD	Indoor Air (PPBV): Summer Data 15 Samples: # Obs. Mean Range / Winter Data 16 Samples: # Obs. Mean Range Outdoor Air: Summer & Winter 6 Samples Each: # Obs. Mean Range Benzene 15 7.6 0.39-48 16 4.8 0.53-23.6 12 0.57 0.33-0.77
Proctor (1989)	UK	Offices (10) Trains (20)	Not Given	Not Given	Pump w/Tenax Sorbent, 1 hr. samples,	A. Mean Median Range / A. Mean Median Range ($\mu g/m^3$) Benzene 6 3.1 0.6 - 26 11.8 11.6 0.9 - 28.6 Offices(NS) / Train(NS) Benzene 12 10 3 - 31 7.4 5.1 2.9 - 29.3

Table 6. Continued.

Proctor, et al. (1989a)	UK	Betting Shops (6)	See chart	Not Given	Tenax TA, 3 l/hr. briefcase, GC/MS

Compound	N	Site/smoke	Pop/smokers	Qty, Mean ($\mu g/m^3$)
Benzene	3	A/S	20/5	14.3
	2	B/S	10/2	14
	2	C/S	7/3	21
	2	D/S	15/5	18.5
	2	E/S	10/2	18.5
	1	E/Outside	Hvy. Traffic	22
	2	F/NS	11/0	9.5
	2	F/Outside	Med. Traffic	15

Proctor, et al. (1989b)	UK	Office (1)	265 ft^2/person	Not Given	Tenax, 10 ml/min. GC/MS, pump Concs in $\mu g/m^3$

Compound	Smokers' Office A. Mean	Smokers' Office Median	Nonsmokers' Office A. Mean	Nonsmokers' Office Median
Benzene	13	8	12	10

Proctor, et al. (1991)	UK	Homes & work	Varied	Varied	Personal sampler 24 hour samples, 52 women

Compound	Smoke/Work			Smoke/No work			No smoke/Work			No smoke/No work			All Subjects		
	Mean	Median	Range	Mean	Median	Range	Mean	Median	Range	Mean	Median	Range	Mean	Median	Range
Benzene	15.7	13.3	3.2-48.7	21.6	13.4	5.2-103	60.7	15.5	0.7-510	13.2	10.4	0.2-32.1	26.5	12.8	0.2-510

Sheldon, et al. (1988b)	USA	Hospital (1) Nursing Home (2) Offices (3)	Not Given	Not Given	Pump w/Tenax 12 hr sample GC/MS

Mean Concentration (ng/L)

	Martinsburg, WV			Fairfax, VA		Worcester, MA		Washington, DC	Cambridge, MA	Martinsburg, WV
	Hospital (new)[a]			Office (new)[b]		Nursing Home (new)[c]		Office (old)	Office/School (old)	Nursing Home (old)
	Trip 1 (7/84)	Trip 2 (10/84)	Trip 3 (8/85)	Trip 1 (1/85)	Trip 2 (4/85)	Trip 1 (4/85)	Trip 2 (8/85)	Trip 1 (8/84)	Trip 1 (2/85)	Trip 1 (7/84)
Benzene	1.55	2.13	2.88	2.74	4.95	1.70	2.44	5.61	4.50	3.13

[a] Building completed approximately 34 weeks before first monitoring trip.
[b] Building completed approximately 1 week before first monitoring trip.
[c] Building completed approximately 4 weeks before first monitoring trip.

Sheldon, et al. (1988a)	USA	Office Building (1)	Not Given	Not Given	Pump w/Tenax 12 hr sample GC/MS

	Concentration ($\mu g/m^3$)			
	Indoors[a] July	Sept.	Dec.	Outdoor[b] all trips
Benzene	5	7	7	3

([a]Mean of six 12-hr avgs. at 5 indoor locations. [b]Mean of 18 12-hr avgs. at one outdoor location.)

Sheldon, et al. (1990)	USA	Homes (12)	16 individuals	Not Given	24 Hour Samples w/Tenax, GC/MS

	Mean Concentration (ng/l) + S.D.		
	Outdoor (n=4)	Indoor (n=12)	Personal (n=8)
Benzene	12±8.8	8.7±2.6	11±4.0

Sterling, et al. (1988)	USA & Canada	Offices (see table for numbers)	Not Given	Not Given	Not Given

Compound	N	Range	Median
Benzene	27	ND-1.4 mg/m^3	trace

Table 6. Continued.

<table>
<tr><td>Wallace, (1986)</td><td>USA</td><td>Various (TEAM study)</td><td>Not Given</td><td>Not Given</td><td>Personal and Outdoor samples</td><td>
Population-Weighted Arithmetic Mean Exposures (24 Hour Samples) µg/m³
<table>
<tr><th>Sites</th><th colspan="2">Benzene</th></tr>
<tr><th></th><th>PE[a]</th><th>Out</th></tr>
<tr><td>New Jersey</td><td></td><td></td></tr>
<tr><td>Fall 1981</td><td>28</td><td>9</td></tr>
<tr><td>Summer 1982</td><td>NC[b]</td><td>NC</td></tr>
<tr><td>Winter 1983</td><td>NC</td><td>NC</td></tr>
<tr><td>N. Carolina</td><td>9</td><td>12</td></tr>
<tr><td>N. Dakota</td><td>NC</td><td>NC</td></tr>
<tr><td>California</td><td></td><td></td></tr>
<tr><td>LA:Winter84</td><td>18</td><td>16</td></tr>
<tr><td>LA:Spring84</td><td>9</td><td>4</td></tr>
<tr><td>CC:Spring84</td><td>7</td><td>2</td></tr>
</table>
[a] Personal Exposure
[b] Not Calculated--did not meet quality control criteria.
</td></tr>
<tr><td>Wallace, et al. (1987)</td><td>USA</td><td>Homes</td><td>Not Given</td><td>Not Given</td><td>Personal Pumps w/ Tenax sorbent, 12 hr samples GC/MS</td><td>
<table>
<tr><th colspan="5">Personal Air Exposures-Unweighted Geometric Mean</th></tr>
<tr><th></th><th colspan="2">n</th><th colspan="2">Benzene</th></tr>
<tr><th></th><th>S</th><th>NS</th><th>S</th><th>NS</th></tr>
<tr><td>NJ(F)</td><td>153</td><td>188</td><td>18</td><td>11</td></tr>
<tr><td>NJ(S)</td><td>69</td><td>75</td><td>NR</td><td>NR</td></tr>
<tr><td>NJ(W)</td><td>24</td><td>22</td><td>NR</td><td>NR</td></tr>
<tr><td>LA(W)</td><td>29</td><td>85</td><td>18</td><td>14</td></tr>
<tr><td>LA(SP)</td><td>11</td><td>40</td><td>8</td><td>7</td></tr>
<tr><td>AP(SP)</td><td>19</td><td>49</td><td>8</td><td>7</td></tr>
<tr><td colspan="5">Overnight Indoor Conc.-Weighted Geometric Mean (µg/m³)</td></tr>
<tr><td>NJ(F)</td><td>252</td><td>94</td><td>16</td><td>8.4</td></tr>
<tr><td>NJ(S)</td><td>111</td><td>44</td><td>NR</td><td>NR</td></tr>
<tr><td>NJ(W)</td><td>37</td><td>12</td><td>NR</td><td>NR</td></tr>
<tr><td>LA(W)</td><td>56</td><td>58</td><td>17</td><td>11</td></tr>
<tr><td>LA(SP)</td><td>23</td><td>28</td><td>4.8</td><td>4.5</td></tr>
<tr><td>AP(SP)</td><td>35</td><td>33</td><td>4.9</td><td>4.4</td></tr>
</table>
F=Fall S=Summer W=Winter SP=Spring
</td></tr>
<tr><td>Weschler, et al. (1990)</td><td>USA</td><td>Office Building</td><td>Not Given</td><td>Not Given</td><td>Passive Samplers 4 Periods During 1 Year</td><td>
<table>
<tr><th colspan="5">VOC (µg/m³) Building 2 on 4th Floor During Four Sampling Periods</th></tr>
<tr><th></th><th>6/25/87-
7/16/87</th><th>9/9/87-
10/1/87</th><th>11/6/87-
12/4/87</th><th>3/3/88-
3/15/88</th></tr>
<tr><td>Benzene</td><td>ND</td><td>ND</td><td>1.3</td><td>ND</td></tr>
</table>
</td></tr>
</table>

Table 7. Nitrosamines measured under realistic conditions.

<table>
<tr><th>Author & Date</th><th>Country</th><th>Building Type</th><th>Occupancy</th><th>Ventilation</th><th>Sampling</th><th colspan="6">Concentrations/Comments</th></tr>
<tr><td rowspan="11">Hoffman, et al. (1987)</td><td rowspan="11">USA & Austria</td><td rowspan="11">Various</td><td rowspan="11">Not Given</td><td rowspan="11">Not Given</td><td rowspan="11">Pump w/liquid traps, GC/TEA, 1-4 hr continuous samples</td><td colspan="2"></td><td colspan="2">NDMA</td><td colspan="2">NDEA ($\mu g/m^3$)</td></tr>
<tr><td colspan="2">Train-Bar</td><td colspan="2">0.11-0.13</td><td colspan="2">ND</td></tr>
<tr><td colspan="2">Bar</td><td colspan="2">0.24</td><td colspan="2">ND</td></tr>
<tr><td colspan="2">Sports Hall</td><td colspan="2">0.09</td><td colspan="2">ND</td></tr>
<tr><td colspan="2">Betting Parlor</td><td colspan="2">0.05</td><td colspan="2">ND</td></tr>
<tr><td colspan="2">Residence, NS</td><td colspan="2"><.003</td><td colspan="2">ND</td></tr>
<tr><td colspan="2">Office</td><td colspan="2">0.03</td><td colspan="2">0.03</td></tr>
<tr><td colspan="2">Conference Room</td><td colspan="2">0.02-.033</td><td colspan="2">0-.02</td></tr>
<tr><td colspan="2">Work Room</td><td colspan="2">0.023</td><td colspan="2">0</td></tr>
<tr><td colspan="2">Restaurant</td><td colspan="2">0-0.05</td><td colspan="2">0</td></tr>
<tr><td colspan="2">Dance Hall</td><td colspan="2">0.07</td><td colspan="2">0.2</td></tr>
<tr><td rowspan="10">Stehlik, et al. (1982)</td><td rowspan="10">Austria</td><td rowspan="10">Offices
Restaurants
Bars</td><td rowspan="10">see chart</td><td rowspan="10">Not Given</td><td rowspan="10">Pump w/liquid traps, GC/TEA, 1-4 hr continuous samples</td><td>Room size</td><td>Room Type</td><td># of People</td><td>Tobacco Consumed</td><td>NDMA (ng/L)</td><td>NDEA (ng/L)</td></tr>
<tr><td>$207 m^3$</td><td>Working Room</td><td>7</td><td>Continuous (2hr)</td><td>0.024</td><td>BD</td></tr>
<tr><td>301</td><td>Conference Room</td><td>15</td><td>26 cig., 1 pipe 6 cigarillos (2hr)</td><td>0.031</td><td>BD</td></tr>
<tr><td>70</td><td>Office</td><td>6</td><td>27 cig. (2hr)</td><td>0.03</td><td>0.03</td></tr>
<tr><td>50</td><td>Sm. Conf. Room</td><td>12</td><td>37 cigs., 4 pipes 3 cigars (2hr)</td><td>0.02</td><td>0.02</td></tr>
<tr><td>120</td><td>Suburban Rest.</td><td>20</td><td>20-30 cigs, 2 pipes (2hr)</td><td>BD</td><td>BD</td></tr>
<tr><td>160</td><td>Vienna Rest.</td><td>23</td><td>20 cigs., (1hr)</td><td>0.01</td><td>BD</td></tr>
<tr><td>180</td><td>Vienna Rest. 2</td><td>25</td><td>25-30 cigs., (1hr)</td><td>0.04</td><td>BD</td></tr>
<tr><td>160</td><td>Vienna Rest. 3</td><td>23</td><td>15-20 cigs., (1hr)</td><td>0.05</td><td>BD</td></tr>
<tr><td>320</td><td>Dancing Bar</td><td>30-70</td><td>Not Determ.(4hr)</td><td>0.07</td><td>0.2</td></tr>
</table>

Table 8. PHA measured under realistic conditions.

Author & Date	Country	Building Type	Occupancy	Ventilation	Sampling	Concentrations/Comments
U.S. EPA (1988)	USA	Homes (8)	Not Given	Not Given	Pump w/XAD-4 Sorbent, GC/MS 8 hr Samples	
Daisey, et al. (1989)	USA	Homes (7)	Not Given	0.13-0.89 ACH	Pump w/Teflon coated fiberglass filter, 48 hr samples	
Grimsrud, et al. (1990)	USA	Office Buildings (40)	Not Given	Not Given	Gravimetric PM3.0 126 RSP samples analysed for B(a)P	
Lioy, et al. (1987)	USA	Homes (4)	Not Given	Not Given	PM10 extraction	
Waldman, et al. (1989)	USA	Homes	Not Given	Not Given	PM10 extraction	BaP Range nd - 8.6 ng/m^3

U.S. EPA (1988):

(Selected PAH measured in living rooms)

	HOME (ng/m^3)							A. Mean		
Compound	1NS	2S	3S	4S	5S	6S	7NS	8NS	S	NS
Naphthalene	800	1100	1100	1100	2200	4200	1800	880	1940	1160
Acenaphthylene	18	37	17	48	120	59	10	8.9	56	12
Phenanthrene	71	87	80	200	210	110	59	86	137	72
Fluoranthene	7.6	8.6	6.5	19	23	6.4	7.2	12	13	9
Pyrene	4.6	5.2	4.0	11	17	9.5	5.6	7.4	9	6
Benzo(e)pyrene	0.74	3.2	1.3	3.7	10	6.5	0.68	1.4	5	1
Benzo(a)pyrene	0.28	1.2	0.34	1.4	3.3	1.4	0.31	0.83	1.5	0.47
Quinoline	9.4	240	76	480	1100	300	23	9.1	439	13.8
Isoquinoline	21	140	34	300	620	170	35	16	253	24

Daisey, et al. (1989):

House	Wood burning	PAH (ng/m^3)								
		FLU	PYR	BEP	BBF	BKF	BAP	BGHIP	IND	TOTAL
102	+	0.72	0.47	0.48	0.52	0.24	0.66	1.23	1.77	6.1
	-	1.18	0.98	0.41	0.24	0.10	0.17	0.15	0.12	3.4
106	+	0.32	0.62	0.65	0.68	0.29	1.24	6.20	3.54	13.5
	-	0.58	0.70	0.42	0.11	0.04	0.11	0.33	0.16	2.4
108	+	0.96	0.50	0.38	0.40	0.19	0.43	0.55	1.06	4.5
	-	0.11	0.03	<0.06	0.04	0.02	0.03	0.08	0.09	0.4
203	+	0.81	0.58	0.95	0.51	0.21	0.40	0.75	0.98	5.2
	-	0.07	0.14	<0.06	<0.007	0.007	<0.009	<0.01	<0.02	0.3
204	+	0.16	0.02	0.14	0.10	0.03	0.07	0.12	0.20	0.8
	-	0.09	0.22	0.07	0.02	0.01	<0.009	0.02	0.03	0.5
208	+	0.65	0.65	1.36	1.22	0.48	1.34	0.87	2.23	8.8
	-	0.07	0.05	<0.06	0.009	0.005	<0.009	<0.01	<0.02	0.2
300	+	0.18	1.53	0.31	0.27	0.09	0.33	0.25	0.39	3.4
	-	0.50	0.31	0.43	0.04	0.02	0.02	0.10	0.14	1.6

(FLU=Fluoranthene, PYR=Pyrene, BEP=Benzo(e)pyrene, BBF=Benzo(b)fluoranthene, BKF=Benzo(k)fluoranthene, BAP=Benzo(a)pyrene, BGHIP=Benzo(ghi)perylene, IND=indeneo(1,2,3,-cd)pyrene)

Grimsrud, et al. (1990):

	Mean Concentration B(a)P (ng/m^3)
Non smoking Areas	0.4
Smoking Areas	1.1

Lioy, et al. (1987):

Home	N	B(a)P G. Mean	Maximum (ng/m^3)
1	14	0.5	4.8
2	13	1.1	4.4
3	14	0.8	2.3
6	13	0.3	1.4

receive would provide an independent assessment as to whether these health claims are realistic.

Dose: Dose is defined as the amount of a substance that actually enters the body. For airborne materials the dose is a function of the concentration of a substance, the duration of exposure, the rate of respiration, and the percentage of material potentially retained by the lungs.

Concentration: Concentrations of RSPs were determined as the mean difference between nonsmoking and smoking conditions as shown in Table 9.

Duration of exposure: In order to determine the duration of exposure in each of the five categories, data on time activity patterns were needed. Though there were several references available describing studies which performed time/activity surveys of one type or another, there were few that were adequate. The requirements that needed to be met included:

1. Data needed to be American or Canadian
2. Study needed to be of adults
3. Study could not be of select subpopulations
4. Study needed to include most of the entire day.

Five publications met the four chosen criteria (Jenkins et al. 1990; Juster and Stafford 1990; Shaw 1983; Spengler et al. 1985; Szalai et al. 1972). Each author's activity categories were allocated to one of the following locations that were chosen to match exposure categories used for the literature review.

Location — Exposure Category

1. Home, awake -------------- Home
2. Home, asleep ------------- Home
3. Work --------------------- Office, workplaces
4. Public Transportation----- Public transportation
5. Restaurant --------------- Restaurant
6. Bar ---------------------- Bar/Taverns
7. Other, public ------------ Office, workplaces (similar to office environment)
8. Outdoor ------------------ None

Time allocations for each category were then averaged to produce an average day based on the five studies reviewed. Time spent in each category is expressed separately for males, females, employed, and unemployed persons. Time spent in each activity category is expressed in minutes per day and hours per day averaged over seven days per week. If the average day did not add up to 1440 min (24 h), each category was adjusted by the percentage of the error to produce a 24-h day.

There were fewer data available regarding employed/unemployed time activity patterns than for male/female time activity patterns. Because of this, it was necessary to subdivide some authors' categories into more than one of the five chosen for

Table 9. Mean respirable particles µg/m³ in smoking and nonsmoking areas in real-life situations.

		Smoking			Nonsmoking			Diff.in Means
Category	# of Studies	N	Mean	Range	N	Mean	Range	S - NS
Homes	14	951	49.5	17-212	905	22.3	7-77.1	27.2
Offices and Public Places	24	805	67.7	12-2700	640	45.9	nd-240	21.8
Restaurants	11	257	131.5	nd-685	335[b]	89.7	c	41.8
Bars/Taverns	4	9	103.7	c	c	c	c	103.7[d]
Trains	1	20	216	70.8-325	20	186	63.3-450	30

a - The mean is calculated by weighting the mean values in each study based on sample size and the calculating an overall arithmetic mean. If actual values for nonsmoking or smoking areas were not given, but UVPM values were available, the UVPM values were utilized in obtaining the weighted means. For example, if a total RSP mean value and UVPM mean value were available for a smoking area but not for a nonsmoking area, a nonsmoking area value was obtained by subtracting the UVPM value from the total RSP value.

b - Derived from total RSP-UVPM.

c - No ranges available; no data available.

d - Some of this RSP would be due to sources other than tobacco smoke. If properties are similar to restaurants, this mean would be approximately 48.3.

Table 10. Carbon monoxide concentrations (ppm) in smoking and nonsmoking areas in real-life situations. Conversion factor: 1ppm = 1.15 mg/m^3.

Category	No. of Studies	N	Smoking Mean	Smoking Range	N	Nonsmoking Mean	Nonsmoking Range	Diff.in Means S - NS
Offices and Public Bldgs.	13	697	2.95	0.1-8.7	275	2.99	0.7-4.0	-0.04
Restaurants	5	107	3.6	0.4-9.0	---	------------		---
Taverns/Bars	2	5	6.4	-------	---	-------------		---
Trains	2	18	2.2	1.0-5.2	10	1.30	0.5-2.9	0.90
Buses	1	35	6.0	3.7-10.2	---	----	-------	---
Autos	1	---	----	--------	213	11.6	8.8-22.3	---

Homes - Very little information on homes
Yuill et al. (1989); 76 homes, 0.7 mean, range 0-4.0
No data on smoking or nonsmoking.

Table 11. Nicotine concentrations ($\mu g/m^3$) in smoking and nonsmoking areas in real-life situations.

	Smoking				Nonsmoking			
Category	No. Studies	Sample Sites	Mean	Range	No. Studies	Sample Sites	Mean	Range
Offices and Public Bldgs.	14	673	6.2	ND-69.7	5	270	0.3	0.1-2.1
Restaurants	10	390	5.7	0-37.2				
Taverns/Bars Betting Shops	4	17	19.1	3-65.5	1	2	1.2	0.4-2.0
Homes	1	98	3.7	0.1-12.0	3	28	0.29	0-1.0
Trains	1	20	15.3	0.6-49.3	1	20	4.5	0.5-21.2

this review. To do this, the proportion determined from the male/female time activity pattern was used to divide that author's category. For example, time at home for employed and unemployed persons was determined by Spengler et al. (1985) but not divided into waking and sleeping time. The amount of time determined to be spent sleeping in the male/female time allocation was subtracted from Spengler's home time to produce home-awake and home-asleep values for employed/unemployed persons. The time activity patterns calculated from the literature are listed in Tables 12 and 13.

Respiration rates: Respiration rates were taken from Rosenblatt et al. (1982):

1) Adult male, light work—28.6 L/min (1.7 m^3/h)
2) Adult male, resting—7.43 L/min (0.4 m^3/h)
3) Adult female, light work—16.3 L/min (1.0 m^3/h)
4) Adult female, resting—4.5 L/min (0.3 m^3/h).

These figures assume 16 h of rest and 8 h of light work per day, and are in agreement with those from other sources (USEPA 1989).

An average of approximately eight hours per day is spent sleeping. This leaves eight waking hours per day spent at "light work" and eight hours spent "resting". Since no single activity period is likely to be all "light work" or all "resting", the two values were averaged to produce a respiration rate for "awake". These values are as follows:

Male, awake—1.05 m^3/h
Male, asleep—0.4 m^3/h
Female, awake—0.65 m^3/h
Female, asleep—0.3 m^3/h.

Retention efficiency: Retention efficiency for sidestream smoke particles has been reported by Hiller et al. (1982, 1987) to be 11%.

Results of dosimetric calculations

In any exposure situation, the retained dose may be calculated by the following equation:

Dose = Concentration × duration × respiration rate × % retention.

Concentration is the concentration of RSP measured in the various categories of exposure in Table 9.

Duration for that category is taken from the time/activity tables (Tables 12 and 13).

Respiration rates are calculated from Rosenblatt. The "home, asleep" category is given the resting respiration rate. All other categories are assigned the "awake" respiration rate.

Percent retention is 11% as calculated by Hiller.

Exposure to ETS can come in any number or combination of situations. To estimate the breadth of possible ETS exposures, doses of ETS have been calculated for four different scenarios:

1) Male and female—exposed at home, in restaurants, bars and other public places, but not at work or while traveling. This essentially calculates the ETS exposure one may expect during nonworking hours.

2) Male and female—exposed only at work and while traveling (assume all transportation by train). This will produce a conservative estimate of occupational exposures.

3) Worst case exposure, male and female—exposed at home and while traveling, works in a bar and is also exposed in other public places (assumes use of the average exposure values).

4) Employed vs. unemployed males—exposed in all facets of life, employed person works in office environment. Employed and unemployed females would be essentially the same but with different respiration rates.

The calculations for each are as follows:

1) Male and female—exposed at home, in restaurants, bars and other public places, but not at work or while traveling. Dose = (concentration; home × duration; awake x respiration rate; awake × retention) + (concentration; home × duration; asleep × respiration rate; asleep × retention) + (concentration; restaurant × duration x respiration rate x retention) + (concentration; bar × duration × respiration rate × retention) + (concentration; offices, × duration; other, public × respiration rate × retention).

Male Dose = $(27.2 \times 6.4 \times 1.05 \times 0.11) + (27.2 \times 7.5 \times 0.4 \times 0.11) + (41.8 \times 0.5 \times 1.05 \times 0.11) + (103.7 \times 0.8 \times 1.05 \times 0.11) + (21.8 \times 1.6 \times 1.05 \times 0.11)$

Male Dose = 45.11 μg/day, 16.46 mg/y

Female dose = $(27.2 \times 8.7 \times 0.65 \times 0.11) + (27.2 \times 7.8 \times 0.3 \times 0.11) + (41.8 \times 0.4 \times 0.65 \times 0.11) + (103.7 \times 0.9 \times 0.65 \times 0.11) + (21.8 \times 1.6 \times 0.65 \times 0.11)$

Female Dose = 34.28 μg/day, 12.51 mg/y

2) Male and female—exposed only at work and while traveling.

Male Dose = 17.19 μg/d, 6.27 mg/y

Female dose = 6.94 μg/d, 2.53 mg/y

3) Maximum exposure, male and female—exposed at home and while traveling, works in a bar and is also exposed in other public places.

Male Dose = 108.65 μg/d, 39.66 mg/y

Female Dose = 57.62 μg/d, 21.03 mg/y

Table 12. Total time allocations for male/female.

Location	Males		Females	
	Min/day	Hr/day	Min/day	Hr/day
1. Home, awake	386	6.4	521	8.7
2. Home, Asleep	452	7.5	470	7.8
3. Work	296	4.9	167	2.8
4. Travel	81	1.4	67	1.2
5. Restaurant	31	0.5	26	0.4
6. Bar	48	0.8	54	0.9
7. Other, public	94	1.6	95	1.6
8. Outdoor	52	0.9	40	0.7
TOTAL	1,440	24.0	1,440	24.1*

* Totals do not add up to 24 hours due to rounding.

Table 13. Total time allocations, employed, and unemployed persons.

Location	Employed		Unemployed	
	Min/day	Hr/day	Min/day	Hr/day
1. Home, Awake	427	7.1	733	12.2
2. Home, Asleep	511	8.5	499	8.3
3. Work	276	4.6	5	0.1
4. Travel, Public	81	1.4	37	0.7
5. Restaurant	17	0.3	20	0.3
6. Bar	33	0.6	36	0.6
7. Other, Public	61	1.0	68	1.1
8. Outdoor	34	0.6	42	0.7
TOTAL	1,440	24.1*	1,440	24.0

* Totals do not add up to 24 hours due to rounding.

4) Employed vs. unemployed males—exposed in all facets of lifestyle, employed person works in office environment.
Employed Male Dose = 60.06 µg/d, 21.92 mg/y
Unemployed Male Dose = 62.34 µg/d, 22.76 mg/y.

There are several chemical and exposure pattern differences between direct smoking and ETS exposure. However, expressing ETS exposure in cigarette equivalents is one way to develop a sense of the magnitude of exposure.

Arundel et al. (1988) has calculated a retained dose of particles of 10.56 mg/cigarette and 8.48/mg cigarette for male and female direct smokers, respectively. Using these figures, the dose in cigarette equivalents of particles for each of the four exposure scenarios becomes:

1) Exposed at home, in restaurants and in bars:
Male—1.56 cigarette equivalents per year
Female—1.48 cigarette equivalents per year.

2) Exposed at work and travel only:
Male—0.59 cigarette equivalents per year
Female — 0.30 cigarette equivalents per year.

3) Maximum, works in a bar, exposed in all facets of life:
Male—3.76 cigarette equivalents per year
Female—2.48 cigarette equivalents per year.

4) Employed vs. unemployed males:
Employed—2.08 cigarette equivalents per year
Unemployed—2.15 cigarette equivalents per year.

Clearly, such calculations of cigarette equivalents have little or no relevance to any assessment of the potential risk from exposure to ETS. The mainstream smoke particles inhaled during the act of puffing on a cigarette will be quite different from ETS particles in terms of their precise chemical composition, their size distribution and the route in which they are taken into the body. However, the calculation of cigarette equivalents does at least allow a subjective impression of the relative doses involved in active smoking compared to everyday exposure to ETS.

DISCUSSION

Indoor air and ETS review

Respirable particulate matter: Table 9 shows the mean RSPs in smoking and nonsmoking areas in real life conditions. The mean differences between nonsmoking and smoking conditions are 27.2 µg/m^3 for homes, 21.8 for offices and public facilities, 41.8 for restaurants, in excess of 48.3 for bars and taverns, and 30 for trains.

Carbon monoxide: Table 10 shows carbon monoxide concentrations (ppm) in smoking and nonsmoking areas in real life conditions. In offices, where the data allowed for a smoking/nonsmoking comparison, the mean difference was 0.28 µL/L (0.32 mg/m^3). Because of the magnitude of this difference compared to the mean levels measured and ranges reported, the significance of this difference must be questioned. There are essentially no data since 1982 on nonsmoking conditions in restaurants or bars. The slightly higher levels in these areas indicate that smoking may account for at least part of the CO.

There is little information on CO in homes. Yuill and Comeau (1989) report on home CO, but they do not indicate whether smoking was present.

The information on CO levels in transportation vehicles indicates little difference between smoking and nonsmoking areas on trains. Buses have higher levels (6.0 µL/L; 6.9 mg/m^3) of CO; but from the information presented it is impossible to determine if the concentration is affected by tobacco smoke or by vehicle exhausts. The higher level of CO (11.6 µL/L; 13.3 mg/m^3) in autos where no smoking took place indicates that the impact is from vehicle exhausts (Flachsbart et al. 1987).

Nicotine: Table 11 shows nicotine concentrations in smoking and nonsmoking areas. Nicotine, as expected, is considerably lower in concentration in nonsmoking compared to smoking areas. The means of 6.2, 5.7 and 3.7 µg/m^3 for offices and public buildings, restaurants and homes, respectively, where smoking occurred, are extremely low exposures compared to the levels of many other volatile and semivolatile substances found in indoor air. Smoking sections of trains are slightly higher and, as expected, bars and taverns exhibited the highest mean levels (19.1 µg/m^3).

Nitrogen dioxide: Most studies which measure nitrogen dioxide (NO_2) in the indoor environment evaluate the effect various appliances, such as gas stoves or kerosene heaters, have on NO_2 concentrations. Only three studies attempted to evaluate the impact of ETS on NO_2 levels in homes (Dumont 1986; Good et al. 1982; Hosein et al. 1985). Houses where smoking occurred had approximately 3.0 µg/m^3 higher nitrogen dioxide levels than houses with no smoking. There are no studies which evaluate the effect of ETS on NO_2 levels in offices, restaurants, bars, or transport vehicles.

Formaldehyde: There is a substantial amount of information regarding formaldehyde levels indoors. However, little of it evaluates the potential effect of ETS on formaldehyde levels. Of the literature reviewed, one study of 41 homes (Stock 1987) and one study of two office buildings (Hedge et al. 1990) compared formaldehyde levels to smoking status. The residential study found no increase in formaldehyde levels with increased levels of smoking. The office study found approximately a 10 nL/L (12.3 $\mu g/m^3$) increase in formaldehyde levels in a designated smoking area over a nonsmoking area of one building. However, there was no difference between the designated smoking area in one building and another nonsmoking building. Because of the limited number of samples and the number of confounding sources for formaldehyde these results must be interpreted with caution.

Benzene: Five studies contained benzene data in smoking and nonsmoking areas (see Table 6). In two of these studies, nonsmoking areas reportedly had higher concentrations of benzene. In three studies, nonsmoking areas had lower concentrations than smoking areas. The differences are minimal, especially when outdoor concentrations also are considered.

The assumption was made that in studies where smoking/nonsmoking was not reported by the author, that there was some smoking occurring. Where smoking is assumed to take place, the highest mean level recorded was 15.7 $\mu g/m^3$. However, in nonsmoking areas the highest mean was 60.7. In summary, there are few data to support a conclusion that smoking has a significant impact on benzene concentration in offices.

The data on benzene in homes suggest that smoking homes have a higher concentration than nonsmoking homes by approximately 3.5 $\mu g/m^3$. It is difficult to separate home-only data from personal exposure monitor data except for two studies where indoor air benzene ranges from 4.8-14.8 $\mu g/m^3$. The one overnight study in homes by Wallace et al. (1987) shows an increase of approximately 3.1 $\mu g/m^3$ in smoking homes vs. nonsmoking homes.

There are few data on benzene on public transportation. A paper by Proctor (1989) on 20 trains shows a slightly higher mean concentration of benzene in smoking versus nonsmoking areas. The mean differences are small.

Polyaromatic hydrocarbons (PAH's) and nitrosamines: PAH's are commonly found in indoor air. Except for naphthalene, quinoline, and isoquinoline, the levels measured are in the low ng/m^3 range (Table 8). Few studies have compared PAH levels in smoking and nonsmoking environments. The two studies in this review which have compared smoking/nonsmoking areas indicate that between 50% and 80% of the concentration of various PAHs may come from tobacco smoke. Because of the paucity of data, this must be interpreted with caution. The presence of these substances has also been documented in wood smoke, automotive exhaust, foods, alcoholic beverages, and cosmetics (NTP 1989).

Two studies have reported the presence of N-nitrosodiethylamine (NDEA) and N-nitrosodimethylamine (NDMA) in smoke-filled rooms (Table 7). These are not tobacco-specific nitrosamines. The lack of reported background levels and the unusually high level of smoking prevents the evaluation of ETS contribution to these substances. Other nitrosamines reported to be found in tobacco smoke have either not been monitored or not been reported in ambient air where ETS is present.

The U.S. Surgeon General (1986) and NRC (1986) reports include summary tables of known or suspect human carcinogens present in concentrated sidestream and mainstream tobacco smoke. Concentrated sidestream and mainstream tobacco smoke are not representative of ambient air ETS because the concentrated smoke is subject to dilution in ambient air, removal by sinks or filtration, and possible transformation (Reasor 1987).

Based on current literature, it appears that ETS has an effect on the levels of nicotine and respirable particles in an indoor environment. There also is a slight increase in NOx levels in the presence of ETS. ETS appears to have less effect on the levels of carbon monoxide, formaldehyde, or benzene.

Odor and irritation: Studies by Cain et al. (1987), Weber (1984), and Weber and Grandjean (1987) indicate that levels of ETS which produce carbon monoxide concentrations below 1.5-2.0 $\mu L/L$ (1.7-2.3 mg/m^3) also will be acceptable to 80% or more of the occupants in terms of irritation, odor, and overall quality. Where a moderate amount of smoking occurs, this level is unlikely to be approached. This conclusion is reflected in ASHRAE Standard 62-1989 (ASHRAE 1989), which does not separate smoking and no-smoking areas in terms of recommended ventilation rates.

It is possible that the 1.5-2.0 $\mu L/L$ (1.7-2.3 mg/m^3) level of carbon monoxide may be exceeded in some cases. This would occur either in heavy smoking situations, such as those found in bars or smoking lounges, or where inadequate ventilation occurs.

Dosimetric calculations

One can calculate the doses of RSP retained from ETS. This ranges from approximately 3 mg/y for a female exposed only at work to approximately 40 mg/y for a male exposed in all facets of his life. Occupational exposure is only a minor portion of total exposure in most cases. Exposures in one's private life may produce the largest retained dose of ETS particulates.

For exposures received while in transit, it was assumed that all transit time was spent in the smoking section of trains. Actual time allocation data (Jenkins et al. 1990) indicate that only 5% of travel time is spent on public transport. It is believed that when traveling by auto, nonsmokers will generally choose to travel with other nonsmokers. There are no data comparing particulate levels in autos where smoking occurs to levels were there is no smoking. However, carbon monoxide levels of 8.8-22.3 μL/L (10.1-25.6 mg/m^3) found by Flachsbart et al. (1987) suggest that exposures in automobiles come primarily from vehicle exhaust and not ETS. Thus, the choice of trains as a surrogate for ETS exposure while in transit is conservative.

The estimated mean RSP dose of exposure to the population of nonsmoking adults is based on the difference between smoking and nonsmoking environments. There is a possibility that a person could be exposed to the high end of the range of RSPs as reported in the literature. The likelihood is that the bulk of the RSPs in those situations would be from sources other than tobacco smoke.

Persons also may be exposed to the upper limits of ETS—derived RSP ranges. Generally, these are for short time intervals. The mean difference values for the various categories of exposure should reflect the overall minimum and maximum exposure such that the total dose for the year would be included.

Attempts to calculate increased risk or excess mortality from lung cancer (Repace 1985; NRC 1986) and heart disease (Wells 1988; Glantz and Parmley 1991) reportedly resulting from ETS exposure are not uncommon. These calculations, however, rely almost exclusively on epidemiologic studies that have no adequate measure of exposure or dose. Such studies are known to be subject to problems of bias (Lee 1987) and confounding factors (Koo et al. 1988) which have not been taken adequately into account.

One of the paradigms of toxicology is that the magnitude of the dose determines the response. Comparing the dose one may receive from ETS to the magnitude of claimed health effects provides one measure of the accuracy of those claims.

Other studies that have calculated ETS dosage (Arundel et al. 1988) have reported values similar to those calculated here. They also have found wide discrepancies between the level of risk calculated by the epidemiology studies and that which can be supported by dosimetric calculations. Wells (1991) and Repace and Lowrey (1991) have both attempted to address this discrepancy. Wells argues that the majority of the "tar" fraction of ETS may be in the vapor phase. He claims that this vapor phase would be retained 100%, producing the majority of the dose one would receive. Thus, he suggests that particles are not an accurate measure of ETS dose. However, the compounds he lists as candidates for vapor phase tar components are not convincing in terms of their potential human health effects. They also are substances that have only been measured in concentrated sidestream and mainstream smoke, not ambient ETS. Until levels of these compounds are actually shown to increase in the presence of ETS, his argument must be considered speculative.

Repace and Lowrey (1991) calculate a daily inhaled dose of ETS particles between 1.4 and 14 mg/d. Calculations based on literature values of ETS concentrations from this paper indicate an inhaled dose of between 0.1 and 0.06 mg/d. When one considers that only 11% of these particulates are retained, the actual dose becomes 0.01 to 0.006 mg/d or 1/140 to 1/233 of the dose claimed by Repace and Lowrey.

Until the problems of confounding and bias in the epidemiology studies are resolved, dosimetric considerations can be the only independent confirmation of the accuracy of their claims. At this point, it can only be concluded that the estimated dose of ETS one can be expected to receive does not support the health risk claims being made by USEPA (1990) and others.

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DISTRIBUTION OF HYDROGEN SULFIDE IN JIDDAH ATMOSPHERE

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A comprehensive field study of atmospheric hydrogen sulfide concentrations was conducted in Jiddah, Saudi Arabia for the period 1984 through 1987. Hydrogen sulfide trends were developed for five stations in Jiddah. Daily, monthly and annual means, maximum and mean maximum are reported. The average H_2S concentration for 1984, 1985, 1986, and 1987 was 0.071 µL/L, 0.063 µL/L, 0.039 µL/L, and 0.042 µL/L, respectively. A decrease in H_2S concentration from 1984 to 1987 was observed. The four-years average H_2S concentration was 0.054 µL/L and a maximum of 0.460 µL/L was recorded once at Station 104 in 1984. The statistical significance of data and background information for air quality standards for the city are discussed. Analysis of data shows lower mean than any international air quality standard.

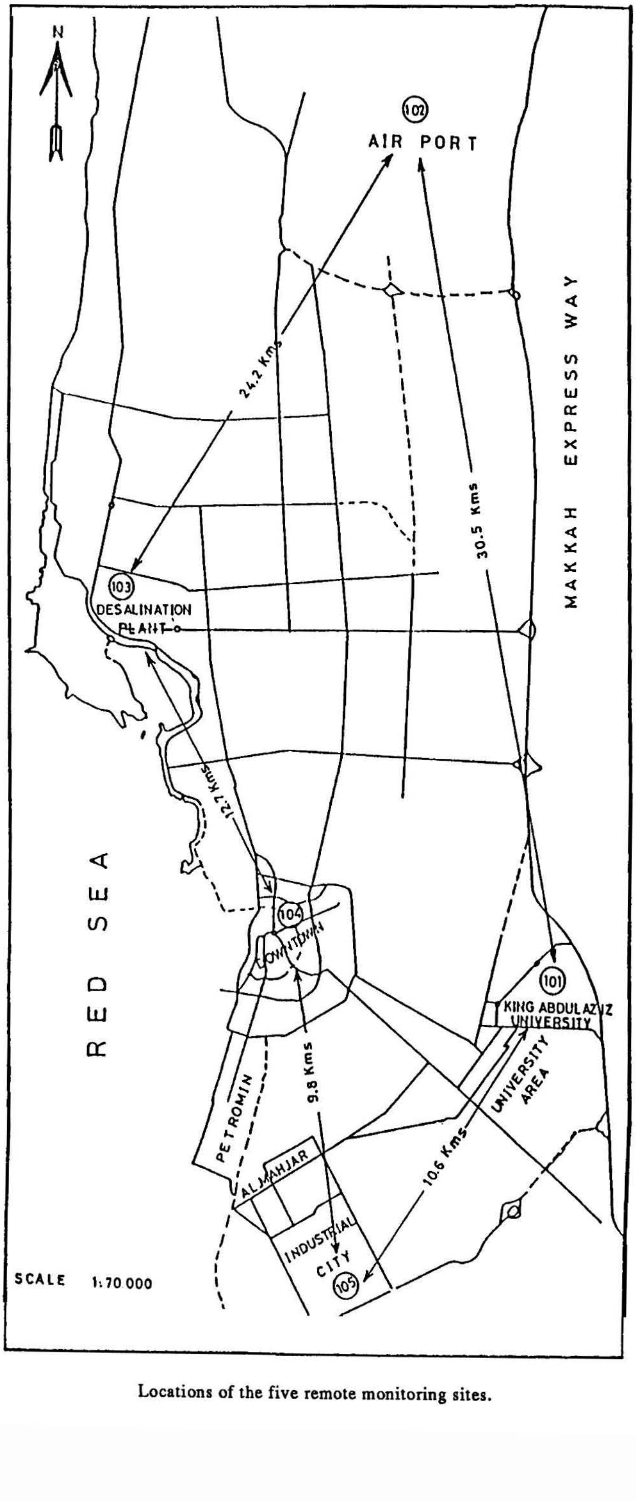
INTRODUCTION

Hydrogen sulfide is considered one of the hazardous gases emitted to the atmosphere (Stern 1977). This gas originates from the continental surfaces (soil), water marshes and the costal zones (Jaeschke et al. 1978; Jaeschke et al. 1980; Hansen et al. 1978). Hydrogen sulfide (H_2S) released into the atmosphere is oxidized and the main oxidizing agents are probably OH-free radicals (Cox and Sandalls 1974). The intensity of sunlight, particulate matter and, trace gases in the atmosphere control the concentration of OH-free radicals to a great extent. Therefore, a decrease in the H_2S concentration causes an increase in SO_2 concentration.

The objective of this research is to collect enough data on the concentration of hydrogen sulfide in Jiddah and to analyze it statistically to estimate the air quality trends, and to supply background information for air quality standards for the city. To achieve this objective, five stations were established in Jiddah (Sabbak 1990) to help in finding the most polluted areas in the city. Analysis of the collected data gives an indication on the general trend of pollution in the city which might provide information on the following topics:

(1) control the direction of city growth and expansion,
(2) strategies for reducing pollution in urban areas,
(3) advise public on potential health hazards, and
(4) redesigning of traffic routes.

McKee (1980) discussed in depth the dependence of pollutants (oxidants in his case) on locality. He indicated that the effect of oxidants varies from one area to another. These variations should be considered in evaluating problems and developing a control program.



Locations of the five remote monitoring sites.

PROJECT DESIGN AND EXPERIMENTATION

Project design and experimentation procedures were identical to those discussed in a previous publication (Sabbak 1990).

The ambient air quality data base used in this investigation was obtained from monitoring instruments that operate continuously producing a measurement every hour for a possible total of 8760 hourly measurements in a year per station. A valid annual mean requires at least 5856 (8 months) hourly observations to be included in the statistical analysis (CEQ 1979). In order to supply background information for the air quality standard for the city of Jiddah, it was necessary to determine the maximum H_2S concentrations, meaning the highest possible concentration that could be reached at a certain time. The mean of the maxima of each year was calculated and used to estimate the number of daily and annual exceedings. In order to perform a city trend analysis, all sites were given equal weight.

An intensive field study of atmospheric H_2S was conducted since January 1984 (see map). The diurnal, monthly, and annual profiles of H_2S will be discussed below.

A Monitor Lab. Hydrogen Sulphide Model 8450 based on the principle of a flame photometric detector (FPD) was used for the detection of hydrogen sulfide. It uses chemiluminescence of activated molecular sulfur species produced by a hydrogen hyperventilated air diffusion flame. Air containing the sulfur molecules enters through the burner which also holds the flame. This flame is also surrounded by hydrogen which is enclosed by the flame chamber due to one wall of that chamber being a clear optical window. A photomultiplier measures the chemiluminescence emission energy intensity level through this window and converts it into electrical signals with the precision of ±1% of the full scale minimum detectable concentration of 4 nL/L.

This analyzer model (8450) uses a SO_x (sulfur oxides) scrubber in the sample line before the air sample enters the analyzer to eliminate all sulfur compounds other than hydrogen sulfide.

To calibrate the H_2S analyzer, a permeation tube is used. It permeates H_2S gas at the rate of 100 nL/L using a special calibrator supplied by Monitor Lab. (Model No. 8500) in the system.

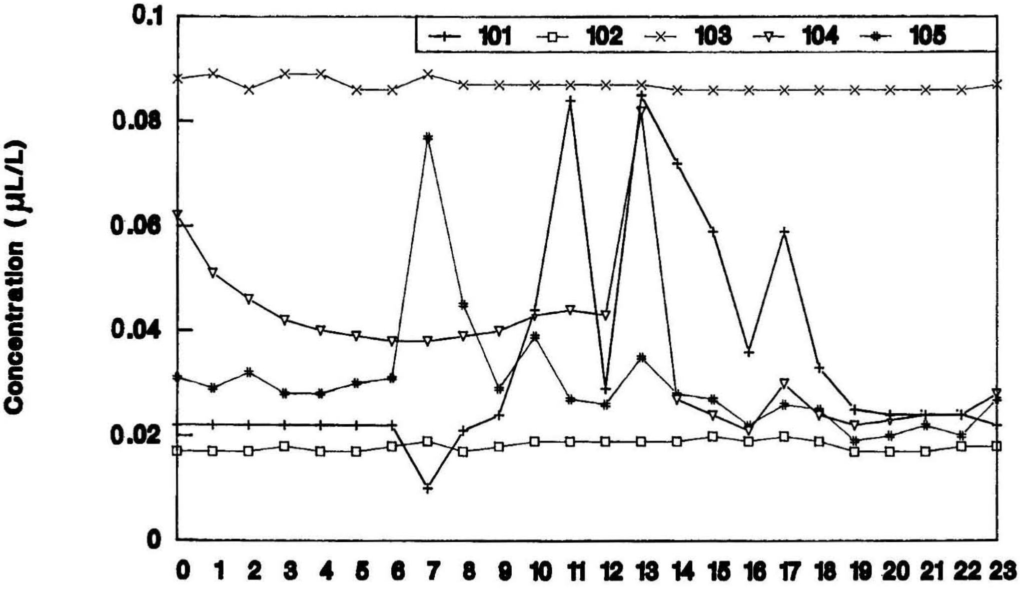


Fig. 1. Hourly average hydrogen sulfide concentrations on July 22, 1987.

RESULTS AND DISCUSSION

Figure 1 shows the hourly average H_2S concentrations for each station on July 22, 1987. Other days for the studied period (1984-87) follow similar trends. Station 102 (airport area) shows the lowest concentration on that day (0.018 µL/L), while station 103 (desalination plant area) shows the highest (0.086 µL/L). Hydrogen sulfide concentrations at Station 101 (university area), 104 (downtown area) and 105 (industrial city area) show relatively same daily mean (0.040, 0.041, and 0.036 µL/L, respectively). The concentration of pollutants is normally a function of wind speed and direction. The prevailing wind on July 22, 1987 was WSW at Station 101, NNW at Station 102, W to WSW at Station 103, NW to NNW at Station 104, and N to NNW at Station 105. Since two water treatment plants and the fish market are spread out on the coastal area (NNW to Stations 104 and 105 and SSW to Station 103), it is possible that the high level of concentration was a result of advection from the Red Sea coastal zone. The university water treatment plant is located just WSW to the university campus and the high concentration of H_2S recorded at Station 101 could be attributed to its existence in that neighborhood. The lowest wind speed on July 22, among all five locations, was at Station 103 (7.6 mph or 12.2 km/h) and the highest at Station 105 (10.3 mph or 16.5 km/h).

Monthly profile

The mean concentration values for all five stations established for a specific month were averaged to get the city monthly means. The maximum concentration recorded at any station per specified month was considered to be the city monthly maximum concentration.

Figure 2 shows the four-year monthly mean H_2S concentrations. The monthly mean concentration values of H_2S during the year 1984 were the highest, especially during the summer period; high temperature and wind speed and direction are responsible for such high concentration. The 1985 monthly mean is lower than that of 1984; and both 1986 and 1987 are lower than 1985.

The monthly maximum concentration of H_2S follows the same trend mentioned above for the monthly mean (Fig. 3). The highest monthly mean and maximum concentrations were recorded during the months of July (0.147 µL/L) and September (0.416 µL/L) 1984, respectively. It is worthwhile to mention here that usually wherever the daily maximum appears, it does not last for more than one hour or, at worst, starts to decline after two hours.

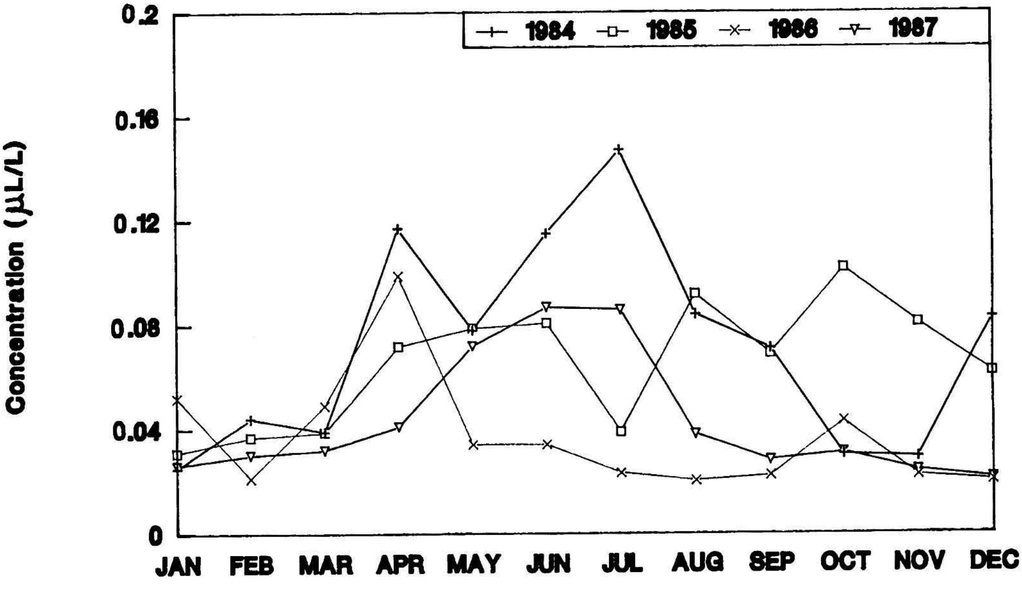


Fig. 2. Monthly mean hydrogen sulfide concentrations 1984-1987.

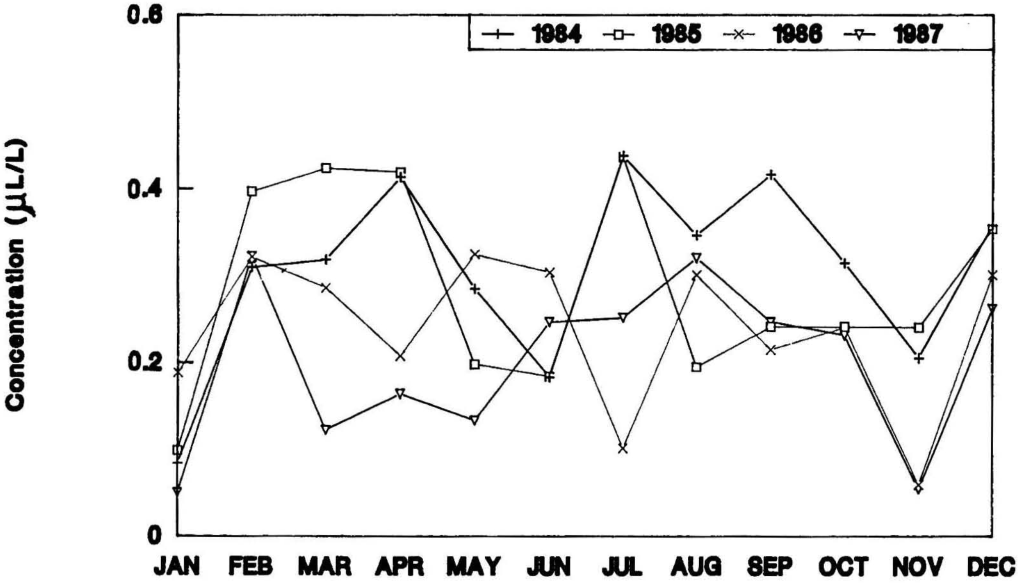


Fig. 3. Monthly maximum hydrogen sulfide concentrations 1984-1987.

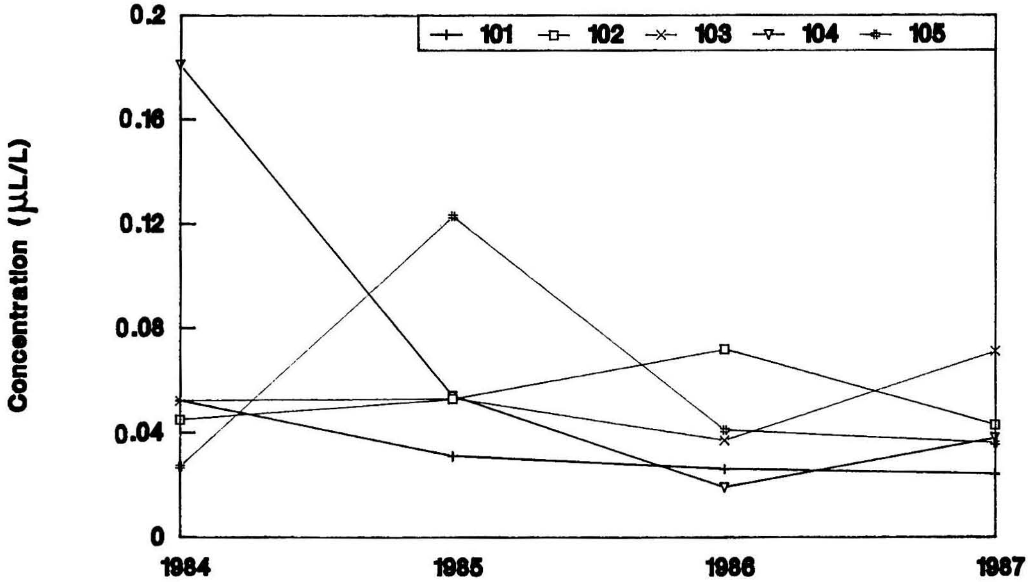


Fig. 4. Annual mean hydrogen sulfide concentrations 1984-1987.

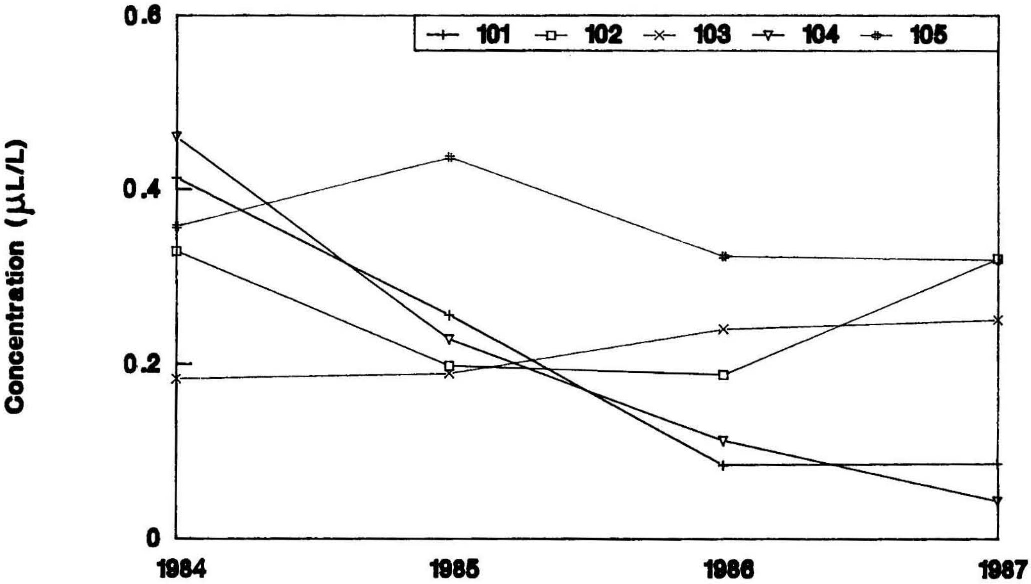


Fig. 5. Annual maximum hydrogen sulfide concentrations 1984-1987.

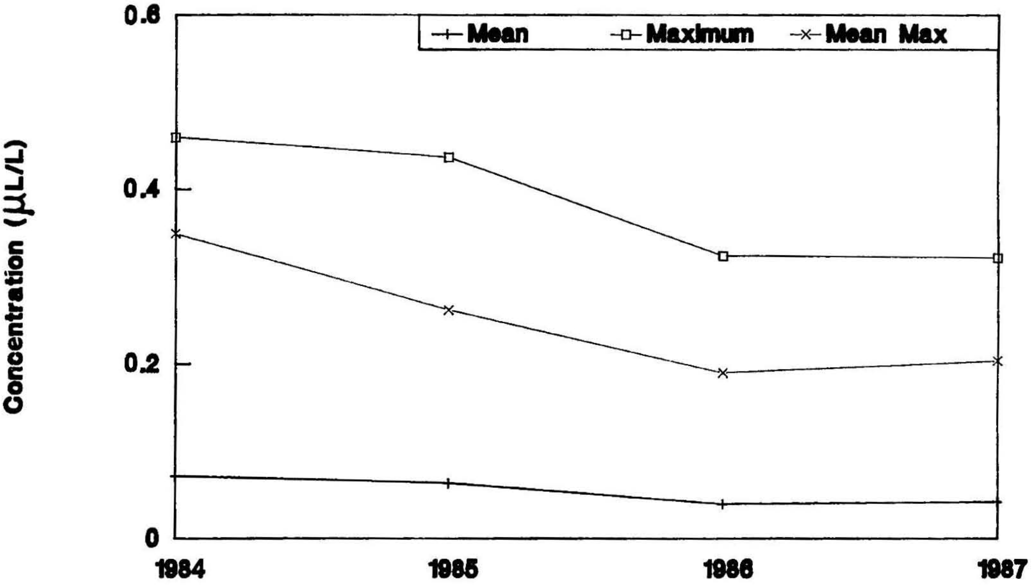


Fig. 6. Annual mean, maximum, and mean maximum hydrogen sulfide concentrations 1984-1987.

Annual profile

The annual mean of the H_2S concentration for each station was calculated for the specified year utilizing the monthly means of that year. The annual mean concentration values for all five stations were averaged to get the city annual mean (Fig. 4). The daily maximum H_2S concentration recorded at any station per specified year was considered to be the city annual maximum concentration (Fig. 5). The annual maximum H_2S concentration values for all five stations were averaged to get the city annual mean maximum concentration. The annual mean, mean maximum, and maximum H_2S concentration values were plotted together in the same graph for comparison (Fig. 6).

STATISTICAL DISCUSSION

Table I shows the frequency distribution of the hourly mean H_2S concentrations in all five stations in the Jiddah area for the year 1987. It is clear from the table that about 67.5% of the data falls in the range between 0.000 to 0.029 µL/L. The next highest frequency of 25.4% was for the range between 0.030 to 0.049 µL/L and the rest of the considered ranges, 0.050 - 0.499 µL/L, form only 7.1% of the frequency. This suggests that the most probable range is 0.010 to 0.049 µL/L.

Each site was examined for trend using the SuperCalc-5 Data Analysis technique utilizing the hourly mean values. Calculations of the arithmetic mean, standard deviation, concentration range, and % confidence level (Table 2) for all stations (101-105) and all years (1984-1987) were carried out. The sites mean values show a downward trend (concentration slightly decreased) for four stations (101, 102, 104, and 105) and a slightly upward trend for one station (103).

The calculated confidence level ranged from 80% to 99.9%. These results are in agreement with the diurnal profile.

Table 1. Frequency distribution of hourly mean H_2S concentrations in all five stations in the Jiddah area for the year 1987.

Sta-tion	Concentration Ranges (µL/L)														Total Number/ Percentages
	0.000 0.009	0.010 0.019	0.020 0.029	0.030 0.039	0.040 0.049	0.050 0.059	0.060 0.069	0.070 0.079	0.080 0.089	0.090 0.099	0.100 0.199	0.200 0.299	0.300 0.399	0.400 0.499	
101	0	1554	2489	428	231	125	78	64	42	27	14	0	0	0	5052
	0	30.8	49.3	8.5	4.6	2.5	1.5	1.3	0.8	0.5	0.3	0	0	0	100
102	273	2897	1637	385	32	26	0	0	0	0	330	0	0	0	5580
	4.9	51.9	29.3	6.9	0.6	0.5	0	0	0	0	5.9	0	0	0	100
103	0	291	1837	2018	916	121	42	58	116	0	0	411	0	0	5810
	0	5.0	31.6	34.7	15.8	2.1	0.7	1.0	2.0	0	0	7.1	0	0	100
104	163	387	2157	1930	628	105	83	71	68	89	25	6	3	0	5715
	2.9	6.8	37.7	33.8	11.0	1.8	1.5	1.2	1.2	1.6	0.4	0.1	0	0	100
105	322	3021	1872	477	193	97	14	3	0	0	0	0	0	0	5999
	5.4	50.4	31.2	8.0	3.2	1.6	0.2	~0	0	0	0	0	0	0	100
Av. %	2.6	29.0	35.9	18.4	7.0	1.7	0.8	0.7	0.8	0.4	1.3	1.4	0	0	100

*Number of hourly concentrations ** Percentages

Table 2. Hourly H_2S concentrations (μL/L) in the Jiddah area.

Station		Year			
		1984	1985	1986	1987
101	Mean	0.039	0.031	0.026	0.024
	STD	0.023	0.017	0.010	0.005
	C.R.	0.001-0.077	0.003-0.059	0.000-0.052	0.008-0.040
	%C.L	90	90	99	99.9
102	Mean	0.037	0.036	0.024	0.022
	STD	0.016	0.019	0.013	0.007
	C.R.	0.011-0.063	0.005-0.067	0.003-0.045	0.002-0.042
	%C.L	90	90	90	99.5
103	Mean	0.038	0.030	0.037	0.044
	STD	0.020	0.015	0.017	0.022
	C.R.	0.005-0.071	0.000-0.059	0.004-0.070	0.000-0.087
	%C.L	90	95	95	95
104	Mean	0.045	0.042	0.019	0.018
	STD	0.021	0.023	0.013	0.007
	C.R.	0.00-0.186	0.004-0.080	0.002-0.036	0.000-0.036
	%C.L	95	90	80	99
105	Mean	0.052	0.050	0.041	0.036
	STD	0.015	0.029	0.019	0.003
	C.R.	0.003-0.101	0.002-0.098	0.004-0.078	0.026-0.046
	%C.L	99.9	90	95	99.9

C.R. = concentration range (μL/L)
% C.L. = % Confidence level.

The hourly mean of all stations was averaged and city hourly means were calculated. These hourly means were used as an input for the overall linear regression to predict the overall trend for the city. The result of the overall linear regression shows a downward trend (reduction of H_2S concentration) which is in accordance with the above discussion (monthly and annual profile).

The daily, monthly, and annual hydrogen sulfide concentrations for the last four years show, in general, a gradual reduction in concentrations (annual mean of 0.071, 0.063, 0.039, 0.042 μL/L for the years 1984, 85, 86, and 87, respectively). The four years (1984-87) average hydrogen sulfide concentration of 0.054 μL/L is lower than some international standards (0.14 μL/L for the USA) (USEPA 1971; Gravitz 1985; Suggs 1983). The last two years (1986 and 1987) mean and maximum values show lower concentration levels, probably because the activities causing the increase of H_2S concentration were reduced.

Acknowledgment — The author is indebted to the King Abdulaziz University for supporting this project. He is grateful to Prof. Halit Goknil for helpful discussions. His thanks are also due to Mr. Mohammed Younas and Mr. Mumtaz Alam for their technical assistance during the course of this project.

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MONITORING OF WATER QUALITY IN UPPER MUKUVISI RIVER IN HARARE, ZIMBABWE

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The impact of discharges from a fertilizer plant on the quality of the upper Mukuvisi River water was studied between the months of January 1989 and September 1990. Samples were collected at a point upstream from the effluent canal from the fertilizer plant, immediately downstream from the fertilizer plant and about 3 km downstream of the fertilizer plant. The water quality parameters which were monitored were temperature, pH, suspended solids, dissolved solids, conductivity, biological oxygen demand, dissolved oxygen, nitrates, phosphates, chlorides, potassium, calcium, Cu(II), Zn(II), Pb(II), Co(III), Ni(II), Cr(III), and Cr(VI). Pollution of the river waters by the fertilizer plant is evidenced by an increase in the levels of DS, NO_3^-, P-PO_4^{3-}, Cl^-, K, Ca, Cu, Fe, Zn, Pb, Co, and Cr, a drop in pH, and an increase in conductivity as the river transcended past the plant.

INTRODUCTION

Pollution of surface and underground water systems is one of the major environmental problems faced worldwide. Numerous studies, especially in developed countries, have been carried out (Baschom 1982; Canter 1979; Pardue et al. 1988). There are many reported cases of pollution of surface waters by discharges from human activities. In the United Kingdom, Woodward (1984) reported depletion of oxygen around Trent Falls in the Humber Estuary which receives industrial and sewage discharges. In Florida, Thomas et al. (1984) noticed an increase in algal blooms and heavy aquatic growth due to high concentrations of nutrients in water pumped from agricultural lands into the upper St. Johns River. In Greece, Samanidou et al. (1989) reported increases in levels of NO_3^- and NH_4^+ near agricultural areas and sewage discharge points in the Thermaikos Gulf. In Greece and also in Russia, increases in the levels of plant growth nutrients, PO_4^{3-}, NO_3^- and K^+, in the areas around the waste ejection points of fertilizer plants have been reported (Ouzounis et al. 1989; Gladushko 1979). It is therefore important to monitor the quality of the river waters that pass through potential pollution sources so as to avoid water pollution problems in the future. In Africa, limited work has been carried out on pollution of river waters (Marshall and Falcona 1973; Greichus et al. 1978; Jonnalagadda et al. 1990, 1991).

This paper presents the results of studies on the influence of fertilizer plant discharges on the quality of the receiving Mukuvisi River waters.

Mukuvisi River is one of the three major rivers supplying Lake Chivero, the main water source of the city of Harare. Lake Chivero is a large dam covering an area of 2500 ha, with a water holding capacity of about 247 M m^3. It is supplied by three major rivers, Marimba, Manyame, and Mukuvisi, which form the main drainage system of the City of Harare. The city covers an area of about 559 km^2 and is situated at a height of 1492 m above sea level. The average annual rainfall is 800 mm and the temperatures range from about 6°C in winter to 29°C in summer. The usual rainy months are November to April and the dry months are May to October.

The Mukuvisi River flows through both industrial and residential areas of Harare receiving waste discharges at various points and is suspected to be highly polluted (Fig.1). In its upper reaches, it receives effluents from a phosphate fertilizer manufacturing plant which uses phosphate rock, sulphur, iron pyrites, lime, and bauxite as its major raw materials. These raw materials are contaminated with a variety of heavy metals. The major products from the fertilizer plant are superphosphates, sulphuric acid and alum. The major wastes include among other things gypsum (80 Gg/y), pyrites cinder (50 Gg/y), alum sludge, and fluoride-rich scrubbing alcohol. The semisolid wastes are disposed into slime dams and dumps. Effluent arises mostly as leachwater from these dump sites.

After the fertilizer plant, the river passes through the residential areas of Braeside, Mbare, Waterfalls, Highfields, and Glenora. At various points along the river, poor people whithout any easy access to piped clean water can be seen using the untreated river water for washing, irrigation of vegetable gardens, and even drinking purposes.

The aim of this study was to evaluate the impact of the fertilizer plant discharges on the quality of the receiving upper Mukuvisi River waters.

METHODOLOGY

Levels of various water quality parameters were measured at four sampling sites. The Mutare Road Bridge about 1 km upstream from the fertilizer plant served as a reference point (Point 1). Just after the suspect fertilizer plant was Point 2 and at the Mutare Rail Bridge about 3 km downstream from the plant was Point 3 (Fig. 1). The other sampling point was a canal which carries discharges from an underground water collecting station between the fertilizer plant and the river (Point 4).

Water sampling was carried out periodically between January 1989 and September 1990. During the months of January to March 1989 and January to March 1990, samples were collected on a weekly basis. During the months of August and September 1989 and 1990, samples were collected biweekly. Intensive sampling on a daily basis was done from the 11th to the 16th of March 1990.

Water samples were collected just below the water surface using 2-L polythene bottles which were previously soaked in 10% nitric acid and thoroughly rinsed with de-ionised distilled water. At each sampling point, three samples were collected within a distance of 10 m. All samples were tightly sealed and immediately taken to the laboratory for analysis. The samples for heavy metal analyses were filtered immediately using 0.45-µm filter paper mounted on a pyrex filter holder with the filtrates acidified to pH 2 with A.R.-grade nitric acid in order to keep the metals in solution. The samples were stored in the dark at room temperature. The water temperature was recorded on site. The pH and dissolved oxygen were measured on site often. The rest of the parameters were analysed in the laboratory.

The various parameters were determined using standard procedures (APHA 1975; APHA 1980). The pH was determined using a GRIFFIN Model 80 pH meter and an Orion combination pH electrode. Suspended solids (SS) and dissolved solids (DS) were separated by filtering the water through 0.45-µm filter paper and both determined according to standard procedures (APHA 1975). Conductivities were measured at 25°C directly in S using a WPA CMD 400 digital conductivity meter. K^+ and Ca^{2+} were measured using flame atomic emission spectroscopy (FAES) and flame atomic absorption spectroscopy (FAAS), respectively (Dean and Rains 1975). Dissolved oxygen (DO) was measured using the Winkler Method (APHA 1980). Biological oxygen demand (BOD) levels were measured by incubating the water samples for five days in tightly stoppered bottles in the dark and determining the oxygen consumed in the five days (APHA 1980). Chloride was measured volumetrically by the Mohr Method. 100-mL portions of the water samples were titrated with a standard solution of silver nitrate at pH 8 in the presence of a 0.005 mol potassium chromate indicator. An indicator blank titration was run to correct for the end point error. Nitrate was measured colorimetrically by measuring the intensity of the yellow colour developed by the reaction of Brucine with nitrates (Jenkins and Medsker 1964). Inorganic phosphates ($P\text{-}PO_4^{3-}$) were measured colorimetrically using the phosphomolybdenum method after conversion to orthophosphates by digestion with persulphate (APHA 1975). Analytical grade sodium nitrate and potassium dihydrogen phosphate were used to prepare standard solutions for nitrate and phosphate

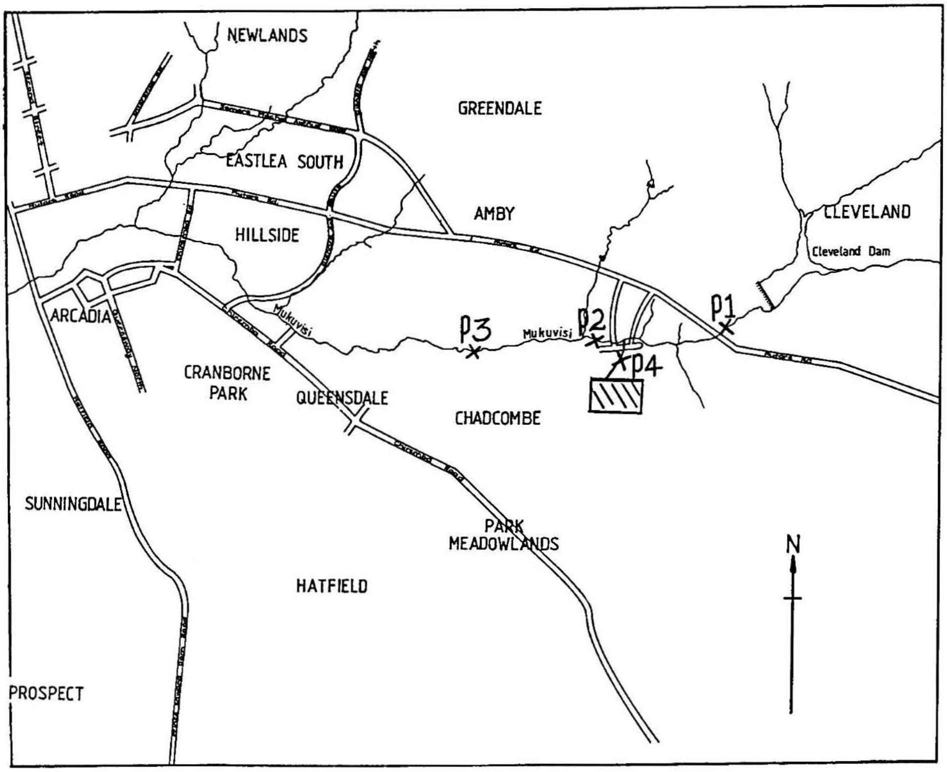

Fig. 1. Map of eastern Harare showing Sampling Points 1, 2, 3, and 4 indicated as P1, P2, P3, and P4.

Table 1. Levels of the various parameters for samples collected in August and September, 1989 (mean values for four samplings).

PARAMETERS	POINT 1	POINT 2	POINT 3	EFFLUENT
Temp.(oC)	19.0± 3.6	18.8± 0.5	15.5± 0.6	21.5± 4.7
DS (mg/L)	64 ±23	887 ±519	284 ±123	1890 ±560
Cond.(µS/cm)	190 ±72	1550 ±135	325 ±110	2140 ±970
pH	6.9± 0.3	3.9± 0.4	7.2± 0.2	3.7± 0.2
NO_3^- (mg/L)	4.0± 1.3	42.0± 23.1	13.5± 11.7	17.5± 12.7
PO_4^{3-}(mg/L)	4.3± 2.1	11.0± 3.9	9.3± 1.4	11.7± 12.1
Cl^- (mg/L)	18.9± 9.0	41.7± 17.9	19.4± 10.6	5.9± 1.0
K^+ (mg/L)	14.7±11.8	36.9± 8.1	11.6± 10.2	46.3± 9.6
Ca^{2+} (mg/L)	59.7±15.8	122 ± 16	111 ± 39	154 ± 40

Table 2. Levels of the various parameters for samples collected between January and March, 1990 (mean values for 12 samplings).

PARAMETERS	POINT 1	POINT 2	POINT 3	EFFLUENT
Temp.(oC)	22.0± 1.2	23.2± 1.4	21.0± 0.7	26.2± 3.5
DS (mg/L)	154 ±18	420 ±251	263 ±68	1794 ±359
Cond.(µS/cm)	147 ±72.2	546 ±161	345 ±74	2450 ±757
pH	7.1± 0.2	5.2± 1.0	7.8± 0.2	3.3± 0.5
NO_3^- (mg/L)	1.6± 1.3	12.1± 6.9	1.7± 0.9	35.1± 14.7
PO_4^{3-}(mg/L)	0.9± 0.9	6.6± 5.9	1.6± 1.8	80.3± 33.2
Cl^- (mg/L)	12.6± 4.8	17.0± 8.5	28.8± 5.5	44.5± 10.1
K^+ (mg/L)	6.5± 5.1	10.4± 7.1	6.2± 2.9	15.9± 7.5
Ca^{2+} (mg/L)	2.4± 1.3	18.9± 4.9	36.4± 4.3	62.1± 15.8
DO (mg/L)	3.6± 1.2	4.9± 1.4	4.4± 1.7	4.0± 1.7
SS (mg/L)	25.0±16.5	27.0± 11.4	19.3±12.7	57.0± 59.7
BOD (mg/L)	2.1± 1.2	2.1± 1.1	2.1± 1.8	1.5± 1.1

Table 3. Concentrations of heavy metals in the water phase for samples collected on 30 September 1990 measured in mg/L and the pH values at each sampling point.

PARAMETERS	POINT 1	POINT 2	POINT 3
pH	7.43	5.65	6.46
Pb	0.020	3.67	0.528
Cr(III)	0.056	0.200	0.260
Cr(VI)	0.007	0.008	ND
Cu	0.0475	0.062	0.045
Zn	0.0623	0.768	0.635
Ni	0.0337	0.046	0.0725
Co	0.0305	0.183	0.175
Fe	0.0405	0.140	0.538

N.D. = NOT DETECTED

Table 4. Average levels of exchangeable heavy metal cations in the sediment phase for samples collected between July and September 1990 measured in mg/L (mean of three samplings).

PARAMETERS	POINT 1	POINT 2	POINT 3	EFFLUENT
Pb	0.38 ± 0.13	1.11 ± 0.93	0.40 ± 0.22	2.73
Cr	3.42 ± 1.78	8.57 ± 4.74	5.87 ± 3.81	13.89
Cu	0.18 ± 0.12	1.78 ± 1.92	0.89 ± 0.63	1.54
Zn	0.94 ± 0.87	2.85 ± 1.13	2.79 ± 1.74	1.54
Ni	1.96 ± 1.44	2.93 ± 2.17	3.16 ± 3.66	0.52
Co	2.72 ± 1.67	6.22 ± 4.17	3.86 ± 2.74	6.03
Fe	130 ±24	218 ±11.8	212 ±18	186

Table 5. Sample calculation of Water Quality Index values using quality parameters for Point 2 measured on March 2, 1990.

Variable	Quantity found	I_i	W_i	$I_i^{W_i}$
DO (mgL-1)	5.95	66	0.17	2.04
Faecal coliforms (No. per mL)	10.0	90	0.15	1.96
pH	6.14	25	0.12	1.47
BOD (mgL-1)	3.6	90	0.10	1.56
NO_3^- (mgL-1)	17.0	20	0.10	1.35
PO_4^{3-}(mgL-1)	0.5	20	0.10	1.35
Temperature (°C)	1.0	98	0.10	1.58
Suspended solids(mgL-1)	14.5	90	0.08	1.43
Total solids (mgL-1)	332.0	60	0.08	1.39
WQI				52.82

Table 6. Water Quality Index values for various samples collected between January 1989 and September 1990.

Date	Water Quality Index, WQI		
	POINT 1	POINT 2	POINT 3
14 Mar. 1989	73.4	60.4	75.9
15 Aug. 1989	75.3	44.4	82.8
29 Aug. 1989	63.1	44.4	58.6
30 Aug. 1989	77.0	29.4	54.4
04 Jan. 1990	54.6	38.2	62.2
29 Jan. 1990	71.7	55.0	72.3
05 Feb. 1990	74.0	55.5	75.2
19 Feb. 1990	90.4	54.2	54.7
11 Mar. 1990	59.5	52.8	67.7
19 Mar. 1990	52.4	40.6	47.9

determinations, respectively. Both standards and unknowns were treated exactly the same way and processed at the same time.

The trace heavy metals were extracted from the water using n-amylmethylketone (n-AMK) after chelation with ammonium pyrrolidine dithiocarbamate (ADPC) (Tisue et al. 1985). The organic layer was aspirated into the atomic absorption spectrophotometer without further concentration. Cr(III) was determined after coprecipitation with Fe(III) followed by acid digestion to redissolve (Tisue et al. 1985). Quantitation was done using the Standard Curve Technique. Blank determinations on the materials used in the analysis were carried out for all the determinations.

Sediment samples were collected immediately below the water surface from the same sampling points as the water samples using a polythene scoop into polythene bags previously soaked in dilute nitric acid and rinsed thoroughly with deionized water. Once back in the laboratory, the sediments were centrifuged at 5000 rpm for 30 min to remove excess water and stored under refrigeration. For analysis the sediment was thawed, air-dried, and sieved through an 80-mesh sieve. Exchangeable cations in the sediment were determined by FAAS after extraction with 1-mol acetic acid, evaporation of the acetic acid, and dissolution of the residue in hydrochloric acid (Xing-Chu and Zhu Ying-quan 1985). Quantitation was done by the Standard Curve Method.

RESULTS AND DISCUSSION

The results for the various parameters are summarized in Tables 1 to 4 and in Figs. 2 to 12. Figures 2 to 12 show the results for individual samplings from 1989 to 1990 graphically. A typical calculation of collective Water Quality Indices is shown in Table 5 and a summary of some WQI values is shown in Table 6.

A close examination of the averaged values for the dry months in 1989 and the rainy months in 1990 (Tables 1 and 2) shows that virtually the levels of all the parameters, except DO and BOD, increased moving from Point 1 to Point 2, indicating that the pollution source is between the two points. The high levels of these parameters in the effluents from the fertilizer plant confirm that the plant is a major source of emission into the upper Mukuvisi River water. In the rainy months of 1990, for instance, the pH dropped from an average of 7.1 at Point 1 to 5.2 at Point 2. This fall in pH was likely due to the acidic effluent (pH ~3.3) in the drainage canal from the

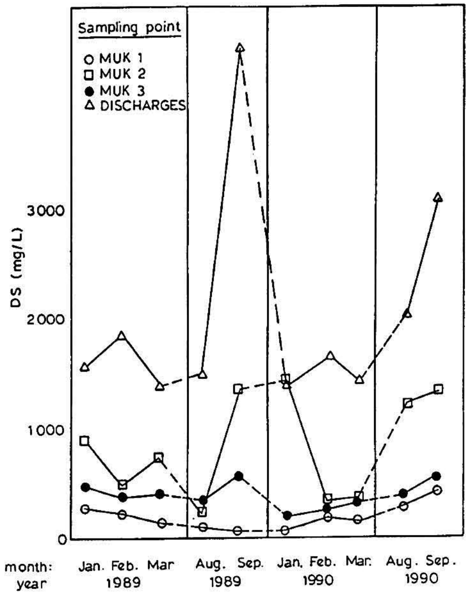

Fig. 2. Dissolved solids concentration levels.

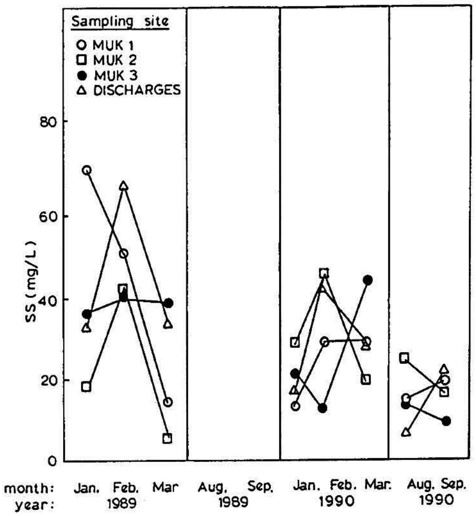

Fig. 3. Suspended solids concentration levels.

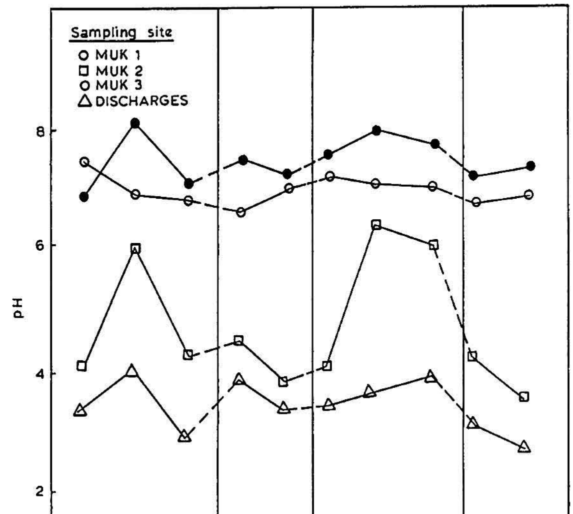

Fig. 4. The pH profiles at the various sampling sites.

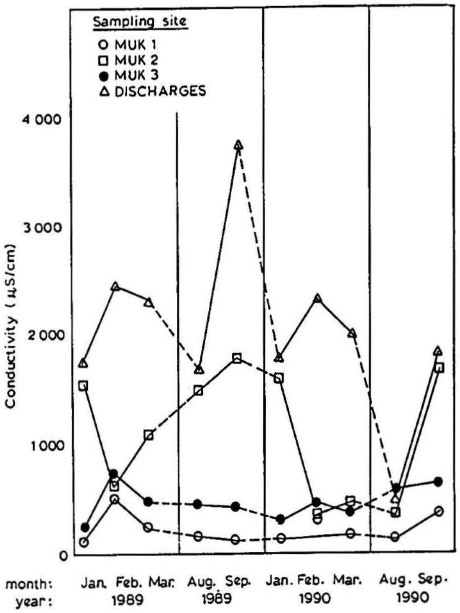

Fig. 5. Conductivity measured in micro Siemens.

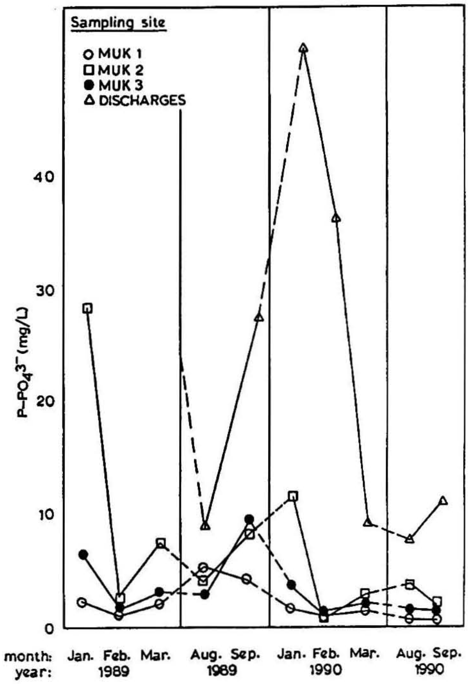

Fig. 6. Phosphate concentration levels.

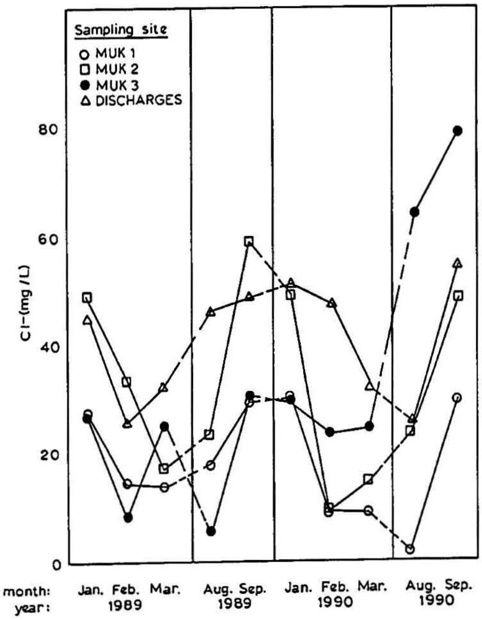

Fig. 7. Chloride concentration levels.

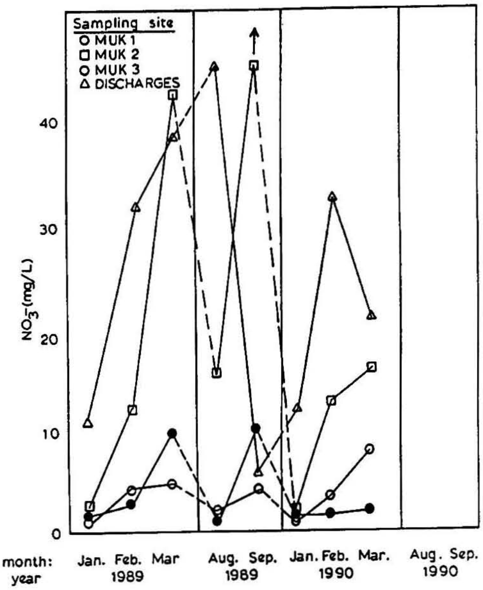

Fig. 8. Nitrate concentration levels.

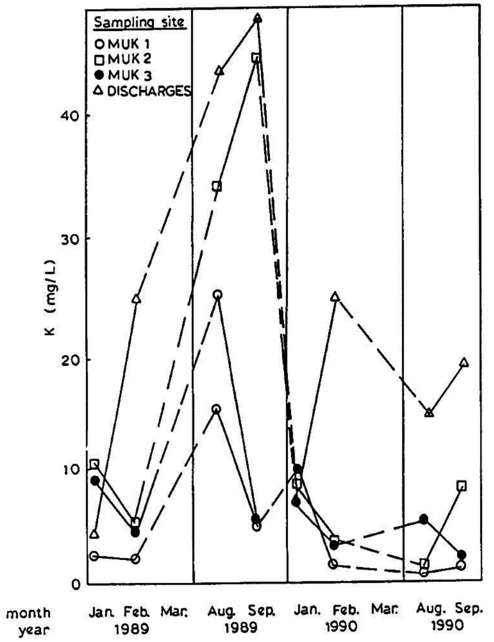

Fig. 9. Potassium concentration levels.

fertilizer plant. Levels of DS, NO_3^-, PO_4^{3-}, and Ca^{2+} increased by factors of 3, 7, 7, and 8, respectively, moving from Point 1 to Point 2. Increases in the levels of K^+ and Cl^- were slight (~1.5×) (Table 2). Levels of DO and BOD did not show a consistant pattern and were generally within acceptable limits at all sampling points (WHO 1989; Rhodesia Effluent Regulations 1977). There was no indication of thermal pollution. There was generally a decrease in the level of pollutants at Point 3 indicating some degree of natural recovery and self-purification in a distance of only 3 km. Figures 2 to 12 show that, in general, there was an increase in the concentrations of the various parameters at Point 2 as compared to Point 1 and also a decrease in the concentration levels in the rainy months due to dilution.

The concentrations of all heavy metals studied showed an increase in going from Point 1 to 2 (Table 3). The most significant increases were recorded for Pb, Cr(III), Zn, Co, and Fe by factors of 184, 3.6, 12.3, 12.3, and 3.5, respectively. The increases recorded for Cr(VI), Cu, and Ni were less significant.

Levels of the exchangeable heavy metal cations in the sediment (as determined by extraction with 1-mol acetic acid) showed trends similar to those observed

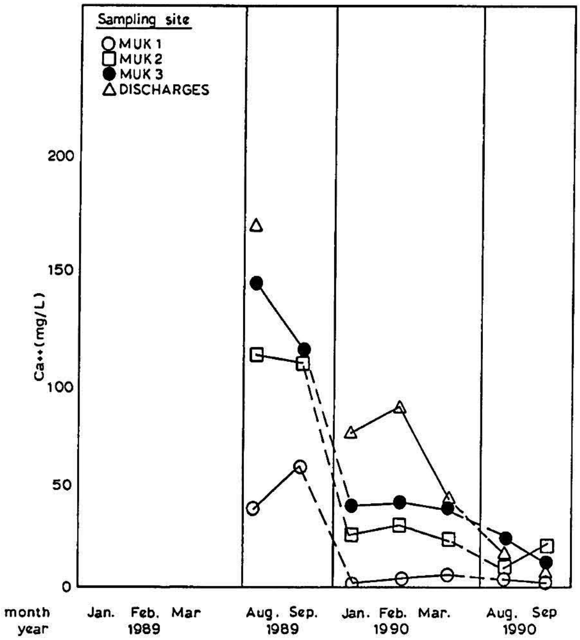

Fig. 10. Calcium concentration levels.

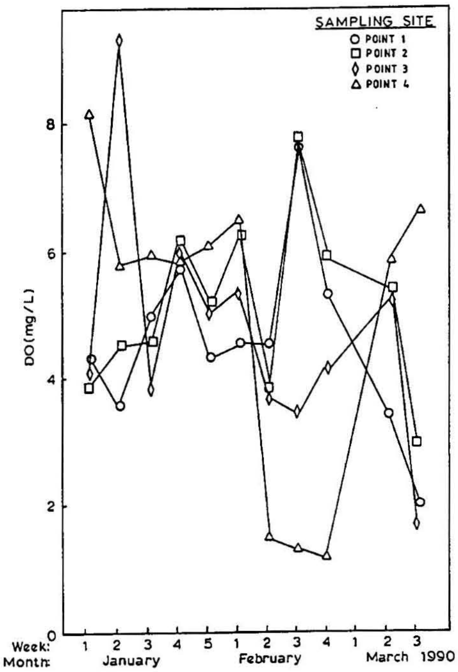

Fig. 11. Dissolved oxygen concentration levels.

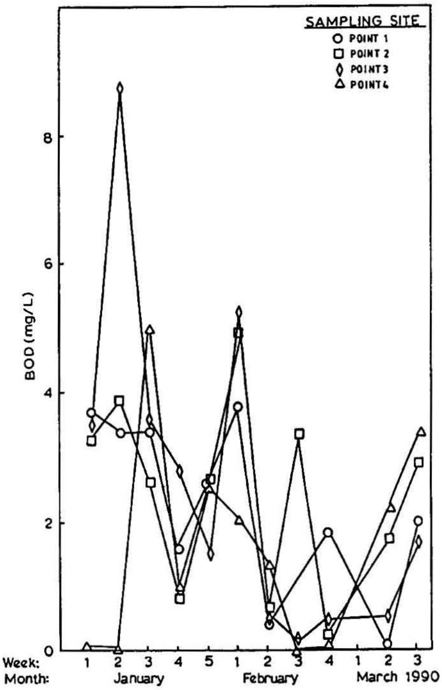

Fig. 12. Biological oxygen demand levels.

for the water phase levels. Pb increased by a factor of 2.9, Cr by 2.5, Cu by 10, and Zn by 3. Levels of Ni, Co, and Fe also increased to some extent. These results confirm pollution of the upper Mukuvisi water by effluents from the fertilizer plant. This is further supported by the fact that, except for Ni, the levels of exchangeable cations in the sediment from the effluent canal are all much higher than at Point 1 and, except for Zn and Cr, are comparable to those at Point 2. Nickel was lower in the effluent canal than at Point 1, yet, it increased by a factor of 1.5 at Point 2. This observation may be due to the fact that, in the effluent, Nickel exists mainly in the solution phase due to the low pHs (<3.3) (Table 2). A similar trend was observed for Zn, and Cu, probably for the same reason.

As a result of the recovery of pH, the levels of Pb, Cu, Zn, and Co in the water phase at Point 3 were lower than at Point 2. The same trend is discernible for exchangeable cations of these metals in the sediments from Point 3. For Cr and Fe, water levels showed a slight increase at Point 3, although their exchangeable cations in the sediment dropped to some extent. Ni showed an increase in both water and sediment exchangeable cation levels, suggesting another pollution source between Sampling Points 2 and 3. Such pollution could be coming from industries along the north bank of the river between the two points (Fig. 1).

A mathematical assessment of the quality status of the Mukuvisi River waters using combined data.

The overall quality status of the Mukuvisi River waters at the three sampling points was estimated using the Water Quality Index (WQI) (Ott 1978). This combines nine water quality parameters into one numerical indicator of the water quality: DO, fecal coliforms, pH, BOD5, nitrates, phosphates, temperature, turbidity, and total solids (Ott 1978; Canter 1977; 1979; Knox 1989). Parameters which were not monitored were estimated using the best available information. Fecal coliforms were not determined in this study and a constant value of 10 counts per mL was used throughout. Turbidity was considered to be equivalent to suspended solids levels since turbidity is directly proportional to the concentration of suspended solids. A sample calculation of WQI values is shown in Table 5. The subindex value for the i^{th} parameter is I_i and the importance weight for the i^{th} parameter is W_i. The various subindex values were aggregated using a geometric mean:

$$WQI = \prod_{i=1}^{n} I_i^{wi}$$

The mathematical classification of the water is as follows: 0-25, very bad; 26-50, bad; 51-70, medium; 71-90, good; and 91-100, excellent (Ott 1978). According to this scale, it can be seen that the water was generally good to medium at Point 1, deteriorated to bad or very bad at Point 2 pointing to the fertilizer plant as a source of pollution. There was recovery at Point 3 to medium to good water again. The reason for this seemingly good recovery could be due to the sudden rise in pH to an average of 7 to 7.5 at Point 3 as compared to 4.5 to 5.5 at Point 2. The WQI values for the various samples are shown in Table 6.

The overall data show considerable pollution of the upper Mukuvisi River from the fertilizer plant to the extent that the water fails the Water Quality Index evaluation at Point 2. There are indications of natural recovery within a stretch of only 3 km at Point 3.

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EFFECT OF REUSE OF HIGH-BOD WASTEWATERS FOR CROP IRRIGATION ON SOIL NITRIFICATION

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Biochemical oxygen demand (BOD) of wastewater is an important criterion for judging the suitability of wastewaters for irrigation. Wastewaters with a wide range of BOD (0 to 1000 mg/L) were used for irrigation of a variety of crops. Soil NO_3-N and NH_4-N were monitored before sowing and after harvest of crops, thrice a year for a period of six years. This paper gives an account of the seasonal changes in soil pH, EC, NO_3-N, and NH_4-N as affected by wastewaters with five levels of BOD. The work indicates the significance of the growing-season temperature on nitrification and other aerobic processes in the soil, particularly, under irrigation with wastes having higher oxygen demand.

INTRODUCTION

Urbanization and industrialization lead to the generation of large volumes of wastewater from domestic, commercial, industrial, and other sources. Indiscriminate discharge of such wastewaters into natural water courses is likely to pollute them. One alternate disposal operation is the disposal of wastes onto agricultural land. The Indian climate is predominantly semitropical and subtropical with seasonal rainfall and low humidity; thus, a considerable demand for irrigation water exists. Wastewater recycling in agriculture results in recycling of useful components of wastewater, i.e., irrigation water, plant nutrients, and organic matter for the production of crops.

Several researchers have studied the effect of sewage on the physicochemical and biological properties of soil (Vimal and Talashilkar 1985). A review of current technologies, treatment performance, and research needs has been given by Crites (1984). No harmful effects on soils due to long-term irrigation with treated wastewater was observed by Reynolds (1980). Guidelines for the safe use of wastewater in agriculture and aquaculture have also been given (Mara and Caincross 1989). The conditions of arid and semi-arid climates with prolonged warmer periods and seasonal rainfall from the monsoons prevailing in Asia are conducive to a perpetual demand for irrigation water. Land-applied wastewater undergoes physicochemical and biological treatment in the soil matrix. In order to prove the long-term effect of wastewater irrigation on soil nitrification, the content of NO_3-N and NH_4-N in the soil profile up to 15 cm using domestic wastewaters with five levels of BOD (from 0-1 g/L) was studied in field conditions.

MATERIALS AND METHODS

The studies were conducted in a randomized plot design in micro plots of 2.5 m × 2.5 m and provided with vertical polyethylene lining to a depth of 1 m. The experiment consisted of five treatments. Their make-up is described in Table 1. Each treatment was replicated four times. The characteristics of irrigation waters representing different BOD levels are given in Table 2.

Quantities of nitrogen, phosphate, and potash added by irrigating the crops were calculated using the mean concentration of these nutrients in irrigation waters. Where the anticipated contribution of NPK fell short of the recommended level for the crop, supplemental fertilizers were applied to ensure that the crops in every treatment received at least the recommended levels of NPK. Under some treatments, the anticipated nutrient contribution exceeded the recommended NPK.

Table 1. Treatment details.

S.No.	Treatment BOD levels (mg/L)		Details about source of BOD/ irrigation water and makeup of treatments	Quantity used
	Range	Average		L/m^2
1.	0 or negligible	0	Water	52.80
2.	25-75	50	Stabilization pond effluent	52.80
3.	100-200	150	Settled sewage	52.80
4.	350-450	400	Settled sewage + raw sludge slurry	52.20 0.60
5.	950-1050	1000	Settled sewage + raw sludge slurry	51.36 1.44

Table 2. Average characteristics of irrigation waters.

S. No.	Characteristic	Water	Stabilization pond effluent	Settled sewage	Raw sewage I	Raw sewage II
1.	EC (dS/m)	0.22	0.58	0.63	0.72	0.78
2.	pH	8.1	8.2	8.1	8.0	7.8
3.	Nitrogen (mg/L)	-	32.0	37.0	55.0	68.0
4.	Phosphate (mg/L)	-	8.1	8.8	13.9	17.4
5.	Potash (mg/L)	-	8.3	9.6	11.0	13.4
6.	BOD (mg/L)	-	50.0	160.0	410.0	1020.0
7.	COD (mg/L)	-	98.0	260.0	670.0	1610.0

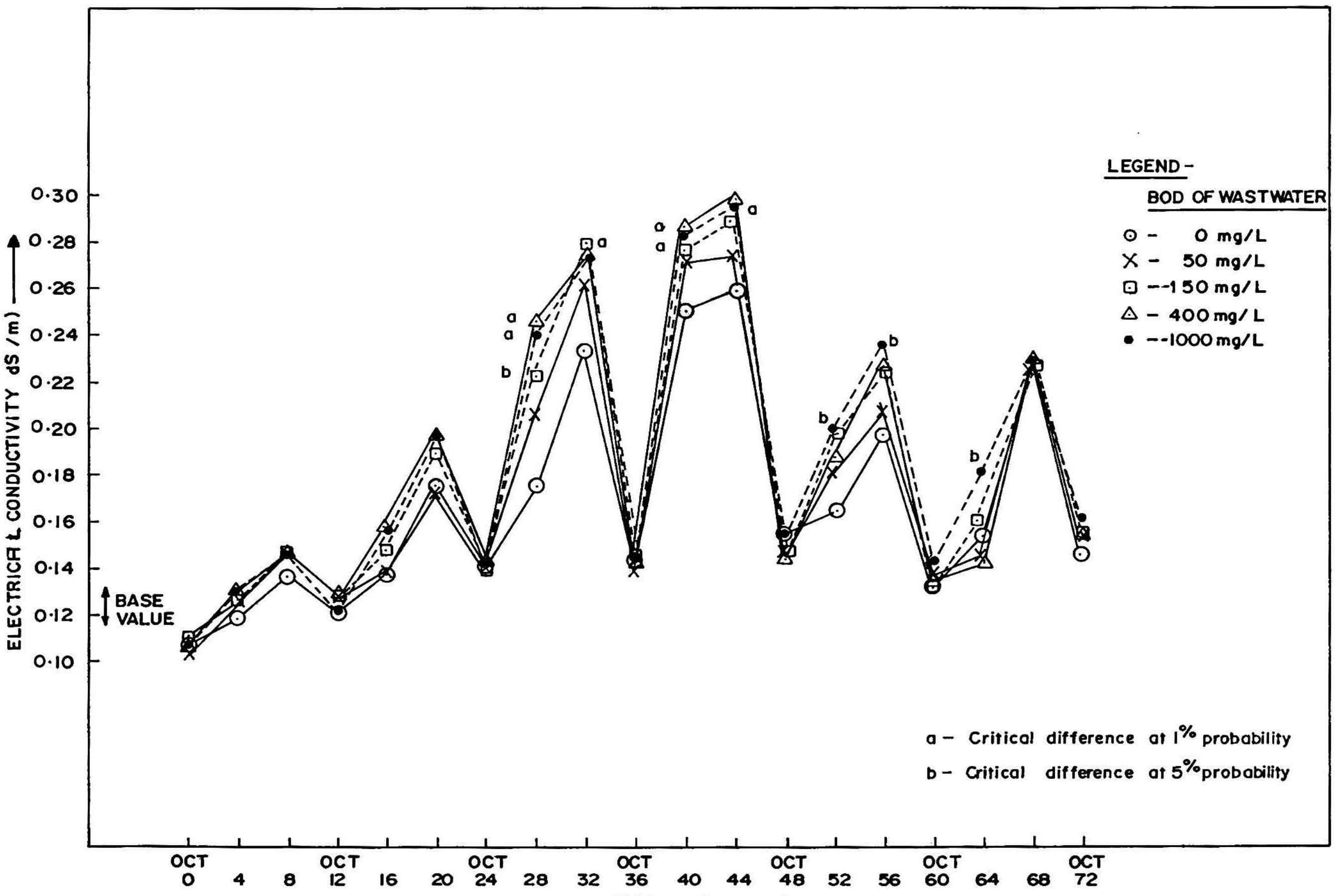

Fig. 1. Seasonal changes in EC of soils irrigated with domestic wastewaters of varying BOD levels (base value 0.125+-0.007 dS/m).

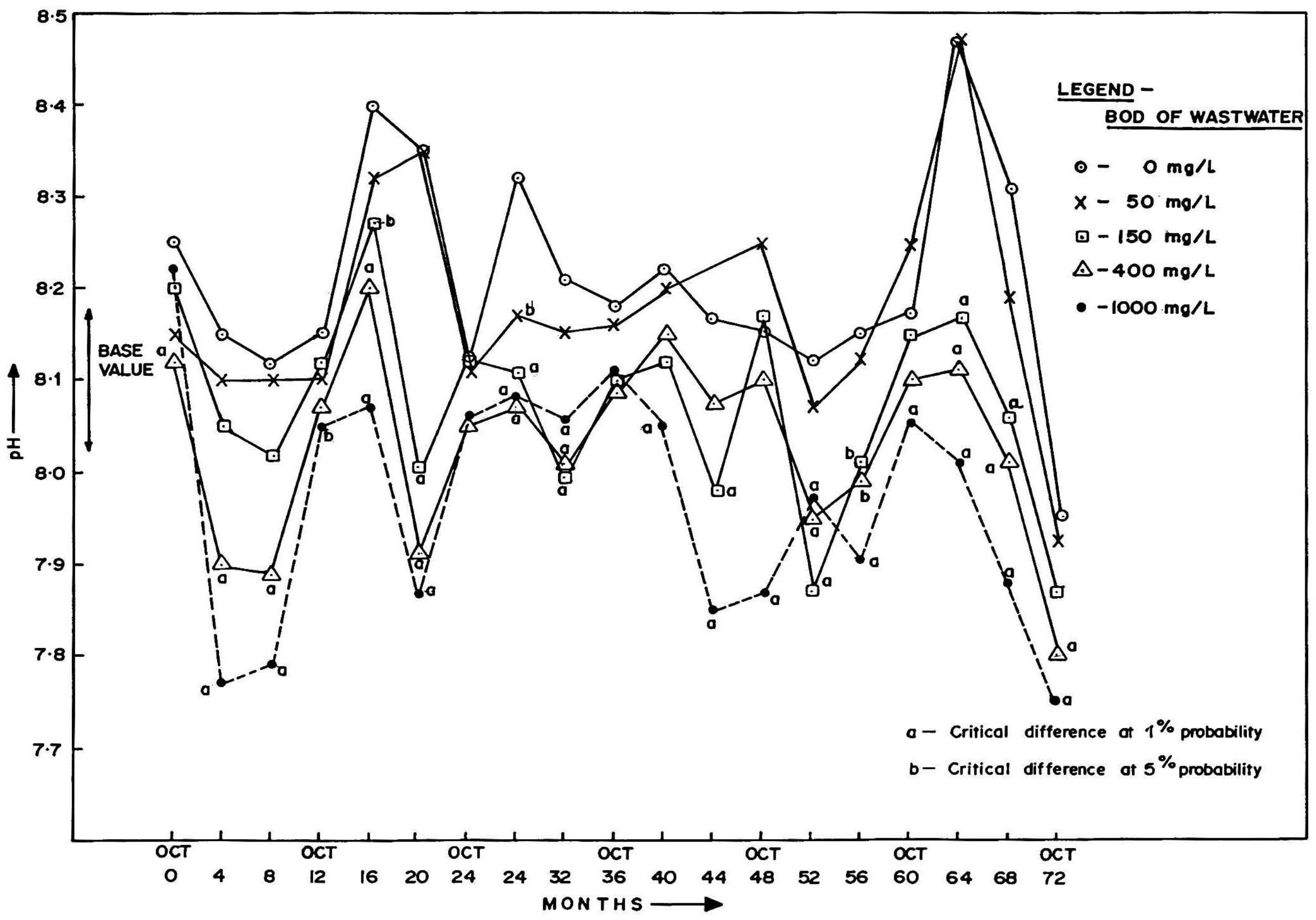

Fig. 2. Seasonal changes in pH of soils irrigated with domestic wastewaters of varying BOD levels (base value 8.10+-0.08).

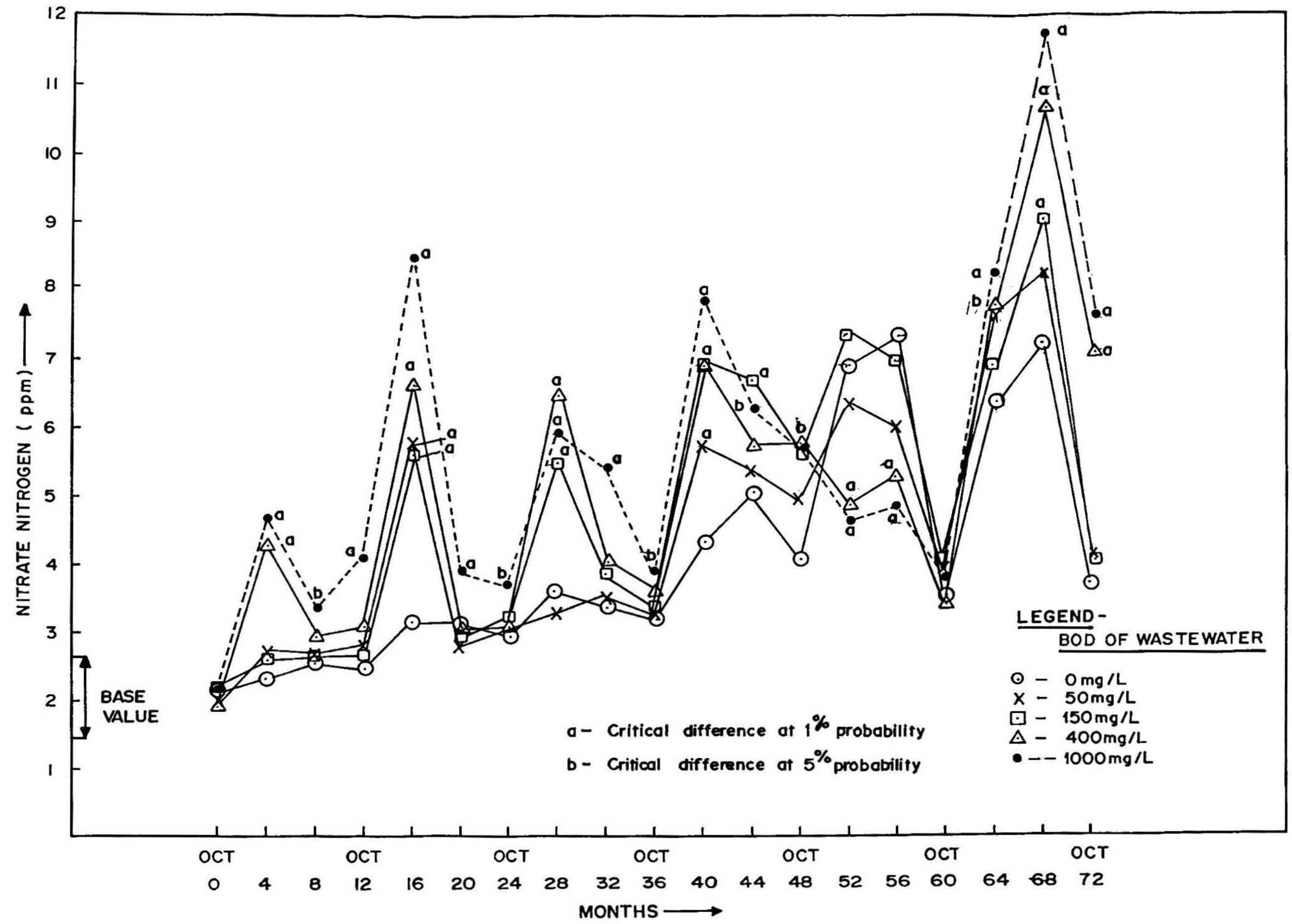

Fig. 3. Seasonal changes in nitrate-N content of soils irrigated with domestic wastewater of varying BOD levels (base value -2.02+-0.58 ppm or mg/kg).

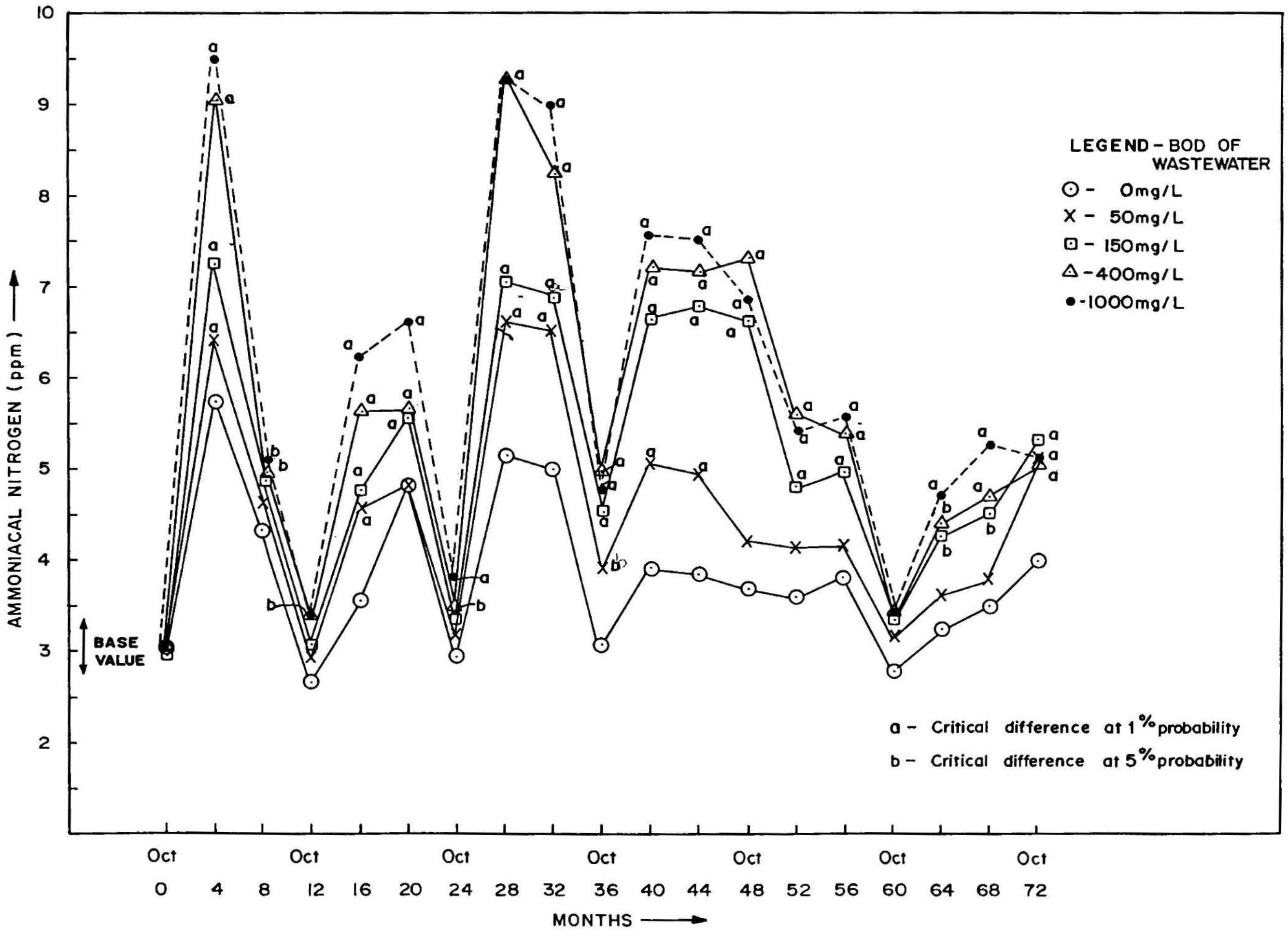

Fig. 4. Seasonal changes in ammoniacal N-content of soils irrigated with domestic wastewaters of varying BDO levels (base value 3.06+-0.29 ppm or mg/kg).

Soil samples were collected before sowing or transplanting and after the harvest of every crop. Samples were analyzed for pH, electrical conductivity, NO_3-N, and ammoniacal N as described by Jackson (1967). The results shown in Figs. 1 to 4 illustrate the changes in important soil characteristics that have relevance with the irrigation with waste waters of varying levels of BOD. Each value is the mean of four replicates. Statistical analysis of variance (F-test) was carried out for all the parameters under study (Cox and Cochran 1962).

RESULTS AND DISCUSSION

Growth and yield of crops and uptake of nutrients have been reported earlier by Nashikkar and Shende (1988). Electrical conductivity (EC) of the soils is presented in Fig. 1. The lack of change indicates that the BOD level of the irrigation water did not have any significant influence on this characteristic. An ameliorating effect of the monsoon rains was observed at all the post-monsoon (October) stages. Similar observations were made by Chauhan et al. (1988). In relation to the base value, the EC of soil seems to have increased under all treatments including plain water irrigation with negligible BOD.

There was a tendency for the soil pH to decrease as the BOD of the wastewater increased (Fig. 2). Although the increase in pH was apparent at the initial stages of the experiment, it became significant at the later stages. This effect is attributable to the release of organic acids during the decomposition of organic matter contributed by the high BOD wastewaters.

The relation of nitrate and ammoniacal forms of nitrogen is considered to be indicative of the oxygen status of soil which might have been influenced by irrigation with varying levels of BOD of the wastewaters. Nitrification activity in the soil was not adversely affected by irrigation with high BOD wastewaters, but the level of nitrates formed under irrigation with high BOD wastewaters seemed to be on the low side, considering the high supplies of nitrogen applied through such irrigation (Figs. 3 and 4). The level of ammoniacal nitrogen in the soil increased significantly, especially under high BOD wastewater irrigation.

The distribution and amount of both the forms of nitrogen were greatly influenced by the atmospheric conditions. The conversion of NH_4-N to NO_3-N was adversely affected during cooler seasons, probably due to lesser availability of oxygen in the soil, due to saturation of the soil during the rainy season. During the rainy season, the degradation rate of complex organic molecules was slowed. Oxygen stress in the soil appeared to be a consequence of irrigation with wastewaters of high BOD concentrations, implying an inadequate pace of degradation of complex organic molecules and oxidation of NH_4-N into NO_3-N during the cooler seasons.

During the summer season (April-August) when the soil-oxygen relations improved due to rapid evaporation of water, the conversion of NH_4-N to NO_3-N was accelerated. Leaching of NO_3-N during monsoons resulted in lesser NO_3-N and NH_4-N content in the soil at all the post-monsoon stages in October.

Statistical evaluation of the data collected over a period of 72 months revealed significant differences in soil NH_4-N, NO_3-N, pH, and EC due to various loading rates as compared to the control treatment. Changes observed in a particular sampling period, however, showed marginal differences due to a particular loading rate of wastewater when compared with the initial values. The NH_4-N, NO_3-N, and EC of the soil tended to increase gradually, whereas a decrease was observed in the soil pH due to the irrigation with wastewaters.

The results indicate that temperature plays an important role in the feasibility of using high BOD wastewaters for irrigation. Wastewaters of domestic origin can be better used in warm-climatic conditions. Thus, reuse of wastewater which is a renewable resource can achieve conservation of water, a scarce commodity in most developing countries with tropical and subtropical climatic conditions.

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TRACE AND HEAVY METALS IN SAN ANDRES LAGOON, TAMAULIPAS, MEXICO

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Concentrations of trace and heavy metals (Cd, Co, Cu, Fe, Mn, Ni, Zn, and Pb) were determined in San Andres Lagoon, Tamaulipas, Mexico at eleven stations in four seasons: Rain-84; North; Dry; and Rain-85. In Rain-84, we found higher concentrations of these metals (except iron) than in other seasons. Cobalt was not detected in this lagoon water. The results are compared with metals concentrations in estuarine water in Mexico and Terminos Lagoon water and are briefly discussed. Metals concentrations were higher than reported values in the North Pacific water.

INTRODUCTION

In order to understand the role of trace metals in various biochemical and geochemical processes occurring in natural water, it is important to determine their concentrations in these waters (Bender and Gagner 1976; Boyle et al. 1977; Moore 1978). The concentrations of these metals are usually controlled by pH and pE values of natural water which determine whether the metal is in free form or forms complexes with the constituents of natural water (Ahrland 1985). However, processes such as adsorption onto particle surfaces or coprecipitation with solid phases can change the concentration of these metals in the marine environment (Bruland et al. 1974; Bruland 1980). The involvement of trace metals has also been found in cycles of micronutrients and skeletal material (Bruland 1985). The fluvial and industrial effluents result in high concentrations of trace metals in the coastal zone and account for the bioaccumulation and biomagnification effects of trace metals in coastal water (Forstner and Wittman 1979). The sediments can concentrate or liberate metals into the water column depending on the physicochemical conditions; salinity, temperature, particle size, and pH (Philips 1976, 1980; Mance 1987; Pesch and Morgan 1978).

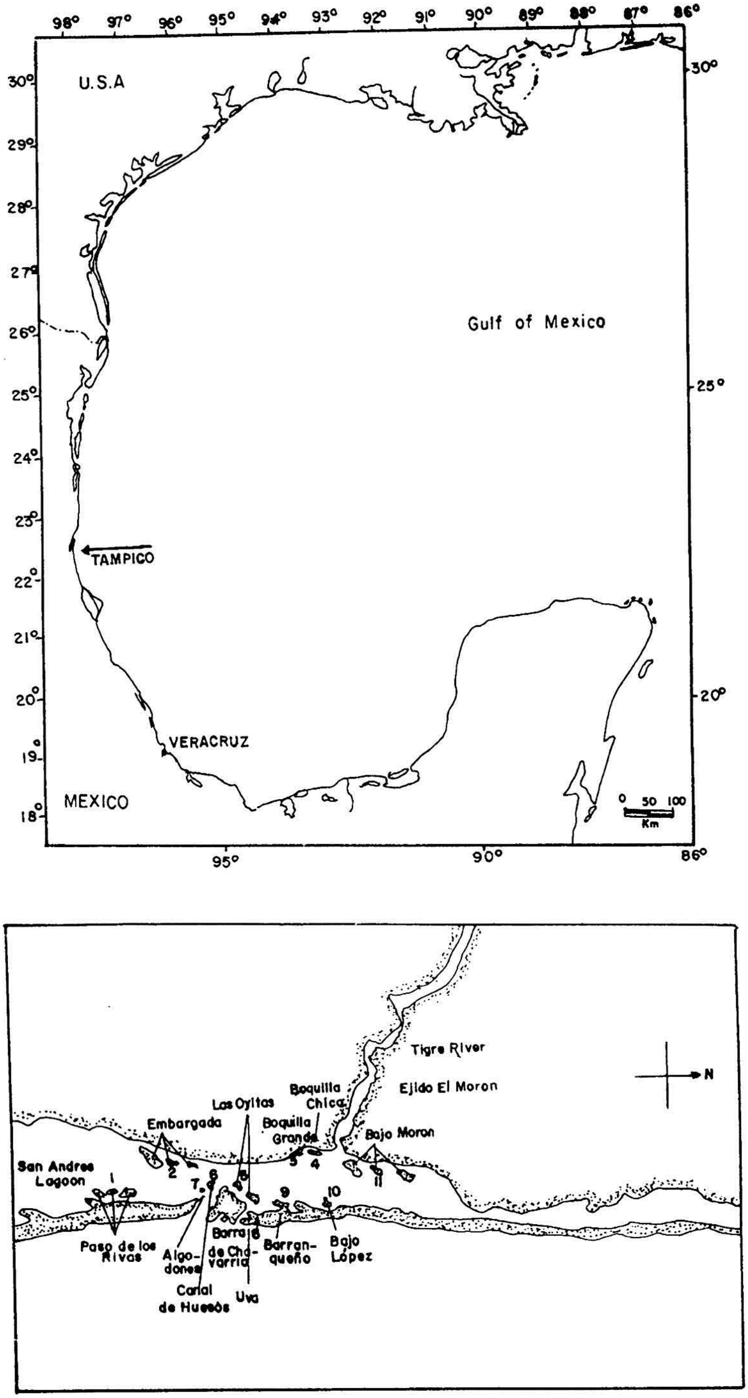

Fig. 1. Sampling sites of determinations in the San Andres Lagoon.

A number of studies have been carried out in the coastal, estuarine, and lagoon environments in order to quantify the heavy metals flux in the sediments (Bryan 1971; Burton 1986; Thrower and Eustance 1973; Watling 1983; Pempkowiak 1991). A recent study by Paez et al. (1987), in the tropical coastal lagoon sediment in the Mexican Pacific, estimates the flux of magnitude of heavy metals accumulated in the sediments. In recent years, we have been interested in determining trace and heavy metals concentrations in the lagoons in Mexico in order to understand processes occurring in the lagoons and to establish the levels of metal pollution in Mexican lagoons (Vazquez et al. 1986, 1987, 1990).

In the present work, we have determined the concentrations of trace and heavy metals (Cd, Co, Cu, Fe, Mn, Ni, Zn, and Pb) in the San Andres Lagoon water in Tamaulipas. This lagoon is located north of two industrial ports, Tampico and Altamira. In this industrial zone, the basins of the Panuco and Tamesi Rivers are localized and have industrial effluent throughout the year. All these activities and the input of the Tiger River, which runs through an agricultural and cattle-raising region, may affect the biogeochemistry of the San Andres Lagoon. The determinations were made in different seasons; Rain-84 (August-September 1984); North (October-December 1984); Dry (April 1985); and Rain-85 (April-June 1985). The results are compared with the North Pacific water and with the Terminos Lagoon, Mexico, the important lagoon of southern Gulf of Mexico in which drainage basins of the rivers that discharge into it are unpolluted. The results are also compared with the established metal concentrations in the Secretaria de Ecologia and Desarrollo Urbano Report (SEDUE 1986), which is a regulation to prevent and to control contamination in the coastal waters of Mexico.

EXPERIMENTAL

The samples were collected at eleven stations during a period from August 1984 to June 1985. The locations of the stations are shown in Fig. 1. The samples were taken in Nan Dorn bottles, previously soaked in Aqua Regia (Kremling 1983). All these samples were filtered through 0.45-µm filters (Millipore Corporation) and were stored in plastic bottles of 1000 mL that already had 1 mL of concentrated HNO_3 to acidify the samples to pH 1.6 - 2.0.

The concentrations of Cd, Co, Cu, Ni, and Zn in water samples were analyzed by the ion exchange column technique (Bruland et al. 1985). This technique employs Chelex-100 (sodium form, 100 - 200 mesh), precleaned with 4 N HCl and 2.5 N HNO_3, rinsed with distilled water and converted to ammonia form prior to loading in columns. Samples were adjusted to pH 6 with ammonium acetate and were drawn through a column containing 7.5 mL of Chelex-100 resin (flow rate: 1-2 mL min^{-1}). The columns were then rinsed with 20 mL ultrapure ammonium acetate (pH 5.8) and 20 mL distilled water to rinse off the bulk of the alkali and alkaline earth metals (Kingston et al. 1978). The trace metals were eluted with 20 mL of ultrapure 2 N HNO_3, providing a concentration factor of 100:1. The eluted samples were analyzed with a Perkin Elmer 2380 atomic absorption spectrophotometer equipped with an HGA-400 graphite furnace. Lead, iron, and manganese concentrations were determined directly by atomic absorption spectrophotometer. Standards were obtained from Titrisol, Merck and were prepared by spiking water samples which had been stripped of trace metals by passage through a column of the chelating resin. A blank was prepared by processing water in the absence of the spike. The absorbance from the blank was subtracted from the absorbance of the samples and standards. The three replicates samples were analyzed and the values were averaged. Estimated precision of the analysis was approximately ± 8% (RSD).

The hydrological parameters, temperature, salinity, pH, and dissolved oxygen were measured in situ. Salinity measurements were done with an Autosal Salinometer. The pH measurements were done with a 605 Beckman Metrohm pH meter, and a Corning glass pH electrode and Orion calomel reference electrode were used. NBS buffers as standards were taken to determine the pH of the samples. The micronutrients (N-NO_3, N-NO_2, NH_3 and P-PO_4) were analyzed by method of an FIAstar Analyzer (1986). For alkalinity determinations, the samples were brought back to a Mexico City laboratory to perform the Edmond Method (1970).

RESULTS AND DISCUSSION

The values for the hydrological parameters in San Andres Lagoon waters at four different seasons are given in Table 1. The temperature values are in agreement to those reported from the Terminos Lagoon; however, salinity values are higher than those of salinities found in the Terminos Lagoon water. This is probably due to the dry season and the beginning of the rainfall season that results in higher temperatures (Table 1).

The pH values of the water are comparable to the Terminos Lagoon values and are nearly the same as

Table 1. Conservative and nonconservative parameters of San Andres Lagoon, Tamaulipas, Mexico in four different seasons: 1) Rain-84, August-September 1984; 2) Dry, April 1985; 3) North, October-December 1984; IV. Rain-85, April-June 1985.

SEASON	AV.	MIN.	MAX.	SEASON	AV.	MIN.	MAX.
	TEMPERATURE				SALINITY		
I	28.7	27.4	30.8	I	21.1	10.0	28.0
II	25.5	22.0	29.0	II	28.3	16.0	40.0
III	29.4	27.0	32.0	III	34.0	27.0	36.0
IV	30.2	28.0	32.5	IV	40.0	38.0	42.0
TER-L*	29.9	28.6	30.5	TER-L*	32.3	19.2	37.7
	pH			DISSOLVED OXYGEN (μ mol L^{-1})			
I	7.57	7.40	7.80	I	150	105	178
II	7.65	7.35	7.95	II	136	111	170
III	7.72	6.00	8.30	III	180	100	279
IV	8.14	7.80	8.40	IV	145	87	265
TER-L*	7.76	7.55	7.89	TER-L*	82	60	102
TOTAL ALKALINITY (m mol/kg)				NITRATE (μ mol L^{-1})			
I	2.35	1.64	2.95	I	21.5	1.16	4.33
II	2.20	0.90	2.79	II	0.95	0.63	1.61
III	2.52	1.63	2.79	III	1.07	0.58	1.89
IV	1.02	0.79	2.03	IV	1.02	0.79	2.03
				TER-*	2.55	0.03	6.79
NITRITE (μ mol L^{-1})				AMMONIA (μ mol L^{-1})			
I	0.21	0.01	0.48	I	0.78	0.03	2.02
II	0.20	0.09	0.39	II	1.97	0.61	4.84
III	0.36	0.06	0.47	III	2.69	0.47	5.17
IV	0.36	0.04	0.42	IV	2.03	0.91	4.21
TER-L*	0.81	0.24	2.58	TER-L*	15.0	4.28	25.3
ORTHOPHOSPHATE (μ mol L^{-1})							
I	0.06	0.03	0.36				
II	1.17	0.36	1.98				
III	0.04	0.03	0.06				
IV	0.03	0.03	0.04				
TER-L*	0.82	0.48	2.31				

* Terminos Lagoon

Table 2. Comparison of concentration of metals ($\mu g\ kg^{-1}$) in different environments. 1: San Andres Lagoon water, average from Rain-84 to Rain-85 seasons. 2: Terminos Lagoon water (Paez et al. 1987). 3: SEDUE 1986.

Metal	San And-L[1]	Ter-L[2]	SEDUE[3]
Cd	0.33	0.02	1.00
Cu	1.82	1.76	-
Fe	23.4	62.0	-
Mn	0.72	0.38	-
Ni	1.08	-	1.08
Pb	1.38	-	1.00
Zn	5.12	-	9.76

the marine pH (7.5-8.4, Butler 1982). The oxygen concentrations were found to be higher than the Terminos Lagoon values. This suggests a slower respiration process in San Andres Lagoon compared to Terminos Lagoon. The alkalinity values were higher than the values reported for seawater (salinity, S = 35, pH = 8.110, total alkalinity, A_T = 2.40 m mol/kg, Millero 1979). This difference may be due to fluvial aport (Butler 1982).

The average concentrations for the nutrients are in agreement with the marine nutrient concentration and are comparable to those reported in the Terminos Lagoon. This indicates no eutrophication in San Andres Lagoon. Municipal or agricultural effluents, in general, do not alternate nutrients concentrations (Perkins 1974).

The average concentrations of cadmium, copper, iron, manganese, nickel, lead, and zinc in the San Andres Lagoon water at four seasons are shown in Fig. 2. Cobalt was not detected in any of the seasons. Except for iron, higher concentrations of these metals were found in the Rain-84 season than in other seasons. This indicates a larger input of these metals in the August 1984 rainfall. The concentration of these metals decreases in other seasons. Probably, the metals are involved in biogeochemical cycles, either actively as micronutrients and skeletal materials, or passively by adsorption onto particle surfaces, or coprecipitation with various solid phases. These processes dominate over atmospheric or other inputs in the October 1984 to June 1985 seasons.

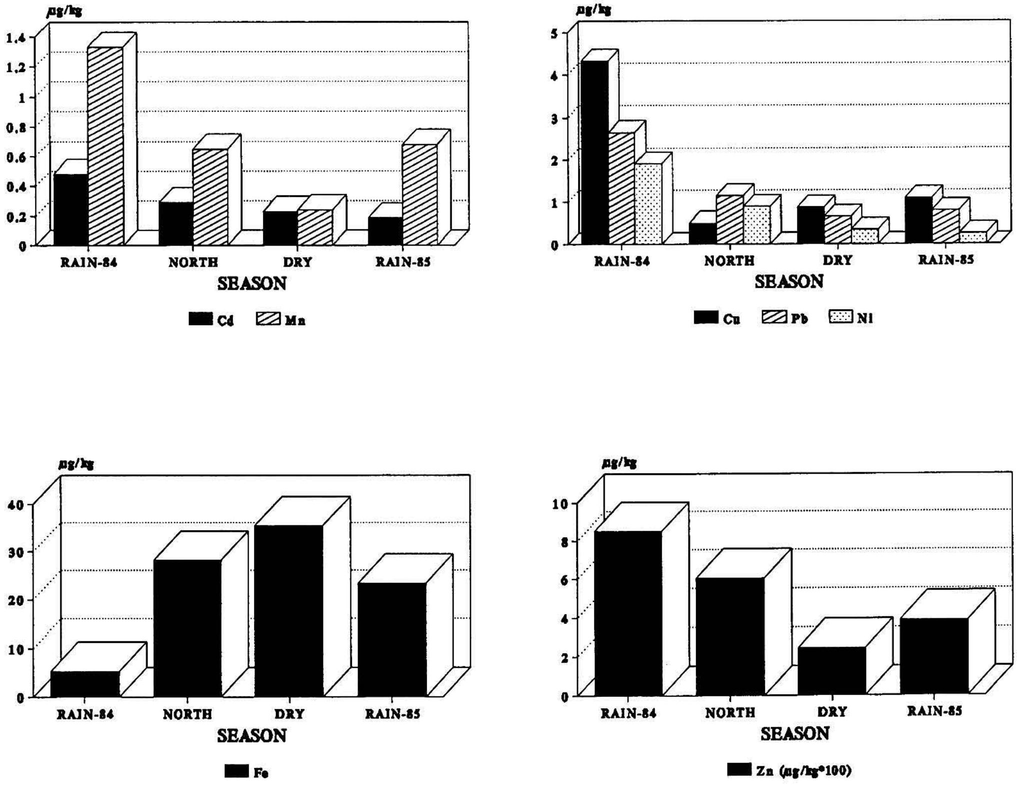

Fig. 2. Concentrations of metals in the San Andres Lagoon water in four different seasons.

The average metal concentrations in the San Andres Lagoon from the Rain-84 to Rain-85 seasons are compared with the estuarine water in Mexico, (SEDUE 1986) and the Terminos Lagoon water (Paez et al. 1986) and are presented in Table 2.

The cadmium concentration in the San Andres Lagoon is in agreement with the limits established from SEDUE (1986) while it is higher by an order of magnitude than the Terminos Lagoon water. The copper results are lower than the 50 μg kg^{-1} concentration in SEDUE and are similar to the Terminos Lagoon water. The nickel and zinc concentrations are in reasonable agreement with the values reported from SEDUE.

Iron and manganese, in general, are not considered toxic; however, high concentrations of iron under marine pH and pE conditions make insoluble oxides, that affect marine organisms (Clark 1986). The iron concentration in the San Andres Lagoon water is lower than that of the Terminos Lagoon water iron concentration, and the manganese value is higher than the reported value from water of the Terminos Lagoon.

The trace and heavy metals concentrations of the San Andres Lagoon water are higher than that of the corresponding concentration of these metals in North Pacific water (Bruland 1980). This was expected because San Andres Lagoon has local inputs while the North Pacific seawater goes through internal biogeochemical cycles of the sea which are responsible for their low concentrations.

CONCLUSIONS

The concentrations of cadmium, nickel, and zinc are either lower than or equal to the limit established for coastal water of Mexico (SEDUE 1986). Lead concentration is somewhat higher than the value reported in SEDUE (1986). The comparison of our results with the Terminos Lagoon water and with the North Pacific water suggests an anthropogenic metals input in the San Andres Lagoon water. The higher Pb concentration can be controlled by minimizing industrial Pb input into the San Andres Lagoon.

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EFFECT OF THERMAL POWER EFFLUENTS ON THE COMMUNITY STRUCTURE AND PRIMARY PRODUCTION OF PHYTOPLANKTON

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Effluents discharged by the coal-fired thermal power house at Obra (22° 52' N lat. and 83° 5' E long.) reach into the nearby flowing Rihand river and alter the ecological features of the river ecosystem. Temperature and pH of the receiving river water increased while the transparency, dissolved oxygen, chloride, NO_3-N, and PO_4-P decreased. In the effluent zone of the river, no phytoplankton existed during a one-year study period (January to December 1987). Chlorophycean members like *Spirogyra* and *Scenedesmus* which were present in the unaffected upstream (control site) were replaced by Bacillariophycean members like *Pinnularia* and *Nitzschia* with reduced phytoplankton density in the downstream-affected water. At the control site (average of 12 months), Chlorophyta density contributed 335 unit L^{-1} to the total phytoplankton density (774 unit L^{-1}) followed by Cyanophyta (260 unit L^{-1}) and Bacillariophyta (188 unit L^{-1}). At the affected site maximum of 112, the unit L^{-1} contribution was by Bacillariophyta followed by 90 unit L^{-1} of Chlorophyta and 60 unit L^{-1} of Cyanophyta to the total phytoplankton density (221 unit L^{-1}). Phytoplankton diversity indices and primary production were reduced in the affected zone. Chloride and PO_4-P together accounted for 54% ($p<0.01$) of the variability to the Bacillariophyta density, while no clear influence on Chlorophyta and Cyanophyta density was observed. Total phytoplankton density was changed by 28% ($p<0.05$) by chloride itself. Gross and net primary productivities were significantly ($p<0.01$) influenced by alteration of the NO_3-N concentrations of the water.

INTRODUCTION

Rapid increases in the construction of coal-fired thermal power houses in India are releasing effluents and gases in increasing quantities. River water is used as coolant in power houses. The waste materials produced from coal combustion consist of ash slurry and fly ash. In the tropics, the temperature of receiving water is close to the upper tolerance limits of most species and the effluents from the thermal power stations are 8 to 10°C higher than the river water (Mazumdar et al. 1990). Uncontrolled dumping of untreated ash slurry makes the river water turbid and changes the dissolved oxygen level, pH, and quantity of the trace elements (Subramanian et al. 1990). There are reports on the phytoplankton periodicity, primary production (Zutshi and Vass 1977; Pollingher 1981,

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1986; Khan and Zutshi 1980; Pollingher et al. 1988) and thermal stratification in rivers and lakes. Information is limited on the effect of ash effluents on the nutrient concentration of the receiving water bodies (Subramanian et al. 1990) and phytoplankton periodicity, diversity, and primary production (Srivastava 1990; Srivastava and Ambasht 1990; Ambasht and Srivastava 1991). The present paper describes the results of our study on the River Rihand (a tributary of River Ganga) at Obra in North India (22° 52' N lat. and 83° 5' E long.) affected by a thermal power house. The objectives were to find out the effect of

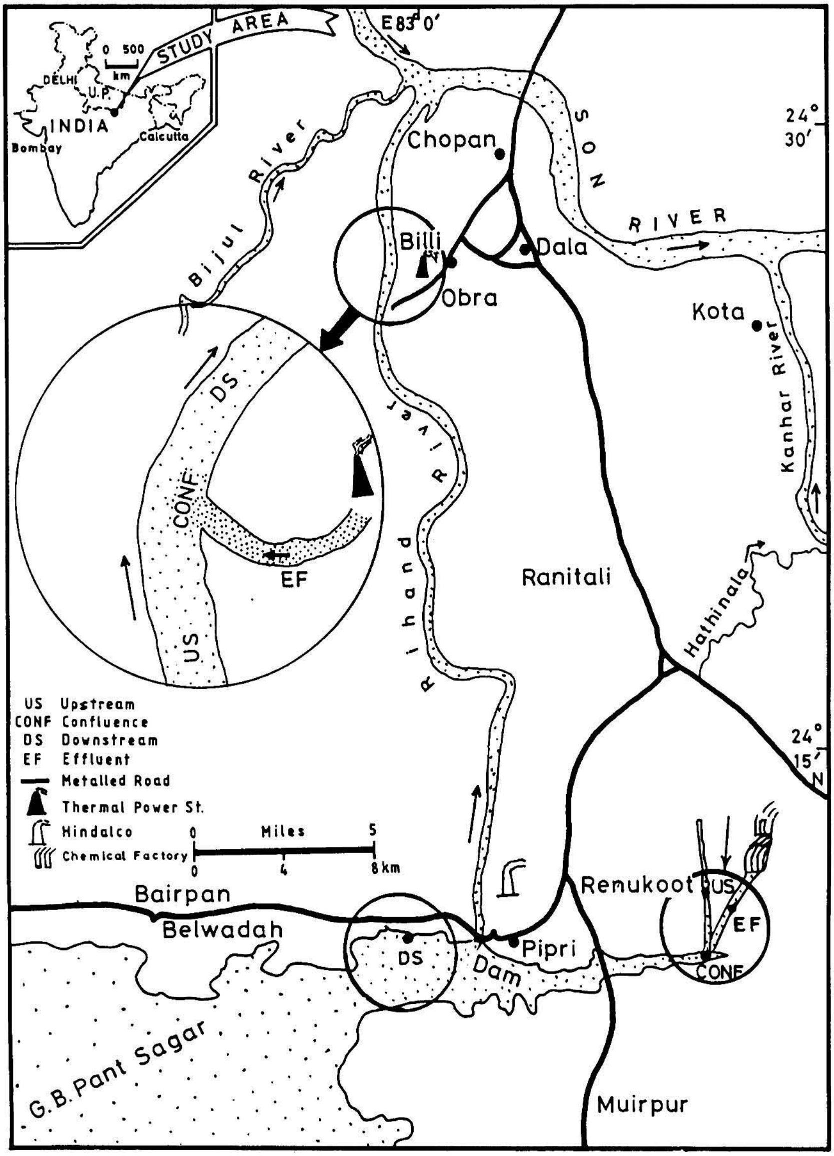

Fig. 1. Map showing the encircled sampling points in the Obra-Renukoot region.

thermal power effluents on the nutrient concentration, phytoplankton periodicity, density, diversity, and primary production of the river. Furthermore, the limiting nature of nitrate-N and phosphate-P and their relationship with bottom sediments and the removal of phytoplankton species have also been evaluated.

MATERIALS AND METHODS

Study site

The Rihand River originates in the hills of the north of the Madhya Pradesh State and flows north into the state of Uttar Pradesh. At Renukoot in U.P. through the river damming, the G.B. Pant Sagar reservoir has been created for water storage, irrigation, fish culture, and hydroelectric generation. The Rihand River further flows down through Obra and joins River Son which in turn joins River Ganga. The study was carried out at Obra where the thermal power plant burns 15 000 tons of coal per day (generating 500 MW electricity) and releases the effluents in the nearby Rihand River (Fig. 1).

Three sampling sites along the river and effluent channel have been selected. These are: (1) effluent channel, (2) effluent-affected downstream, 1 km away from the confluence on the right bank, and (3) effluent-unaffected on the left bank of the river (control site).

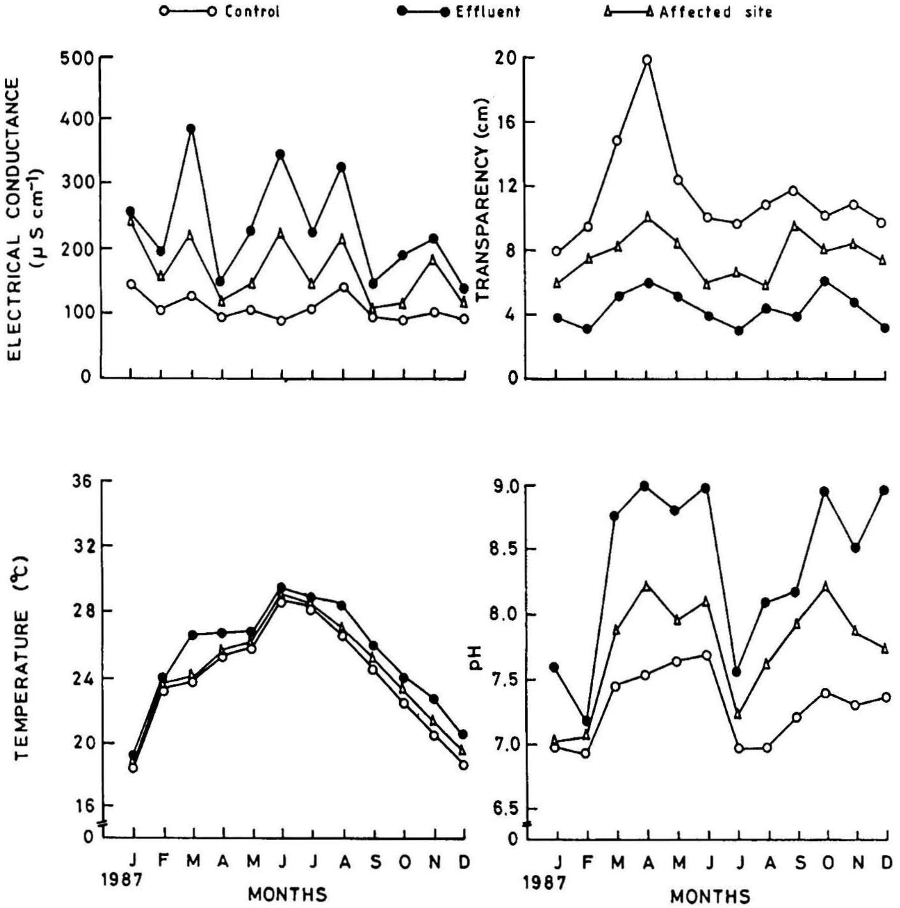

Fig. 2. Monthly variation in physical parameters of water at different sites.

Sampling

Water samples from the three sites were collected in polyethylene containers in triplicate at monthly intervals between January and December of 1987. Temperature, pH and electrical conductivity were measured immediately, Dissolved oxygen was fixed in BOD bottles.

Bottom sediment samples from each site were collected in polyethylene bags, transported to the laboratory and spread out for air drying. A suspension of 10 g of air-dried soil and 50 mL of water was shaken for 15 min in a shaker. After standing for a further 30 min, pH and electrical conductivity (at 25°C) were measured with the help of a Century digital portable kit (C.K 704).

Phytoplankton samples were collected in a bottle by allowing 50 L of water to pass through a plankton net of bolting silk No. 75. The sample was preserved in 4% formalin (APHA 1985).

Water analysis

Temperature was recorded by a Celcius thermometer and transparency by a Secchi disc (20 cm Ø). The pH and electrical conductivity (EC) were measured by a Century digital portable kit. Dissolved oxygen was estimated by Winkler's Modified Iodide-Azide Method and chloride by the Mohr's Method. Colorimetrically nitrate-N was measured by the Phenoldisulphonic-acid Method and phosphate-P by the Stannous Chloride Method. The methods used for dissolved oxygen, NO_3-N and PO_4-P are described in the Standard Methods (APHA 1985).

Sediment analysis

Nitrogen was measured by the Kjeldahl Method using $K_2SO_4 + CuSO_4$ and selenium powder as catalyst. Available phosphorus was measured by the Molybdophosphoric Blue-color Method (Jackson 1958).

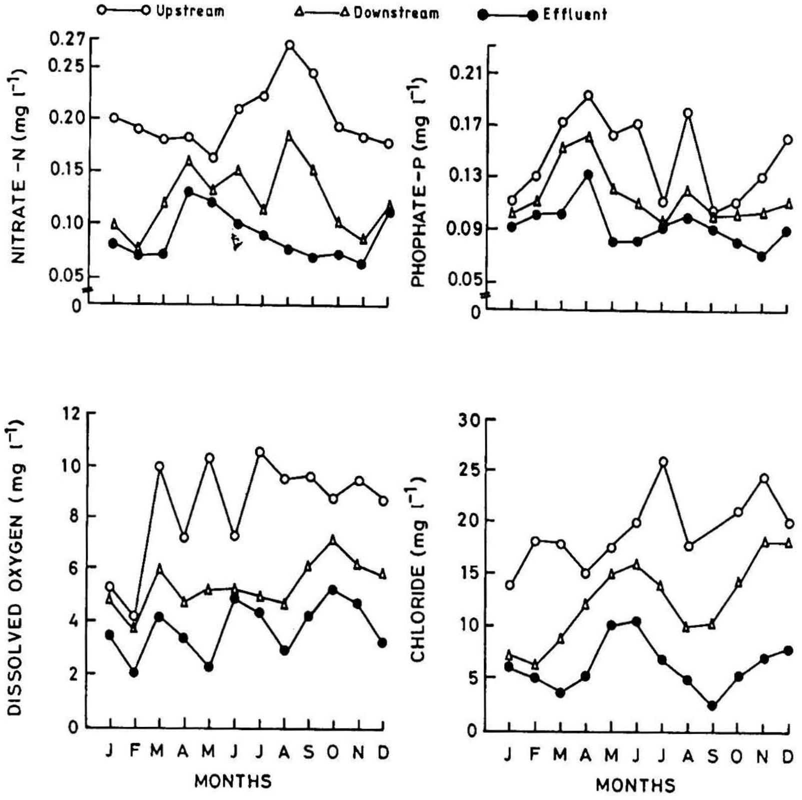

Fig. 3. Monthly variation in chemical parameters of water at different sites.

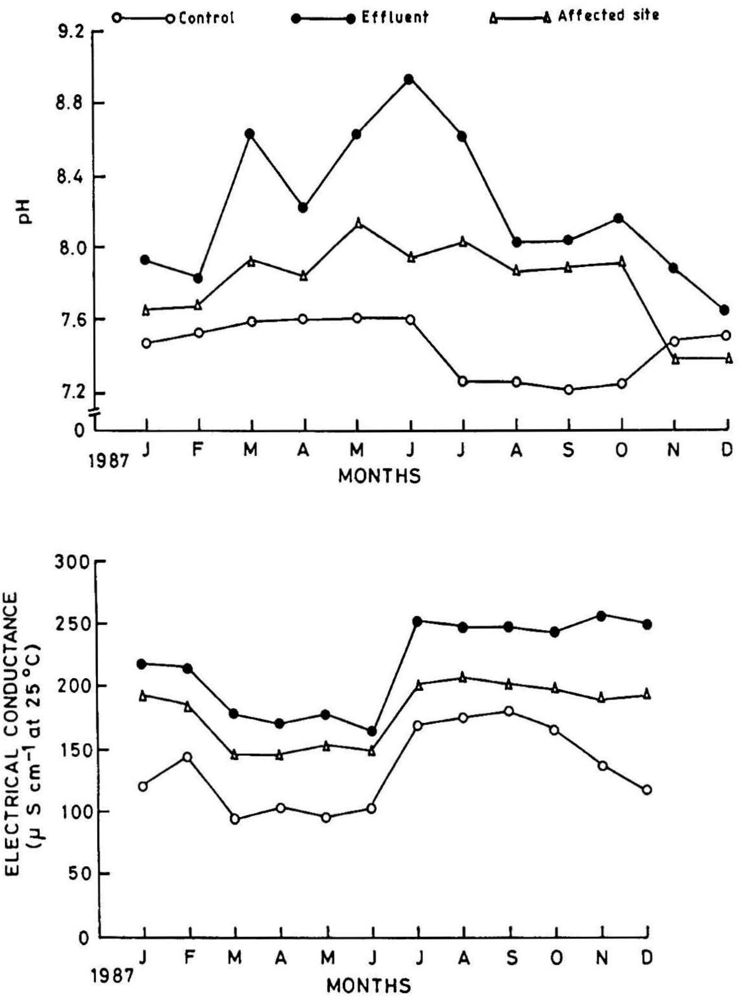

Fig. 4. Monthly variation in pH and electrical conductance of bottom sediment at different sites.

Phytoplankton

The collected water samples were allowed to settle; 1 mL of the aliquot of the concentrate was placed on a haemocytometer; and phytoplankton species were identified and counted (Smith 1950; Edmundson 1959).

Diversity indices

The Shannon Index (H') was calculated by using the modified formula given by Shannon and Weaver (1963).

$$H' = -3.3219 \sum \frac{ni}{N} \log \frac{ni}{N}$$

where ni = number of species and N = total number of individuals.

The Index of Dominance (Cd) was calculated by using the formula given by Simpson (1949).

$$Cd = \sum \left(\frac{ni}{N}\right)^2$$

The species richness (d) was calculated by using the formula given by Margalef (1964).

$$d = \frac{S-1}{\log N}$$

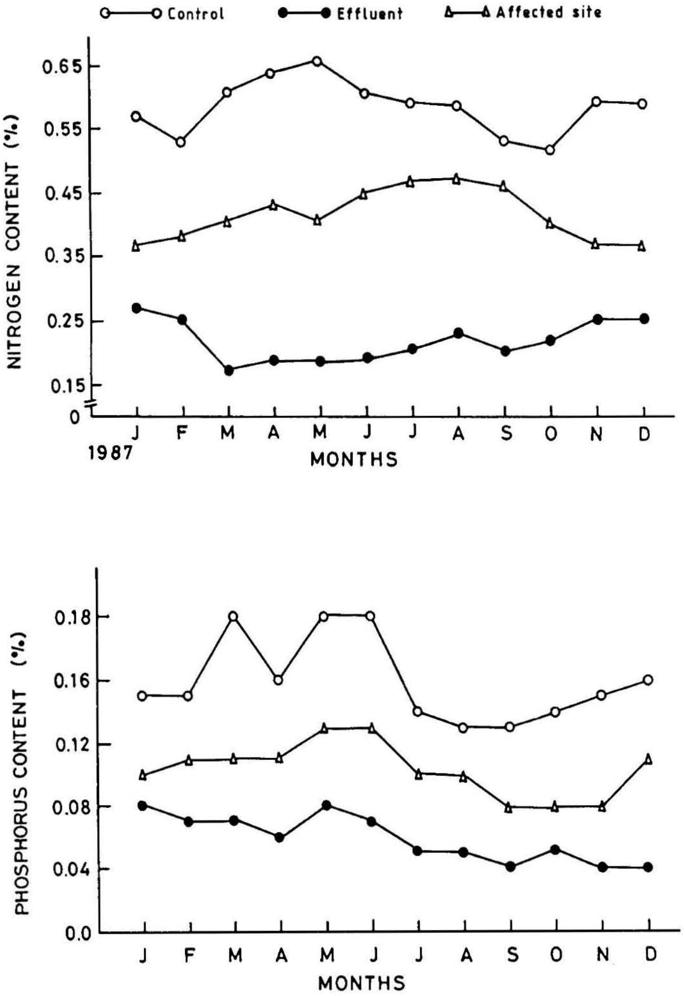

Fig. 5. Monthly variation in nitrogen and phosphorus contents of bottom sediment at different sites.

where S = number of species and N = number of individuals.

Primary production

Primary productivity of the phytoplankton was estimated using the Light and Dark Bottle Method (Vollenweider 1969 and Odum 1971). The gross and net primary productivity are expressed in mg C m^{-3} h^{-1}.

STATISTICAL TREATMENTS

Statistical analyses of the physico-chemical parameters and phytoplankton production were made using computer programmes.

(1) Analysis of variance of water and sediment properties was computed between site, month, and site and month interaction.

(2) Correlation coefficients were calculated between physico-chemical properties of water and sediment at each site.

(3) A step-wise multiple regression equation was performed with phytoplankton density and production as dependent variable and pH, NO_3-N, Cl, and PO_4-P as independent variable.

RESULTS AND DISCUSSION

Water quality

The temperature variation trend was similar at all the sites between 18.5°C to 29.5°C (Fig. 2). Effluent temperature was always higher in the range of 0.5°C to 1°C than that of the river water receiving effluents. The highest temperature was observed in the summer, followed by the rainy season, with the least in the winter season. The variation of temperature was significant ($p<0.005$) between sites and months. The pH was near neutral (6.9-7.3) at the control site, alkaline (up to 8.5) at the effluent site, and 7.1 to 8.2 at the affected site (Fig. 2). In the summer season, the pH was higher than in the other two seasons. This may

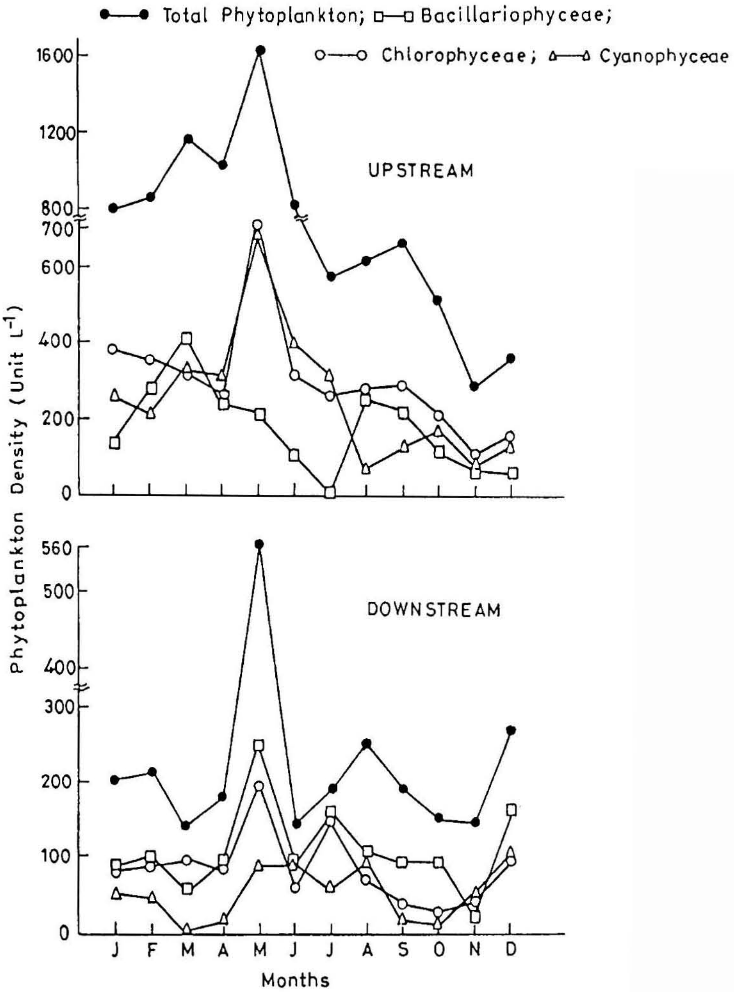

Fig. 6. Monthly variation in phytoplankton density.

Table 1. Monthly variations in phytoplankton diversity (H'), Index of Dominance(Cd) and species richness (d) at different sites.

Months	Control site			Affected site		
	H'	Cd	d	H'	Cd	d
Jan	3.0	0.14	3.1	2.1	0.25	2.0
Feb	3.1	0.13	3.4	2.4	0.20	2.4
Mar	2.6	0.22	3.3	1.8	0.34	1.6
Apr	2.6	0.20	3.1	2.2	0.22	2.1
May	3.3	0.12	3.8	3.1	0.13	3.3
Jun	2.7	0.20	3.4	1.3	0.46	1.1
Jul	2.4	0.26	2.8	1.5	0.39	1.0
Aug	2.6	0.21	2.8	2.0	0.30	1.9
Sep	3.0	0.16	3.6	2.2	0.25	2.0
Oct	2.8	0.18	3.3	2.2	0.24	2.1
Nov	2.8	0.15	3.2	2.2	0.23	2.1
Dec	3.1	0.14	4.0	2.7	0.16	2.8
Average	2.8	0.18	3.3	2.1	0.26	2.1

be due to the reduced water level in the river, whereas the amount of effluent discharged remained the same. It varied significantly between sites and months ($p<0.005$). Electrical conductivity of the effluent water was 2 to 4 times higher (150 to 375 $\mu S\ cm^{-1}$) than the water at the control site (100 to 150 $\mu S\ cm^{-1}$). High electrical conductance indicates a high level of dissolved ions. The transparency at the affected site was lower due to the high level of suspended and dissolved materials. Seasonally, it was lower in the rainy season due to increased input as surface runoff. Statistical variation of electrical conductance was significant ($p<0.005$) between sites only, whereas transparency varied significantly between sites ($p<0.005$) and months ($p<0.005$). The dissolved oxygen chloride, nitrate-N and phosphate-P were always highest at the control site followed by the affected site and least at the effluent site (Fig. 3). Statistically, these were highly significant ($p<0.005$) between sites and months.

Sediment quality

The trend of variance in the pH and electrical conductance was similar to that of the water quality (Fig. 4), having higher values at the effluent site. The change between sites and months was significant ($p<0.005$) in both cases. Total nitrogen and available phosphorus concentration were significantly ($p<0.005$) higher at the control site. Seasonally, they were higher in the rainy season at the control site and in the summer season at the affected site (Fig. 5).

Phytoplankton

Thirteen genera belonging to Chlorophyta, Bacillariophyta, and Cyanophyta were present at the control site. There was none at the effluent site while some reappeared at the affected site. At the control site, Chlorophyta dominated with *Spirogyra* and *Scenedesmus* while *Pinnularia* and *Nitzschia* (Bacillariophyta) dominated at the affected site.

This change in the phytoplankton species density is due to the thermal power effluents. Total phytoplankton density at the control site was 773 unit L^{-1}, from which Chlorophyta was 335, Cyanophyta 259, and Bacillariophyta 188 unit L^{-1}. At the affected site, Bacillariophyta was 112, Chlorophyta 90, and Cyanophyta 60 unit L^{-1} (Fig. 6). Seasonal density at the control site was summer > winter > rainy; while at the affected site, it was rainy > winter > summer. Higher density of the phytoplankton at the control

Table 2. Effects of nutrient concentration on density and primary production of phytoplankton (by stepwise multiple regression analysis). The squared multiple correlation coefficient (R^2) and variance ratio (F) are also shown.

Phytoplankton	Regression equations	R^2	F
Phytoplankton density	**Control site**		
Bacillariophyta	BAC = 135.4+2308.2 PO_4^- 14.9 Cl	0.54**	5.39**
Total phytoplankton density	TOT = 1379-31.6 Cl	0.28*	4.05*
Primary productivity			
Gross primary productivity	GPP = 127.2-2.88 Cl	0.31*	4.50*
Net primary productivity	NPP = 74.9-1.73 Cl	0.38*	3.98*
	Affected site		
Phytoplankton density			
Bacillariophyta	BAC = -93.3+1666 PO_4	0.25*	3.61*
Cyanophyta	CYA = 40.1+5.51 Cl-502-502.2 PO_4	0.74***	13.48***
Total phytoplankton density	TOT = -257.7+65.5 pH	0.07^{ns}	0.81^{ns}
Primary productivity			
Gross primary productivity	GPP = 115.9-10.2 pH	0.24^{ns}	3.19*
	GPP = 139.9+204.3 NO_3^- 16.7 pH	0.45*	3.76*
Net primry productivity	NPP = 645.78.6 pH	0.26*	3.62*

R^2 values are significant *p<0.01; **p<0.05; ***p<0.1

F values are significant *p<0.1; **p<0.025; ***p<0.005. ns = not significant.

site was associated with higher dissolved oxygen and nutrient concentration in the water. The stepwise multiple regression equation showed that, at the control site, chloride and phosphate together accounted for a 54% (p<0.01) change in the Bacillariophyta density, while no clear influence on Chlorophyta and Cyanophyta was observed. Chloride itself showed a 28% (p<0.05) change in the total phytoplankton density (Table 2). At the affected site, phosphate caused a 26% (p<0.05) change in the Cyanophyta density which rose to 74% when chloride was entered as a second variable.

Diversity indices

The Shannon Index varied from 2.4 to 3.3 with the mean of 2.8 at the control site and from 1.3 to 3.1 (mean 2.1) at the affected site (Table 1). Seasonally, it was higher in summer, followed by the winter and rainy seasons. A higher diversity index within a narrow range shows greater stability, i.e., they can resist the adversities of the environment better (Stub et al. 1970). Bechtel and Copeland (1970), Schindler (1974), and Wu and Antonovics (1975) have shown an increasing diversity in the downstream, away from the effluent-discharge point. The Index of

Table 3. Variance ratio (F) for physico-chemical parameters of water and sediment at different sites and months.

Parameter	Site	month	Site x month
Water			
Temperature	8*	8*	0.11^{ns}
Electrical conductance	72**	0.87^{ns}	0.15^{ns}
Transparency	238*	1.7**	0.63^{ns}
pH	131*	6	0.69^{ns}
Total solids	52*	4*	0.38^{ns}
Chloride	97*	1.9*	0.63^{ns}
Nitrate-N	345*	3.6	1.98*
Phosphate-P	68*	2.1*	0.88^{ns}
Sediment			
Total nitrogen	1532*	1.7***	4.7*
Available phosphorus	612*	13*	1.1^{ns}
Electrical conductance	229*	22*	1.1^{ns}
Organic carbon	6855*	13*	3.3*

F values are significant at *$p<0.005$; **$p<0.025$; ***$p<0.1$; ns = not significant.

Dominance was inversely proportional to the Shannon Index; it varied from 0.12 to 0.22 with a mean of 0.18 at the control site and 0.13 to 0.46 (mean 0.26) at the affected site. Species richness was directly proportional to the Shannon Index which was higher at the control site (2.8 to 4.0) than the affected site (1.0 to 3.3).

Primary production

Primary production of the fresh-water ecosystems gives quantitative information regarding the amount of energy available to other trophic-level organisms and the nutritional status. At the control site, the gross primary productivity varied from 35.5 to 125.0 mg C m^{-3} h^{-1}, while, at the affected site, it was from 25.0 to 52.5 mg C m^{-3} h^{-1}. Similarly, net primary productivity ranged from 25.0 to 75.5 mg C m^{-3} h^{-1} and 17.5 to 32.5 mg C m^{-3} h^{-1} at control and affected sites, respectively (Fig. 7). Higher production rate at the control site, obviously, could be due to higher concentration of NO_3-N and PO_4-P of the water, and total-N and available P of the sediment. Fairly reduced rates of production at the affected site are due to the cumulative effect of pollutants. Statistically, it is also proven that NO_3-N, PO_4-P, and chloride, together as well as singly, influences the gross and net primary productivity significantly ($p<0.05$) (Table 3). Seasonally, phytoplankton production at the control site was highest in summer, possibly due to the increase in bright solar radiation, low water level, and dominance of chlorophycean members. Bayne et al. (1983) have also reported similar findings.

Thus, it is found that the effluents from the thermal power plant reduce the nutrients (NO_3-N, total-N, PO_4-P, and available P), phytoplankton diversity, and rate of primary production in the Rihand River at Obra. The replacement of the Chlorophyta dominance by Bacillariophyta is an indicator of pollution.

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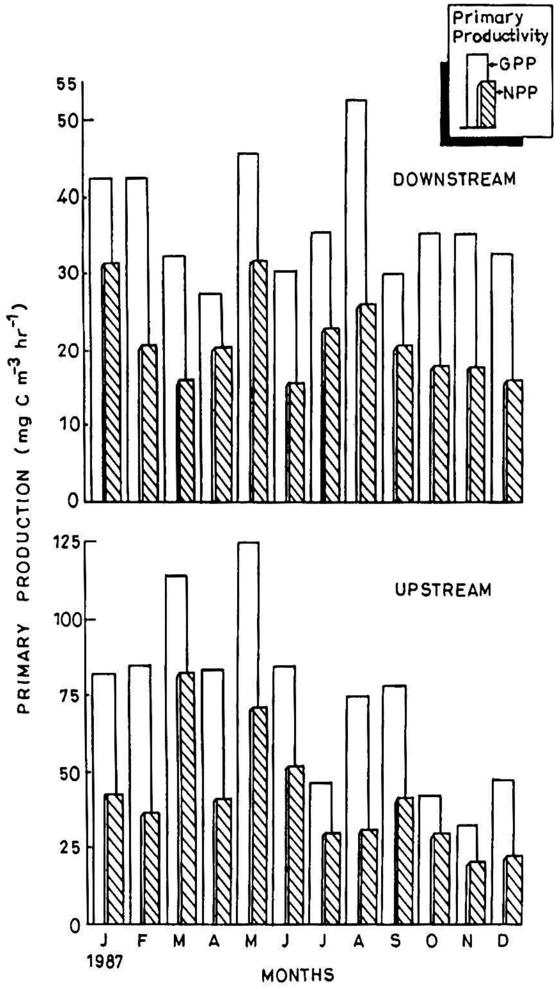

Fig. 7. Gross and net primary productivities of phytoplankton.

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LETTERS TO THE EDITOR

AN ESTIMATE OF ADULT MORTALITY IN THE UNITED STATES FROM PASSIVE SMOKING

Dear Editor:

In studies of environmental tobacco smoke (ETS) and lung cancer in females, risk is often estimated by comparing never smokers married to smokers and never smokers married to non-smokers. If a proportion of the never smokers are misclassified, and are actually current or former smokers, the relative risk estimate will be biassed upward (due to the well documented tendency for smokers to marry smokers more than expected by chance). The existence of such bias was recognized by Wells in his 1988 paper from which this correspondence has emanated. However Wells and I differ in our opinion as to the magnitude of the bias. To what extent can the bias explain the reported association between spouse smoking and lung cancer, for which a recent meta-analysis based on 30 studies (Lee 1991) gives a relative risk estimate of 1.19 (95% confidence interval [CI] 1.09-1.31)? In his latest letter (Wells 1992), Wells estimates the bias to be negligible, at around 1.02, his latest methodology and data being described in detail elsewhere, in the second draft of the EPA report on ETS (EPA 1992). I have recently reviewed the whole issue of misclassification in depth, in a book (Lee 1992a), and in a document which gives some additional details (Lee 1991). A major purpose of this letter is to summarize the main reasons why I believe Wells is wrong, incorporating where appropriate material from some recently published studies. Some other issues arising out of the ongoing correspondence, raised by both Wells and Repace, are also considered at the end of this letter.

The first error Wells makes is in applying misclassification rates, estimated from data virtually all of which comes from North American, European, and Australian populations, to results of lung cancer studies conducted in Japan, Hong Kong, and China. (13 of the 30 studies were conducted in these three Asian populations.) It may be true that the elevation in lung cancer risks reported in the Orient cannot be explained by the magnitude of smoking habit misclassification reported in the Occident (including for convenience Australia in the Occident!). However, given the strong suspicion that misclassification rates are likely to be much higher in the Orient than the Occident (smoking by women is socially unacceptable in Japan, for example), this is scarcely a helpful observation. Until we get good data on smoking habit misclassification rates in Oriental populations, we have to content ourselves with trying to determine whether the increase in lung cancer reported in Occidental populations can be explained by reported misclassification rates in Occidental populations.

The second error Wells makes is in underestimating the extent of misclassification rates in Occidental populations. Based on data from seven studies, Wells (Table 1) estimates that 1% of true current regular smokers and 15.1% of true current occasional smokers are misclassified as never smokers. As is clear from Table 2, misclassification rates in studies considered by Wells are systematically lower than in studies not considered by Wells, and more appropriate estimates of the two rates of misclassification as never smokers would seem to be 1.62% and 21.52%. Using other parameters estimated by Wells, one can then demonstrate (Table 3) that 6.17% of ever smokers are misclassified as never smokers and that, because occasional smokers and long-term ex-smokers are overrepresented, these cause equivalent bias to 2.50% of average ever smokers being misclassified as never smokers. Using techniques as described in Lee (1991), and assuming a smoking habit concordance ratio of 3.0, one can then demonstrate that adjusting for this 2.5% level of misclassification would reduce the meta-analysis for the U.S. data, based on 11 studies, from 1.18 (95% CI 1.02-1.37) to 1.00 (95% CI 0.85-1.17), and for all the Occidental data, based on 17 studies, from 1.23 (95% CI 1.08-1.40) to 1.07 (95% CI 0.93-1.23). Using a concordance ratio of 4.0, which may be more appropriate (Lee 1992a), would reduce the estimate further, to 0.97 (95% CI 0.83-1.14) for the U.S. data and to 1.04 (95% CI 0.91-1.20) for the total Occidental data.

These analyses confirm conclusions in my book (Lee 1992a) that misclassification of smoking can perhaps completely explain the weak positive association of lung cancer risk with spousal smoking

Table 1. Summary of Wells' data in females on misclassification of current smokers, adapted from EPA (1992), based on seven studies.

		True smoking status[a]		
Self reported smoking status	Non-smoker	Occasional smoker	Regular smoker	Total
Never	3080	30	14	3124
Former	944	16	15	975
Current		153	1372	1525
Total		199	1401	

Misclassification rates:

Proportion of self-reported non-smokers who are smokers

= (30 + 14 + 16 + 15) / (3124 + 975) = 0.0183

Proportion of self-reported non-smokers who are regular smokers

= (14 + 15) / (3124 + 975) = 0.0071

Proportion of true regular smokers misclassified as never smokers

= 14 / 1401 = 0.0100

Proportion of true occasional smokers misclassified as never smokers

= 30 / 199 = 0.1508

* Women with cotinine levels 30+% of those of self-reported smokers are classified as regular smokers, with 10-30% as occasional smokers.

reported for European and U.S. women. It can also explain the association reported in men (Lee 1992a).

Wells suggests that misclassification rates determined from what he describes as "community surveys" may overestimate the rate that actually existed in the epidemiological studies of ETS and lung cancer. While it is certainly true (Lee 1988) that the circumstances under which data were collected may quite strongly affect the rate, it should be realized that both the studies cited in Table 2 and the lung cancer epidemiological studies were conducted using a wide variety of study designs and data collection techniques; some of the epidemiological studies were themselves of the "community survey" type. To try to conclude, as Wells does, that misclassification rates relevant to the combined lung cancer studies are some large factor less than those estimated from Table 2 seems highly speculative. Wells notes that rates were quite low among cases in the Fontham et al. (1991) study, the only one of the 30 epidemiological studies that has used cotinine determinations. The relevance of this observation is dubious. "Current smoking" in lung cancer studies usually refers to smoking habits at the time of diagnosis or onset of disease. A large proportion of smokers give up smoking shortly after diagnosis or onset (and will not be smoking in hospitals anyway) so that cotinine tests conducted subsequently are of limited value.

Wells argues that misclassification rates cannot explain the larger lung cancer relative risks reported for *heavy* smoking by the husband. Although there is a tendency for risks to be higher in the highest exposure group than in the lowest exposure group, Wells' meta-analysis of risk for heavy exposure is

Table 2. Misclassification of current smoking habits in females[a]. Data from 13 studies.

Study	Cited by Wells	Self-reported non-smokers Number	True smokers[b]	misclass. rate (%)
1. Coultas et al (1987)	Yes	466	23	4.9%
2. Cummings et al (1990)	Yes	368	3	0.8%
3. Haddow et al (1986)	Yes	232	3	1.3%
4. Haddow et al (1987)	No[c]	2871	112	3.9%
5. Haddow et al (1988)	Yes	1508	13	0.9%
6. Heller et al (1989)	No	1428	26	1.8%
7. Lee (1987)	Yes	458	10	2.2%
8. Sears et al (1992)	No	699	45	6.4%
9. Pierce et al (1987)	Yes	311	19	6.1%
10. Riboli et al (1990)				
- 3 regions	Yes	757	4	0.5%
- other regions	No	612	43	7.0%
11. Slattery et al (1989)	No	379	8	2.1%
12. Wagenknecht et al (1992)	No	1723	62	3.6%
13. Woodward et al (1991)	No	2271	51	2.2%
Total		14083	422	3.00%
Cited by Wells		4099	75	1.83%
Not cited by Wells		9984	347	3.48%
Not cited excluding Haddow et al (1987)		7113	235	3.30%
Total for males[d]		6338	267	4.21%
Total regardless of sex[e]		21149	713	3.37%

[a] Most studies do not provide data on numbers of current smokers, or that subdivide non-smokers into never and former smokers, or allow separation of true regular and occasional smokers, so data are not presented on percent of true smokers misclassified as never smokers.

[b] Cotinine 10+% of that of self-reported smokers or nearest cut-off available.

[c] Wells (EPA 1992) rejected this study for reasons unstated.

[d] Data from studies 1, 2, 6, 7, 9, 11, 12, 13 and also Wald et al (1984).

[e] Data for females and males combined including additionally data from Dickinson et al (1988), Perez-Stable et al (1992) and Thompson et al (1990) not given separately by sex.

Table 3. Estimation of the proportion of typical ever smokers misclassified as never smokers.

Step	Procedure
1	Use Table 1 data but inflate the numbers of self-reported non-smokers who are true smokers by a factor 3.00/1.83 = 1.638 to take account of the higher misclassification rates shown in Table 2. Elements 30, 14, 16, 15 of Table 1 become 49.13, 22.93, 26.20 and 24.57.
2	Correct the misclassification rates of smokers as never smokers Proportion of true regular smokers = 22.93/1419.49 = 0.0162 Proportion of true occasional smokers = 49.13/228.33 = 0.2152
3	Assume[a] (1) excess risk of regular smokers = 9 (2) excess risk of occasional smokers = 1.8 (3) excess risk of misclassified former smokers = 0.9 (4) proportion of current smokers who are occasional smokers = 0.1 (5) proportion of ever smokers who are former smokers = 0.355 (6) proportion of true former smokers misclassified as never smokers = 0.1081
4	From assumptions (4) and (5) 100 ever smokers are divided into 58.05 regular, 6.45 occasional, 35.50 former
5	From assumptions (1), (2) and (3) calculate the average excess risk of the 100 ever smokers as 5.628
6	Apply the misclassification rates to give 6.166 misclassified smokers, made up of 0.9404 regular, 1.3880 occasional, 3.8376 former
7	Calculate the average risk of the misclassified smokers as 2.2820
8	Express this risk as a fraction of that of typical ever smokers = 2.2820/5.628 = 0.405
9	Adjust the misclassification rate of 6.17% by this fraction to give a rate of 2.50% of typical ever smokers misclassified as never smokers

[a] Assumptions (1)-(4) and (6) are as used by Wells in EPA (1992). Assumption (5) is based on data given by Wells for Correa et al (1983) in his worked example. Assuming instead values of 0.2, 0.3 and 0.4 gives estimates of 2.26%, 2.41% and 2.59% for the proportion of typical ever smokers misclassified as never smokers.

misleading. Four points should be realized: (1) No study has actually reported a statistically significant trend in risk among the exposed groups in relation to level of exposure (Layard 1990); (2) Those studies which have not presented data on risk by level of ETS exposure are typically those that found no difference in risk between exposed and unexposed groups. Those that have presented data are clearly selected to have atypically high risks; (3) There are many possible indices of level of exposure and cutoff points that can be used to define "high exposure". Scientists may publish, and meta-analysts may select, those that show the clearest trend and highest risk in the exposed group. See, for example, my comments (Lee 1992b) on the Fontham et al. (1991) study; (4) It has been demonstrated (Lee 1987) that smoking habit concordance rises with amount smoked, so that the misclassification bias will rise with level of exposure, creating a spurious trend in the absence of any effect of ETS exposure. Bias due to confounding by other risk factors may also rise with amount smoked by the husband.

Wells notes that those studies of ETS and lung cancer that have considered data on diet have not found diet to be a confounding variable. When one is considering variables estimated to cause a bias of order 1.10, it is perhaps unsurprising that significant confounding has not been detected in view of the relatively low power of these studies. It seems, however, that non-smokers exposed to ETS may be more likely to be at risk of lung cancer than non-exposed non-smokers regardless of ETS exposure. Analyses of data from the large U.K. Health and Lifestyle Survey, an interim report of which has been published (Thornton and Lee 1992), has shown very clearly that smoking and ETS exposure are both associated with reduced consumption of fruit and vegetables, increased consumption of fatty foods, and increased consumption of alcohol, all reported lung cancer risk factors. (Though these factors have not been clearly demonstrated to increase risk specifically in lifelong non-smokers, it seems a priori implausible that they should modify risk in smokers but not in non-smokers.) These risk factors were also associated with amount smoked, and reduced beta-carotene intake has been shown to be associated with amount of ETS exposure (Le Marchand et al. 1991).

In discussing the evidence on workplace ETS exposure and lung cancer, Wells refers to data from Fontham et al. (1991) and Janerich et al. (1990). He does not make it clear that meta-analysis of all currently available data shows no statistically significant association at all (relative risk from 11 studies 1.02, 95% limits 0.93-1.12). Nor do the data support an association with childhood ETS exposure (Relative risk from 11 studies 0.94, 95% limits 0.84-1.06). Risk assessments which concentrate solely on the evidence based on spousal ETS exposure, with all its inherent problems of bias arising from smoking habit misclassification and from confounding, and which ignore the evidence from workplace ETS exposure and from childhood ETS exposure are obviously highly biased.

Repace (1992), in his latest contribution to the correspondence arising from Wells' seminal paper (1988), states that I continue "to insist that the shape of the dose-response relationship between tobacco smoke exposure and lung cancer risk is linear over the three orders of magnitude dose range between active and passive smoking". Not so. I merely noted the approximate linear relationship observed epidemiologically between number of cigarettes smoked actively and risk of lung cancer, the detailed arguments that have been presented in support of *low-dose* linearity (Peto 1977), and the fact that the EPA recommend for routine use in risk assessment a dose-response relationship that becomes linear at *low doses* (Anderson et al. 1983). Actually I find Doll and Peto's (1978) arguments in favour of a quadratic component in the dose-response relationship quite compelling, and I suggest Repace and Lowrey study these authors' reasons for rejecting in model-fitting the data indicating an apparent drop-off in response at very high numbers of cigarettes smoked.

The sublinear relationship that Repace fits, though it provides a reasonable fit to the observed data from CPS-II, is unattractive for a number of reasons. Not only is it not linear at low doses, and not only does it ignore Doll and Peto's reasons for rejecting the data for very heavy smokers, but it does not provide for any background risk at all. To assume *all* lung cancer deaths in smokers and non-smokers alike are due to exposure to cigarette smoke is, to say the least, an extreme view! Even using this implausible formula, it is notable that Repace still does not explain the anomaly that started this branch of correspondence off in the first place - namely the fact that the epidemiological data (if assumed to be unbiassed) suggests an excess lung cancer risk in relation to ETS exposure 10-20% of that associated with active smoking, while the dosimetric data suggest a factor orders of magnitude lower. Assuming non-smokers married to smokers have about three times the ETS exposure of non-smokers married to non-smokers, one can readily calculate from Repace's formula that any claimed risk from ETS should be no more than about 3% of that reported for active smoking. Using a more appropriate formula, which takes account of background, and becomes linear at low doses, would produce an estimate of around 0.5%. And even this is probably as overestimate, as Repace's estimates of average tar exposure of non-smokers is higher than that of other workers (Lee 1992a).

The overall picture is quite clear. Marriage to a smoker is an index of exposure to ETS which produces estimates of lung cancer risk which are considerably biased. The claim that exposure to ETS increases risk of lung cancer among non-smokers remains unconvincing.

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AN ESTIMATE OF ADULT MORTALITY IN THE UNITED STATES FROM PASSIVE SMOKING: A FURTHER REPLY

Dear Editor:

In his letter, Lee (1993) questions my paper (Wells 1988) on deaths in the U.S. from passive smoking, although the attack this time is centered more on the Wells/Stewart method of calculating misclassification bias as presented in the recent draft on lung cancer from passive smoking issued by the U.S. Environmental Protection Agency (USEPA 1992). As noted in that report, there are three key factors that determine the misclassification bias, namely: (1) the fraction of true smokers who are misclassified as never smokers, i.e., the misclassification rate; (2) the active smoker relative risk; and (3) the fraction of the population who are smokers. Further, it is noted that with the same data inputs, the Wells/Stewart mathematical model yields essentially the same results for the bias as the latest Lee mathematical model (Lee 1991). Hence our differences, which are large, now have entirely to do with the input data.

With regard to misclassification rates, it is curious that Lee (1984) and I (Wells 1986) started out with simple misclassification rates, namely, the percent of ever smokers misclassified. Then Lee (1987) made a great advance when he divided the misclassifieds into: (1) current regular smokers; (2) current occasional smokers; and (3) ex-smokers, because, as he said at the time, "most of the estimated bias comes from subjects who...are surely regular smokers". Since then our paths have diverged. We have sought studies where, with the cooperation of the authors, we have been able to determine the cotinine levels of each individual current smoker misclassified as a never smoker, so we could distinguish accurately the misclassified regular smokers from the misclassified occasional smokers. We have developed mathematics to deal with the three types of misclassification. Meanwhile Lee (1991) has retreated to mathematics which can handle only one type of misclassification and has chosen as his single measure (Table 2, Lee 1993) a mixture of misclassified smokers, namely all current smokers plus ex-smokers who are misclassified either as never or as ex-smokers. The latter point is important because the passive smoking methodology deals essentially entirely with never smokers. The inclusion of smokers misclassified as ex-smokers introduces an unnecessary element of uncertainty in the level of misclassification among never smokers.

The studies in Table 2 of Lee (1993) listed as used by us were not, as Lee says, "selected". They included all of the studies of females where we could get cotinine levels of individual misclassified smokers, except the item "Riboli, other regions" where we decided to limit ourselves to the countries of interest, namely the U.S., Greece, Japan, Hong Kong, and China. By our criteria of counting as misclassified smokers only those with cotinine levels greater than 10% of self-reported smoker mean, the "Riboli, other regions" should be 21/613 = 3.4%, not the 43/612 = 7.0% shown by Lee. The studies we used represent a good cross section with misclassification rates from 0.9% (Lee's basis) among white women in Maine to 4.9% for Hispanics in New Mexico. Misclassification rates usually run higher among minority groups. Lee (1993) is wrong in stating that no reason was given in USEPA (1992) for omitting Haddow et al. (1987). The reason given was that the authors recommended that the study not be used for smoker misclassification purposes (private communication from G.J. Knight). The smoking status data were taken from laboratory slips and were used simply to simulate what might happen in routine clinical practice where anyone handy could have filled out the slips and where it could have been done weeks or months in advance of drawing the blood sample. We tried to get individual cotinine data from the Slattery and Wagenknecht groups but were unsuccessful. We also tried the Pojer group (Pojer 1984), but were advised that their basic data had not been retained. Going down the list in Table 2 of Lee (1993), the Heller study was not available to us. Little is known about the Sears study except that it was commissioned by the R.J. Reynolds Tobacco Company, and the misclassification rate they observed for female regular smokers reporting as never smokers was five times the average of the values found in the seven studies cited by us. The Wagenknecht et al. (1992) paper reports 49 of 1750 white nonsmokers (never plus ex), or 2.8%, were misclassified. For blacks, the rate was 96/1695 = 5.7%. I don't know where Lee (1993) got his 62/1723 = 3.6%. Lee's data from Woodward et al. have been hard to track. There are no misclassification data in the Woodward reference cited by Lee (Woodward 1991) for either males or females. In a companion paper, Woodward and Tunstall-Pedoe (1992) report an overall preferred "deceiver" rate of 2.2% for males plus females and never smokers plus ex-smokers, using a combination of serum cotinine, carbon monoxide, and thiocyanate tests. There were

3977 subjects of which 55% (2187) were female. I don't know where Lee (1993) got his 51/2271 = 2.2%. Woodward and Tunstall-Pedoe (1992) used a low cut point of 14.7 ng/mL, or about 5% of usual smokers' mean serum cotinine level, to distinguish true non-smokers from smokers, but stated that cut points up to 30 ng/mL were also satisfactory. At 30 ng/mL, there would be far fewer "deceivers'. Woodward and Tunstall-Pedoe (1992) was supported in part by the Tobacco Products Research Trust.

The hazards of using a mix of data taken from males plus females and smokers misclassified both as ex-smokers and never smokers are illustrated by the cotinine data of Perez-Stable et al. (1992).They found 12 smokers to be misclassified as never or ex. Only three were true regular smokers, and all three were male self-reported ex-smokers. Of the remaining nine, only three were women. Two of the nine (gender not reported) had cotinine levels marginally above the 30% of the self-reported smokers' mean which we use to distinguish occasional smokers from regular smokers, so they were very light regular smokers.

In summary, we believe our misclassification rates are the best that have so far been obtained and are much more accurate than those provided by Lee's approach. Further, we believe that these rates are high relative to the actual misclassification rates in the passive smoking studies for the reasons discussed in Wells (1991).

Incidentally, Lee (1993) states we are in error to apply Occidental misclassification rates to Oriental studies because he believes the Oriental rates to be much higher. However, the Riboli et al. data for Japan, China, and Hong Kong in Table B-3 of USEPA (1992) indicate 3/350 = 0.86% of ex- plus never smokers misclassified (Lee' basis) vs. 75/4099 = 1.83% for all the studies cited in Table B-3. This hardly indicates that these Asian countries have misclassification rates substantially higher than those of the West.

So far we have discussed only misclassification rates, just one of the three important parameters cited above. Lee is silent on the other two. Yet, in the ten U.S. studies cited both in Lee (1991), on which Lee (1993) is based, and USEPA (1992), he has used a higher smoker risk in six including all four of those

Table 1. Differences in data input between Lee (1991, 1993) and Wells/Stewart (USEPA 1992) for the four U.S. passive smoking studies of females that have the highest statistical weight.

Study	Per cent of U.S. weight	Misclassification rates (Lee's basis)		Ever smoker relative risk		Smoker prevalence	
		Lee	EPA	Lee	EPA	Lee	EPA
Fontham (1991)	35	2.5	0.5[a]	9.04	8.0[b]	49	42[c]
Garfinkel (1981)	25	2.5	1.5	9.27	3.5[d]	49	33[e]
Garfinkel (1985)	15	2.5	1.5	9.15	6.0[f]	49	46[g]
Janerich (1990)	10	2.5	1.5	10.32	8.0[b]	49	46[g]

[a] Assumes no misclassification of current smokers; they were eliminated by cotinine test.

[b] Based on an average of seven U.S. smoking studies and one U.K., average date data was gathered was 1982.

[c] Based on national statistics for age range of cases.

[d] From 12 year follow-up in 1982 U. S. Surgeon General's report.

[e] From Hammond (1966).

[f] A typical U. S. female smoker risk for 1976, the average year the data were gathered.

[g] From national statistics for 1985.

with the highest statistical weight. For the Garfinkel (1981) cohort study, his excess smoker risk is high by a factor of 8.27/2.5 = 3.3. For the same study he is using a female smoking prevalence of 49% when the predecessor paper (Hammond 1966) shows 33%. These differences are detailed in Table B-2 of USEPA (1992) and in Table 1. These errors together with his bloated misclassification rates explain the difference between his estimates of smoker misclassification bias (1.18 for the U.S. studies) and our 1.04.

Lee is also silent concerning Table 1 in my 1992 letter (Wells 1992) where it was shown that errors I had pointed out earlier and that he now admits reduced his estimate of smoker misclassification bias for combined worldwide studies from 1.24 (Lee 1987) to 1.02. Fortunately, he is no longer using these erroneous procedures. We also recommended that he use female misclassification data to correct female passive smoking relative risks, a step that he has almost accomplished in his current Table 2.

Lee states that my comments (Wells 1992) on highest exposures are misleading. For a list of ten studies with significant trends, see USEPA (1992) Table 5-11. Lee thinks that higher smoker-smoker concordance can explain the high exposure relative risks in the 1.8-2.2 range, but he presents no data or calculations to support his assertion.

Lee's comments on diet are qualitative and not nearly as persuasive as the data presented in USEPA (1992) pp. 5-22 to 5-24 and Table 5-13 showing that the passive smoking studies are not confounded by diet. Since USEPA (1992) was issued, Fontham et al. (1992), for their large U.S. study, have stated that "it does not appear that dietary intake of β-carotene is related to the spouse's smoking habits".

Lee is correct that a meta-analysis of the better studies of the effects of ETS in the workplace indicates a relative risk of 1.0. However, like the latitude effect in the household studies (Wells 1992), the workplace studies in more suitable climates and cultures (Kalandidi et al. 1990, Greece, OR = 1.7; Fontham et al. 1991, southern U.S., OR = 1.34; Shimizu et al. 1988, Japan, OR = 1.2) show higher relative risks than those from less suitable places (Garfinkel et al. 1985, northern U.S., OR = 0.93; Kabat 1990, northern U.S., OR = 1.00; Lee et al. 1986, U.K., OR = 0.63; Janerich et al. 1990, northern U.S., OR = 0.91) where the passive smoking signal is more likely to be overpowered by background effects.

Leaving all the arguments about misclassification and bias aside, Lee is still faced with (1) the recent work of Reif et al. (1992) showing that dogs living in a house with smokers have more lung cancer than dogs living in a house with no smokers; and (2) the recent paper by Trichopoulos et al. (1992) showing that female never smokers exposed to ETS have more epithelial, possibly precancerous, lesions in their lungs than never smokers not exposed to ETS.

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BOOKS

Proceedings of the International Conference on Industrial Waste Minimization '92. Pen-Chi Chiang, Yang Ku, Kevin Shang-Lien Lo and Dyi-Hwa Tseng, eds. National Taiwan University, Taipei, 1992. 568 pp. $50.00 hardcover English version; $50.00 softcover Chinese version.

Waste minimization, including source reduction and waste reuse and recycle, is more effective in reducing environmental damage, human health risk, liability, and cost than control at the end of the pipe. The papers published in this book evaluate the environmental policies and regulations in various countries of hazardous and solid wastes, source reduction, and recycling; they discuss various incentives, limitations, and options with respect to the successful implementation of waste minimization approaches. The book can be divided into three sections covering the following topics.

The first topic deals with "Waste Minimization Strategies and Tools for Government", an overview on how regulation procedures can be used for enforcement of waste minimization actions.

The second section is devoted to the problem of "Waste Minimization in Industry". In this section, an overview of problems related to the implementation of waste minimization programs in industry is given. Special attention is paid to the problem of waste reduction vs. legal liability and to activities and programs within industry to reduce hazardous waste generation.

The third section is devoted to the presentation of case studies of successful waste minimization and waste reduction techniques and technologies, as well as economic analyses of waste minimization. A significant number of papers in this section comes from Taiwan. That country has undertaken extensive efforts to clean up the environmental damage caused by intensive development. Now step-by-step, recycling and reuse approaches are implemented in various small businesses based on Taiwan's own technical and technological solutions. Similar approaches are observed in Iran, India, and Thailand. A few papers from England, South Africa, and Australia focus on solutions for a wide international market.

This book is a valuable source of information on methods of minimizing the amount of wastes through technical and technological means and methods to force industry to minimize waste by legislative means. Additionally, the book provides information about waste problems in fast-developing countries.

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Chemistry for the Protection of the Environment. Vol. 42 in the Environmental Science Research Series. L. Pawlowski, W.J. Lacy, and J.J. Dlugosz, eds. Plenum Press, New York, N.Y., 1992. 824 pp. (ISBN 0-306-43904-2) $149.50 ($179.40 outside USA and Canada).

Environmental Chemistry is an important area of the protection of the environment. Most changes about humans or within humans are chemical. So, understanding changes in the environment would be impossible without understanding the chemistry.

Thus, it is not surprising that chemists around the world are involved in studies focused on the degradation as well as restoration of the environment. For more than a decade, scientists from all over the world have been meeting every second year in serial conferences on *Chemistry for the Protection of the Environment.*

During each of these conferences, chemical aspects of the degradation of the biosphere and attempts to restore the environment are discussed. Proceedings of the 7th Conference held in Lublin, Poland in 1989 have just been published by Plenum Press as Vol. 42 of the *Environmental Research Science Series.*

The Conference was an interdisciplinary approach to environmental problems, particularly those of the aquatic environment. Special attention was given to the joint U.S.-Polish projects on new methods of analysis and application of ozone treatment technology to water and wastewater. Problems faced by Eastern European countries, important while approaching Common Europe with its high standards of environmental quality, have been of special interest.

Chemical methods for the protection of the environment were categorized in the following main groups: hydrologic and geochemical implications of waste disposal scenarios; monitoring methods for surface and ground water and analysis of pollutants; pathways of chemicals in the environment; application of ion-exchange processes for water preparation; coagulation, flocculation, and sorption processes in water and wastewater treatments; and application of oxidation-reduction processes for pollution control in water.

Some attention was also given to other chemical methods applicable to environmental processes or pollutant removal.

The book is a valuable source of information for scientists working in the environmental protection area.

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A Directory of European Environmental Organizations. Mireille Deziron and Leigh Bailey. Blackwell Publishers, Cambridge, MA, 1991. 177 pp. (ISBN 0-631-18386-8) $59.95 hardcover.

This useful directory provides a listing of organizations with the European community concerned with environmental issues. It includes the names and addresses of key officials in Europe. It also provides a listing of international, national, governmental, and nongovernmental organizations, including structural charts of their complex organizations. A useful feature of the book is a description of the functions of these organizations. This book is recommended as a library reference.

Marine Ecology of the Arabian Region. Charles Sheppard, Andrew Price, and Callum Roberts. Harcourt Brace Jovanovich, London, 1992. 359 pp. (ISBN 0-12-639490-3) £29.95/$64.00 hardcover.

In this book, the authors present an overview of the available information on the area, review the processes at work in the various marine and intertidal systems, and consider the human dimension in the region. Some of the world's poorest as well as richest nations border these seas, making diverse claims on their resources and subjecting the region to a variety of pressures. This part of the Indian Ocean bordering Arabia is a rich and complex ecosystem of coral reefs, mangrove coastlines, and deeper water communities. Only reunited with the Indian Ocean by quite recent rises in sea level, it contains both areas of relative simplicity and areas where certain species' assemblages are surprisingly diverse. The area divides into several large semi-enclosed water bodies, leading to quite distinct habitats in proximity to each other. The overall aridity of the surrounding land areas makes these seas some of the most extreme marine climates on earth. Due to its oil resources and rich marine life, this area is of considerable interest to those who are concerned with the development and protection of human health and the environment. This book is recommended as a library reference and as a desk copy for those concerned with the marine environment.

Restoring the Land. Environment and Change in Post-Apartheid South Africa. Mamphela Ramphele, ed. Panos Publications Ltd., London, 1991. 216 pp. (ISBN 1-870670-27-2) £7.95 softcover.

This book claims that apartheid has played a major role in the degradation of the South African environment. The results of apartheid are overcrowded townships, smog-thickened air, eroded soils that are ravine-scarred and stripped of vegetation, people and land threatened by uncontrolled disposal of toxic waste, polluted rivers, and the misuse of pesticides. The book is written by South Africans from trade unions, universities, community groups, environmental advocates, and members of the media. They contribute examples of how decades of inequality, resettlement policies, and overuse of natural resources have resulted in careless disregard for the environment. The problems to be tackled are immense, as the book claims. Several cases illustrate the potential for change. For example, the Richtersveld National Park now involves local people in its management following negotiations between the government's National Parks Board and the local community. The contributors put forward priorities for future action. One of the greatest challenges facing the future leadership of South Africa will be to balance the demand for more equitable development with the urgent need to address environmental problems.

Rethinking the Ozone Problem in Urban and Regional Air Pollution. National Research Council. National Academy Press, Washington, D.C., 1991. 489 pp. (ISBN 0-309-04631-9) $47.95 hardcover.

Despite more than 20 years of regulatory efforts, concern is widespread that ozone pollution in the lower atmosphere, or troposphere, threatens the health of humans, animals, and vegetation. This report describes how scientific information can be used to develop more effective approaches to control ozone. It covers the latest data and analysis on how tropospheric ozone is formed, how accurately it is measured, deficiencies in efforts to control the problem, promising approaches to reducing ozone precursor emissions, and what additional research is needed. With a wealth of technical information, the book discusses atmospheric chemistry, the role of oxides of nitrogen and volatile organic compounds in ozone formation, monitoring and modeling the formation and transport processes, and the potential effects of alternative fuels on the tropospheric ozone problem. In addition, the committee provides criteria for designing more effective ozone control efforts. This most useful report is highly recommended as a library reference and as a desk copy for those concerned with atmospheric ozone pollution.

Soil Vapor Extraction Technology. Tom A. Pedersen and James T. Curtis. Noyes Data Corporation, Park Ridge, N.J. 1991. 316 pp. (ISBN 0-8155-1284-8) $54.00 hardcover.

This book is a reprint of a report prepared for the U.S. Environmental Protection Agency. It consists of papers presented at a workshop held in June 1989. The text is also available from the National Technical Information Center in Springfield, VA.

Valuing the Environment. Economic Approaches to Environmental Evaluation. Annabel Coker and Cathy Richards, eds. Belhaven Press, London, 1992. 183 pp. (ISBN 1-85293-2120) £35.00 hardcover.

This volume is the result of a multidisciplinary workshop held by Middlesex Polytechnic's Flood Hazard Research Centre in May 1990. The workshop was designed to bring together those concerned with economics and environmental protection working in the field of coastal management. They addressed various issues raised by the problem of how to value coastal environments. A major achievement of this workshop was to bring together specialists from disparate backgrounds to clarify the issues relating to the present situation relative environmental evaluation and site assessment and to the direction of future research. The workshop also attempted to clarify terminology and agree upon definitions of terms in common usage, such as the distinction between evaluation and valuation.

Characteristics of Potential Repository Wastes. Oak Ridge National Laboratory. U.S. Dept. of Commerce, Springfield, VA. 22161; 1992. Vols. 1-4, (DOE/RW-0184-R1) softcover.

Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards. International Atomic Energy Agency. Unipub, Lanham, Md. 20704-4391; 1992.74 pp. $40.00 plus postage softcover.

Gender Bias: Roadblock to Sustainable Development. Jodi L. Jacobson. Worldwatch Paper 110. Worldwatch Institute, Washington, D.C.; 1992. 60 pp., $5.00 softcover.

Issues in the Environment. Kristine Napier, ed. American Council on Science and Health, Inc. New York, NY 10023-5860; 1992. 91 pp., softcover.

Issues in Tobacco. Kristine Napier, ed. American Council on Science and Health, New York, NY 10023-5860; 1992. 77 pp., softcover.

Materialienband zur Radioaktivität in Trinkwasser, Grundwasser, Abwasser, Klärschlamm, Reststoffen und Abfällen. (Material Volume and Radioactivity in Drinking Water, Underground Water, Waste Water, Sludge, Leftover Materials, and Waste.) S. Abelmann, T. Bünger, H.U. Fusban, H. Rühle, H. Viertel, I. Gans. Institut für Wasser-, Boden- und Lufthygiene Bundesgesundheitsamtes. Berlin, Germany; 1991. softcover.

Phytotoxizitätsuntersuchungen an Wildkräutern und einer Kulturpflanze. (Phytotoxicity Studies on Wild Herbs and on a Cultured Plant. A. Marschner. Gustav Fischer Verlag, Stuttgart/New York; 1992. 162 pp., softcover.

Smoking or Health...It's Your Choice. Cathy Becker Popescu. American Council on Science and Health, New York, NY 10023-5860; 1992. 26 pp., softcover.

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ERRATUM

corrected 16 Jun. 93/AP

Watanabe, I. Estimates of methane emission from large stationary combustion sources. Environment International 18, pp. 271-282; 1992.

The author regrets that on page 281 line 4, the words "7.4 Tg of methane" should be replaced by 0.74 Tg of methane. In addition, Table 4 contains several errors. The correct version of the section, "possible potential emission" is as follows:

Table 4. Estimation of removal and emission rate of methane at large stationary combustion sources (part).

" Wrong "

[Possible potential emission]

	Prod. COG or BFG(Gm^3)	Methane conc. (%)	Methane amount (Gg)	Releas. ratio(%)	Emis. rate (Mg/year)
[From coke oven through coke-oven gas (COG) release]					
World	126 [e]	25	225,000	(3)[f]	(6,750,000)
Japan	13.7[e]	25	24,464	(3)[f]	(734,000)
[From hot blast furnace through blast-furnace gas (BFG) release]					
World	576 [e]	0.5	20,571	(3)[f]	(615,000)
Japan	117 [e]	0.5	4,179	(3)[f]	(125,000)

" Correct "

[Possible potential emission]

	Prod. COG or BFG(Gm^3)	Methane conc. (%)	Methane amount (Gg)	Releas. ratio(%)	Emis. rate (Mg/year)
[From coke oven through coke-oven gas (COG) release]					
World	126 [e]	25	22.500	(3)[f]	(675,000)
Japan	13.7[e]	25	2,446	(3)[f]	(73,400)
[From hot blast furnace through blast-furnace gas (BFG) release]					
World	576 [e]	0.5	2,057	(3)[f]	(61,500)
Japan	117 [e]	0.5	0.418	(3)[f]	(12,500)

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NEW PATENTS

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5108590

WATER DISPENSER

Denni DiSanto

Disclosed is a self service water dispensing apparatus especially adapted to be located inside a grocery store. This apparatus includes a housing which provides a rigid support structure having a base section which has integral therewith a water storage tank, and an upper section immediately above the base section which includes a plurality of water filling stations. The upper section and base section are joined together and are contiguous with each other along a common generally horizontal plane located about waist high to a typical adult user. This provides a compact and convenient to use structure. The water filling stations each comprise a recessed cubicle having a top wall with a delivery spout therein, an open front side into which a water bottle is placed beneath the spout for filling, and a floor including a drain. Manually operable control switches are at each vending station. When one of these switches is actuated a pump is energized to pump water from the storage tank to the spout in the filling station associated with the manually operable control switch actuated. A reverse osmosis water purifying unit purifies water from a public supply source and delivers the purified water to the storage tank. A float detects when the level of purified water in the storage tank is low, causing water from a public supply source to be fed through the reverse osmosis unit. As ozone generator periodically generates ozone which is mixed with purified water in the storage tank, and a tap in the storage tank is used for dispensing the ozone treated water to a mister system for spraying produce with the ozone treated water. Spraying produce with ozonated water kills bacteria growing in the misting system. Waste water from the reverse osmosis unit is fed to the cooling tower of the refrigeration system for the grocery store, thereby conserving water.

5108593

APPARATUS FOR COLLECTING SUBSTANCES FLOATING IN AN EFFLUENT STREAM

Frank P D'Ascensio, Mario Graglia, Salvator Mayrina, Ronald Kumetz assigned to Passaic Valley Sewerage Commissioners

A hollow, floatable, hydrodynamically shaped member supports a screen in canopy-like fashion and is secured to a harness for being lowered into and raised from an effluent stream such as in a closed sewage system. The member floats on the stream and floating substances therein are collected by the screen for subsequent analysis or the like, as may be required for pollution control or related purposes. The harness includes a line for tethering the floatable member so that said member rises and falls with the rising and falling of the stream level. The hollow, floatable member has a removable cap, whereby ballast can be added or removed for adjusting the buoyancy thereof.

5108701

PROCESS FOR RAPID STERILIZATION OF BIOLOGICAL MEDIA

Zairani Zakaria, Edwin D Neas assigned to CEM Corporation

A process for rapidly sterilizing biological media, such as broths and gels used as incubation or growth media to test the presence of microorganisms, such as bacteria, includes applying microwave radiation to such an aqueous biological medium contained in a microwave transmissive pressure retaining container, such as a capped cylinder made of polytetrafluoroethylene, which cap is preferably equipped with ports, by directing the microwave radiation responsive to container pressure through the container and onto the medium in such amount that the pressure in the container and the temperature of the medium are raised above ambient pressure and temperature, and maintaining such raised pressure and temperature for a short time, usually less than ten minutes, which is sufficient to sterilize the medium. In a preferred operation the microwave heating at elevated pressure and temperature takes place for about five minutes, the microwave heating of the medium takes place in a radiation confining chamber of a microwave apparatus, a plurality of containers for the biological medium is present in such chamber, which are kept in motion by an oscillating turntable, the pressure is controlled and monitored, and after sterilization is complete the medium is controllably cooled and is poured out into an incubating container, such as a Petri dish, or into a plurality of such containers.

5111882

USE OF TRACERS TO MONITOR IN SITU MISCIBILITY OF SOLVENT IN OIL RESERVOIRS DURING EOR

Joseph S Tang, Bradford C Harker, Calgary, Canada assigned to Exxon Production Research Company

A method for monitoring in situ miscibility of a solvent with reservoir oil by using at least two tracers having different boiling points and being miscible with the solvent. The tracers are mixed with the solvent, injected into a well and produced from another well. Appropriate analysis of the produced tracers will reveal whether the solvent is first contact miscible. The tracers are selected from the group consisting of halocarbons, halo-hydrocarbons, sulfur hexafluoride, tritiated or carbon 14 tagged hydrocarbons, tritium gas and radioactive isotopes of inert gases.

5109665

WASTE HEAT RECOVERY BOILER SYSTEM

Shinichi Hoizumi, Tsugutom Teranishi, Hitachi, Japan assigned to Hitachi Ltd

A waste heat recovery boiler system has a plurality of waste heat recovery boilers each having a main steam generator and a reheater capable of generating main steam and reheat steam by heat derived from a hot waste gas introduced into the waste heat recovery boiler. The flows of main steam from the main steam generators are joined to form a single flow of main steam to be used in an external installation, and the flows of reheat steam from the reheaters are joined to form a single flow of reheat steam to be used in the external installation. The steam discharged from the external installation is distributed to the reheaters. Flow rate controllers are provided for controlling the flow rates of the steam through the reheaters in relation to the hot waste gas supplied to the respective waste heat recovery boilers.

5112215

APPARATUS FOR COMBUSTION, POLLUTION AND CHEMICAL PROCESS CONTROL

Michael Frish, Joseph Morency, Stephen A Johnson, Arthur Boni assigned to Physical Sciences Inc

Disclosed is a system for regulating the efficiency of a combustion process by detecting radiant energy emitted from ash particles entrained in the gas stream exiting the combustion chamber of a boiler or incinerator. The intensity of selected wavelengths of light emitted from the particles is indicative of the temperature of the particles. The change in the intensities of the selected wavelengths of light, and thus of the temperature of the gas stream at the furnace exit, is monitored, and a feedback control mechanism is used to regulate one or more combustion, pollution control, or heat transfer parameters thereby maximizing the thermal efficiency of the combustion process in the boiler or incinerator.

5112477

PURIFIED WATER AND ICE DISPENSING APPARATUS

Jerry J Hamlin

A vending machine that dispenses either purified ice or purified water in predetermined quantities in response to a fixed payment by a user. The machine consists of compartmentalized sections for each specific function, comprising a water purification and storage portion, an ice making portion, an ice storage portion, and a product dispensing and control portion. Water from an outside source is processed to eliminate particulate and chemical impurities and it is stored for ready availability to purchasers. At the same time, a portion of the purified water is converted to ice and similarly stored in a separate compartment. Just prior to dispensation to a purchaser, the water is further treated by ultraviolet radiation to eliminate micro-organisms. As the supplies of either water or ice are depleted, the machine automatically replenishes them by processing more feed water.

5113770

APPARATUS FOR INCINERATING WASTE MATERIALS

Murray C Godbe, Howard H Nichols

The waste incinerating system of Nichols U.S. Pat. No. 3,905,312 issued Sep. 16, 1975 is improved to prevent decreases in combustion temperature to an extent such that there is a danger of flame-out and consequent choking of the furnace chamber with wastes fed into such furnace chamber for incineration. A substantially immediately responsive, radiation sensing control, normally in the form of a standard radiation pyrometer focused on a radiation-responsive target in the furnace chamber, is incorporated in the system to augment fuel supply substantially immediately when required.

5114277

VITRIFIED UNDERGROUND STRUCTURES

Mark Murphy, James Buelt, James A Stottlemyre, John S Tixier assigned to Battelle Memorial Institute

A method of making vitrified underground structures in which 1) the vitrification process is started underground, and 2) a thickness dimension is controlled to produce substantially planar vertical and horizontal vitrified underground structures. Structures may be placed around a contaminated waste site to isolate the site or may be used as aquifer dikes.

5116401

HERBICIDE AND METHOD WITH THE GLYPHOSATE-UREA ADDUCT OF SULFURIC ACID

Donald C Young assigned to Union Oil Company of California

Herbicidal compositions are provided which contain combinations of glyphosate (N-(phosphonomethyl)glycine) and sulfuric acid, and/or combinations of glyphosate, sulfuric acid and a chalcogen-containing compound of the formula R1-CX-R2 wherein X is a chalcogen compound of the formula R1-CX-42 wherein X is selected from oxygen and sulfur, R1 and R2 are independently selected from hydrogen, monovalent organic radicals, NR3R4 and NR5, at least one of R1 and R2 being NR3R4 or NR5, R3 and R4 are independently selected from hydrogen and monovalent organic radicals, and R5 is a divalent organic radical. Such compositions contain reaction products of glyphosate and sulfuric acid, and/or of glyphosate, sulfuric acid and the chalcogen compound, and they may also contain excess glyphosate or sulfuric acid. They effect more rapid, more thorough, broader spectrum vegetation control, and are more stable chemically and less toxic than other phyphosate-containing herbicides.

5116414

LONG-TERM CONTROL OF ROOT GROWTH

Frederick G Burton, Dominic A Cataldo, John F Cline, W Eugen Skiens assigned to Battelle Memorial Institute

A method and system for long-term control of root growth without killing the plants bearing those roots involves incorporating a 2, 6-dinitroaniline in a polymer and disposing the polymer in an area in which root control is desired. This results in controlled release of the substituted aniline herbicide over a period of many years. Herbicides of this class have the property of preventing root elongation without translocating into other parts of the plant. The herbicide may be encapsulated in the polymer or mixed with it. The polymer-herbicide mixture may be formed into pellets, sheets, pipe gaskets, pipes for carrying water, or various other forms. The invention may be applied to other protection of buried hazardous wastes, protection of underground pipes, prevention of root intrusion beneath slabs, the dwarfing of trees or shrubs and other applications. The preferred herbicide is 4-difluoromethyl-N, N-dipropyl-2, 6-dinitroaniline, c ommonly known as trifluralin.

5117116

METHOD AND DEVICE FOR MONITORING UV RADIATION

John E Bannard, Dennis D Maguire, Nottingham, United Kingdom assigned to Cybrandian Limited

A device for monitoring UV radiation received by the skin comprises a housing. Adhesive on a face of the housing secures the device to the skin. A patch of irreversible UV sensitive material which changes color on being subjected to UV radiation is applied to an inner surface of the housing and receives UV radiation reflected from the skin. The color of the UV sensitive patch is compared with reference colors on the housing for determining the quantity of UV radiation to which the skin has been subjected.

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Software Survey Section

Editor's Note: The following Software Description has been submitted by our readers in response to our call for an open exchange of information on software programs. It is offered without review or comment to provide a rapidly published, easily accessible avenue of communication. Other readers with relevant software packages are invited to complete and submit a Software Description Form (found at the end of this section).

Software Package EI-060-S92

DELTA

Contributor: Instituto Vasco de Estudios e Investigation (IKEI), General Concha 7, 1 Izda., Bilbao, Vizcaya, Spain

Brief Description: DELTA provides a new tool designed to give all the information on local, national and E.E.C. environmental laws. The data base contains a list of environmental laws and the limits imposed by these laws, which can be modified by the user. As there is an industrial classification for each product-process line a list of the limits can be obtained. A file containing a list of companies can be created, together with their fuel consumption, type of industry (industrial classification) and other general data. Therefore, the software gives the possible impact and the laws affecting each company. Thus, it can be considered a very useful tool for environmental assessment.

Demonstration disk is available.

Potential Users: Environmental agencies.
Fields of Interest: Industry, environmental assessment.

** This application program in the area of environmental assessment has been developed in CLIPPER to run under DOS 3.1 or higher. It is available on 5-1/4", 1.2MB density floppy diskette. Required memory is 6MB.

** Distributed by contributor.

** User training is required. It is self-documenting. Source code is available.

** The package is fully operational. It has been in use at 2 sites for approximately 6 months. The contributor is available for user inquiries.

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SOFTWARE DESCRIPTION FORM

Title of Software Program: ____________________

Contributor: ____________________

Institution: ____________________

Address: ____________________

____

Telephone: ____________________

Type of program: [ ] Application [ ] Utility [ ] Other ____________

Category: ____________________ (ie., Psychological assessment, statistics, thermodynamics, etc.)

Potential users: ____________________

Field/s of interest: ____________________

Developed for (name of computer/s): ____________________

in (language/s): ____________________

to run under (operating system): ____________________

available on: [ ] Floppy diskette Specify:

Size ________ Density ________ [ ] Single-sided [ ] Dual-sided

[ ] Magnetic Tape Specify:

Size ________ Density ________ Character set ____________

Hardware required:

Memory required: ____________ User training required: [ ] Yes [ ] No

Documentation: [ ] None [ ] Minimal [ ] Self-documenting

[ ] Extensive external documentation

Source code available: [ ] Yes [ ] No

Stage of development: [ ] Design complete [ ] Coding complete

[ ] Fully operational [ ] Collaboration welcomed

Is program in use? [ ] Yes How long? _____ How many sites? ____________

[ ] No

Is the contributor available for user inquiries?: [ ] Yes [ ] No

Distributed by: ____________________

Cost of program: ____________________

Demonstration disk available? [ ] Yes Cost: ____________

[ ] No

(continued)

Description of what software does (maximum of 200 words):

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Sir Arthur Watts, KCMG, QC

formerly The Legal Adviser, Foreign and Commonwealth Office, London

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A Selection of Papers
P. J. MASON (UK), Large-eddy simulation of dispersion in convective boundary layers with wind shear.
T. VESALA & J. KUKKONEN (Finland), A model for binary droplet evaporation and condensation, and its application for ammonia droplets in humid air.
J. P. GARCIA, S. BEYNE-MASCLET, G. MOUVIER & P. MASCLET (France), Emissions of volatile organic compounds by coal-fired power stations.
G. J. D. KIRK & RACHHPAL-SINGH (Philippines), Simultaneous transfer across an air-water interface of gases that interact through acid-base reactions.
D. M. LEAHEY & M. C. HANSEN (Canada), Estimates of dark ecosystem respiration of CO_2 from the city of Calgary, Alberta.

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A Selection of Papers

G. SUBKLEW, J. WOLF, E. UHLIG & H. HACKFORT (Germany), Two-stage fluidized bed for the incineration of chemotoxic waste.

M. AIDENT, M. FOSTER & W. STOLTE (USA), Motco superfund site cleanup and restoration.

B. D. AMIRO & P. A. DAVIS (Canada), A pathways model to assess transport of radionuclides from terrestrial and aquatic surfaces to the atmosphere.

L. R. WATERLAND, D. J. FOURNIER Jr., J. W. LEE & G. J. CARROLL (USA), Trace metal fate in a rotary kiln incinerator with an ionizing wet scrubber.

C. R. BRUNNER (USA), Biological sludge incineration.

M. T. GALCERAN, R. RUBIO, G. RAURET & L. ALONSO (Spain), Assessment of groundwater contamination subsequent to an environmental release.

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- National and international recommendations and practices to help bring about lasting improvement in environmental protection

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Article: Repace, J.L.; Lowrey, A.H. A.quantative estimate of nonsmokers' lung cancer from passive smoking. Environ. Int. 11:3-22; 1985.

Report: NIH (National Institutes of Health). Report of the National Institutes of Health ad hoc working group to develop radioepidemiological tables. NIH 85-2748. Washington, D.C : U.S. Department of Health and Human Services; 1985.

Book: Henderson, P.M. Inorganic geochemistry. New York, NY: Pergamon Press; 1982.

Regulation: USEPA (U.S. Environmental Protection Agency). National primary drinking water regulations: fluoride. 40 CFR Parts 141, 142 and 143. Fed. Reg. 50:47142-48933; 1985.

Proceedings: Swedjemark, G.A.; M.jönes, L. Exposure of the Swedish population to radon daughters. Berglund, B.; Lindvall, T.; Sundell, J., eds. Proc. 3rd international conference on indoor air quality and climate. Vol. 2. Stockholm: Swedish Council for Building Research; 1984:37-43.

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Marine Pollution Bulletin is concerned with the rational use of maritime and marine resources in estuaries, the seas and oceans, as well as with documenting marine pollution and introducing new forms of measurement and analysis. A wide range of topics are discussed as news, comment, reviews and research reports, not only on effluent disposal and pollution control, but also on the management and protection of the marine environment in general. A distinctive feature of the *Bulletin* is the number of different categories of articles which are published. Papers (*Reports*) form the core of the journal, while *Baselines* document measurements which are expected to have value in the future. *Reviews* are generally invited by the editors on subjects which cross traditional lines, but suggestions for topics are welcomed. *Viewpoints* are a less formal forum for scientists to comment freely on matters of relevant national and international importance. The *Laws of the Sea* column explains and comments on new or impending national and international legislation relating to the use of the sea. Other sections of the *Bulletin* include *News, New Products, Thesis Records, Conference Reports, Conference Diary* and *Book Reviews.*

A Selection of Papers (*Reports*)
M. EKKER, S.-H. LORENTSEN & N. RØV (Norway), Chronic oil-fouling of grey seal pups at the Froan breeding ground, Norway.
H. HERAS, R. G. ACKMAN & E. J. MACPHERSON (Canada), Tainting of Atlantic salmon (*Salmo salar*) by petroleum hydrocarbons during a short-term exposure.
N. YAMASHITA, T. SHIMADA, S. TANABE, H. YAMAZAKI & R. TATSUKAWA (Japan), Cytochrome P-450 forms and its inducibility by PCB isomers in black-headed gulls and black-tailed gulls.
Laws of the Sea
G. PLANT (UK), Legal aspects of deliberate marine pollution during the Gulf War.
Viewpoints
R. A. KENCHINGTON (Australia), Decision making for marine environments.
A. R. D. STEBBING (UK), Environmental capacity and the precautionary principle.
Baselines
G. C. CRIPPS (UK), Baseline levels of hydrocarbons in seawater of the Southern Ocean: natural variability and regional patterns.
J. G. SINGH, I. CHANG-YEN, V. A. STOUTE & L. CHATERGOON (West Indies), Hydrocarbon levels in edible fish, crabs and mussels from the marine environment of Trinidad.

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