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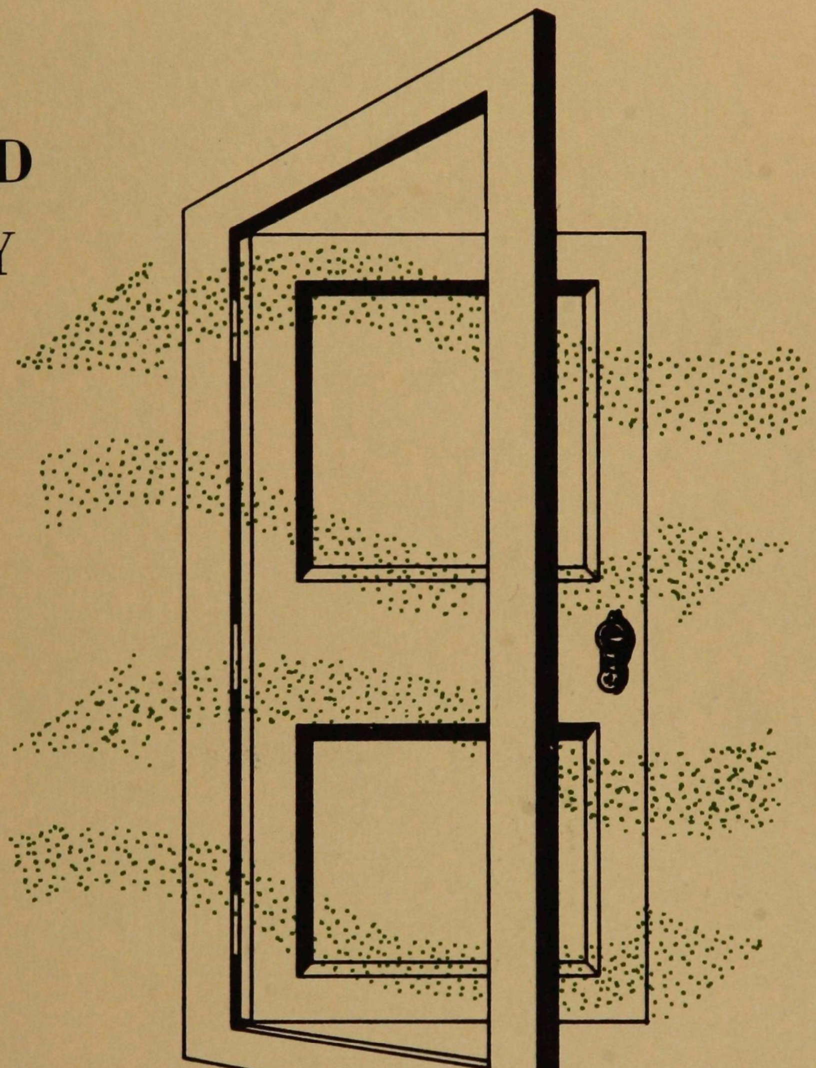
INDOOR-OUTDOOR AIR POLLUTION RELATIONSHIPS: Volume II, AN ANNOTATED BIBLIOGRAPHY



U.S. ENVIRONMENTAL PROTECTION AGENCY

INDOOR-OUTDOOR AIR POLLUTION RELATIONSHIPS: Volume II, AN ANNOTATED BIBLIOGRAPHY

John J. Henderson
Ferris B. Benson
D.E. Caldwell

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FOREWORD

This bibliography was compiled over a period of years by Mr. Ferris B. Benson of the Human Studies Laboratory, National Environmental Research Center (NERC), and Mr. John J. Henderson, formerly with the NERC, but currently with the Enforcement Division, Environmental Protection Agency, Region VI. Mr. D.E. Caldwell of the Information Services Division, Office of Administration, assisted these authors in putting the abstracts in a form suitable for publication.

The authors wish to express their appreciation to Dr. R. J. M. Horton for his assistance in all phases of the preparation of this document, but especially for helping to locate sources of pertinent information.

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INDOOR-OUTDOOR AIR POLLUTION RELATIONSHIPS: AN ANNOTATED BIBLIOGRAPHY

INTRODUCTION

The following abstracts constitute an annotated bibliography of all publications containing information related to indoor-outdoor air pollution relationships that could be located by the authors. The annotations describe the scope of the studies and briefly summarize major results which are related to indoor-outdoor pollution. In addition, a brief description of the experimental procedures employed is normally included.

The publications included are arranged alphabetically by author and numbered sequentially. Following the bibliography, the publications are indexed by subject, geographical location, author, and title.

Most of the publications included in this bibliography have been reviewed in a report that was prepared as a companion document to this report. An abstract of this literature review is given as Reference 26.

BIBLIOGRAPHY

1. Adams, K.F. and H.A. Hyde. Pollen Grains and Fungus Spores Indoors and Out at Cardiff. J. Palynology. 1:67-69, 1965.

Indoor and outdoor pollen and spore samples were collected at four sites in Cathays Park, Cardiff, Wales, during June 1959, June to September 1962, and June to August 1963. The sites were as follows: (1) roof of museum in park (elevation 60 feet), (2) roof of Natural Science Building in park, 200 yards from Site 1 (elevation 47 feet), (3) first-floor room of a hospital in a built-up area 1500 yards from Site 1 and 1430 yards from Site 2, and (4) ground-floor room of building at Site 2. Indoor concentrations of pollen and spores were much lower than outdoor concentrations (0.2 to 8.4 percent of outdoor levels). These percentages are much lower than those reported in other studies.

Samples were collected using a Hirst spore trap. Windows and doors at the two inside sites were kept closed during the tests. Grass and nettle pollens and *Cladosporium, Basidispores,* and *Ascospores* were identified and counted. In none of the years of the study were indoor-outdoor samples taken at the same elevation, and only in 1963 were samples taken at the same location.

2. Air Conditioning Aids Allergy Victims. Air Cond., Heating, and Ventilation. 53:71, September 1956.

Rigid laboratory tests conducted as recommended by the pollen survey committee of the research council of the American Academy of Allergy showed that air conditioning reduced the amount of pollen in a test room by 98 percent over that registered outside at the height of the ragweed season. Despite the fact that doors were opened as much as 20 to 30 times each day, pollen counts in the air-conditioned test room averaged under 1 grain/yd^3. At the same time in a non-air-conditioned test room next door, pollen counts were as high as 37.3 grains/yd^3.

This was a very brief and highly general article based on results obtained by Dr. O.D. Chapman, professor of bacteriology at New York State University of Medicine in Syracuse. No detailed results other than those given above are included.

3. Air Filtering System Designing Committee: Studies Concerning the Effects of Atmospheric Pollution on the Indoor Environment and Measures to Prevent Pollution; The Method to Evaluate the Indoor Dust Concentration in the Building Ventilated by the Equipment with Air Filters. Air Cleaning (Tokyo). 4(5):1-31, January 1967.

Dust concentrations inside and outside an office building were measured to determine the effect of air filters installed in ventilation equipment. Two filters with high dust-removing efficiency were used. Dust-removal efficiency of the filters was calculated from upstream and downstream concentrations, and an equation for calculating the quantity of dust generated in a room was developed. The amount of dust generated was found to be proportional to the number of people in the room. Indoor suspended particulate concentration was 24 percent of outdoor concentration with air filters in operation. Particle size distributions were: inside – 99 percent less than 0.7 micron; outside – 89 percent less than 0.7 micron. This degree of cleaning was due to a relatively airtight building with a positive indoor pressure and a carefully designed air-conditioning system. With the air filters removed on one floor being sampled, the indoor concentration was found to be 76 percent of outdoors, rather than equal to outdoors, due to the back flow of cleaned air from other floors.

Dust samples were obtained with a filter paper dust sampler. Concentrations were determined by weight and optical density.

4. Berdyev, Kh. B., N. V. Pavlovich, and A. A. Tuzhilina. Effect of Motor Vehicle Exhaust Gases on Atmospheric Pollution in Dwellings and in a Main Street. Hyg. and Sanitation (Moscow). 32:424-426, April-June 1967.

Air was sampled for suspended particulates, lead, carbon monoxide (CO), and nitrogen oxides (NO_x) on one of the main traffic routes in Dushambe, Russia. The street was 33 feet wide and lined with three-story houses which were separated from the street by a single row of trees, the crowns of which reached to the third story. Simultaneous samples were taken in the living rooms of a neighboring house in its first and third stories, at the centers of the rooms, with open windows facing the street, during hours of highest traffic. Concentrations of carbon monoxide, nitrogen oxides, lead, and suspended particulates were high in both street and houses. The highest concentrations of carbon monoxide were found in the third story, those of suspended particulates and lead in the first story. Concentrations of nitrogen oxides were the same in the street and in both stories of the houses.

5. Biersteker, K., H. de Graaf, and Ch. A. G. Nass. Indoor Air Pollution in Rotterdam Homes. Int. J. Air Water Pollut. 9:343-350, 1965.

Indoor and outdoor smoke and sulfur dioxide (SO_2) concentrations from 800 paired samples for 60 houses in winter were analyzed. Concentrations of smoke in living rooms averaged 80 percent of outdoor concentrations, and those of sulfur dioxide, 20 percent. These percentages showed little or no change with increasing concentrations outdoors. The probability of having more smoke indoors than outdoors was approximately 20 percent; for sulfur dioxide, the probability was less than 2 percent. Smoking significantly increased the amount of smoke found in living rooms. Fifty percent of the homes were heated with closed coal heaters, but statistical analysis showed the heating method had no significant effect on indoor smoke or sulfur dioxide concentrations. The data do suggest, however, that faulty chimneys and heaters may play a bigger role in air pollution mortality than so far has been suspected. The data also suggest that newer homes tend to have less sulfur dioxide in the living rooms than older homes.

6. Brief, R.S. Simple Way to Determine Air Contaminants. Air Engineering. 39-41, April 1960.

The number of air changes necessary to make an enclosed contaminated space suitable for entry or the rate of contaminant build-up can be determined using an alignment chart described in this article. This technique could probably be applied to indoor-outdoor pollution relationships if concentrations remained constant over a reasonable length of time.

7. Bush, A.F. and M. Segall. Reduction of Air Pollutants in Building Air Conditioning Systems. University of California, Los Angeles, Calif.

This is a general discussion based on previous studies which are only briefly summarized. The previous studies are primarily in terms of human reaction, and indoor-outdoor concentration data are not presented. According to the authors, air-conditioning systems can be designed, built, and operated to remove air pollutants so that indoor air in buildings and vehicles will be continuously comfortable and free from stress effects of air pollution. Activated carbon treatment with adequate detention time can remove virtually 100 percent of smoke effects. A water spray cooler alone may remove up to 25 percent of oxidants, and cooling coils with low ventilation rates may remove up to 20 percent. Pollutants which can be easily removed by air conditioning include oxidants, ozone, aldehydes, heavy hydrocarbons, oxides of nitrogen, and sulfur dioxide. Several substances are not removed unless extensive pretreatment is performed; these include carbon monoxide, carbon dioxide, nitric oxide, light hydrocarbons, and hydrogen.

8. Calder, K.L. A Numerical Analysis of the Protection Afforded by Buildings against BW Aerosol Attack. Office of the Deputy Commander for Scientific Activities, Fort Detrick. Maryland. BWL Technical Study No. 2. October 1957.

A previously developed mathematical model provides a numerical analysis of the protection afforded by buildings against a biological warfare (BW) aerosol attack. The ratio of the aerosol dosage accumulated inside a building to the total dosage experienced outside is considered. The ratio covers a wide range of values of building ventilation rate, decay constant for the aerosol inside the building, and period of exposure of the building to the aerosol cloud. Two different periods of accumulation of inside dosage are also considered. One general conclusion of the analysis is that the inside dosage depends primarily on the magnitude of the total outside dosage and not on how the latter quantity is accumulated as a function of time.

References 47 and 71 contain additional evaluations of the interior effects of BW aerosols.

9. Carey, G.C.R., J.J. Phair, R.J. Shephard, and M.L. Thomson. The Effects of Air Pollution on Human Health. Amer. Ind. Hyg. Ass. J. 19:363-370, 1958.

Air pollution measurements were made in the homes of cardiorespiratory cripples and at three outdoor locations in Cincinnati from October 2 to December 17, 1956. Indoor smoke averaged 55 percent of outdoor concentrations; total indoor gaseous acid averaged 51 percent of outdoor concentrations. Indoor smoke was roughly 15 percent higher inside with windows open than with windows closed. Lowest concentrations of domestic smoke occurred between noon and 6 p.m., highest concentrations between 6 a.m. and noon, with high hourly peaks between 6 and 9 a.m. Concentrations between 6 p.m. and 6 a.m. were about 2.5 times afternoon values.

AISI tape samplers and hygrothermographs were used to take hourly measurements of smoke, temperature, and humidity both indoors and out. Wilson sequence samplers were used to obtain hourly values of total gaseous acid outdoors, and indoor sampling of gaseous acid was done on a limited bases with midget sequence samplers.

Additional results of this study are presented in References 59, 76, 77, and 78.

10. Chamberlain, A.C. In: Symposium on Plume Behavior, Int. J. Air Water Pollut. 10:403-409, 1966.

Indoor-outdoor percentages for sulfur dioxide (SO_2) and radioiodine from previous studies[5,52] are compared in terms of ventilation rate and decay constant for deposition indoors. The author concludes that walls and ceilings should provide a "perfect sink" for sulfur dioxide. For a perfect sink, the rate of sorption is controlled by the rate of diffusion across the boundary layer to the surface, and thus the level of sulfur dioxide in a room should be reduced by vigorous internal circulation of air, which would decrease the boundary-layer resistance.

11. Cleary, G.J. and G.R.B. Blackburn. Air Pollution in Native Huts in the Highlands of New Guinea. Arch. Environ. Health. 17(5):785-794, November 1968.

The degree of air pollution in native huts in the New Guinea highlands has been assessed. The average smoke density and concentrations of aldehydes and carbon monoxide measured in the eastern highlands, at an altitude of 7200 feet, were 666 $\mu g/m^3$, 1.08 ppm, and 21.3 ppm, respectively; but these figures do not include peak values of 4862 $\mu g/m^3$, 3.8 ppm, and 150 ppm which were obtained on one occasion soon after startup of the fire. Comparable average values in the western highlands, at 4000 to 5200 feet, were 359 $\mu g/m^3$, 0.67 ppm, and 11.3 ppm, respectively. Smoke density was highly correlated with aldehyde concentrations in both areas: R = +0.93 and +0.88; and with carbon monoxide: R = +0.87 and +0.72. Air pollution may be a contributing factor in the genesis and maintenance of the prevalent nontuberculous lung disease in New Guinea highlanders.

12. Creip, L.H. and M.A. Green. Air Cleaning as an Aid in the Treatment of Hay Fever and Bronchial Asthma. J. Allergy. 7:120-131, 1936.

In order to evaluate the performance of an electrostatic air cleaner during ragweed season, slides were exposed outside a hospital in Pittsburgh and in two adjoining rooms inside the hospital. The rooms were identical except that one had an electrostatic air cleaner fitted in the window. Windows and doors in both rooms were kept closed. Pollen counts in the room without the air cleaner were 9.4 percent of outside counts. In the room with the air cleaner, the count was zero. Thus, the authors concluded that the electrostatic air cleaner was 100 percent efficient in removing pollen from the air.

The results presented above were a very minor portion of the article, which dealt primarily with the operation and use of the air cleaner and its application in the treatment of hay fever and asthma patients.

13. De Fraja Frangipane, E., C.F. Saccani, and V. Turolla. Outdoor and Indoor Air Pollution. New Ann. Hyg. Microbiol. (Rome). 14(6):403-421, November-December 1963.

The article is devoted to a review and summary of work reported by other authors. The authors conclude that "the too-few investigations conducted up to 1963 describe poorly defined but important differences between the state of indoor and outdoor air pollution; probably affecting these differences are various factors such as building construction and utilization, etc." Subsequent articles by the authors will give results of original air pollution investigations.

14. Dingle, A.N. and E.W. Hewson. An Experimental Study of Ragweed Pollen Penetration. J. Air Pollut. Cont. Ass. 8:16-22, 1958.

Simultaneous indoor and outdoor ragweed pollen samples were collected from August 20 to September 9, 1955, at a field site adjacent to the North Campus of the University of Michigan at Ann Arbor. The test house was a field-office type building of frame construction built on heavy skids. The test room portion of the house was 12 feet square and had one window in the west wall and a door and window in the south wall. Twenty-two tests were conducted with window openings varying from 0 to 12 inches and average wind speeds during the tests varying from 3 to greater than 8 mph. With windows closed, average indoor-outdoor percentages varied from 18 percent for wind speeds of less than 8 mph to 71 percent for wind speeds greater than 8 mph. With windows open, indoor-outdoor percentages averaged from 34 to 68 percent for various wind speeds and window openings. The average percentage for all tests was 39 percent. The tests indicated that penetration of pollen into the test room was related to wind speed and gustiness. Penetration of pollen into the room with windows closed was quite different from that with windows open, but the amount of window opening seemed to make little difference. With windows closed, the indoor-outdoor percentage tended to remain fairly constant at around 20 percent when wind speed was less than 8 mph. As wind speed increased, the percentage increased nearly linearly from 20 percent at 8 mph to 97 percent at 15.1 mph.

The pollen samples were collected on millipore filters using a flow rate of 10 liters/min. Twelve paired indoor-outdoor samples were collected during each test. Before each test, the test room was closed and cleaned thoroughly.

15. Dworin, M. A Study of Atmospheric Mold Spores in Tucson, Arizona, Ann. Allergy. 24:31-36, January 1966.

A 1-year survey was made of the atmospheric content of fungal spores in Tucson, Arizona, using the culture plate technique. The airborne fungal spores were identified in the atmosphere and in three homes with different types of cooling systems. The spores were quantitated monthly to determine any correlation between them and climatological data. The most prevalent fungal spores in order of their frequency were *Alternaria, Pullularia, Hormodendrum, Aspergillus, Helminthosporium,* and *Penicillium*. It was not possible to establish any seasonal trend. The home with evaporative cooling showed a higher fungal spore count than did two air-conditioned homes. There was no significant difference between the spore count in a home that had an electronic air filtration unit and one which had only an air conditioner. Relative humidity was the only climatological factorwhich showed a statistically significant correlation with the monthly spore count.

16. Eichmeier, J. The Variation of the Natural Small and Large Ion Concentration Indoors. Int. J. Biometeorology. 13(1):51-60, 1969. Text in German.

Small and large ion concentrations were measured in a normal room with open or closed windows, in a windowless room, and in a windowless, metal-shielded room. A particle counter and a dot recorder were used. In the first room, the large ion concentration was higher by an open window, fluctuating between 500 and 8000 liters/m^3. It was at a maximum in the morning and afternoon, and subsided over the weekend. The maximum value coincided with the higher air pollution caused by the morning and afternoon traffic rush hours. The small ion concentration was higher by a closed window. In the windowless room, the small ion concentration was, on the average, somewhat higher than in the room with windows; the large ion concentration was lower. When the door of the room was open, the large ion concentration increased and the small ion concentration decreased. In the metal-screened room, the small ion concentration was three times as large as in the open air. Opening the door for a longer period of time increased the large ion concentration.

17. Field Study of Air Quality in Air Conditioned Spaces. Arthur D. Little, Inc. Cambridge, Mass. RP-86. March 1969.

Indoor and outdoor concentrations of particles, sulfur dioxide (SO_2),and ozone (O_3) were measured for three air-conditioned offices in Boston and Cambridge, Mass., during the 1968 air-conditioning season. There was very little improvement in ozone concentrations at any of the locations, and sulfur dioxide and particulate were significantly improved at only one location. This location had a more efficient air-cleaning system than the other two, consisting of a central unit having, in succession, an electrostatic precipitator, roll screen backing filter, water spray, and cooling coils. At the other locations, only roughing filters were employed. Interior generation of pollutants is also suspected of contributing to the difference between the offices. The office building in which improvement was noted over outside conditions is noted to be an exceptionally clean area devoted exclusively to office work where smoking is not permitted. The other two offices were in a building which housed both offices and laboratories and in which smoking was permitted.

Continuous records of indoor and outdoor particulate matter were obtained with a Gelman tape sampler. Sulfur dioxide and ozone were measured with an Atlas two-channel sulfur dioxide-ozone analyzer. Detailed tabulations are included for sulfur dioxide and ozone, but particulate sampling results are presented only graphically.

Two additional research phases were recommended as a result of this study. Results of the first are described in Reference 18.

18. Field Study of Air Quality in Air Conditioned Spaces, Second Season (1969-1970). Arthur D. Little, Inc. Cambridge, Mass. RP-86. February 1970.

This is a continuation of the study reported in Reference 17. Three additional air-conditioned offices in Boston, Mass., were sampled for particulate, sulfur dioxide (SO_2), and ozone (O_3) using the same equipment and procedures described in Reference 17. These buildings were sampled during both the air-conditioning and the heating seasons. Decreases in particulate concentrations indoors relative to outdoors were found to be related to the cleaning efficiency of the air-conditioning system. The more sophisitcated (and expensive) the system, the better the job. Indoor sulfur dioxide concentrations were reduced to 60 percent of outdoor levels without air conditioning. Water sprays in the air-conditioning system were required to effect further reductions, but reductions to 30 percent of outside levels could be obtained with sprays. Indoor ozone levels without air conditioning were about 50 percent of outside levels. Air-conditioning systems with electronic precipitators tended to increase this value, but never enough to be of concern. Outdoor changes in particulate concentrations were found to follow a well defined diurnal pattern, being lowest at night and rising to midday peaks, normally at about 11:00 a.m., which were 2 to 3 times higher than nighttime levels. Similar peaks were identified for the gases, but they did not occur on such a regular daily basis. Indoor concentrations of both particulate and the gaseous pollutants were found to respond promptly to outdoor changes, even when outdoor levels changed by a factor of 4 to 5 within 1 to 2 hours. The author was surprised to find that outdoor particulate concentrations were higher in winter than summer at only one of the sites investigated. Outdoor sulfur dioxide concentrations were higher in the winter at all three sites. Ozone levels were not greatly different, but did show higher peak values during the winter.

Additional research under a wider range of more carefully controlled conditions is recommended on the basis of this study.

19. Flensborg, E.W. and T. Samsoe-Jensen. Studies in Mold Allergy; 3. Mold Spore Counts in Copenhagen. Acta Allergologica (Copenhagen). 3:49-65, 1950.

Outdoor spore samples were taken by exposing petri dishes, containing agar with extract of malt, twice daily for 15 minutes from March 1947 to January 1949 at 60 cm above ground in a garden in Copenhagen. Indoor samples were taken in various rooms in the homes of asthmatic children during November 1947, February 1948, and May 1948. Comparisons of indoor and outdoor concentrations can be made based on the results presented. However, it should be noted that only 19 indoor samples were taken during 3 months, whereas 1342 outdoor samples were taken during nearly 2 years. Several of the spores identified were found to have seasons, and the phasing of these seasons relative to the indoor sampling periods also affects the comparisons. The most common mold found outdoors was *Hermodendron* (53 percent of the total colonies found), followed by *Pullularia* (18 percent), *Penicillium* (15 percent), *Alternaria* (2.6 percent), and *Phoma* (1.5 percent). Indoors, the most common mold was *Penicillium* (59 percent), followed by *Aspergillus* (14 percent), *Hermodendron* (12 percent), *Pullularia* (10 percent), *Verticillium* (1.5 percent), *Alternaria* (1.3 percent), *Mucor* (0.7 percent), and *Phoma* (0.3 percent). Except for *Penicillium*, indoor mold colonies averaged from 20 to 86 percent of the number outdoors. *Penicillium* was much more plentiful (346 percent) indoors. Seasons identified for the various molds were as follows: *Penicillium* — none; *Hermodendron* — late May to mid-October, *Pullularia* — mid-September to mid-October, *Alternaria* — August and September, *Phoma* — March to October.

20. Georgii, H.-W. Investigation of the Air Exchange between Rooms and the Air Outside. Arch. Meteor. Geophys. Bioklimat., Ser. B (Germany). 5:191-214, 1954.

This paper is concerned with the natural air exchange between a room and the extraneous air as affected by wind conditions, temperature, the pores of the walls, and cracks in doors, windows, and floors. Measurements of ventilation rate were obtained by liberating water vapor, carbon dioxide, or aerosols in the test rooms and measuring the change in concentration with time. For ground-floor and basement rooms, the temperature difference between inside and outside air was found to be the primary influence on ventilation, and wind speed was secondary. For rooms on higher floors, this relative importance was reversed. For intermediate floors, the relative importance is probably more nearly equal. By comparing ventilation rates for carbon dioxide with those for aerosols, it was possible to separate ventilation through the walls from that through cracks in doors, windows, and floors.

21. Gip, L. The Indoor Occurrence of Airborne Dermatophytes. Acta Dermato-Venereol (Stockholm). 49(Suppl. 58):36-54, 1966.

The air of the washroom in a communal bathhouse and the dressing room in an automobile factory was examined monthly for 1 year for the presence of dermatophytes. The investigation of the air in the washroom revealed the presence of dermatophytes in June, August, and December. T. mentagrophytes var. granulos. was the only type of dermatophyte identified. Airborne dermatophytes were found in the automobile factory dressing room in September, December, January, February, March, and April. T. mentagrophytes var. interdigital., T. terrestre, and M. gypseum were identified. This investigation indicates that dermatophytes, and even geophilic dermatophytes, are widely present in indoor environments. Their broad epidemiologic roles as exogenous agents of infection with fungous diseases is still open to question and requires further study.

22. Goldwater, L.J., A Manoharan, and M.B. Jacobs. Suspended Particulate Matter, Dust in "Domestic" Atmospheres. Arch. Environ. Health. 2:511-515, May 1961.

Suspended particulate matter in indoor and outdoor air was determined at 30 locations (10 offices, 11 living rooms, 7 bedrooms, 2 laboratories) in the New York area during February and March 1960. Indoor concentrations were found to average 75 percent of outdoor concentrations, but the difference was not significant at the 5 percent level. The difference in ash content of the samples was highly significant at the 1 percent level, however, indicating that indoor air has more organic material and outdoor air more inorganic material.

High-volume samplers with 11-cm Schleicher and Schuell Fast-Flo No. 2W analytical filter paper were used. A 1-hour sample was first collected inside the room, then one of the windows was opened and another 1-hour sample was taken from outdoor air. Thus, indoor and outdoor samples were not taken simultaneously. In sampling indoor air, there was a certain amount of recirculation of air since the volume sampled was about twice the volume of the room.

23. Grafe, K. Calculated Versus Continuously Measured SO_2 Concentrations with Regard to Minimum Stack Heights and Urban Renewal. In: Proc. Int. Clean Air Congress (Part 1). London, The National Society for Clean Air, 1966. p. 256-258.

Sulfur dioxide (SO_2) concentrations were measured simultaneously in a room 40 m^2 with three windows and two doors and outdoors, in Hamburg, Germany, from October 1965 to February 1966. Inside sulfur dioxide concentrations ranged mostly from 4 to 10 percent of outside levels when outdoor concentrations were greater than 0.4 mg/m^3. Only when the wind blew nearly directly on the windows did the values increase to 28 percent, and in the case of strong winds even to 42 percent. If one or more of the windows was open, the values amounted to 80 to 100 percent. Comparison of half-hour-average concentrations over a 5-month period indicates an overall average indoor concentration 22 percent of the outdoor levels. For periods when the room was not entered, the average was 18 percent. The author concludes that, even when outdoor concentrations are high, indoor concentrations in well closed rooms will generally be small enough to be neglected.

Continuous SO_2 concentrations were measured indoors and outdoors with Woesthoff ultra-gas-analysis devices, and half-hour averages were extracted from the data.

Indoor-outdoor sampling was only a small portion of this article, which dealt primarily with the relationships between stack height, wind direction, and outdoor concentrations. Indoor-outdoor sampling results are not presented in detail, but are briefly summarized and illustrated by a single figure.

24. Gruber, C.W. and E.L. Alpaugh. The Automatic Filter Paper Sampler in an Air Pollution Measurement Program. Air Repair. 4:143-147, 1954.

The indoor-outdoor relationships presented are only a minor portion of the article, which deals with general use and application of the AISI tape sampler. Indoor-outdoor samples were taken at the Bureau of Smoke Inspection and at a residence, both in Cincinnati, during October and November 1952 and January 1953. At the Bureau of Smoke Inspection, indoor particle concentrations were 105 percent of outdoor concentrations; during 13 of 24 sampling periods, indoor levels were greater than outdoor levels. At the residence, indoor concentrations were 86 percent of outdoor concentrations; during 8 of the 24 sampling periods, indoor levels were greater than outdoor levels.

AISI tape samplers were used over a 6-hour sampling period and were then spot-shade evaluated by reflectance. Due to the 6-hour sampling period, many of the spots were excessively dark, and spots with less than 50 percent reflectance were used, although Beer's law cannot accurately be applied in those cases.

25. Hauser, T.R. The Analysis of the Aliphatic Fraction of Air Particulate Matter. Ph.D. dissertation, University of Cincinnati. 1971. p. 57-62, 105-107.

Results of indoor sampling constitute only a small part of this dissertation, but the results obtained are of interest. Due to the unique pattern which was found to result from the analysis of the aliphatic fraction of particulate matter from tobacco smoke, this method can be used to determine the contribution of cigarette smoking to indoor pollution. Analysis of particulate matter from the filter of an air conditioner serving a large office in Pittsburgh indicated that, except for stirred up dust and lint, the most significant contribution of particulates to the filter was that of cigarette smoke particulates.

26. Benson, F.B., J.J. Henderson, and D.E. Caldwell. Indoor-Outdoor Air Pollution Relationships: A Literature Review. U.S. Environmental Protection Agency, Research Triangle Park, N.C. Publication No. AP 112. August 1972.

This publication is a review of the majority of the literature included in this bibliography. It was found that extensive measurements had been and were being made of outdoor pollution. In contrast, considering the importance of the problem, very little data had been gathered on indoor pollution. Based on the review, however, it was possible to infer relationships between indoor and outdoor pollution and to identify factors which affect these relationships. The relationships identified are recognized as being only tentative, however, and further research is recommended to determine their validity. Except for bacteria and perhaps for mold and fungus spores, indoor pollution levels appear to be controlled primarily by outdoor concentrations. Other factors which influence indoor pollution levels include internal activities and pollutant generation, atmospheric conditions and natural ventilation, time, location, type of building, and air-conditioning and filtration systems. The data for particulates and nonreactive gases indicate a possible reduction of indoor concentrations relative to outdoor concentrations with increasing outdoor concentrations. However, until further supporting data are obtained, it appears best to assume indoor concentrations equal to outdoor concentrations. Relative indoor concentrations of pollen and reactive gases decrease with increasing outdoor concentration. Bacteria concentrations indoors appear to be more closely related to the presence and activities of people inside than to outdoor concentrations.

27. Hiraoka, M., M. Takauchi, A. Ikeda, and T. Murakami. Air Pollution in Structures. J. Japan Soc. Air Pollut. 5(1):227, 1970. Text in Japanese.

Carbon monoxide pollution at the Kyoto central wholesale market was investigated. The market is characterized by proximity of roofs of buildings and the use of small automotive vehicles for transporting goods. At six locations, measurements were taken for 24 hours at 2.4 meters above the ground. Whether 1-hour or 8-hour averages, the concentrations were the highest around 9 a.m. For a day when the average wind speed was less than 1 m/sec, 8-hour average concentrations were as high as 20 ppm at most locations.

28. Holcombe, J.K. and P.W. Kalika. The Effects of Air Conditioning Components on Pollution in Intake Air. Presented to the semiannual meeting of the Amer. Soc. of Heating, Refrig., and Air-cond. Eng. Philadelphia. January 24-28, 1971.

To determine information available concerning the ability of commercial air-conditioning equipment to reduce concentrations of pollutants in the air drawn into a building, a literature search and a survey of air-conditioning equipment manufacturers and others knowledgeable in the field of air pollution were conducted. Based on the information obtained, a mathematical expression was developed to describe various types of air-conditioning systems in terms of indoor and outdoor pollutant concentrations, the pollutant removal capability of the systems, the system design parameters, and the internal generation of pollutants (see Reference 39). Finally, the mathematical expression was verified by application of actual measurements obtained for two air-conditioned buildings in Hartford, Conn. (see Reference 103). The authors' conclusions were as follows: "(1) Substantial air pollutant removal efficiency information is available for filters, electrostatic predipitators, and activated charcoal components. For other components, only scattered and largely inadequate information is available at the present time, particularly for gaseous pollutants. [Available information is tabulated in the report.] (2) Information on indoor-outdoor air pollutant relationships was reported from only a handful of research programs. (3) Information on the relationship of indoor pollutant concentrations to indoor activities, numbers of occupants, and types of configurations of furnishings is virtually non-existant. (4) Based on limited measurements in air conditioned office buildings, internal generation of suspended and soiling particulate matter is a significant parameter in estimating indoor concentrations of these pollutants. (5) The use of a generalized theoretical approach for predicting indoor-outdoor air pollutant relationships appears to be a potentially valuable technique."

29. Horton, A.D. and A.S. Meyer. Gas Chromatographic Determination of Volatile Air Pollutants (Annual Progress Report for Period Ending October 31, 1967). Analytical Chemistry Division, Oak Ridge National Laboratory. Tennessee. Contract W-7405-Eng-26. January 1968. p. 30-32.

Analyses of volatile hydrocarbons in charcoal and air samples from nuclear reactor contaminants and various indoor and outdoor sites in the vicinity of Oak Ridge National Laboratory were carried out. Total hydrocarbons were determined by use of the flame-ionization detector; unsaturated hydrocarbons were determined on the same column by subtracting from the total hydrocarbons those that passed through a perchlorate olefin absorber. Data on oxygenated hydrocarbons were obtained by subtracting the hydrocarbons that passed through a 1 percent solution of $NaHSO_3$ from total hydrocarbons. Identifiable hydrocarbons were determined with a column of 3 percent (by weight) squalene. Results of all determinations are given. Depending on the environment, the extent of contamination of air and of charcoal by volatile organic compounds varies from day to day or even from hour to hour. For outdoor samples, the concentration of contaminants is directly proportional to the density of automobiles operating in the immediate vicinity of the sampling point. Newer buildings, in general, are less contaminated than older ones.

30. Indoor-Outdoor Carbon Monoxide Pollution Study. The General Electric Company, Re-entry and Environmental Systems Division. Philadelphia. Contract No. CPA 70-77. In preparation.

Carbon monoxide, hydrocarbons, particulates, and lead were monitored for approximately 6-month periods inside and outside of two buildings in New York City. Traffic and meteorological conditions were also recorded. Data were obtained continuously during the test periods, which included both heating and nonheating seasons. One of the buildings, a high-rise apartment, was an air-rights structure which straddled the Cross Bronx Expressway. The other building was a conventional high-rise structure.

Final results of this study were not available when this bibliography was prepared, but the simultaneous indoor and outdoor measurements of the pollutants, collected continuously over a period of time, should provide highly valuable information on indoor-outdoor pollution relationships.

31. Ishido, S. Air Pollution in Osaka City and Inside Buildings. Department of Home Economics, Osaka City University, Osaka, Japan.

Based on data from earlier studies (e.g., References 33 and 35), the author concludes the following: (1) even in a relatively airtight building, indoor suspended particulate is completely under the influence of outdoor changes; (2) changes in indoor levels lag behind outdoor changes; (3) the range of indoor suspended particulate is smaller than that of outdoor particulate; (4) indoor suspended particulate levels are nearly equal to outdoor levels if mean values over a 24-hour period are considered; (5) electrical dust collectors are highly effective in eliminating indoor suspended particulate matter.

32. Ishido, S. Study of Air Quality in Buildings; 1. Degree of Weariness Related to the CO_2 Concentration and Polluted Environment. Air Cleaning (Tokyo). 3:11-15, 1965.

Measurements of carbon dioxide (CO_2) concentrations inside four office buildings are presented. Very little indoor-outdoor data are presented, but outside levels of approximately 0.03 percent can be assumed. Inside concentrations in the four buildings considered ranged from 0.03 to 0.32 percent. Based on measurements in one building, concentrations generally increased from the first to the fourth floor. Concentrations in a new air-conditioned building were found to be higher than those in an older building without air conditioning during the summer, but concentrations in the winter were lower in the new building. Assuming 10 m^3 space per person and 18 liters/hr exhaled per person, it was calculated that a recirculation rate of 30 m^3/hr would maintain the carbon dioxide concentration within the room at below 0.1 percent when a person was doing office work.

33. Ishido, S. Variations in Indoor and Outdoor Dust Densities. Bull. Dept. Home Econ., Osaka City Univ. (Osaka). 6:53-59, March 1959.

Indoor and outdoor measurements of particulate concentrations were made at the following locations in Osaka in 1958: an apartment, a residential store, a hospital, and a school. The measurements indicated the following indoor-outdoor percentages: apartment, 114 percent; store, 98 percent; hospital, 101 percent; school, 102 percent. At each location, the indoor and outdoor diurnal patterns were nearly identical. The author concludes that outdoor suspended particulate levels have a direct and controlling effect on indoor levels and that this holds true not only in small rooms as found in apartments, but also in hospitals and schools.

Samples were collected hourly during 24-hour periods, and "dust densities" (number of particulates per cubic centimeter) were determined with a Labor Science Research Institute type dust meter using 400X, 200W diagonal illumination.

34. Ishido, S., K. Kamada, and T. Nakagawa. Free Dust Particles and Airborne Microflora. Bull. Dept. Home Econ., Osaka City Univ. (Osaka). 4:31-37, 1956.

Dust Particles – Indoor and outdoor particle concentrations were determined for a relatively new second floor apartment (not air conditioned) for 24-hour periods during each of the following months: November 1955, March 1956, May 1956, and June 1956. Monthly average indoor-outdoor particle concentrations ranged from 84 to 98 percent. For each sampling period, indoor and outdoor diurnal patterns were nearly identical. The author concludes that dust concentrations are, for the most part, controlled by outdoor air conditions. The generation of dust through daily activities is of comparatively short duration and is not directly reflected in daily variations in indoor dust concentration.

Samples were collected during 24-hour periods in each month, and "dust densities" (number of particles per cubic centimeter) were determined with a Labor Science Research Institute type dust meter using 400X, 200W diagonal illumination.

Airborne Microflora – Number of bacteria indoors and outdoors was determined by exposing petri dishes for 5 minutes each hour during October and November 1955 at two locations: the apartment described above and a new two-story house in the suburbs. Additional exposures were made at the apartment during May and June 1956. During the fall, indoor concentrations of bacteria were higher than outdoor concentrations at the apartment (average indoor-outdoor percentages of 225 and 169 percent, respectively, for 24- and 48-hour cultures), and at the house, they were much higher (1425 and 1183 percent, respectively). During the spring, indoor concentrations were somewhat lower than those outside at the apartment (93 percent in May, 76 percent in June). The data indicated much higher concentrations of bacteria in the house than in the apartment, both in number of colonies and in percentage of outdoor concentrations. Indoor-outdoor percentages in the apartment were much lower in the spring than in the fall. Both of these results are somewhat surprising because of the magnitudes of the differences found. The authors did not identify any bacterial colonies; perhaps identification would have helped clarify the results somewhat by establishing the type of bacteria predominant at each location, inside and outside, during each season. It is the authors' conclusion that the number of bacteria inside does not reflect fluctuations in outdoor air, but that the influence of living conditions and daily activities on changes in numbers of bacteria is great.

Portions of this study were reported earlier in Reference 35.

35. Ishido, S., T. Tanaka, and T. Nakagawa. Air Conditions in Dwellings with Special Reference to Numbers of Dust Particles and Bacteria. Bull. Dept. Home Econ., Osaka City Univ. (Osaka). 3:35, 1955.

See Reference 34.

36. Jacobs, M.B., L.J. Goldwater, and A. Fergany. Comparison of Suspended Particulate Matter of Indoor and Outdoor Air. Int. J. Air Water Pollut. 6:377-380, October 1962.

Suspended particulate matter in indoor and outdoor air was determined at 21 locations (17 homes, 4 small manufacturing plants) in West Queens, N.Y., during April and May 1961. Average indoor-outdoor percentages were 106 percent for homes and 150 percent for factories. There seemed to be a markedly greater amount of suspended particulate matter in carpeted rooms than in uncarpeted rooms, but this difference was not statistically significant.

Sampling procedures and equipment were the same as those described for Reference 22.

37. Jacobs, M.B., A. Manoharan, and L.J. Goldwater. Comparison of Dust Counts of Indoor and Outdoor Air. Int. J. Air Water Pollut. 6:205-213, August 1962.

The dust count and particle size of suspended particulate matter of indoor and outdoor air were determined at 30 locations (18 houses, 10 offices, 2 laboratories) in the New York area during February and March 1960. The indoor dust count ranged from 1.4×10^6 to 53.4×10^6 particles/ft^3 with a median of 10.7×10^6. The outdoor count ranged from 2.1×10^6 to 53.1×10^6 particles/ft^3 with a median of 14.6×10^6. However, this indoor-outdoor difference was not significant at the 5 percent level. The median particle size for both indoor and outdoor air was 0.6 micron. The indoor-outdoor difference in particle size was less than 0.2 micron and was not significant at the 5 percent level.

Samples were taken over a 2-minute period using a modified high-volume sampler. There was a 1-hour time lag between indoor and outdoor samples.

A portion of this study was reported earlier in Reference 48.

38. Jimenez-Diaz, C., J.M. Ales, F. Ortiz, F. Lahoz, L.M. Garcia, and G. Canto. The Aetiologic Role of Molds in Bronchial Asthma. Acta Allergologica (Copenhagen). Suppl. 7:139-149, 1960.

A wells centrifuge was used to obtain spore samples of indoor and outdoor air at different points in Madrid and in several towns on the Spanish coast. Samples were collected each week at different times of the day all year round. Overall, indoor-outdoor percentages were 378 percent for Madrid, 230 percent for the coast, and 302 percent for both areas combined. The indoor-outdoor relationship varied from molds which were only found outdoors (*Oospora* and *Helminthosporium*) to one which was more than 20 times as plentiful indoors as out (*Penicillium*). *Penicillium* and *Cladosporium* were nearly always the predominant genera found; in indoor air, *Penicillium* predominated, and in outdoor air, *Cladosporium* predominated. Indoor-outdoor percentages for these molds were 1207 percent and 94 percent, respectively. The indoor-outdoor percentages found in this study were unusually high compared to other reported results.

39. Kalika, P.W., J.K. Holcombe, and W.A. Cote. The Re-use of Interior Air. Amer. Soc. Heating, Refrig., Air-cond. Eng. J. 12:44-48, November 1970.

Theoretical and experimental results are presented to show quantitative and qualitative aspects of indoor-outdoor air pollution rel. ionships for air-conditioned buildings. A simple theoretical model of an air-conditioning system based on a single conditioned space provides significant insight into this relationship; complicating factors can be introduced without damage to the validity of the model. Experimental measurements include respirable and total suspended particulate, soiling particulate, and carbon monoxide (CO) at two air-conditioned office buildings in Hartford, Conn., in the summer of 1969 (see Reference 103). The interior environment was found to be cleaner with respect to suspended particles than to soiling particles due to the inability of the air-conditioning system to filter out the finer particles associated with soiling. Carbon monoxide was consistently measured at greater concentration indoors than outdoors, probably because of the introduction of 100 percent make-up air from outside in the morning at the time of peak outdoor concentrations. Calculations indicate the significance of internal pollutant generation in establishing interior air quality in an air-conditioned structure. Guidelines are given for the design and operation of air-conditioning systems to improve the indoor pollution environment rather than simply to control temperature.

40. Kanitz, S. Observations on Atmospheric Pollution from Suspended Dust by Means of an Automatic Sampler. J. Hyg. Prevent. Med. (Italy). 1:57-68, 1960.

Indoor and outdoor suspended dust (soiling index) samples were collected in a residential area and in an industrial area of Genoa in June and November. Percentages of indoor to outdoor concentrations in June were 48 percent for the residential area and 44 percent for the industrial area. In November, percentages were 60 percent for the residential area and 36 percent for the industrial area. The author gives equal importance to outside pollution level and the presence and activities (e.g., smoking) of individuals inside in determining indoor pollution levels.

Indoor-outdoor sampling results were only a small portion of this article, which was devoted mainly to describing the automatic sampler and to outdoor sampling. The sampler is an automatic unit which yields dust concentrations in terms of "soiling index" which is expressed in "OD units/cm^2/m^3."

41. Kato, K. Ions in Air: 2. Ions and Air Pollution; 3. Ions and Public Health. Clean Air (Tokyo). 2(1):48-53, 1964. Text in Japanese.

In Part 2 of the study on ions in air, data are given on the relations between ions, dusts, exhaust gas, and smoking. The author measured dust, carbon dioxide (CO_2), and small positive and negative ions at five locations. Generally, in industrial areas there is a greater concentration of positive ions than negative ions, and the reverse is true for residential areas. It is graphically illustrated that the amounts of carbon dioxide and dust present in the air are directly proportional to each other, but the quantities of dust and ions present are inversely proportional. For exhaust gas, an experiment was performed in which gas was released into a room for 10 minutes. The ion concentration was reduced from 1110/cm^3 to 120/cm^3. Other experiments indicate that the presence of people in a room diminishes the number of ions. Also, it was shown that in air-conditioned rooms, twice as many small ions are present as in outdoor air. The concentration of small ions was reduced to about one-tenth by polyethylene and vinyl filters and to one-fifth or one-third by polyurethane and glass fiber filters. In Part 3, the relation between ions and heating devices (infrared ovens, gas stoves, and electric stoves) is covered. Some mention is made of the effects of ions on the human body. The ion concentrations of some hot springs are given, indicating that from 7 to 20 times as many ions are present in these areas as in the city environment.

42. Konno, K. Concentration of Air Contamination in Outdoor and Indoor. J. Japan Soc. Air Pollut. (Japan). 4(1):142, 1969. Text in Japanese.

The concentration of air contamination is discussed with special reference to sulfur dioxide and dust particles. Diagrammatic and numerical results of the air pollution measurements both indoors and outdoors, with or without air-cleaning filters, are presented. The data were gathered at a building in central Tokyo. When air conditioning is in operation, the outdoor pollution penetrates indoors through the mechanical ventilation system as well as the natural ventilation of opening and closing doors. Mathematical formulas are developed whereby, under either the existence of air conditioning or static conditions, the concentration of pollution indoors after time (T) can be calculated from variables such as outdoor pollution concentration, initial indoor concentration, concentration at T equals infinity, volume of air intake, rate of natural ventilation, rate of particle filtration, etc. By initially fixing the desired indoor concentration and giving the observed values to the other variables, the rate of particle filtration, and hence the desired type of filter, can be computed.

43. Kranz, P. Indoor Air Cleaning for Allergy Purposes. J. Allergy. 34:155-164, 1963.

This article discusses the amount of air cleaning required to reduce outdoor pollen levels to acceptable values. It is based on tentative pollen levels found by others; no actual indoor-outdoor data are presented. The presentation is in engineering terms, and charts are used to show the air cleaning required for various house conditions and outdoor pollen levels. Air leakage into a house, or infiltration, must be very carefully controlled in order to achieve satisfactory indoor pollen levels.

44. Kruglikova, Ts.P. and V.K. Efimova. Residential Indoor Air Pollution with Atmospheric Sulfur Dioxide. Hyg. and Sanitation (Moscow). 23:75-78, March 1958.

Indoor and outdoor air samples were collected, and sulfur dioxide (SO_2) contents were determined for (1) residences in an industrial (chemical and crude oil processing plants) area of Moscow, (2) residences on two streets away from any industrial area, and (3) a botanical garden located a considerable distance from any industries or residences. Sulfur dioxide was found inside in the industrial area even with windows closed; but with the windows closed, indoor sulfur dioxide concentrations stayed at a more constant level than outdoor concentrations. During the winter, maximum indoor levels in the residential area exceeded those in the industrial area. These high concentrations were attributed to small boiler-operated heating plants. The authors concluded that there was a good correlation between indoor and outdoor sulfur dioxide in industrial, residential, and control areas.

45. Lampert, F.F. Effect of Garages and Filling Stations Located in Residential Sections on Health and Living Conditions. Hyg. and Sanitation (Moscow). 24(3):74-76, 1959.

Carbon monoxide (CO) samples were collected in control dwellings and in six residential buildings with garages. In two buildings, the garages were parts of the buildings. In three buildings, the garages were detached by 5 to 17 meters. One garage was located as recommended by the sanitary clearance regulation (distance not specified). In addition, the effects of a filling station located 18 meters from the windows of an apartment house were investigated. The study showed that garages and the filling station contributed measurably to polluting the indoor residential air, and pointed to the need for suitable sanitary clearance zones.

For this study, household gas appliances were shut off during sampling in all cases.

46. Lefcoe, N.M. and I.I. Inculet. Particulates in Domestic Premises; 1. Ambient Levels and Central Air Filtration. Arch. Environ. Health. 22:230-238, February 1971.

Air particulates were sampled in Ontario, Canada, in a home with central ventilation and an electrostatic filter, rated at 90 percent efficiency at 1000 ft^3/min, in the main air duct. Particle counts were lower during periods of minimal activity, and during such periods, counts were significantly lower with the filter than without. Cleaning and dusting overwhelmed the filter. Smoking one cigar raised particle counts from 10 to 100 times. These counts stayed up at least 3 hours when the filter was off and from 1 to 2 hours when the filter was on. Actual efficiency of the filter was determined as 80 percent for particles $\geq$0.3 micron, 83 percent for particles $\geq$0.5 micron, and 86 percent for particles $\geq$1 micron.

Air samples were taken hourly from the return air duct upstream of the filter from 10 a.m. to 4 p.m. Particles were counted with a light-scattering particle counter. A 1-minute counting period was used for each of the following size ranges: $\geq$0.3 micron, $\geq$0.5 micron, $\geq$1 micron, and $\geq$2 microns. Nature of activity in the house was recorded hourly. Outside measurements were not made.

47. Lenoe, F.L. BW Evaluation of Pressurized Building No. 7-635 at Naval Civil Engineering Laboratory (1952). Physical Defense Division, Camp Detrick. Maryland. Special Report No. 171. May 1954.

Two series of tests were conducted involving the pressurized building, a normal, unpressurized building, and a "filter wall unit" at Port Hueneme, California, September 10 to 19, and October 20 to 24, 1952. A biological warfare (BW) simulant, Bacillus globigii, a nonpathogenic spore-forming organism, was used for the tests. Respiratory exposure dosages on the order of 2.0 x 10^6 organisms were prevalent outside the buildings for the 3-hour period of each test. The normal, unpressurized building gave approximately a 10-fold reduction in respiratory exposure, and this reduction was increased to 100-fold in 30 minutes by the introduction of 2500 ft^3/min of filtered air into the building. In the building pressurized by a Chemical Corps E35 Collective Protector, even greater reductions were effected, and respiratory exposures were not significantly above background counts. The E35 Protector was also shown to be superior to the filter wall unit, which functions under negative pressure and thus allows leakage into the building. No major differences in reductions were found with varying pressures of the Protector. The Protector is not described.

Aerosol samples were collected during the tests by drawing air through cotton collectors at 12 liters/min. At certain stations inside the buildings, duplicate samples were collected by drawing air through millipore filters at 15 liters/min.

References 8 and 71 contain additional evaluations of the interior effects of BW aerosols.

48. Manoharan, A., M.B. Jacobs, and L.J. Goldwater. Dust Counts in "Domestic" Atmospheres. Proc. 54th Annual Meeting Air Pollut. Cont. Ass. 1961.

    See Reference 37.

49. Maunsell, K. Air-borne Fungal Spores Before and After Raising Dust. Int. Arch. Allergy. 3:93-102, 1952.

    Spore counts were made in eight homes in London during November through March before, during, and after raising dust by shaking bedding and brushing carpets and walls. During the raising of dust, spore counts were 14.5 times higher than before raising dust. At 2 minutes after dust raising had stopped, the ratio had fallen to 4.3 times, and after 15 minutes to 2.6 times. The predominant genus in the undisturbed air in most of the homes was *Penicillium*; in other homes *Pullularia* and *Cladosporium* were predominant. The increase of spores through raising dust was due mainly to an increase of *Penicillium, Cladosporium, Pullularia,* and yeasts. Colonies of spores of larger sizes were practically absent from the air of undisturbed rooms, but occurred in small numbers during and after the raising of dust.

    Series of seven petri dishes were exposed at various heights in each home. Each series was exposed for 15 minutes. All windows were closed about 10 minutes before sampling. One series was exposed before dust raising, one during, one 2 minutes after dust raising had stopped, and one 15 minutes after. Much of this article is devoted to a discussion of the limitations of the sedimentation method of sampling and the advantages of sampling by impaction, such as when using the "slit sampler." No outdoor sampling results are presented.

50. Maunsell, K. Concentration of Airborne Spores in Dwellings Under Normal Conditions and Under Repair. Int. Arch. Allergy. 5:373-376, 1954.

    Spore counts were determined for bedrooms on the ground or first floor of eight houses in London during January, February, and April 1951. Two rooms were in "disturbed" houses. In one of these, a wall was being torn down in an adjacent room. There was no common door, but both rooms opened onto a common hall. In the other, a door led to a landing on the roof, which was being repaired. The six undisturbed rooms were sampled as part of another study.[51] There was a 23-fold increase in *Penicillium* concentration and an 11-fold increase in overall spore concentration in the disturbed rooms relative to the undisturbed rooms. The results indicate that spores are readily spread inside buildings from one room to another and from one floor to another.

    A slit-sampler was used to sample the airborne spores by impaction on rotating petri dishes. Windows and doors were kept closed for half an hour before sampling and during sampling. No outdoor measurements are reported.

51. Maunsell, K. Quantitative Aspects of Allergy to House Dust. Proc. First Int. Congress Allergy. 1952. p. 306-314.

    The concentrations of airborne spores in undisturbed bedrooms with windows closed were compared with outdoor concentrations. Samples were collected in London during January, February, and April 1951. *Pencillium* was the predominant spore both indoors and outdoors during the months of this study. Indoor-outdoor percentages of total spores and of *Penicillium* were 79 and 76 percent, respectively. The author was surprised that the concentrations of *Penicillium* and total spores were not higher indoors than outdoors. Much of the article dealt with a survey regarding the location of houses in which patients had lived at the onset of dust allergic symptoms. It was found that a highly significant number of these houses (78 percent) were built on damp soil, on a relatively low level, near waterways (both open and underground).

    A slit-sampler was used to sample airborne spores by impaction.

52. Megaw, W.J. The Penetration of Iodine into Buildings. Int. J. Air Water Pollut. 6:121-128, 1962.

Measurements of deposition of iodine-131 in three buildings (one office, one house, and one recently constructed, well made hut) near Windscale, England, were made 1 week after the accidental release of radioiodine from a nuclear reactor there in October 1957. Additional experiments were conducted on the hut using artificially produced Aitken nuclei. The time integral of volumetric concentration inside a building, which varied from 20 to 80 percent of outside concentrations in these studies, was found to determine the quantity of material inhaled by people inside buildings. Therefore, although the deposition of a material in buildings will be much less than outside, the quantity inhaled may be as much as 80 percent of that outside. A measure of protection against inhalation inside could be obtained by keeping windows and doors shut while material was passing, then opening them immediately after it had passed.

Measurements for this study included gamma dose rate outside and inside the buildings, and the amount of iodine deposited on papers lying on the floor, on dust inside the buildings, and on grass outside.

53. Miura, T., K. Kimura, K. Kimotsuki, H. Okusa, O. Tada, and T. Sawano. Comparison of the Concentration of Suspended Particulate Matter and Gaseous Pollutants between Indoor Air and Outdoor Air in Urban Areas. J. Sci. Labour (Tokyo). 41(10):493-500, 1965. Text in Japanese.

The concentration of suspended particulate matter and gaseous pollutants of indoor and outdoor air in Tokyo was determined at several locations, including factories, business machine rooms, and offices. Suspended particulate concentrations were determined by a Roken type long-term recording impactor, and gas analysis for sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and aldehyde (HCHO) of indoor and outdoor air was carried out at the same time. The electromicrographs revealed that most of the particulate matter in the urban area was microfine,seeming to be carbon particles and some mist particles. The concentration of suspended particulate matter of the outdoor air in the urban area ranged from 0.05 to 0.5 mg/m^3 and that of the indoor air in air-conditioned rooms ranged from 0.01 to 0.3 mg/m^3. The attenuation efficiency of an air filter with electrostatic precipitator for suspended particulate matter was high. The concentration of sulfur dioxide of the indoor air was lower than that of outdoor air, but the differences were not marked in cases of nitrogen dioxide and aldehyde.

54. Narasaki, M. Change of Dust Concentration Indoors. Clean Air (Tokyo). 3(4):32-35, 1965. Text in Japanese.

Factors which affect the change of dust concentration indoors are the concentration of outdoor dust, dust generation due to combustion or air flow, and sedimentation. The relation between dust concentration indoors and out is graphed for periods during which the air conditioner was on and off. Tests were performed for dust sedimentation and also when carbon dioxide (CO_2) and dusts were generated in the same room. It was observed that the smaller the particle size, the smaller the sedimentation ratio, the ratio being the greatest at the moment dust generation stopped. The ratio was also larger in rooms with ventilation than without. A theory for quantitative investigation is given.

55. Nelson, T., B.Z. Rappaport, and W.H. Welker. The Effect of Air Filtration in Hay Fever and Pollen Asthma; Further Studies. J. Amer. Med. Ass. 100:1385-1392, 1933.

In order to determine the effects of filtered air on patients suffering from hay fever and asthma, filtration units were installed in two wards in a hospital in Chicago. Pollen counts were determined from gravity slides collected daily in each ward, in a control ward, and outdoors. Samples were collected from August 15 to September 22, during the ragweed season. In the control ward, indoor-outdoor percentages averaged 36 percent. In the wards with filtration units, the average was 3 percent. There was no tendency for pollen concentrations in the wards with filtration units to follow those outdoors.

Indoor-outdoor sampling was only a small portion of this article, which dealt primarily with the application of air filtration in the treatment of patients.

56. Nilsby, I. Allergy to Molds in Sweden, a Botanical and Clinical Study. Acta Allergologica (Copenhagen). 2:57-90, 1949.

Mold spore counts were determined in Oerebro, Sweden, from August 1946 to December 1947. Petri dishes were exposed for 30 minutes each day on a balcony in an open area on the outskirts of the city. During the same period, petri dishes were exposed for 15 minutes in various homes and industries in the area. The most common mold found in outdoor air was *Hormodendrum* (68 percent of the total number of colonies), followed by *Penicillium* (11 percent), *Pullularia* (6.6 percent), yeasts (3.6 percent), *Botrytis* (1.5 percent), and *Aspergillus* (1.3 percent). Pronounced seasonal variations were found, with a mold season from June to October. *Hormodendrum* showed the most noticeable seasonal variation, and *Penicillium* showed no seasonal variation. No difference was found in spore content of the air, either qualitatively or quantitatively, from the city to a distance of 6.2 miles outside the city. Indoors, the most common mold found was *Penicillium* (44 percent), followed by *Hormodendrum* (28 percent), yeasts (10 percent), *Aspergillus* (6.2 percent), *Pullularia* (5.6 percent), *Mucor* (2.8 percent), and *Alternaria* (2.1 percent). In dry, hygenic living quarters, spores averaged 5 colonies per dish (38 percent of outdoor values). In homes with bad hygenic conditions, the count was 55 (423 percent).

Indoor sampling results were only a small portion of this article, which dealt mainly with more extensive outdoor sampling. Indoor-outdoor comparisons in the article are qualitative; however, rough indoor-outdoor comparisons can be inferred from the data presented.

57. Parnell, L. Atmospheric Pollution and Its Significance in Air Conditioning. Heating and Ventilating Eng. (London). 37:296-302, December 1963.

This paper includes general discussions of measurement methods for atmospheric particles, types and relative efficiencies of air filters, and methods for evaluating filters. It does not contain data on either indoor or outdoor concentrations.

58. Parvis, D. Condensation Nuclei in the Air of Artificially Heated Environments. Annali della Sanita Publia (Italy). 13:1569-1581, November-December 1952.

Number of condensation nuclei and number of "dust grains" in the city of Milan were measured outdoors and inside of various premises with hot-water heating, central air conditioning, convection heating, electric heating units with open resistance, and cast iron coal stoves with nonconducting linings. The inside measurements were approximately 50 percent lower than outside. The heating systems are rated on the basis of mean values of condensation nuclei and dust grains and on the basis of mean indoor concentrations related to outdoor concentrations. Number of dust grains in the outside air was found to vary insignificantly, and all results varied insignificantly with respect to air velocity measured in the center of rooms. Lowest levels of condensation nuclei were found in air-conditioned and electrically heated rooms, and highest levels in rooms heated by coal stoves.

Condensation nuclei were measured using Aitken's apparatus, and dust grains were counted with Owen's apparatus. No detailed description of the air measurements is included except that they were made between 11:00 a.m. and 1:00 p.m. on the days of the study. Chemical characteristics and dimensions of the nuclei and dust grains were not considered.

59. Phair, J.J., G.C.R. Carey, R.J. Shephard, and M.L. Thomson. Some Factors in the Design, Organization, and Implementation of an Air Hygiene Survey. Int. J. Air Pollut. 1:18-30, 1958.

In 1952, a project was initiated in Cincinnati which had as its primary objective the solution of problems encountered in the design, organization, and implementation of morbidity surveys attempting to relate human reactions to the low levels of atmospheric contamination commonly found in ubran areas of the United States. This article is a review of experience gained from nearly 2000 patient visits, and contains recommendations regarding planning and operation of future large-scale air hygiene surveys.

Little new data is presented in this article. It is based on data presented in Reference 9. Results of 2 days of sampling for gaseous acid in December at an old peoples' home are presented. Gaseous acid concentrations averaged 131 percent of outside concentrations in a room with windows open, but only 34 percent of outdoor concentrations inside a room with windows closed.

60. Phair, J.J., R.J. Shephard, G.C.R. Carey, and M.L. Thomson. The Estimation of Gaseous Acid in Domestic Premises. Brit. J. Ind. Med. (London). 15:283-292, October 1958.

Two-hourly Wilson sequence samplers were operated inside and outside a room in Cincinnati General Hospital for a 2-month period to determine sulfur dioxide (SO_2) concentrations. With increasing outdoor concentrations, the proportion penetrating into the room decreased (partly because many peaks were of comparatively short duration). The inside values did not show the same sharp peaks as outside values. There was a maximum correspondence between outside and inside levels with a lag of between 0 and 2 hours, the exact value being perhaps somewhat closer to 2 hours. Due to the nearly 2-hour lag, it follows that when outside concentration is falling rapidly the inside value may exceed the outside value.

The indoor-outdoor relationships presented were only a minor portion of the article, which dealt mainly with development and use of a small sequence sampler for use in domestic premises.

61. Portheine, F. To the Problem of Passive Smoking: Remarks to the Article by H.P. Harke in Muench Med. Wschr.; 112(51):2328-2334, 1970. Muench Med. Wschr. (Munich). 113(18):707-709, 1971. Text in German.

Despite the inadequacies of the methods used by Harke to analyze carbon monoxide (CO) emissions and concentrations, relatively high concentrations were measured. Other investigations measured maximum concentrations of 80 ppm carbon monoxide in rooms where an excessive amount of cigarettes had been smoked. Measurements by the writer yielded 5 to 25 ppm carbon monoxide in rooms where normal quantities of cigarettes had been smoked. In closed vehicles with the engine shut off, the measured carbon monoxide value from a normal amount of cigarette smoking was 166 ppm. A nonsmoking driver inhales just as much as the smoker in such cases. Measurements of carbon monoxide in open air, at a height of 1.6 meters above ground and 20 cm off the road bank of a busy Duseldorf road revealed that, on a day of good dispersion conditions, the values corresponded closely to those in heavily smoked rooms. The fact is stressed that carbon monoxide concentrations of less than 50 ppm penetrate into the blood only after hours of exposure depending on lung ventilation.

62. Prince, H.E. and M.B. Morrow. Molds in the Etiology of Asthma and Hay Fever with Special Reference to the Coastal Areas of Texas. Southern Med. J. 30:754-762, 1937.

Petri dishes were exposed for 2 minutes each day from September 1934 to June 1935 in Galveston, Texas. One series of samples was collected by holding the plates outside an open window on the ninth floor of an isolated office building, with agar surfaces facing directly into the wind. During the same period, another series of samples was collected indoors in a home. Results are tabulated and plotted by month. The plotted results indicate nearly parallel curves for number of colonies indoors and outdoors except in spring, when indoor colonies considerably exceed outdoor colonies. Indoor-outdoor percentages by month varied from 50 to 300 percent and averaged 126 percent, but the authors felt "no material difference had been found in the number of indoor and outdoor colonies."

Indoor-outdoor sampling results were only a small portion of the article, which dealt primarily with more extensive outdoor sampling and the treatment of mold-sensitive patients with mold extracts.

63. Rappaport, B.Z., T. Nelson, and W.H. Welker. Effect of Air Filtration in Hay Fever and Pollen Asthma. J. Amer. Med. Ass. 98:1861-1864, 1932.

In order to evaluate the performance of an air filtration unit, two of the units were installed in an eight-bed hospital ward in Chicago. The units gave a complete air change in the room every 6 minutes. Pollen slides were collected daily in the room, both directly in front of the outlet of each machine and at points distant from them. Slides were also collected outdoors on a porch adjoining the ward. Samples were collected from August 19 to September 22, during the ragweed season. With the air filters in operation, average indoor pollen counts were 4.5 percent of outside counts, indicating an efficiency of 95.5 percent for the filters. During most of the sampling period, the filters were over 98 percent efficient. However, the units created a feeling of stuffiness, producing severe discomfort on hot and humid days.

The discussion of indoor-outdoor sampling was only a small portion of the article, which dealt primarily with the application of air filtration in the treatment of hay fever and asthma.

64. Rennerfelt, E. Some Investigations of the Fungus Diaspore Content of the Air. Svensk Botanisk Tidskrift (Stockholm). 21:283-294, 1947.

Indoor spore samples were collected twice monthly in 1946 at the Forest Research Institute near Stockholm. Outdoor samples were collected at the experimental field near the Institute. Indoor spore concentrations averaged 34 percent of outdoor concentrations. *Penicillium* was the only genus found more frequently indoors than outdoors. In outdoor air, *Cladosporium* was the predominate genus found. Most of the article is devoted to outdoor sampling results.

Spore samples were collected by exposing petri dishes in a horizontal position; the plates were observed for 8 to 10 days, and then fungus colonies were counted. Dishes were exposed every fourteenth day around the first and fifteenth of each month.

65. Report on Lead Pollution Survey. Tokyo Metropolitan Environmental Pollutions Research Institute (Japan). March 1971. Text in Japanese.

The urine and blood of people in the neighborhood of 11 busy intersections in Tokyo were tested for lead concentration; carbon monoxide (CO) and lead concentrations in the atmosphere were also measured. The samples were collected for 10 to 14 hours. The average lead concentration at the intersection was 100 ppm, the area along the road averaged 84.4ppm, and the hinterland averaged 44.8 ppm. Although the relationship between carbon monoxide and lead varied depending upon traffic, the recurrent coefficient varid from 1.6 to 3.4, with a tendency to increase. The correlation between carbon monoxide and lead concentration was significant in every area, with a minimum of 0.670. The indoor lead concentration is influenced by the atmospheric concentration unless there is any source of lead generation inside the building.

66. Richards, M. Atmospheric Mold Spores In and Out of Doors. J. Allergy. 25:429-439, 1954.

Indoor and outdoor spore samples were collected daily except Sunday for 1 year in Cardiff, Wales. Indoor samples were collected by exposing a pair of petri dishes each morning at 10 a.m. for 10 minutes in the bedroom of a house which appeared to be a normal, dry, clean dwelling and not itself a source of molds. A pair of outdoor samples were collected at the same time on a lawn 60 yards from the house. Indoor-outdoor percentages of mold concentrations averaged 19 percent. The same molds were found indoors and outdoors, and in approximately similar proportions. No mold was found more frequently indoors than outdoors. From June to October, *Cladosporium* was the most prevalent mold found both indoors and outdoors. During the rest of the year, *Penicillium* predominated. *Penicillium* showed little variation in level throughout the year. Based on this study and review of several previous studies, the author concludes that, in normal dry houses the most important source of airborne mold spores is the outside air; relatively few spores are produced indoors and released into the air. In moldy houses, the mold spore content of the air may be different, quantitatively and qualitatively, from that of outside air.

67. Richardson, N.A. and W.C. Middleton. Evaluation of Filters for Removing Irritants from Polluted Air. Heating, Piping, and Air Cond. 30:147-154, 1958.

Indoor and outdoor air samples were taken and oxidant and nitrogen dioxide contents were determined as part of an evaluation of two air filter media. Most of the testing was with activated carbon filters varying in air detention time between 0.032 and 0.0030 second. A particulate filter which effectively removes particles to less than 0.05 micron was also tested. The effectiveness of activated carbon in removing oxidants was directly related to detention time. Nitrogen dioxide was reduced by activated carbon only during early use of the filter. The particulate filter decreased the concentration of oxidants and nitrogen dixoide by a small amount.

Although air samples were taken, the filters were evaluated by their effectiveness in reducing human sensory irritation resulting from Los Angeles smog. Sensory response of a group of subjects working in a filtered atmosphere was compared with that of a similar group working in a nonfiltered atmosphere in adjacent, identical rooms. With activated carbon filters, a significant decrease in irritation was found over the entire range of detention times. With the particulate filter, no decrease in sensory irritation was found.

68. Ripe, E. Mold Allergy; I. An Investigation of the Airborne Fungal Spores in Stockholm, Sweden. Acta Allergologica (Copenhagen). 17:130-159, 1962.

Four indoor and two outdoor spore samples were collected five days a week from February 1, 1959, to February 1, 1960, in Stockholm, Sweden. Indoor sampling sites included a home, an office, an apartment, and an industrial plant. Outdoor samples were taken at an airport observatory and on a high point in the center of Stockholm. Excluding the industrial plant, indoor spore concentrations were less than 50 percent of outdoor concentrations; however, the relation varied from a mold which was only found indoors *(Monilia)* to one which was found in more than 10 times greater abundance outdoors *(Epicoccum)*. The same molds were normally found indoors and outdoors, but proportions were quite different. *Penicillium, Aspergillus, Mucor, Monilia,* and *Rhizopus* were found more frequently indoors; other genera were found more frequently outdoors. From June to October, *Cladosporium* was predominant, especially outdoors. During the remainder of the year, *Penicillium* and yeast were predominant. Spore concentrations were found to be highest outdoors and next where there was most activity. They did not correlate with humidity, but did follow weather variations. Concentrations rose during warm and sunny weather, after rain during the warm season, and during the fall of leaves. They sank during the winter, during rain and snow, and during very dry weather.

Samples were collected by exposing petri dishes containing tomato agar each morning between 11:00 and 11:30 a.m. In addition, petri dishes with malt extract agar were exposed once a week. A record was kept of weather, temperature, humidity, and any cleaning or repair work done during the time of exposure.

69. Romagnoli, G. Studies on the Climatic Conditions in Some Elementary Classrooms of Novara. Italian Review of Hyg. (Italy). 21:410-419, 1961.

Indoor and outdoor samples of "dust" were collected at six schools in the city of Novara. Two of the schools were located in the central area of the city, one in a suburban residential area, one in a suburban industrial area, and two in rural areas. Overall average dust counts indoors and outdoors and the indoor-outdoor precentage concentrations were as follows: (1) central — indoor 368, outdoor 662, 56 percent; (2) suburban residential — indoor 258, outdoor 280, 92 percent; (3) suburban industrial — indoor 340, outdoor 752, 45 percent; (4) rural — indoor 444, outdoor 690, 64 percent. The average particle size of dust in empty classrooms was 0.5 micron; during class, the average particle size was 1.2 microns. The author notes that "dust content of the air in the classrooms does not seem to reflect the outside situation and the values inside were always lower than those outside."

Samples were collected before classes (7:30 to 8:30 a.m.), during classes (10:30 to 11:30 a.m.), and after classes (4:00 to 5:00 p.m.) using an Owen's dust counter. Concerning the Owen's dust counter, the author mentions being "aware that the pollution values obtained with it are not perfectly reliable."

Bacteria concentrations were also measured inside the classrooms, but outside concentrations are not reported. Concentrations were found to be affected primarily by the presence of students, rising to up to 10 times before-class levels during class and falling rapidly after class. No remarkable quantitative or qualitative differences were found for the various locations considered.

70. Rostrup, O. Some Investigation of the Fungus-Spore Content in the Air. Botanisk Tidsskrift (Copenhagen). 29:32-41, 1908.

Indoor and outdoor spore samples were collected during 1903 and 1904 in Copenhagen by exposing petri dishes with beer wort, gelatin, or apple extract, or sweat-spoons with gelatin for 15 minutes. Indoor samples were collected in an apartment and outdoor samples in a park and on a street corner. Indoor spore concentrations averaged 57 percent of outdoor concentrations but varid from a mold which was only found indoors *(Aspergillus)* to three which were found in approximately 5 times greater abundance outdoors *(Hermodendron, Cladosporium,* and *Botrytis). Penicillium* and *Mucor* were always found in more abundance indoors. Results for other sampling locations, including a train compartment and a steamship, are also tabulated in the article. Indoor and outdoor samples were not collected at the same location, but this was a surprisingly comprehensive sampling program to be undertaken so long ago.

71. Sanders, W.M. BW Evaluation of Port Hueneme Pressurized Building 7-635, January 1955. Physical Defense Division, Camp Detrick. Maryland. Interim Report No. 104. September 1955.

This report covers tests to determine the amount of protection against biological warfare (BW) aerosols afforded by a building pressurized above outside static pressure and constructed with three different roof shapes: slant with no eaves, slant with eaves, and flat. Bacillus globigii was used for the aerosol in the tests. Respiratory exposure dosages averaged 2.6×10^6 organisms along the front of the building and 1.0×10^6 organisms along the rear. With a positive pressure inside the building and air being brought in through a Chemical Corps E35 Protector, the respiratory exposures inside were not significantly above background. With no filtered air entering the building, the respiratory exposures inside averaged approximately 2 percent of outside exposures. The results indicate that no particular roof shape gave more protection, but that slight internal pressure above atmospheric gave adequate protection.

Outdoor aerosol samples were collected by drawing air through cotton collectors at 5 liters/min. Indoor samples were collected by drawing air through membrane filters at 10 liters/min (test with filtered air) or 5 liters/min (test without filtered air).

Reference 8 and 47 contain additional evaluations of the interior effects of BW aerosols.

72. Segall, M. The Reduction of Smog Effects in California Institute of Technology Campus Buildings. Physical Plant Department, California Institute of Technology. Progress Report No. 3. 1964.

The report summarizes all tests and investigations made during 1963 concerning the smog problem in campus buildings. Smog intensity was measured outside and inside seven buildings with various types of air-conditioning and air-cleaning systems. Air-conditioning/cleaning systems include air conditioning with 0 to 90 percent recirculation of air, a spray type adiabatic air washer, and a saturating air washer. Reductions of total oxidants inside the seven buildings ranged from 20 to 94 percent. Unfortunately, the air-conditioning system which produced the greatest reduction in total oxidants is not described. These investigations show quite conclusively that maximum air recirculation is very effective in reducing oxidant levels indoors.

Oxidant levels were measured using portable total oxidant analyzers inside and outside the buildings during periods of smog (usually in August).

73. Seisaburo, S., K. Kiyoko, and N. Tatsuko. Free Dust Particles and Airborne Microflora. Bull. Dept. Home Econ., Osaka City Univ. (Osaka). 4:31-37, March 1959.

Summer measurements of free dust particles and airborne bacteria in concrete apartments, Japanese style wooden houses, and outside air in Toyonaka City are reported and compared with previously made winter measurements. Almost all measurements reported are for the apartments. Similar diurnal patterns for particles are found inside and outside during both summer and winter. A positive correlation between indoor and outdoor dust density, which was not affected by interior activities, was established. Indoor bacteria concentrations were not found to be related to outdoor concentrations. They were low from late night to early morning and high during waking hours, and concentrations seem to be essentially dependent on the degree of human activity. Particle concentrations were greater during the winter than during the summer, but bacteria concentrations up to 10 times higher than winter levels were measured during the summer.

74. Sekigawa, T. Ions in Air. II. Clean Air (Tokyo). 3(3):46-50, 1965. Text in Japanese.

A study was made on the physical aspects of air pollution in relation to the present situation in cities and according to methods of measurement of very small particles. The dusts present in the center of Tokyo were classified according to particle sizes of 19 ± 2 microns, 7.5 ± 0.3 microns, and 0.9 ± 0.1 micron. The study of extremely small particles (less than 0.1 micron) has not been extensive. Methods of measurement generally used are the coagulation method (density of fog generated by the particle is measured), the diffusion coefficient method (Stokes-Cunningham equation used to calculate the particle size from the diffusion coefficient), and the charge separation method (particle size obtained from mobility of the charged particle). Measurement of floating dust and polluted air indoors by the mobility spectrum is illustrated. An automatic recording-type impactor was used for measuring the weight of floating dusts, and HM-type large-size ion meter was used for measuring ion concentration. Hourly variations of floating dust concentration indoors and out are graphed, as are variations of small ions based on temperature, humidity, and wind direction. In connection with the ion spectrum, small and medium ions can be separated clearly in clean air, but the spectrum becomes continuous as pollution increases. Roughly speaking, the quantity of small ions present is inversely proportional to the amount of dust in the air. Medium-size ions increase as humidity increases.

75. Setterstrom, C. and P.W. Zimmerman. Sulphur Dioxide Content of Air at Boyce Thompson Institute. Contr. Boyce Thompson Inst. 3(3):171-178, 1938.

The sulfur dioxide (SO_2) content of the prevailing atmosphere at Boyce Thompson Institute was determined continuously from November 1, 1936, to November 1, 1937, with minor interruptions. For the year period, the average reading, including zero readings, was 0.033 ppm. Maximum concentration recorded was 0.75 ppm. The gas was present in concentrations of 0.01 ppm and over 62.2 percent of the time. Correlation of sulfur dioxide concentrations with the wind direction indicates that the sulfur dioxide comes largely from New York City (15.4 miles SSW to Times Square, which marks the approximate center of the metropolitan area). A study of the relationships between concentrations of sulfur dioxide in the atmosphere and in the air of a greenhouse shows that greenhouse concentrations are approximately 90 percent of atmospheric when ventilators are partly open and 60 percent when ventilators are closed. The fact that the many plants grown throughout the year in the institute greenhouses are considered comparable to plants grown in areas where there is no sulfur dioxide is an indication that exposure to sulfur dioxide in prevailing concentrations and durations has no unfavorable effect on plant life.

76. Shephard, R.J. Topographic and Meteorological Factors Influencing Air Pollution in Cincinnati. AMA Arch. Ind. Health. 19:44-54, 1959.

Analysis of hourly records of suspended particulate matter obtained for periods of 4 to 8 months from 60 homes in Cincinnati reveal large differences in domestic concentrations over short distances in the city, depending on whether windows were open, relationship of home to pollution sources, wind direction, and thermal inversions. No new indoor-outdoor data are presented in this article; it is based on data presented in References 9 and 77.

77. Shephard, R.J., G.C.R. Carey, and J.J. Phair. Critical Evaluation of a Filter-strip Smoke Sampler Used in Domestic Premises. AMA Arch. Ind. Health. 17:236-252, 1958.

Indoor and outdoor measurements of suspended particulate matter were made in Cincinnati at an experimental laboratory, a large old peoples' home, and a city home. Indoor and outdoor concentrations were nearly equal when the outdoor air was heavily contaminated (levels greater than 4.0COH/1000 linear foot). At lower levels, indoor concentrations were approximately 130 percent of those outdoors. Indoor concentrations lagged behind outdoor concentrations by 1 to 2 hours, and during periods of high pollution there was less fluctuation about peak values indoors than outdoors due to the "buffering capacity" of the inside air. Measurements inside the city home indicated that "under normal atmospheric conditions, the main component of suspended matter in the home was drawn from outside air, while during 'smog' periods the correspondence of the two measurements was even closer."

Samples were obtained with AISI tape samplers with millipore or Whatman filter paper and a flow rate of 3.5 to 4.0 liters/min. The indoor-outdoor relationships presented were only a minor portion of the article, which dealt primarily with domestic use of the AISI sampler in an air-hygiene survey.

Other results of this study are presented in Reference 9.

78. Shephard, R.J., M.E. Turner, G.C.R. Carey, and J.J. Phair. Correlation of Pulmonary Function and Domestic Microenvironment. J. Appl. Physiol. 15:70-76, 1960.

This article is based on analysis of suspended particulate, gaseous acid, and temperature and humidity measurements presented in References 9, 60, and 77. Indoor and outdoor levels of suspended particulates showed fair agreement when windows were kept open, but when windows were closed indoor concentrations were sometimes less than half the outdoor levels, particularly at night. Diurnal variations were found both inside and outside, but indoor curves showed fewer sharp peaks and often lagged behind outdoor levels by an hour or more. Levels were higher throughout the night and typically reached a sharp peak at 8:00 a.m. Night levels of total gaseous acid tended to be higher in early autumn; but during the winter, the day and night levels were similar. Indoor levels were somewhat lower than outdoors, and there was even less difference between day and night values.

79. Skvortsova, N.N. Pollution of Atmospheric Air with Carbon Monoxide in the Vicinity of Ferro-metallurgical Plants. Hyg. and Sanitation (Moscow). 22:3-9, 1957.

Atmospheric air samples were collected in the vicinity of two industrial plants, one with an open hearth furnace and the other with a blast furnace, and in living quarters close to these industries. Indoor and outdoor concentrations of carbon monoxide (CO) are reported for various distances (50 to 1000 meters) from the plants. Both carbon monoxide concentration and percentage of indoor to outdoor concentration generally decreased with increasing distance from the plants. Concentrations were higher in the vicinity of the blast furnace. Simultaneous study of atmospheric and indoor air for 24 hours showed a parallel pattern of indoor and outdoor concentrations. Results of much of the indoor-outdoor sampling which the author mentions doing are not presented in the article (e.g., 80 samples collected in a control area are never mentioned again).

80. Spagnolini, D. Research and Considerations on Air Pollution by Carbon Monoxide in Some Public Garages in Rome. Igiene Sanita Pubblica (Rome). 23(11-12):539-551, November-December 1967. Text in Italian.

Measurements of air samples, taken twice in five public and one private garage during the morning and evening rush hours and during the day, yielded carbon monoxide levels between 10 and 100 ppm. This level is tolerable for a prolonged period of work, with no danger of chronic intoxication.

81. Spiegelman, J., G.I. Blumstein, and H. Friedman. The Effects of an Air Purifying Apparatus on Ragweed Pollen, Mold, and Bacterial Counts. Anal. Allergy. 19:613-618, 1961.

To evaluate the effectiveness of an air conditioner and an electrostatic air purifier, daily pollen counts were taken for the 2-week period of August 28 to September 10, 1960, at a medical center in Philadelphia. Pollen samples were taken outside and inside four adjacent rooms with different ventilating conditions including: (1) no air conditioning, windows open, (2) air conditioner operating, (3) air purifier only operating, windows open, and (4) air purifier and air conditioner operating. During the first 6 days, there was no filter in the air conditioners; during the next 8 days, the standard filter was used. Inside the room with windows open, indoor concentrations averaged 68 percent of outdoor concentrations during the first 6 days and 28 percent during the next 8 days. Outdoor concentrations were lower during the first period, the mean being 47.4 grains/yd^3, as compared with 90.7 grains/yd^3 during the second. Use of the air conditioner reduced the indoor-outdoor percentage to 2 percent without the filter and 1 percent with the standard filter. Neither the standard filter not the electrostatic air purifier caused a significant reduction in pollen counts. A similar bacteria and mold count phase was also carried out, but no outside samples were collected. The results showed bacteria and mold counts in the air conditioned rooms to be only 9 percent of the counts with open windows. Again, neither filter nor air purifier gave significant reductions in concentrations.

All samples were taken at the seventh-floor level with a Marx Volumetric Impinger. The rooms were unoccupied, and doors were kept closed during sampling.

82. Spiegelman, J. and H. Friedman. The Effect of Central Air Filtration and Air Conditioning on Pollen and Microbial Contamination. J. Allergy. 42:193-202, 1968.

Pollen and microbial counts were made between June 13 and September 26, 1967, in two identical houses in Philadelphia, one of which was air conditioned and also equipped with a high-efficiency forced-air filtration system, and outdoors adjacent to the houses. (These are the same houses evaluated in an earlier study reported in Reference 83.) With the air conditioner and filtration system turned off, pollen concentrations were equal in the two houses and were about 5 percent of outdoor concentrations. Use of the air conditioner reduced concentrations to 1 percent of outside levels. Use of the air filter did not further reduce the pollen count. Some results of the microbial portion of the study are presented, but outdoor sampling results are not mentioned. Air conditioning also reduced the microbial concentrations relative to the non-air-conditioned house, but again the air filtration system did not effect further reductions.

Pollen was collected using a rotoslide sampler. A 2-hour sample was taken in each 24-hour period. Mold and bacteria samples were obtained by exposing petri dishes for 15 mintues each day.

83. Spiegelman, J., H. Friedman, and G.I. Blumstein. The Effects of Central Air Conditioning on Pollen, Mold, and Bacterial Concentrations. J. Allergy. 34:426-431, 1963.

Pollen, mold, and bacteria samples were collected between June 15 and October 1, 1962, in two identical houses in Philadelphia, one of which was centrally air conditioned, and outdoors adjacent to the houses. (The same houses are evaluated in the later study reported in Reference 82.) Pollen counts inside the non-air-conditioned house averaged 6 percent of outside levels. Air conditioning further reduced the concentration to 2 percent of outside levels. Concentrations of mold and bacteria showed no definite indoor-outdoor pattern, and counts were generally below 20 colonies/dish for either mold or bacteria in all of the locations. Failure to find an indoor-outdoor pattern may be due, in part, to transportation of these contaminants into the houses by the occupants.

Sampling methods used were as summarized for Reference 82. Bacteria and mold colonies were not identified.

84. Sreeramulu, T. Concentrations of Fungus Spores in the Air Inside a Cattle Shed. Acta Allergologica (Copenhagen). 16:337-346, 1961.

The air inside a cattle shed on a dairy farm in India was sampled from January 5 to 30, 1959, using a Hirst spore trap. The shed was open, without walls on the sides, so that outside air could freely enter the shed and dilute concentrations inside. No outside samples were taken for comparison with those in the shed. Concentrations and identifications are reported, but they are expected to be of little application in this country. The diurnal patterns reported may be of some interest. *Cladosporium* was found in higher concentrations during the daytime, with the maximum usually occurring around noon. *Fusarium* and *Basidiospores* were found more at night, with their maximums in the early morning hours. Spores of the *Aspergilli* type were found more commonly in the afternoon, with peaks around 6:00 p.m.

85. Stocks, P. Air Pollution and Cancer Mortality in Liverpool Hospital Region and North Wales. Int. J. Air Pollut. 1:1-13, 1958.

See Reference 86.

86. Stocks, P., B.T. Commins, and K.V. Aubrey. A Study of Polycyclic Hydrocarbons and Trace Elements in Smoke in Merseyside and Other Northern Localities. Int. J. Air Water Pollut. 4:141-153, 1961.

Indoor and outdoor air samples were collected for one or more years from October 1956 to 1958 at a large bus garage, an automobile repair shop, a large clerical office, and a large steelworks in Wales. Samples were analyzed for smoke, polynuclear hydrocarbons, metals, and to a very limited extent, sulfur dioxide. Seasonal and annual variations are reported. The study showed that indoor concentrations of smoke were the same as outdoor levels in the bus garage, somewhat higher in the automobile repair shop, and somewhat lower in the office. Indoor hydrocarbon levels were somewhat higher than outdoor levels in the bus garage, often considerably higher in the automobile repair shop, and considerably lower in the office. Indoor sulfur dioxide levels in the bus garage were less than one-third of outdoor levels. Indoor metal levels in the bus garage were, in general, somewhat higher than outdoor levels; exceptions were zinc, copper, nickel, antimony, and cobalt, which were found in lesser amounts. In the automobile repair shop, metal concentrations were, in general, somewhat lower than outdoor levels; exceptions were lead and vanadium, which were considerably higher, and nickel, which was considerably lower. Metal concentrations in the research laboratory of the steelworks were considerably lower than outdoor levels, but at other buildings at the steelworks were always very much higher than outdoor levels.

A portion of this study was reported earlier in Reference 85.

87. Submarine Atmosphere Habitability Data Book. Washington, D.C., Bureau of Ships, Navy Department, 1962.

This reference does not contain indoor-outdoor air pollution data, but the atmospheric monitoring equipment used in submarines is described. This equipment includes: (1) Mark IV Atmosphere Analyzer with channels for carbon monoxide (CO), carbon dioxide (CO_2), Freon 12, oxygen (O_2), hydrogen (H_2), and UV (ozone, mercury vapor, aromatic hydrocarbons); (2) portable atmosphere monitoring units including Beckman visual indication paramagnetic oxygen analyzer, Dwyer orsat for carbon dioxide, NBS detector tubes for carbon monoxide, and MSA and Davis catalytic combustion units for hydrogen and hydrocarbons; and (3) semiquantitative instruments for checking unusual occurrences (the nucleus of these instruments is the Draeger Gas Detector Kit with a complete selection of tubes for various contaminants).

88. Swaebly, M.A. and C.M. Christensen. Molds in House Dust, Furniture Stuffing, and in the Air Within Homes. J. Allergy. 23:370-374, 1952.

Petri dishes were exposed for 12 minutes at several different times of day in 15 homes in St. Paul during the spring and early summer of 1950 and 1951; dishes were exposed outdoors at the same times and locations. (Results are presented for only seven of these locations.) In addition, dust samples were collected from vacuum cleaners in 76 homes in St. Paul and Minneapolis during the winters of 1950 and 1951, and new and used furniture stuffing was obtained from furniture repair shops in these cities. Indoor-outdoor sampling indicated spore counts, in colonies per dish, ranging from 13 to 80 outdoors and, under various reported conditions, from 0 to 46 indoors. Mean indoor concentration was 12 colonies per dish, or 32 percent of the outdoor mean. *Penicillium* and *Aspergillus* were the predominant molds in indoor air, while *Alternaria* and *Cladosporium* predominated outdoors. Mean numbers of mold and bacteria colonies found per gram of house dust were approximately 180,000 and 10,700,000 respectively. Mold colonies per gram of new furniture stuffing were as follows: cotton – 11,000, kapok – 4,000, foam rubber – 1,000. Bacteria colonies per gram were: cotton – 1,680,000, kapok – 22,000, foam rubber – 60. No results for molds or bacteria in used furniture stuffing were presented other than that they were "present in considerably greater numbers in some used materials."

89. Tomson, N.M., Z.V. Dubrovina, and M.I. Grigor'eva. Effect of Viscose Production Discharges on the Health of Inhabitants. In: U.S.S.R. Literature on Air Pollution and Related Occupational Diseases (Levine). 8:140-144, 1963.

Indoor and outdoor air samples were collected from December 18 to 27, 1957, near a viscose plant which discharged carbon bisulfide (CS_2), hydrogen sulfide (H_2S), and sulfur dixoide (SO_2) to the atmosphere; 264 open air and 93 living quarters samples were collected. Concentrations of the different pollutants were higher indoors than outdoors in 42 percent of the samples. Average indoor-to-outdoor percentages ranged from 67 to 90 percent.

90. Vaughan, W.T. and L.E. Cooley. Air Conditioning as a Means of Removing Pollen and Other Particulate Matter and of Relieving Pollinosis. J. Allergy. 5:37-44, 1933.

In order to evaluate the performance of an air conditioner, comparative ragweed pollen counts were made during September and October 1932 at three locations – an air-conditioned room, an adjacent non-air-conditioned room, and a window sill outside the second room — at a hospital in Richmond, Virginia. Pollen counts in the non-air-conditioned room were 33 percent of outdoor counts. The air conditioner further reduced the count to 0.2 percent of the outdoor count.

Microscope slides coated with a thin layer of vaseline were used to collect samples. Only eight samples, ranging from 1 to 9 days duration, were taken during the 29-day sampling period. Only four of these were collected in the non-air-conditioned room, covering a period of 11 days.

This article dealt primarily with experimental tests of the air conditioner which were not directly applicable to indoor-outdoor relationships.

91. Volksch, G. The Climate in Operating Rooms and its Effect on the Hygienic Properties of the Air. Angew. Meteorol. 5(9-11):340-346, 1968. Text in German.

Detailed measurements of humidity, temperature, dust concentration, bacterial count, and air movement were made over the course of a year in five different operating rooms in German cities; only one of the operating rooms was air conditioned. Compared to an accepted norm of 20 to 25 °C and a relative humidity of 50 to 60 percent, only 27.2 percent of the measurements revealed acceptable conditions – the temperature being too hot or too cold 5.9 to 11.3 percent of the time, and the humidity being too low or too high 31.7 to 36.9 percent of the time. Especially during the summer, the temperature and humidity often rose to levels producing marked discomfort. The average dust concentration was 59 x 10^6 particles/m^3 The average bacterial count was 1600/m^3 in the four operating rooms without air conditioners and 230/m^3 in the one which was air conditioned. The bacterial count depended on the frequency of use of the operating room, and increased in direct proportion to the relative humidity, but was unrelated to the dust concentration.

92. Wallace, M.E., R.H. Weaver, and M. Scherago. A Weekly Mold Survey of Air and Dust in Lexington, Kentucky. Anal. Allergy. 8:202-211, 1950.

Airborne spores were collected by exposing two petri dishes (one with Sabouraud's agar and one with potato-glucose agar) for 15 minutes once each week from July to October and again for 3 weeks in January at two outdoor locations – the Kentucky Agricultural Experiment Station Farm and Main Street, Lexington – and three indoor locations – a theater and two residences. Dust samples were also collected at the indoor locations.

The overall indoor-outdoor percentage for total mold spores, considering all samples from both seasons, was 33 percent. For *Penicillium*, the overall percentage was 34 percent; for *Aspergillus*, it was 29 percent. *Penicillium* and *Aspergillus* were the predominant genera found both summer and winter from all sources of samples. *Penicillium* was equally common from all sources in both seasons. *Aspergillus* was more prevalent in dusts than in either indoor or outdoor air. Mold counts in the theater were very low, possibly due to a large air-conditioning system; but dust samples yielded relatively high counts. The authors comment that "there was no significant effect of any climatic condition except possibly temperature on the numbers or types of mold in the air."

93. Walter, R.E. Studies on the Nature of Urban Air Pollution. 1967. London Conference on Museum Climatology, Sept. 18-23, 1968. Published by the International Institute for Conservation of Historic and Artistic Works, the National Gallery, Trafalgar Square, London, England. (rev. ed. May 1968). p. 65-69.

Studies were made of suspended matter, i.e., particles and droplets having diameters less than 5 microns which do not settle rapidly under gravity and which are small enough to be inhaled into the respiratory tract. Coal smoke is an important component of suspended matter, but inorganic salts, fine particles of ash, and acid droplets are also present. The studies were made with both the optical microscope and the electron microscope. Where comparisons could be made of estimations of mass from electron micrographs with those from smoke filter measurements, the results were in reasonable agreement. Another study was made to determine concentrations of smoke, sulfur dioxide, and particulate acid outdoors, indoors in a naturally ventilated gallery, and indoors in an air-conditioned gallery.

94. Weatherly, M.L. Air Pollution Inside the Home. Warren Spring Laboratory Investigation of Atmospheric Pollution, Standing Conference of Cooperating Bodies, May 16, 1966.

See Reference 95.

95. Weatherly, M.L. Air Pollution Inside the Home. In: Symposium on Plume Behavior. Int. J. Air Water Pollut. 10:404-409, 1966.

Smoke and sulfur dioxide (SO_2) were measured inside and outside a small room (office-laboratory) in central London during January, February, and March 1960. Concentrations of smoke indoors averaged 95 percent of outdoor levels. There was no consistent difference between indoor and outdoor levels when outdoor concentrations were below 300 $\mu g/m^3$. Above this level, indoor concentrations relative to outdoor concentrations decreased. Maximum indoor-outdoor difference was 22 percent when outdoor concentration was 800 $\mu g/m^3$. The correlation between indoor-outdoor percentage and outdoor concentration was significant at the 1 percent level. Sulfur dioxide concentrations were always less indoors, averaging 40 percent less. There was no indication that the percentage difference increased with outdoor concentration. Results for both smoke and sulfur dioxide appeared to be unaffected by whether or not the window was open. Based on these results and a review of previous literature, the author concluded that, when pollution is high outdoors, both smoke and sulfur dioxide concentrations are less, and often much less, indoors. When pollution outside is moderate to low, smoke indoors is about the same as outside, but sulfur dioxide is always less.

This study is also reported in Reference 94.

96. Whitby, K.T., A.B. Algren, and R.C. Jordan. Size Distribution and Concentration of Air-borne Dust. Trans. Amer. Soc. Heating, Air-cond. Eng. 61:463-482, 1955.

Indoor air samples were obtained with an AISI tape sampler at the University of Minnesota Particle Technology Laboratory from February 17 to March 3. Soiling index, concentrations, and size distributions were calculated. No outdoor sampling was done with the indoor sampling. Mean soiling index was 1.4 COH/1000 linear feet, and mean concentration was 96 $\mu g/m^3$. Mean volume size distribution was 3.5 microns, mean number size distribution was 0.65 micron, and mean particle size was 2.29 microns. Indoor sampling results were only a small portion of the paper, which dealt primarily with apparatus and methods for determination of size distribution and concentration.

97. Whitby, K.T., A.B. Algren, R.C. Jordan, and J.C. Annis. The ASHAE Air-borne Dust Survey. Heating, Piping and Air Cond. 29:185-192, 1957.

Indoor and outdoor air samples were taken in Pittsburgh, Pa., Louisville, Ken., Akron, Ohio, and Minneapolis, Minn., and particle size distributions and concentrations by weight, light transmission (soiling index), and dustfall were calculated. Inside locations included residences, laboratories, and offices and represented a range of conditions from old downtown-area buildings with no air cleaning to modern air-conditioned offices. Outside sampling was in areas ranging from commercial districts to clean residential areas. The difference between inside and outside dustfall levels and size distributions was found to be significant at the 5 percent level. In Minneapolis, the difference in heating season and nonheating season dustfall and size distribution was found to be significant at the 5 percent level.

Size and concentration by weight and light transmission were determined from samples collected on 47-mm millipore filters. Dustfall was determined from samples collected on standard microscope slides, and results were expressed in O.D.D. units. (The authors note that one O.D.D. unit is approximately equal to 1.66 tons/mi^2/month.) The number of samples from various locations varied considerably.

98. Whitby, K.T., R.C. Jordan, and A.B. Algren. Field and Laboratory Performance of Air Cleaners. Amer. Soc. Heating, Refrig., Air-cond. Eng. J. 4:79-88, 1962.

Dust samples were collected in a home during the heating season (October 1959 to January 1960) to measure the dustfall in various rooms of the house, determine a dust balance for the house, and determine the efficiency of a filter and electrostatic air cleaner in the heating system. The dust balance showed that 2000 grams was collected in the vacuum cleaner, 60 grams was collected in air cleaners, and 480 grams settled on the floor. Thus, dust caught in air cleaners represents 12.5 percent of the dustfall in the home, and only 3 percent of the dust with which the housewife must contend. There was a small but significant reduction in dustfall during electrostatic air cleaner operation, and COH (soiling particulate) levels were also significantly reduced. However, most of the dust generated in each room settled before it could be transported to the return air ducts. The authors comment that the furnace fan is almost as good a collector as a filter in the heating system, but the filter is necessary to prevent dirt buildup on the fan and heat transfer surfaces.

Weights were determined for dust collected in the vacuum cleaner, dust collected in air cleaners, and settled dust on microscope slides. COH levels were determiend using an AISI tape sampler. No outdoor samples were collected for comparison.

99. Wilson, M.J.G. Indoor Air Pollution. Proc. Roy. Soc., Ser. A (London). 300:215-221, 1968.

The pollutant absorbtion qualities of interior finishes were tested by liberating a pollutant in a test room to give a concentration of about 1 mg/m^3 and then studying the decay of concentration during the return to equilibrium. The test room was a chemical laboratory with a volume of 47 m^3 and an area of about 124 m^2. It had no artificial ventilation and no fabric furnishings. Half-lives, corrected for air leakage, were found to be as follows: hydrogen chloride (HCl) 7 minutes, sulfur dioxide (SO_2) 40 to 60 minutes, smoke 145 to 300 minutes. The results indicated that the rate of removal of sulfur dioxide was limited mainly by the properties of the surfaces, and only slightly by transport to the surfaces. The ceiling (fiberboard painted with eggshell paint) was reasonably effective in removing sulfur dioxide, but walls (emulsion paint), floor (lacquered cork), and treated wood surfaces were not. Measurements of equilibrium concentrations of sulfur dioxide and smoke were also made. Indoor concentrations of sulfur dioxide were always more than 25 percent of the outdoor value, approaching 100 percent when outdoor concentrations were low. Indoor smoke concentrations were found to be almost as large as those outdoors.

100. Winslow, C.E.A. and W.W. Browne. The Microbic Content of Indoor and Outdoor Air. Monthly Weather Review. 42:452-453, 1914.

During the first 6 months of 1914, air samples were collected and examined for microbes (mold and bacteria). Outside samples were taken in the country and in the streets of New York City. Indoor samples were taken in offices, factories, and schools in New York and Washington, D.C. The number of microbes in city air was somewhat higher than in country air. Indoor counts were higher than outdoor city counts, with the following indoor-outdoor percentages: offices — 167 percent, factories — 169 percent, schools — 133 percent. Streptococci were identified in the samples, and the data indicated the following indoor-outdoor percentages: offices — 200 percent, factories — 391 percent, schools — 273 percent.

Microbe samples were collected by drawing 5 ft^3 of air through sand, washing the sand with water, and plating aliquot portions of the water. Cultures were made at 20°C on gelatin and 37°C on litmus-lactose-agar to get microbes capable of development at body temperature. The number of mouth streptococci in the air were estimated by isolating pure cultures from characteristic colonies on litmus-lactose-agar plates. No attempt was made to identify any bacteria or mold colonies other than streptococci. Indoor and outdoor samples were not taken at the same locations.

101. Yaglou, C.P. and L.C. Benjamin. Diurnal and Seasonal Variations in the Small-ion Content of Outdoor and Indoor Air. Trans. Amer. Soc. Heating and Ventilation Eng. 40:271-288, 1934.

Daily observations of the small ion content of outdoor and indoor air from May 1930 to May 1933 disclose definite diurnal and seasonal variations depending largely upon local and general meteorological conditions. The most important climatic factors affecting the small ion content of outdoor air appear to be the interdiurnal changes of temperature and humidity. A drop in the interdiurnal temperature and humidity is, as a rule, preceded or accompanied by a sharp rise in the ion content of air, and vice versa, provided that the drop or rise in temperature and humidity does not continue more than 2 days. Cloudiness, high humidities, and light or moderate precipitation have a detrimental effect on the small ion content of outdoor air. Heavy precipitation results in a considerable increase in the number of small negative ions, and when the precipitation is accompanied with thunder and lightning, both positive and negative ions attain very high values. In winter, the concentration of small ions in indoor air is considerably lower than that in outdoor air. In summer the reverse seems to hold true. Adverse weather of short duration does not conspicuously affect the indoor concentration in spite of powerful effect on the outdoor ions. Persistent bad weather tends to equalize the outdoor and indoor ion numbers.

102. Yates, M.W. A Preliminary Study of Carbon Monoxide Gas in the Home. Environ. Health. 29(5):413-420, March-April 1967.

One-hundred-and-fifty investigations were made on incidents involving human exposure to carbon monoxide (CO) in the home environment from October 1964 through March 1965. One-thousand-and-sixty-one combustion appliances were tested for the emission of carbon monoxide in 372 residential establishments, and 40 percent of the homes investigated contained one or more appliances that were found to be emitting carbon monoxide. Twenty-five percent of all appliances tested were discharging carbon monoxide into the room atmsophere and 24 percent of those that were found positive were emitting carbon monoxide in the range of 200 ppm and over by volume in air. Forty percent of the people who lived in houses that were found to be positive for carbon monoxide gave clinical histories similar to those of carbon monoxide anoxia. From the limited data collected, it is quite probable that continued exposure to subacute concentrations of carbon monoxide in homes could be a predisposing cause of some undiagnosed illnesses. Carbon monoxide from home combustion appliances is due to a multiplicity of causes and can only be detected by scientific instruments. There are, however, some warning signs that should be regarded with suspicion, such as the odor of combustion products, the presence of smoke, and sooty deposits aroung heat registers, exhaust discharges, and vent pipe joints. As a result of this study, a number of recommendations are made.

103. Yocom, J.E., W.L. Clink, and W.A. Cote. Indoor/Outdoor Air Quality Relationships. J. Air Pollut. Contr. Ass. 21:251-259, May 1971.

Indoor and outdoor air samples were taken in Hartford, Conn., during the winter of 1969 and during the summer, fall, and winter of 1969-70. Two homes were sampled during the preliminary program in the winter of 1969 to verify procedures and equipment and to assess the effects of heating and cooking systems. During the primary program, suspended particulate, soiling particulate, carbon monoxide (CO), and sulfur dioxide (SO_2) were measured at pairs of homes, office buildings, and public buildings. Results of the preliminary study indicated that gas heating systems did not affect indoor carbon monoxide concentrations, but that gas stoves and attached garages were a significant source of indoor carbon monoxide. Sulfur dioxide was found to penetrate structures and diffuse into their interiors to variable degrees which may depend on atmospheric stability and level of activity inside. Results of the primary program indicated that suspended particulate matter readily penetrated private homes in the summer. Penetration was more on the order of 50 percent in other buildings and other seasons. Carbon monoxide readily penetrated all the structures. Anomalies were readily related to source and ventilation variables. Internal generation of pollutants was a significant factor in the measured interior concentrations in some of the structures.

Two self-contained, portable instrument packages were constructed for the primary program. The major components of each trailer package were a central vacuum pump for drawing air samples through particulate collection filters, four paper-tape soiling samplers, a conductimetric analyzer for sulfur dioxide, an infrared analyzer for carbon monoxide, a master control unit, and supporting apparatus to make the trailer self-contained. Each pair of buildings was sampled simultaneously for a 2-week period. Four sampling points were selected for each structure: far outside, near outside, near inside, and far inside. Suspended particulate samples were collected for 12-hour day and night periods, soiling particulate samples for 2-hour periods, and gaseous samples for 5-minute periods.

Results of this study are also reported in References 104 and 105. Reference 105 covers results of the preliminary study, and Reference 104 includes the preliminary study and the summer portion of the primary study. This article covers the entire program, but does not include some detailed information included in the earlier publications. Additional analyses of the data for air-conditioned buildings reported in this article are given in References 28, 39, and 106.

104. Yocom, J.E., W.L. Clink, and W.A. Cote. Indoor/Outdoor Air Quality Relationships. Presented at the 63rd annual meeting of the Air Pollution Control Association, St. Louis. June 14-18, 1970.

See Reference 103.

105. Yocom, J.E., W.A. Cote, and W.L. Clink. Summary Report of a Study of Indoor-Outdoor Air Pollutant Relationships to the National Air Pollution Control Administration. The Travelers Research Corp. Hartford, Conn. Contract No. CPA-22-69-14. 1969.

See Reference 103.

106. Yocom, J.E. and W.A. Cote. Indoor/Outdoor Air Pollutant Relationships for Air-Conditioned Buildings. Amer. Soc. Heating, Refrig., and Air-cond. Eng. New York, 1971. Preprint of paper for inclusion in ASHRAE Transactions.

This paper is based on measurements made in two air-conditioned offices in Hartford, Conn. These results are also presented in Reference 103, but this paper includes some additional analysis of the results. Roughing filters used in air-conditioning systems are effective in the removal of relatively large particles. They are not especially effective in the removal of that portion of particulate matter which contains benzene soluble organic material or inorganic lead nor of that portion which accounts for soiling properties. As might be expected, carbon monoxide, being unreactive, is not affected by air conditioning components; however, the method of operating such a system can have considerable effect on inside levels. (See Reference 39.)

107. Yoshizawa, S., Y. Kobayashi, and E. Hashimito. Indoor Effects of Air Pollution. J. Japanese Soc. Air Pollut. 2(1):68-69, November 1967. Presented to the semiannual meeting of the Amer. Soc. of Heating, Refrig., and Air-cond. Eng. Philadelphia. January 24-28, 1971.

Theoretical formulas are developed for determining the amount of gaseous pollutant adsorbed by an indoor environment. These formulas define the amount of gas adsorbed by a surface and the remainder of gas in and out of a room. The formulas are too complex to present here. Based on previous experimental work, the adsorption rate for sulfur dioxide (SO_2) on an oil paint finish is given as 0.244 m^3/hr with no air movement and 1.48 m^3/hr with an air movement of 18 m^3/hr.

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