# Air Quality of American Homes

Abstract. *In a survey of particulate fallout in homes it was found that there is a relation between pollution inside and outside a home. The level inside the home also depends on the location of the home (urban, suburban, or rural). Bathrooms and kitchens show heavier particle fallout than living rooms or bedrooms.*

The quality of the air in American homes was recently measured as part of a field program administered by the AAAS and funded by the National Science Foundation. College teachers (103) from 53 different colleges participated in one of the four National Science Foundation Chautauqua-type short courses conducted as part of the program. The course on air pollution was given by Drs. V. J. Schaefer and V. A. Mohnen. The program consisted of a series of intensive lectures and illustrated talks given alternately in successive 2-day presentations at the Field Museum in Chicago, the University of Maryland at College Park, Clark College at Atlanta, Georgia, and the University of Texas at Austin.

Toward the end of the first session in November 1970, a research project was adopted by each of the four groups. This project consisted of measurements of the dust fall ("settleable particles") within the individual homes (living quarters ranging from small apartments to large, rambling homes in urban, suburban, and country environments) of the participants and some of their colleagues and students. The foils, as well as the holders, used in our experiments were dimensionally duplicates of the so-called "Haftfolie nach Diem" (*1*). The aluminum foils measured 7.6 cm in length and 4.1 cm in width. Over 25 $cm^2$ of each sheet was coated with silicone adhesive SR-516 (General Electric). This coating material is better by far than Vaseline and eliminates quite a few disadvantages that were inherent in the original sedimentation foil (*2*). The sedimentation foil technique was first used to measure dust fall in London. Its use in air pollution is restricted, owing to the fact that one cannot quantitatively collect dust that is brought down by rain.

More than 1000 of the specially treated and weighed aluminum foils were placed in various rooms of the homes (more than 100 homes were tested) and left in position for 30 days. Upon retrieval, they were again weighed, and some were analyzed for special types of impurities; quite a few were examined under various degrees of magnification, and a number of photomicrographs were prepared of typical samples. Figure 1 illustrates photomicrographs of slides exposed for 30 days in two rooms of a home.

The sedimentation measurements were obtained from the mass which collected on the aluminum sheets that were attached to simple holders and then exposed to particulate fallout from the air during the period from 15 December 1970 to 15 January 1971. About 25 percent of the 1072 measurements were obtained from foils that were set up in pairs. Measurements were made inside homes in four regions of the country, and, in addition, a few individuals exposed foils outside of their homes. In the Chicago region, foils were placed in 14 homes, ranging from the inner city, to the suburbs, and as far away as Oshkosh, Wisconsin. In the Washington, D.C., region, there were 35 homes from central Virginia through Maryland to Pennsylvania. There were 22 homes in the Atlanta region from Greenville, South Carolina, through Georgia to central Tennessee. Finally, there were 17 homes in the Austin–San Antonio, Texas, region.

The accuracy of the sedimentation foil measurements can be evaluated by examining the correlation between measurements on foils exposed in pairs so that both members of a pair have sampled the same particulate fallout. Such studies (*3*) indicated that most such comparisons showed variations of

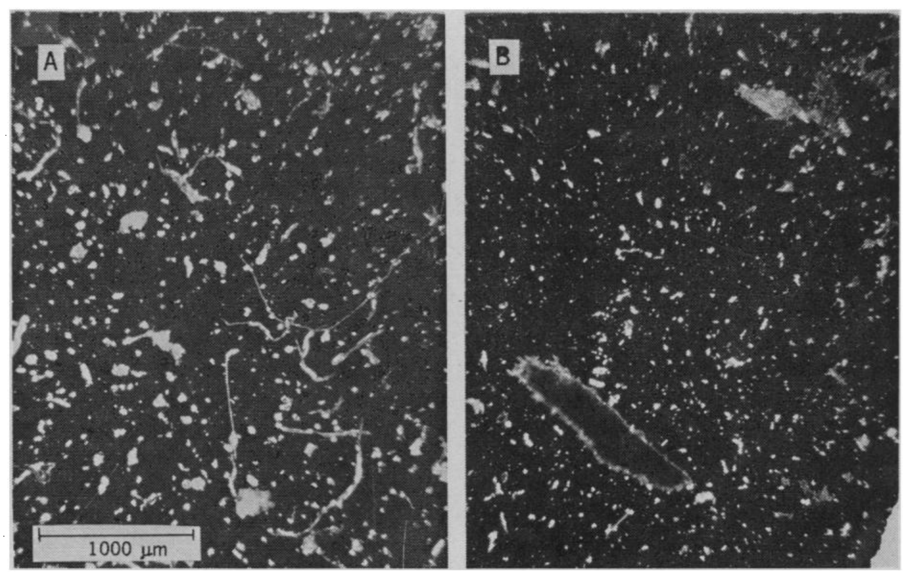


**Fig. 1. Photomicrographs of two sedimentation slides taken in a home: (A) bathroom; (B) woodworking shop.**

Table 1. Sedimentation regimes.

| Sedimentation (mass per foil) (mg) | Regime |
|---|---|
| 0.75 | Island in large freshwater lake |
| <2.25 | Uninhabited areas with thick vegetation cover |
| 2.25 to 4.5 | Areas of low population density, general background of eastern United States |
| 4.5 to 9 | Residential areas in suburbs and small cities on the periphery of industrial areas |
| 9 to 18 | Cities, industrial areas, shopping centers |
| >18 | Downtown areas of cities, immediately adjacent to some "dusty" types of industries, adjacent to busy highways |
| All ranges, depending on wind and rain during period | Deserts and areas with large blocks of bare ground |

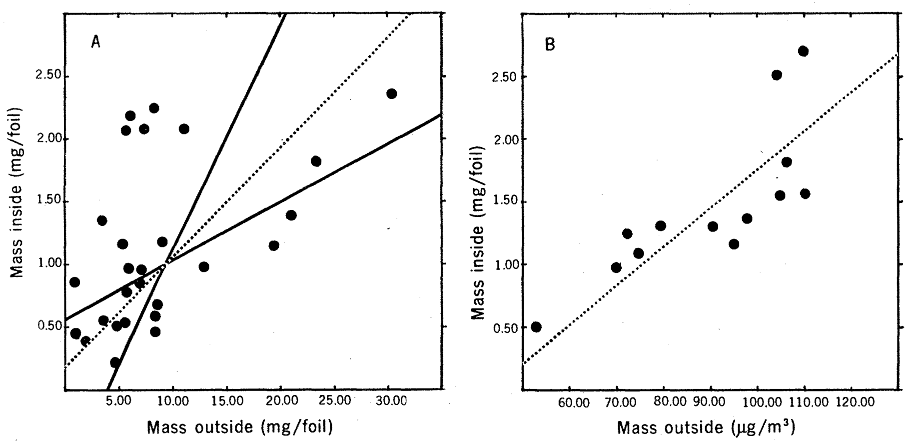


Fig. 2. (A) Correlation between inside and outside measurements; (B) correlation between inside measurements and calculated particulate concentrations. In each case a linear relation is observed between the average mass of particulate matter deposited inside and outside the home.

less than 3 mg, the correlation coefficient being $\rho = 0.47$.

In order to determine the reproducibility of sedimentation foil measurements in a more controlled environment, D. G. Hicks of Georgia State University, Atlanta, exposed 16 foils in a single array. The mean value of the mass collected per foil is 0.22 mg per foil, and the standard deviation of the 16 measurements is 0.08 mg. This distribution is consistent with a normal distribution, resulting from statistical fluctuations in the measurements.

Twenty-six measurements of mass were made at various homes with foils placed in the outside air ($M_o$), and these measurements can be compared with the average (*4, 5*) mass per foil collected inside the respective homes ($M_{av,i}$). Figure 2A shows the correlation between the inside and outside measurements. The linear regression lines are shown, and the correlation coefficient is $\rho = 0.46$. The dotted line is the orthogonal mean square regression line (*4*) for which the following equation can be written:

$$M_{av,i} = 0.2 \text{ mg} + 0.1\, M_o$$

Another comparison between particulate concentrations inside and outside the home was obtained in the Chicago area. This was done by relating the average mass per foil measured inside the home with the annual geometric micrograms per cubic meter) (*6*) determined by means of a diffusion model mean of particulate concentrations (in based on all particulate sources in the Chicago region. Figure 2B shows the correlation between the inside measurements and the calculated particulate concentrations. The correlation coefficient is $\rho = 0.7$, and here again there is a linear relation between particulate concentrations inside and outside the home.

In order to be able to better relate the dust fall inside homes to the sedimentation that occurs outside in various densely populated or remote areas, we present in Table 1 a general classification of sedimentation regimes. The underlying measurements were obtained from our own network and are averages of measurements on over 6000 foils exposed during the period from March through August 1970 (*7*).

A comparison of the results from home to home and from region to region reveals the following correlation. In the cases where the windows were open most of the time during the experiment, the average mass collected per foil was dramatically higher than in the cases where the windows were kept closed. For example, for suburban homes with closed windows (720 measurements), the mean value of the mass collected was 1.54 mg per foil, whereas for suburban homes with open windows (68 measurements), most in the Atlanta region, the mean value was 3.77 mg per foil.

Figure 3 summarizes the average mass collected on the sedimentation foils in homes with closed windows. The highest mass occurred in urban

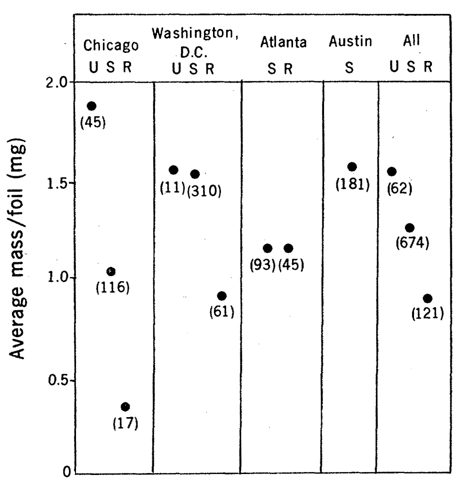


Fig. 3 (top). Average mass collected on sedimentation foils in different homes. This sample does not include homes in which the windows were open most of the time; *U*, urban homes; *S*, suburban homes; *R*, rural homes. The numbers in parentheses indicate the number of measurements.

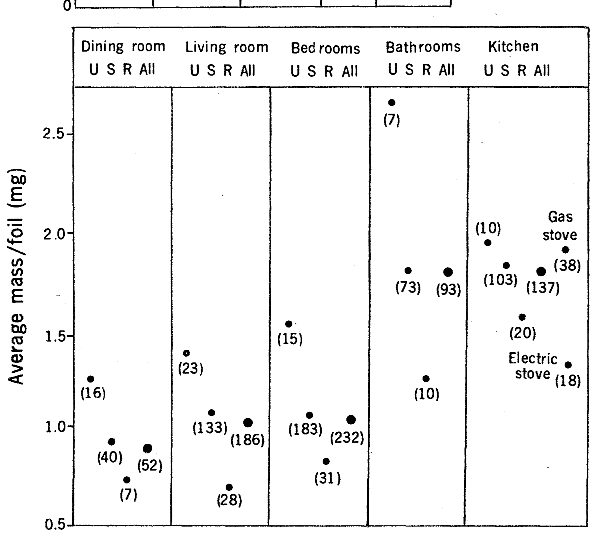


Fig. 4 (bottom). Average mass collected on sedimentation foils in different rooms. This sample does not include homes in which the windows were open most of the time.

Chicago and was about one-half of the mass collected in homes where the windows were kept open. In the progression from an urban to a rural environment, the average mass collected in the 30-day period decreased by about a factor of 2.

Figure 4 compares the masses collected in various rooms of the home. The values corresponding to the bathroom and the kitchen measurements are significantly higher than for the other rooms. Kitchens with gas stoves (38) contained more than the overall average particulate mass, and those with electric stoves (18) contained less. In the progression from rural to urban areas, for homes with closed windows, the relative comparison between rooms did not change, and the particulate concentrations in the suburban homes were approximately the same as the overall averages, with the rural areas contributing less and the urban areas contributing more.

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### References and Notes

1. M. Diem, *Staub* **21**, 345 (1961).
2. A. W. Hogan, *J. Appl. Meteorol.* **10**, 592 (1971).
3. H. Cramer, *Mathematical Methods of Statistics* (Princeton Univ. Press, Princeton, N.J., 1946).
4. In order to reject measurements which might have come from damaged or contaminated foils, a two-step procedure was used. First, we calculated the mean and standard deviation by using all of the measurements; then any measurements lying more than 2 standard deviations from the mean were omitted, and the remaining sample was used to calculate a new mean and standard deviation. This procedure usually resulted in the rejection of approximately 10 percent of the events and gave a significant decrease in the standard deviation. The fractional uncertainty, that is, the standard deviation over the mean, is between 50 and 80 percent for most of the averages computed.
5. The rate of particulate fallout is given in milligrams per foil per month and can be easily converted to other measures of the rate of sedimentation. For example, 1 mg per foil per month is approximately equal to 1 pound per 1000 square feet per year.
6. *Argonne Nat. Lab. Center Environ. Stud. Rep. IIPP-3* (March 1970).
7. V. A. Mohnen, *Conservationist* **25** (No. 1), 10 (Aug.–Sept. 1970).
8. We are especially grateful to Dr. J. Mayor and H. Foncannon of the Commission on Science Education of the AAAS for the opportunity two of us (V.J.S. and V.A.M.) had to present the short course on Air Pollution. We are especially indebted to the teachers who participated in the field phase of this program and provided us with data. A considerable number of these teachers conducted special research studies, and all of the data were sent to one of us (V.R.V.) who developed the computer program and analyzed all of the slides. We thank R. J. Cheng of the Atmospheric Sciences Research Center for the photomicrographs of the sample slides. Supported by the National Science Foundation.

15 June 1971; revised 4 October 1971

# Copper on Intrauterine Devices Stimulates Leukocyte Exudation

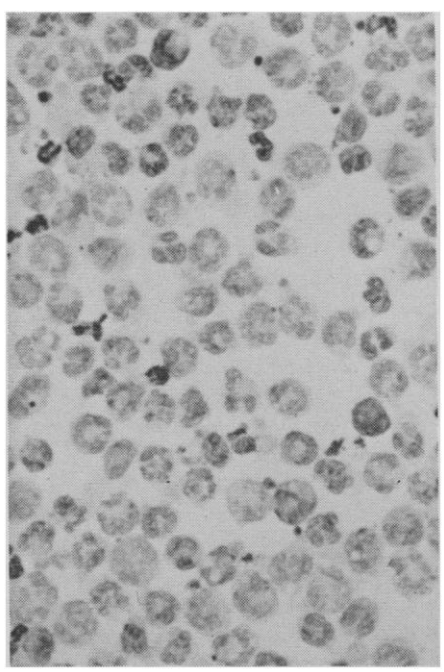
Abstract. *Metallic copper in the uterine or abdominal cavities of rats or monkeys stimulates an impressive local exudation of polymorphonuclear leukocytes. This cellular response to copper persists for at least 7 months, without significant local tissue damage or detectable systemic effects on the test animal. This finding provides a possible explanation for the capacity of copper to increase impressively the antifertility effect of polyethylene intrauterine contraceptive devices.*

Metallic copper has been shown to exert a potent antifertility effect in the uterine cavity (*1*). The pregnancy rate in women using the "Tatum T" plain polyethylene intrauterine contraceptive device was found to be 18 percent per year, whereas this rate was reduced to 0.5 percent or less by addition of a coil of fine copper wire (200 mm$^2$ surface area) to this device. A fine copper wire placed in the lumen of one rat uterine horn completely prevented pregnancies in that horn, without influencing the number of fetuses in the control horn, an indication that the copper wire was acting locally, not systemically, to produce an antifertility effect. The mechanism of action of copper in this situation is unknown.

Parr and colleagues (*2*) have demonstrated a correlation between mobilization of leukocytes into the uterine cavity and the efficacy of various types of intrauterine contraceptive devices. The evidence indicated that the persistent low-grade inflammation with accompanying leukocyte emigration resulted in local conditions toxic for the fertilized egg. El Sahwi and Moyer (*3*) have found a quantitative relation between the presence of leukocytes and the antifertility effect.

We now report observations in rats and monkeys on the local mobilization of leukocytes in response to implantation of polyethylene or metallic copper devices. The devices were inserted aseptically into the uterus or into the abdominal cavity. At intervals from 10 days to 7 months smears were made of the surface coatings of the devices, and the adjacent tissues were fixed for study by light and electron microscopy.

The results (Table 1 and Figs. 1 and 2) show that metallic copper alone or a copper-clad polyethylene device in the



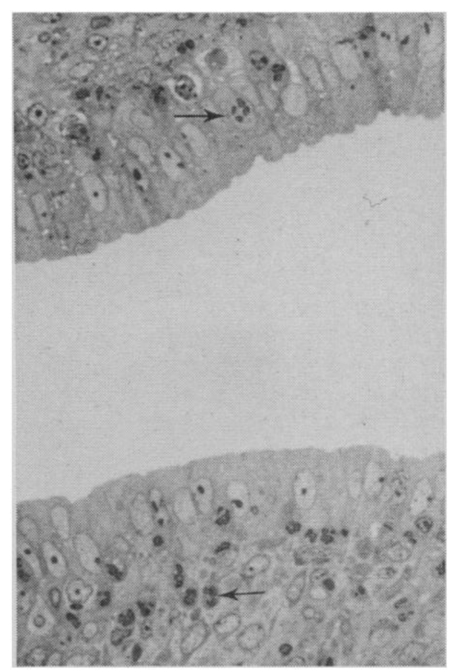


Fig. 1 (left). Smear of surface of a copper wire that had been in a rat uterine horn for 10 days. Numerous polymorphonuclear leukocytes are seen. [Tissue was air dried, and Wright-Giemsa stained (×412)]. Fig. 2 (right). Rat uterine horn fixed 10 days after insertion of a thin copper wire. The lumen (open space) and endometrium are shown. Numerous polymorphonuclear leukocytes (arrows point to examples) are seen in the stromal and in the surface epithelial layers. Fixed with glutaraldehyde and osmium, and embedded in Epon; thick section stained with azure A at alkaline *p*H (×128).