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COMPARISONS OF ELEMENTS AND INORGANIC COMPOUNDS INSIDE AND OUTSIDE OF RESIDENCES

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The results of more than 1 yr of air monitoring inside and outside of five homes in each of two communities are presented for SO_2, NO_2, mass respirable particles, SO_4, Al, Br, Cl, Mn, Na, and V. Outdoor measurements across the home site in each city are consistent with proximity to outdoor sources. Looking across indoor residential sites in each city, the home appears to alter outdoor concentrations in several ways. Indoor levels of SO_2, SO_4, Mn, and V are lower than those measured outdoors. These constituents are thought generally to result from outdoor sources. The other constituents studied are at times found in excess within homes. In some cases the source or sources of excess concentration of a particular constituent could be identified; often, however, the source of excess indoor concentration could not be identified.

Introduction

Only a few published studies exist that relate indoor residential air quality to concentrations observed outdoors. Also lacking are long-term measurements on several homes in a community (with the exception of Spengler *et al.*, 1981; 1979). Several studies have analyzed for gases or total suspended particles (TSP) inside and outside of homes. Alzona *et al.* (1979) and Moschandreas *et al.* (1979) are among the few that have reported on constituents of atmospheric particulate matter inside homes and outside.

The sources of indoor aerosols are plentiful and, if they cannot be accounted for, their presence would confuse the relationship between indoor and outdoor concentrations of undifferentiated particles. In this report we analyze for two cities a set of elements contained on particles that help to differentiate portions of the aerosol. One city (Steubenville, OH) is an industrial city in a river valley and the other (Portage, WI) is a rural farming community. The elements and constituents serve as "tags" for sources. The partitioning of the "tag" elements either inside or out identifies whether a particular constituent is likely to have been generated inside or out; and, for outdoor sources, the partitioning indicates the extent of penetration from the outside in. The concept of "tag" elements has been used successfully in the ambient environment, where the elemental composition of an aerosol source is known, to identify the impact of various sources on outdoor receptors (NAS, 1979). Unfortunately, we do not have information on the elemental composition of the large list of potential sources of indoor aerosols.

Experimental

Ten homes were selected for analysis from the residential sampling network established as a part of Harvard's prospective epidemiologic study of the health effects of suspended particles and sulfur oxides (Ferris *et al.*, 1979). Five homes were chosen for study from Steubenville, OH (Fig. 1) and five homes from Portage, WI (Fig. 2). Of the six cities under investigation in the epidemiologic study, Steubenville and Portage represent extremes in average pollutant concentration. Steubenville is a highly industrialized city situated on the Ohio River. Complex topography and localized pollutant sources are expected to produce concentration gradients across ground-level sites in Steubenville. Portage is a rural farming community located approximately 50 km north of Madison, WI. A 524 MW coal-fired power

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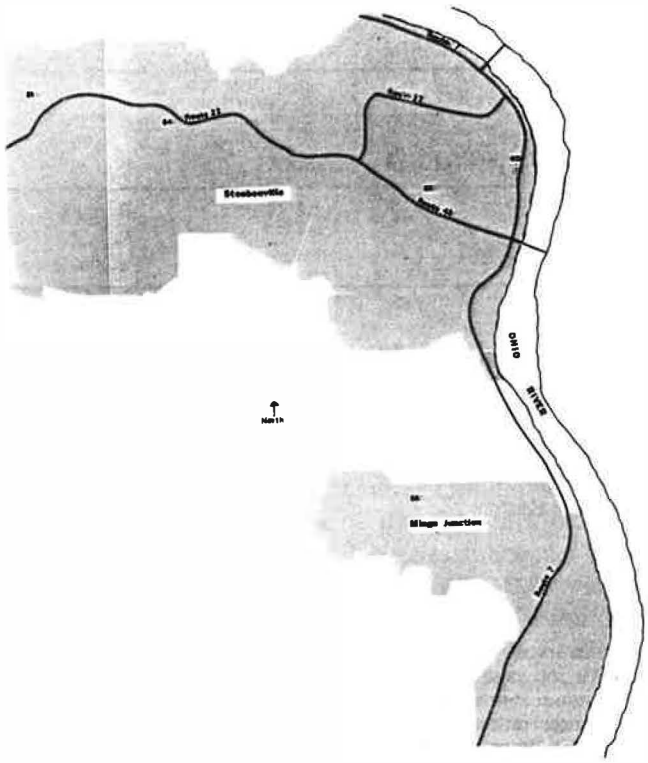

Fig. 1. Home sites in Steubenville, OH.

plant located in Portage has produced measurable but minor effects on air quality in the area.

Site selection

The residential sites were selected from among 19 sampling locations previously established in the two cities as a part of an indoor residential and outdoor sampling network. The initial selection of the 19 homes for the epidemiologic study was based upon geographic distribution and convenience rather than on random sampling considerations. In an earlier study of smoke and SO_2 levels inside and outside of residential buildings, experimenters were forced to abandon initial plans for random sampling because of a high refusal rate (Biersteker *et al.*, 1965). Furthermore, Biersteker *et al.* attempted to acquire data for only 1 week of successive daily observations, but we required that volunteers be willing to have their homes used as a "laboratory" for at least 1 yr.

Multiple and complex factors are known or suspected to influence the relationship between indoor and outdoor air quality. First, there are fixed factors such as home location, building construction and materials, heating and cooking appliances, and ventilation systems. Second, there are variable factors such as cigarette smoking, hobbies, time of year, aerosol sprays, and schedules for cleaning, cooking, and other dust- or pollution-raising activities. Tables 1 and 2 identify the home characteristics in Steubenville and Portage that we suspect would affect indoor air quality. However, many factors other than those identified can affect indoor air quality.

A final set of homes were selected to provide at least one full year of concurrent data. Among homes meeting this criterion, the final selection of the 10 sites was made to maximize the distance between homes, to allow for the observation of any spatial differences across each city.

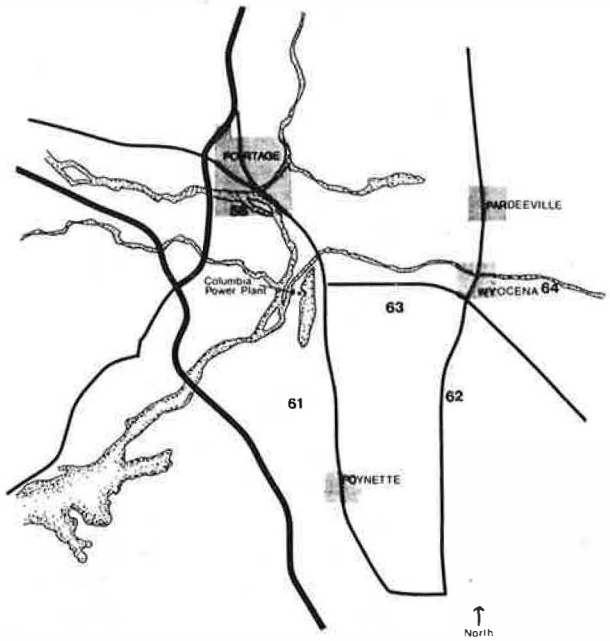

Fig. 2. Home sites in Portage, WI.

Sampling

General methods for air sampling have been described elsewhere as part of the previously mentioned prospective epidemiologic study (Ferris *et al.*, 1979). A subset of samples available from that study were selected for the elemental analysis. The air sampling and the instrumental neutron activation trace element analysis of this set of samples have been described by Colome and Spengler (1982).

Results

The results are presented in two sections. First, each of the 10 homes is presented as a single sampling unit in Tables 1–12. Next, the five residential sampling locations in each city are presented to show differences across the sampling locations within each city. These differences are presented separately across the indoor sites and the outdoor sites. The magnitude and possible sources of any differences are discussed.

Site comparisons

Throughout this section the home sites are referred to by the coding numbers used in the Harvard epidemiologic study of air pollution (Ferris *et al.*, 1979). Each site is individually described, in Table 1 for Steubenville and

Table 1. Synopsis of characteristics of Steubenville homes selected for elemental analysis.

Home Site No.	Heating System: Heating Delivery System	Heating System: Heating Fuel	Cooking and Ventilation: Cooking Fuel	Cooking and Ventilation: Kitchen Vent Present?[a]	Cooling System	Number of Resident Cigarette Smokers	Location	Comments
51	Radiator	Gas	Gas	Yes	None	1	West and away from industrial activity	SO_2 and NO_2 reduced indoors; higher indoor levels of Cl and possibly MRP.
52	Forced air	Gas	Gas	Yes	Central	1	Western ridge overlooking Ohio River	All constituents except for Cl reduced indoors by 20%–60%; Cl appears higher indoors in log-transformed data.
54	Radiator	Gas	Electric	Yes	Central	0	Western plateau above Ohio River	All constituents except for SO_2 and Cl reduced indoors by 20%–70%; highly variable SO_2 concentrations show no statistically significant indoor–outdoor differences.
55	Forced air	Oil	Electric	Yes	Central	0[b]	South of other sites in Mingo Junction	SO_2, NO_2, Al, Br, Mn, Na, V reduced indoors; no significant differences for MRP or Cl. This home illustrates that inside and outside respirable aerosols are not necessarily homogeneous.
60	Radiator	Gas	Gas	Yes	2 room units	0[b]	Downtown Steubenville north of major industries	SO_2, NO_2, Al, Br, Mn, Na reduced indoors; no significant differences for MRP, Cl, or V.

[a] Kitchen ventilation to the outside in all homes.
[b] One pipe smoker.

Table 2. Synopsis of characteristics of Portage homes selected for elemental analysis.

Home Site No.	Heating System		Cooking and Ventilation		Cooling System	Number of Resident Cigarette Smokers	Location	Comments
	Heating Delivery System	Heating Fuel	Cooking Fuel	Kitchen Vent Present?				
58	Forced air	Gas[a]	Electric	No	3 room units	1	Downtown Portage	SO_2, NO_2, and SO_4 reduced indoors; higher indoor levels of MRP, Br, Cl, and Na. A few high indoor Na values observed.
61	Forced air	Wood	Gas	No	None	0	South of power plant	New home with wood furnace in basement/garage. SO_2, SO_4, and V reduced indoors; higher indoor levels of NO_2, MRP, Al, Br, Cl, and possibly Mn. Indoor NO_2 mean approx. twice outdoor level.
62	Forced air	Oil and gas[b]	Electric	No	None	0	Southeast of power plant	LPG heater, with poor ventilation to outside, in room with NO_2 monitor. SO_2, SO_4, Br, Mn, and possibly Na reduced indoors; mean indoor NO_2 level approx. twice outdoor level.
63	Stove	Wood[c]	Gas	No	1 room unit	0	East of power plant	Primary heating by Franklin-style wood-burning stove. According to resident, basement LPG water heater may have been unvented during sampling period. SO_2, SO_4, Br, and possibly V reduced indoors; higher indoor levels of NO_2, MRP, Cl, and possibly Al. NO_2 elevation striking.
64	Forced air	Gas	Electric	Yes	None	0	East of power plant	SO_2, SO_4, Br, V, and possibly Mn reduced indoors; higher indoor levels of NO_2, MRP, and Cl. Sources not identified for NO_2 or MRP.

[a]Gas in Portage is bottled LPG.
[b]Two furnaces.
[c]Forced air/gas used now for backup.

in Table 2 for Portage. The comment sections of Tables 1 and 2 indicate significant differences between indoor and outdoor constituents at each site. All 10 homes are equipped with storm windows that are designed, in part, to reduce infiltration. In addition, in all homes with kitchen ventilation fans, the exhaust is to the outside.

The results, by home, are presented in Tables 3–12. Because the distribution of concentrations is positively skewed, average values and variance estimates are also presented by geometric means and geometric standard deviations, as well as for arithmetic means. Tests of significance for differences between indoor and outdoor concentrations for all paired (by sampling day) indoor–outdoor observations are shown in the right sections of the tables. The paired t statistic and associated probabilities for the indoor/outdoor differences for the log-transformed data are presented under the "geometric" columns of the tables. Finally, the tables present significance levels for the paired t statistic on the untransformed data.

Comparisons across sampling sites

In this section we examine any differences that exist in mean air pollution concentration across each city; as well as differences that might exist across both inside and outside sampling locations. Analysis of variance (ANOVA) is the logical method to apply when looking for differences among several sampling locations. However, these data violate ANOVA modelling assumptions. The concentration distributions by sampling site frequently have different variances and the positively skewed distributions can lead to various patterns in the residuals of the ANOVA model. The variances of these distributions are frequently stabilized by taking logarithmic transformations of the original data. Therefore, ANOVA results are presented for the log-transformed variables. In addition, we show the results of a nonparametric ANOVA test that does not require the assumption of equal variance. Significance levels for the nonparametric ANOVA are provided by the Kruska–Wallis approximation to the χ^2 test. The results are discussed separately for each constituent.

Sulfur dioxide. For sulfur dioxide no differences were observed across outdoor sites in either city. In Table 13 we observe that no significant differences are detected across the five outside sampling locations in Steubenville and the five in Portage. In Fig. 3, note that the mean arithmetic concentrations differ by up to 25 $\mu g/m^3$; however, the variation of observations is such that no overall differences emerge on the ANOVA tests. In Fig. 4 the outdoor concentrations of SO_2 in Portage are much lower than observed at any site in Steubenville; furthermore, no differences are apparent among the five outdoor sampling locations at the Portage homes.

In Table 14 ANOVA results across the indoor sites are presented. Again, no significant concentration differences were observed across the indoor sampling locations within either city. In Fig. 3 note that the mean indoor concentration for Steubenville site 54 is 20 $\mu g/m^3$ higher than in several other homes; however, no statistically significant overall differences exist. The observation of no significant differences is consistent with a continuum of concentration averages derived from highly variable data. For Portage, in Fig. 4, we noted far more striking similarity across all homes. The indoor mean levels are nearly constant at all sites, several times lower than the Steubenville observations, and nearly a constant proportion of outside concentrations.

Nitrogen dioxide. In Steubenville there are no significant outdoor differences for nitrogen dioxide. The story is different in Portage, where all ANOVA tests indicate the presence of significant differences. In Fig. 4 it is apparent that Portage site 58 has a higher outdoor NO_2 mean than do the other four Portage sites. Portage site 58 is located within the downtown commercial section of that town and would be under the greatest influence of emissions from automobile and space-heating sources.

The indoor comparisons across sites are made in Table 14. The indoor concentrations across all five Steubenville sites are significant on all three ANOVA tests. In Fig. 5, note that Steubenville site 60 is on the higher end with a mean concentration of about 60 $\mu g/m^3$ and that Steubenville sites 51 and 55 are on the lower side with mean concentrations of about 35 $\mu g/m^3$. Following log transformation, and based upon scores from the nonparametric ANOVA test, Steubenville sites 60 and 55 are, respectively, on the high and low side of the distribution of concentrations.

Steubenville site 60 has a gas-fired stove that might be the reason for high indoor concentrations, while site 55 has an electric stove. Site 51, with a mean indoor concentration close to the lower level of site 55, has a gas stove without concomitant high indoor NO_2 levels. In Table 14 significant differences for indoor NO_2 are found in Portage on all ANOVA tests. In Fig. 4 the reasons for this observation are clear. Portage site 63 is almost 20 $\mu g/m^3$ higher than the next highest indoor observation. Portage site 58, with an electric stove and no identified sources of NO_2, is on the lower side of the indoor mean concentration values.

Mass respirable particles. In Table 13 we see that there are no differences outdoor across the homes in Portage. In Steubenville, only the nonparametric test indicates that differences exist across the outdoor sites. The large within-site variance, particularly at Steubenville site 52, leads to an insignificant F test. According to the scoring on the nonparametric ANOVA, Steubenville sites 55 and 52 have high concentrations, while site 51 has a low concentration. Site 52 is close to the major concentration of industrial facilities, site 55 is also located near a concentration of industrial activity to the south of Steubenville, and site 51 is furthest away from the valley. Across the outdoor sites in Portage there are no sig-

Table 3. Indoor to outdoor Steubenville comparisons: Site 51. For each city, the number (n) of observations is given with the arithmetic mean concentration ($\bar{X}$), the standard error of the arithmetic mean (S.E.), the geometric mean ($\bar{X}_g$), and the geometric standard deviation (σ_g). Paired t tests show any differences between indoor and outdoor concentration levels. The number of pairs (n pairs) is given with the results of the paired t test for the log-transformed and untransformed data. Significant differences between indoor and outdoor levels are indicated by a directional arrow in the I $\gtrless$ O column (e.g., if $>$ is given in this column the indoor mean concentration is significantly higher than the outdoor concentration).

	Indoor					Outdoor					Paired t Test (H_0: Indoor = Outdoor)				
											n	Geometric			Arithmetic
	n	$\bar{X}$	S.E.	$\bar{X}_g$[a]	σ_g[b]	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	Pairs	t	p	I $\gtrless$ O	P
SO_2 ($\mu g/m^3$)	30	32.8	6.3	14.6	4.82	30	53.5	8.8	34.8	2.95	28	−4.57	0.0001	<	(0.0095)
NO_2 ($\mu g/m^3$)	30	35.3	3.4	32.2	1.51	30	61.5	10.6	50.4	1.77	28	−4.76	0.0001	<	(0.015)
MRP ($\mu g/m^3$)	30	28.6	4.9	22.0	2.16	30	29.8	9.1	18.2	2.57	28	1.71	0.099	≥	(0.81)
SO_4 ($\mu g/m^3$)	30	9.4	1.5	7.1	2.22	30	11.1	2.2	8.0	2.32	28	−1.04	0.31		(0.20)
Al (10 ng/m^3)	30	33.5	6.3	23.6	2.53	30	40.4	11.2	23.1	3.04	28	0.13	0.90		(0.37)
Br (ng/m^3)	30	21.5	4.5	15.3	2.24	30	21.1	5.9	13.6	2.42	28	0.78	0.44		(0.89)
Cl (ng/m^3)	25	160.3	19.6	146.1	1.56	19	117.4	15.9	107.4	1.50	15	4.27	0.0008	>	(0.0002)
Mn (ng/m^3)	30	29.9	7.2	18.8	2.70	30	44.3	13.9	20.9	3.56	28	−0.72	0.48	≤	(0.056)
Na (10 ng/m^3)	30	15.8	3.3	11.4	2.27	30	19.3	5.3	10.8	3.01	28	0.37	0.71		(0.19)
V (100 pg/m^3)	30	35.4	10.7	17.2	3.29	30	37.3	9.7	19.9	3.14	28	−0.83	0.41		(0.86)

[a] Defined as: $\bar{X}_g = \exp\left[\frac{1}{n}\sum \ln x_i\right]$, where: $x_i \equiv$ concentration; $n \equiv$ number of observations.

[b] Defined as: $\sigma_g = \exp\left[\left\{\frac{1}{n-1}\sum (\ln x_i - \ln \bar{X}_g)^2\right\}^{1/2}\right]$.

The geometric standard deviation, σ_g, is a unitless multiplication factor within which 68% of the data are expected to lie for a log-normal distribution.

Table 4. Indoor to outdoor Steubenville comparisons: Site 52. For notation, see Table 3.

	Indoor					Outdoor					Paired t Test (H_0: Indoor = Outdoor)				
											n	Geometric			Arithmetic
	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	Pairs	t	p	I $\gtrless$ O	P
SO_2 ($\mu g/m^3$)	27	34.5	6.5	16.2	5.11	25	80.7	13.1	44.8	4.09	25	−3.64	0.0013	<	(0.0004)
NO_2 ($\mu g/m^3$)	30	47.9	4.2	43.1	1.64	27	62.2	5.3	55.1	1.72	27	−2.11	0.045	<	(0.015)
MRP ($\mu g/m^3$)	30	30.1	5.2	23.8	1.85	29	54.7	11.6	31.7	3.15	29	−1.73	0.095	≤	(0.0016)
SO_4 ($\mu g/m^3$)	30	9.7	2.1	6.5	2.04	29	22.1	4.7	12.6	3.09	29	−4.75	0.0001	<	(0.0003)
Al (10 ng/m³)	31	18.9	3.4	13.2	2.29	30	45.9	8.3	27.8	3.22	30	−4.52	0.0001	<	(0.0002)
Br (ng/m³)	31	25.3	5.7	16.6	2.45	30	39.4	6.4	26.9	2.64	30	−2.99	0.0056	<	(0.06)
Cl (ng/m³)	29	220.5	14.2	211.2	1.35	24	191.6	20.2	168.4	1.72	22	1.86	0.077	≥	(0.24)
Mn (ng/m³)	31	50.4	12.1	24.6	3.62	30	87.2	18.1	42.7	4.01	30	−4.12	0.0063	<	(0.02)
Na (10 ng/m³)	31	18.0	3.6	10.5	3.12	30	37.5	7.4	20.4	3.62	30	−5.25	0.0001	<	(0.0001)
V (100 pg/m³)	31	80.0	22.9	28.1	4.77	30	165.0	47.8	55.5	5.22	30	−5.32	0.0001	<	(0.004)

Table 5. Indoor to outdoor Steubenville comparisons: Site 54. For notation, see Table 3.

	Indoor					Outdoor					Paired t Test (H_0: Indoor = Outdoor)				
											n	Geometric			Arithmetic
	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	Pairs	t	p	I $\gtrless$ O	P
SO_2 ($\mu g/m^3$)	30	54.8	10.1	27.2	4.73	29	69.2	11.2	39.4	4.05	28	−1.07	0.29		(0.31)
NO_2 ($\mu g/m^3$)	30	47.3	4.9	40.2	1.95	29	59.9	4.8	55.5	1.48	28	−3.23	0.0033	<	(0.0005)
MRP ($\mu g/m^3$)	30	22.1	3.9	15.7	2.47	30	41.1	7.0	29.5	2.34	29	−5.02	0.0001	<	(0.0001)
SO_4 ($\mu g/m^3$)	30	6.8	0.9	5.4	2.04	30	15.6	2.5	21.0	2.46	29	−5.93	0.0001	<	(0.0001)
Al (10 ng/m³)	30	14.2	3.3	9.3	2.44	30	43.6	7.4	32.2	2.19	29	−8.41	0.0001	<	(0.0001)
Br (ng/m³)	30	15.9	3.6	10.9	2.22	30	32.9	8.5	22.4	2.18	29	−5.82	0.0001	<	(0.055)
Cl (ng/m³)	29	182.7	19.5	166.2	1.52	24	188.1	16.3	174.2	1.49	23	−0.51	0.61		(0.80)
Mn (ng/m³)	30	27.9	6.3	17.4	2.70	30	64.9	13.5	42.4	2.41	29	−9.40	0.0001	<	(0.0003)
Na (10 ng/m³)	30	12.5	2.7	8.4	2.41	30	26.9	5.3	18.1	2.41	29	−6.57	0.0001	<	(0.0002)
V (100 pg/m³)	30	32.9	8.0	16.4	3.40	30	61.0	10.6	36.7	3.21	29	−5.26	0.0001	<	(0.0001)

Table 6. Indoor to outdoor Steubenville comparisons: Site 55. For notation, see Table 3.

	Indoor					Outdoor					Paired t Test (H_0: Indoor = Outdoor)				
											n	Geometric			Arithmetic
	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	Pairs	t	p	I $\gtrless$ O	P
SO_2 ($\mu g/m^3$)	27	33.1	5.9	14.4	5.30	30	55.1	6.6	37.4	3.17	27	−3.71	0.0010	<	(0.0002)
NO_2 ($\mu g/m^3$)	26	34.6	4.5	26.6	2.52	29	64.1	7.5	53.6	2.03	25	−5.48	0.0001	<	(0.0001)
MRP ($\mu g/m^3$)	29	36.0	4.0	27.7	2.41	29	42.1	5.4	29.6	2.97	28	−0.34	0.73		(0.26)
SO_4 ($\mu g/m^3$)	30	5.8	0.7	4.4	2.19	29	11.5	1.6	7.6	3.03	28	−4.70	0.0001	<	(0.0001)
Al (10 ng/m³)	30	43.5	18.7	20.0	3.25	30	70.9	13.3	36.9	4.42	29	−2.98	0.0059	<	(0.19)
Br (ng/m³)	30	15.6	2.2	11.6	2.25	30	31.4	5.4	20.0	2.86	29	−3.43	0.0019	<	(0.0013)
Cl (ng/m³)	29	237.8	29.7	207.4	1.71	23	348.8	70.3	258.7	2.14	21	−1.29	0.21		(0.14)
Mn (ng/m³)	30	30.4	4.5	20.0	3.01	30	70.4	13.4	38.9	3.99	29	−3.69	0.0010	<	(0.0004)
Na (10 ng/m³)	30	15.8	2.1	11.3	2.65	30	29.4	5.5	16.6	3.64	29	−1.84	0.076	≤	(0.012)
V (100 pg/m³)	30	32.8	8.5	11.9	5.13	20	71.8	17.3	33.5	4.22	29	−3.95	0.0005	<	(0.006)

Table 7. Indoor to outdoor Steubenville comparisons: Site 60. For notation, see Table 3.

	Indoor					Outdoor					Paired t Test (H_0: Indoor = Outdoor)				
											n	Geometric			Arithmetic
	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	Pairs	t	p	I $\gtrless$ O	P
SO_2 ($\mu g/m^3$)	27	40.1	5.5	24.9	3.53	28	64.9	11.3	37.5	3.34	27	−2.11	0.044	<	(0.011)
NO_2 ($\mu g/m^3$)	27	60.1	7.6	46.6	2.20	28	73.6	7.5	62.0	1.91	27	−3.92	0.0006	<	(0.0001)
MRP ($\mu g/m^3$)	28	36.2	8.7	21.4	3.00	29	37.3	8.1	26.0	2.21	28	−1.35	0.19		(0.74)
SO_4 ($\mu g/m^3$)	28	9.5	1.7	6.7	2.44	29	13.2	3.1	9.5	2.13	28	−2.23	0.035	<	(0.056)
Al (10 ng/m³)	28	33.0	6.4	19.1	3.57	29	44.6	5.9	34.7	2.18	28	−3.19	0.0036	<	(0.036)
Br (ng/m³)	28	41.2	11.6	22.5	2.95	29	50.7	9.9	35.0	2.38	28	−3.77	0.0008	<	(0.03)
Cl (ng/m³)	21	207.1	30.3	175.9	1.80	25	235.8	48.9	192.3	1.80	18	−0.89	0.38		(0.36)
Mn (ng/m³)	28	43.8	10.4	23.4	3.40	29	57.1	11.5	35.5	2.80	28	−2.67	0.013	<	(0.014)
Na (10 ng/m³)	28	23.7	5.8	13.8	3.01	29	28.6	5.4	20.6	2.18	28	−2.59	0.015	<	(0.040)
V (100 pg/m³)	28	80.6	19.7	34.8	4.13	29	80.2	17.9	41.4	3.59	28	−1.09	0.28		(0.97)

Table 8. Indoor to outdoor Portage comparisons: Site 58. For notation, see Table 3.

	Indoor					Outdoor					Paired t Test (H_0: Indoor = Outdoor)				
											n	Geometric			Arithmetic
	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	Pairs	t	p	I $\gtrless$ O	P
SO_2 ($\mu g/m^3$)	38	3.6	0.4	2.9	1.99	37	13.3	3.6	6.7	3.11	36	−4.51	0.0001	<	(0.011)
NO_2 ($\mu g/m^3$)	36	14.1	1.3	12.1	1.92	37	28.0	2.5	24.8	1.65	34	−5.30	0.0001	<	(0.0001)
MRP ($\mu g/m^3$)	38	32.5	2.7	27.9	1.85	37	9.2	1.6	6.6	2.56	36	8.96	0.0001	>	(0.0001)
SO_4 ($\mu g/m^3$)	38	3.4	0.5	2.2	2.99	38	5.0	0.7	3.6	2.28	37	−3.29	0.0022	<	(0.0005)
Al (10 ng/m³)	38	7.9	0.7	6.9	1.84	38	13.6	4.2	7.7	2.67	37	−0.73	0.47		(0.184)
Br (ng/m³)	38	27.8	2.9	23.2	1.90	38	20.2	2.4	16.2	1.95	37	2.82	0.0077	>	(0.0176)
Cl (ng/m³)	33	278.3	46.3	210.3	2.20	26	149.4	16.8	130.5	1.72	22	3.10	0.005	>	(0.0104)
Mn (ng/m³)	38	6.7	0.8	5.6	1.86	38	7.6	1.0	5.9	2.00	37	−0.71	0.48		(0.3058)
Na (10 ng/m³)	38	26.1	9.2	7.7	4.38	38	7.7	1.2	5.4	1.91	37	1.79	0.082	≥	(0.054)
V (100 pg/m³)	38	9.1	1.7	6.3	2.78	38	11.5	2.0	7.6	2.68	37	−1.57	0.12		(0.219)

Table 9. Indoor to outdoor Portage comparisons: Site 61. For notation, see Table 3.

	Indoor					Outdoor					Paired t Test (H_0: Indoor = Outdoor)				
											n	Geometric			Arithmetic
	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	Pairs	t	p	I $\gtrless$ O	P
SO_2 ($\mu g/m^3$)	34	3.5	0.8	2.6	1.99	35	10.1	4.3	4.3	2.89	34	−3.09	0.004	<	(0.122)
NO_2 ($\mu g/m^3$)	34	25.7	2.0	23.0	1.63	34	14.5	2.4	10.4	2.29	33	6.83	0.0001	>	(0.0001)
MRP ($\mu g/m^3$)	34	13.5	1.2	11.7	1.82	35	10.3	1.8	7.5	2.47	34	2.90	0.0065	>	(0.118)
SO_4 ($\mu g/m^3$)	34	3.3	0.6	1.9	2.91	35	5.4	1.0	3.6	2.42	34	−5.28	0.0001	<	(0.014)
Al (10 ng/m³)	34	14.8	1.7	12.2	1.88	35	10.3	1.1	8.3	2.09	34	2.61	0.014	>	(0.013)
Br (ng/m³)	34	23.8	7.5	12.1	2.64	35	10.1	1.1	8.4	1.86	34	5.30	0.0001	>	(0.083)
Cl (ng/m³)	26	155.3	13.9	146.7	1.43	21	82.3	6.5	78.9	1.35	15	5.30	0.0001	>	(0.0004)
Mn (ng/m³)	34	9.6	0.8	8.6	1.64	35	8.5	1.3	6.3	2.18	34	2.16	0.038	>	(0.456)
Na (10 ng/m³)	34	7.7	0.8	6.6	1.91	35	7.4	1.0	5.4	2.48	34	1.32	0.20		(0.780)
V (100 pg/m³)	34	6.9	1.0	4.6	2.94	35	13.2	2.2	9.0	2.62	34	−3.58	0.0011	<	(0.0027)

Table 10. Indoor to outdoor Portage comparisons: Site 62. For notation, see Table 3.

	Indoor					Outdoor					Paired t Test (H_0: Indoor = Outdoor)				
											n	Geometric			Arithmetic
	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	Pairs	t	p	I $\gtrless$ O	P
SO_2 ($\mu g/m^3$)	25	3.3	0.6	2.7	1.87	31	11.1	6.3	4.0	2.63	24	−2.35	0.028	<	(0.256)
NO_2 ($\mu g/m^3$)	33	32.6	4.4	24.5	2.23	33	15.3	3.3	10.3	2.26	31	5.12	0.0001	>	(0.002)
MRP ($\mu g/m^3$)	34	8.5	1.3	6.7	2.18	34	8.2	1.6	6.2	2.38	33	0.71	0.0001		(0.668)
SO_4 ($\mu g/m^3$)	34	3.9	0.7	2.7	2.34	34	5.2	1.0	3.5	2.45	33	−4.61	0.0001	<	(0.0036)
Al (10 ng/m^3)	34	12.1	1.4	10.4	1.68	34	10.6	1.1	8.6	2.02	33	1.61	0.12		(0.30)
Br (ng/m^3)	34	6.1	0.6	5.5	1.54	34	8.6	0.8	7.5	1.70	33	−4.09	0.0003	<	(0.0001)
Cl (ng/m^3)	24	88.8	4.1	86.9	1.23	30	85.3	4.1	83.4	1.23	21	0.86	0.40		(0.42)
Mn (ng/m^3)	34	5.2	0.8	4.3	1.77	34	6.9	1.1	5.2	2.04	33	−3.09	0.0041	<	(0.008)
Na (10 ng/m^3)	34	6.1	0.8	4.5	2.32	34	7.8	1.1	5.5	2.50	33	−1.53	0.14	≤	(0.041)
V (100 pg/m^3)	34	10.0	1.7	7.1	2.53	34	10.2	1.9	6.7	2.75	33	0.35	0.73		(0.87)

Table 11. Indoor to outdoor Portage comparisons: Site 63$_1$ For notation, see Table 3.

	Indoor					Outdoor					Paired t Test (H_0: Indoor = Outdoor)				
											n	Geometric			Arithmetic
	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	Pairs	t	p	I $\gtrless$ O	P
SO_2 ($\mu g/m^3$)	32	4.1	1.3	2.8	1.97	33	10.9	4.7	4.8	2.86	30	−2.47	0.020	<	(0.17)
NO_2 ($\mu g/m^3$)	30	52.0	3.5	48.7	1.46	33	13.7	2.2	10.9	1.92	29	15.54	0.0001	>	(0.0001)
MRP ($\mu g/m^3$)	31	14.8	1.9	11.2	2.37	33	8.3	1.7	6.4	2.44	29	3.91	0.0005	>	(0.0001)
SO_4 ($\mu g/m^3$)	32	4.0	0.7	2.9	2.17	33	4.9	1.0	3.2	2.47	30	−2.59	0.015	<	(0.0049)
Al (10 ng/m^3)	32	15.4	4.1	10.9	1.68	34	11.0	1.3	9.1	1.87	31	1.82	0.079	≥	(0.25)
Br (ng/m^3)	32	7.47	0.75	6.6	1.61	34	9.1	1.0	7.9	1.71	31	−2.80	0.0089	<	(0.0079)
Cl (ng/m^3)	30	138.9	14.9	125.5	1.58	23	86.8	5.6	83.1	1.36	20	4.84	0.0001	>	(0.0005)
Mn (ng/m^3)	32	8.6	1.4	6.6	1.98	34	7.5	1.1	5.9	2.00	31	1.14	0.26		(0.29)
Na (10 ng/m^3)	32	9.4	1.2	7.4	2.09	34	8.6	1.4	5.9	2.57	31	1.39	0.17		(0.52)
V (100 pg/m^3)	32	9.6	1.6	7.4	2.07	34	11.5	2.0	8.1	2.39	31	−0.79	0.44	≤	(0.042)

Table 12. Indoor to outdoor Portage comparisons: Site 64. For notation, see Table 3.

	Indoor					Outdoor					Paired t Test (H_0: Indoor = Outdoor)				
											n	Geometric			Arithmetic
	n	$\bar{\bar{X}}$	S.E.	$\bar{X}_g$	σ_g	n	$\bar{X}$	S.E.	$\bar{X}_g$	σ_g	Pairs	t	p	I ≷ O	P
SO_2 (μg/m³)	29	3.2	0.6	2.6	1.86	30	10.6	5.0	5.0	2.62	25	−4.16	0.0003	<	(0.14)
NO_2 (μg/m³)	33	22.4	1.6	20.1	1.71	35	19.9	2.3	15.7	2.13	33	2.01	0.052	>	(0.23)
MRP (μg/m³)	32	12.2	1.7	9.9	2.12	35	8.4	1.5	6.4	2.36	32	4.31	0.0002	>	(0.0013)
SO_4 (μg/m³)	33	3.3	0.6	2.1	2.78	35	4.6	0.9	3.1	2.45	33	−3.23	0.003	<	(0.018)
Al (10 ng/m³)	33	9.6	1.2	7.6	2.08	35	10.8	1.2	8.9	1.94	33	−1.29	0.21		(0.33)
Br (ng/m³)	33	5.9	0.5	5.3	1.63	35	8.8	0.9	7.7	1.68	33	−4.44	0.0001	<	(0.0004)
Cl (ng/m³)	29	109.2	8.6	102.8	1.41	25	92.4	8.6	86.5	1.41	23	2.13	0.045	>	(0.11)
Mn (ng/m³)	33	5.4	0.5	4.8	1.64	35	7.4	1.1	5.9	1.85	33	−1.88	0.070	≤	(0.062)
Na (10 ng/m³)	33	6.8	0.8	5.1	2.59	35	8.2	1.2	5.9	2.36	33	−1.20	0.24		(0.14)
V (100 pg/m³)	33	7.4	1.2	5.6	2.28	35	12.0	2.0	8.7	2.38	33	−3.26	0.0026	<	(0.0008)

Table 13. Analysis of variance across outdoor sites.

	Steubenville					Portage				
	F	ANOVA log C_0 $p > F$	ANOVA C_0 $p > F$	Nonparametric ANOVA $p \cong \chi^2$ [a]	Comment	F	ANOVA log C_0 $p > F$	ANOVA C_0 $p > F$	Nonparametric ANOVA $p \cong \chi^2$	Comment
SO_2	0.15	0.96	0.39	0.76		1.09	0.36	0.98	0.23	
NO_2	0.40	0.81	0.74	0.45		11.08	0.0001	0.0001	0.0001	581
MRP	1.83	0.13	0.26	0.009	(52,551);(51↓)	0.20	0.94	0.89	0.91	
SO_4	1.32	0.26	0.06	0.25		0.15	0.96	0.99	0.97	
Al	0.98	0.42	0.11	0.07	~(55↑)(51↓)	0.40	0.82	0.84	0.82	
Br	4.14	0.003	0.07	0.002	60,52↑;51↓	10.94	0.0001	0.0001	0.0001	581
Cl	5.90	0.0002	0.003	0.0002	55↑;51↓	5.93	0.0002	0.0001	0.012	581
Mn	1.89	0.11	0.23	0.04	(51↓)	0.26	0.90	0.92	0.94	
Na	1.96	0.10	0.23	0.06	(51↓)	0.07	0.99	0.99	0.99	
V	2.10	0.084	0.005	0.07	(52↑);51↓)	0.48	0.75	0.88	0.80	

[a]Kruskal–Wallis χ^2 approximation.

Parentheses indicate a weak tendency to be higher or lower than concentration in other sites.

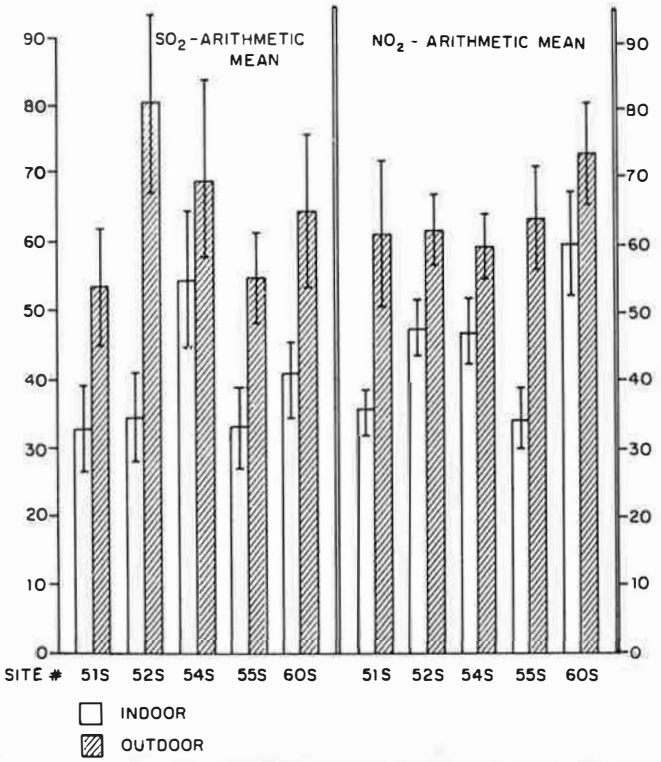

Fig. 3. Values of SO_2 and NO_2 ($\mu g/m^3$) for Steubenville sites.

nificant differences for mass respirable particle (MRP) concentrations.

The ANOVA results for indoor MRP levels are presented in Table 14. A situation similar to that observed outside in Steubenville exists inside. The results on the log-transformed data and on the original variables are not significant, and only the nonparametric test indicates a significant difference among the indoor Steubenville sites. Here, the nonparametric score indicates that site 54 has a lower, and site 55 has a higher, concentration distribution than do the other sites. This is not readily apparent in the arithmetic average concentration comparison in Fig. 5. In Portage the situation is clearer; all ANOVA tests are highly significant. Indoors in Portage, site 58 has a considerably higher concentration than the other Portage sites, while site 62 is on the low side. Site 58 is the one home in Portage with a resident who smoked cigarettes. Site 62, which was observed to have relatively high NO_2 levels, has an indoor mean concentration of fine particles similar to the mean outdoor concentration. As shown in Figs. 5 and 6, there are no clear relationships between indoor and outdoor MRP concentrations across the city sites. The excess indoor particle concentrations in Portage indicate sources of respirable aerosols within the homes. The considerably higher outdoor concentrations in Steubenville still tend to exceed the levels observed indoor in that city.

Water soluble sulfate. Table 13 shows that SO_4 levels outside are not significantly different across sites in either city. The somewhat higher average for Steubenville site 52 is the reason that the F test on Table 13 has a p value of 0.06 for the untransformed concentrations. Almost equal mean values are observed outside in Portage (as shown in Fig. 6).

Similarly, the indoor SO_4 values in Table 14 are not significantly different across sites in either city. As shown in Fig. 5, the proportional relationship between indoor and outdoor respirable sulfate in Steubenville appears to vary from home to home.

Aluminum. Outdoor values of Al are not significantly different in Portage and are significant at the 0.07 level in Steubenville only on the nonparametric test (Table 13). On the nonparametric test the score for Steubenville site 55 is high and that for site 51 low. That result is consistent with Fig. 7.

The indoor levels of Al, however, do appear to differ. In Steubenville, the high indoor variance at site 55 produced an insignificant F test on the nontransformed data. For the log-transformed data and nonparametric tests, the results are significant. On these latter two tests, site 51 (and to a lesser extent sites 55 and 60) show elevated indoor Al concentrations; in addition, site 54 has lower indoor Al concentrations.

In Portage all ANOVA tests are significant for the indoor concentrations. Portage sites 61, 62, and 63 appear to cluster at the higher concentration end and sites 58 and 64 are on the lower end. While these Portage differences are significant statistically, the magnitudes of the mean concentration differences are not as dramatic as are differences observed in Steubenville (compare Fig. 7 with Fig. 8).

Bromine. Outdoor levels for Br are significantly different for both cities (Table 13). In Steubenville, the outdoor levels at sites 60 and 52 tend to be higher and site 51 again is low. In Portage, only site 58, which is within the downtown area, stands out from the other sites with higher concentrations of Br.

Data on Table 14 indicate that indoor Br levels are highest in Steubenville at site 60 and tend to be low at sites 54 and 55 (see Fig. 7). In Fig. 8 it is shown that Portage sites 58 and 61 have high indoor levels of Br that are in excess of the outdoor levels, indicating an indoor source for bromine. The indoor Br levels in these Portage homes equals or exceeds the indoor means in Steubenville.

Chlorine. Both cities have significantly different chlorine concentrations across outdoor sites (Table 13). In Steubenville, as apparent in Fig. 7, site 55 is high and site 51 is again low. Portage site 58, in the downtown section, shows higher outdoor Cl levels than do the other sites in that city (Fig. 8).

Indoor differences are also apparent for chlorine (Table 14). In Steubenville, sites 52 and 55 show higher indoor Cl concentrations and site 51 has lower levels (Fig. 7). It should be noted that the low indoor observation at site 51 is still higher than the mean value observed outside at that site. In Portage we see that site 58 has a

Table 14. Analysis of variance across indoor sites.

	Steubenville					Portage				
	F	ANOVA log C_I $p > F$	ANOVA C_I $p > F$	Nonparametric ANOVA $p > \chi^2$ [a]	Comment	F	ANOVA log C_I $p > F$	ANOVA C_I $p > F$	Nonparametric ANOVA $p > \chi^2$	Comment
SO_2	1.23	0.30	0.14	0.22		0.16	0.96	0.95	0.91	
NO_2	3.51	0.0092	0.0022	0.0069	60↑;55,(51)↓	24.12	0.0001	0.0001	0.0001	63↑,58↓
MRP	1.64	0.17	0.31	0.033	(55↑)[b];(54↓)	20.02	0.0001	0.0001	0.0001	58↑,62↓
SO_4	1.70	0.15	0.17	0.22		0.99	0.41	0.90	0.43	
Al	4.10	0.0036	0.18	0.0001	51(55,60)↑;54↓	5.05	0.0007	0.039	0.0015	61,62,63,↑; 58,64↓
Br	3.47	0.0097	0.024	0.0065	60↑;54,55↓	35.40	0.0001	0.0001	0.0001	58,(61)↑
Cl	2.93	0.0233	0.079	0.0115	52,55↑;51↓	7.89	0.0001	0.0001	0.0001	58↑;62,64↓
Mn	0.71	0.59	0.21	0.39		7.29	0.0001	0.001	0.0001	61↑;62,64↓
Na	1.12	0.35	0.24	0.18		1.90	0.11	0.009	0.21	(58↑)[c]
V	3.01	0.020	0.023	0.050	60(52)↑; 55,51(54)↓	1.51	0.20	0.44	0.45	

[a] Kruska–Wallis χ^2 approximation.
[b] Parentheses indicate a weak tendency to be higher or lower than concentration in other sites.
[c] Unlogged concentration picked up random high indoor sodium values in site 58.

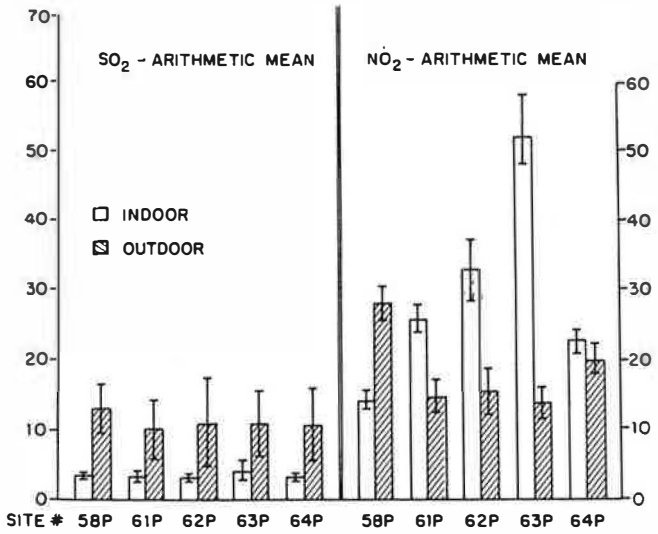

Fig. 4. Values of SO_2 and NO_2 ($\mu g/m^3$) for Portage sites.

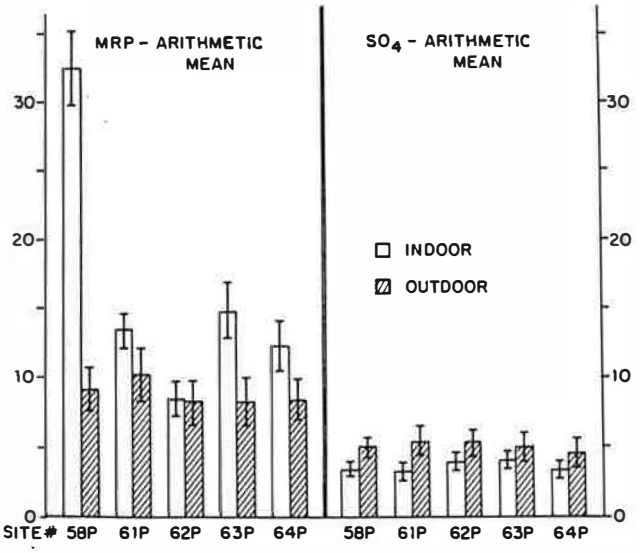

Fig. 6. Values of MRP and SO_4 ($\mu g/m^3$) for Portage sites.

higher indoor Cl mean and sites 62 and 64 are low. The high indoor Cl mean at site 58 exceeds the high outdoor mean at that site (Fig. 8).

Manganese. Outdoor manganese patterns are quite different in Portage and Steubenville (Figs. 9 and 10). The values in Steubenville are considerably higher than those in Portage and the standard errors of the means in Steubenville are much larger. On the log-transformed and untransformed data the ANOVA results for Steubenville are not significant. This is largely due to the large outdoor variance. On the nonparametric test there is an indication that site 51 in Steubenville is lower than the other sites (Table 13). In Portage there are no apparent differences outdoors in mean manganese levels (Table 13).

The indoor results for manganese are presented in Table 14. In Steubenville there are no statistically significant differences among the indoor sites. In Fig. 9 it can be seen that a large scatter exists in the indoor manganese levels and about the estimates of the site means. All ANOVA tests for indoor manganese concentrations in Portage indicate that significant differences exist between sites. Site 61 has higher indoor levels, and sites 62 and 64 have lower levels. While these differences are significant statistically, their magnitude is not meaningful in comparison to the scatter exhibited inside Steubenville homes (see Figs. 9 and 10).

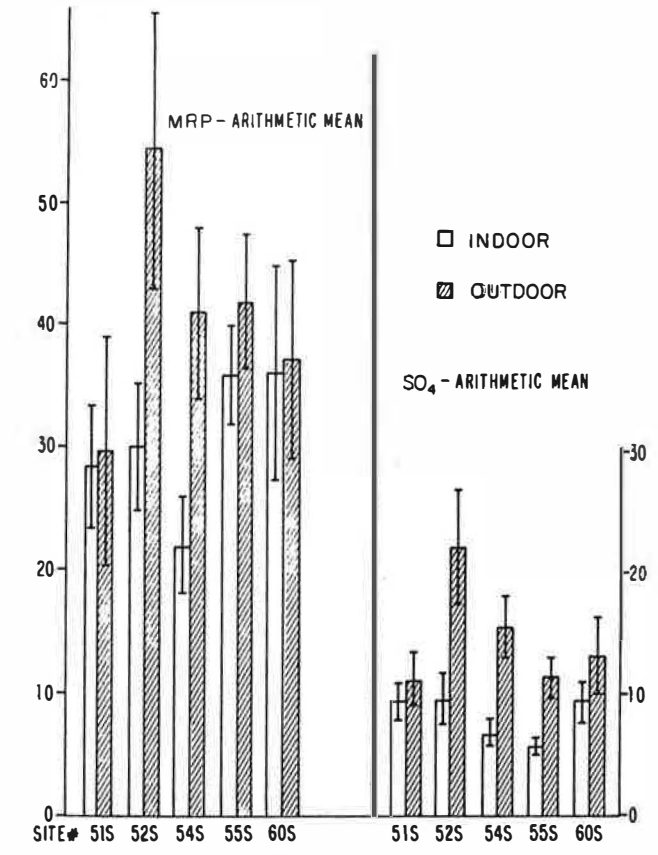

Fig. 5. Values of MRP and SO_4 ($\mu g/m^3$) for Steubenville sites.

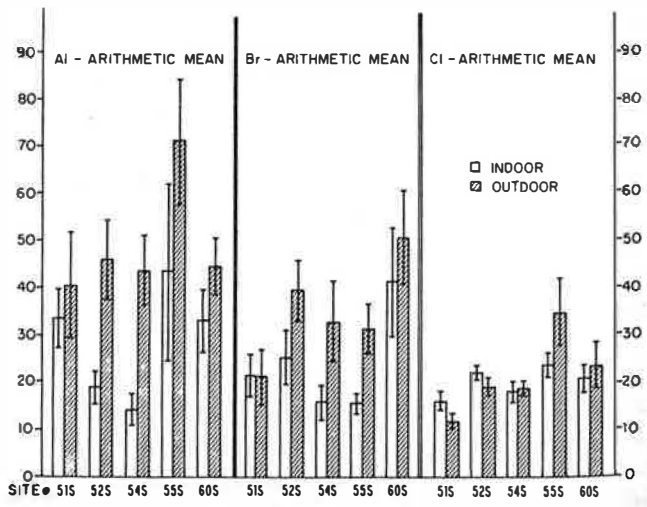

Fig. 7. Values of Al and Cl (10 ng/m³) and Br (ng/m³) for Steubenville sites.

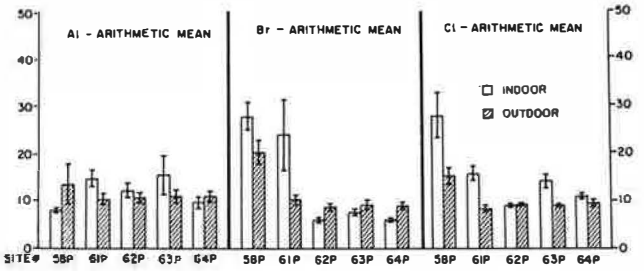

Fig. 8. Values of Al and Cl (10 ng/m³) and Br (ng/m³) for Portage sites.

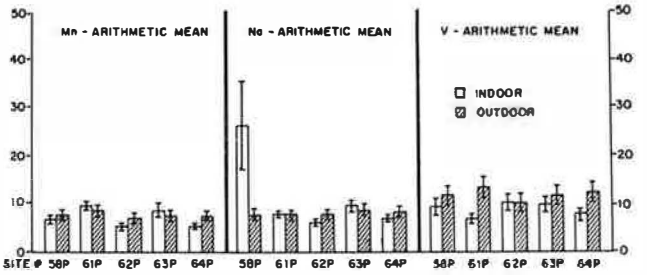

Fig. 10. Values of Mn (ng/m³), Na (10 ng/m³), and V (100 pg/m³) for Portage sites.

Sodium. Sodium concentrations are not found to vary across outdoor Portage sites; in Steubenville only the nonparametric test indicates that site 51 has lower outdoor values (Table 13).

Indoor sodium concentrations do not vary across indoor sites in Steubenville (Table 14 and Fig. 9). In Portage, only the nontransformed data indicate that significant differences exist for Na indoors. This situation clearly illustrates the violation of the ANOVA assumption of equal variance for the concentration distribution at each site. A few high indoor Na concentrations at site 58 raised the arithmetic average and created the significant result in Table 14. It is noteworthy, however, that several high indoor sodium values existed inside this home.

Vanadium. Vandium concentrations across outdoor Steubenville sites differ. Site 52 has a high average V concentration with a large standard error (Fig. 9). At the other extreme, site 51 in Steubenville has low concentrations. Outside in Portage, no significant differences in vanadium concentrations exist.

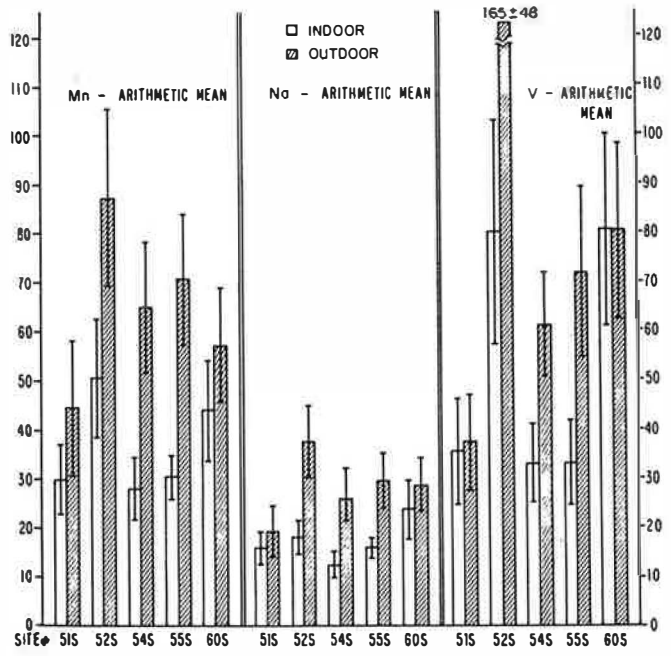

Fig. 9. Values of Mn (ng/m³), Na (10 ng/m³), and V (100 pg/m³) for Steubenville sites.

Indoor in Steubenville, there are indications for differences in mean concentration (Table 14). Sites 60 and 52 in Steubenville tend to be high, and sites 55, 51, and 54 low. In Portage, no significant indoor differences for V exist (Table 14 and Fig. 10).

Discussion

This paper shows that the home as a sampling unit allows observation of many of the "fine" features of differences between indoor and outdoor air quality that are not apparent for data aggregated across homes within a city. In addition to the citywide differences reported elsewhere (Colome and Spengler, 1981) there are many home-to-home differences found here.

Outdoor concentrations of most constituents in Steubenville are relatively high. The indoor values in Steubenville for all constituents, except for chlorine, are lower than or equal to the outdoor levels. Chlorine is significantly elevated inside one Steubenville home and elevated within another Steubenville site ($p = 0.08$ for log-transformed data). We are not certain of the source of chlorine indoors, but cleaning agents would be likely sources.

The outdoor concentrations in Portage are considerably lower and allow for more "expression" of indoor sources with the reduced background. Concentrations of SO_2, SO_4, Mn, and V tend to be reduced indoor in Portage. These are all constituents associated with outdoor sources. Elevated indoor concentrations of NO_2, MRP, Al, Br, Cl, and Na are observed in one or more of the Portage homes. Three of the four Portage homes with elevated NO_2 levels either had gas-fired stoves or sources of open gas flames used for heating. The fourth home had elevated indoor NO_2 levels that were not explainable from available information on likely sources. High indoor MRP levels were most pronounced in the one Portage home with a cigarette smoker. Elevated levels of Al, Br, Cl, and Na did not follow any pattern that we could interpret. It is likely that the complicated pattern and multiplicity of indoor sources will make it difficult to estimate indoor exposure to all components of the aerosol. Gravimetric determination of respirable particle levels, therefore, does not fully describe the pattern of aerosol exposure. The reactive nature of SO_2

makes it difficult to estimate indoor levels; and, for NO_2, the presence or absence of open indoor flames will help explain a large fraction of the variation in indoor concentration.

For outdoor sites in Steubenville, nonparametric tests show significant outdoor differences across sites. The site furthest away from the industrial activity in the Ohio River Valley tends to be lower for MRP, Al, Br, Cl, Mn, Na, and V. One or more of the homes nearest the valley's industrial activity tend to be elevated for MRP, Al, Br, Cl, and V. For bromine, the highest levels were observed nearest the downtown section and on the valley ridge, while the lowest concentration was observed furthest away on the plateau. For chlorine, the western plateau site was again low and the southern site in Mingo Junction was highest. The outdoor picture in Portage is much more uniform across the city, with similar mean outdoor concentrations for most constituents. Elevations of NO_2, Br, and Cl at the downtown site are significant. Outdoor elevation of Br and NO_2 is consistent with higher density of automobile emissions, but the source of Cl is not clear.

Indoor in both sites, a much more complicated picture emerges. Significant differences among indoor sites in Steubenville were observed for NO_2, Al, Br, Cl, and V. The relative rankings for outdoor mean concentration do not correspond well with indoor mean levels. One of the homes with gas cooking had a higher NO_2 level than the other homes. However, both a gas-cooking and an electric-cooking home were among the lower concentrations for indoor NO_2. For this sample of homes the use of a gas or electric stove did not correspond well with indoor NO_2 levels. This might be expected with different cooking habits and the use of ventilation hoods. Different MRP concentrations occur in Steubenville only on the nonparametric test. Other indoor differences are observed for Al, Br, Cl, and V. No consistency emerges that would allow us to predict at this stage which homes would have elevations of any of these constituents. More significant differences exist across the indoor, as compared with outdoors, in both cities. In Portage, the homes with the highest outdoor NO_2 concentrations had the lowest indoor concentration; one home, with a wood stove for heating and a gas-cooking stove, had an indoor concentration higher than observed anywhere else in the town, indoor or out. The downtown site with the highest outdoor Br and Cl concentrations also had the highest indoor concentration of these elements. However, there was a cigarette smoker in this home, and this factor could have contributed to these levels. No patterns emerge to provide a rationale for the other significient indoor observations in Portage.

Conclusion

There is considerable variation in air quality when a single home is considered the unit of measurement. The general features as measured outside the home are consistent with what we currently know about the location and elemental composition of sources of pollutant emissions. However, upon looking inside, there are factors which we cannot presently account for that change the composition of airborne constituents. To be able to use effectively this information in order to promote public health, we will need to know more about which putative toxic airborne components are associated with the trace constituents recovered here. More information is also needed to define the characteristics of the house and of indoor sources that modify the indoor composition of airborne constituents.

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