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EXTENSIVE 1-YEAR SURVEY OF TRACE ELEMENTS AND COMPOUNDS IN THE AIRBORNE SUSPENDED PARTICULATE MATTER IN CLEVELAND, OHIO

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16. Abstract

Concentrations of 75 chemical constituents in the airborne particulate matter were measured in Cleveland, Ohio, during 1971 and 1972. Values covering a 1-year period (45 to 50 sampling days) at each of 16 sites are presented for 60 elements. A lesser number of values are given for sulfate, nitrate, fluoride, acidity, 10 polynuclear aromatic hydrocarbon compounds, and the aliphatic hydrocarbon compounds as a group. Methods used included instrumental neutron activation, emission spectroscopy, gas chromatography, combustion techniques, and colorimetry. Uncertainties in the concentrations associated with the sampling procedures, the analysis methods, the use of several analytical facilities, and samples with concentrations below the detection limits are evaluated in detail. The data is discussed in relation to other studies and source origins. The trace constituent concentrations as a function of wind direction are used to suggest a practical method for air pollution source identification.

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EXTENSIVE 1-YEAR SURVEY OF TRACE ELEMENTS AND COMPOUNDS IN THE AIRBORNE SUSPENDED PARTICULATE MATTER IN CLEVELAND, OHIO

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SUMMARY

The concentrations of some 75 chemical constituents in the airborne particulate matter collected on 762 filters were measured in Cleveland, Ohio, during 1971 and 1972. Values for 45 to 50 days over a 1-year period at each of 16 sites for 60 elements, and for a lesser number of days for sulfate, nitrate, fluoride, acidity, 10 polynuclear aromatic hydrocarbon compounds, and all of the aliphatic compounds as a group were determined. Means, standard deviations, range of values observed, maximum values, and a number of samples analyzed are presented. Methods of analysis included instrumental neutron activation, gas chromatography, colorimetry, and combustion techniques. Uncertainties are evaluated in detail to establish concentration ranges. This large data base (~30 000 values) permitted substantial statistical analysis (comparisons, correlations, etc.) within the data set. Comparison of these concentration ranges with data for Paris, France; Heidelberg, West Germany; Gary, Indiana; East Chicago, Illinois; and Cleveland's western suburbs showed that only for a few elements were levels significantly different. Only for lead did the concentrations approach levels set for control purposes in two states (California and Colorado). The bromine/lead mean values across the city indicated automobile fuel combustion as the primary lead and bromine source. The potential of trace constituents for source detection and identification is discussed. Sulfate, nitrate, fluoride, and pH levels were similar to those observed by others. Elemental carbon percentage levels were peculiarly invariant across the city, even though widely different environments were involved. However, benzo(a)pyrene, the most suspect as a carcinogen among the polynuclear aromatic hydrocarbons, strongly showed source-related effects. Benzo(a)pyrene concentrations across the city were at a mean level of about 1 ng/m^3, a value similar to that reported for other locations, but ranged as high as 130 ng/m^3 downwind of extensive coke oven operations.

INTRODUCTION

Investigation of the total suspended particulate matter (TSP) in the ambient air has progressed from determination of simple mass loading (ref. 1) through particle size classifications and distributions (ref. 2). Recently, studies to characterize ambient urban air in terms of its chemical and physical properties have emerged (refs. 3 and 4) as successors to those directed toward establishing analytical procedures (refs. 5 and 6). Because the high loadings of TSP in the urban air are created by man's activities, and thus can be controlled, it is important that they be well-characterized to enable assessment of their potential hazard and the determination of the need for control.

Characterization of urban TSP in terms of its trace elements and compounds is the first step in this process and is crucial to the understanding of the dangers from particulate matter and the establishment of safe or tolerable levels. Such a study, initiated in January 1971, was carried out as a cooperative undertaking by the City of Cleveland's Division of Air Pollution Control (DAPC) and the Lewis Research Center of the National Aeronautics and Space Administration. Its goal was to determine the trace element and compound concentrations in the particulate matter in the ambient air at selected locations in, or adjacent to, Cleveland and to use appropriate element and compound relations in conjunction with meteorological considerations as tracers to pinpoint or identify specific pollution sources. DAPC personnel operated the sampling network (high-volume sampler maintenance, sample handling, and weighing). Lewis personnel were responsible for the overall program planning, the field methodology, the analytical procedures, and the data handling and analysis.

This report presents the results of that study, which has received the support and cooperation of John C. Burr, Jr., of the Ohio Environmental Protection Agency, Columbus, Ohio, and George T. Craig and C. Lawrence Cornett of the Division of Air Pollution Control, City of Cleveland.

EXPERIMENTAL PROCEDURE

Sampling

At the start of this program, DAPC was regularly operating 20 monitoring sites in or adjacent to the City of Cleveland. Sixteen of these sites were chosen to provide representation for all segments of the city (population, industry, etc.). At these sites, additional high-volume air samplers which were equipped with air-volume flow rate recorders and motor-speed control regulators (variable-voltage transformers) to adjust the flow rate were installed. These modifications were necessitated by the use of

Whatman No. 41 (W-41) made by Whatman, Inc., Clifton, N. J., as the filter medium. The flow characteristics of W-41 are significantly different from those of the glass fiber filter normally used for total suspended particulate (TSP) monitoring. The W-41 paper filter is an acceptable filter medium when used as described in references 7 and 8.

In addition to the 16 Cleveland sampling sites, Lewis established seven sampling sites in the western suburbs. The locations of these sites are given in figure 1, along with a wind rose showing the percentage of the time the wind is expected to blow from a given direction as measured at Cleveland Hopkins Airport. At some sites wind direction - wind speed equipment was installed for continuous recording with the cooperation of the Cleveland School District. However, the data obtained were insufficiently complete for our use. The environments surrounding the 16 Cleveland monitoring sites and the seven Lewis suburban sites are described in table I.

Analysis

Neither the federal nor the state of Ohio agencies at the start of the effort had designated any levels or concentrations of elements or, for that matter, any element itself as toxic. However, in view of our interest in source identification by using trace constituents, it was decided that as many elements as possible would be determined and that the most sensitive, practical, and economical method available was instrumental neutron activation analysis (INAA) (ref. 5). Fifty-four elements ultimately were determined by this technique. Vanadium (V) was determined by both INAA and emission spectroscopy (ES). Because of its short half-life, it was initially thought to be difficult to detect by INAA but turned out otherwise. Vanadium data are the means of ES and INAA values. An additional five elements (beryllium (Be), bismuth (Bi), cadmium (Cd), lead (Pb), and silicon (Si)), which were not readily detected by INAA, were also determined by ES. Because of the high sensitivity of INAA, filter-handling cassettes were used (ref. 9) to keep sample contamination to a minimum. After exposure in a high-volume air sampler, a filter was folded lengthwise, equilibrated in laboratory air, and weighed. The portion to be analyzed was cut across the fold, no closer than 2.5 centimeters from an edge in an attempt to obtain a representative sample. Since only portions of the filter and its deposit were analyzed, the filter medium and the deposited sample had to be homogeneous with respect to the elements. Studies made in this laboratory by Liu showed the elemental variation across a sample to be ±5 percent. The filter also had to be low in interferring elements (such as sodium) for INAA. From our tests and those of others (refs. 5 and 6), we concluded that W-41 filters best met these requirements. Since W-41 is quite hygroscopic, special procedures (refs. 7 and 8) were followed to avoid erroneous gravimetric results. By using these procedures the TSP values obtained with W-41 filters (handled as described in refs. 7 and 8) are comparable with those obtained with glass fiber filters.

Hydrocarbon compounds were determined by gas chromatography. Duplicate quarters of 20.3- by 25.4-centimeter (8- by 10-in.) glass fiber filters that were run simultaneously with the W-41 filters were extracted (Soxhlet) with benzene, and evaporated to dryness in a Kuderna-Danish concentrator. The aliphatic components were separated by dissolving the residue in hot trimethylpentane and eluting them through 3 centimeters of 40- to 140-mesh silica activated at 140° C (413 K). The remaining sample residue, which contained the aromatic hydrocarbon fraction, was then dissolved in reagent-grade carbon disulfide and analyzed by gas chromatography, using OV-7 (Ohio Valley Specialty Chemical Co., Marietta, Ohio) on Chromasorb W (Johns-Manville Corp., N. Y., N. Y.). The temperature was raised from 250° to 280° C (523 to 553 K) at 10 degrees per minute, beginning 2 minutes after injection. Concentration levels of ten specific polynuclear aromatic hydrocarbons were determined; the aliphatics, however, were measured as a single group.

Carbon concentrations were determined in two ways: either the total carbon was determined under oxidizing conditions, or only the carbon in forms that would be pyrolyzed or volatilized at temperatures to 950° C (1223 K) was determined under inert-atmosphere conditions. This latter carbon would be that contained in carbon compounds and is called combined carbon in this report. The determination of combined carbon was carried out by the analysis of 9.62-square-millimeter circles cut from the fiberglass filters used for the hydrocarbon determinations. In an effort to roughly separate organic and inorganic combined carbon, such as carbonates, the filters were first ignited at 650° C (923 K) in a platinum boat in a stream of helium, which will decompose or volatilize organic carbon compounds. The volatile products were then passed over cobaltic oxide and copper gauze at 950° C (1223 K) (ref. 10). The carbon dioxide (CO_2) produced was catalytically reduced to methane over 400° C (673 K) Raney nickel (ref. 11) and was subsequently measured with a flame ionization detector (FID) (ref. 11). Inorganic combined carbon was then determined by heating the sample to 950° C (1223 K) under the same conditions. This should decompose inorganic carbonates. The methane produced was again measured. The results were quantitated against potassium biphthalate and primary standard calcium carbonate preignited at 550° C (823 K). This technique afforded detection of picogram quantities. Total carbon content was also determined on a smaller number of samples by using high-temperature oxidizing conditions to convert the carbon to CO_2, which was detected by a thermal conductivity detector (ref. 12).

The values for water-soluble sulfates, nitrates, fluorides, and pH of the particulate matter were determined from a 1.9-centimeter (3/4-in.) sample strip cut across the fold of a glass filter. This strip was refluxed with water for 90 minutes, the solution filtered, and the filtrate adjusted to a volume of 80 cubic centimeters, making each cubic centimeter of solution equivalent to 0.1 percent of the sample (406 cm^2).

Sulfates were determined by a barium chloride turbidimetric method (ref. 13). After quantitative reduction with hydrazine sulfate (as recommended by Richard Thompson of the U.S. Environmental Protection Agency's National Environmental Research Laboratory, Research Triangle Park, N.C.), nitrates were determined colorimetrically with N (1-napthyl)-ethylenediamine dihydrochloride by the Saltzman method (ref. 14) for nitrite. Fluorides were determined electrochemically with a fluoride specific ion electrode (ref. 15), and pH was determined on a 1-percent aqueous suspension of TSP with a glass electrode.

TREATMENT OF DATA

Interlaboratory Comparisons

Neutron activation analyses were provided by four different laboratories (identified here as analysts A, B, C, and D). In order to provide some basis for interlaboratory comparisons, two equivalent pieces were cut from a filter and each piece was sent to a different laboratory. This was done for a number of filters.

Twenty-four filters were analyzed by both analysts A and B. Because of differing detection limits for different elements and analysts and the variability of gross amounts of TSP on the various filters, there were only 13 elements for which both analysts reported unambiguous amounts on all 24 filters. After preliminary graphical analysis, seven of these filters were discarded from this analysis because of apparent gross discrepancies in one or more elements. There remained 17 filters with 13 elements each for comparing analyst A and analyst B. These data are presented in table II.

Twenty other filters were analyzed by both analysts B and C. Using the same statistical reasons and the same statistical criteria employed for comparing Analysts A and B, we found no apparent gross discrepancies. There are, therefore, 20 filters with seven elements each for comparing analyst B and analyst C. These data are presented in table III.

Twenty filters were analyzed by both analysts B and D, and 10 filters were analyzed by both analysts C and D. Preliminary graphical analysis revealed that analyst D's results were not at all comparable with those of analysts B and C. For some elements, analyst D reported values that were as much as several orders of magnitude greater than those reported by analyst B or C. This situation was reversed for other elements. There was no apparent pattern to this behavior, and it was decided to simply discard all of analyst D's values. These data are not included herein.

We were thus left with comparisons between analysts A and B and between analysts B and C but not directly between analysts A and C. The data were analyzed by the following method: We assumed that there was an underlying linear relation between the values reported by each laboratory for each element but that there was an experimental error involved in each reported value. We thus assumed that

$$x_i = X_i + \delta_i$$

and

$$y_i = Y_i + \epsilon_i$$

represent the reported values, where X_i and Y_i are the true unknown mean values and ϵ_i and δ_i are the errors. The underlying linear relation is thus of the form

$$Y_i = \alpha + \beta X_i$$

The appropriate procedure for analyzing data according to this model is described in references 7, 8, and 16.

We also recognized that in this type of experiment the experimental errors often tend to be proportional to the amount of material actually present. We thus also analyzed the data by using the preceding model but with the logarithms of the reported concentrations.

Table IV is a summary of the results from the model when the reported values were used directly. The table presents the estimated parameters α and β for each element. Also given are the correlation coefficients R between the elemental values reported by each pair of analysts. If both analysts were indeed reporting the same concentrations, and if there were no interlaboratory errors, the values of these parameters would be

$$\alpha = 0$$

$$\beta = 1.0$$

$$R = 1.0$$

There is also a statistical test available for determining if the estimated value of β is significantly different from the desired value of $\beta = 1.0$. The test statistic is described in reference 16. It has the Student's t-distribution. Table IV also presents these t-statistics, and those significant at the 5 percent confidence level are footnoted. There is no known procedure for testing if the estimate of α is significantly different from zero.

For the comparison of analysts A and B (table IV), the estimated lines are generally close to the expected case of $\alpha = 0, \beta = 1.0$. The correlation coefficients are almost all quite close to 1.0, indicating good fits to a linear relation. There are three elements (sodium (Na), arsenic (As), and samarium (Sm)) with slopes significantly larger than $\beta = 1.0$, and five elements (chromium (Cr), cobalt (Co), zinc (Zn), selenium (Se), and bromine (Br)) with slopes significantly less than $\beta = 1.0$. The remaining elements may be assumed to have slopes of $\beta = 1.0$. It is not known if there is some systematic procedural difference between the analysts which might account for this grouping of the elements. Since a statistical test for $\alpha = 0$ does not exist, direct examination of the estimated α's was used. This procedure indicated that these estimates were not large compared with the means of the elemental concentrations being fitted.

For the comparison of analysts B and C (table IV), all the slopes are greater than $\beta = 1.0$ and, for all the elements except Br, are significantly so. This indicates that analyst C consistently reported larger values than analyst B. All the correlation coefficients are large, indicating good linear fit. The estimated α's are not large compared with the means of the elemental concentrations being reported.

Table V is a summary of the results when the model is used to analyze the logarithms of the reported concentrations. For the comparison of analysts A and B, the overall deviation from $\alpha = 0, \beta = 1.0$ is not too marked. All the correlations are large, indicating good linear fits. Only the slope for Na is significantly different from $\beta = 1.0$. In this formulation of the model, the quantity ϵ^{α} plays a role similar to the slope β in the linear-linear model. The values of ϵ^{α} are listed. They range from a maximum of 2.20 to a minimum of 0.44, with most near 1.0.

For the comparison of analysts B and C, all the correlations are close to 1.0, indicating good linear relations. Again Na is the only element with a slope significantly different from $\beta = 1.0$. All α's are positive, however, so that all of the factors ϵ^{α} are greater than 1.0. This indicates that analyst C tended to report larger values than analyst B. This conclusion is in qualitative agreement with the analysis of the raw data in table IV.

The overall conclusions that may be drawn from this analysis are as follows: Regardless of which form of the model is used, the correlations indicate that the assumption of an underlying linear relation is sound. From these models it appears that there are some systematic discrepancies between laboratories. The discrepancies are highly dependent upon the particular elements when comparing analysts A and B. But they do indicate that analyst C consistently reported larger values than analyst B. This conclusion is based only upon seven elements, however, and need not be true for the remaining elements. Without much more detailed data for more elements, it cannot be determined how such differences might be attributed to differing analytical procedures. Because of both the limited number of laboratories and the lack of appropriate statistical methodology for the models considered, it is quite difficult to objectively quantify the uncertainties in the measurements. The largest differences from laboratory to laboratory are about ±50 percent of the mean of two reported values for some elements. The differences are considerably smaller for most of the elements.

Data and Measurement Uncertainties

As noted previously, except for five elements, all analyses were made by INAA. Most of this work was done at the Lewis Plum Brook Reactor Facility (ref. 5). Two other laboratories whose INAA results are included in this study used the same general procedure. Since the computer program for data reduction was corrected to conform with calibration standards, the precision of the determinations was chosen as an indication of accuracy. Thus, the precision of the analyzed values for each element for the actual samples was determined by using the relative error assigned to each determination. This value was used for determining both the accuracy of the method (comparison with standards) and the precision of the sample analyses.

Table VI is a comprehensive listing of the uncertainties associated with the constituents and their associated methods. The uncertainties are tabulated for each element in columns 3 and 4 of table VI. These values and the other values discussed here and tabulated in columns 3 to 6 are all 1 relative standard deviation.

The elements Be, Br, Cd, Pb, and Si were determined by a single laboratory by emission spectroscopy (ES). The reproducibility of the measurements made, in comparison with standards containing the expected elements, was ±25 percent. Actual analyzed samples were somewhat different in character and had a reproducibility (sample measurement uncertainty) of ±12 percent. These uncertainties are also tabulated in columns 3 and 4 in table VI.

Sulfate, nitrate, and fluoride uncertainties which were determined by comparison with standards were ±2, ±2, and ±3 percent, respectively. Sample measurement uncertainty was ±1 percent for all three. Measurements of pH were within ±0.01 pH unit when compared with standard solutions, and the sample measurement uncertainty was also ±0.01 pH unit. The uncertainties associated with values obtained for combined carbon, total carbon (ref. 12), and the hydrocarbons are also listed in table VI.

Two other sources of error or uncertainty deserve attention. The accuracy (comparison with standards) of the high-volume sampling technique is unknown. The precision (sampling method uncertainty) of our high-volume sampling for TSP (refs. 7 and 8) was ±8 percent with both W-41 and glass fiber filters. Because the analyses were performed on relatively small segments of the sample, a further uncertainty of ±5 percent was present because of the variability of the distribution of the particulate matter across the active surface of the filter.

The last column of table VI lists the total uncertainty in two parts: One is entitled "Table VIII" and applies to comparisons within our data set. For this use we felt that the uncertainty from a comparison with standards (column 3) was inapplicable, and it was not used. The values in the column entitled "Table VIII" were found by a standard propagation-of-errors treatment (ref. 17). Specifically, this treatment entails taking the square root of the sum of the squares of each of the uncertainties listed. For example, for silver (Ag) this would be $\pm\sqrt{23^2 + 8^2 + 5^2}$, or ±25 percent. Since the values listed are believed to be at the level of 1 relative standard deviation, we have doubled the calculated result to obtain what for normally distributed data would correspond to about a 95 percent confidence level. Thus, 50 percent is entered for Ag under "Table VIII."

The comparisons made in table IX are with data from other laboratories, and we felt that the uncertainty associated with a "comparison with standards" should be included. For Ag this gave $\pm\sqrt{23^2 + 23^2 + 8^2 + 5^2}$, or ±33 percent. This was doubled and entered under "Table IX" as 66 percent. The rest of the entries were similarly obtained.

RESULTS AND DISCUSSION

Trace Elements

Seven hundred and sixty-two filters which were collected from August 10, 1971, to August 10, 1972, were analyzed for as many as 54 elements by INAA and for five elements by ES. There were, therefore, some 30 000 values to be stored and analyzed in various ways. In this report the mean and maximum concentrations, some concentrations as a function of wind direction, and some elemental ratios are considered. Values at or below the sensitivity of the analytical method, "less than" values, were eliminated from the tabulations, making some tabulated values actually biased upward for some elements.

Table VII lists values for 59 elements at each of the 16 sampling sites operated by DAPC and at each of the seven sites operated by Lewis. The number of samples analyzed, the number of values obtained, the geometric mean, the normal standard deviation, the maximum value found, and the geometric mean of the percentage by weight based upon the TSP are given. Seven elements (strontium (Sr), zinc (Zn), molybdenum (Mo), rhodium (Rh), neodymium (Nd), gadolinium (Gd), and platinum (Pt)) were below the detection limits of the method, which are estimated as follows: Sr, 1 ng/m^3; Zr, 1 ng/m^3; Mo, 1 ng/m^3; Rh, 0.05 ng/m^3; Nd, 0.3 ng/m^3; Gd, 1 ng/m^3; and Pt, 1 ng/m^3. Of those elements listed, only the values for lead (Pb) approach proposed or established standards (e.g., 1500 ng/m^3 in California and 5000 ng/m^3 in Colorado).

The range of elemental concentrations that was typically found for the 59 elements listed in table VII is shown in figure 2. Elements having measurable concentrations for 75 percent or more of the filters analyzed (i.e., 25 percent or less of the analyzed filters had elemental concentrations below the detection limit) are plotted in figure 2(a). Elements having measurable concentrations for less than 75 percent of the filters analyzed (i.e., more than 25 percent of the filters analyzed had elemental concentrations below the detection limit) are plotted in figure 2(b). In figure 2(a) the geometric mean of each data set is indicated by a horizontal tick midway on each solid line. The solid line represents ±2 standard geometric deviations. The upper horizontal tick represents the maximum observed concentration of the element and is generally at the end of the dashed line which extends beyond the upper end of the solid line. However, for antimony (Sb) the maximum observed concentration is within the ±2 standard geometric deviation. This suggests that the distribution for Sb is either not lognormal (as implied by the use of geometric means and standard geometric deviations) or that the 682 values for Sb, being but a subset of the total yearly set of 5840 values, may not be lognormal. (Subsets of lognormally distributed sets are not necessarily lognormal themselves.) In figure 2(b), only the ranges of concentrations and the geometric means of the observed concentrations for each element shown are indicated.

The basis for separating the elements in figure 2 is relatively straightforward. For only four elements (Si, V, Pb, and Bi), were no less-than values obtained for every filter analyzed. The less-than values are those below the detection limit of the method. In an effort to determine how the lack of the lower values affects the mean, we progressively eliminated the lowest values in groups of 20 for two elements, Si and Sb, which had complete or nearly complete data sets. Silicon was chosen because it was quite constant across the city and represents minimum variability. Antimony, on the other hand, was chosen because of its high variability. Progressive elimination of the lower values causes the mean value to increase.

This increase for Si and Sb is plotted in figure 3 on the abscissa as the ratio of the geometric mean obtained after progressively eliminating the 20 lowest values remaining in the set (except, of course, for the first point) to the original geometric mean. The ordinate scales show both the increasing incremental elimination of the lower values and the percentage of the data set remaining. The differences between Si and Sb are probably the extreme case.

The average uncertainty at the 95 percent confidence level for the elements shown in table VI under "Table IX" is ±50 percent. With this criterion, the data in figure 3 show that a 50 percent increase in the geometric mean occurs for Si when 62 percent of the values remain in the data set; but for Sb, when 85 percent of the values remain. It seemed reasonable to strike an approximate average value to be applied to the whole set of elements. Thus, 75 percent was chosen as the percentage of the data set necessary for realistic statistical treatment. For this reason, although the geometric mean of the values observed for the element is shown in figure 2(b), no standard deviation is given. The numbers below the chemical symbols for the elements in figure 2 indicate the fraction of the filters analyzed for which values were obtained.

The elements with large standard deviations are associated with localized sources. Those with small standard deviations suggest earth crust, weak, or uniformly distributed source contributions. In addition, some elements were poorly resolved. Hence, only a very small number of relatively high values were considered (e.g., Ni).

Suburban air is compared with that within the city in table VIII. The total mass loading (TSP) in ng/m^3 (ref. 18) and the concentrations of 23 elements in ng/m^3 are given for the city and for the western suburbs. The urban TSP values cover 1 year (Aug. 1971-Aug. 1972). The suburban TSP values are for the year 1972, but the elemental suburban values cover only five to eight sampling days in 1972. The wind varied typically as it did in Cleveland and contributed little or no bias. Thus, the averages of 45 to 55 values at 16 stations are compared with the averages of five to eight values at seven stations.

This approach of taking averages over all sites gives a broad overview and naturally introduces a large variability in the data base and thus reduces the confidence in the differences observed. From table VIII it is nevertheless interesting to note that 12 of the ratio ranges of the elemental values in the city to those in the suburbs (column 4) are within the ratio of the TSP range observed, which is 2.7 ± 0.3. This suggests that these elements are associated with either weak or widespread sources (manmade or natural). For example, it is evident from consideration of Pb and Br data presented subsequently that automotive fuel combustion is probably one of these widespread sources. On the other hand, those elements with high urban/suburban ratio ranges indicate contributions from strong local sources.

Urban/suburban ratio ranges higher than 2.7 ± 0.3 indicate contributions from local sources in the city. Notable among these are Be, chlorine (Cl), Cr, and Sb (table VIII). Antimony is particularly interesting since it shows up at relatively high concentrations at a number of sites, usually (as shown later) associated with a given wind direction. Certain sources of Sb are known (e.g., Pb and Zn operations), but sources for some locations presently cannot be explained. Anomalously high values of Sb have also been noted in reference 19. Its use as a traceable element shows promise, since it is usually encountered at low, relatively invariant concentrations irrespective of wind direction.

Six elements (V, Cu, Zn, As, Se, and Br) have urban/suburban ratio ranges less than 2.7 ± 0.3 (table VIII). The concentrations found for Cu may be influenced by motor contributions from the high-volume samplers (ref. 20). The low value for Br could result from the decomposition of the lead salt formed from automotive combustion as a function of time. The upper ratio range limits for the other four elements (V, Zn, As, and Se) approach the lower ratio range limit for TSP and perhaps may not be significant.

In column 5 of table VIII the ratios of the urban/suburban values to the TSP ratio are listed. These ratios, or enrichment factors, indicate the degree to which each elemental concentration in the city is "enriched" over its concentration in the suburbs. Seventeen elements have enrichment factors in the range 1.0 ± 0.2. They are the same 12 elements noted previously in column 4 plus V, manganese (Mn), copper (Cu), Zn, and Se. These five elements are now included because the propagation-of-errors treatment included the uncertainty in the TSP data and thus increased the ratio range to be considered in the comparison. The elements As and Br have enrichment factors less than 1.0 ± 0.2, which indicates enrichment in the suburbs over the corresponding concentrations found in the city. Local specialized sources in the suburban area are few in number and are generally not well distributed, with the exception of coal combustion for greenhouse operation. Considerable amounts of As and Br have been found in coal flyash (ref. 21).

Values from other investigations for selected elements are presented in table IX. These cover the work of Bogen in Heidelberg, West Germany (ref. 4); Belot, Diop, and Marine in Paris, France (ref. 22); and Dams, Robbins, Rahn, and Winchester in East Chicago, Illinois, and Niles, Michigan (ref. 23). The data for Cleveland are much more extensive than for the four other cities since they represent mean values over many sites for a whole year. The individual elemental Cleveland values, although comparable to values in at least one of the other cities, do not fit the overall pattern of any one of these areas.

However, the low value for V (10.5 ng/m^3, table VIII) is consistent with findings for areas that produce electric power predominantly by burning coal, as is done in Cleveland, rather than oil (ref. 19). Home heating is predominantly by gas.

Source Identification

Figure 4 shows the mean levels of Sb and Cd at the 16 sampling sites. Antimony concentrations are particularly high at sites 6 and 13. The difference in the Cd/Sb ratio at these sites indicates that different sources for these elements may be involved. Site 13 is adjacent to a chemical specialties plant that produces Sb compounds. Site 6, however, is adjacent to a totally different industrial environment containing, in particular, an electric-lamp-filament manufacturing plant.

The Br/Pb ratios, along with their standard deviations and the maximum values observed, are shown in table X. A Br/Pb ratio of 0.21 ± 0.16 in the ambient air is reported to be indicative of an automotive fuel combustion source (ref. 24). All the means for the 16 sites are well within this range. The percentages of the paired Br and Pb values used to determine the means are also listed in table X. These percentages further indicate that Pb sources in Cleveland are predominantly automotive. However, some higher maximum values (e.g., at sites 7, 10, and 13) indicate other possible strong sources of Br.

There is also some indication that Br/Pb ratios tend to be higher when the wind is from the north than when it is from the south. It may be that northerly winds coming off Lake Erie and crossing heavy traffic arteries pick up automotive aerosols which are monitored before sufficient time has elapsed for the initial Br/Pb ratio of 0.39 to adjust to the steady-state equilibrium range, 0.21±0.16. However, since a number of these ratios exceed 0.39, local industrial sources of aerosol containing Br are probably responsible. This is particularly true at site 13, which is quite close to metallurgical operations (iron and steel manufacturing and coke ovens, in particular).

Trace element concentrations correlated with wind direction show much potential for source identification. For a homogeneous topography, one-point wind data may be sufficient, but for a variable topography such as exists in Cleveland (flood plain, elevations, valleys, lakefronts, tall buildings) care must be exercised to determine that the meteorological data do, in fact, apply to the region under consideration. Wind data in Cleveland are regularly available from only two sites - one at the far southwest edge and one from the lakefront near downtown.

In this report, wind data are applied to only two sites. By using resultant vector wind direction data from the National Weather Service (NWS) at Cleveland Hopkins Airport on the far southwest side of Cleveland (ref. 25), mean concentrations as a function of wind direction weighted for directional stability are plotted for TSP in figure 5, for Fe in figure 6, and for Sb in figure 7 for site 12, which is near the NWS weather station. The directional stability factor for the wind (totally stable ≡ 1) is defined as the ratio of the vector wind velocity v_i to the scalar wind speed s_i for the ith day. The mean stability-weighted mean concentration of each element $\overline{C}$ for each of 16 vector wind directions (0^o, 22.5^o, 45^o, 67.5^o, . . ., etc.) for which data were available was obtained from the equation

$$\overline{C} = \frac{\sum_i \frac{v_i}{s_i} C_i}{\sum_i \frac{v_i}{s_i}}$$

where C_i is the observed concentration for the element on the ith day. The summations were made over the days for which data were obtained. Values of v_i and s_i are available from the NWS data tabulations (ref. 25). In the polar plots, each wind directional line bisects a sector covering $22\frac{1}{2}^{\circ}$ (e.g., at 90° (east) the sector coverage is from $78\frac{3}{4}^{\circ}$ to $101\frac{1}{4}^{\circ}$). The relatively high concentrations of Fe and Sb at 45° are possibly the result of a suburban municipal incinerator and an industrial area 1 to $1\frac{1}{2}$ miles upwind (northeast).

Wind data are also available from Burke Lakefront Airport. The effect of wind direction at site 10 is shown in figures 8 and 9, where concentration roses for terbium (Tb) and europium (Eu) are plotted. In general, there is poor correlation between Tb and Eu at each of the 16 sites in our network, with the exception of site 10. For this site the linear correlation coefficient over all paired values is 0.745. However, this high correlation coefficient is somewhat misleading as it is primarily a reflection of three rather large values recorded on those days when the 24-hour resultant wind was from the WNW (280° to 305°).

Values found for Fe, Th, V, lanthanum (La), Sm, and As indicate that strong sources exist for these elements for ENE and NNW directions at site 10. A specific source is not known. The development of a catalog of sources and corresponding elemental ratios will permit the use of trace element data such as these as specific source identifiers.

Coal-burning electric power generators are located at $337\frac{1}{2}^{\circ}$ (NNW) and 45° (NE) from site 10. The former generator has a lower stack and is somewhat closer and, therefore, should have more discernible effects. These effects are evident in figures 10 and 11, for cesium (Cs) and Sb, respectively, and demonstrate higher concentrations from the NNW than from the NE. Zoller, et al. (ref. 19) have utilized vanadium and its ratio with other elements for source identification. The values we obtained from the NNW for V, Mn, and Fe (figs. 12 to 14, respectively) compare favorably with their analyzed content in coal. The V/Fe ratio of 0.002 obtained from the NNW compares well with the coal values obtained by Sheibley (ref. 26) and Abernethy, Peterson, and Gibson (refs. 27 and 28). Additional wind data would permit consideration of values at adjacent monitoring stations, leading to identification of specific sources by triangulation and clustering (pattern recognition) techniques (ref. 29). Obviously, monitoring equipment that collects data as a function of wind direction obviates the need for separate wind monitoring. Such equipment is currently under test and evaluation as the basis of a complete source identification system (ref. 30).

Sulfate, Nitrate, Fluoride, and pH

Table XI compares the data for sulfate (SO_4^{-2}), nitrate (NO_3^{-}), fluoride (F^{-}), pH, and total carbon on a daily basis; and table XII, on a monitoring site basis. The numbers in parentheses in table XII indicate the number of filters analyzed. A number of high daily values were obtained, particularly at site 3, where 0.200 $\mu g/m^3$ was recorded for NO_3^-; at site 15, where 0.110 and 0.230 $\mu g/m^3$ were recorded for F^-; at site 21, where 0.160 $\mu g/m^3$ was recorded for F^-; and at site 5, where 0.140 $\mu g/m^3$ was recorded for F^-. Highest daily values for SO_4^{-2} were 37 $\mu g/m^3$ at site 9 and 30 $\mu g/m^3$ at sites 5 and 14. Values for pH were constant at an average value of 7.6.

The National Air Pollution Control Administration (NAPCA) (ref. 31) found concentrations of water-soluble fluorides (calculated as F^-) in nonurban areas in 1966 and 1967 to range from less than 0.05 $\mu g/m^3$ (the lower detection limit) for 97 percent of the samples to a maximum of 0.16 $\mu g/m^3$. In urban areas 87 percent of the samples had less than 0.05 $\mu g/m^3$ of F^-, and the rest ranged from 0.05 to 1.89 $\mu g/m^3$. Israel (ref. 32) found predominant annual mean values of about 2 $\mu g/m^3$ adjacent to an aluminum (Al) reduction plant. Our average value of 0.02 $\mu g/m^3$ and locally higher values in the vicinity of certain industrial operations indicate that F^- levels in Cleveland in 1972 were similar to those of references 30 and 31. Even these locally higher values (e.g., 0.23 $\mu g/m^3$) were far below concentrations believed to be harmful to man (cf., e.g., the Soviet Union standard of 10 $\mu g/m^3$ for 24-hr average concentration (ref. 33)).

Sulfates in TSP in the area including Cleveland (north-central region around the Great Lakes) over the years 1968 to 1970 averaged from 11 to 13 $\mu g/m^3$ (ref. 34). The average sulfate value for Cleveland (21 $\mu g/m^3$) is somewhat higher, but this probably reflects the higher level of industrial activity in Cleveland than in the referenced locations.

Sulfur dioxide concentrations from ambient air measurements showed very poor correlation with sulfate concentrations. This lack of correlation has also been reported for other areas (ref. 35).

Nitrate (NO_3^-) concentrations from the National Air Surveillance Network (NASN) for 1965 ranged from 2.6 to 4.3 $\mu g/m^3$, for an average of 3.1 $\mu g/m^3$ for seven eastern cities (ref. 36) (Cleveland not included). Our average nitrate value, 0.08 $\mu g/m^3$, is significantly lower - in fact, our maximum (0.2 $\mu g/m^3$) is an order of magnitude below the NASN value. This might be explained by the fact that values for NO_2 at the NASN site in Cleveland (ref. 18) for 1972 were 27 percent below the average value for 1968 to 1971. This was possibly the result of increased precipitation in 1972 (43 percent above normal). If it is assumed that NO_2 is a source of nitrates, the removal of both NO_2 and NO_3^- by precipitation could be a contributing factor to the low values found (ref. 18). No correlation with wind direction was discernible for these constituents in Cleveland.

Hydrocarbons

Ten polynuclear aromatic compounds were identified. Their mean concentrations for the last half of 1971 and the first half of 1972 are listed for the 16 sampling sites in table XIII. The aliphatics were separated as a group, and their concentrations are listed in table XIV. The number of samples analyzed, the values obtained, their geometric mean, their standard deviation, the maximum value, and the percentage by weight of TSP are presented in these tables.

Because of its suspected carcinogenic properties for humans (ref. 37), extensive environmental data exist for 3,4-benzopyrene (benzo(a)pyrene, BaP) and its relatively innocuous isomer, 1,2-benzopyrene (benzo(e)pyrene, BeP), and these only are discussed. The U.S. Public Health Service reported a value of 24 ng/m^3 for BaP in Cleveland for the period January-March 1959 (ref. 38). However, NASN values for BaP taken in 1966 averaged 3.2 ng/m^3 (refs. 39 and 40). (The NASN sampling site is the same as our site 4, where an average BaP value of 0.6 ng/m^3 and a maximum of 15 ng/m^3 were found.) The average of the maximum site values determined by NASN was 11.2 ng/m^3. The average of the maximums for the 16 sites in our study was 16.2 ng/m^3, with the highest maximum being 130 ng/m^3 at site 9, which is downwind of extensive coke oven operations. The NASN 1966 study further reports 2.8 ng/m^3 as the arithmetic average value for BaP in urban areas. The average of the geometric means in our study was 0.87 ng/m^3, and three sites had means greater than 1.0 ng/m^3.

A recent (1971-72) study in Los Angeles (ref. 41) measured concentrations at four sites and found BeP/BaP ratios of 2.7, 3.6, 0.9, and 3.0, respectively. In our study, BeP was also found in most instances in larger amounts than BaP, and the ratios of the geometric means of BeP to BaP varied from 1.08 to 1.72. Table XV summarizes the data.

The data indicate that the hydrocarbon content of the TSP is predominantly aromatic; the ratio of the aromatic content to the aliphatic content was 15 to 1. (On the basis of simulated tests, the extraction of hydrocarbons was estimated to be about 75 percent efficient.) Undoubtedly, only higher molecular weight material is retained on the filter.

Carbon

The mean carbon concentration at each of the 16 urban sites, its standard deviation, the maximum, and the mean of its percentage of the TSP together with the number of samples analyzed and the number of values obtained are listed in tables XVI and XVII. The average of the geometric means before benzene extraction is 10 700 ng/m^3, or 9.3 percent of the TSP. After extraction the average reduces to 8200 ng/m^3, or 7.2 percent of the TSP, indicating that about 23 percent by weight of the carbon is soluble in hot benzene. Since solubility in hot benzene implies a degree of organic character, this procedure provides a measure of the organic carbon content of the TSP. This content was found to be about 1.5 percent. The procedure noted in the section Analyses, in which low- and high-temperature ignitions are used, indicated that the inorganic fraction was generally less than 1 percent. The difference between the sites with the highest carbon concentrations (e.g., sites 9 and 15), which are adjacent to industrial processes capable of producing large amounts of combined carbon, and the sites with the lowest carbon concentrations (e.g., sites 6, 7, 8, 12, and 14), which are in nonindustrial, predominantly residential areas is surprisingly small. Percentagewise, the difference is in reverse order, but this is due to the level of total TSP, which overwhelms the combined carbon contribution. The NASN site (site 4) had a concentration of 12 000 ng/m^3, or 13 percent of the TSP for combined carbon before extraction. These values are considerably above the average.

In another series of analyses covering five sampling days, total carbon content was determined by using high-temperature oxidizing conditions. For the few days and sites where both combined carbon and total carbon were determined, the value for total carbon was from 1.5 to 2 times higher. Twelve additional samples were analyzed by both methods. The results indicate that the total carbon method (high-temperature oxidizing conditions) gives values 2.25 times higher on the average. This would indicate that about one-half of the carbon in the TSP is elemental carbon, assuming that only a small amount of elemental carbon is produced during pyrolysis. Concentrations of total carbon are listed in tables XI and XII.

CONCLUSIONS

A sampling network in Cleveland, Ohio, and a procedure for determining the concentration of 59 elements and compounds at the trace level in the suspended particulate matter in the ambient atmosphere has been described. It was noted that, of the elements determined, only lead approached levels established by two states for control purposes. Bromine/lead ratios at all monitoring sites were consistent with automotive fuel combustion as the predominant source. Cadmium and antimony levels were particularly high at two sites, but differing relative amounts indicated different source types. Urban concentrations for most elements were generally about twice the suburban values, but some were six times greater. Data for benzo(a)pyrene in or on particulate matter indicated levels in Cleveland comparable to those in other cities. From a five-day data set, sulfate, nitrate, fluoride, and pH showed minimum variations. The analysis of elemental and compound concentrations in terms of wind direction indicated their usefulness as in-situ tracers for potential or actual polluting sources.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, August 15, 1975,
647-90.

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TABLE I. - SAMPLING SITES

(a) Cleveland Division of Air Pollution Control network

Site	Location	Description
1	Air Pollution Control Office 2785 Broadway Cleveland, Ohio	Adjacent to heavy industry on the north, west, and south and to an interstate highway on the east
3	Brooklyn YMCA 3881 West 25 St. Cleveland, Ohio	Predominantly upwind from heavy industry and downwind from mixed residential, commercial, and industrial environments
4	Cleveland Health Museum 8911 Euclid Ave. Cleveland, Ohio	Surrounded by predominantly residential environment but with heavy rush-hour automobile traffic
5	Cleveland Pneumatic Tool 3781 East 77 St. Cleveland, Ohio	Surrounded by mixed industrial and commercial environment and predominantly downwind from heavy automobile traffic
6	Collinwood High School 15210 St. Clair Ave. Cleveland, Ohio	Surrounded by mixed residential, commercial, and industrial environment
7	Cudell Recreation Center 1910 West Blvd. Cleveland, Ohio	Surrounded by residential environment with heavy rush-hour traffic on north and east
8	Estabrook Recreation Center 4125 Fulton Rd. Cleveland, Ohio	Surrounded by mixed residential, commercial, and industrial environment but with heavy rush-hour traffic on east and west
9	Fire Station 13 4749 Broadway Cleveland, Ohio	Predominantly downwind (east) of heavy industry and a major traffic artery; the dirtiest site in the Cleveland network
10	Fire Station 19 East 55 St. and St. Clair Ave. Cleveland, Ohio	Because of winds off Lake Erie, often affected by two nearby (1/2 to 1 mile) electric powerplants and a major traffic artery; surrounded on east, south, and north by industry and commerce
12	George Washington Elementary School 16210 Lorain Ave. Cleveland, Ohio	Predominantly commercial and residential environment with major traffic arteries to the south and west
13	Harvard Yards 4150 East 49 St. Cleveland, Ohio	A municipal supply depot on a major traffic artery, south of a steel-rolling mill; surrounded by aluminum, zinc, and other chemical and metallurgical operations; adjacent to lead fabricating shop
14	John F. Kennedy High School 17100 Harvard Ave. Cleveland, Ohio	Surrounded predominantly by residential environment but on a major traffic artery with heavy rush-hour traffic

TABLE I. - Concluded.

(a) Concluded.

Site	Location	Description
15	P. L. Dunbar Elementary School 2200 West 28 St. Cleveland, Ohio	Surrounded by predominantly residential environment but adjacent to mixed metallurgical processing to the south and (although generally upwind of) heavy industry to the east
17	Fire Station 29 East 105 St. and Superior Ave. Cleveland, Ohio	Surrounded by mixed residential and commercial environment with heavy rush-hour traffic on north and east
20	St. Joseph High School 18491 Lake Shore Blvd. Cleveland, Ohio	Located on shore of Lake Erie to the north with heavy rush-hour traffic to the south and residential and commercial environments to the east, south, and northeast
21	Supplementary Education Center 1365 East 12 St. Cleveland, Ohio	Located in downtown Cleveland with heavy railroad traffic to the north, a commercial environment to the east, south, and west, and heavy industry further south (1 to 3 miles)

(b) Lewis Research Center suburban network

Site	Location	Description
91	Berea High School 165 East Bagley Rd. Berea, Ohio	Located on northwest corner of two streets that carry heavy rush-hour traffic; primarily residential environment, but on Cleveland Hopkins Airport (~1 mile north) flightpath
92	Olmsted Falls High School 26939 Bagley Rd. Olmsted Township, Ohio	Located about 1/4 mile from nearest medium-traffic-density street, 1/2 mile north of Ohio Turnpike, and 1/2 mile south of major railroad line; mostly rural area, that is, houses along streets with large open or farmed fields
93	North Olmsted High School 5755 Burns Rd. North Olmsted, Ohio	Located 1/2 mile south of major traffic artery; surrounded by residential environment
94	Holly Lane Elementary School 3057 Holly Lane Westlake, Ohio	Located 1/2 mile south of major traffic artery; surrounded by sparsely settled suburban area
95	Bay High School 29230 Wolf Rd. Bay Village, Ohio	Located 300 feet north of well-traveled road; surrounded by medium-density residential environment
96	Rocky River High School 20951 Detroit Rd. Rocky River, Ohio	Located on southeast corner of two medium-traffic-density streets with heavy rush-hour traffic; surrounded by low-density residential environment
97	Fairview High School 4507 West 213 St. Fairview Park, Ohio	Located 1/4 mile south of a heavily traveled major highway; surrounded by high-density suburban residential environment

TABLE II. - COMPARISON OF ANALYST A AND ANALYST B

Site	Date	Analyst A	Analyst B	Site	Date	Analyst A	Analyst B	Site	Date	Analyst A	Analyst B
Sodium concentration, ng/m^3				Chromium concentration, ng/m^3				Cobalt concentration, ng/m^3			
1	8/10/71	1000	1350	1	8/10/71	75.1	67	1	8/10/71	3.95	4.20
10		808	1140	10		62.7	59	10		4.07	4.90
12		102	420	12		38.5	25	12		1.32	1.10
17		591	960	17		51.5	36	17		6.37	5.70
20		390	720	20		49.4	28	20		4.69	3.50
21		410	610	21		42.4	28	21		1.85	1.50
1	8/16/71	446	600	1	8/16/71	30.3	17	1	8/16/71	3.76	3.00
5		264	310	5		85.6	63	5		27.80	20.70
7		63	150	7		9.0	6	7		.92	.70
9		385	650	9		34.9	34	9		11.90	11.60
15		477	770	15		19.8	13	15		2.84	2.30
13	8/18/71	607	1080	13	8/18/71	53.6	34	13	8/18/71	6.97	6.00
15	8/18/71	1400	2060	15	8/18/71	75.0	53	15	8/18/71	8.85	6.20
7	8/19/71	350	590	7	8/19/71	33.9	21	7	8/19/71	2.29	1.60
8	8/19/71	259	520	8	8/19/71	28.4	17	8	8/19/71	2.36	1.90
10	8/19/71	746	1240	10	8/19/71	104.0	63	10	8/19/71	8.91	6.60
13	8/25/71	289	520	13	8/25/71	42.9	40	13	8/25/71	2.24	3.00
Aluminum concentration, ng/m^3				Manganese concentration, ng/m^3				Zinc concentration, ng/m^3			
1	8/10/71	6440	6620	1	8/10/71	590	658	1	8/10/71	2620	1850
10		7400	8740	10		299	305	10		1990	1500
12		3170	3720	12		70	114	12		612	410
17		7100	8630	17		227	276	17		1024	570
20		5530	6530	20		140	164	20		877	570
21		3190	3000	21		128	122	21		775	460
1	8/16/71	4891	4410	1	8/16/71	220	229	1	8/16/71	687	410
5		1760	2000	5		121	136	5		459	250
7		1760	1640	7		54	52	7		150	90
9		3230	4170	9		208	254	9		1190	990
15		3240	3130	15		67	76	15		386	190
13	8/18/71	4160	6400	13	8/18/71	349	427	13	8/18/71	1381	660
15	8/18/71	8140	8090	15	8/18/71	365	353	15	8/18/71	1517	850
7	8/19/71	3280	3310	7	8/19/71	262	265	7	8/19/71	851	480
8	8/19/71	3070	3330	8	8/19/71	116	127	8	8/19/71	640	270
10	8/19/71	6200	5700	10	8/19/71	383	378	10	8/19/71	2765	1180
13	8/25/71	2500	2710	13	8/25/71	322	323	13	8/25/71	422	110
Scandium concentration, ng/m^3				Iron concentration, ng/m^3				Arsenic concentration, ng/m^3			
1	8/10/71	1.85	1.61	1	8/10/71	19 000	18 760	1	8/10/71	25.90	73
10		1.94	2.04	10		11 700	15 370	10		13.72	35
12		.78	.62	12		2 980	2 660	12		2.59	11
17		1.97	1.59	17		8 790	8 000	17		7.07	29
20		1.73	1.22	20		3 430	5 500	20		12.18	34
21		.96	.62	21		4 560	3 090	21		7.14	17
1	8/16/71	1.35	.90	1	8/16/71	8 330	6 510	1	8/16/71	63.00	127
5		.45	.34	5		2 850	2 510	5		2.59	7
7		.42	.31	7		2 660	2 250	7		2.38	9
9		.90	.91	9		4 880	5 750	9		4.97	23
15		1.03	.72	15		5 090	4 000	15		3.50	6
13	8/18/71	1.60	1.46	13	8/18/71	16 900	17 120	13	8/18/71	17.08	40
15	8/18/71	2.49	1.59	15	8/18/71	17 200	13 160	15	8/18/71	19.32	70
7	8/19/71	.90	.63	7	8/19/71	4 050	3 310	7	8/19/71	8.05	9
8	8/19/71	.83	.60	8	8/19/71	2 870	2 410	8	8/19/71	6.44	13
10	8/19/71	1.76	1.30	10	8/19/71	13 200	10 350	10	8/19/71	12.95	57
13	8/25/71	.58	.62	13	8/25/71	21 040	23 840	13	8/25/71	2.94	19

TABLE II. - Concluded.

Site	Date	Analyst A	Analyst B	Site	Date	Analyst A	Analyst B
Selenium concentration, ng/m^3				Samarium concentration, ng/m^3			
1	8/10/71	17.10	12.10	1	8/10/71	0.60	0.68
10	↓	13.00	8.10	10	↓	.90	1.00
12	↓	8.78	3.40	12	↓	.33	.37
17	↓	17.30	7.70	17	↓	.68	.78
20	↓	21.20	7.50	20	↓	.59	.63
21	↓	11.00	4.90	21	↓	.37	.41
1	8/16/71	14.80	6.00	1	8/16/71	.50	.42
5	↓	11.80	5.90	5	↓	.70	.16
7	↓	3.10	.90	7	↓	.20	.14
9	↓	8.13	5.50	9	↓	.39	.52
15	↓	7.05	3.50	15	↓	.34	.36
13	8/18/71	19.40	6.30	13	8/18/71	.45	.85
15	8/18/71	32.50	3.50	15	8/18/71	.79	1.00
7	8/19/71	13.00	8.90	7	8/19/71	.50	.60
8	8/19/71	12.70	3.70	8	8/19/71	.30	.35
10	8/19/71	18.80	10.20	10	8/19/71	.72	.78
13	8/25/71	19.00	2.10	13	8/25/71	.25	.26
Bromine concentration, ng/m^3				Strontium concentration, ng/m^3			
1	8/10/71	110	92	1	8/10/71	1.54	1.01
10	↓	370	299	10	↓	1.74	1.22
12	↓	123	137	12	↓	.68	.40
17	↓	192	195	17	↓	1.69	.98
20	↓	134	109	20	↓	1.52	.77
21	↓	163	130	21	↓	.96	.35
1	8/16/71	175	128	1	8/16/71	1.15	.49
5	↓	116	98	5	↓	.56	.23
7	↓	256	189	7	↓	.38	.15
9	↓	232	210	9	↓	.87	.62
15	↓	174	132	15	↓	.90	.48
13	8/18/71	204	210	13	8/18/71	1.35	.90
15	8/18/71	505	354	15	8/18/71	1.90	.83
7	8/19/71	342	277	7	8/19/71	.82	.32
8	8/19/71	312	264	8	8/19/71	.69	.33
10	8/19/71	741	595	10	8/19/71	1.47	.70
13	8/25/71	106	71	13	8/25/71	.34	.28

TABLE III. - COMPARISON OF ANALYST B AND ANALYST C

Site	Date	Analyst B	Analyst C
Sodium concentration, ng/m^3			
1	8/22/71	820	1350
3		270	470
5		680	860
8		240	374
10		420	816
12		160	352
15		970	1213
17		500	879
20		320	492
21		910	1513
1	8/28/71	510	717
5		570	765
9		2180	2766
10		400	796
12		130	281
13		420	768
14		190	424
17		500	1223
20		80	230
21		140	332
Aluminum concentration, ng/m^3			
1	8/22/71	2 430	3 299.0
3		1 960	2 511.0
5		2 410	2 746.0
8		1 440	1 833.0
10		6 820	7 572.0
12		1 170	1 359.0
15		3 010	3 785.0
17		4 820	5 763.0
20		2 290	2 843.0
21		3 550	4 562.0
1	8/28/71	1 490	2 022.0
5		2 960	3 848.0
9		1 580	2 187.0
10		14 360	17 810.0
12		840	1 118.0
13		1 730	2 450.0
14		1 280	1 686.0
17		3 420	6 773.0
20		760	937.5
21		1 810	2 313.0
Chlorine concentration, ng/m^3			
1	8/22/71	3710	4674
3		2080	2502
5		1780	2069
8		790	978
10		1650	1547
12		650	774
15		5630	6772
17		1130	1408
20		690	769
21		4420	5783
1	8/28/71	1070	1296
5		1760	2413
9		7240	9276
10		120	232
12		100	169
13		2470	3145
14		290	514
17		1820	703
20		90	218
21		190	297

Site	Date	Analyst B	Analyst C
Vanadium concentration, ng/m^3			
1	8/22/71	6.60	10.89
3		4.70	5.62
5		7.90	7.03
8		2.90	3.83
10		13.30	15.51
12		3.30	3.27
15		10.10	10.56
17		11.70	13.61
20		5.20	6.55
21		9.40	13.34
1	8/28/71	7.00	9.62
5		9.70	13.34
9		7.60	9.65
10		29.20	37.31
12		5.00	7.69
13		6.00	8.09
14		4.70	7.47
17		11.60	18.61
20		5.20	6.64
21		7.10	9.76
Manganese concentration, ng/m^3			
1	8/22/71	129	185.3
3		37	57.3
5		97	119.3
8		38	51.4
10		91	114.6
12		33	43.3
15		48	58.6
17		104	141.0
20		51	70.9
21		338	484.7
1	8/28/71	129	196.1
5		129	193.6
9		395	539.2
10		67	105.8
12		32	48.6
13		102	154.3
14		42	58.8
17		97	146.4
20		18	19.7
21		69	96.0

Site	Date	Analyst B	Analyst C
Bromine concentration, ng/m^3			
1	8/22/71	90	109.1
3		116	135.3
5		130	134.0
8		136	166.1
10		228	250.4
12		234	233.8
15		172	198.4
17		262	274.6
20		98	105.7
21		131	154.4
1	8/28/71	74	75.6
5		178	217.2
9		163	172.9
10		115	145.8
12		103	113.1
13		95	96.6
14		170	177.1
17		198	282.8
20		16	17.8
21		69	87.4
Antimony concentration, ng/m^3			
1	8/22/71	32	122.3
3		2	8.2
5		59	192.9
8		7	18.4
10		10	19.2
12		6	13.0
15		19	17.3
17		12	24.9
20		6	13.3
21		48	186.6
1	8/28/71	2	4.7
5		46	84.8
9		24	41.9
10		1	4.1
12		1	2.3
13		212	406.5
14		7	11.5
17		2	6.2
20		1	2.2
21		3	6.7

TABLE IV. - SUMMARY OF LINEAR RELATIONS

USING CONCENTRATIONS[a]

(a) Comparison of analyst A and analyst B:
$B = \alpha + \beta A$

Element	α	β	R[b]	t[c]
Na	105	1.38	0.98	[d]6.2
Al	-272	1.16	.95	1.7
Sc	0	.82	.92	-1.8
Cr	-2	.76	.93	[d]-2.7
Mn	4	1.07	.99	1.5
Fe	-1144	1.08	.96	1.0
Co	0	.76	.99	[d]-6.3
Zn	-42	.63	.93	[d]-4.6
As	6	2.27	.94	[d]10.0
Se	4	.14	.26	[d]-3.7
Br	13	.76	.98	[d]-5.8
Sm	0	1.47	.73	1.7
Th	0	.61	.90	[d]4.2

(b) Comparison of analyst B and analyst C:
$C = \alpha + \beta B$

Na	173	1.26	0.97	[d]3.9
Al	151	1.24	.99	[d]5.5
Cl	-131	1.28	.99	[d]6.6
V	0	1.30	.98	[d]5.1
Mn	0	1.40	.998	[d]21.8
Br	0	1.14	.96	2.0
Sb	5	2.19	.96	[d]12.1

[a]Concentrations were measured in ng m^{3}.
[b]Correlation coefficient.
[c]Student's t distribution.
[d]Significant at 5 percent confidence level.

TABLE V. - SUMMARY OF LINEAR RELATIONS USING LOGARITHMS OF CONCENTRATIONS[a]

(a) Comparison of analyst A and analyst B:
$B = \alpha + \beta A$

Element	α	β	R[b]	t[c]	e^{α}
Na	0.79	0.79	0.94	[d]-2.6	2.20
Al	-.20	1.07	.96	.85	.82
Sc	-.11	1.03	.95	.42	.90
Cr	-.33	1.11	.96	1.40	.72
Mn	.13	.96	.98	-.75	1.14
Fe	-.44	1.10	.98	1.83	.64
Co	-.07	1.00	.98	.05	.93
Zn	-.70	1.15	.95	1.71	.50
As	.49	.97	.89	-.23	1.63
Se	-.83	1.37	.56	.85	.44
Br	-.05	.99	.97	-.21	.95
Sm	.20	1.58	.68	1.68	1.22
Th	-.28	1.15	.91	1.16	.76

(b) Comparison of analyst B and analyst C:
$C = \alpha + \beta B$

Na	0.79	0.79	0.97	[d]-4.00	2.20
Al	.11	1.00	.99	0	1.12
Cl	.45	.89	.97	-1.97	1.57
V	.08	1.04	.96	.53	1.08
Mn	.07	1.04	.99	1.49	1.07
Br	.03	1.01	.99	.28	1.03
Sb	.39	.98	.97	-.31	1.48

[a]Concentrations were taken in ng/m^3.
[b]Correlation coefficient.
[c]Student's t distribution.
[d]Significant at 5 percent confidence level.

TABLE VI. - UNCERTAINTIES ASSOCIATED WITH ELEMENTS,

RADICALS, AND COMPOUNDS

[Sampling method uncertainty, 8 percent; surface homogeneity uncertainty, 5 percent.]

Element or compound	Analytical method used[a]	Comparison-with-standards uncertainty,[b] percent	Sample measurement uncertainty,[b] percent	Total uncertainty,[c] percent	
				Table VIII	Table IX
Ag	INAA	23	23	50	66
Al	INAA	>40	>40	>82	>116
As	INAA	8	8	26	30
Be	ES	25	12	30	58
Bi	ES	25	12	30	58
Br	INAA	2	2	18	20
Ca	INAA	20	20	46	58
Cd	ES	25	12	30	58
Ce	INAA	>40	>40	>82	>116
Cl		2	2	18	20
Co		3	3	20	20
Cr		5	5	20	24
Cs		28	28	58	66
Cu		3	3	20	20
Fe		2	2	18	20
Hg		18	18	40	54
In		>40	>40	>82	>116
La		25	25	52	74
Mg		30	30	62	88
Mn		1	1	18	18
Na		3	3	20	20
Pb	ES	25	12	30	58
Sb	INAA	10	10	28	34
Se	INAA	2	2	18	20
Si	ES	25	12	30	58
Sm	INAA	13	13	32	42
Sn		13	13	32	42
V		7	7	20	26
Zn		1	1	18	18
Se		25	25	52	74
SO_4^{-2}	See text	2	1	18	18
NO_3^-		2	1	18	18
F^-		3	1	18	20
pH		[d].01	[d].01	18	18
C (organic)		2	7	24	24
C (total)		5	5	20	24
HC		4	4	20	24

[a]INAA = instrumental neutron activation analysis; ES = emission spectroscopy.
[b]Values are ±1 relative standard deviation $(S/\overline{X})$ 100, where

$S = \sqrt{\sum_{i=1}^{n} (X_i - \overline{X})^2/(n - 1)}$, X_i is the individual measured value, and $\overline{X}$ is the mean of the set of n values.

[c]Values are ±2 relative standard deviations.
[d]pH unit.

TABLE VII. - LISTING OF ANNUAL MEANS BY ELEMENT AND MONITORING SITE - AUGUST 10, 1971 TO AUGUST 10, 1972

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent	Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
			Beryllium							Aluminum			
1	46	37	0.17	0.23	0.98	9.4×10^{-5}	1	46	45	3600	1800	9 100	2.3
3	53	23	.14	.18	.67	12.0	3	53	53	2500	2200	10 000	2.7
4	29	11	.10	.086	.29	6.1	4	29	29	3200	2000	9 500	2.7
5	41	19	.15	.12	.38	12.0	5	41	41	2700	1100	5 700	2.6
6	33	8	.089	.013	.60	5.7	6	33	33	2700	1900	9 900	2.6
7	52	24	.14	.22	.87	11.0	7	52	52	2400	1500	6 900	2.5
8	48	24	.13	.20	.77	10.0	8	48	48	2600	2400	9 900	2.6
9	46	26	.14	.19	.65	10.0	9	46	46	2900	1300	5 700	2.3
10	51	32	.21	.28	1.40	12.0	10	51	50	4400	4100	24 000	3.0
12	50	20	.10	.098	.39	13.0	12	50	50	1600	960	4 100	2.3
13	33	22	.12	.19	.83	6.2	13	33	33	3200	3200	15 000	2.1
14	34	9	.11	.15	.42	14.0	14	34	33	1800	1100	4 600	2.5
15	52	27	.14	.26	1.10	9.1	15	52	52	2900	3100	16 000	2.5
17	45	23	.18	.19	.76	11.0	17	45	45	4000	1800	8 800	2.9
20	36	17	.19	.19	.76	17.0	20	36	36	2000	1700	7 000	2.7
21	40	23	.20	.45	1.6	11.0	21	40	40	4000	4000	17 000	2.9
91	5	5	.037	.031	.084	5.0	91	5	5	2000	740	2 700	2.6
92	5	5	.021	.017	.040	4.0	92	5	5	1600	710	2 600	2.8
93	6	6	.015	.021	.060	2.0	93	6	6	1700	690	2 600	2.7
94	7	7	.018	.028	.084	2.0	94	7	7	1600	530	2 400	2.1
95	5	5	.019	.021	.060	3.0	95	5	5	1600	800	2 900	2.6
96	6	6	.037	.028	.65	5.0	96	7	5	1700	1000	3 300	2.5
97	7	7	.021	.035	.084	3.0	97	8	8	1700	720	3 000	2.3
			Sodium							*Silicon*			
1	46	42	1400	1500	8 200	0.86	1	46	46	13 000	8 700	56 000	7.9
3	53	46	810	1100	6 300	.87	3	53	53	7 400	6 500	30 000	8.1
4	29	25	1100	2700	11 000	.90	4	29	29	10 000	7 700	35 000	8.5
5	41	34	700	530	2 200	.66	5	41	41	8 000	3 300	17 000	7.6
6	33	28	850	2000	10 000	.81	6	33	33	8 400	6 700	32 000	7.9
7	52	45	820	1400	6 000	.84	7	52	52	7 700	7 200	38 000	8.0
8	48	41	730	1500	6 800	.72	8	48	48	7 900	7 700	37 000	8.0
9	46	40	1100	1400	5 800	.88	9	46	46	9 100	3 900	19 000	7.4

10	51	45	1000	1200	5 200	.69	10	51	51	13 000	12 000	66 000	8.8
12	50	43	430	800	3 900	.64	12	50	50	5 200	2 700	13 000	7.7
13	33	28	700	630	2 500	.43	13	33	33	9 900	15 000	84 000	6.6
14	34	26	520	490	2 200	.73	14	34	34	5 700	3 500	17 000	7.9
15	52	49	990	970	5 700	.86	15	52	52	8 700	7 600	29 000	7.5
17	45	39	890	1700	9 200	.66	17	45	45	13 000	9 200	55 000	9.7
20	36	33	440	260	1 300	.57	20	36	36	5 300	4 600	19 000	7.1
21	40	34	1100	1700	8 400	.80	21	40	40	12 000	13 000	50 000	8.5
91	5	5	610	1200	2 900	.79	91	5	5	5 800	3 000	10 000	7.6
92	5	5	300	330	940	.52	92	5	5	4 700	3 100	10 000	8.5
93	6	6	310	280	900	.48	93	6	6	5 000	3 200	9 600	7.9
94	7	7	320	400	1 200	.43	94	7	7	5 000	2 500	9 700	6.8
95	5	5	320	340	960	.51	95	5	5	4 300	2 500	7 500	6.8
96	7	7	340	550	1 600	.47	96	6	6	4 800	3 700	11 000	6.9
97	8	8	350	600	1 900	.47	97	7	7	5 200	3 400	11 000	7.1
			Magnesium							Sulfur			
1	46	28	1700	960	4600	1.1	1	46	7	28 000	26 000	80 000	18.0
3	53	32	750	930	3600	.83	3	53	13	16 000	14 000	55 000	16.0
4	29	19	980	1100	5100	.86	4	29	6	16 000	13 000	41 000	12.0
5	41	22	930	640	2500	.85	5	41	4	15 000	13 000	35 000	15.0
6	33	16	1200	750	2800	1.1	6	33	8	11 000	5 400	22 000	14.0
7	52	32	1100	900	2900	1.0	7	52	8	11 000	6 900	27 000	12.0
8	48	30	840	950	3900	.85	8	48	7	13 000	9 900	33 000	16.0
9	46	24	1500	780	3300	1.1	9	46	6	13 000	6 400	23 000	15.0
10	51	32	1700	1200	5700	1.1	10	51	11	12 000	7 400	27 000	11.0
12	50	28	570	590	2300	.83	12	50	9	8 300	6 600	20 000	14.0
13	33	26	1600	1400	5600	1.0	13	33	5	18 000	8 900	32 000	13.0
14	34	17	900	490	2000	1.2	14	34	5	7 100	4 800	16 000	9.0
15	52	33	1400	1600	8500	1.1	15	52	11	13 000	22 000	65 000	15.0
17	45	27	1300	900	4300	1.1	17	45	7	12 000	8 000	24 000	11.0
20	36	24	800	910	4200	.94	20	36	8	8 200	5 900	18 000	17.0
21	40	26	1700	1700	5500	1.2	21	40	5	20 000	11 000	35 000	16.0
91	5	4	670	460	1200	.87	91	5	(a)	------	------	------	----
92	5	4	360	200	630	.64	92	5	(a)	------	------	------	----
93	6	4	410	150	570	.67	93	6	(a)	------	------	------	----
94	7	5	490	360	860	.74	94	7	↓	------	------	------	----
95	5	5	650	340	1100	1.0	95	5	↓	------	------	------	----
96	7	4	630	220	850	.96	96	7	↓	------	------	------	----
97	8	5	290	510	130	.42	97	8	↓	------	------	------	----

[a]Below detection limit.

TABLE VII. - Continued.

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
			Chlorine			
1	46	45	2800	3000	13 000	1.8
3	53	53	1500	2000	8 200	1.7
4	29	29	1500	3100	14 000	1.2
5	41	40	1600	1800	10 000	1.6
6	33	33	1100	1800	9 500	1.1
7	52	52	1300	2000	8 900	1.4
8	48	48	1000	1800	7 800	1.0
9	46	46	2300	2200	9 300	1.9
10	51	51	1600	1500	6 800	1.1
12	50	49	590	870	4 500	.89
13	33	33	1900	2500	9 900	1.3
14	34	33	740	880	4 400	1.0
15	52	52	2400	6200	35 000	2.1
17	45	45	1400	2100	12 000	1.0
20	36	36	770	810	3 400	1.0
21	40	40	2200	2800	14 000	1 5
91	5	5	540	1500	3 400	.70
92	5	5	320	300	860	.56
93	6	6	330	240	770	.51
94	7	7	200	430	1 200	.28
95	5	5	320	360	1 000	51
96	7	7	330	620	1 800	.46
97	8	8	330	650	2 000	.44
			Potassium			
1	46	30	1900	1400	5 400	1.3
3	53	29	1300	900	3 500	1.3
4	29	18	1400	1000	3 400	1.1
5	41	22	1500	1600	7 800	1.4
6	33	23	1300	840	3 600	1.2
7	52	28	1200	620	2 800	1.1
8	48	26	1200	1400	5 900	1.2
9	46	28	1500	990	4 100	1.3

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
			Scandium			
1	46	45	0.86	0.51	2.3	5.4×10^{-4}
3	53	53	.55	.61	3.8	6.0
4	29	29	.76	.53	2.2	6.4
5	41	41	.61	.24	1.1	5.8
6	33	33	.70	.50	2.4	6.7
7	52	52	.58	1.4	9.8	6.0
8	48	48	.56	.76	3.9	5.7
9	46	46	.71	.39	2.0	5.8
10	51	51	1.1	1.0	6.6	7.4
12	50	50	.35	.24	1.3	5.2
13	33	33	.79	.79	3.7	5.2
14	34	34	.38	.32	1.6	5.2
15	52	52	.59	.75	3.8	5.2
17	45	45	.96	.47	2.4	7.1
20	36	36	.52	3.6	2.2	7.0
21	40	40	.94	1.1	4.8	6.7
91	5	5	.38	.16	.60	4.9
92	5	5	.33	.21	.60	5.8
93	6	6	.34	.18	.62	5.4
94	7	7	.34	.14	.58	4.6
95	5	5	.35	.16	.56	5.5
96	7	6	.35	.23	.73	4.9
97	8	8	.36	.20	.69	4.8
			Titanium			
1	46	37	370	260	1400	0.22
3	53	48	280	280	1100	.30
4	29	26	300	300	1500	.27
5	41	39	300	210	910	.29
6	33	31	370	320	1700	.34
7	52	47	280	210	1000	.28
8	48	41	280	230	850	.27
9	46	34	290	190	900	.23

10	51	32	1700	1400	7 500	1.2		10	51	45	490	400	1800	.33	
12	50	30	660	380	1 600	.99		12	50	40	160	150	640	.24	
13	33	22	1500	1300	5 300	1.0		13	33	29	330	260	900	.21	
14	34	23	860	580	2 300	1.3		14	34	29	260	180	710	.36	
15	52	31	2700	4900	21 000	2.4		15	52	41	280	250	900	.24	
17	45	29	1800	2700	15 000	1.3		17	45	41	450	270	1400	.33	
20	36	23	800	620	2 300	1.2		20	36	32	210	130	580	.29	
21	40	20	1900	2000	7 900	1.4		21	40	33	430	430	1500	.28	
91	5	2	1100	56	1 200	1.3		91	5	5	170	88	280	.22	
92	5	1	1000	----	1 000	1.7		92	5	4	110	76	230	.19	
93	6	1	1100	----	1 000	1.6		93	6	6	140	47	210	.23	
94	7	2	1100	15	1 200	1.2		94	7	7	130	42	180	.17	
95	5	1	880	----	880	1.4		95	5	5	120	69	230	.19	
96	7	2	1000	160	1 100	1.3		96	7	5	130	110	320	.19	
97	8	3	1000	230	1 300	1.2		97	8	7	140	50	190	.18	
			Calcium								Vanadium				
1	46	29	6200	5000	19 000	4.2		1	46	46	16.0	11.0	110.0	0.010	
3	53	34	3400	2700	10 000	3.6		3	53	53	8.3	6.4	30.0	.0090	
4	29	19	3800	2100	7 900	3.2		4	29	29	11.0	7.7	34.0	.0095	
5	41	24	2700	1100	5 800	2.6		5	41	41	10.0	5.2	27.0	.0099	
6	33	27	3000	2200	8 800	2.9		6	33	33	11.0	5.5	35.0	.010	
7	52	35	3100	2700	17 000	3.2		7	52	52	9.2	8.8	79.0	.0094	
8	48	31	3000	2200	10 000	3.1		8	48	48	8.4	9.4	52.0	.0085	
9	46	33	4500	2400	11 000	3.9		9	46	46	10.0	3.6	22.0	.0085	
10	51	35	4200	2600	12 000	3.1		10	51	51	14.0	8.9	59.0	.0097	
12	50	34	2000	870	3 800	3.0		12	50	50	5.5	3.5	20.0	.0083	
13	33	27	4100	2900	11 000	3.0		13	33	33	11.0	10.0	56.0	.0074	
14	34	29	1900	1100	4 000	2.5		14	34	34	6.2	4.2	18.0	.0086	
15	52	34	5500	7400	36 000	4.7		15	52	52	12.0	10.0	48.0	.010	
17	45	34	3900	1900	8 900	2.9		17	45	45	13.0	5.0	30.0	.0097	
20	36	24	1800	1500	6 600	2.8		20	36	36	6.9	5.5	24.0	.0092	
21	40	25	5000	3500	15 000	3.6		21	40	40	15.0	13.0	54.0	.010	
91	5	2	3100	820	3 700	3.4		91	5	5	6.5	1.8	9.0	.0085	
93	6	↓	1600	----	1 600	2.3		93	6	6	5.4	2.1	9.9	.0086	
94	7	↓	1400	----	1 400	1.2		94	7	7	5.8	1.9	9.0	.0079	
95	5	↓	1300	----	1 300	2.1		95	5	5	6.4	1.7	10.0	.010	
96	7	3	1900	230	2 200	2.3		96	7	7	6.1	2.6	11.0	.0089	
97	8	2	2300	230	2 400	2.7		97	8	8	6.1	2.2	10.0	.0083	

TABLE VII. - Continued.

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent	Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
			Chromium							Cobalt			
1	46	45	29.0	25.0	110	0.018	1	46	45	4.0	7.2	38.0	0.0025
3	53	53	13.0	19.0	96	.014	3	53	53	1.6	2.7	11.0	.0018
4	29	29	16.0	16.0	72	.014	4	29	29	2.1	1.4	6.9	.0017
5	41	41	26.0	21.0	86	.025	5	41	41	3.4	5.0	28.0	.0032
6	33	32	24.0	22.0	100	.022	6	33	33	4.4	11.0	46.0	.0042
7	52	52	15.0	15.0	65	.015	7	52	52	1.5	1.9	11.0	.0016
8	48	47	13.0	18.0	65	.013	8	48	48	1.4	2.2	9.2	.0015
9	46	46	20.0	20.0	91	.016	9	46	46	3.5	5.7	23.0	.0028
10	51	50	29.0	25.0	110	.020	10	51	51	3.3	3.0	15.0	.0023
12	50	49	10.0	12.0	63	.015	12	50	50	1.1	1.9	11.0	.0017
13	33	33	26.0	22.0	110	.017	13	33	28	3.5	5.3	25.0	.0025
14	34	30	9.3	14.0	66	.013	14	34	34	1.1	1.7	9.5	.0015
15	52	51	19.0	28.0	120	.016	15	52	52	2.3	5.4	35.0	.0020
17	45	45	19.0	14.0	68	.014	17	45	45	2.6	6.8	46.0	.0019
20	36	35	15.0	34.0	150	.020	20	36	36	2.3	12.0	69.0	.0030
21	40	40	20.0	19.0	67	.014	21	40	40	3.1	25.0	610.0	.0022
91	5	5	5.5	13.0	25	.0072	91	5	5	.82	.27	1.3	.0011
92	5	4	3.1	11.0	22	.0051	92	5	5	.75	.66	1.8	.0010
93	6	5	2.4	9.7	22	.0039	93	6	6	.67	.45	1.35	.0010
94	7	6	3.0	9.3	23	.0040	94	7	7	.70	.38	1.35	.00095
95	5	5	3.0	8.2	19	.0048	95	5	5	.80	.31	1.13	.0010
96	7	6	3.4	8.9	22	.0048	96	7	6	.75	.53	1.55	.0010
97	8	8	3.5	8.3	24	.0048	97	8	8	.75	.48	1.58	.0010
			Manganese							Nickel			
1	46	45	280	200	800	0.18	1	46	2	56.0	39.0	89.0	0.045
3	53	53	100	94	430	.11	3	53	2	98.0	95.0	180.0	.092
4	29	29	140	120	540	.12	4	29	1	83.0	----	83.0	.048
5	41	40	150	140	660	.15	5	41	1	59.0	----	59.0	.083
6	33	33	130	93	480	.12	6	33	0	-----	----	-----	-----
7	52	52	130	100	720	.13	7	52	2	16.0	1.1	17.0	.030
8	48	48	110	100	500	.11	8	48	3	33.0	14.0	50.0	.029
9	46	46	220	150	700	.18	9	46	1	85.0	----	85.0	.077
10	51	51	170	110	520	.12	10	51	6	74.0	90.0	230.0	.064

12	50	50	81	63	320	.12	12	50	3	55.0	20.0	80.0	.12
13	33	33	190	130	500	.12	13	33	2	110.0	70.0	170.0	.040
14	34	33	81	71	270	.11	14	34	2	27.0	15.0	39.0	.054
15	52	52	150	150	610	.13	15	52	1	24.0	----	24.0	.035
17	45	45	150	83	430	.11	17	45	3	58.0	69.0	150.0	.039
20	36	36	100	120	470	.14	20	36	3	27.0	41.0	82.0	.045
21	40	40	190	190	730	.13	21	40	2	83.0	6.9	88.0	.057
91	5	5	73	42	140	.090	91	5	1	98.1	----	98.1	.090
92	5	5	57	48	130	.10	92	5	(a)	-----	----	-----	-----
93	6	6	59	33	110	.090	93	6	(a)	-----	----	-----	-----
94	7	7	67	36	130	.090	94	7	(a)	-----	----	-----	-----
95	5	5	72	34	120	.011	95	5	(a)	-----	----	-----	-----
96	7	7	71	34	130	.090	96	7	(a)	-----	----	-----	-----
97	8	8	65	34	140	.080	97	8	(a)	-----	----	-----	-----
Iron							Copper						
1	46	45	9500	5 400	25 000	6.0	1	46	33	82.0	230.0	1100.0	0.054
3	53	53	2600	2 500	10 000	2.8	3	53	36	190.0	190.0	700.0	.20
4	29	29	3900	2 700	11 000	3.3	4	29	22	83.0	170.0	620.0	.068
5	41	41	3400	1 600	7 600	3.2	5	41	28	130.0	270.0	1300.0	.13
6	33	33	3400	2 500	10 000	3.2	6	33	28	100.0	90.0	310.0	.092
7	52	52	2900	2 600	25 000	3.0	7	52	36	80.0	83.0	280.0	.082
8	48	48	2600	3 700	19 000	2.6	8	48	32	94.0	110.0	390.0	.095
9	46	46	5800	5 500	25 000	4.7	9	46	29	57.0	120.0	560.0	.051
10	51	51	6800	5 900	36 000	4.7	10	51	38	180.0	280.0	1100.0	.13
12	50	48	1700	1 200	5 600	2.6	12	50	36	34.0	43.0	170.0	.051
13	33	33	9000	7 800	26 000	6.0	13	33	27	60.0	68.0	270.0	.043
14	34	34	1700	1 600	7 100	2.4	14	34	29	59.0	80.0	280.0	.082
15	52	52	4500	5 800	20 000	3.9	15	52	33	57.0	94.0	330.0	.049
17	45	45	4800	2 700	15 000	3.5	17	45	36	85.0	200.0	1100.0	.062
20	36	36	2500	11 000	64 000	3.4	20	36	26	53.0	85.0	280.0	.079
21	40	40	6100	8 400	32 000	4.3	21	40	26	990.0	850.0	3000.0	.74
91	5	5	1800	930	3 200	2.4	91	5	5	71.0	18.0	84.0	.090
92	5	5	1500	1 300	3 300	2.7	92	5	4	51.0	25.0	90.0	.090
93	6	6	1400	1 000	3 400	2.2	93	6	5	41.0	19.0	61.0	.060
94	7	7	1500	1 000	3 600	2.0	94	7	5	38.0	7.7	51.0	.050
95	5	5	1600	1 000	3 300	2.6	95	5	2	17.0	23.0	38.0	.020
96	7	6	1700	1 200	3 400	2.4	96	7	6	200.0	570.0	1400.0	.29
97	8	8	1600	1 100	4 000	2.2	97	8	8	83.0	420.0	1200.0	.11

[a]Below detection limit.

TABLE VII. - Continued.

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
Zinc						
1	46	45	750	860	4100	0.47
3	53	53	310	430	2300	.34
4	29	29	440	350	1700	.37
5	41	41	400	320	1400	.38
6	33	33	470	500	2200	.44
7	52	52	380	330	1700	.40
8	48	48	340	450	2700	.34
9	46	46	470	320	1800	.38
10	51	51	540	750	4400	.38
12	50	49	230	170	650	.35
13	33	33	440	480	1800	.30
14	34	34	230	230	1200	.31
15	52	52	390	350	1500	.34
17	45	45	470	350	1300	.35
20	36	35	320	800	3000	.42
21	40	40	420	450	1900	.30
91	5	5	310	160	550	.39
92	5	5	270	210	650	.47
93	6	6	230	180	580	.36
94	7	7	240	300	900	.32
95	5	5	320	270	770	.51
96	7	6	250	240	680	.36
97	8	8	230	270	900	.30
Gallium						
1	46	8	4.0	3.4	10.0	0.0025
3	53	9	2.3	1.4	5.1	.0023
4	29	8	2.4	2.3	8.3	.0023
5	41	8	1.7	.78	3.1	.0019
6	33	14	3.4	2.2	9.4	.0038
7	52	10	1.8	.73	3.3	.0019
8	48	10	2.3	2.7	9.0	.0022
9	46	11	2.7	1.5	5.8	.0026
10	51	12	2.1	1.7	5.2	.0016
12	50	14	1.5	1.5	6.4	.0019
13	33	14	2.9	3.7	13.0	.0017

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
Arsenic (Concluded)						
15	52	47	15.0	23.0	82.0	.013
17	45	38	19.0	22.0	130.0	.014
20	36	33	15.0	23.0	110.0	.020
21	40	32	29.0	300.0	1900.0	.020
91	5	4	8.5	9.5	24.0	.010
92	5	4	15.0	36.0	75.0	.020
93	6	5	15.0	19.0	47.0	.020
94	7	6	13.0	14.0	42.0	.010
95	5	4	8.2	8.9	23.0	↓
96	7	3	15.0	10.0	27.0	
97	8	6	10.0	10.0	31.0	
Selenium						
1	46	45	4.9	5.5	50.0	0.0031
3	53	53	3.8	3.5	17.0	.0041
4	29	29	6.4	5.3	28.0	.0055
5	41	41	3.8	3.6	16.0	.0036
6	33	30	8.8	5.4	27.0	.0086
7	52	52	4.1	4.3	21.0	.0042
8	48	48	4.0	5.3	20.0	.0040
9	46	46	3.8	3.0	15.0	.0031
10	51	50	5.3	4.2	19.0	.0036
12	50	50	2.6	2.1	8.8	.0038
13	33	26	6.6	7.9	27.0	.0046
14	34	33	2.9	3.3	15.0	.0041
15	52	52	4.1	5.0	33.0	.0035
17	45	45	5.5	4.3	17.0	.0041
20	36	36	3.4	10.0	54.0	.0046
21	40	40	5.5	6.3	30.0	.0039
91	5	5	3.0	2.3	7.4	.0030
92	5	5	3.2	3.2	9.2	.0050
93	6	6	3.0	2.7	8.7	.0040
94	7	7	3.4	2.5	8.3	.0040
95	5	5	3.3	2.1	7.2	.0050
96	7	6	3.6	3.5	9.1	.0050
97	8	8	3.6	2.6	9.2	.0040

14	34	10	1.9	.60	2.8	.0025
15	52	12	2.2	1.7	6.5	.0017
17	45	15	3.3	8.1	33.0	.0024
20	36	11	1.5	.95	3.8	.0026
21	40	13	5.1	4.2	13.0	.0037
91	5	1	1.6	----	1.6	.0010
92	5	1	3.7	----	3.7	.0060
93	6	1	3.3	----	3.3	.0040
94	7	2	1.8	1.2	2.7	.0010
95	5	1	2.9	----	2.9	.0040
96	7	(a)	---	----	----	------
97	8	(a)	---	----	----	------
Arsenic						
1	46	42	25.0	41.0	230.0	0.016
3	53	43	15.0	30.0	180.0	.016
4	29	23	14.0	24.0	110.0	.012
5	41	35	13.0	14.0	64.0	.012
6	33	28	37.0	100.0	390.0	.035
7	52	42	14.0	23.0	98.0	.014
8	48	38	14.0	29.0	130.0	.013
9	46	40	16.0	21.0	110.0	.013
10	51	45	21.0	25.0	130.0	.014
12	50	37	9.3	13.0	64.0	.013
13	33	26	14.0	25.0	130.0	.0086
14	34	26	8.6	11.0	39.0	.012
Bromine						
1	46	45	180	170	690	0.11
3	53	53	200	150	740	.22
4	29	29	230	220	980	.20
5	41	41	180	160	760	.17
6	33	33	240	200	880	.22
7	52	52	240	280	1600	.25
8	48	48	220	280	1400	.22
9	46	46	190	150	900	.15
10	51	51	320	220	1200	.22
12	50	50	170	180	1000	.26
13	33	32	130	120	470	.088
14	34	34	120	130	530	.16
15	52	52	190	190	790	.16
17	45	45	390	480	2600	.29
20	36	36	140	230	1100	.19
21	40	39	200	140	730	.14
91	5	5	280	220	690	.37
92	5	5	150	56	210	.25
93	6	6	89	28	130	.14
94	7	7	130	90	330	.17
95	5	5	100	39	160	.16
96	7	6	170	130	410	.24
97	8	8	190	150	530	.25

[a]Below detection limit.

TABLE VII. - Continued.

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent	Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
Rubidium							Indium						
1	46	27	12.0	8.3	41.0	0.0076	1	46	18	0.22	0.15	0.53	14.0×10^{-5}
3	53	30	5.4	4.3	17.0	.0054	3	53	11	.079	.055	.22	7.3
4	29	20	7.3	4.0	15.0	.0054	4	29	9	.11	.079	.25	10.0
5	41	21	5.6	2.1	11.0	.0054	5	41	6	.095	.029	.14	9.6
6	33	14	8.1	3.8	16.0	.0081	6	33	7	.089	.069	.22	10.0
7	52	29	5.2	2.6	12.0	.0052	7	52	9	.11	.12	.37	10.0
8	48	28	4.8	3.4	14.0	.0052	8	48	12	.12	1.6	5.3	12.0
9	46	27	8.1	8.0	36.0	.0070	9	46	7	.096	.039	.15	8.4
10	51	32	8.7	5.6	27.0	.0064	10	51	13	.13	.13	.55	9.6
12	50	28	3.4	1.5	7.1	.0050	12	50	8	.063	.095	.31	9.4
13	33	11	11.0	8.2	27.0	.0066	13	33	11	.078	.053	.19	5.3
14	34	23	4.0	2.5	11.0	.0060	14	34	13	.051	.045	.14	7.2
15	52	32	7.3	10.0	46.0	.0067	15	52	8	.11	.13	.37	7.6
17	45	31	7.4	3.8	18.0	.0055	17	45	11	.11	.15	.55	8.8
20	36	15	4.7	8.1	34.0	.0074	20	36	8	.039	.038	.11	8.1
21	40	22	9.9	12.0	44.0	.0070	21	40	10	.16	.16	.49	11.0
91	5	2	5.0	.48	5.4	.0050	91	5	2	.090	.010	1.07	10.0
92	5	1	5.2	-----	5.2	.0080	92	5	1	.040	-----	.040	7.0
93	6	↓	7.4	-----	7.4	.010	93	6	1	.060	-----	.070	10.0
94	7	↓	6.2	-----	6.2	.0070	94	7	2	.070	-----	.070	7.0
95	5	↓	4.9	-----	4.9	.0070	95	5	1	.050	-----	.050	8.0
96	7	2	8.1	2.5	10.0	.010	96	7	2	.070	.010	.090	9.0
97	8	2	5.4	3.4	8.1	.0060	97	8	3	.090	.020	.12	10.0
Silver							Tin						
1	46	20	1.3	1.0	8.6	8.3×10^{-4}	1	46	26	210.0	200.0	1000.0	0.14
3	53	23	.93	.53	2.1	9.6	3	53	31	98.0	77.0	290.0	.10
4	29	14	1.0	.50	2.0	7.6	4	29	22	100.0	68.0	290.0	.086
5	41	18	1.1	.82	3.5	11.0	5	41	23	76.0	42.0	170.0	.072
6	33	12	1.1	.75	3.0	10.0	6	33	23	96.0	70.0	340.0	.093
7	52	27	.82	.48	2.1	8.7	7	52	31	88.0	43.0	230.0	.093
8	48	16	1.2	6.4	26.0	11.0	8	48	29	93.0	120.0	610.0	.097
9	46	16	1.1	.82	4.0	9.4	9	46	30	120.0	74.0	400.0	.10
10	51	27	1.2	.70	3.5	8.2	10	51	32	110.0	63.0	260.0	.086

12	50	24	.57	.34	1.6	8.4	12	50	31	54.0	23.0	100.0	.082
13	33	12	1.4	.92	3.7	9.0	13	33	18	130.0	100.0	390.0	.094
14	34	11	.47	.27	.96	7.1	14	34	28	52.0	36.0	170.0	.073
15	52	23	1.1	1.9	6.9	10.0	15	52	29	110.0	170.0	860.0	.098
17	45	19	1.0	1.3	6.1	7.4	17	45	32	96.0	63.0	290.0	.072
20	36	13	.53	.29	1.2	10.0	20	36	18	46.0	32.0	120.0	.074
21	40	25	1.5	.75	3.0	11.0	21	40	23	110.0	150.0	700.0	.080
91	5	(a)	----	----	-----	---------	91	5	2	71.0	26.7	92.0	.070
92	5		----	----	-----	---------	92	5	1	34.0	-----	34.0	.050
93	6		----	----	-----	---------	93	6	1	47.0	-----	47.0	.060
94	7		----	----	-----	---------	94	7	2	47.0	2.7	49.0	.040
95	5		----	----	-----	---------	95	5	1	46.0	-----	46.0	.070
96	7		----	----	-----	---------	96	7	2	40.0	.74	40.0	.040
97	8		----	----	-----	---------	97	8	3	65.0	15.0	81.0	.070
			Cadmium							Antimony			
1	46	44	5.7	17.0	91.0	0.0036	1	46	44	47.0	160.0	1100.0	0.030
3	53	52	3.2	20.0	250.0	.0034	3	53	52	10.0	110.0	650.0	.011
4	29	29	2.3	7.1	26.0	.0019	4	29	28	19.0	56.0	260.0	.017
5	41	41	4.7	11.0	83.0	.0045	5	41	41	32.0	220.0	1100.0	.031
6	33	33	5.8	110.0	620.0	.0055	6	33	33	110.0	1300.0	5000.0	.10
7	52	51	4.0	12.0	52.0	.0040	7	52	51	10.0	79.0	420.0	.011
8	48	48	3.2	10.0	37.0	.0033	8	48	47	9.6	140.0	760.0	.0098
9	46	46	3.4	7.6	26.0	.0028	9	46	43	33.0	160.0	560.0	.027
10	51	51	4.3	11.0	78.0	.0029	10	51	51	19.0	72.0	370.0	.013
12	50	50	1.7	4.6	21.0	.0025	12	50	48	5.4	58.0	350.0	.0080
13	33	33	4.7	19.0	85.0	.0031	13	33	33	310.0	1800.0	6000.0	.21
14	34	34	1.8	3.7	16.0	.0025	14	34	33	11.0	210.0	1200.0	.015
15	52	52	5.6	53.0	610.0	.0048	15	52	51	18.0	110.0	510.0	.016
17	45	45	3.9	6.6	24.0	.0029	17	45	45	22.0	87.0	430.0	.016
20	36	36	3.4	9.1	95.0	.0046	20	36	36	13.0	60.0	260.0	.018
21	40	40	4.3	15.0	67.0	.0031	21	40	40	26.0	100.0	440.0	.019
91	5	5	1.4	.65	2.5	.0010	91	5	5	4.9	15.0	35.0	.0060
92	5	5	1.5	.63	2.3	.0020	92	5	5	5.7	14.0	30.0	.010
93	6	6	1.7	.61	2.4		93	6	6	4.3	4.4	13.0	.0070
94	7	7	1.6	.57	2.4		94	7	7	6.4	21.0	57.0	.0090
95	5	5	1.8	.64	2.8		95	5	5	5.3	5.6	15.0	.0080
96	6	6	1.4	.74	2.7	.0010	96	7	6	8.8	81.0	190.0	.010
97	7	7	1.5	.92	3.0	.0020	97	8	8	8.6	78.0	210.0	.010

[a]Below detection limit.

TABLE VII. - Continued.

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent	Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
Iodine							Lanthanum						
1	46	9	2.9	2.5	6.9	0.0026	1	46	31	3.9	3.1	13.0	0.0023
3	53	9	3.2	3.5	11.0	.0031	3	53	36	2.3	2.4	11.0	.0024
4	29	3	2.4	1.7	4.6	.0021	4	29	19	3.0	2.2	9.4	.0027
5	41	4	3.0	1.3	4.5	.0028	5	41	29	2.6	1.5	6.3	.0024
6	33	9	2.3	1.0	4.2	.0029	6	33	25	3.6	3.0	12.0	.0034
7	52	16	3.9	3.5	13.0	.0043	7	52	37	2.7	3.0	13.0	.0028
8	48	20	3.6	2.4	12.0	.0037	8	48	34	2.3	2.9	14.0	.0023
9	46	10	3.9	2.5	9.0	.0036	9	46	26	2.7	1.4	6.9	.0019
10	51	4	2.0	1.6	4.0	.0018	10	51	34	4.2	2.9	14.0	.0026
12	50	12	1.7	1.3	4.3	.0030	12	50	37	2.6	3.7	17.0	.0037
13	33	5	4.9	2.7	10.0	.0034	13	33	25	2.9	3.0	13.0	.0018
14	34	10	2.3	2.0	7.3	.0032	14	34	21	2.5	1.9	6.6	.0033
15	52	17	6.0	13.0	55.0	.0043	15	52	41	2.7	2.7	11.0	.0023
17	45	9	3.0	1.5	4.9	.0024	17	45	35	4.2	4.6	28.0	.0030
20	36	10	1.5	.99	4.0	.0031	20	36	30	2.0	1.7	6.1	.0023
21	40	4	3.5	1.4	5.1	.0036	21	40	27	3.8	4.1	18.0	.0025
91	5	1	5.4	-----	5.4	.0070	91	5	4	1.5	.47	2.1	.0020
92	5	1	3.2	-----	3.2	.0050	92	5	5	1.1	.52	1.8	
93	6	1	3.9	-----	3.9	.0050	93	6	6	1.4	.88	3.1	
94	7	(a)	---	-----	----	------	94	7	7	1.8	1.6	5.3	
95	5		---	-----	----	------	95	5	4	1.3	.56	2.0	
96	7		---	-----	----	------	96	7	5	1.3	.97	2.6	
97	8		---	-----	----	------	97	8	7	1.5	.50	2.2	
Cesium							Cerium						
1	46	30	1.5	6.2	34.0	9.5×10^{-4}	1	46	16	6.3	3.4	16.0	0.0041
3	53	33	.56	3.2	18.0	5.7	3	53	13	3.5	4.8	19.0	.0036
4	29	22	.67	.46	1.7	5.5	4	29	9	3.2	2.2	8.6	.0023
5	41	25	.54	.24	1.3	5.2	5	41	5	3.9	.86	5.0	.0030
6	33	22	.59	.41	1.8	5.9	6	33	12	4.6	2.4	13.0	.0037
7	52	34	.45	.27	1.1	4.7	7	52	16	3.9	8.3	28.0	.0034
8	48	31	.59	2.4	13.0	5.9	8	48	13	4.5	7.3	23.0	.0038
9	46	31	.91	6.2	33.0	8.1	9	46	15	3.1	3.8	13.0	.0023
10	51	35	.80	.55	2.4	5.8	10	51	16	4.9	4.4	15.0	.0034

12	50	33	.32	.16	.79	4.9
13	33	17	.68	1.1	4.2	5.2
14	34	29	.41	3.2	17.0	5.9
15	52	32	.99	21.0	120.0	8.5
17	45	33	.77	.45	2.0	5.6
20	36	23	.56	5.8	20.0	8.5
21	40	25	.98	1.8	6.6	7.2
91	5	5	.28	.34	.93	4.0
92	5	5	.25	.44	1.03	4.0
93	6	6	.24	.32	.92	4.0
94	7	7	.21	.31	.94	2.9
95	5	5	.23	.35	.91	4.0
96	7	6	.26	.32	.93	4.0
97	8	8	.27	.34	1.13	3.6

12	50	12	4.6	4.0	13.0	.0057
13	33	11	6.1	5.1	18.0	.0040
14	34	7	3.0	2.8	9.4	.0040
15	52	15	3.6	6.4	17.0	.0028
17	45	15	4.8	3.3	11.0	.0033
20	36	10	6.7	23.0	74.0	.0066
21	40	9	4.0	4.0	14.0	.0029
91	5	(a)	---	-----	----	------
92	5	↓	---	-----	----	------
93	6		---	-----	----	------
94	7		---	-----	----	------
95	5		---	-----	----	------
96	7		---	-----	----	------
97	8	↓	---	-----	----	------

Barium

1	46	14	76.0	64.0	230.0	0.049
3	53	23	43.0	29.0	140.0	.043
4	29	13	51.0	40.0	160.0	.046
5	41	14	46.0	25.0	82.0	.044
6	33	17	52.0	34.0	140.0	.049
7	52	19	42.0	35.0	160.0	.040
8	48	18	42.0	35.0	150.0	.038
9	46	19	51.0	26.0	100.0	.045
10	51	27	67.0	50.0	240.0	.050
12	50	19	22.0	13.0	54.0	.035
13	33	18	49.0	78.0	320.0	.032
14	34	13	29.0	15.0	63.0	.039
15	52	17	43.0	43.0	150.0	.041
17	45	22	63.0	33.0	140.0	.046
20	36	17	22.0	20.0	67.0	.037
21	40	13	74.0	67.0	210.0	.049
91	5	1	52.0	----	52.0	.049
92	5	↓	26.0	----	26.0	.043
93	6		30.0	----	30.0	.040
94	7	↓	24.0	----	24.0	.020
95	5	(a)	----	----	-----	-----
96	7	(a)	----	----	-----	-----
97	8	(a)	----	----	-----	-----

Samarium

1	46	38	0.49	0.56	3.5	3.1×10^{-4}
3	53	41	.32	.25	1.1	3.3
4	29	23	.40	.28	1.0	3.4
5	41	32	.36	.35	2.2	3.3
6	33	24	.44	.32	1.2	4.2
7	52	42	.34	.35	2.1	3.3
8	48	38	.31	.33	1.5	3.1
9	46	37	.38	.18	.89	3.0
10	51	44	.56	.48	2.9	3.8
12	50	40	.25	.17	.79	3.7
13	33	28	.54	1.9	10.0	3.3
14	34	26	.24	.18	.68	3.4
15	52	46	.34	.34	1.5	2.9
17	45	36	.57	.71	4.6	4.2
20	36	33	.25	.23	.99	3.3
21	40	31	.55	.61	2.3	3.8
91	5	5	.27	.11	.43	3.0
92	5	5	.19	.061	.27	↓
93	6	6	.17	.073	.26	
94	7	7	.24	.14	.49	
95	5	5	.18	.067	.28	
96	7	6	.20	.11	.35	
97	8	7	.20	.071	.30	↓

[a]Below detection limit.

TABLE VII. - Continued.

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent	Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
Europium							Ytterbium						
1	46	37	0.081	0.062	0.24	5.1×10^{-5}	1	46	22	0.52	0.65	2.5	3.2×10^{-4}
3	53	40	.054	.054	.22	5.8	3	53	30	.34	.42	1.5	3.6
4	29	23	.085	.073	.29	7.1	4	29	18	.51	.39	1.4	4.3
5	41	28	.057	.033	.17	5.2	5	41	18	.40	.38	1.3	4.4
6	33	25	.094	.090	.41	8.9	6	33	13	.56	.93	3.0	6.1
7	52	39	.058	.044	.18	5.7	7	52	28	.43	.53	2.2	4.6
8	48	38	.053	.066	.27	5.2	8	48	26	.36	.90	4.0	3.9
9	46	32	.066	.044	.18	5.2	9	46	22	.53	.73	2.4	5.0
10	51	42	.12	.82	5.3	8.3	10	51	31	.58	.78	3.0	4.2
12	50	38	.038	.024	.13	5.7	12	50	26	.42	.34	1.4	6.3
13	33	21	.087	.074	.30	5.7	13	33	15	.67	1.1	2.9	4.3
14	34	25	.045	.024	.11	6.6	14	34	22	.30	.36	1.1	4.6
15	52	41	.063	.067	.31	5.5	15	52	30	.61	.88	3.4	5.7
17	45	36	.12	.18	1.0	8.6	17	45	24	.67	3.8	18.0	5.0
20	36	30	.043	.037	.15	5.7	20	36	15	.37	.75	2.1	5.9
21	40	30	.099	.12	.38	6.9	21	40	20	.86	1.2	3.9	6.4
91	5	5	.043	.026	.090	6.0	91	5	2	.40	.55	.91	4.0
92	5	5	.030	.026	.070	5.0	92	5	1	.89	----	.87	15.0
93	6	6	.035	.013	.054	6.0	93	6	1	1.0	----	1.0	10.0
94	7	7	.038	.012	.055	5.0	94	7	2	.21	.17	.35	2.0
95	5	5	.035	.012	.052	6.0	95	5	1	.88	----	.88	14.0
96	7	5	.029	.024	.070	4.0	96	7	1	1.1	----	1.1	16.0
97	8	8	.042	.029	.098	6.0	97	8	3	.70	.35	1.1	8.0
Terbium							Lutetium						
1	46	37	0.013	0.039	0.15	7.9×10^{-6}	1	46	26	0.16	0.070	0.60	10.0×10^{-5}
3	53	42	.0089	.026	.090	9.7	3	53	31	.086	.054	.23	9.0
4	29	28	.010	.035	.12	8.7	4	29	22	.13	.075	.32	11.0
5	41	35	.0099	.040	.15	9.1	5	41	23	.092	.035	.18	9.7
6	33	23	.0079	.044	.21	7.6	6	33	20	.12	.066	.30	12.0
7	52	43	.0080	.037	.20	7.7	7	52	32	.081	.051	.26	8.6
8	48	38	.0080	.027	.10	7.7	8	48	30	.091	.10	.53	9.4
9	46	42	.010	.043	.18	8.3	9	46	30	.12	.046	.24	11.0

10	51	47	.018	.087	.35	12.0		10	51	34	.15	.083	.39	11.0
12	50	42	.0071	.028	.11	10.0		12	50	31	.062	.034	.19	9.2
13	33	22	.019	.20	.77	14.0		13	33	16	.13	.098	.38	10.0
14	34	24	.0042	.023	.10	5.9		14	34	25	.058	.028	.14	8.7
15	52	39	.013	.059	.26	11.0		15	52	31	.096	.10	.44	8.9
17	45	43	.013	.054	.21	9.6		17	45	33	.14	.092	.43	10.0
20	36	23	.0059	.042	.17	10.0		20	36	17	.078	.060	.23	12.0
21	40	38	.015	.13	.61	11.0		21	40	24	.15	.89	4.4	11.0
91	5	4	.013	.034	.070	20.0		91	5	2	.069	.010	.077	8.0
92	5	5	.022	.027	.070	40.0		92	5	1	.087	-----	.087	14.0
93	6	3	.020	.027	.050	30.0		93	6		.086	-----	.086	10.0
94	7	3	.014	.018	.030	20.0		94	7		.076	-----	.076	
95	5	5	.012	.011	.030	20.0		95	5		.078	-----	.078	
96	7	4	.020	.020	.050	30.0		96	7	↓	.080	-----	.080	↓
97	8	4	.013	.023	.040	10.0		97	8	2	.061	.021	.078	7.0
			Dysprosium								Hafnium			
1	46	22	0.25	0.15	0.71	1.5×10^{-4}		1	46	44	0.51	0.85	5.1	3.2×10^{-4}
3	53	26	.20	.96	5.0	2.1		3	53	53	.24	.36	2.2	2.7
4	29	18	.27	.16	.68	2.1		4	29	29	.37	.33	1.4	3.1
5	41	18	.18	.081	.42	1.7		5	41	40	.37	1.5	9.4	3.4
6	33	23	.22	.13	.55	2.1		6	33	29	.49	.58	2.6	4.7
7	52	27	.18	.13	.75	1.8		7	52	50	.28	.51	2.8	2.9
8	48	23	.18	.19	.86	1.8		8	48	45	.25	.61	2.7	2.5
9	46	25	.20	.084	.45	1.7		9	46	45	.31	.32	1.5	2.5
10	51	28	.31	.19	.84	2.3		10	51	49	.46	.63	4.1	3.2
12	50	25	.12	.059	.29	1.8		12	50	47	.17	.29	1.7	2.6
13	33	21	.25	.23	.94	1.6		13	33	19	.58	3.8	14.0	4.4
14	34	21	.12	.085	.34	1.7		14	34	33	.17	.24	1.2	2.4
15	52	27	.19	.18	.67	1.8		15	52	47	.27	.43	2.1	2.3
17	45	27	.29	.14	.57	2.2		17	45	44	.43	.65	4.2	3.1
20	36	19	.11	.092	.32	1.8		20	36	33	.33	.91	3.5	4.4
21	40	19	.27	.26	.96	2.0		21	40	39	.41	.80	4.6	2.9
91	5	2	.21	.042	.24	2.0		91	5	5	.23	.96	2.1	3.0
92	5	1	.17	-----	.17	3.0		92	5	5	.12	.070	.24	2.1
93	6	1	.17	-----	.17	2.0		93	6	6	.13	.092	.30	2.0
94	7	2	.14	.003	.14	1.0		94	7	6	.17	.11	.36	2.0
95	5	1	.15	-----	.15	2.4		95	5	5	.16	.16	.47	2.6
96	7	3	.14	.021	.16	1.7		96	7	6	.15	.11	.32	2.2
97	8	3	.15	.051	.21	1.8		97	8	8	.18	.14	.5	2.4

TABLE VII. - *Continued.*

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
Tantalum						
1	46	21	0.15	1.3	25.0	9.3×10^{-5}
3	53	31	.094	.10	.52	11.0
4	29	18	.12	.085	.31	9.9
5	41	32	.23	.56	2.1	22.0
6	33	9	.14	.20	1.5	14.0
7	52	33	.12	2.5	14.0	13.0
8	48	30	.087	.094	.36	8.4
9	46	22	.12	.067	.26	9.7
10	51	33	.21	.12	.56	14.0
12	50	25	.066	.052	.22	9.2
13	33	13	.40	2.4	8.0	21.0
14	34	13	.070	.050	.16	8.7
15	52	29	.11	.47	2.5	9.2
17	45	28	.13	.20	1.1	10.0
20	36	23	.12	.44	2.2	14.0
21	40	25	.12	.18	.68	7.9
91	5	4	.078	.026	.11	11.0
92	5	3	.052	.012	.060	8.0
93	6	5	.060	.063	.18	10.0
94	7	6	.062	.027	.11	9.0
95	5	5	.052	.032	.10	8.0
96	7	5	.061	.060	.15	9.0
97	8	5	.036	.043	.11	5.0
Tungsten						
1	46	8	9.0	12.0	39.0	0.0054
3	53	10	4.7	6.8	23.0	.0041
4	29	6	9.6	14.0	36.0	.0069
5	41	11	11.0	26.0	73.0	.010
6	33	16	13.0	43.0	140.0	.011
7	52	9	5.0	18.0	55.0	.0044
8	48	9	6.7	14.0	43.0	.0051
9	46	7	7.3	3.2	12.0	.0062
10	51	18	9.6	11.0	37.0	.0066

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
Iridium						
1	46	6	1.4	2.1	5.7	0.00077
3	53	8	.99	.57	2.4	.00096
4	29	6	.93	.34	1.4	.00092
5	41	7	.94	.96	3.2	.00086
6	33	8	1.1	.67	2.3	.0012
7	52	14	.83	1.2	4.6	.00078
8	48	8	1.5	1.8	5.6	.0012
9	46	7	1.1	.49	2.0	.00084
10	51	9	1.4	1.4	4.9	.00097
12	50	16	.78	.67	2.1	.0012
13	33	7	1.4	1.4	3.9	.00079
14	34	12	.88	.64	2.5	.0010
15	52	13	.99	1.2	4.9	.00077
17	45	15	1.4	2.2	7.6	.00097
20	36	6	1.1	1.2	3.5	.0010
21	40	4	1.6	1.1	3.4	.0012
91	5	(a)	----	----	---	------
92	5	↓	----	----	---	------
93	6	↓	----	----	---	------
94	7	↓	----	----	---	------
95	5	↓	----	----	---	------
96	7	↓	----	----	---	------
97	8	↓	----	----	---	------
Gold						
1	46	(a)	0.0	-----	-----	--------
3	53	(a)	.0	-----	-----	--------
4	29	1	.12	-----	0.12	2.1×10^{-4}
5	41	(a)	.0	-----	-----	--------
6	33	↓	.0	-----	-----	--------
7	52	↓	.0	-----	-----	--------
8	48	↓	.0	-----	-----	--------
9	46	↓	.0	-----	-----	--------
10	51	↓	.0	-----	-----	--------

12	50	10	3.6	12.0	38.0	.0055	12	50	↓	.0	-----	-----	--------
13	33	8	5.1	6.1	17.0	.0039	13	33	↓	.0	-----	-----	--------
14	34	10	5.4	13.0	39.0	.0064	14	34	1	.078	-----	.078	1.3
15	52	10	7.8	22.0	69.0	.0059	15	52	1	.31	-----	.31	8.2
17	45	12	7.5	16.0	41.0	.0049	17	45	3	.14	0.015	.16	2.1
20	36	19	11.0	31.0	93.0	.016	20	36	(a)	.0	-----	-----	--------
21	40	7	6.2	8.2	19.0	.0048	21	40	1	.14	-----	.14	2.3
91	5	1	2.63	----	2.63	.0025	91	5	(a)	-----	-----	-----	--------
92	5	1	2.42	----	2.42	.0040	92	5	↓	-----	-----	-----	--------
93	6	(a)	-----	----	------	------	93	6	↓	-----	-----	-----	--------
94	7	↓	-----	----	------	------	94	7	↓	-----	-----	-----	--------
95	5	↓	-----	----	------	------	95	5	↓	-----	-----	-----	--------
96	7	↓	-----	----	------	------	96	7	↓	-----	-----	-----	--------
97	8	↓	-----	----	------	------	97	8	↓	-----	-----	-----	--------
Rhenium							Mercury						
1	46	1	0.12	---	0.17	1.8×10^{-4}	1	46	38	0.69	0.89	4.5	4.7×10^{-4}
3	53	↓	.34	---	.34	4.7	3	53	49	.55	.75	4.2	6.1
4	29	↓	.19	---	.19	3.0	4	29	26	.76	.92	4.2	6.4
5	41	↓	1.2	---	1.2	4.5	5	41	35	.59	1.5	8.1	5.5
6	33	(a)	----	---	----	--------	6	33	23	.56	12.0	56.0	5.8
7	52	↓	----	---	----	--------	7	52	46	.44	.60	3.4	4.5
8	48	↓	----	---	----	--------	8	48	39	.36	1.4	8.1	3.8
9	46	↓	----	---	----	--------	9	46	36	.53	2.1	13.0	4.5
10	51	↓	----	---	----	--------	10	51	45	.63	.71	3.1	4.6
12	50	↓	----	---	----	--------	12	50	45	.34	.50	2.6	5.2
13	33	↓	----	---	----	--------	13	33	21	.65	.79	2.7	4.6
14	34	↓	----	---	----	--------	14	34	32	.48	2.8	16.0	6.9
15	52	↓	----	---	----	--------	15	52	46	.50	.87	4.5	4.5
17	45	↓	----	---	----	--------	17	45	41	.51	1.1	6.7	3.8
20	36	↓	----	---	----	--------	20	36	32	.36	.64	2.6	5.0
21	40	↓	----	---	----	--------	21	40	38	1.3	1.8	7.3	9.8
91	5	↓	----	---	----	--------	91	5	4	.2	.27	.71	4.0
92	5	↓	----	---	----	--------	92	5	4	.16	.30	.55	3.0
93	6	↓	----	---	----	--------	93	6	6	.17	.048	.26	3.0
93	6	↓	----	---	----	--------	93	6	6	.17	.048	.26	3.0
94	7	↓	----	---	----	--------	94	7	7	.13	.17	.41	2.0
95	5	↓	----	---	----	--------	95	5	4	.17	.17	.45	2.8
96	7	↓	----	---	----	--------	96	7	6	.28	.52	1.4	4.0
97	8	↓	----	---	----	--------	97	8	7	.36	.23	1.7	4.0

[a]Below detection limit.

TABLE VII. - Concluded.

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, ng m^3	Maximum value, ng m^3	Geometric mean, percent	Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng m^3	Standard deviation, ng m^3	Maximum value, ng m^3	Geometric mean, percent
			Lead							Thorium			
1	46	46	850	480	2500	0.54	1	46	44	0.61	0.43	1.7	3.8×10^{-4}
3	53	53	720	480	2700	.79	3	53	53	.35	.77	4.5	3.8
4	29	29	840	580	2400	.71	4	29	29	.49	.39	1.5	4.1
5	41	41	700	470	2200	.66	5	41	40	.40	.25	1.1	3.7
6	33	33	860	640	3500	.81	6	33	29	.47	.37	2.0	4.5
7	52	52	860	900	4900	.89	7	52	51	.35	.32	1.4	3.6
8	48	48	780	860	4500	.79	8	48	48	.36	.91	4.5	3.7
9	46	46	680	420	2500	.56	9	46	45	.49	.38	1.9	4.1
10	51	51	1100	730	4600	.74	10	51	51	.62	.59	2.7	4.3
12	50	50	580	550	3100	.86	12	50	48	.20	.18	.88	3.1
13	33	33	520	430	1700	.35	13	33	28	.59	.58	2.5	4.2
14	34	34	440	350	1800	.62	14	34	33	.28	.18	.84	3.9
15	52	52	750	660	3100	.66	15	52	51	.37	.67	4.1	3.3
17	45	45	1200	790	4700	.89	17	45	44	.68	.48	2.6	5.0
20	36	36	460	700	3800	.61	20	36	36	.37	1.5	8.7	5.0
21	40	40	810	850	4500	.58	21	40	40	.55	.56	1.7	3.9
91	5	5	700	411	1400	.91	91	5	5	.27	.15	.43	4.0
92	5	5	430	130	640	.75	92	5	5	.19	.17	.41	3.0
93	6	6	290	95	380	.45	93	6	6	.27	.19	.59	4.0
94	7	7	430	200	720	.58	94	7	7	.23	.12	.40	3.0
95	5	5	350	170	610	.56	95	5	5	.20	.13	.39	3.0
96	6	6	500	360	1100	.72	96	7	6	.24	.15	.50	3.4
97	7	7	460	320	1000	.63	97	8	8	.28	.12	.47	4.0

Bismuth							Uranium						
1	46	46	1.6	2.3	11.0	0.0010	1	46	10	0.64	0.54	1.9	4.2×10^{-4}
3	53	53	1.0	1.5	5.6	.0011	3	53	10	.53	.24	.91	5.2
4	29	29	.91	1.2	5.4	.00077	4	29	10	.72	.43	1.8	5.9
5	41	41	1.4	2.1	12.0	.0013	5	41	4	.58	.74	1.8	6.4
6	33	33	.98	1.5	5.5	.00093	6	33	13	1.0	1.4	5.3	9.9
7	52	52	1.1	1.2	5.0	.0011	7	52	12	.31	.19	.64	3.3
8	48	48	1.2	2.1	9.5	.0012	8	48	7	.39	.56	1.7	3.4
9	46	46	1.2	2.0	8.3	.0010	9	46	11	.68	.44	1.4	6.1
10	51	51	1.4	1.7	8.0	.00094	10	51	13	.68	.79	2.8	4.4
12	50	50	.69	.67	3.2	.0010	12	50	11	.32	.21	.79	5.2
13	33	33	1.6	3.1	12.0	.0011	13	33	15	1.9	3.1	13.0	12.0
14	34	33	.74	1.2	5.0	.0010	14	34	8	.47	.65	2.1	6.7
15	52	52	1.5	2.5	11.0	.0013	15	52	16	.70	1.1	4.5	6.0
17	45	45	1.2	1.5	5.7	.00090	17	45	19	.79	.60	2.6	5.9
20	36	36	.91	1.3	5.5	.0012	20	36	17	.38	.80	3.4	6.2
21	40	40	1.5	3.1	14.0	.0011	21	40	9	1.3	.91	2.9	8.1
91	5	5	.56	.48	1.3	.00070	91	5	1	.49	----	.49	4.6
92	5	5	.33	.17	.61	.00060	92	5	1	.28	----	.28	4.6
93	6	6	.23	.13	.44	.00040	93	6	(a)	----	----	-----	---------
94	7	7	.32	.32	1.0	.00040	94	7	↓	----	----	-----	---------
95	5	5	.34	.15	.61	.00054	95	5	↓	----	----	-----	---------
96	6	6	.31	.37	1.1	.00045	96	7	↓	----	----	-----	---------
97	7	7	.51	.64	1.8	.00070	97	8	↓	----	----	-----	---------

[a]Below detection limit.

TABLE VIII. - COMPARISON OF URBAN AND SUBURBAN AVERAGE CONCENTRATIONS FOR SELECTED ELEMENTS

Element	Urban concentration,[a] U, ng/m^3	Suburban concentration,[a] S, ng/m^3	Ratio of urban to suburban concentrations,[a] U/S	Enrichment factor, (U/S)/2.7
Be	0.14±0.04	0.023±0.007	6.1±2.6	2.3±1.0
Na	850±170	360±72	2.4±0.7	.9±0.3
Mg	1 180±732	500±310	2.4±2.1	.9±0.8
Al	2 910±2386	1 700±1394	1.7±1.9	.6±0.7
Si	9 020±2700	4 970±1490	1.8±0.7	.7±0.3
Cl	1 540±278	237±43	6.5±1.6	2.4±0.7
Ca	3 630±1670	1 810±830	2.0±1.3	.7±0.5
V	10.5±2.1	5.96±1.20	1.8±0.5	.7±0.2
Cr	18.9±3.8	3.4±0.7	5.6±1.6	2.1±0.6
Mn	148±27	66.3±11.9	2.2±0.6	.8±0.2
Fe	4 450±800	1 590±286	2.8±0.7	1.0±0.3
Co	2.58±0.52	.75±0.15	3.4±0.9	1.3±0.4
Cu	130±26	72.0±14	1.8±0.5	.8±0.2
Zn	413±74	264±48	1.6±0.4	.6±0.2
As	17.4±4.6	12.1±3.1	1.4±0.5	.5±0.2
Se	4.70±2.42	3.30±1.72	1.3±0.9	.5±0.4
Br	196±35	158±28	1.2±0.3	.4±0.1
Cd	3.90±1.10	1.55±0.46	2.5±1.0	.9±0.4
Sn	99.3±32	54.9±18	1.8±0.8	.6±0.3
Sb	43.4±12.1	6.29±1.76	6.9±2.7	2.5±1.0
Hg	.578±0.231	.223±0.089	2.6±1.4	1.0±0.6
Pb	759±228	451±135	1.7±0.7	.6±0.3
Bi	1.26±0.38	.371±0.101	3.4±1.4	1.3±0.6
TSP	[b]118 000±21 000	44 000±7900	2.7±0.3	1.0±0.2

[a]Plus or minus values represent 1 standard deviation.
[b]Mean of 1971 and 1972 values.

TABLE IX. - AVERAGE TRACE ELEMENT CONCENTRATIONS IN AIR OF FIVE CITIES

Element	Cleveland, Ohio, 1971 (a)	Heidelberg, West Germany, 1971 (ref. 4)	Paris, France, 1971 (ref. 22)	East Chicago, Indiana, 1970 (ref. 23)	Niles, Michigan, 1970 (ref. 23)
	Concentration, ng/m^3				
Cl	1540±308	153	7063	(b)	(b)
La	2.5±1.8	.62	3.42	5.9	1.3
Na	850±170	224	1823	455	170
Co	2.6±0.5	2.2	6.67	2.6	.95
In	[c].10±0.1	.24	(b)	.1	.04
Fe	4450±890	1041	3500	13 800	1900
Sc	.70±0.1	.50	.70	3.1	1.2
Mn	148±27	23.6	82.5	255	62.0
Cs	.50±0.30	.57	(b)	(b)	(b)
Br	196±39	30.5	433	67	32
Ag	1.1±0.7	4.2	(b)	2.4	1
Sb	43±15	5.1	50.8	25	5.8
Cd	3.9±2.3	26.8	19.5	(b)	(b)
Cr	19±15	4.6	15.1	113	9.5
Hg	.58±0.31	.17	11.2	4.8	1.9
Sn	99±42	71.6	(b)	(b)	(b)
Ce	[c]4.9±5.7	1.0	14.0	13	.82
Sm	.36±0.15	.24	.42	.41	.24

[a]Plus or minus values represent 1 standard deviation.
[b]Concentration below detection limit.
[c]Minimum uncertainty.

TABLE X. - BROMINE/LEAD RATIOS

Site	Mean Br/Pb ratio obtained	Standard deviation, 1σ	Maximum Br/Pb ratio obtained	Correlation, coefficient, R	Percentage of mean values in range 0.21±0.16
1	0.209	0.127	0.657	0.895	89
3	.274	.083	.467	.941	83
4	.274	.150	.730	.562	66
5	.253	.110	.560	.753	81
6	.276	.123	.640	.732	79
7	.283	.179	1.31	.792	77
8	.281	.093	.609	.969	83
9	.275	.125	.748	.827	80
10	.298	.155	1.03	.850	73
12	.302	.112	.704	.963	78
13	.255	.491	2.93	.755	88
14	.262	.113	.635	.783	82
15	.250	.398	.476	.547	90
17	.324	.209	.602	.685	74
20	.309	.152	.746	.788	69
21	.250	.100	.506	.762	85
Average	0.273	0.170	0.835	0.787	80

TABLE XI. - SULFATE, NITRATE, FLUORIDE, AND TOTAL CARBON MEAN CONCENTRATIONS AND pH COMPARED ON A DAILY BASIS

Date	Mean	Standard deviation, 1σ	Mean	Standard deviation, 1σ	Mean	Standard deviation, 1σ	Mean	Standard deviation, 1σ	Mean	Standard deviation, 1σ
	Sulfate concentration, $\mu g/m^3$		Nitrate concentration, $\mu g/m^3$		Fluoride concentration, $\mu g/m^3$		pH, pH units		Total carbon concentration, percent	
5/24/72	26	3.4	0.13	0.03	0.010	0.006	7.4	0.4	16	3
6/2/72	15	2.7	.072	.094	[a].024	.04	7.5	.5	18	3
6/20/72	15	6.1	.076	.03	[b].034	.05	8.3	.5	15	5
7/2/72	19	5.4	.055	.02	[c].03	.05	7.7	.4	20	8
7/8/72	25	5.9	.067	[d].04	.013	.015	7.1	.6	14	2

[a]Maximum value, 0.140 $\mu g/m^3$.
[b]Maximum value, 0.230 $\mu g/m^3$.
[c]Maximum values, 0.110 $\mu g/m^3$ and 0.160 $\mu g/m^3$.
[d]Maximum value, 0.200 $\mu g/m^3$.

TABLE XII. - SULFATE, NITRATE, FLUORIDE, AND TOTAL CARBON MEAN CONCENTRATIONS AND pH COMPARED ON A SITE BASIS

Site	Sulfate concentration, $\mu g/m^3$		Nitrate concentration, $\mu g/m^3$		Fluoride concentration, $\mu g/m^3$		pH, pH units		Total carbon concentration, percent	
	Mean	Standard deviation, 1σ	Mean	Standard deviation, 1σ	Mean	Standard deviation, 1σ	Mean	Standard deviation, 1σ	Mean	Standard deviation, 1σ
1	22.0(2)	5.7	0.019(2)	0.015	0.039(2)	0.001	7.1(4)	0.6	26.5(2)	5.0
3	17.4(5)	7.0	.104(5)	.061	.011(5)	.004	7.4(7)	1.3	25.6(5)	14.7
4	18.7(3)	2.1	.101(3)	.068	.007(3)	.004	7.4(4)	.9	25.3(3)	5.0
5	20.8(5)	7.8	.087(5)	.039	.036(5)	.058	7.6(6)	1.0	17.9(5)	9.4
6	18.2(5)	8.0	.067(5)	.037	.007(5)	.003	7.3(6)	1.6	20.2(5)	7.3
7	15.5(4)	6.6	.057(4)	.027	.022(3)	.025	7.6(4)	.7	20.8(4)	2.5
8	15.8(4)	8.9	.078(5)	.053	.007(5)	.003	7.9(5)	1.4	15.7(5)	13.5
9	30.8(4)	5.8	.085(5)	.023	.033(5)	.029	7.6(8)	1.0	54.0(5)	38.7
10	20.8(5)	5.9	.090(4)	.016	.012(5)	.011	7.7(7)	1.0	29.2(5)	7.6
12	17.6(5)	5.5	.064(4)	.016	.006(3)	.001	8.0(7)	.7	17.2(5)	6.8
13	20.8(5)	4.4	.059(5)	.010	.015(5)	.009	7.5(6)	.9	26.8(5)	10.6
14	22.6(5)	6.3	.106(4)	.028	.010(4)	.004	8.0(6)	1.0	15.3(5)	3.8
15	22.0(5)	5.0	.062(5)	.030	.074(5)	.098	7.1(7)	1.7	23.8(5)	6.1
17	20.0(5)	5.9	.066(5)	.050	.008(5)	.003	7.4(6)	1.0	31.4(5)	10.5
20			.070(1)		.006(1)		7.9(2)	.4	45(1)	
21	26.3	2.5	.095(3)	.057	.057(3)	.089	7.2(3)	1.2	32.0(3)	3.6

[a]Numbers in parentheses after means indicate the number of filters analyzed.

TABLE XIII. - MEAN CONCENTRATIONS OF 10 POLYNUCLEAR AROMATIC COMPOUNDS

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, 1σ, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
3, 4-Benzopyrene						
1	25	22	1.4	12	41	0.00075
3	40	37	.62	.69	3.1	.00057
4	25	23	.64	3.0	15	.00076
5	30	28	.58	.85	3.3	.00055
6	24	22	.71	.87	3.0	.00075
7	40	38	.46	.57	2.1	.00050
8	36	28	.44	.69	2.3	.00052
9	32	30	3.6	24	130	.00180
10	36	33	.74	1.5	7.2	.00050
12	33	32	.43	.46	2.0	.00051
13	25	23	.85	2.8	14	.00056
14	24	22	.47	1.0	3.7	.00064
15	24	21	.51	.81	3.5	.00033
17	36	32	.91	1.2	49	.00064
20	20	19	.50	1.6	6.9	.00062
21	24	22	1.1	4.1	17	.00065
Mean	29	27	0.87	3.5	16	0.00067
1, 2-Benzopyrene						
1	25	25	2.0	12	52	0.00110
3	40	40	.85	1.9	11	.00075
4	25	25	1.1	1.5	5.6	.00130
5	30	30	.76	2.0	10	.00072
6	24	23	.77	1.2	5.4	.00080

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, 1σ, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
1, 2-Benzofluorine						
1	25	24	1.4	3.4	10	0.00078
3	40	36	1.3	2.2	8.7	.00110
4	25	24	1.7	1.9	6.8	.00200
5	30	28	1.2	1.8	6.8	.00120
6	24	20	1.5	3.7	12	.00150
7	40	37	.92	2.5	9.9	.00099
8	36	33	1.2	1.8	7.6	.00140
9	32	32	2.8	9.7	43	.00140
10	36	33	1.1	3.0	14	.00073
12	33	27	1.1	2.1	9.1	.00120
13	25	24	2.6	3.1	9.9	.00170
14	24	22	1.5	5.8	27	.00210
15	24	23	1.0	1.5	5.7	.00017
17	36	33	1.7	3.6	12	.00120
20	20	17	1.3	2.0	6.0	.00150
Mean	29	27	1.5	3.1	12	0.00130
Benz-m, n, o-fluoranthene						
1	25	25	0.62	3.4	15	0.00035
3	40	39	.58	8.2	51	.00051
4	25	23	.52	2.0	9.6	.00062
5	30	30	.69	7.6	41	.00066
6	24	20	.60	.85	3.0	.00064

7	40	39	.74	1.7	8.3	.00080	7	40	38	.60	1.0	4.0	.00067
8	36	35	.66	1.1	5.0	.00078	8	36	33	.45	9.9	56	.00051
9	32	32	5.3	15	78	.00270	9	32	32	1.70	4.3	17	.00087
10	36	35	1.0	2.1	8.6	.00071	10	36	33	.52	.98	3.7	.00036
12	33	33	.62	.94	4.7	.00073	12	33	29	.38	1.0	5.1	.00043
13	25	25	1.2	3.8	14	.00074	13	25	24	.79	.94	3.6	.00052
14	24	23	.65	1.0	3.9	.00084	14	24	21	.51	.88	3.6	.00066
15	24	24	.67	1.1	3.8	.00074	15	24	22	.71	15	71	.00051
17	36	35	1.2	1.5	5.6	.00086	17	36	34	.67	2.8	12	.00048
20	20	20	.65	2.1	8.1	.00074	20	20	18	.77	1.4	4.9	.00092
21	24	24	1.3	3.4	8.5	.00076	21	24	21	.97	1.2	5.0	.00059
Mean	29	29	1.2	33	15	0.00094	Mean	29	27	0.70	3.9	19	0.00058
			Pyrene							Benzacradine			
1	25	22	0.13	0.38	14	0.000073	1	25	8	0.51	4.2	12	0.00024
3	40	36	.19	.22	.88	.00016	3	40	12	.61	3.1	8.8	.00058
4	25	23	.22	.35	1.6	.00025	4	25	5	2.0	1.1	3.8	.00220
5	30	29	.17	.20	.69	.00016	5	30	10	.70	1.5	4.9	.00061
6	24	20	.22	.21	.68	.00022	6	24	6	1.5	3.4	7.7	.00140
7	40	35	.13	.20	1.0	.00014	7	40	16	.80	1.8	6.0	.00095
8	36	33	.20	.38	2.0	.00024	8	36	8	.79	1.4	3.7	.00086
9	32	30	.41	1.5	7.5	.00020	9	32	10	1.4	2.5	6.3	.00062
10	36	30	.18	.24	1.0	.00012	10	36	12	1.2	10	31	.00081
12	33	26	.15	.18	.69	.00016	12	33	15	.99	2.6	6.5	.00120
13	25	22	.34	.67	2.9	.00022	13	25	5	.69	1.7	3.8	.00054
14	24	23	.18	.14	.57	.00025	14	24	9	.76	1.9	5.0	.00091
15	24	22	.14	.34	1.4	.000089	15	24	4	.54	1.7	3.2	.00025
17	36	29	.20	.17	.56	.00014	17	36	11	.84	3.8	12	.00067
20	20	17	.16	.40	1.5	.00019	20	20	5	2.7	3.4	9.1	.00280
21	24	17	.26	.26	1.0	.00016	21	24	8	1.9	4.5	11	.00110
Mean	29	25	0.20	0.36	1.6	0.00017	Mean	29	9	1.1	3.0	8.4	0.00099

TABLE XIII. - Concluded.

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, 1σ, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent	Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, 1σ, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
			Benzanthracene							Perylene			
1	25	25	1.3	15	68	0.00074	1	25	24	0.29	1.7	6.5	0.00016
3	40	39	.92	28	140	.00080	3	40	38	.20	.85	4.5	.00017
4	25	24	1.3	17	82	.00160	4	25	23	.26	1.2	5.8	.00029
5	30	29	.83	13	70	.00078	5	30	27	.18	.68	3.5	.00017
6	24	21	1.1	8.9	36	.00110	6	24	21	.22	.36	1.2	.00024
7	40	39	.67	10	64	.00074	7	40	38	.19	.66	2.5	.00021
8	36	32	.71	8.9	43	.00081	8	36	31	.16	.25	.81	.00019
9	32	31	4.1	16	71	.00210	9	32	31	1.0	2.1	9.7	.00053
10	36	33	1.0	8.3	44	.00071	10	36	34	.25	.59	2.3	.00017
12	33	33	.70	7.2	38	.00083	12	33	31	.15	.24	.98	.00018
13	25	24	1.2	13	63	.00082	13	25	24	.30	.75	2.7	.00020
14	24	22	.88	3.9	12	.00120	14	24	22	.17	.29	1.3	.00022
15	24	23	.54	6.8	31	.00037	15	24	21	.14	.16	.67	.00001
17	36	34	.99	24	140	.00070	17	36	32	.27	.58	2.6	.00019
20	20	19	1.0	32	140	.00130	20	20	20	.20	.52	2.1	.00025
21	24	23	1.2	6.0	18	.00073	21	24	22	.28	.62	2.0	.00017
Mean	29	28	1.2	14	66	0.00095	Mean	29	27	0.27	0.72	3.1	0.00021
			3,4-Benzfluoranthene							1,12-Benzoperylene			
1	25	25	4.5	29	120	0.0025	1	25	23	2.0	8.9	35	0.0011
3	40	40	1.8	3.7	17	.0015	3	40	36	1.0	4.7	25	.00086
4	25	25	2.7	4.1	16	.0031	4	25	19	1.5	5.5	16	.0018
5	30	30	1.8	5.9	29	.0017	5	30	26	1.5	8.2	35	.0014
6	24	23	2.0	4.8	18	.0020	6	24	20	1.1	3.5	13	.0011
7	40	38	1.3	3.7	16	.0014	7	40	37	.95	5.5	20	.0010
8	36	35	1.5	3.1	13	.0017	8	36	30	1.1	8.0	43	.0012
9	32	32	16	33	170	.0080	9	32	30	5.7	13	69	.0028
10	36	35	2.4	4.8	26	.0017	10	36	30	1.5	3.2	10	.0010
12	33	32	1.0	2.4	9.9	.0012	12	33	28	.91	4.0	16	.0011
13	25	24	3.5	32	150	.0023	13	25	20	1.1	2.6	8.9	.00074
14	24	22	1.3	3.0	11	.0019	14	24	21	1.2	2.8	10	.0016
15	24	23	1.8	15	70	.0012	15	24	18	.93	2.5	7.7	.00067
17	36	34	2.6	4.7	20	.0018	17	36	27	2.6	5.0	17	.0018
20	20	20	1.5	6.4	24	.0018	20	20	16	.78	2.7	7.9	.00099
21	24	24	3.2	9.6	28	.0019	21	24	22	1.7	9.4	36	.0011
Mean	29	28	3.1	10	46	0.0022	Mean	29	25	1.6	5.6	23	0.0013

TABLE XIV. - MEAN CONCENTRATIONS OF THE ALIPHATICS AS A GROUP

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, 1σ, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
1	13	13	0.87	0.72	2.6	0.00044
3	22	22	.77	.51	2.1	.00064
4	10	9	.64	.46	1.6	.00072
5	16	16	.82	.82	2.7	.00079
6	17	17	.71	.49	2.0	.00072
7	20	20	.78	.35	1.7	.00089
8	24	24	.67	.55	2.6	.00085
9	10	10	1.4	.68	2.7	.00053
10	18	17	.82	.65	2.4	.00049
12	17	17	.70	.53	1.7	.00088
13	13	13	.75	.92	3.3	.00043
14	13	13	.63	.42	1.4	.00084
15	11	11	1.1	.53	1.9	.00076
17	20	20	1.2	.66	3.3	.00087
20	9	9	.88	.36	1.5	.00090
21	12	11	1.1	.66	2.3	.00060
Mean	15	15	0.86	0.58	2.2	0.00071

TABLE XV. - AVERAGE CONCENTRATIONS OF 3,4-BENZOPYRENE AND RATIOS OF 1,2-BENZOPYRENE TO 3,4-BENZOPYRENE

Location	Year	3,4-Benzopyrene concentration, ng/m^3	Ratio of 1,2-benzopyrene to 3,4-benzopyrene concentration, BeP/BaP	Reference
Cleveland	1959	24	-------	19
Cleveland (NASN site)	1966	3.2	-------	22,23
Cleveland (site 4)	1972	.6	-------	This study
Urban sites (maximums)	1966	11.2	-------	22,23
Urban sites (maximums)	1972	16.2	-------	This study
Urban sites	1966	2.8	-------	22,23
Urban sites (this study)	1971-72	.9	-------	This study
Los Angeles	1971-72	----	0.9-3.6	24
Cleveland	1971-72	----	1.1-1.7	This study

TABLE XVI. - MEAN CONCENTRATIONS OF CARBON BEFORE EXTRACTION WITH BENZENE

Site	Number of filters analyzed	Number of value obtained	Geometric mean, ng/m^3	Standard deviation, 1σ, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
1	24	24	10 000	4 500	25 000	5.7
3	42	42	10 000	3 200	19 000	9.0
4	24	24	12 000	330 000	1 600 000	13
5	29	29	11 000	3 300	21 000	10
6	24	24	9 200	2 500	14 000	9.6
7	41	41	9 200	2 900	17 000	10
8	36	36	8 700	2 700	16 000	10
9	32	32	15 000	5 300	27 000	7.3
10	37	37	11 000	3 800	21 000	7.2
12	32	32	9 000	2 800	18 000	11
13	25	25	11 000	5 000	27 000	7.2
14	24	24	9 000	3 100	18 000	12
15	24	24	13 000	470 000	2 300 000	9.2
17	36	36	12 000	2 700	18 000	8.2
20	20	20	10 000	2 800	15 000	12
21	24	24	11 000	3 400	20 000	7
Mean	29	29	10 700	53 000	260 000	9.3

TABLE XVII. - MEAN CONCENTRATIONS OF CARBON AFTER EXTRACTION WITH BENZENE

Site	Number of filters analyzed	Number of values obtained	Geometric mean, ng/m^3	Standard deviation, 1σ, ng/m^3	Maximum value, ng/m^3	Geometric mean, percent
1	24	24	7 500	2 700	15 000	4.1
3	42	42	8 200	2 200	13 000	7.1
4	24	24	8 600	240 000	1 100 000	9.6
5	29	29	8 400	2 500	15 000	8.0
6	24	24	7 100	1 600	10 000	7.4
7	41	41	7 100	2 000	12 000	7.8
8	36	36	6 600	1 700	12 000	7.8
9	32	32	11 000	4 000	20 000	5.3
10	37	37	8 300	2 400	14 000	5.6
12	32	32	7 100	1 900	12 000	8.4
13	25	25	8 100	2 400	16 000	5.3
14	24	24	7 700	2 900	16 000	10
15	24	24	10 000	390 000	1 900 000	7.1
17	36	36	8 400	2 100	12 000	6.0
20	20	20	8 500	2 300	12 000	10
21	24	24	9 000	2 600	15 000	5.4
Mean	29	29	8 200	42 000	200 000	7.2

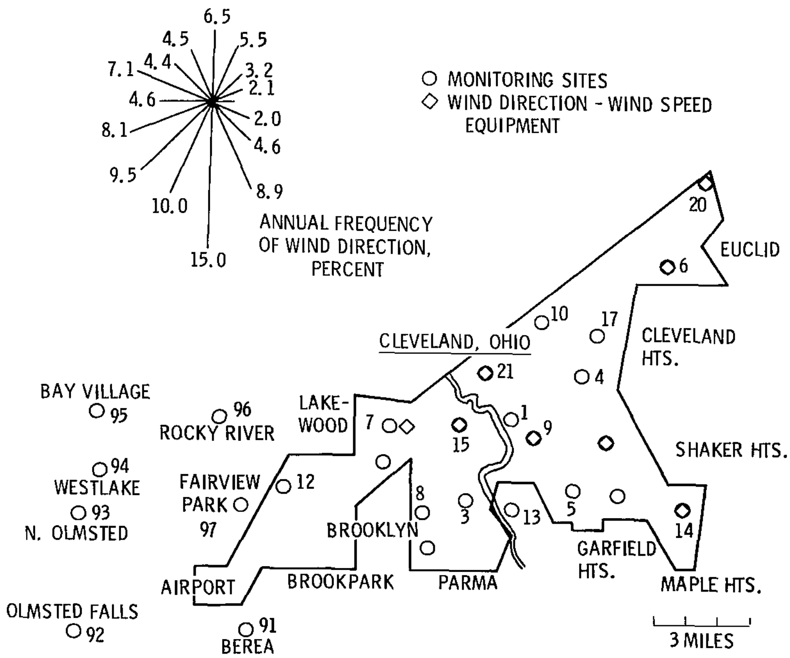
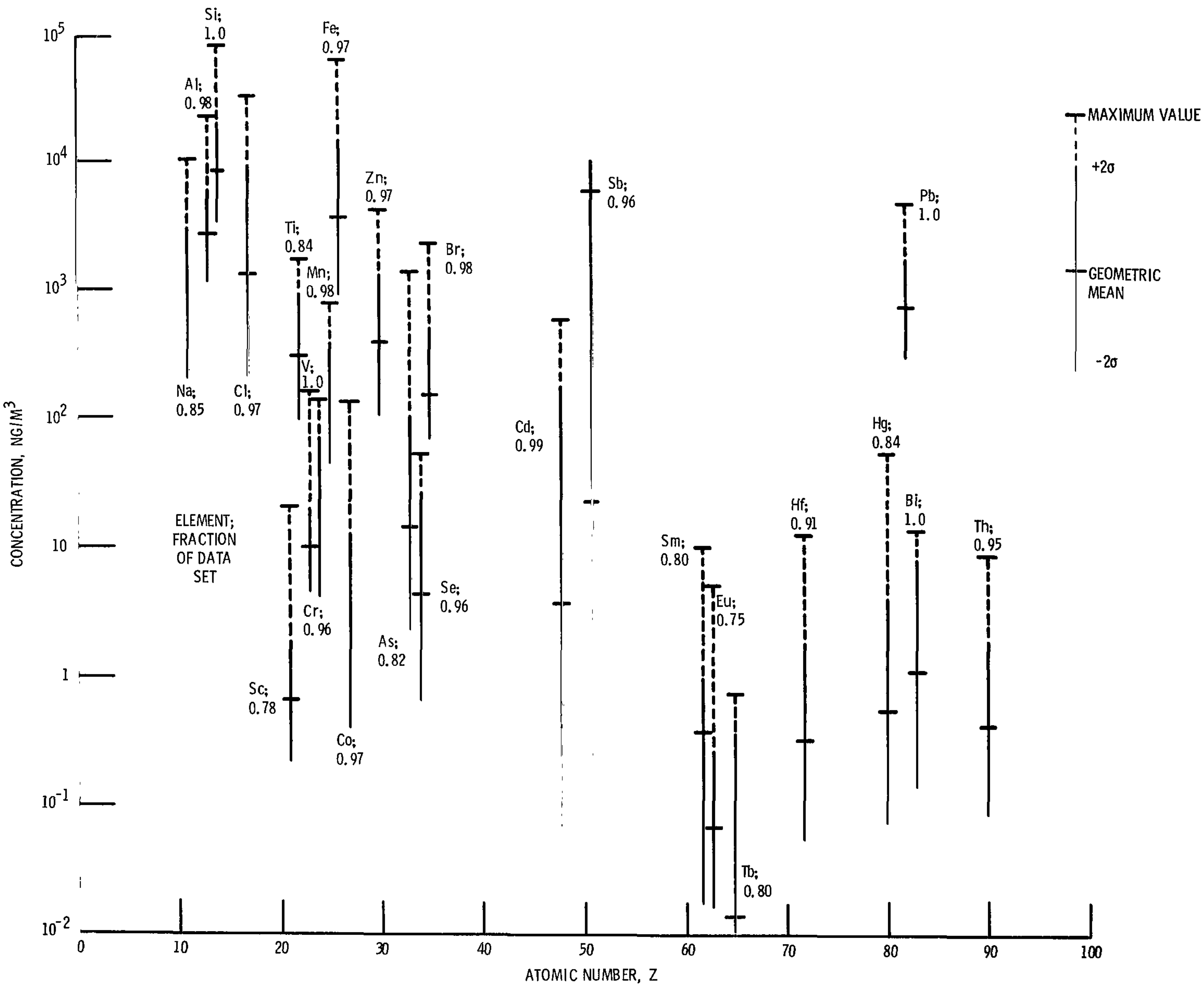
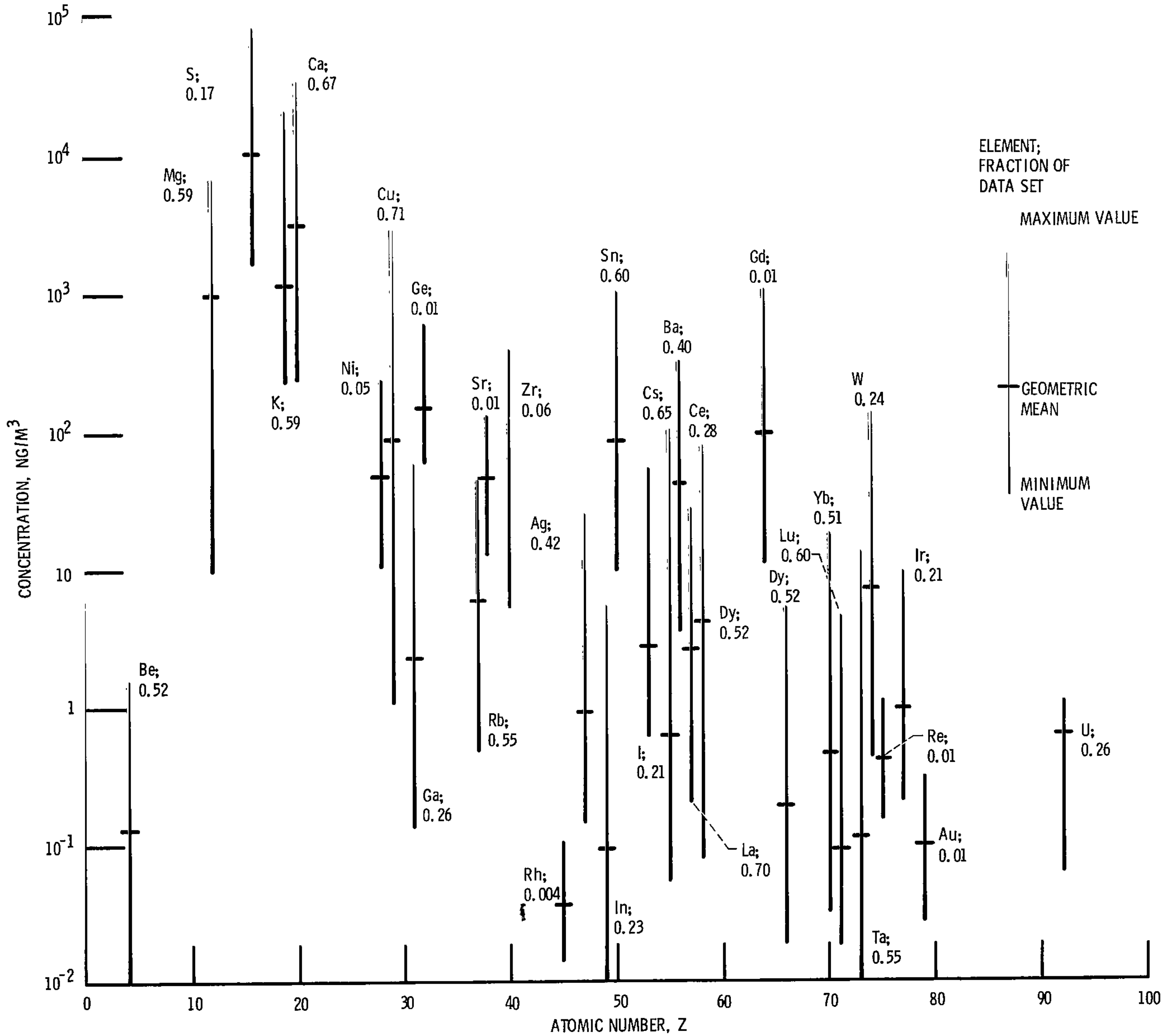


Figure 1. Sampling site locations.



(a) Elements having data sets more than 75 percent complete.

Figure 2. - Concentration of elements as function of atomic number.



(b) Elements having data sets less than 75 percent complete.

Figure 2. - Concluded.

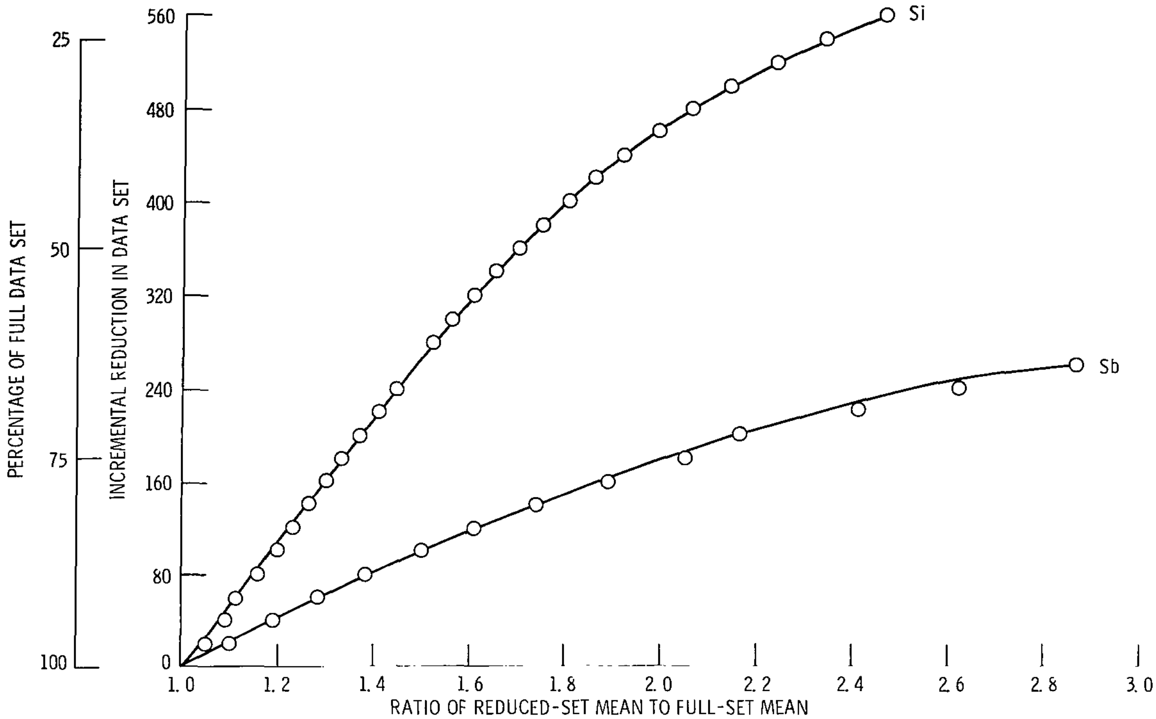


Figure 3. - Effect of values below the detection limit upon the set mean. Full set is 705; silicon data set is 100 percent complete; antimony data set is 96 percent complete.

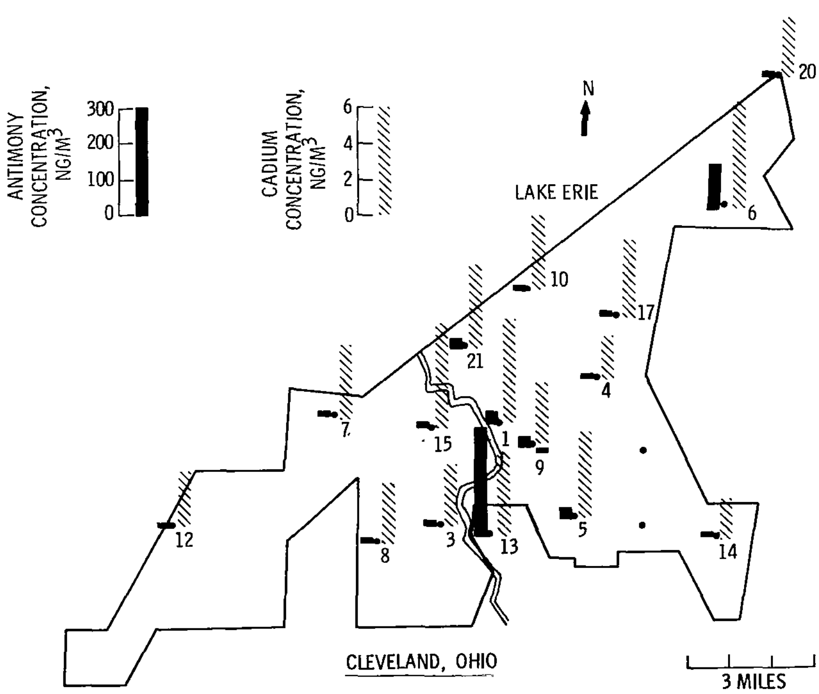


Figure 4. - Antimony and cadmium levels.

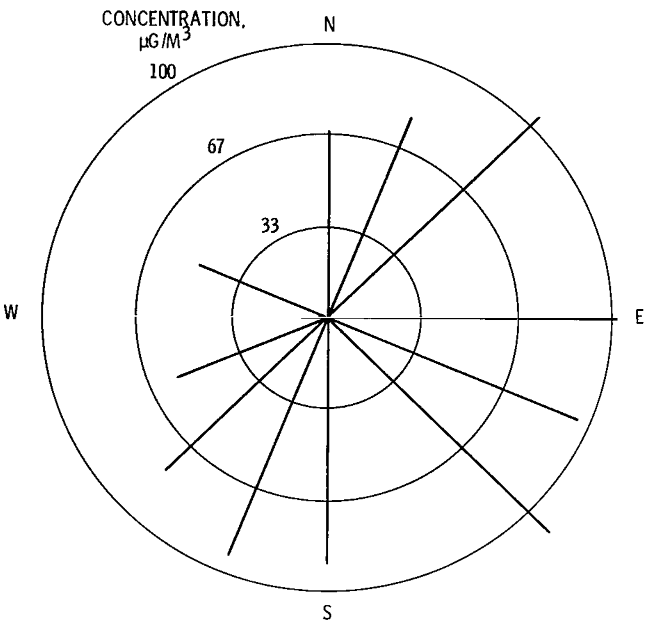


Figure 5. - Concentration rose for particulates at site 12. Weather data from Cleveland Hopkins Airport.

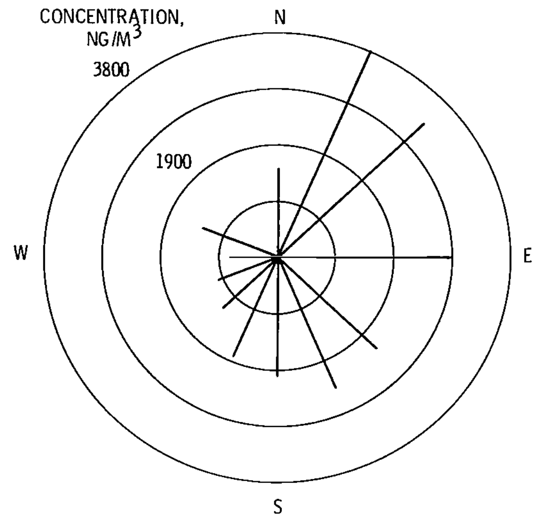


Figure 6. - Concentration rose for iron at site 12. Weather data from Cleveland Hopkins Airport.

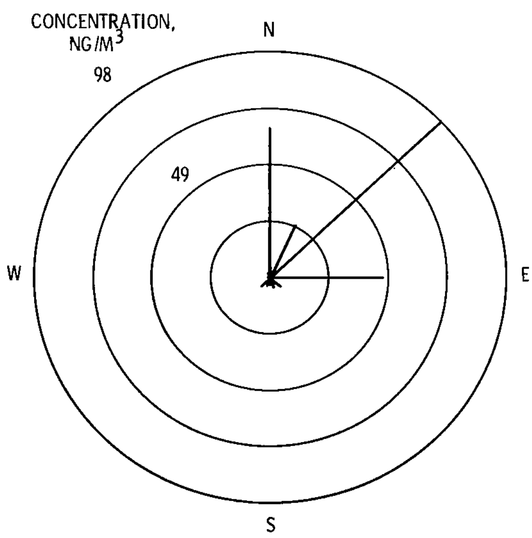


Figure 7. - Concentration rose for antimony at site 12. Weather data from Cleveland Hopkins Airport.

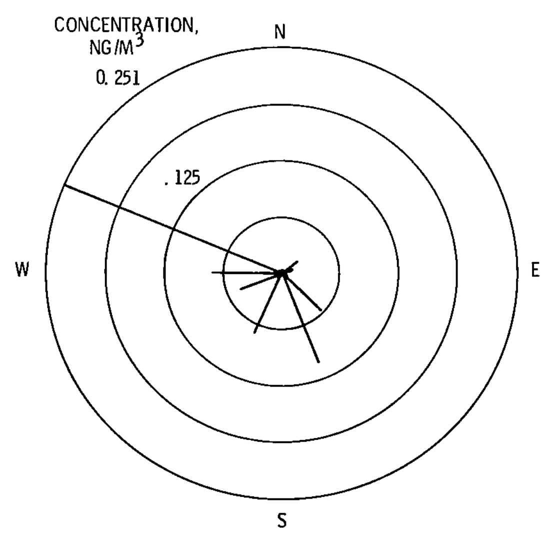


Figure 8. - Concentration rose for terbium at site 10. Weather data from Burke Lakefront Airport.

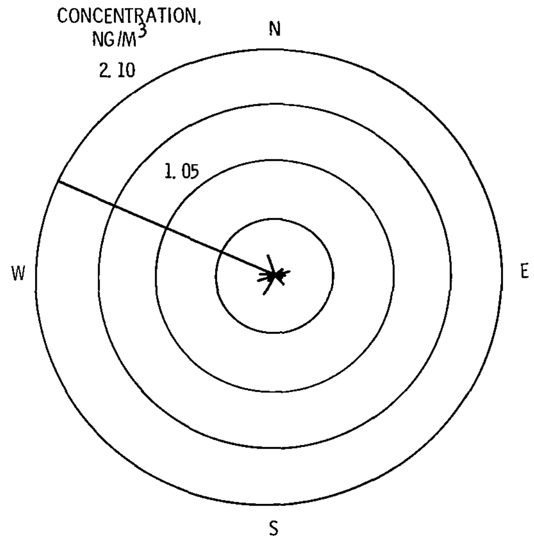


Figure 9. - Concentration rose for europium at site 10. Weather data from Burke Lakefront Airport.

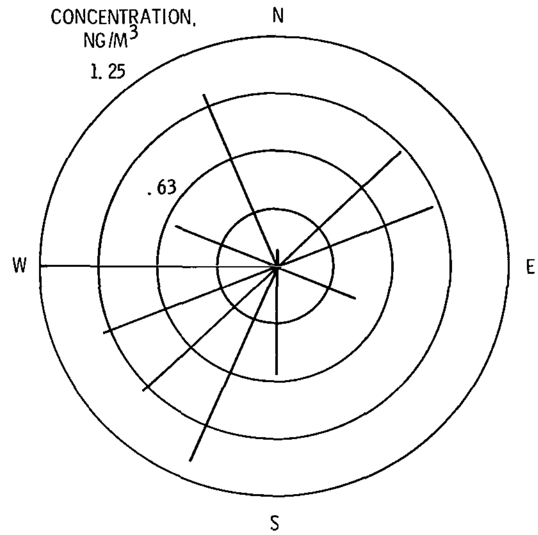


Figure 10. - Concentration rose for cesium at site 10. Weather data from Burke Lakefront Airport.

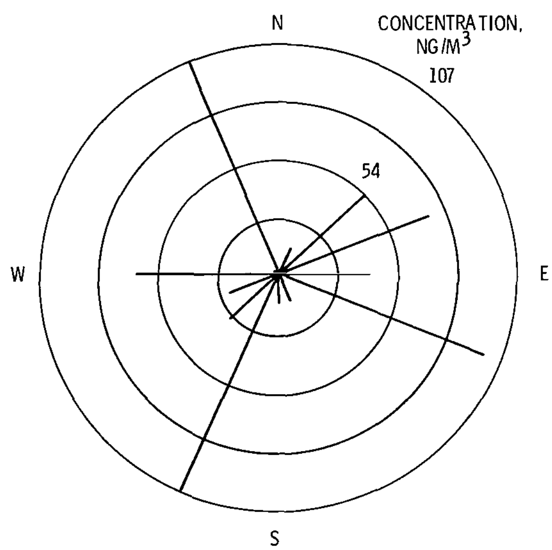


Figure 11. - Concentration rose for antimony at site 10. Weather data from Burke Lakefront Airport.

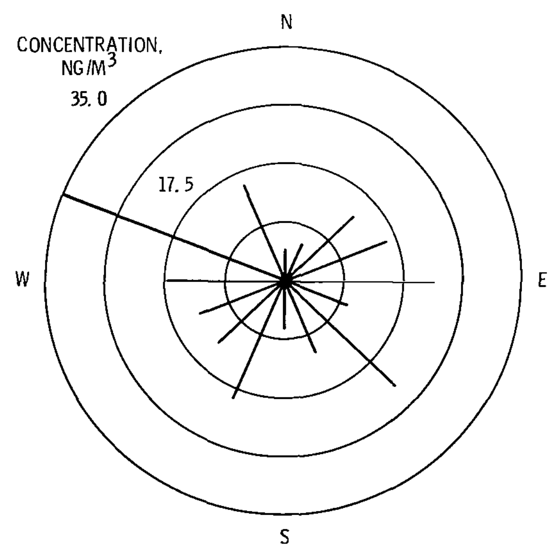


Figure 12. - Concentration rose for vanadium at site 10. Weather data from Burke Lakefront Airport.

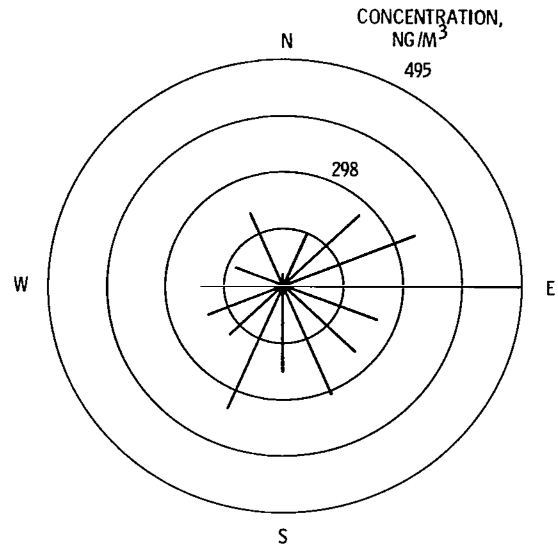


Figure 13. - Concentration rose for manganese at site 10. Weather data from Burke Lakefront Airport.

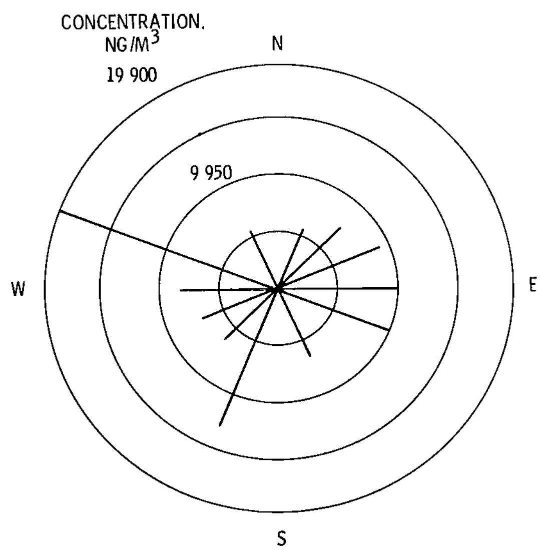


Figure 14. - Concentration rose for iron at site 10. Weather data from Burke Lakefront Airport.

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