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Transactions of the Kansas Academy of Science, Vol. 72, No. 2, 1969
This issue was published September 17, 1969

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Abstract

Several analyses of variance tests were performed on data obtained from a dust collection network. The results indicate that very careful attention to design of the system, strict control of modifying influences, and close adherence to rigid collection and analytical procedure are necessary for duplicable results to be recorded. Human activities, natural phenomena, and atmospheric differences encountered at moderate distances between sites all tend to introduce modifying variables.

Introduction

Over the past century several investigators have collected and studied atmospheric dust, both quantitatively and qualitatively, using different procedures or methods and for various reasons (Udden, 1898; Free, 1911; Winchell and Miller, 1918; Alexander, 1934; Robinson, 1936; Chepil, 1957; Delaney *et al.,* 1967). However, except for Delaney, *et al.,* none of these studies were conducted with replication or precision of sampling over extended periods. That problem was of concern when a network of dust collecting stations was set up at 14 locations around the United States east of the Rocky Mountains in 1963 (Smith and Twiss, 1965). Originally only one location had more than one dust trap; however, in 1965 three more stations were established at Manhattan Kansas, with one station consisting of five containers (Krauss, 1967).[3] The data obtained from this study were to be used (1) as a method of tracing dust origin and movement, (2) to determine if the chemical or physical properties of the dust were such that it would alter the same properties of the soil upon which it settled, and (3) to determine the rate of dust settlement or soil renewal.

This paper presents the statistical clculations of differences in quantity and aggregation of dust between sites and months using data

Transactions of the Kansas Academy of Science, Vol. 72, No. 2, 1969. Published September 17, 1969.

[1] Contribution from the Soil and Water Conservation Research Division, Agricultural Research Service, USDA, in cooperation with the Kansas Agricultural Experiment Station. Department of Agronomy Contribution No. 1034.

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[3] Krauss, Roland K. 1967. The influence of atmospheric dust upon the Florence soils of eastern Kansas. Unpublished M.S. thesis, Kansas State University Library, Manhattan, Kansas.

from the dust collected at the Manhattan, Kansas, and Coshocton, Ohio, sites.

Materials and Methods

Dust was collected in standard copper Weather Bureau rain gage overflow containers 2 feet tall and 8 inches in diameter. Methods of placement, collection, etc. have been described previously (Smith and Twiss, 1965).

The containers at Coshocton, Ohio, were placed only a few feet apart whereas those at Manhattan, Kansas, were placed at four separate locations (Fig. 1). However, all Manhattan subsites, except M8, were similar with respect to soil, aspect, and vegetative cover, thus holding all variables except climate constant. Subsite M8 was the first container set in operation in a separate study. It was placed at the Manhattan city limits on Kansas State University property; hence, it was much closer to industrial and agricultural activity than the other Manhattan subsites (Fig. 2). It was also closer to river bottom areas, 2 to 3 miles from the Big Blue and Kansas rivers.

The simple analysis of variance was used to test the means of M1, M2, M3, and M4 compared with the means of C1 and C2 (Coshocton subsites) in the month-by-month test. All other analysis of variance tests used the two-way classification as described in Snedecor (1956) or Fryer (1966). Duncan's NMRT (Fryer, 1966) was used to determine which means were unequal when differences were significant.

Results and Discussion

Comparisons of Subsite and Monthly Means. Six different analyses of variance tests were used to compare the means of the quantity of dust collected at the two sites, testing not only the difference between means of subsites, but also the difference between means of months studied. The results are listed in Tables 1 through 6.

Different numbers of months were used in different analyses and different monthly means were computed for each subsite in each analysis. That was intentional because not all subsites have been operating the same length of time and also because of known biased or missing data. Initially, a table was drawn up listing all data received from each subsite. Then for each analysis of variance computed, all data that could be used, including no more than two computed using the missing data formula, were lifted from the table and the analysis computed. This method of selecting data for each analysis permitted maximum use of available data and resulted in a more valid interpretation.

The first comparison in Table 1 shows that subsite M4 collected significantly more dust over the 24 months thany any of the three other subsites. In 9 of the 24 months of the test, subsite M4 collected an amount equal to one of the other three, and in only 2 months did it collect less than any of the other three. The remaining 6 months it collected an amount somewhere between the limits of the range but different from any of the three other three. No reasonable explanation can be

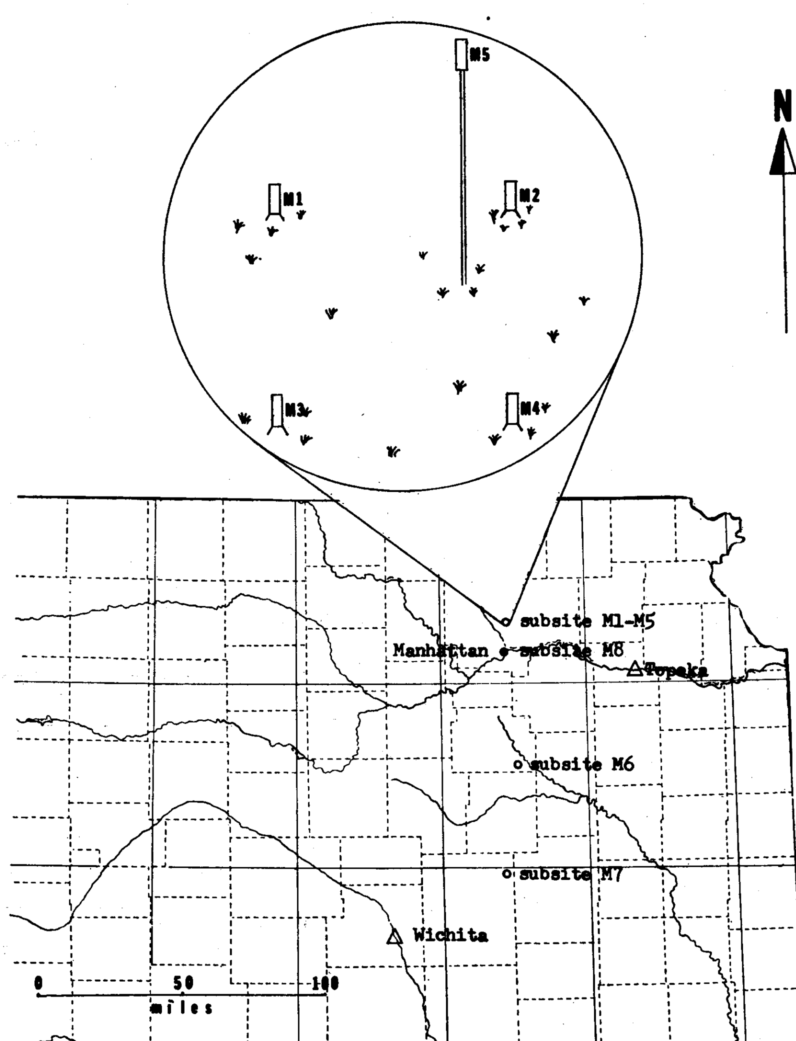

Figure 1. Location and placement of containers at the Manhattan, Kansas, subsites.

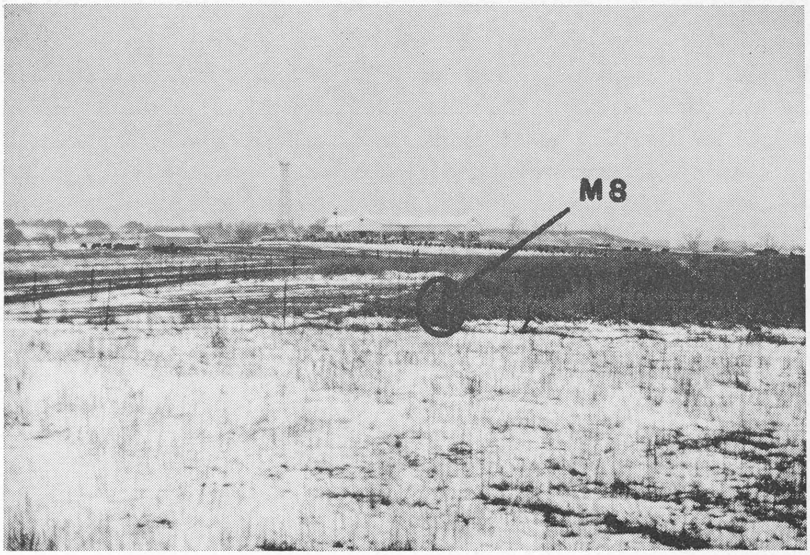

Figure 2. Location of subsite M8 with respect to agricultural and industrial activity.

given for this behavior except that all other containers as well as the pole holding the elevated container were north, west, or northwest of subsite M4 and much of the strong wind activity is from these directions. It is possible that the other subsites created sufficient wind turbulence to introduce a biased result. Or if the wind was of the correct velocity and from the right direction during a rainstorm, then water dripping from the outside of the elevated container (subsite M5) may also have introduced a bias. No difference visible to the naked eye between M4 and the other

Table 1. Analysis of variance of the quantity of dust collected at Manhattan subsites M1 through M4.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Containers	3	355	118	4.72†
Months	23	31,076	1,351	54.04†
Error	69	1,691	25	
Total	95	33,122		

† Significant at the 1 percent level.

Duncan's NMRT indicates the following array of means at the indicated significance level (1 percent).

Subsites			
M2	M1	M3	M4
27.1	28.6	28.9	32.4

three surface containers was ever detected when the sample was collected the first of each month.

The second test, which indicated no significant difference between containers, is shown in Table 2. Again M4 collected the most dust but not significantly more.

The third test indicated that the original Manhattan subsite (M8) collected significantly more dust than any of the other five subsites, M1 through M5 (Table 3).

The results indicate that industrial or agricultural activity or river bottoms about 2 miles from subsite M8 apparently slightly modify the quantity of dust collected. Clay mineralogy studies of samples of the river bottom soils are underway to determine if these bottoms do contribute a modifying characteristic.

Table 2. Analysis of variance of the quantity of dust collected at Manhattan subsites M1 through M5.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Containers	4	396	99	1.83 NS
Months	19	32,851	1,729	32.01†
Error	74	3,990	54	
Total	97	37,237		

† Significant at the 1 percent level.
NS Not significant.

Duncan's NMRT indicates the following array of means at the indicated significance level (1 percent).

Subsites

M2	M5	M3	M1	M4
26.1	26.2	27.0	27.3	31.5

Table 3. Analysis of variance of the quantity of dust collected at Manhattan subsites M1 through M5 and M8.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Containers	5	3,328	665	9.78†
Months	19	41.593	2,189	32.20†
Error	93	6,312	68	
Total	117	51,233		

† Significant at the 1 percent level.

Duncan's NMRT indicates the following array of means at the indicated significance level (1 percent).

Subsites

M2	M5	M1	M3	M4	M8
25.1	25.2	26.2	26.4	30.7	39.9

The fourth test included all eight subsites comprising the Manhattan site with results that indicated that the subsite 100 miles south (M7) and the original Manhattan subsite (M8) caught significantly more dust than any of the other six subsites (Table 4).

Possible reasons for the greater catch at M8 were described previously. The larger catch at M7 apparently was due to either a climatological or site influence or an unknown bias.

The fifth test, comparing means at Coshocton, Ohio, produced no significant difference in the results (Table 5).

The sixth comparison indicated that a highly significant difference in quantity of dust collected existed between the average of means of subsites M1 through M4 compared with the average of means of the two Coshocton subsites, C1 and C2 (Table 6).

Table 4. Analysis of variance of the quantity of dust collected at all eight Manhattan subsites.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Containers	7	1,994	285	2.30*
Months	9	19,761	2,196	17.71†
Error	61	7,583	124	
Total	77	29,388		

* Significant at the 5 percent level.
† Significant at the 1 percent level.

Duncan's NMRT indicates the following array of means at the indicated significance level (5 percent).

Subsites

M2	M3	M1	M6	M4	M5	M8	M7
19.9	20.8	21.2	24.7	25.5	25.6	33.0	33.9

Table 5. Analysis of variance of the quantity of dust collected at Coshocton subsites C1 and C2.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Containers	1	3	0.33	0.02 NS
Months	32	7,340	229.00	14.60
Error	32	502	15.70	
Total	65	7,845		

NS Not significant.

Duncan's NMRT indicates the following array of means at the indicated significance level (NS).

Subsites

C1	C2
16.99	17.46

Table 6. Analysis of variance of the quantity of dust collected by the average of the means of subsites M1 through M4 and C1 and C2.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Containers	1	880	880	8.9†
Months	17	4,797	282	2.8*
Error	17	1,676	99	
Total	35	7,353		

* Significant at the 5 percent level.
† Significant at the 1 percent level.

Duncan's NMRT indicates the following array of means at the 1 percent level.

Subsites	
Coshocton	Manhattan
14.9	24.7

Only 18 months of data were available for this test, as subsites C1 and C2 were not kept separate through the collection process for the last 6 months subsites M1 through M4 existed. Hence, the means were different from those of the preceding tests. As shown in Table 6, the Manhattan site is apparently closer to a dust source area than the Coshocton site. The difference between months in this test was significant, but not highly so, which indicates a similarity in weather patterns at the two sites but a difference in magnitude of dust collected. Manhattan, being closer to the dust source region, would collect more dust while Coshocton, although collecting less dust, would be affected by the same storm movements that pass through Manhattan.

Comparison of Manhattan and Coshocton Means by Months. A second comparison included the simplest analysis of variance determinations in which means of M1, M2, M3, and M4 were tested against means of C1 and C2 on a monthly basis.

As indicated in Table 7, whenever significance occurred, the Manhattan means were greater than the Coshocton means except for 2 months, probably because Manhattan is closer to the dust source area than is Coshocton.

Comparison of Size of Materials Trapped. Finally, because a petrographic study of the dust mineral grains indicated that the elevated container (subsite M5) collected more aggregated material[4] than did the other subsites, another analysis of variance was performed to test the validity of that phenomenon (Table 8).

[4] Aggregated material referred to here includes clay-sized material that clings together to form tiny microscopic clods or soil aggregates and which, because of their size are collected in the sand and silt fraction of the dust rather than in the clay fraction. This was corroborated using the petrographic microscope.

Only two reasons seem to explain these differences. It is possible that the higher windspeed at the elevated subsite created certain aerodynamic effects which carried the finer dust particles in the streamlines of windflow up and over the lip of the collection container, preventing collection of such fine dust, while larger heavier particles would cross the

Table 7. Analysis of variance tests of the means of subsites M1 through M4 compared with means of subsites C1 and C2, on a monthly basis, tested for quantity, and listed in ordered array.

Month	Calculated F	Ordered array
August 1965	5.17 NS	Not significant
September 1965	125.50†	Manhattan > Coshocton
October 1965	0.67 NS	Not significant
November 1965	52.80†	Manhattan > Coshocton
December 1965	841.00†	Coshocton > Manhattan
January 1966	21.77†	Manhattan > Coshocton
February 1966	9.78*	Coshocton > Manhattan
March 1966	10.30*	Manhattan > Coshocton
April 1966	28.90†	Manhattan > Coshocton
May 1966	20.97†	Manhattan > Coshocton
June 1966	136.40†	Manhattan > Coshocton
July 1966	14.68*	Manhattan > Coshocton
August 1966	140.00†	Manhattan > Coshocton
September 1966	52.00†	Manhattan > Coshocton
October 1966	0.30 NS	Not significant
November 1966	245.00†	Manhattan > Coshocton
December 1966	7.04 NS	Not significant
January 1967	42.00†	Manhattan > Coshocton

* Significant at the 5 percent level.
† Significant at the 1 percent level.
NS Not significant.

Table 8. Analysis of variance of the percentage of aggregated material collected at subsites M5, M6, M7, and one sample per month from one of subsites M1 through M4.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Containers	3	9,695	3,232	6.86†
Months	10	7,436	744	1.58 NS
Error	30	14,135	471	
Total	43	31,266		

† Significant at the 1 percent level.
NS Not significant.

Duncan's NMRT indicates the following array of means at the 1 percent level.

Subsites

M1–4	M6	M7	M5
9.0	16.5	22.1	48.4

streamlines of windflow and be collected. The second reason could be that birds used the subsite as a perch and certain organic cementing agents were knocked from their feathers when they alighted and took off. (Months when droppings were in evidence on the screens were considered biased, so data from such months were not used.) Clay X-ray diffractograms (Grim, 1953) exhibited no real difference in kinds or relative amounts of different clays present. Increased work is going on in an attempt to verify the above posits or to discover other reasons.

Conclusions

Meaningful dust collection studies require careful design, strict control of numerous modifying influences, and collection and analytical procedures confined to very close tolerances. These requirements were demonstrated by lack of significant differences between means from the Coshocton subsites, C1 and C2, but presence of significant differences between means from Manhattan subsites M1 through M4. Possibly the differences among subsites M1 through M4 can be attributed to aerodynamic effects as well as animal (coyotes and/or deer) and bird activity. New experimental work should consider spacing collection containers farther than 15 feet apart in a straight line perpendicular to the dominant wind direction, fencing tight enough to exclude animals such as coyotes and deer, and providing other bird perches in the proximity of the site.

Where sites or subsites are spaced more than a mile apart, climatic variables precluding controls begin to be introduced. Varying wind velocities and gustiness, vegetation differences, and rainfall differences each promote differences in dust deposition. When distances range up to hundreds of miles, as between Manhattan and Coshocton, then dust source area and major storm front movements are about the only two variables that can be used to relate the two sites.

Equally important is proper placement of the collection containers with respect to human influence. As subsite M8 illustrated, nearness to industrial activity (even though small in this case), nearness to cultivated fields and/or livestock feeding and working operations, and possibly nearness to broad, flat, river bottom areas are likely to influence the amount of dust collected.

Finally, strict control of analytical procedures is essential if duplicable results are to be obtained when working with samples this small.

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