MEASUREMENT OF SMOKE AND A STUDY OF ITS EFFECT UPON HEALTH IN KNOXVILLE

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Table of Contents

1. Preface

2. Method of Studying Smoke Conditions

    (a). Location of Stations

    (b). Collection of Jars

    (c). Analysis of Sample

    (d). Calculation of Results

3. Index to Stations

4. Observed Data

5. Graphs

6. Atmospheric Smoke in its Relation to Health

7. Conclusion

Preface

A survey of the soot fall in Knoxville was made during the year 1927 by Martin F. Quinn and Albert H. Cooper while working on their theses at the University of Tennessee. There had been no important effort to decrease the amount of smoke in Knoxville up to that time. A Smoke Abatement Bureau was established in 1928, and after several months of work, chiefly in industrial plants, it was desirable to see what effect certain isolated reductions in smoke had had on the average soot fall.

With the object of obtaining this data, a second survey was started Febuary 1, 1929 by Robert C. Burton and was continued to May 1, 1930 by George R. Calhoun. They, too, submitted their results in theses at The University of Tennessee. This work has been carried out for the remainder of 1930 and the results of the surveys, together with certain related meteorological data for the three years, are presented in the following pages.

Method of Studying Smoke Conditions

There are several methods of determining the amount of atmospheric pollution, and many machines and processes have been developed for this purpose. The ones most effective are:

a. Filtration

b. Ringelmann tests

c. Counting process determination

d. Ultra-Violet light incidence

e. Soot fall determinations

The results from filtration have been found to be inaccurate due to moisture in the atmosphere and the relatively small samples obtained by filtering a large volume of air.

Ringelmann tests are comparisons of the density of smoke with a chart of standard blackness. This can be used only in determining the relative density of the smoke issuing from a particular stack.

In the Counting process the pollution of the atmosphere is determined by actually counting the number of smoke particles present in a volume of air.

The amount of Ultra+Violet light is determined in smoky regions and in regions free from smoke under the same atmospheric conditions. There is a definite relation between the amount of smoke present in the atmosphere and the amount of Ultra-Violet light screened out.

The method in use by the Bureau of Mines is the soot fall or precipitation method. This is the method that has been used throughout this investigation. The Mellon Institute of Industrial

Research has recommended the following procedure:

Location of Stations

"Take a map of your city and select twn or twelve centers having in mind that you wish to obtain soot fall samples which, when pooled, will represent average atmospheric conditions. You must not hesitate to select a center in what you know to be the smokiest or, on the other hand, a center which you know to be practically free from smoke. The best plan is to forget what you know of smoke conditions, and to consider your city simply as a geographical area.

When you have the general centers in mind, then select ten or twelve buildings, school houses, settlement houses, engine houses, or private dwellings, on the roofs of which you feel certain you will be permitted to place soot fall jars. Do not place a jar on the roof of a building which is between two higher buildings, nor near chimneys. Jars should be placed on the roofs of buildings which are at least two stories high. Attempt to avoid buildings with gravel roofs."

Jars

The jars which are to be used in summer months are known as battery jars. The diameter of these jars is four inches and the height ten inches. The exact inside diameter of each jar should be determined by the use of a caliper. It is best to purchase about three dozen of these glass jars. Before the jars are placed out, scratch the number of the station on them 1a, 1b, 2a, 2b, etc.

During the winter months, copper cans, tinned inside, four inches in diameter and ten inches high are used."

Collection of Jars

"Jars should be placed on buildings on the first of each month. If it takes two days to distribute the jars, make a note of the fact, and at the end of the month collect the jars first which were placed out on the first day. At the end of the month, the collecter of the jars must carry clean ones with him to put in place of the ones which he collects."

In the second survey of smoke in Knoxville every effort possible was made to duplicate the procedure first used, including the selection of stations, period of collection, method of collection, and method of analysis.

The Method of Procedure for both Surveys is as follows:

Selection of Stations

The territory included within the city limits of Knoxville was considered simply as a geographical area. This territory was divided into twenty-three squares of equal areas, and a station was selected near the center of each square, irrespective of any known source of smoke. Each station was assumed to be typical of its particular area, and the average of all stations to be representative of the city at large.

Four dozen battery jars which were 6.25 inches in diameter and eight inches high were bought. Twenty-four of these jars were put out and tweny-four taken up at the first or as near the first of each month as possible. We used these battery jars in the winter months as well as in the summer. But, in the coldest weather we had sometimes as many as eight or tem to freeze and break in one month. This, however, did not happen more than once or twice a year, and November seemdd to be the fatal month. In all cases the dates for depositing and collecting the jars were recorded and all differences in period corrected by varying the conversion factor used in calculating results. In one or two instances the jars at certain stations were moved to other nearby points due to inconveniences of different kinds. For instance, the owner of a house complained about our walking on the roof saying it caused it to leak. In another case we had to get on top of the kitchen table of a family in order to climb up through the roof. This seemed too much of an imposition upon them, so the jar was moved. None of them were moved far enough from the original station to vary the result any noticeable amount.

The nest step in the procedure after collecting the jars was that of analyzing each sample. The steps of analysis may be listed as follows:

1. A Gooch crucible was prepared and weighed; (2) the water in the sample jar was decanted through the crucible and the contents of the jar completely transferred to the crucible with the aid of a rubber policeman. The filtering process was very slow and it sometimes took as long as an hour to filter one sample, until Dr. Robertson suggested that a rubber stopper with one hole in it be placed in the mouth of the Gooch crucible and a glass tube be inserted in this hole and allowed to extend into water just above the bottom of the sample jar. By means of the suction pump the water was drawn from the jar through the filter and into the flask. This had two advantages. First, the water was not contaminated with the soot in the bottom of the jar and filtered quicker. Second, one did not have to pour from the jar into the crucible every few minutes. This little apparatus saved a considerable amount of time in filtering the samples; (3) the crucible was dried in an

oven at 110° for several hours and weighed. The gain in weight was due to total soot fall; (4) the crucible was burned to constant weight over a Fisher burner. The loss in weight represented combustible matter.

The weights obtained in the above method were in grams and represented a period of thirty days. The unit had to be changed to <u>tons per square mile per year,</u> in order to make our data comparable with that of other cities.

We may show by a few calculation how the change was made and how the following results were obtained:

1 gram per day per jar = .0000011025 tons per jar per day

Area of jar mouth = 30.07 square inches

$$30.07 \text{ square inches} = \frac{1}{133{,}504{,}808} \text{ square miles}$$

Therefore, 1 gram per jar per day = .0000011025 =

$$\frac{1}{133{,}504{,}808}$$

.0000011025 x 133,504,808 = tons per square mile per day

and, 147.189 x 365 = 53,723.985 (tons per square mile per year when accumulating at the rate of one gram per jar per day). Therefore, the conversion factor for a thirty day collecting period would be:

$$\frac{53{,}724}{30} = 1790.8 \quad \text{conversion factor}$$

Suppose that upon analysis of a sample which had been exposed for thirty days the following weights were obtained:

Weight of crucible = 17.8300 g.

Weight of crucible plus soot = 17.9764 g.

After drying at 110° -

Weight of crucible plus soot = 17.9160 g.

After burning with Fisher burner

$$\begin{array}{r} 17.9764 \text{ g.} \\ \underline{17.8300} \\ .1464 \text{ g.} \end{array} = \text{weight of total soot}$$

$$\begin{array}{r} 17.9764 \text{ g.} \\ \underline{17.9160} \\ .0604 \text{ g.} \end{array} = \text{weight of combustible matter}$$

.1464 g. x 1790.8 = 262.17 tons total soot fall per square mile per year.

$100 \times \frac{.0604}{.1464} =$ 41.2 % combustible matter

Index to Stations

1. Maplehurst Park
2. Gulf Refinning Company
3. Flenniken School
4. Woodlawn Pike
5. Texaco Refinning Company
6. Rose Lumber Company
7. Atkin Hotel
8. University Farm
9. 2025 Ogden Avenue
10. Melrose
11. Seventeenth and Laurel
12. Mississippi and Western
13. Middlebrook Pike
14. Baxter and Wray
15. Knox Apartments
16. 2800 Magnolia
17. Knoxville High School
18. Moses School
19. Beaumont School
20. Oakwood School
21. Pershing and Chimauga
22. Belle Morris School
23. Brownlow School
24. Mountain View School

The tables on the following pages give the rate of soot fall by months during the three years of the survey, the percent of total which was combustible, and the rate of fall of combustible matter. The figures in column marker A are the rates of soot fall in tons per square miles per year. The figures in the column marked B are the percents of the totals which are combustible. The total combustible is given in tons per square mile per year on separate pages which are headed Rate of Fall of Combustible Matter.

The black figures are those obtained by actual measurements. The red figures are estimated values which were made either when the sample was lost or the value obtained was unreasonable. The estimates were based upon the records of the station for other months and general trend of values of other stations for the same month.

The graphs are self-explanatory and were made from data obtained from the smoke survey and from the Annual Meteorological Summary which was gotten from the U. S. Department of Agriculture, Weather Bureau.

It will be noticed that station 24 was changed from Greene School to Mountain View School. This was necessary since the ladder previously used was not available.

Rate of Soot Fall and Percent of Combustible Matter

1927

	January		February		March		April	
	A	B	A	B	A	B	A	B
1.	481	54.4	647	31.7	752	59.3	188	30.1
2.	256	53.	188	39.2	240	23.	482	33.9
3.	168	58.2	345	26.4	240	24.1	180	34.5
4.	115	60	247	66.6	303	81.4	267	54.4
5.	105	47.7	156	40.3	172	43.	172	38.3
6.	287	67.9	300	70.	289	70.4	325	61.8
7.	780	50.1	1044	28.8	714	52.1	388	34.9
8.	213	54.3	227	51.3	329	31.8	197	47.1
9.	245	59.1	264	66.3	262	55.8	240	63.1
10.	105	72.7	150	50.	146	46.2	95	49.2
11.	395	51.4	375	53.3	208	34.3	107	39.5
12.	542	45.2	354	40.	388	40.9	436	49.
13.	188	58.	258	37.7	229	28.2	220	44.5
14.	237	49.7	332	42.8	182	42.8	243	37.3
15.	202	52.6	251	42.6	256	38.2	160	39.7
16.								
17.	259	54.4	187	65.9	263	55.6	196	52.6
18.	219	51.4	220	42.1	144	38.2	155	37.9
19.	188	51.6	190	41.7	215	44.2	156	35.7
20.	211	51.6	268	27	196	35.4	235	38.9
21.	198	52.6	331	32.3	171	39.9	204	37.3
22.	155	61.4	199	33.2	177	49.3	197	43.7
23.	272	60.7	275	55	173	54.5	164	37.3
24.	465	54.9	443	34.9	258	25.2	213	40.
A	263	55.34	326	42.2	274	44.1	227	42.
CA	263	55.34	314	44.1	274	44.1	227	42.

Rate of Soot Fall and Percent of Combustible Matter (continued)

1927

	May		June		August		September	
	A	B	A	B	A	B	A	B
1.	292	49.3	173	39.	189	34.2	219	37.8
2.	269	26.7	306	27.9	324	24.8	293	27.2
3.	372	23.8	264	34.1	198	35.	236	29.8
4.	282	62.	149	57.5	162	53.	184	59.3
5.	192	48.3	70	44.7	81	47.5	161	37.6
6.	590	74.5	216	62.3	238	64.2	271	56.9
7.	514	43.7	396	27.3	418	36.7	456	38.9
8.	200	45.	175	40.	186	38.	227	41.9
9.	275	43.8	465	71.7	251	41.5	268	48.7
10.	192	48.3	70	44.7	81	47.5	88	49.7
11.	235	34.7	94	35.	119	38.8	150	36.2
12.	463	40.7	377	24.1	420	29.6	379	34.3
13.	248	48.5	124	46.	161	40.7	208	43.6
14.	309	38.8	279	39.5	239	39.4	288	41.2
15.	240	40.	200	31.5	178	35.3	165	30.4
16.								
17.	250	40.	459	45.2	204	47.6	228	52.9
18.	143	31.	150	30.	140	34.5	172	29.8
19.	252	35.2	200	35.	172	38.9	218	34.4
20.	221	35.7	137	26.3	184	32.8	215	37.6
21.	295	27.6	151	33.3	176	29.7	188	33.8
22.	165	36.2	186	36.5	181	38.9	194	34.7
23.	208	39.7	134	34.8	142	40.4	167	36.8
24.	323	38.7	200	40.	244	37.5	291	41.8
A	290.1	41.6	225	39.5	207	38.	229	39.8
CA	282.5	41.6	217	38.9	207	38.	229	39.8

Rate of Soot Fall and Percent of Combustible Matter (continued)

1927

	October		November		December		Average		Cor. Average	
	A	B	A	B	A	B	A	B	A	B
1.	204	44.9	390	31.4	420	48.2	344	41.6	344	41.6
2.	366	36.9	167	31.3	225	40.	290	31.9	284	32.5
3.	188	41.4	231	47.6	250	50.	244	35.4	244.5	36.6
4.	101	53.5	122	56.3	130	55.	189	60.1	182.8	60.5
5.	258	33.3	164	44.5	175	45.	152	38.4	154.1	39.
6.	511	53.8	1208	43.6	392	56.2	413	61.3	402.5	62.1
7.	720	40.9	1303	30.6	1000	40.	648	37.4	680	37.6
8.	359	43.4	298	43.1	324	47.3	262	44.2	248.5	43.9
9.	258	47.3	202	46.7	225	50.	290	56.	284	56.3
10.	118	38.7	152	52.6	153	52.1	115	49.7	118.2	49.8
11.	188	44.3	204	47.1	250	45.5	202	42.9	202	42.9
12.	356	25.4	255	32.7	350	40.	395	35.1	391	35.5
13.	287	37.5	218	49.8	225	50.	206	43.7	207.8	44.4
14.	214	44.9	305	32.3	325	40.	263	40.7	268.5	40.6
15.	219	38.1	167	49.5	249	48.4	204	39.8	207	39.9
16.										
17.	237	34.7	250	35.	275	50.	277	50.5	272	48.4
18.	295	40.8	200	45.	225	50.	186	38.2	187.7	39.1
19.	566	26.7	580	28.7	282	39.1	282	37.6	274.6	37.8
20.	191	32.7	202	46.9	225	50.	199	35.6	201.3	36.8
21.	120	38.2	162	64.6	200	55.	195	38.4	195.5	39.4
22.	196	31.4	139	40.4	152	36.4	177	39.9	177	39.9
23.	170	35.	150	40.	175	40.	174	42.4	196.5	42.4
24.	214	45.6	200	50.7	400	50.	295	41.	295.5	41.6
A	280	39.8	333	43.5	278	46.7	264.5	42.7		
CA	275	39.6	315.7	43.	288	46.8			263	43.

Rate of Total Soot Fall and Percent Combustible Matter

1929

	February		March		April		May	
	A	B	A	B	A	B	A	B
1.	350	54.7	479	40.5	400	45.	265	50.2
2.	258.8	43.7	283	32.4	268	24.9	331	34.9
3.	223.2	53.1	385.8	26.2	274.3	30.2	393.5	29.4
4.	128.1	20.0	150.4	29.5	150	40.	150	60.
5.	196.5	47.1	204	40.1	322	54.3	305.8	50.4
6.	361	69.6	407.5	73.5	550	70.	695	67.
7.	1000	40.	1049.8	43.5	699	37.6	1053	43.1
8.	270	40.	645	36.2	264	54.3	268	46.5
9.	178	44.	230	50.5	284.8	62.1	228	57.4
10.	223.8	38.8	225	40.	131.2	53.	194	38.1
11.	465	50.4	286	45.3	249.8	44.3	244.3	52.9
12.	398	31.9	449	33.4	425	35	408	36.6
13.	294	48.7	258.5	45.6	293.2	45.6	271	5.8
14.	342.8	39.	867	26.4	436	36.7	628	43.3
15.	211.7	43.9	280	35.	248.1	35.3	246	44.5
16.	205	44.5	250	40.	144.2	39.6	198	42.
17.	355	38.4	186.2	43.6	251.5	43.5	263.9	41.6
18.	245.7	47.5	214.1	37.9	195.2	37.9	216.2	46.5
19.	196.5	38.7	170.5	32.9	223.6	36.5	250	35.
20.	544.5	45.7	345	32.4	248.4	34.6	334.3	44.4
21.	123.2	35.2	211.9	45.7	167.8	31.2	229	44.9
22.	190	23	322	26.9	333	30.	150	45.
23.	173	35.5	218	27	350	20.3	207.4	48.8
24.	593	42.1	593	42.1	288.2	36.1	245.5	41.7
A	265	42.5	384	38.25	301	42.1	344	46.3
CA	300.5	42.3	363	37.	300	40.7	324	45.8

Rate of Total Soot Fall and Percent Combustible Matter (continued)

1929

	June		July		August		September	
	A	B	A	B	A	B	A	B
1.	270	58.2	136.3	38.8	205.6	53.6	141	51.5
2.	260	33.9	299.	31.8	250.5	31.4	182.3	47.1
3.	286.8	31.9	246	27.6	250	30.	164.5	42.2
4.	161.8	66.9	69.6	45.2	78.3	45.7	104.3	72.7
5.	236	37.2	164.8	38.6	212.3	40.5	264	52.8
6.	634	71.5	370.4	58.7	230.5	45.	189.6	50.4
7.	738	45.9	544	46.3	476	44.6	496	52.2
8.	260	39.2	250	36.	254.6	34.5	270.5	49.
9.	208	51.8	154.8	50.2	129	39	131.7	61.6
10.	159.7	49.6	96	54	103	36.8	108	54.4
11.	202.8	51.2	121.1	53.9	152.2	44.3	168.8	61.3
12.	485	36.2	372	39	475	38.9	577	56.6
13.	304.5	44.6	313	38.6	296	13.6	288.3	44.
14.	388	38.6	411.5	32.3	331	32.4	318.4	43.2
15.	198.8	38.2	162.8	32.3	246.2	44.6	241.6	44.5
16.	152	39.	185	58.1	242	31.1	225	35.
17.	230	43.4	183	43.4	226	39.4	312	54.9
18.	243	27.6	160	47.3	197	39.1	247.7	43.7
19.	278	35.9	209	34.6	283.5	26.3	275	40.
20.	212	39.1	170.7	33.1	181.3	31.9	269.8	58.8
21.	228.6	26.6	206	27.6	269	26.9	202	34.2
22.	164.5	39.1	140.7	30.4	179	30.5	147	41.8
23.	194.2	45.4	126	40.7	184.3	37.3	175	50.
24.	235.8	37.7	163.5	44.4	198	39.7	234	51.
A	290	42.8	219	40.8	237.5	37.4	238.2	49.
CA	280.5	42.8	217.5	41.2	237.5	37.4	238.2	49

Rate of Total Soot Fall and Percent Combustible Matter (continued)

1929

	October		November		December		Average		Cor. Average	
	A	B	A	B	A	B	A	B	A	B
1.	184	53.			350.	50.	225.6	44.5	252.8	45.0
2.	330	28			275.	45.	246.8	30.8	249.3	33.0
3.	548	16			225.	40.	280.1	28.3	272.4	29.7
4.	113	50			150.	50.	100.7	41.2	114.1	43.6
5.	258	45			300.	45.	216.3	40.6	223.9	41.0
6.	250	50.			300.	50.	361.	54.4	362.2	55.1
7.	706	48.4			121.5	40.8	691.6	40.2	725.4	40.2
8.	207.5	51.6			261.	41.1	270.1	39.1	268.2	38.9
9.	218.2	56.4			260.	57.9	188.4	48.2	188.4	48.2
10.	130.8	56.			225.	55.	127.3	42.3	145.1	43.2
11.	250.	55.			279.2	51.6	216.9	45.5	219.9	46.3
12.	518	35.4			600.	40.	409.1	34.	428.	34.9
13.	390	43.8	240	50.6	400.	45.	294.7	38.09	304.3	38.7
14.	308	39.4			458.5	47.6	426.3	35.3	426.3	35.3
15.	226.5	45.3			275.	45.	197.8	36.5	212.3	37.1
16.	165.2	44.7			240.	45.	161.4	37.2	182.4	38.
17.	197.8	53.8			258.5	54.2	223.9	41.4	223.9	41.4
18.	221.	52.1			275.	50.	193.9	37.9	201.3	39.1
19.	374.	41.2			325.	40.	524.	30.0	436.4	29.2
20.	150.	51.6			225.	50.	245.6	37.1	243.7	38.3
21.	196.	29.8			250.	30.	183.5	30.2	189.4	30.2
22.	133.5	45.6			250.	45.	139.0	29.6	167.7	32.4
23.	143.2	49.8			200.	50.	178.4	33.9	179.1	36.8
24.	162.2	63.8			137.2	56.5	349.2	41.3	371.	41.3
A	268.1	45.	240	50.6	586.3	49.9	268.6	38.2		
CA	266.	46.1			349.5	46.6			274.4	39.

Rate of Total Soot Fall and Percent Combustible Matter

1930

	January		February		March		April		May	
	A	B	A	B	A	B	A	B	A	B
1.	274	50.1			617	44.	175	40.	174	45.
2.	209.4	45.7			950	40.5	325	38.	312	37.6
3.	200	40.			339	28.7	209	23.1	241	46.7
4.	130	45.			102.4	6.3	110	43.	106	65.6
5.	159	48.0			268.5	46.4	91.4	61.2	396	39.6
6.	1282	45.1			437	37.8	767	38.1	598	46.
7.	764	50.3			1060	57.1	172.5	15.7	538	53.
8.	250	40.			765	32.2	393	27.7	238	42.6
9.	160	56.3			272	48.	183	37.8	198	59.2
10.	203	47.8			317.5	37.4	125	40.	121	42.9
11.	279	56.4			687.4	47.6	135	45.	207	53.3
12.	500	35.			879	26.1	1740	18.95	479	48.6
13.	319.5	56.5			424.9	46.8	520	34.9	272	42.7
14.	400	40.			389	36.5	860	12.1	436	35.8
15.	250	45.			790	15.9	215.3	31.9	200	46.
16.	210	45.			177.5	39.8	167.5	30.	161	40.8
17.	225	45.			249	46.1	181.2	38.	196	54.1
18.	250	45.			227.7	50.8	182.5	35.1	201	57.5
19.	275	40.			183.5	42.9	187.5	27.5	234	39.
20.	200	45.			622.5	42.1	391.	28.8	345	45.
21.	104.8	36.1			780	40.8	231	60.2	370	42.8
22.	225	40.			333	45.9	250	45.	203	44.6
23.	190	40.			226	34.9	154.4	25.3	155	42.3
24.	650	45.			976	20.4	320	30.1	332	29.8
A	375.5	49.2			503	38.04	386.8	32.	276	45.8
CA	321.0	45.0			503	38.04	382.5	34.4	279	40.8

Rate of Total Soot Fall and Percent Combustible Matter (continued)

1930

	June		July		August		September		October	
	A	B	A	B	A	B	A	B	A	B
1.	360	22.	186.83	34.7	168	30.9	166.4	47.6	206.8	50.4
2.	324.1	60.5	425.2	30.	186	34.5	325	61.	222.7	40.7
3.	250	30.	347.37	28.3	296	23.8	128.28	30.15	100.6	41.4
4.	149.6	46.	100.89	42.5	46.	80.2	108.4	31.14	162.2	26.7
5.	215.9	36.2	215.76	30.37	31.	36.2	152.78	46.8	146.3	59.7
6.	617.7	35.	661.94	43.7	763	43.9	332.2	47.5	650	45.
7.	369.5	45.	276	32.	422	44.1	634.3	50.5	371.6	42.5
8.	442.4	18.	275	31.	228	31.9	177.6	49.48	205.	37.25
9.	349.5	20.	194.58	40.37	140	37.1	215.	45.	149.1	57.8
10.	97.7	38.	123.59	33.5	117	41.5	94.4	50.75	103.2	43.7
11.	116.6	42.	154.05	36.6	130	51.6	169.38	54.8	184.1	35.1
12.	420.7	40.	471.02	44.2	442	46.4	477.89	48.8	312.5	39.2
13.	107.2	56.	333	37.3	269	38.4	215.15	51.4	282.3	38.6
14.	254.4	33.	279.9	35.2	234	30.1	235.7	42.6	261.5	42.5
15.	178.4	41.	236	33.9	196	32.7	235.	41.	285	35.8
16.	142.2	38.	170	31.3	232	31.7	188.7	32.8	271.3	38.75
17.	185	35.	190	35.	250	32.6	238.2	47.48	330.7	54.
18.	210	40.	280.7	41.9	255	42.2	183.8	47.5	228.3	47.5
19.	190	35.	411.8	35.4	181	30.6	195	43.	193	39.6
20.	345	28.	332.66	19.5	231	21.7	120.37	45.	166.5	39.9
21.	310	32.	534.7	29.1	307	30.3	428.8	44.6	312	38.8
22.	250	38.	411.87	35.3	578	32.1	228.9	40.	156.9	41.8
23.	168	33.	191.3	34.4	208	30.9	137.31	48	134.2	40.4
24.	324	30.	258.5	32.	324	30.	335.	29.5	124.5	37.5
A	276.3	38.	300.9	34.3	222.7	37.8	227.5	45.4	213.4	42.1
CA	265.	36.3	294.2	34.4	259.5	37.	228.9	44.9	231.7	42.3

Rate of Total Soot Fall and Percent Combustible Matter (continued)

1930

	November		December		Average		Cor. Average	
	A	B	A	B	A	B	A	B
1.	465.	43.	597.5	53	305.6	36.6	308.2	37.5
2.	375.	38.	1510.	46.2	514.	41.7	469.5	42.9
3.	300.	30.	150.	52.1	226.3	34.2	232.8	34.
4.	120.	45.	115.	36.	110.8	44.	113.6	42.5
5.	218.5	49.6	225.	42.	189.	45.4	192.6	45.
6.	615.	40.	218.4	67.3	630.8	44.9	631.	44.5
7.	525.	45.	1012.	55.6	593.7	45.9	558.6	44.5
8.	385.9	44.7	108.4	84.9	326.9	40.9	315.2	39.1
9.	234.3	50.	225.	40.	208.9	45.1	210.9	44.6
10.	197.1	45.6	224.2	52.1	159.8	43.3	156.7	43.
11.	142.2	45.4	150.	45.	229.9	46.9	214.1	46.6
12.	485.	40.	450.	35.	652.	39.	605.	38.4
13.	275.	50.	459.9	32.8	320.2	43.5	316.1	44.1
14.	256.	35.	240.	36.	368.8	33.6	348.7	34.4
15.	187.4	43.5	378.4	50.75	296.	36.8	286.	37.8
16.	277.9	34.5	259.9	49.5	204.8	36.7	205.3	37.4
17.	335.	43.	301.	55.4	249.4	46.8	243.6	44.1
18.	223.9	51.25	208.1	55.8	221.1	47.7	222.2	46.7
19.	175.	35.	157.3	51.9	221.1	38.1	216.6	38.1
20.	235.	25.	204.	53.4	295.4	35.9	281.	35.7
21.	325.	35.	315.	43.	383.5	40.3	365.3	39.3
22.	304.8	43.1	205.8	49.8	310.9	41.8	286.1	41.4
23.	160.	33.	151.5	53.8	169.7	38.7	170.4	37.8
24.	178.8	40.4	166.	49.8	336.5	34.2	362.6	34.
A	235.	44.8	339.6	53.7	305.2	40.1		
CA	291.5	41.	334.6	49.6			304.6	40.5

Rate of Fall of Combustible Matter

1927

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.	Cor.Av.
1.	262	205	445	57	144	67		65	83	92	122	202	143	144
2.	136	74	55	163	72	85		80	80	135	52	90	93	92
3.	98	91	58	62	89	90		70	70	78	110	125	86	89
4.	69	165	246	145	175	86		86	109	54	69	71	114	110
5.	50	63	74	66	51	33		51	60	86	73	79	58	60
6.	195	210	203	201	440	135		153	154	275	526	220	253	250
7.	390	306	372	134	224	108		154	177	294	398	400	242	255
8.	116	116	104	93	90	70		71	95	156	129	153	116	109
9.	145	175	146	151	121	333		104	130	122	94	112	162	160
10.	26	75	67	47	93	31		37	44	46	80	79	57	59
11.	203	202	71	42	81	33		46	54	83	96	114	87	87
12.	245	142	159	214	191	91		124	130	90	83	140	139	139
13.	109	97	65	98	123	57		66	91	108	109	112	90	92
14.	118	142	78	91	120	110		94	119	96	99	130	107	109
15.	106	107	98	63	96	63		63	50	83	83	120	81	83
16.														
17.	141	123	146	103	100	207		97	121	82	87	137	140	132
18.	112	93	55	59	44	45		48	51	120	90	112	71	73
19.	97	79	95	56	89	70		66	75	151	167	110	106	104
20.	109	72	70	91	79	36		60	81	62	95	112	71	74
21.	104	107	68	76	81	50		52	63	46	105	110	75	77
22.	95	66	87	86	60	68		70	67	62	56	55	71	71
23.	165	151	94	61	83	47		57	61	60	60	70	74	83
24.	255	155	65	85	125	80		91	122	98	101	200	121	123
A	145	137	121	97	121	89		79	91	111	145	130	113	
CA	145	135	121	97	118	84		79	91	109	135	135		113

Rate of Fall of Combustible Matter

1929

	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1.	191.5	193.8	180	133	157	53	110	72.5	97.5		175
2.	113	91.6	66.7	115.5	90	90	80	86	93		124
3.	97.5	101	82.3	115.8	91.5	68	75	69	88		90
4.	25.6	45	60	90	108	31	36	75	56.5		75
5.	92.5	81.8	175	154	87.8	63.5	86	139.5	118		135
6.	252	298	385	465	453	216	103.8	95.5	125		150
7.	400	456	262	454	339	252	212	259	343		496
8.	108	233	143	125	102	87.5	88	132.7	107		107
9.	71	116	177	131	108	77.8	70	81	126		150
10.	87	90	69.4	74	79.4	51.8	37.9	58.8	73.2		124
11.	232	129	110.5	129	104	65.2	67.5	103.5	137.5		144
12.	127	150	149	149	175	145	185	326	183		240
13.	143	118	134	149	136	121	40.3	127	171	122	180
14.	134	220	159	272	150	132	107.5	137.5	121		218
15.	93	98	87.5	109	76	52.5	110	107.4	102.7		124
16.	91.5	100	57	83	59	107.4	80	78.8	74		108
17.	136	81	110	110	100	79.4	89	171	106.2		139
18.	117	81	74	216	67	75.5	77	108	115		137
19.	76	56	81.5	87.5	184	72.3	74.6	110	154		130
20.	248	112	86	148	83	56.5	57.7	158.5	77.5		112
21.	43.4	96	52.5	103	61	57.5	72.3	69	58.4		75
22.	43.6	79	246	67.5	64.4	42.4	54.5	61.5	60.9		112
23.	61.5	59	70	101	88	51.2	68.6	87.5	71.4		110
24.	250	250	104	102	89	72.5	78.5	119.3	103.4		775
A	124.2	144.2	117.3	162.5	127	88.5	86.4	121.8	110	122	290
CA	132	138	124	148.5	124	88.4	88.5	113.8	111		160

Rate of Fall of Combustible Matter (continued)

1929

	Average	Cor. Average
1.	126.	136.3
2.	91.7	94.9
3.	89.1	87.8
4.	53.8	60.2
5.	110.9	113.3
6.	250.9	254.2
7.	341.9	347.3
8.	129.7	123.3
9.	110.8	110.8
10.	66.4	74.5
11.	120.5	122.2
12.	180.	182.9
13.	180.1	180.1
14.	165.1	165.1
15.	92.9	96.
16.	78.8	83.8
17.	112.1	112.1
18.	103.3	106.7
19.	99.7	102.5
20.	103.	113.9
21.	68.1	68.8
22.	81.5	83.1
23.	71.3	75.8
24.	194.3	194.3
A	121.7	
CA		129.1

Rate of Fall of Combustible Matter

1930

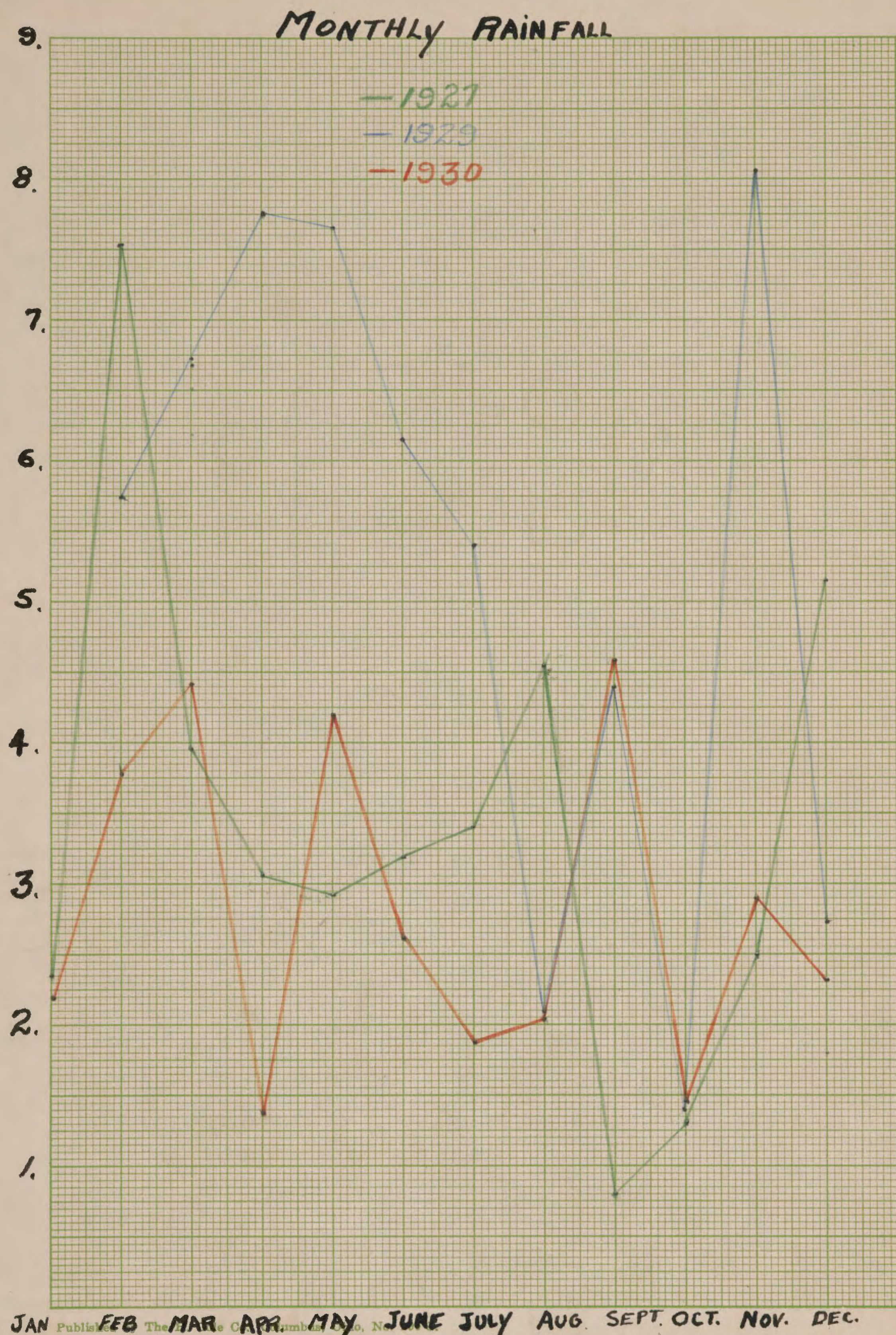
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1.	137.		274.	70.	78.4	78.8	64.86	52.	79.2	104.1	200.	317
2.	96.		385.	123.5	117.	196.	127.5	64.	198.	90.8	146.	695.2
3.	80.		97.3	50.5	113.	75.	98.37	70.	38.9	41.6	90.	78.1
4.	58.5		6.5	47.4	69.5	68.8	42.88	37.	33.87	43.3	54.	41.5
5.	76.5		124.5	60.4	156.4	78.	65.2	11.	70.9	59.7	108.65	94.5
6.	578.5		165.1	293.	275.	216.	298.7	335.	158.19	293.	246.	147.
7.	383.		605.	27.	285.	166.3	88.4	186.	319.6	158.6	236.2	561.
8.	100.		246.	109.	101.5	79.3	86.	73.	87.9	76.5	172.1	91.5
9.	90.		130.5	69.2	117.	69.9	78.5	52.	96.7	86.4	117.1	90.2
10.	97.		132.2	50.	52.	37.1	41.4	48.	47.57	45.2	89.9	116.8
11.	157.		327.	60.6	111.	49.	56.4	67.	92.98	64.7	64.5	67.5
12.	175.		226.8	329.4	232.	168.2	209.	205.	232.45	122.	194.	157.5
13.	180.5		207.5	183.1	116.	60.1	115.3	103.	110.6	118.5	137.5	151.
14.	160.		142.	68.8	156.	83.9	98.73	71.	100.1	112.	89.5	86.4
15.	112.		125.	50.1	92.	73.1	80.17	64.	96.5	104.5	81.5	192.
16.	94.5		69.6	72.1	65.7	54.	53.33	74.	61.8	105.	95.5	128.
17.	101.		114.9	64.	106.	64.8	66.5	82.	113.1	179.3	144.	166.5
18.	112.		115.3	49.7	115.5	84.	117.8	108.	87.21	117.5	114.8	114.1
19.	110.		78.7	50.5	93.	66.5	145.76	55.	83.9	76.5	61.3	81.6
20.	90.		262.	113.	155.	96.5	60.18	50.	54.42	66.5	58.7	108.8
21.	37.6		318.5	139.	158.	99.4	156.	93.	191.4	120.9	61.4	135.
22.	90.		153.	112.8	90.8	95.	109.7	186.	91.5	57.5	131.	102.5
23.	76.		78.4	39.2	65.6	55.5	65.94	64.	65.95	54.3	48.5	81.7
24.	292.		198.5	96.5	98.	97.2	82.68	107.2	100.	46.7	72.	82.5
A	183.3		190.9	103.5	124.5	98.5	103.2	91.2	108.1	89.2	104.7	188.9
CA	145.		190.9	97.0	125.8	92.1	100.3	91.8	109.1	97.7	117.2	161.9

Rate of Fall of Combustible Matter (continued)

1930

	Average	Cor. Average
1.	131.6	132.2
2.	221.4	203.5
3.	73.4	75.7
4.	43.1	45.7
5.	81.1	82.3
6.	274.	272.3
7.	298.	274.2
8.	115.2	111.
9.	90.1	90.7
10.	70.7	68.9
11.	109.9	101.6
12.	215.5	204.1
13.	134.5	143.9
14.	104.	106.2
15.	95.8	97.3
16.	77.9	79.4
17.	118.	109.3
18.	104.3	103.1
19.	83.	82.1
20.	102.1	101.3
21.	151.7	137.3
22.	118.6	110.9
23.	64.3	63.1
24.	96.8	115.
A	103.	
CA		117.7

CORRECTED AVERAGES - TOTAL SOOT-FALL


MONTHLY RAINFALL
—1927
—1929
—1930
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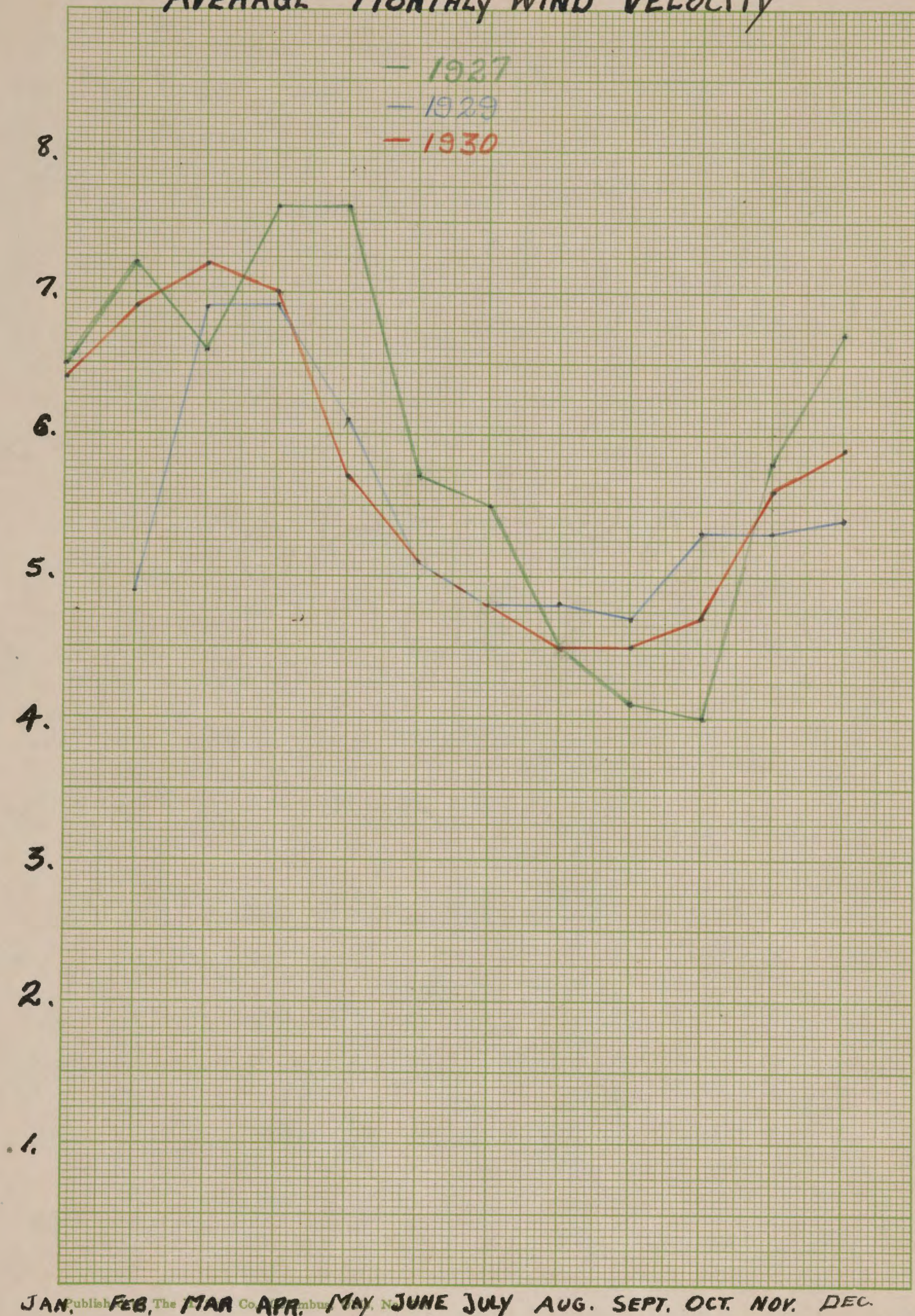
AVERAGE MONTHLY WIND VELOCITY



AVERAGE MONTHLY TEMPERATURE

Atmospheric Smoke in its Relation to Health

There are various opinions as to the extent to which atmospheric smoke may affect health. It has been asserted frequently that atmospheric smoke causes serious irritation of the sensitive membranes of the eyes, ears, nose, and throat. Dr. Robertson, Professor of Chemistry at The University of Tennessee, suggested that if this be true a correlation might be discovered between the number of eye, ear, nose, and throat specialists in the larger cities of the United States and the prevalence of atmospheric smoke. With the view of deciding this point, questionnaires were sent out to the Chambers of Commerce in one hundred and eighty cities in the United States requesting the necessary data for the years 1910, 1920, and 1929. The replies were tabulated by Mr. George R. Calhoun as a part of his thesis. Many of these cities reported that for one reason or another they had no real smoke problem. Among these reasons were mentioned the use of natural gas or hard coal, and the absence of industrial plants. No systematic measurements of the prevalence of smoke had been made in a number of cities where smoke abatement ordinances are in force. From the data which was assembled for about fifty cities, no positive correlation between the number of specialists and the prevalence of smoke could be detected. It was found, for example, that Washington, D. C. and Los Angeles, California have more specialists in proportion to the population than any other cities in the country, yet they are remarkably free from smoke nuisance. In Asheville, N. C., the annual average of soot fall is low, but the number of persons per specialist is low, also. The soot fall is only 240 tons per square mile per year. There are twenty-seven specialists in Asheville which has only thirty-five thousand inhabitants. The low population per specialist may be explained by the fact that Asheville is a noted resort, and many people go there for special treatments.

Nashville has four times as much soot fall as Asheville, but they have almost seven times as many person per specialist as Asheville has.

Knoxville has less soot fall than Nashville and a greater amount than Asheville, while they have fewer persons per specialist than Nashville and more than Asheville.

"To conclude from these reports that atmospheric smoke has no injurious effects upon the mucous membrane of the eye, ear, nose, or throat would be almost as unscientific as to conclude that the existence of a certain correlation between deaths frompneumonia and the prevalence of smoke is proof that these conditions stand in the relation of cause and effect." A great many factors may effect the number of specialists a city will support. In a chart issued by the Chamber of Commerce of El Paso, Texas the climatological data for 35 cities are recorded. Los Angeles is the third highest in this list in the average annual number of days of fog. Asheville, N. C., is first and Seatlle, Washington second. In health resorts and in cities where there is little poverty, the number of specialists per capita might be expected to run high. The attractiveness of a city for the young doctor who is choosing a location for his practice might affect in some measure the number of specialists.

The researches of the last decade which have been most fruitful in establishing the relation of cause and effect between atmospheric smoke and conditions of health are probably those dealing with visible light anf the ultra-violet. It was in 1924 that the interrelations between the latter and vitamin D, the antirachitic vitamin, was established. In 1930 Morris Fishbein,[1] Editor of the Journal of the American Medical Association, stated that although but seven years had elapsed since the identification of vitamin D as distinct from vitamin A, thousands of investigations had been carried on and that such progress had been made as no one would dream possible seven years earlier.

"Through its preventive and constructive agencies, medecine has captured another hill in its war to free man fro the fear of disease. This hill over-looking our smoke-laden cities is commanded by the new knowledge concerning Vitamin D. Ten years ago if it had been suggested that vitamins might be correlated in some way with atmospheric conditions, it would have been recieved as a mere guess. But, today such a a correlation seems to be definitely established in so far as vitamin D is concerned."[2]

Egesterol ($C_{26}H_{42}O$) in human tissue is converted into vitamon D only under the influence of ultra-violet light. Since this vitamin is necessary to normal activities of calcium and phosphorous in the body, the need of pure sunshine is apparent.

The Health Department, City of Knoxville, reports that 19 out of 116 children examined at the free clinic were suffering from rickets. Some of these children are deformed for life, since treatment was not taken soon enough.

1. Foreword to ultra-violet light and vitamin D in nutrition, Blunt and Coway, University of Chicago.

2. Quoted from an address by Dr. J. H. Robertson before the Tennessee Academy of Science at Knoxville, May 8, 1931

Ultra-violet light does not pass through ordinary window glass, and many of the plants that work a number of men who do not get a sufficient amount of sunlight use lamps which give the ultra-violet ray. These lamps have quartz lenses so that the ultra-violet will not be screened out. The ultra-violet light is largely absorbed by dust and smoke in the atmosphere.

In 1927 Bundesen and his co-workers showed that light filtered through the air over the stockyards in Chicago was low in ultra-violet light.

Recently Shrader, Coblenz, and Kerff [1] made a careful series of tests to determine the effect of atmosphereic pollution upon the incidence of solar Ultra-Violet Light in the City of Baltimore, Md. Their work was published in the <u>American Journal of Public Health</u>. for July 1929. From their observations using five different methods, they conclude that only 50 per cent as much ultra-violet light reaches the city as the country surrounding it.

1. Effect of Atmospheric Pollution upon Incidence of Solar Ultra-Violet Light, Shrader, Coblenz, and Kerff, American Journal of Public Health, July, 1929.

The following data is the average temperature variation. The difference between the maximum and minimum temperature was taken for each day and averaged for that month.

	Jan.	Feb.	Mar.	April	May	June
1927	15.1	15.7	18.8	26.5	21.3	17.5
1929	17.	14.	19.4	21.4	18.8	19.8
1930	18.4		20.9	23.7	20.6	23.2

	July	Aug.	Sept.	Oct.	Nov.	Dec.
1927	18.8	18.4	23.2	23.5	18.5	18.1
1929	18.7	20.1	18.5	18.6	12.3	17.8
1930	23.1	23.2	18.4	20.2	17.5	11.9

*Annual Meteorological Summary
With comparative data--1930
Weather Bureau

Conclusion

In order that we may be able to draw a little more accurate conclusion regarding the data shown in the preceding pages as to the comparison of the soot fall in Knoxville for the years 1927, 1929, and 1930, we must bear in mind that the volume of smoke produced and the per cent of the total which falls as soot within the city are values dependent upon variable questions. There has been an effort made to check four of these values. They are: wind velocity, rainfall, average daily temperature, and the average variation of temperature for each day.

The following conclusions have been drawn:

1. Soot fall in 1929 was 11.03% greater than in 1927 and that for 1930 was 10.98% greater than that for 1929.

2. The per cent combustible matter for the three years was practically constant.

3. The wind velocity was:

   6.0 miles per hour in 1927

   5.48 miles per hour in 1929

   5.7 miles per hour in 1930

4. The rainfall was:

   40.7 inches in 1927

   60.7 inches in 1929

   33.67 inches in 1930

5. The average temperature was:

   60.7 degrees in 1927

   58.5 degrees in 1929

   59.4 degrees in 1930

6. There is a slight increase in soot fall in the early spring months. The meteorological survey shows that the average variation of temperature is greater in these months. This data is shown on page 31. Under such conditions there would be a change in the humidity and density of the atmosphere, and the conditions would be more favorable for a higher soot fall.

7. There is a very slight decrease in the soot fall for summer months which shows that the greater portion of smoke is produced by industrial plants and railroads rather than by the heating of buildings.

Approval

The foregoing thesis is hereby approved as a creditable study on an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it is submitted. It is to be understood that by the approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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