PUBLIC HEALTH REPORTS

VOL. 50 OCTOBER 4, 1935 NO. 40

DUST STORMS AND THEIR POSSIBLE EFFECT ON HEALTH*

With Special Reference to the Dust Storms in Kansas in 1935

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In the course of the past year, Kansas has experienced a variety of weather conditions. An unusually severe drought prevailed during the past 3 years, extending into the spring of 1935. New high temperature records were established in the summer of 1934, and the total of nearly 300 deaths from excessive heat was four times the previous high of 75 deaths in 1931. As a result of the drought, dust storms of unprecedented intensity and duration occurred during the 3-month period from (including part of the two months) February to May, inclusive, of the present year. During May 1935, the drought was broken and excessive rainfall was recorded in nearly all parts of the State. Floods occurred, especially along the course of the Solomon, Republican, Blue, Kansas, Marias des Cygnes, and Neosho Rivers. Flood waters reached new high marks; homes, crops, livestock, bridges, highways, and public properties have been destroyed; but, fortunately, the loss of human life has been small. By way of contrast, on June 2, when floods were at their height in eastern Kansas, an unusually severe dust storm occurred at Garden City. For variety, an earthquake occurred in northeastern Kansas on March 31. It was of but a few seconds' duration, and no property damage was recorded. Our purpose in this paper, however, is to present certain data in regard to dust storms.

Kansas has experienced droughts previously, and dust storms have occurred in the central west in previous years, but their duration was limited to a few hours or a day at the most, with only one or two or possibly three storms a year. One of us (Brown) visited the dust-stricken area three times during April and May, and each time encountered one or more dust storms. During these trips several individuals were interviewed who had lived in western Kansas for

* Read before the Fiftieth Annual Session of the Conference of State and Provincial Health Authorities of North America at Atlantic City, N. J., June 14-15, 1935.

more than 50 years and each one made the statement that never in his experience or to his knowledge had such severe dust storms occurred in previous years.

The dust area included portions of five States—Colorado, Kansas, New Mexico, Texas, and Oklahoma. To this area was applied, more or less appropriately, the name of "dust bowl." The approximate center of the area was Liberal, Kans., located in Seward County,

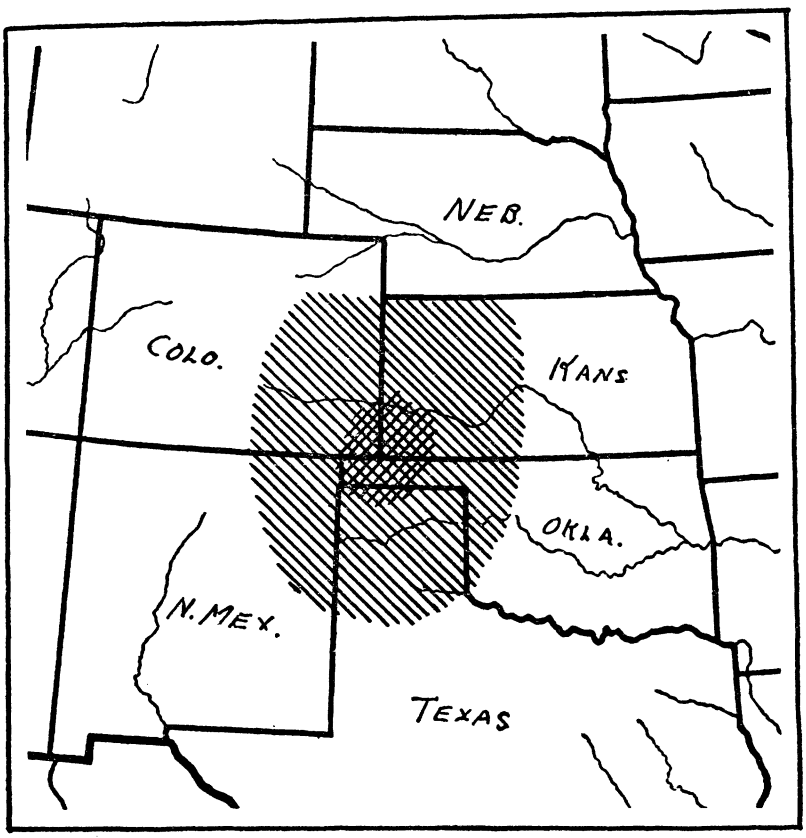

FIGURE 1.—Map showing approximate dust-storm area in five States.

5 miles from the Kansas-Oklahoma State line and some 60 miles from the Kansas-Colorado State line. This area was approximately 400 miles from north to south and 300 miles from east to west. The area most severely affected was within a radius of approximately 100 miles from Liberal. More than 100 counties are located within the area, having an estimated population of approximately 900,000. Severe dust storms were also reported last year in western Nebraska and in the Dakotas.

It is believed that conditions as regards lack of rainfall, dust storms, and illness were similar in each of the five States involved.

On April 29, 1935, under sponsorship of the American Red Cross, a dust conference was held at Liberal with the State health officers of Oklahoma, Colorado, and Kansas in attendance. A comparison of morbidity and mortality for certain of the acute infectious diseases showed similar increases for the three States. Our information and discussion, however, will be limited to conditions existing in Kansas.

Kansas is the geographic center of the United States. The State extends approximately 400 miles east and west and 200 miles north and south. In shape it is almost a perfect rectangle. Contrary to popular belief, Kansas is not flat and featureless. The landscape is far from a monotonous succession of level prairies. It has innumerable hills and picturesque valleys.

The land surface slopes eastward at an average of 8 feet to the mile, with an elevation of 4,135 feet along the western boundary and 734 feet where the Verdigris River crosses the Oklahoma boundary in the southeastern corner of the State. In some places the land slopes steeply or even precipitously. In parts of western and southwestern Kansas are small canyons with steep, bare walls, resembling the gorges of a more mountainous country.

The greater part of western Kansas is covered by a mantle of sand and calcareous clay. The soils of northwestern Kansas comprise a great area formed from wind-deposited material. There are many areas within this region, adjacent to the streams, where the wind-laid soils have been eroded, the underlying rocks exposed, and residual soils formed. These wind-deposited soils are subject to erosion by both wind and water. In the southwest portion of the State are the outwash plains soils (heavy). Both soils are of very fine material, although one is heavier than the other, but both are subject to being carried by heavy winds. Wind erosion occurs during those seasons when the surface soil becomes dry, is not covered by vegetation, and high winds prevail.

The prevailing winds in the western part of the State from April to October, inclusive, are from the south or southwest. During the winter months, north or northwest winds prevail. April is the windiest month of the year.

The average rainfall for the west quarter of the State is approximately 20 inches, with some increase in the total fall in the next 100 miles to the east, increasing to as much as 40 inches or more in the eastern part of the State. A comparison of rainfall recorded in the various counties for the 5-year period 1930–34 shows, almost without exception, noticeable decreases in the past 3 years.

Forty-five Kansas counties are included in the wind-soil erosion area, the total population of which is approximately 330,000. There are nine cities, each with a population in excess of 2,500, the largest being Dodge City, with slightly more than 10,000.

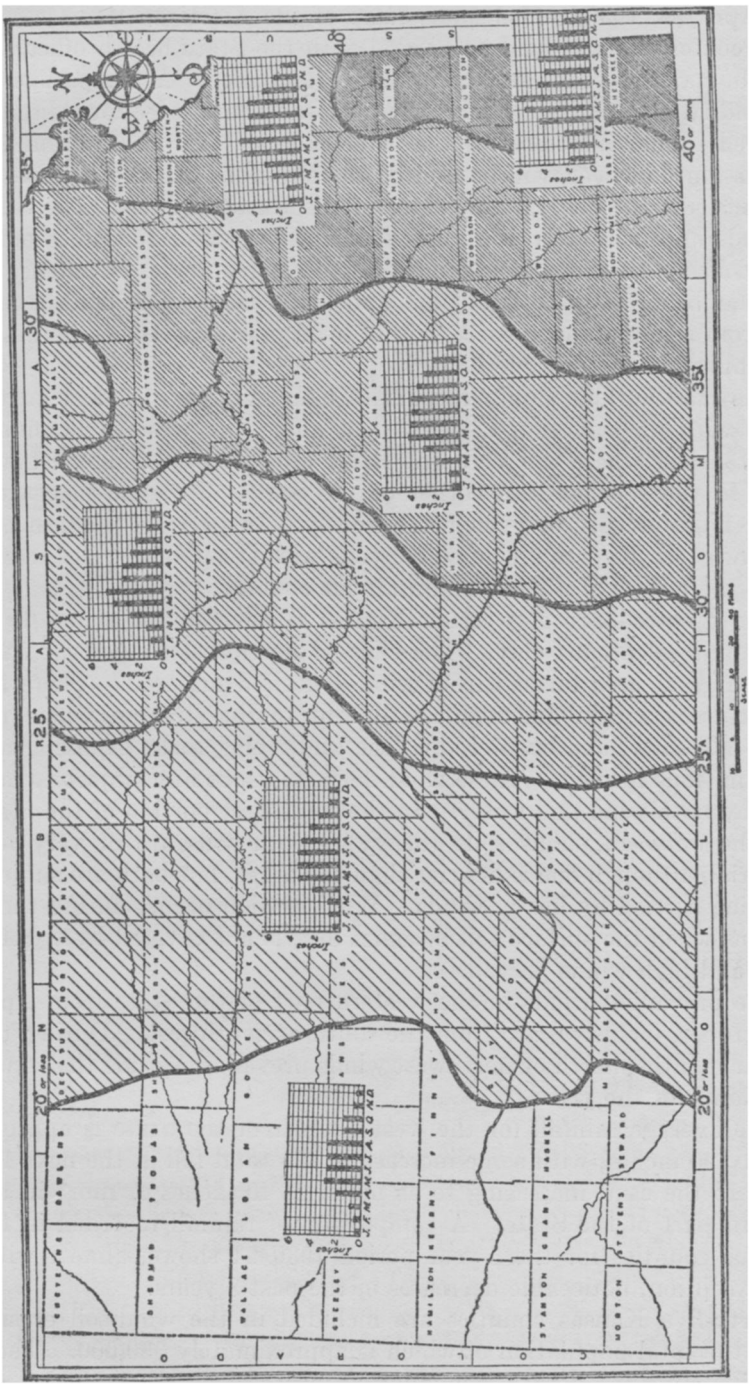

FIGURE 2.—Average rainfall and normal distribution in different areas in Kansas. (Data are for representative stations in each area.)—Courtesy Kansas State Planning Board.

With the exception of this limited number of cities, the area is essentially rural and agriculture is the principal industry. The Kansas State Board of Agriculture estimates that, of the 13,000,000 acres planted to wheat in the fall of 1934, some 9,000,000 acres were sowed in these counties. A limited amount of ground is used for the production of corn, kaffir corn, sargo, and other row crops. The remaining land is used for grazing, and naturally there is some waste land.

There have been two types of dust storms, although both were the result of high winds. One type was the result of the wind blowing the dust from the ground, the cloud rising higher and higher. The other was the result of the dust having been carried into the high air currents and then gradually settling as the wind lessened. Nine storms of the latter type occurred in Topeka during the month of March 1935, the most severe on March 20. On this date, according to S. D. Flora, State meteorologist, visibility decreased steadily from about 4 miles at 8 in the morning to approximately 220 yards at 11:14 a. m., at which it remained until after 4 in the afternoon. The sun was entirely obscured by dust, and artificial illumination was necessary for reading in homes and offices. Airplane pilots are reported to have encountered much dust as high as 10,000 and 15,000 feet.

The most graphic description of a dust storm is that given by A. A. Justice, meteorologist at Dodge City, contained in his official report for the month of April. It follows:

> The storm that will longest be remembered came on the afternoon of Sunday, the 14th, striking at 2:40 p. m. Instant darkness followed, lasting for 40 minutes. Then for a period of about 3 hours there was darkness, with occasional breaks of very short duration. By midnight the dust became light.
>
> Many people were caught out in this storm, and these people had a variety of experiences to relate after the storm had passed. Some children were caught in the park and narrowly escaped serious consequences. Many persons spent several hours in stalled motor cars along the highways. Others relate going for considerable distances on hands and knees seeking shelter. No fatalities are known.
>
> As a meteorological phenomenon this storm was very interesting. Many people saw the dust cloud coming, even though visibility was limited to a few miles by the dust then prevailing. The cloud extended east and west as far as could be seen in a straight line. As it came on it presented a rolling, tumbling appearance, something like a great wall of muddy water. The base of the cloud was inky black, the top portion of a lighter color, due to the amount of light falling on the two portions. The height of the cloud was estimated to be about 1,000 feet. According to the most trustworthy observers, the upper portion of the cloud appeared to be rolling forward and downward, the extreme lower front was lined with columns of rapidly rising dust, as though these were forced out by the falling heavier air layers above and behind. Apparently this was a well-developed polar front; all the air movements in it seemed to conform to the idealized structure of a cold front. According to some who took the trouble to check up on the movements of the front of the storm, it was traveling at about 60 miles per hour in this area.
>
> An interesting thing observed was the great number of birds flying straight in front of the onrushing cloud. Hundreds of geese and ducks and smaller birds too

numerous to count were racing for their lives; and in this instance the race was to the swift, for the strong-winged geese and ducks left the cloud at a safe distance behind while the smaller, weaker birds were caught. The almost entire absence of all birds following the storm is one proof of its severity. Another proof of its severity was shown in the great number of jack rabbits seen lying dead on the prairies during the next few days.

Mr. Justice also states in his report:

The total wind movement in April was the greatest for any month of record. There was a total movement of 13,059 miles (uncorrected), as compared with the previous record of 12,733 miles in April 1877. The precipitation was 0.03 inch.

A severe storm occurred on the 10th–11th in connection with the passage of an intense cyclonic disturbance. During the 2 days there were 41 consecutive hours with dense dust, during which time the visibility ranged between 1,000 and 50 feet. The total wind movement during these 41 hours was 1,111 miles; the maximum velocity for 5 minutes, 38 miles. For long periods of time, semi-darkness prevailed during the daylight hours. Traffic was tied up; business was practically at a standstill; no one ventured out unless compelled to. Further damage was done to surviving wheat, and much soil drifting occurred.

Mr. Justice, in his March report, comments as follows:

The storm of the 26th came at 8:06 p. m., after a fine day. The black cloud came silently from the north, blotting out the stars one by one as suddenly and completely as if they had been snuffed out. Visibility dropped at once to about 100 feet and remained so to midnight and past. Maximum wind velocity, 37 miles from the northeast.

From 11 a. m. of the 15th to past sunrise of the 22d the air was so dusty that the horizon was never visible, the visibility most of the time remaining below 1 mile, and for many hours at a time below 1,000 feet.

Official records of the Dodge City office of the Weather Bureau during the 68-day period of February 21 to April 30, inclusive, show 27 days of "light" dust and 28 days of "dense" dust, a total of 55 days of dust. Only 13 days were reported as dust-free. This may be considered as applying to the greater portion of the "dust bowl."

TABLE 1.—*Temperature and relative humidity records for Dodge City and Wichita, for certain days of dust storms*

Date 1935	7 a. m.		12 noon		7 p. m.	
	Temperature	Relative humidity	Temperature	Relative humidity	Temperature	Relative humidity
DODGE CITY						
Feb. 21	49	43	73	16	65	12
Mar. 15	56	42	79	14	79	9
Mar. 19	47	43	60	33	62	47
Mar. 26	46	55	71	18	67	17
Mar. 30	38	60	38	57	43	46
Apr. 10	42	55	43	55	41	55
Apr. 11	39	63	46	48	46	49
Apr. 14	50	32	82	10	53	33
WICHITA						
Mar. 16	38	51	38	43	36	48
Mar. 20	66	80	65	12	65	16
Mar. 23	58	20	70	76	68	16
Apr. 10	57	95	58	34	48	54
Apr. 11	42	67	46	60	46	56
Apr. 14	58	28			58	34
Apr. 26	50	52	65	34	66	35

FIGURE 3.—The approaching dust storm in the Middle West dust storm area. (Copyrighted photograph. Used by permission of copyright owners.)

FIGURE 4.—The ominous appearance of the nearing wall of dust. (Copyrighted photograph. Used by permission of copyright owners.)

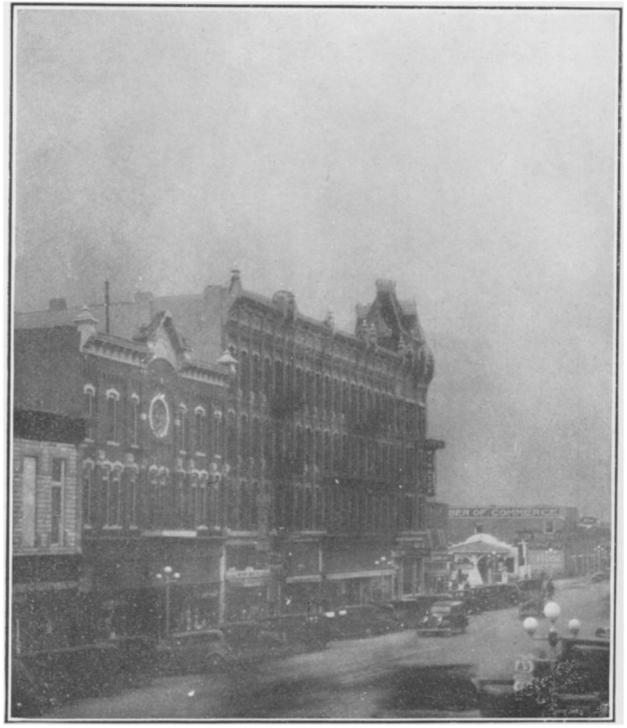

FIGURE 5.—Picture taken at Garden City, Kans., at 5:15 p. m. (Copyrighted. Used by permission of copyright owners.)

FIGURE 6.—Appearance 15 minutes later. Picture taken from same point, at 5:30 p. m. (Copyrighted. Used by permission of copyright owners.)

FIGURE 7.—An originally level wheat field covered with drifts 2 to 4 feet high.

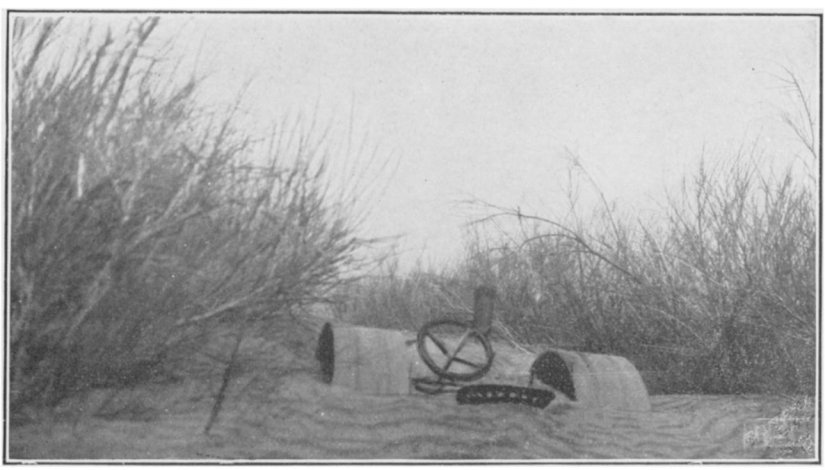

FIGURE 8.—Farm machinery almost covered by soil drifts. (Copyrighted photograph. Used by permission of copyright owners.)

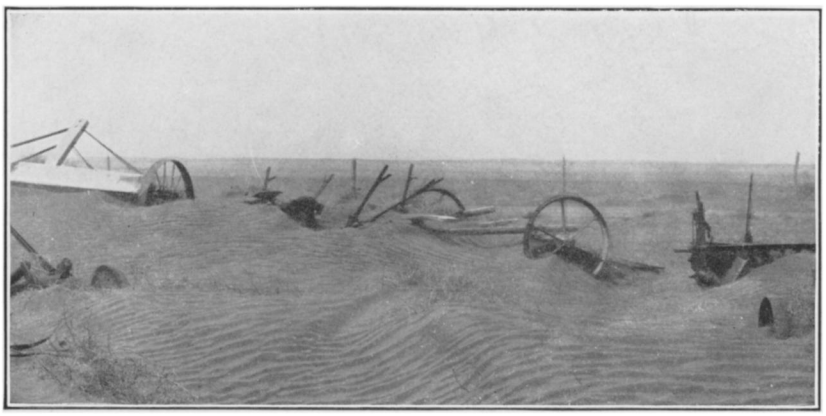

FIGURE 9.—Soil drifts around farm machinery. (Copyrighted photograph. Used by permission of copyright owners.)

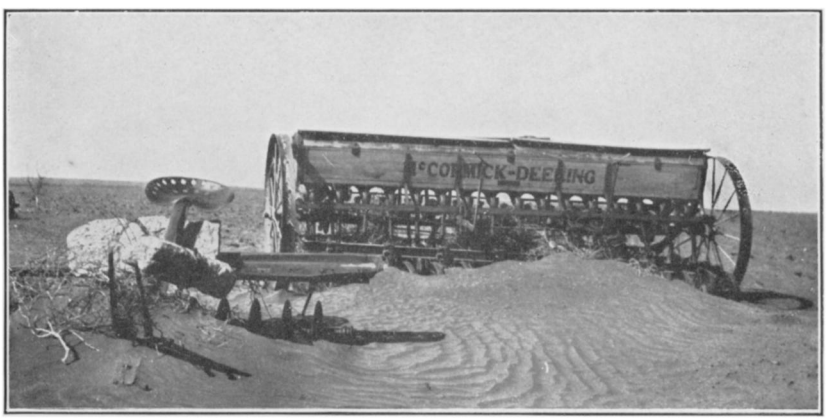

FIGURE 10.—Note soil drift over disk. (Copyrighted photograph. Used by permission of copyright owners.)

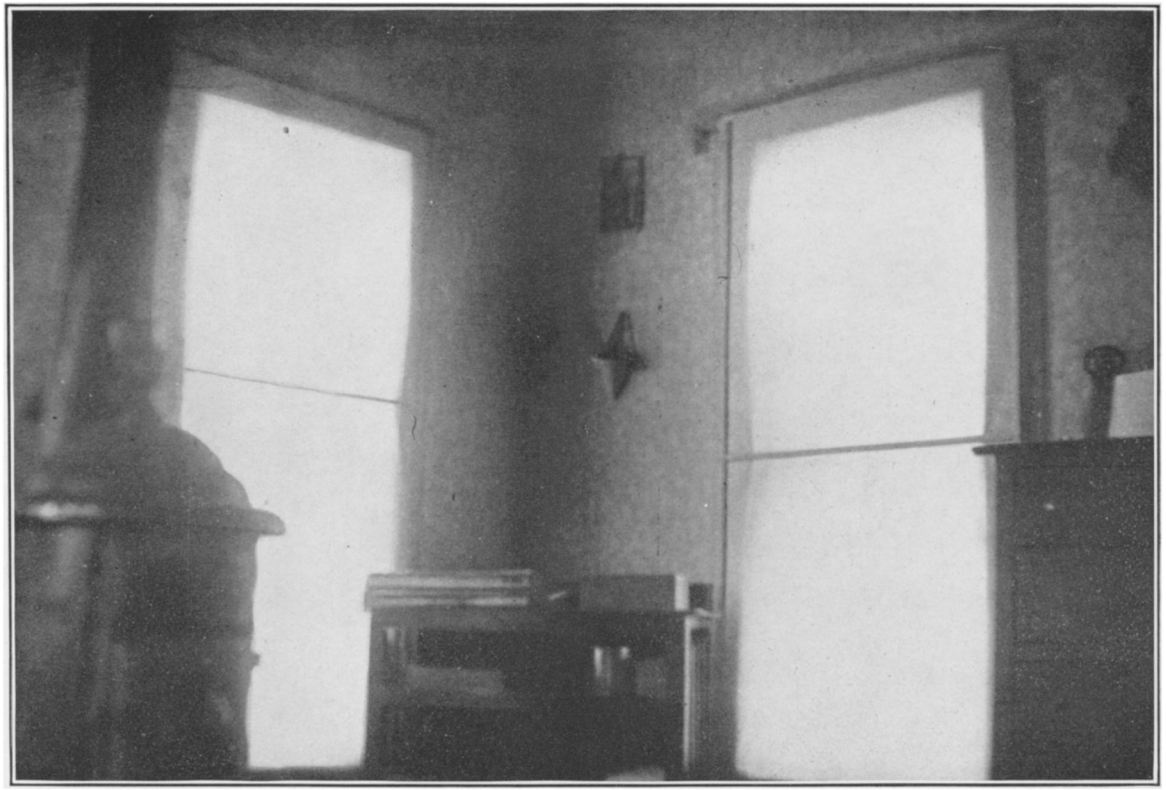

FIGURE 11.—Dustproofing of house by use of translucent glasscloth.

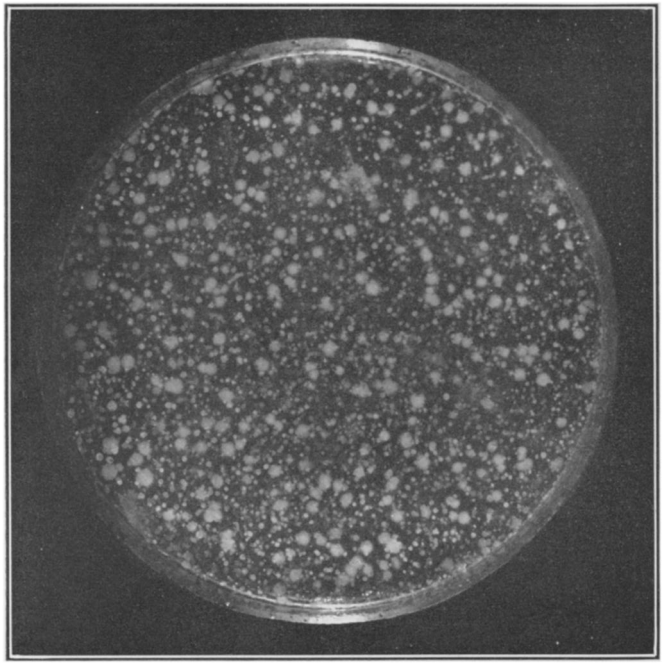

FIGURE 12.—Plate exposure of 1½ minutes at Lawrence, Kans., March 20, 1935, during dust storm.

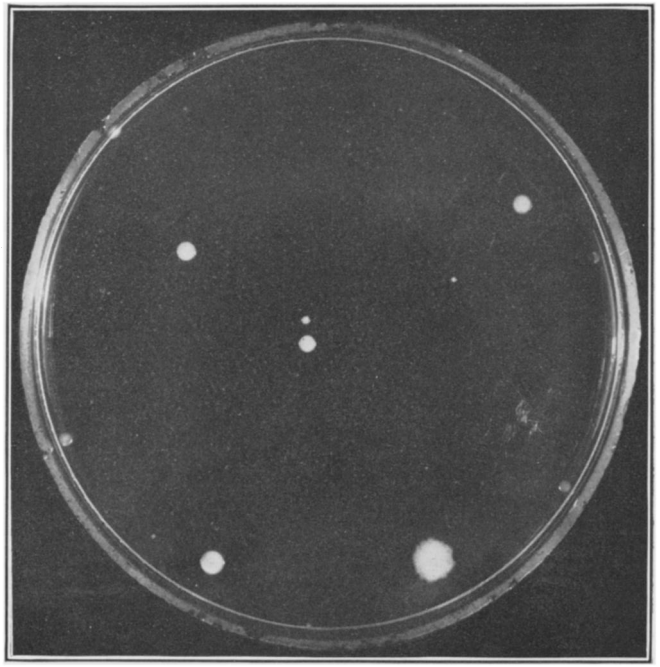

FIGURE 13.—Plate exposure of 1½ minutes at Lawrence during normal weather, March 25, 1935.

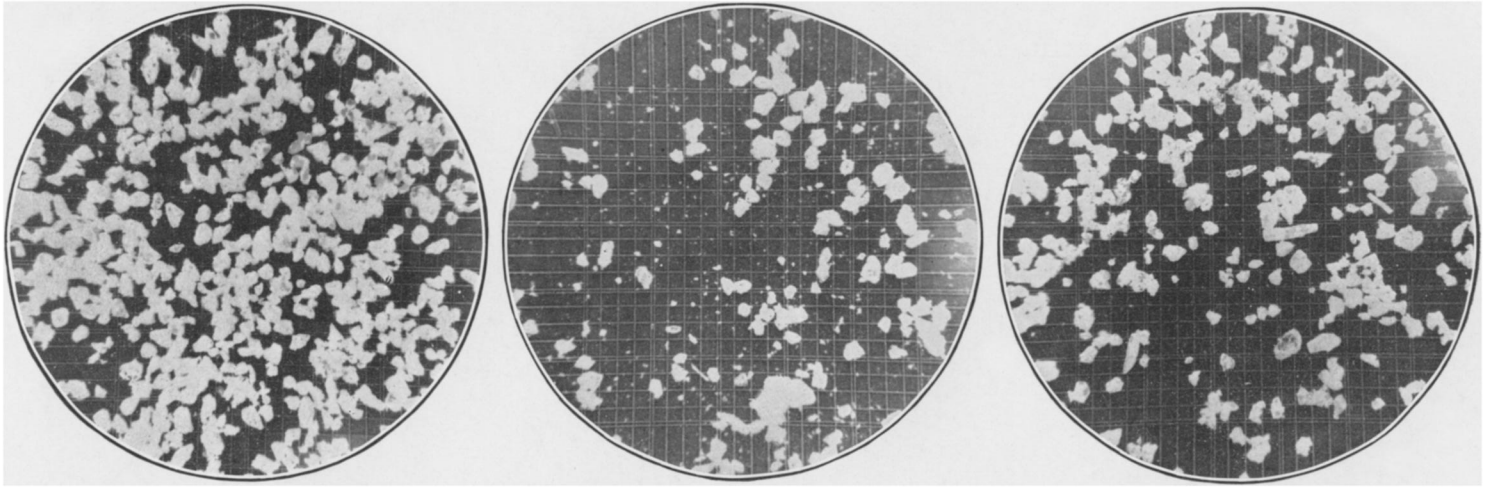

FIGURE 14.—Showing method of determination of particle size. × 50.

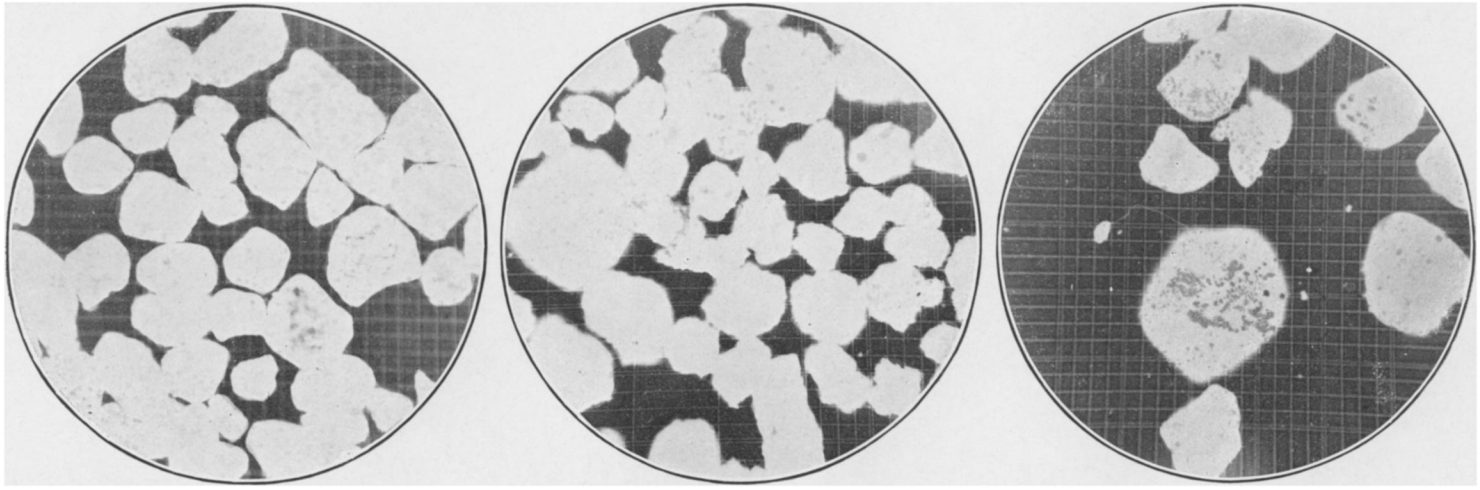

FIGURE 15.—Another photograph of dust particles as seen on haemocytometer slide in determining particle size. × 50.

Of especial interest were the temperature and relative humidity records for certain days when the dust was most dense. At Dodge City on March 15, 1935, at 7 a. m., the temperature was 56° F. and the relative humidity was 42; at 12 noon the temperature was 74° and the relative humidity was 14; and at 7 p. m. the temperature was 79° and the relative humidity was 9. At Wichita, on March 20, at 7 a. m. the temperature was 66° F., with a relative humidity of 90; at 12 noon the temperature was 65°, with a relative humidity of 12; and at 7 p. m. the temperature was 65°, with a relative humidity of 16. These data will be found in table 1.

As a result of the combination of the prolonged drought and the high winds, great damage was done to homes, livestock, and crops and human health was impaired. Authorities state that in some counties the wheat crop is a total loss, as well as some of the spring crops, such as barley and oats. There has been a tremendous loss of livestock. Pastures were so covered with dust that they were unfit for grazing; and even after the rain fell, it was considered they would not have more than 50 percent normal growth for the season.

Fields originally level now have drifts 2 to 4 feet high, Russian thistles or tumble weeds serving as wind retards. Drifts covered fences and in many places blocked highways. One drift in Edwards County was 250 feet long, with a maximum height of 5 feet, a snow fence serving as wind retard. This drift contained approximately 17,000 tons of sand and silt. Ditches along the highways have been filled to the level of the roadbed. In some areas it is said that some houses were surrounded by sand drifts. It was not unusual to see in fields along the highways, farm machinery almost covered by drifts.

The drought ended on May 10–11, when heavy rains fell throughout the State. In one county 6 inches of rain fell within a period of 3 hours. Despite the fact that there was a general rainfall, occasional dust storms were reported in the 2 weeks following. However, vegetation has now taken root, spring crops have been planted, and it is believed that the danger of dust storms during the present season is at an end.

Limited information is available as to the amount of dust that fell during the 3-month period. The following data are supplied by Dr. F. L. Duley, regional director, Soil Conservation Service, Kansas area, and G. B. Killinger, assistant soil expert. This material will be included in a future publication by Dr. Duley and Mr. Killinger.

Jewell County has had a drought for several years. In 1934 the precipitation was only 13.75 inches, whereas the normal rainfall would have been approximately 24.5 for the same period. During the first 4 months of 1935 the precipitation was only 1.77 inches, whereas it should have been approximately 5 inches. This latter 4-month period was the time during which we had our most severe dust storms.

Some measurements on the amount of silt carried by the wind during certain dust storms were recorded as follows:

March 15: Sample collected in shallow bake pan in yard measured equivalent to 4,145 pounds per acre.

March 26: Several small bake pans half full of distilled water on top of three-story hotel showed an average of 2,234 pounds per acre. Soil taken from Government rain gages in area showed an average of 2,000 pounds of soil deposited per acre for one storm.

April 16: Silt collected on hotel in small pan part full of distilled water was equivalent to 913 pounds per acre.

April 22: Pans on hotel had equivalent to 262 pounds per acre.

The total deposit of dust during these five storms was 4.7 tons per acre. There were several other dust storms for which we have no measurements.

The preceding measurements were all made in pans or rain gages and should be fairly representative of the amount of silt carried and deposited by the wind.

Measurements were made of soil deposited on a Russian thistle field when wind movements did not carry the material away. This field was located near cultivated land which was losing soil at a very rapid rate. Three 4-foot square areas were measured and weighed from this field, averaging 74.6 tons of soil deposited per acre.

A sunflower field gained 7.2 tons of soil per acre.

A bluestem pasture gained 5.4 tons of soil per acre.

A forested area gained 14.5 tons of soil per acre.

These latter measurements are probably mostly of soil moved locally, although some of the material was undoubtedly transported for some distance.

Naturally we were interested in the bacterial and chemical content of the dust. Two of us (Brown and Laybourn) made trips into the dust area and exposed agar plates to secure an index of the number of micro-organisms present in the air during dust storms. Dust samples were collected in sterile bottles. One series of plate exposures was made by Cassandra Ritter, bacteriologist, division of sanitation of the State board of health, at Lawrence, on March 20. Other plate exposures were made and dust samples collected by certain county health officers in western Kansas.

In determining the number of bacteria present in the dust carried by the storm, Difco "Standards Method Agar" was used; incubation was for 48 hours at 37° C., and the time of exposure of plates was from 5 to 15 seconds, depending on the severity of the storm. Final calculations were based on the number of organisms impinging on an area of 1 square foot per minute and the results obtained were as follows:

Date	Number of organisms per square foot per minute	County	Location
1935			
Mar. 30	31,000	Douglas	Lawrence.
Apr. 30	89,000	Seward	15 miles northwest of Liberal.
May 2	78,000	Ellis	Hays.
May 8	46,000	Finney	Garden City.
Do	460,000	Ford	Dodge City.
May 10	21,000	Sherman	Goodland.
Do	120,000	Norton	Norton.
Do	130,000	Hamilton	Syracuse.

At the time when the plates were exposed near Liberal on April 30, infusion agar, blood agar, eosin-methylene blue agar, and MacConkey's agar plates were also exposed. Counts were somewhat higher on the infusion and blood agar plates than on the "Standard Methods Agar", but no pathogenic organisms were found on these plates. No organisms of the *coli* group were found on the eosin-methylene blue agar or MacConkey's agar plates.

The predominating bacteria observed on plates exposed during dust storms were spore-forming soil types. Molds were almost as numerous as bacteria, and some yeasts were also observed.

The bacterial content per gram of dust was made on representative samples collected from accumulations and drifts in various parts of the dust area. Semiquantitative determinations of the number of *coli* organisms per gram of dust were also made. In making these determinations, one gram of dust was added to 999 cc of sterile water and thoroughly agitated. Additional dilutions were made and plated, using "Standard Methods Agar", and incubated at 37° C. for 48 hours. The bacterial content per gram of dust sample and the macroscopic appearance of the sample and the place of collection are given in table 2.

TABLE 2.—*Bacterial content per gram of dust*

Date	Number of bacteria per gram of dust	Appearance of sample	County	Location
1935				
Apr. 30	170,000	Fine sand	Seward	15 miles north of Liberal.
Do	220,000	do	Meade	4 miles north of Fowler.
Do	710,000	Fine dust	Seward	Outside window sill, Warren Hotel, Liberal.
Do	760,000	do	do	Floor sweepings, Liberal High School.
Do	410,000	Earthy	do	Lister row, 23 miles northeast of Liberal.
May 2	600,000	Medium fine earth and sand.	Ellis	Hays, north city limits.
Do	170,000	Fine dust and organic debris.	do	Hays, west city limits.
May 7	220,000	Fine dust	Norton	Norton.
May 8	600,000	Medium fine dust	Finney	Garden City, edge of town.
Do	620,000	Fine dust	do	Garden City, in town.
Do	500,000	do	Ford	Dodge City, Main Street.
Do	630,000	do	do	Dodge City, top of First National Bank.
Do	850,000	do	Grant	Ulysses, inside garage.
Do	200,000	do	do	Ulysses, east of town.
May 10	290,000	do	Norton	Norton.
Do	280,000	do	Hamilton	Syracuse, third floor, east side.
Do	310,000	do	do	Syracuse, first floor, west window.
Do	240,000	do	Sherman	Goodland.
Do	310,000	do	do	Do.

Coli determinations were made by adding portions of the 1:1,000 dilutions of dust samples to Durham fermentation tubes containing lactose broth. The usual sanitary water analyses set-up was employed, which included five 10-cc portions, two 1-cc portions, and one 0.1-cc portion. All lactose fermentation tubes showed vigorous gas

production within 48 hours, and transfers were made to eosin-methylene blue agar and Endo's medium. Characteristic organisms of the *coli* group were obtained from only 1 sample of the 19 tested. This sample was collected at Goodland, in Sherman County, and was found to contain not less than 20 *coli* organisms per gram of dust. The majority of the lactose fermentors present in the fermentation tubes were spore fermentors of either the *sporogenes* or *mesentericus* types.

In the determination at Lawrence, "The colonies on the plates appeared very similar to those formed by soil organisms, some of which will appear on plates made from raw waters. This was borne out by a microscopical examination of a number of colonies. Of 11 colonies examined, all but 2 had formed spores in 24 hours; they were all rather large bacillus forms, and most of them were Gram-positive. No coccus forms were found, either in that or later microscopical examinations. This strongly indicated that the bacteria surviving in the dust were resistant soil types."[1]

PHYSIOLOGICAL RESPONSE TO INHALATION OF SILICEOUS DUST

The role of siliceous dusts in production of silicosis is well known. According to Bloomfield and Greenburg, the results of investigations during the last 10 years have led to formulation of the concept that, so far as the fibrosis-producing qualities are concerned, dangerous dusts may be divided into three groups: (*a*) Those completely composed of silica in the form of silicates (that is, silica in the combined state, such as pure asbestos); (*b*) those containing silica in the crystalline form (known as quartz); and (*c*) those containing free silica in a form other than quartz (such as diatomaceous earth). The physiological harmfulness of a dust depends partly on its quartz content.

With regard to harmfulness of a given dust, three factors are of prime importance—the amount suspended in the air, the duration of exposure, and the particle size. As to size, it is now generally agreed that, in the case of quartz-containing dusts, the dangerous particles are usually between one-half to 5 microns in diameter and are practically always less than 10 microns.

In the investigations made by the Public Health Service into the hazards of granite cutting with a dust containing approximately 35 percent quartz, it was concluded that exposure even for considerable periods of time to less than about 10 million particles of dust per cubic foot of air was relatively safe, whereas exposure to concentrations of more than 20 million particles per cubic foot was hazardous. With a dust containing 85 to 90 percent of quartz, a concentration of over 6 to 8 million particles per cubic foot of air is regarded as hazardous.

[1] Ritter: Pub. Health Rep., May 3, 1935, p. 623.

Collis and Yule have studied the mortality experience of an occupational group exposed to silica dust compared with that of the general population and an occupational group exposed to dust not containing silica. Their conclusion is that silica is such a body poison as is lead. Although it affects chiefly the respiratory organs, it also impairs the circulatory system, the nervous system, the digestive organs, and the kidneys and liver, so that should the victim escape death through some respiratory disease, he is more than ordinarily liable to diseases of the other organs mentioned. The authors further state that the silica dust hazard is probably the most widespread and insidious of all hazards in the environment of mankind.

REPORT OF LABORATORY FINDINGS

The six samples of dust submitted to the laboratory were subjected to both physical and chemical examination. The results are tabulated in table 3.

The moisture content was determined by drying at 103° C. The loss on ignition represents organic matter and more firmly bound water. Samples of the dust were fused with a fusion mixture of equal parts of sodium and potassium carbonates to bring the silica and silicates into solution. Upon acidifying, the silica was precipitated and was weighed as such after appropriate dehydration. The metal oxides were precipitated in the filtrate with ammonia, filtered off, ignited, and weighed. Calcium was precipitated as the oxalate in the filtrate from this treatment.

TABLE 3.—*Chemical analyses of dust samples and determination of particle size*

Item of analysis	Sample no.					
	1	2	3	4	5	6
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Moisture	1.9	2.1	2.0	0.03	1.5	0.03
Loss on ignition	6.8	7.4	7.3	.7	8.5	1.5
Silica	72.8	73.6	73.5	92.9	66.9	88.7
Metal oxides	14.8	13.8	15.4	[1] 5.2	15.9	[1] 8.2
Calcium oxide	1.6	1.2	1.3	.2	1.0	.3
Undetermined	2.1	1.9	.5	.97	6.2	1.27
Total	100.0	100.0	100.0	100.99	100.0	100.0
	Particle size (microns)					
Average	38	26	44	185	123	330
Maximum	70	80	90	320	460	770
Minimum	16	2	16	100	80	120

[1] Mostly Al_2O; others were mostly Fe_2O_3.

Locations from which dust samples were taken:

1. Window ledge, Warren Hotel, Liberal, May 10, 1935. Fine dust, medium brown.
2. Ness City sidewalk sweepings, 8:30 a.m., May 10, 1935. Fine dust, medium gray brown.
3. Window ledge, Ness City Hotel, May 10, 1935. Fine dust, medium gray brown.
4. 8 miles north of Liberal, 10:20 a. m., May 11, 1935. Fine sand, medium brown.
5. 8 miles east of Dodge City, 1:30 p. m., May 11, 1935. Earthy appearance, dark brown.
6. 4½ miles east of Lewis, pile on snow fence, 2:30 p. m., May 11, 1935. Medium coarse sand, medium gray brown.

The particle size was determined as follows: The dust sample was thoroughly mixed and a portion dusted as evenly as possible on a haemocytometer slide, which was placed on the stage of a microscope under the low power lens. The microscope was fitted with a metal cylinder surrounding the upright tube and extending several inches above it. It was attached in such a manner as to be lightproof. The top of the metal cylinder was covered with a piece of plain window glass and a piece of frosted glass through which the image of the dust could be examined. After proper adjustment of the sample and microscope, the room was darkened, a piece of photographic printing paper was placed face-down between the two pieces of glass and the sub-stage lamp turned on for a period of 10 to 35 seconds, the time of exposure being determined by experiment. This made possible the direct photographing of shadows of the dust particles without use of films or plates and without the usual photomicrographic apparatus. From the size of the haemocytometer ruling in the finished picture, the magnification could be accurately determined. Particle size was then determined from the finished pictures by measurement with an accurate millimeter rule. This method was devised and the equipment set up by Mr. Harold Clark, a graduate student and assistant instructor in bacteriology at the University of Kansas.

It will be noted that these dust samples average much larger in particle size than the values reported for industrial dusts and outdoor dusts in the foregoing discussion. These values are somewhat corroborated by the finding of Hatch (personal communication to Mr. Boyce) that the dust drifting from the Middle West dust regions as far as Boston had an average particle size of 20 microns.

HEALTH CONDITIONS

In the past 5 months Kansas has experienced its most severe measles epidemic as regards total number of cases. From January 1 to June 8, inclusive, more than 40,000 cases of measles were reported, as compared with the previous high total of 22,464 cases for the 12 months of 1917. One hundred and forty-five deaths from measles occurred in the first 4 months of the present year. The incidence of complications of this disease was also apparently unusually high, especially otitis media.

In addition to measles, acute respiratory infections have prevailed throughout the State in unusually large numbers. The reporting of pneumonia cases, however, cannot be used as an index of the actual number of cases of that disease which actually occurred. Many health officers reported a 50 to 100 percent increase in pneumonia cases in their respective communities as compared with the same

months of 1934. Health officers also advised of a very marked increase in the other complications of the acute respiratory infections, especially sinusitis, laryngitis, pharyngitis, and bronchitis. Large numbers of cases of streptococcic sore throat were reported, and numerous cases of corneal ulcer and eye infections were seen by physicians.

A comparison of death rates for the acute respiratory infections for the first 4 months of each of the past 4 years shows the rate per 100,000 for the 45 counties in 1935 to be 99 as compared with a State rate of 70. The infant mortality rate for the present year for the 45 counties was 80.5, as compared with a rate of 62.3 for the State. These data for the 4-year period will be found in table 4.

TABLE 4.—*Comparison of death rates per 100,000 population for the State and wind-soil erosion counties (acute respiratory infections and infant mortality) for the 4-year period, 1932–35*

Death rate, acute respiratory infections			Infant mortality rate	
Year	State	W. S. E. C.	State	W. S. E. C.
1932	47	41	49.2	51.6
1933	70	73	69.7	81.3
1934	42	33	50.1	48.7
1935	70	99	62.3	80.5

Reports from the principal hospitals in the dust area indicate a very high proportion of admissions for acute respiratory infections in the first 4 months of the present year. In one hospital, 12 percent of admissions in January were for this cause, 14 percent in February, 17 percent in March, and 52 percent in April. For four of the hospitals in 1935, 233 admissions were for acute respiratory infections, with 33 deaths, as compared with 118 admissions and 15 deaths in 1933, and 115 admissions and 15 deaths in 1934. It should be remembered, however, that owing to the publicity given the so-called "dust pneumonias" more patients were sent to hospitals than in previous years. A number of patients were moribund when admitted and died within a few hours. Many cases came from a considerable distance, often during severe dust storms, and probably their resistance was further lowered by reason of the long ride and breathing the dust. Many of the hospitals furnished gauze masks to their patients, which gave them greater comfort in breathing during the storms.

No evidence has been found that any pathogenic organisms were carried by the dust, and therefore the direct cause of the increase in respiratory infections could not be attributed to this factor. The dust, however, was exceedingly irritating to the mucous membranes of the respiratory tract, and in our opinion was a definite contributory factor in the development of untold numbers of acute infections

and materially increased the number of deaths from pneumonia and other complications.

PREVENTION OF DUST INHALATION

Shortly after the beginning of the dust storms, our department issued a statement advocating the wearing of gauze masks during the storms. At the conference in Liberal, previously referred to, the State health officers of Oklahoma, Colorado, and Kansas issued a statement approving the program inaugurated by the American Red Cross, which included—

1. The hospitalization of individuals who were so seriously ill that they could not receive adequate attention at home;
2. The dustproofing of homes in the dust area; and
3. The wearing of masks by all individuals exposed to dust.

Following the conference, the Red Cross issued a call to their various chapters for dust masks, which were made of gauze or cheesecloth. According to their report, more than 17,000 masks were distributed in the next 3 or 4 weeks. In the meantime, large numbers of persons had purchased masks of commercial manufacture, ranging in price from $1 to $4. In our judgment, the light gauze masks are very satisfactory for use even in severe storms.

In our first trip through the dust area and preceding the Liberal conference, we noted a number of homes where the windows had been sealed on the outside with translucent glasscloth. We were also informed by some individuals that they had used gummed paper tape, or linen cloth with a starch paste, or even glue. We believe the most satisfactory method of dustproofing was through the use of glasscloth on the inside of the house.

The American Red Cross made a demonstration in a number of the counties of the method of dustproofing through use of glasscloth, or by calking. The Red Cross furnished the material and the KERC, the labor. The cost of dustproofing a home of 2 or 3 rooms with glasscloth, exclusive of labor, was approximately $3. The glasscloth, when used on the inside of the house, extended past the frame of the windows or doors, and the edges were then sealed to the wall with gummed masking-tape.

The general attitude of those living in this area, even when the storms were at their height, was one of optimism. All that was necessary was rainfall, which would settle the dust and allow the planting of crops.

Rain did fall; it cleaned the air. Crops have been planted and are now growing. The general health has improved, and, for the most part, families are living under normal conditions. It is hoped that dust storms, experienced almost daily for a period of 3 months will never occur again.

SUMMARY AND CONCLUSIONS

1. The dust storms which have occurred in the central west are the climax of a 4-year period of decreased rainfall, a lack of growth of vegetation, and high winds.

2. Crop and livestock losses have been large. It is believed by authorities that, although there has been much shifting of soil, the actual damage to farm lands is small, if any.

3. There is no evidence that pathogenic organisms were actually carried by the dust.

4. The dust acted as an irritant to the mucous membranes of the respiratory tract. Laboratory examinations have shown the dust to have a high silica content.

5. The effect of dust storms on the public health must be divided into "immediate" and "future" effects.

6. The "immediate" effects are shown in the increase in morbidity and mortality from the acute infections of the respiratory tract.

7. The "future" effect is unknown. Possibly over a long period of exposure or repetitions of the storms the end effects would be similar to those from exposure to mine and other industrial dusts.

8. Dustproofing of homes and the wearing of masks are essential to the comfort and welfare of individuals living in the dust area if future storms should occur.

ACKNOWLEDGMENTS

Acknowledgment is made of the courtesy of the following studios for the use of copyrighted photographs: Conard Studio, Garden City, Kans., for figures 3, 4, 5, 6, 8, and 9; Stovall Studio for figure 10.

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