RELATIVE TO

ATMOSPHERIC OZONE

AND THE

BEST METHODS FOR ITS OBSERVATION.

—BY—

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—OF—

OTISVILLE, MICHIGAN.

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ATMOSPHERIC OZONE,

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BY A. W. NICHOLSON, M. D.

Such experiments as I have conducted have principally been made with Schönbein's test of iodide of potassium and starch, that being considered the most reliable test for the presence of ozone.

While the many observations taken by those interested in studying the relation of ozone to prevailing disease are of great value, it cannot be denied that errors creep in and render many *single* observations of little value.

Often an apparent decrease in atmospheric ozone will exist when an increase will be the actual condition. There may be an error by excess of moisture, by an exposure of the test-paper to too great velocity of the wind, etc.

It has been stated that ozone is absent in dwellings. While this statement is not incompatible with any theory concerning the relations of ozone to conditions of health or disease, it is not altogether truthful; for many conditions obtain in the in-door atmosphere that occasion error in the result of a given observation, and, notwithstanding the presence of these conditions, the presence of ozone in dwellings has often been discerned by the writer and by others.

It is true that the results of experiments concerning the amount of ozone in the air above swamps are often negative, yet here there is, without doubt, a source of error in an excess of moisture.

The principal experiments conducted by myself have been to determine the presence of ozone in dwellings, and the probable influences affecting such tests; to determine the relative amount of ozone in pine forests, compared with observations taken in the open country; to ascertain the relative amount of the same element by experiments conducted in the smoky atmosphere in proximity to a large number of "pits" for the manufacture of charcoal; to estimate the amount of ozone existing over swamps; and to compare the amount of the same by the exposure of tests at the differing elevations of four feet and fourteen feet from the ground. Experiments were also made with regard to the influence of decomposing animal excreta upon the test, compared with tests made one hundred feet distant from the first, or from any such element of contamination. Observations also were made to determine the effect of excess of humidity upon the test; and, lastly, to determine the difference in the quantity of active oxygen present in the atmosphere of a malarious region with that of an atmosphere in a non-malarious region, the same test being

employed in both localities, and the observations being taken at the same hours of the day.

Many of these observations may be but repetitions of those made by other observers, but the information already obtained is only sufficient to act as an incentive to other investigators to continue their labors in this direction. If there is no veritable connection between the varying proportions of ozone or active oxygen and health or disease, inquiry should be continued until proof of this fact is substantiated. If there is a relation, though slight, the solution of the problem is worthy of the most untiring study.

In experimenting to determine the proportion in the atmosphere of oxidizing elements bearing a relation to health and disease, it does not seem necessary to employ a test that will verify only the existence of a single factor like that of ozone. Oxygen in a state of activity, whether generated by electrical, or other influences, from oxygen in a nascent condition, or from products that easily liberate oxygen in a state of activity, like the essential oils, peroxide of hydrogen, or resinous compounds, is the desired factor to be searched after by the sanitarian and etiologist. If the test detects compounds that in themselves produce a coloration of the test-paper, it appears equivalent to a determination of an equal amount of active oxygen.

Is ozone to be discovered as existing in dwellings?

Max Von Pettenkofer, of Munich, in an article in the Contemporary Review, entitled, "The Hygienic Influence of Plants," makes the following assertion in regard to the relation of ozone to the appearance or disappearance of disease: "But one fact which was observed from the first, shows that it cannot be so; for the presence of ozone can never be detected in our dwellings, not even in the cleanest and best ventilated. Now, as it is a fact that we spend the greater part of our lives in our houses, and are better than if we lived in the open air, the hygienic value of ozone does not seem so very great."

Such a declaration, proceeding from such an influential origin, would, if erroneous, lead to many false deductions. That it is incorrect, the succeeding exhibit of the results of observations taken by myself, appears to prove. The observations were made with Schönbein's test, moistened before exposure. The apartment where the experiments were made was well constructed, and a free circulation from the external air permitted, when there was the greatest coloration, allowing motion to the air and access of moisture. Where least coloration occurred every avenue to the external air was closed as much as possible.

EXHIBIT A.

DATE.	INTERNAL OBSERVATION.		EXTERNAL OBSERVATION.		REMARKS.
1880.	Night.	Day.	Night.	Day.	
June 10	.....	1	.....	3.5	All numbers correspond to scale of 10 degrees of coloration.
" 11	0	1	2	3	
" 12	1	2	2.5	3	
" 13	2	2.5	3.5	3	Strong wind.
" 14	1	1	3.5	3	
Average	1	1.5	2.9	3.1	

During the Winter, in a north room of my own dwelling, where an effort was made to exclude the factor of ventilation, a coloration of three degrees was obtained. The temperature of the room was fifteen degrees Fahr., and a strong wind was blowing from the north. Externally a coloration of nine degrees was obtained. At the same time, in another north room of the same house, where the temperature amounted to seventy degrees Fahr., a distinct trace was discernable. At another time, when the external air was quiet, there was obtained one degree of coloration in the first room, where the temperature was forty-five degrees Fahr., and in the second room no coloration, with a temperature of seventy degrees Fahr. These results would suggest that a certain amount of motion of the air exceeding that usually existing in dwellings, would be auxiliary to conditions producing a manifestation of the presence of ozone therein. That the excess of moisture *externally* over that in the *interior* of dwellings is not a factor to be considered, seems proved by experiments made by the writer in regard to effects of moisture on the test as existing in dwellings. It was found that in rooms ventilated, when the external air was not disturbed by the influence of storms, the amount of moisture (absolute humidity) internally was equal to the amount of moisture externally, and that there was sometimes an excess of moisture in the interior of a dwelling over that exterior, when the amount of ozone was slight or entirely absent in the dwelling.

It is probable that sunshine is a condition aiding the production of ozone in dwellings, as more ozone was present during the day than night.

Prof. R. C. Kedzie, in his article on "Ozone," which may be found in the Annual Report of the Secretary of the State Board of Health of Michigan for 1875, says: "Ozone is doubtless formed in every sunlit room, and by its formation and destruction a vast amount of *materies morbi* may be destroyed, and it is no satisfactory proof that it is of no worth or influence because no residual ozone remains to act upon our test-paper."

Just what the influence upon the test is that is produced by the presence of carbon compounds, it is difficult to express. That its presence may modify the results of an experiment to ascertain the amount of ozone present is possible. To determine if the presence of pure carbonic acid would decolorize a slip of test-paper, already colored by exposure, I subjected a moistened slip to an atmosphere of carbonic acid by collecting the same over a pneumatic trough. On the gas being washed by passage through water the color upon the slip remained unaltered. On subjecting it to the influence of the gas as it escaped unwashed from the generator, a decolorization immediately occurred. This was found to be due to the presence of sulphurous acid.

Smoke is an element that will decolorize a slip of the test-paper already charged with liberated iodine. It is probable that the volume of smoke that usually, though imperceptibly, escapes from the stove, contains some property, perhaps that of sulphurous acid, that causes a change in the iodine as rapidly as it is liberated, resulting in the formation of a colorless iodate. To demonstrate the effect of gases, or smoke, generated by the stove, I introduced a glass tube through an opening of the stove into the midst of burning coals, and into the outer extremity of the tube I placed some of the test-paper already colored by the action of ozone. The result was a marked loss of the color on the paper. That this was not due to the action of increased temperature was proved by exposing a similar paper to the action of the same temperature at other points.

Although it is apparent that the amount of ozone in dwellings is actually less than that in the external air, it is also true that there exist agents that at present prevent an accurate estimate from being obtained by Schönbein's test. That active oxygen bears to organic life—to physiological or pathological conditions—some essential relation, is a proposition yet open for discussion. To declare that its presence in dwellings is not proved is apparently an error. Even were it absent from dwellings that circumstance could not prove its non-relation to health or disease. Without endeavoring to court discussion upon this important subject, it seems plausible to the writer that no oxygen enters the blood in any other state than as active oxygen. It may be that the large area of the alkaline pulmonary secreting surface, subject to the results of continuous evaporation, is in a condition to effect a generation of sufficient active oxygen to supply the blood with that which it requires. The excess in the external atmosphere may be of importance to the individual when a decrease in the external temperature intuitively directs him to take less deep inspirations than the warmer and drier atmosphere of the dwelling demanded, thus rendering the labor of the lungs less in supplying a given quantity of active oxygen to the blood. If it should be objected that the ratio of active oxygen necessary to sustain the physiological requirements of the blood is not constant, I would inquire if the ratios of most meteorological conditions are constant.

During portions of the months of March and April, 1878, while the ground was frozen, and part of the time overspread with snow, I secured a record of observations of the amount of ozone in a small pine forest about eight miles distant from my usual point of observation. The following exhibit represents the comparative amount existing at both places at the same time:—

EXHIBIT B.

DATE, 1878.	PINE FOREST.		OPEN COUNTRY.		DATE, 1878.	PINE FOREST.		OPEN COUNTRY.	
	Night.	Day.	Night.	Day.		Night.	Day.	Night.	Day.
March 4	6	5	8	4	Mar. 20	4	5	5	3
" 5	6	5	6	4	" 21	5	4	4	4
" 6	6	5	4	5	" 22	5	4	8	5
" 7	6	5	10	8	" 23	5	5	5	5
" 8	4	4	8	7	" 24	4	6	4	6
" 9	5	4	5	4	" 25	5	5	5	5
" 10	5	5	8	4	" 26	5	5	5	5
" 11	5	5	9	8	" 27	4	4	8	5
" 12	5	5	10	9	" 28	4	4	9	8
" 13	6	5	10	9	" 29	4	5	8	4
" 14	4	5	8	9	" 30	5	5	4	4
" 15*	2	4	1	4	" 31	5	5	9	8
" 16	5	5	10	8	April 1	5	5		7
" 17	5	5	9	10	" 2	5	4	5	3
" 18	4	5	9	8	" 3	4	3	4	3
" 19	6	5	8	7	Average	4.80	4.70	6.93	5.90

* Frost on night ozonoscope.

NOTE.—Night observations from 9 P. M. to 7 A. M.; day observations from 7 A. M. to 2 P. M.

It is generally believed that ozone, or that product nearly identical in its nature, the peroxide of hydrogen, exists in excess amidst coniferous vegetation over that found in most other regions, but the above exhibit presents results contrary to that which might be expected to exist. This difference is, no doubt, in a great degree due to the time of year being when there was the least development of vegetable products, to the more confined circulation of the air, and perhaps to excess of humidity. The ground was low.

During the preceding Summer, in the months of August and September, I secured the results of observations taken in the same pine forest, as represented in the following exhibit.

EXHIBIT C.

DATE, 1877.	PINE FOREST.		OPEN COUNTRY.		DATE, 1877.	PINE FOREST.		OPEN COUNTRY.	
	Night.	Day.	Night.	Day.		Night.	Day.	Night.	Day.
Aug. 26	3	4	1	4	Sept. 11	0	1	1	2
" 27	4	3	3	4	" 12	2	3	3	3
" 28	0	1	0	1	" 13	0	3	0	2
" 29	3	4	2	3	" 14	0	4	0	3
" 30	1	3	1	2	" 15	3	3	2	3
" 31	4	2	3	4	" 16	2	3	2	3
Sept. 1	4	4	4	3	" 17	4	4	3	4
" 2	1	4		3	" 18	3	4	1	4
" 3	3	3	3	4	" 19	3	4	2	4
" 4	3	4	3	4	" 20	1	3	1	2
" 5	2	3	2	3	" 21	1	4	1	3
" 6	3	3	3	4	" 22	2	3	0	3
" 7	1	4	1	4	" 23	3	4	1	3
" 8	1	3	1	3	" 24	3	2	3	3
" 9	1	4	1	4	" 25	1	2	2	3
" 10	3	1	3	3	Average	2.09	3.13	1.80	3.16

In the above exhibit we find a considerable difference in the two averages of night ozone, that found in the pine forest being in excess. The variation in the amount of ozone ascertainable during the day was slight. Were a sanitarium to be established in the vicinity of a pine forest for the sake of the salubrity of its immediate atmosphere it would appear expedient to consider other elements liable to affect the health, than ozone alone.

EXHIBIT D.

DATE, 1877.	Coal Pits.		Open Country.		DATE. 1877.	Coal Pits.		Open Country.	
	Night.	Day.	Night.	Day.		Night.	Day.	Night.	Day.
Aug. 1	2	3	2	4	Aug. 12	2	3	3	4
" 2	1	2	1	2	" 13	2	3	3	4
" 3	1	3	1	4	" 14	1	3	2	4
" 4	1	2	0	3	" 15	1	4	3	4
" 5	1	3	1	4	" 16	1	3	1	2
" 6	2	4	4	4	" 17	2	3	1	3
" 7	1	3	2	3	" 18	1	3	0	4
" 8	1	4	3	3	" 19	1	2	1	4
" 9	1	4	2	4	" 20	2	2	1	4
" 10	2	3	3	4	" 21	1	2	2	4
" 11	1	4	0	3	Average	1.33	3.00	1.71	3.57

Exhibit D records the results of observations taken in the borders of a pine forest, but in close proximity to coal-pits, as compared with those taken at a distance and free from any known cause of local disturbance to the test. The heavy night atmosphere at the pits was surcharged with smoke that during the day-time was less concentrated. The results of the observations at this point were, at night, almost negative although recorded as one degree of coloration whenever a trace was discernible. The negative results obtained here are accounted for by the presence of the decolorizing carbonaceous elements of the atmosphere associated with the element of excess of humidity. It does not seem unreasonable to conclude that the quantity of ozone present in an atmosphere subjected to the above mentioned influences, cannot be determined by the employment of Schönbein's test.

During the construction of these coal-pits, in the year preceding these experiments, the amount of sickness at, and near to, them was very great. In a population amounting to 150, nearly one-fourth were simultaneously afflicted with fevers of a periodic type. Clay and porous soils were being overturned for the first time and large belts of timber were being felled, opening avenues to swamps and ponds. The greatest prevalence of sickness was during the burning of some of the pits first constructed. The season during which the observations were taken was marked by a diminution in the number of cases of fever.

Another month's observations taken at the same place gave results almost identical to those above given.

The following exhibit represents the comparative amount of ozone existing over a swamp two miles from the point where the observations were taken with which they are compared. They were also taken simultaneously with those observations relating to the quantity of ozone existing in a pine forest.

EXHIBIT E.

DATE, 1877.	OVER SWAMP.		POINT FREE FROM SUCH INFLUENCES.		DATE, 1877.	OVER SWAMP.		POINT FREE FROM SUCH INFLUENCES.	
	Night.	Day.	Night.	Day.		Night.	Day.	Night.	Day.
Aug. 26	1	2	1	4	Sept. 10	0	0	3	3
" 27	1	2	3	4	" 11	0	1	1	2
" 28	1	1	0	1	" 12	0	3	3	3
" 29	1	3	2	3	" 13	0	1	0	2
" 30	1	1	1	2	" 14	0	2	0	3
" 31	4	5	3	4	" 15	2	2	2	3
Sept. 1	0	1	4	3	" 16	1	2	2	3
" 2	0	0	3	3	" 17	0	3	3	4
" 3	0	1	3	4	" 18	0	1	1	4
" 4	0	3	3	4	" 19	--------	--------	2	4
" 5	0	1	2	3	" 20	0	5	1	2
" 6	0	1	3	4	" 21	0	4	1	3
" 7	0	1	1	4	" 22	0	0	0	3
" 8	0	3	1	3					
" 9	0	5	1	4	Average	0.44	1.92	1.78	3.17

In the above exhibit a great difference is seen to exist between the averages of the two points of observation.

Whether this difference is due to the emission of gases destructive to a large portion of the atmospheric ozone naturally present, or whether the same interferes with a deposition of liberated iodine, or whether the apparent absence is due to an excess of moisture sufficient to decolorize the paper, are inquiries that can only be determined by experimentation. The excess of humidity naturally present at such a point appears to offer some explanation.

The experiments over the swamp were made by suspending slips of test-paper about three feet above the soil. They were exposed to a free circulation of the air but protected from the sunlight. During the time these observations were being taken the several families residing near this swamp suffered more or less from frequent attacks of periodic fever.

With a view to ascertain the comparative results of observations for the presence of ozone as it existed at two differing points of elevation, fifty-four observations were conducted at the elevations of four and fourteen feet from the ground.

The following exhibit contains the results of these observations.

EXHIBIT F.

	Higher Elevation.		Lower Elevation.		Remarks.
	Night.	Day.	Night.	Day.	
	4	9	7	9	Rain all day.
	8	8	9	7	Rain all day.
	7	7	8	8	Rain 1 day.
	9	5	8	5	Rain n night.
	4	4	8	6	Rain in morning.
	7	5	8	5	Rain all day.
	4	5	5	6	Fair.
	5	5	6	5	Fair.
	4	3.5	4	3.5	Fair.
	4	3.5	3	3.5	Rain in night, paper lost color.
	1	4	2	4	Fair.
	2	3	2	3	Fair.
	3.5	.....	3.5	.....	Fair.
	1	4	3.5	4	Fair.
Average..	4.53	5 07	5.50	5.30	

These observations do not demonstrate that actually a greater quantity of ozone was present in the lower stratum of the air than in the upper. The variation of the degree of moisture at the two points may lead to an explanation; yet, the excess of ozone at the lower plane seemed to correspond with presence of aqueous precipitation and a consequent pulverization of the raindrops. This might have led to the generation of ozone by increase of electrical influences, as spoken of by Fox in his work on "Ozone."

At the suggestion of Dr. Baker, Secretary of our State Board of Health, who has made many observations upon the influences of ozone, and to whom I am indebted for much kind assistance, I directed my attention to the relative quantity of ozone existing near decomposing animal excreta as compared with that found one hundred feet distant from any such contaminating influence.

EXHIBIT G.

Date. 1879.	Impure Air.		Pure Air.	
	Night.	Day.	Night.	Day.
June 9	2.5	3.5	4.5	3.5
" 10	2	2.5	3.5	3.5
" 11	1	3	2	3
" 12	2	2.5	2.5	3
" 13	3	.....	3.5	
" 14	3	3	3.5	3
Average	2.3	2.9	3.3	3.2

Both ozonoscopes were suspended at a distance of six feet from the ground, and both were subjected to the influence of the same degree of atmospheric humidity. It is therefore probable that the variation in the degree of coloration was due to the exposure of one ozonoscope to the influences of rapidly oxidizing effete material.

In considering the influences existing that might have occasioned an error in the results of the observations recorded in the foregoing exhibits, none is more apparent than that of excess of moisture. Some atmospheric conditions associated with twenty observations where there was a total absence of coloration are shown in the succeeding exhibit.

EXHIBIT H.

NUMBER OF CASE.	Lowest Temperature.	Velocity of Wind,—Miles per Hour.	Relative Humidity.	REMARKS.
1	44	2	75	Few clouds.
2	37	2	96.6	Cloudy. Frost on test-paper.
3	34	2	96.6	Frost.
4	32	2	96.6	Slightly cloudy.
5	32	2	96.6	Slightly cloudy.
6	32	2	96.6	Slightly cloudy.
7	32	2	96.6	Slightly cloudy.
8	25	2	100	Slightly cloudy.
9	41	2	96.6	Slightly cloudy.
10	45	12	100	75 per cent of clouds. Heavy dew.
11	44	2	100	Heavy dew.
12	57	2	100	Smoky,—75 per cent of clouds.
13	44	2	85	Heavy dew.
14	44	2	100	Heavy dew. No clouds.
15	44	2	100	Heavy dew.
16	59	2	100	Heavy fog,—50 per cent clouds.
17	46	2	96.6	Heavy fog,—75 per cent clouds.
18	49	2	96.6	Heavy dew. No clouds.
19	25	2	100	Frost. No clouds.
20	57	2	96.6	90 per cent clouds.

The above cases represent nearly all those of complete obliteration of color occurring during a period of three years. *These all occurred during the night observation.* With each case there was nearly, or quite, a complete saturation of the atmosphere with moisture.

In one hundred and forty-three observations taken by myself to determine the relative value of Schönbein's test when exposed to the air dry, and when exposed after having been previously moistened, I discovered an excess of coloration in the dry slip over that of the wet slip forty times, the largest excess being five degrees of coloration. During these forty instances the sky

was covered with one hundred per cent of clouds. In only six instances in the whole number of observations was the wet slip colored in excess of the dry when there was one hundred per cent of clouds. When there was less than seventy-five per cent of clouds the *moistened* slip was more greatly colored than the dry. While I at one time thought it possible that some electrical phenomena might be a cause of the ozonoscopic conditions just mentioned, I am now disposed to believe the cause to bear relation more to hygrometric states influenced by the varying per cent of clouds. A *dry* slip is exposed to the influences of these conditions and a gradual deposition of the moisture upon the same, aids rather than retards the coloration. But when a *moistened* slip is exposed to the influences of these conditions of the atmosphere it is liable to become blanched as fast as the iodine is deposited. Cornelius B. Fox says: "If the iodide of starch be so slightly soluble in water, how does it happen that these tests often and rapidly become when they are wet, completely blanched? If a deeply tinted Negretti's test be cut into small portions and placed in a little distilled water, some difficulty will be experienced in rendering the fragments colorless. Many hours, and perhaps a day or two will elapse before all color is removed from them. If, on the other hand, a colored Negretti's test be kept in a moist condition with distilled water, conducted to it by a fine thread of lamp-wick or darning-cotton, the color will rapidly disappear. In the latter experiment the iodide of starch becomes vaporized from the test."

It is thus proved that in more than one-fourth of the cases where observations are taken with Schönbein's test, providing the same proportion of days all cloudy existed as above illustrated, the dry slip will exhibit the greatest coloration, and in the remaining cases the deepest tint would be exhibited by means of the wet slip.

Through the kindness of a friend residing in Litchfield county, of the State of Connecticut, I was enabled to secure results of ozonometric observations among its non-malarious hills, during the summer of the year 1878. The record of these observations is presented in the following exhibit in comparison with the record of observations taken at this point where periodic fevers prevail.

EXHIBIT I.

DATE. 1878.	LITCHFIELD COUNTY, STATE OF CONNECTICUT.		OTISVILLE, MICHIGAN.		DATE. 1878.	LITCHFIELD COUNTY, STATE OF CONNECTICUT.		OTISVILLE, MICHIGAN.	
	Night.	Day.	Night.	Day.		Night.	Day.	Night.	Day.
Aug. 6	4	5	3	3	Sept. 9	0	2	4	2
" 7	4	4	3	3	" 10	0	3	2	3
" 8	3	3	3	4	" 11	0	4	2	2
" 9	4	6	3	4	" 12	2	3	------	3
" 10	4	4	3	4	" 13	1	3	4	4
" 11	3	4	1	1	" 14	0	2	4	1
" 12	3	4	* 0	3	" 15	2	3	1	2
" 13	1	3	3	3	" 16	0	2	5	3
" 14	0	2	4	3	" 17	0	3	2	3
" 15	0	3	4	3	" 18	0	3	3	3
" 16	2	3	4	3	" 19	------	3	------	3
" 17	2	3	1	3	" 20	2	2	3	4
" 18	2	4	1	3	" 21	1	2	3	3
" 27	0	3	† 0	3	" 22	2	3	1	3
" 28	1	3	3	3	" 23	0	2	3	2
" 29	1	3	4	4	" 24	0	2	3	4
" 30	1	2	1	4	" 25	2	3	3	3
" 31	0	3	3	4	" 26	1	2	4	3
Sept. 1	3	2	3	2	" 27	3	2	§ 1	2
" 2	0	2	4	3	" 28	1	3	3	3
" 3	0	3	4	4	" 29	0	3	4	2
" 4	2	1	3	3	" 30	0	2	4	2
" 5	4	1	‡ 0	3	Oct. 1	0	2	3	1
" 6	2	3	‡ 0	3	" 2	2	3	4	3
" 7	0	2	4	4	" 3	3	3	3	2
" 8	1	3	4	2	Average ..	1.38	2.82	2.77	2.90

* Heavy dew in morning.
† Great amount of moisture in night.
‡ Fog in morning.
§ Frost in morning.

The small quantity of ozone exhibited for the night in the record obtained from Connecticut, impresses one with the belief that some atmospheric conditions existed that failed to testify to the actual amount of ozone present. Excess of moisture appears to have been one of these conditions as reported by the observer to me.

As local conditions greatly affect the test for ozone, the observations that might be taken in other parts of this mountainous country might present results more in unison with the popular belief that active oxygen exists in greatest quantities amidst the mountains.

As spoken of, the velocity of the wind, if it is great, and the air is saturated with moisture, will occasion a decolorization of the test-paper unless protected

from its influence. But if a test-paper be exposed to the free action of the wind when the air is not saturated with moisture a greater coloration will often occur than when *protected* from the action of the wind.

COLORATION OF BOTH SIDES OF THE TEST-PAPER.

Although Schönbein's test is considered the most reliable in use for the detection of ozone, something yet remains to be done in order to render even this test perfect, exclusive of the effects of such conditions as already have been mentioned.

In the manufacture of the test-paper used in this State, only one side of it is covered with the preparation that by chemical alteration and change of color enables us to estimate the relative amount of ozone present.* In examining the test-paper, after exposure, I have frequently found that the side of the paper upon which there was none of the preparation, exhibited the greater coloration. To determine, if possible, the cause of this, I recorded in a series of observations, as shown in the following exhibit, the degrees of coloration that appeared upon both sides of the paper. In the first series the number of observations was 34. In nineteen of these observations there was the deeper coloration on the side not having the preparation upon it. The same degree of coloration occurred upon both sides at once in 13 instances. There was a deeper coloration on the side containing the compound of starch and iodide of potassium, twice.

*[Some test-paper prepared in Germany, examined by me, seemed to be like Swedish filter-paper; it was of loose texture, and on exposure was soon colored on both sides alike, but the degree of coloration was more uniform under varying conditions than it is on the paper used by the observers for this Board. The loose-texture paper seemed to be exceedingly prone to take on a color equaling from 2 to 4 on our scale, but did not seem to be as ready to show shades above or below those. On comparing it with our paper, it was found to fade quicker after being moistened, and I came to believe that it was not so accurate as is ours for the purpose of indicating the relative quantities of ozone in the atmosphere.—H. B. B., Sec. S. B. of H.]

EXHIBIT K. *First Series of Observations on the Influence of Relative Humidity upon the Coloration by Ozone of Both Sides of the Test-paper.*

	Coloration, Marked on a Scale of 10°.		Relative Humidity.—Per Cent of Saturation of the Air at the Beginning of the Exposure when the Coloration was as Specified.			
	On Front of Test-paper.	On Back of Test-paper.	All Observations in the Series.	Greatest Color on Front of Paper.	Same Color on Both Sides.	Greatest Color on Back of Paper.
	2	2	82.3	.....	82.3	.....
	1	2	95.3	.....	.....	95.3
	2.5	3	95.3	.....	.....	95.3
	2	3	76.0	.....	.....	76.0
	2	3.5	84.2	.....	.....	84.2
	2.5	3.5	76.0	.....	.....	76.0
	2.5	3.5	74.9	.....	.....	74.9
	2.5	3.5	87.1	.....	.....	87.1
	1	2	100.0	.....	.....	100.0
	3.5	3	89.3	89.3	.....	.....
	1.5	2.5	81.4	.....	.....	81.4
	3.5	3.5	100.0	.....	100.0	.....
	3	3	100.0	.....	100.0	.....
	2	3.5	76.9	.....	.....	76.9
	2.5	2	100.0	100.0	.....	.....
	3.5	3.5	100.0	.....	100.0	.....
	2	3	53.7	.....	.....	53.7
	2.5	3.5	87.1	.....	.....	87.1
	2	2	93.2	.....	93.2	.....
	3	3.5	86.4	.....	.....	86.4
	3	4	85.8	.....	.....	85.8
	2.5	2.5	92.6	.....	92.6	.....
	3	3	92.8	.....	92.8	.....
	2.5	3.5	86.6	.....	.....	86.6
	2.5	3.5	93.1	.....	.....	93.1
	3	3.5	71.0	.....	.....	71.0
	3.5	3.5	100.0	.....	100.0	.....
	3	3	94.4	.....	94.4	.....
	3	3	100.0	.....	100.0	.....
	2.5	2.5	95.0	.....	95.0	.....
	3	3.5	85.8	.....	.....	85.8
	3	3	80.5	.....	80.5	.....
	1.5	2.5	69.4	.....	.....	69.4
	2.5	2.5	100.0	.....	100.0	.....
Total.....	85.5	102.5	2986.1	189.3	1230.8	1566.0
Averages.	2.51	3.01	87.8	94.7	94.7	82.4

Assistant Prof. F. S. Kedzie, of the Agricultural College, at Lansing, Mich., suggests that these conditions may appear from the existence of a thin film, or tough pellicle sometimes formed over the starch compound, thus preventing the access and ready action of ozone in setting free the iodine; the degree of coloration varying according to the condition of the surface of the test-paper, and according to certain conditions of atmospheric humidity existing at the time of the exposure of the test.

It is probably true that varying conditions of moisture have a marked influence with other influences producing the results referred to.

In 16 of the 19 instances when there was a deeper tint on the back of the paper the relative humidity was less than 90 per cent, ranging from 53 per cent upwards. In 3 instances where there was the deeper tint upon the back the relative humidity exceeded 90 per cent. In only one instance did the relative humidity amount to 100 per cent. In only three instances out of the 15 when the front had a coloration equal to that upon the back of the test-paper, or a greater coloration, the relative humidity was less than 90 per cent. In 12 instances when the coloration upon the front was equal to, or greater than that upon the back, the relative humidity exceeded 90 per cent. In 7 of the 15 instances when the degree of coloration on the front was equal to, or greater than, that upon the back, the relative humidity was 100 per cent. This would seem to prove that conditions of moisture have a decided influence in affecting the phenomena in question.

After an exposure of the test-paper for a time sufficient to produce a coloration, if there is a deeper tint upon the back than on the front side a removal of a thin portion of the starch from the front will not disclose as deep a tint as there is upon the back, nor will as marked a coloration appear in front until all the starch is removed, when both sides of the paper exhibit the same degree of discoloration.

The paper which is used in preparing the test readily absorbs a portion of the solution of iodide of potassium contained in the starch-compound, and on exposure to oxidizing elements exhibits chemical change as well as the prepared starch. The difference in the texture of the paper itself from the texture of the starch-compound would suggest the existence, in the paper and compound, of differing qualities for the absorption of moisture.

An *average* degree of moisture seems to be a condition rendering the paper saturated with a solution of iodide of potassium in starch-water a more delicate test than the starch and iodide of potassium test. Where *excess* of moisture obtains, the starch and iodide of potassium test appears to be the most reliable.

The preceding exhibit does not contain as extensive a series of observations as we would wish to have in order to establish conclusive evidence, but was all we had at the time of writing the foregoing. Since that time additional observations have been made, and the results are shown in the following exhibit.

EXHIBIT L.—*Second Series of Observations on the Influence of Relative Humidity upon the Coloration by Ozone of Both Sides of the Test-paper.*

	Coloration, Marked on a Scale of 10°.		Relative Humidity.—Per Cent of Saturation of the Air at the Beginning of the Exposure when the Coloration was as Specified.			
	On Front of Test-paper.	On Back of Test-paper.	All Observations in the Series.	Greatest Color on Front of Paper.	Same Color on Both Sides.	Greatest Color on Back of Paper.
	3.5	3.0	100.0	100.0	----------	----------
	3.0	3.5	85.8	----------	----------	85.8
	3.5	4.5	75.5	----------	----------	75.5
	2.5	3.0	86.2	----------	----------	86.2
	1.5	3.0	83.4	----------	----------	83.4
	4.0	4.0	100.0	----------	100.0	----------
	3.5	3.0	100.0	100.0	----------	----------
	5.0	4.0	91.3	91.3	----------	----------
	3.5	2.5	85.8	85.8	----------	----------
	3.0	3.0	74.5	----------	74.5	----------
	2.0	3.5	75.9	----------	----------	75.9
	3.0	3.0	84.0	----------	84.0	----------
	3.0	3.0	91.4	----------	91.4	----------
	3.5	4.0	83.4	----------	----------	83.4
	3.0	2.5	83.4	83.4	----------	----------
	7.0	3.0	93.1	93.1	----------	----------
	3.0	2.0	100.0	100.0	----------	----------
	8.0	3.0	91.4	91.4	----------	----------
	3.0	2.5	91.6	91.6	----------	----------
	4.0	2.5	100.0	100.0	----------	----------
	3.0	2.5	100.0	100.0	----------	----------
	3.0	3.0	90.6	----------	90.6	----------
	2.5	4.0	100.0	----------	----------	100.0
	3.5	3.5	100.0	----------	100.0	----------
	4.0	4.5	79.7	----------	----------	79.7
	2.5	2.5	92.6	----------	92.6	----------
	2.5	3.0	84.0	----------	----------	84.0
	3.0	3.0	100.0	----------	100.0	----------
	4.0	3.0	92.6	92.6	----------	----------
	2.0	3.0	79.3	----------	----------	79.3
	2.5	3.0	69.6	----------	----------	69.6
	3.5	2.5	93.2	93.2	----------	----------
	3.0	3.0	100.0	----------	100.0	----------
	4.0	3.5	92.6	92.6	----------	----------
	3.5	3.5	100.0	----------	100.0	----------
	8.0	6.0	100.0	100.0	----------	----------
	6.0	5.0	90.5	90.5	----------	----------
	3.5	2.5	100.0	100.0	----------	----------
	3.0	4.0	83.4	----------	----------	83.4
Totals.....	139.5	128.5	3524.8	1605.5	933.1	986.2
Averages...	3.58	3.29	90.4	94.4	93.3	82.2
Av. of both Series.....	3.08	3.16	89.2	94.5	94.1	82.3

In the foregoing exhibit the statement of the relative humidity is made for the time when the test-paper was put out for exposure. In nearly all the cases where there was *less* coloration on the back of the paper than on the front, and a relative humidity of *less* than 90 per cent at the time the test-paper was put out, the relative humidity was over 90 per cent when the paper was compared with the scale, showing that there was an increase of moisture after the paper was first exposed.

When the back of the paper was the most deeply colored, and on its first exposure the relative humidity was more than 90 per cent (another exception to the general rule), there was almost always a considerable decrease in the relative humidity.

SUGGESTIONS FOR IMPROVED METHODS OF OBSERVATIONS.

Negative results obtained by the exposure of Schönbein's test-paper in dwellings seem to be due as much to elements affecting the liberated iodine as to absence of ozone. This test, then, seems to be of little use in determining the presence of ozone in dwellings.

Valuable as are the general results of ozonometric observations, it is obvious that many of them are clouded with error. How to remove these errors is a subject important to all those interested in the study of ozonometry as to its meteorological, physiological, or pathological relations. Much study is yet necessary before the best methods for accurately estimating the quantity of ozone present at any time in the atmosphere will be determined. In the use of Schönbein's test, in order to obtain the maximum results of an observation where it is necessary to guard against excess of moisture, the exposure of a dry and wet slip at the same time, would appear to be a proper method to adopt; also to suspend them at such points as where the condensation of vapor would be least liable to occur. To make the period of time less for the exposure of the test-paper would be another means to obtain maximum results of an observation.

It is well known that by increased velocity of the wind more ozone may be carried to a given point than there would be if the velocity were less. To determine the quantity of ozone, therefore, liable to affect the health of an individual subjected to the influence of rapid currents of air, it is desirable to expose the test-paper to the same current. But the loss of the liberated iodine as a result of such exposure, suggests that in order to obtain the *deepest* coloration the slip must be protected from too great velocity of the wind, especially when there is an excess of moisture in the atmosphere.