ATMOSPHERIC SMOKE VERSUS HEALTH[1]

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In a paper entitled *The Problem of Smoke Abatement* which I read before this academy three years ago, I pointed out numerous ways in which atmospheric smoke has been found to be harmful. In attempting to discuss at this time a particular phase of the subject, namely, atmospheric smoke in its relation to health, I am faced by the difficulty that the various harmful effects of atmospheric smoke are more or less interrelated. For example, health factors cannot be wholly separated from economic factors. Men have died because they could not afford the price of sunshine or of proper food. The depressing effects of bad working conditions take their toll not only in shortening life but in reducing production and profits.

Investigators of the effects of atmospheric pollution have represented a wide variety of professions including medicine, botany, engineering, physics, and chemistry. Many of the problems involved are difficult and the abundant literature is often conflicting. No one individual or single professional group can qualify to speak with authority on all phases of the subject. Only through cooperative study and the exchange of viewpoints can the best results be hoped for.

With respect to physical and chemical damage caused by smoke, recent publications (Baines, 1924; Cohn and Ruston, 1925) show that many of the earlier conclusions are confirmed and that the huge economic losses have not been overestimated. There is a growing tendency to resolve smoke into its components and to study the effects of the component parts. Tar as a rule is more objectionable than ash, and sulfuric acid is more so than either. Sulfuric acid is always present in the smoke from coal and its effects upon vegetation when present in the atmosphere or in irrigation waters has been the subject of careful scientific research under both laboratory and field conditions (Langsdorf, 1927). These studies have led botanists to conclude that the injury to vegetation by smoke is not due primarily to the clogging of the leaf pores (the stomata) by the sooty deposits as was formerly believed, nor chiefly to the interference with pollination, but that the most serious cause of damage is the poisonous acid.

Ordinary coals may contain from 1.5 to 3 per cent of sulphur. Certain Illinois coals have been found to run as high as 4.75 per cent. Tests on the composition of locomotive stack gases at Altoona,

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Pennsylvania (Langsdorf, 1927) showed that about 33 per cent of the sulphur in coal escapes into the atmosphere. On the assumptions that this figure holds for Knoxville, that the coal contains an average of 2 per cent sulphur, and that 425,000 tons are burned annually, a total of about 8,500 tons of sulfuric acid per year would be carried into the atmosphere. The effect of such acid upon soil is cumulative. In St. Louis it is asserted, that as a result of the accumulation of acid in the soil, flowers are injured, blue grass lawns cannot be maintained, and the stately laurel oaks which adorned the city less than thirty years ago have largely disappeared. Because of such damage the authorities of the Missouri Botanical Garden are developing a new tract forty miles beyond the city limits.

The task of determining the effect of atmospheric smoke upon health is a more difficult one than that of determining its injurious effects upon objects of the vegetable and mineral kingdoms. Opinions have been expressed where convincing scientific proof was lacking. Innumerable indications point to harmful effects and there is no lack of medical opinion that smoke is responsible for many ills. The important studies of Dr. Louis Ascher of Konigsberg and other statistical studies have been the basis for many of the opinions which have been expressed. Dean A. S. Langsdorf of Washington University, St. Louis, has recently made a critical examination by the statistical method (Langsdorf, 1927). Such studies seek a correlation between the prevalence of smoke and the mortality due to diseases, especially those of the respiratory tract, and pneumonia in particular (White and Marcy, 1912, 1914). The existence of such correlation is a matter of established fact. On the ground that it is unscientific, Dean Langsdorf objects to the conclusion that the existence of a definite correlation between two factors is proof that they stand in the relation of cause and effect. To this we must agree. As an illustration of the method we may examine a study made in St. Louis for the period 1921-26. The number of deaths due to pneumonia, taken from the official report of the Division of Health, was plotted against the number of smoky days recorded by the local office of the U. S. Weather Bureau. A striking correlation was found, more deaths occurring in the winter when the smoke was the densest. It is conceivable, though hardly probable, that pneumonia, since it is predominatingly a winter disease, would have caused no fewer deaths if no smoke had been in the air. When temperature, humidity, and fog which undergo periodic and seasonal variations were plotted against death from pneumonia, an unmistakable correlation was found to exist in each case.

The death rate from pneumonia in Boston, Massachusetts, was found by William C. White and C. H. Marcy (1912, 1914) to be third in a list of fifteen large cities, being exceeded by Chicago and Pittsburgh only, yet the city of Boston is comparatively free from heavy smoke. Commenting upon this situation Dr. John S. Fullerton says, "I would expect Boston to have a greater mortality from pneumonia

than Pittsburgh, on the sole basis of fact that Boston has relatively more people in the pneumonia ages. I would expect Chicago to have a higher pneumonia mortality than Pittsburgh, because there is a pneumonia obsession in the minds of the medical profession of Chicago."

It is not the statistical method in itself that is objected to, but the drawing of conclusions from insufficient data. Many diseases are undoubtedly the resultant of numerous contributing causes. The more definite information which is made available on any problem whether it be statistical or experimental the nearer will be the approach to the correct solution to that problem.

The opinion has been expressed frequently that atmospheric smoke causes serious irritations of the sensitive membranes of the eyes, ear, nose, and throat. If this be true a correlation between the number of eye, ear, nose, and throat specialists in the larger cities of the United States and the prevalence of atmospheric smoke might well be expected to exist. With the view of deciding this point a questionnaire was sent out from the Department of Chemistry of The University of Tennessee to the Chambers of Commerce in 180 cities in the United States requesting data for the years 1910, 1920, and 1929.[2] 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. In a number of cities where smoke abatement ordinances are in force no systematic measurements of the prevalence of smoke had been made. From the data which we assembled for about 50 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 their population than any other cities in the country, yet they are remarkably free from the smoke nuisance. Among our nearest neighbors, Asheville, N. C., is very high in the number of specialists per capita. Their smoke nuisance is not excessive.

In the course of this investigation, we learned that a similar study had recently been made by Dr. Arthur G. Proetz,[3] who is a nose and throat specialist in St. Louis and a member of the Smoke Abatement League's Committee on Damage and Health.

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 about as unscientific in my opinion as to conclude that the existence of a certain correlation between deaths from pneumonia and the prevalence of smoke is proof that these conditions stand in the relation of cause and effect. A great many factors may

[2]Replies to these were classified and studied by Mr. George C. Calhoun as a part of his thesis on "Smoke Investigations," The University of Tennessee, 1930.

[3]Personal communication from Dean A. S. Langsdorf, Washington University, St. Louis, Mo., April, 1930.

affect 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 on this list in the average annual number of days of fog. Asheville, N. C., is first and Seattle, 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 and the ultraviolet. It was in 1924 that the interrelation between the latter and vitamin D, the antirachitic vitamin, was established. In 1930 Morris Fishbein, Editor of the *Journal of the American Medical Association*, stated that although but seven years had passed since the identification of vitamin D as distinct from vitamin A, thousands of investigations had been made and that such progress had been made as no one would have dreamed possible seven years earlier (Blount and Cowan, 1930).

Through its preventive and constructive agencies, medicine has captured another hill in its war to free man from the fear of disease. This hill overlooking our smoke-laden cities is commanded by the new knowledge concerning vitamin D. Ten years ago the suggestion that vitamins might be correlated in some way with atmospheric conditions would have been received as a mere guess. Today such a correlation appears to be definitely established in so far as vitamin D is concerned.

As early as 1650 the disease known as rickets, which is characterized by malformation of bone, was described by Glisson (McCollum and Simmonds, 1928) who attributed it to unsatisfactory hygienic conditions. It was little understood until it became the subject of intensive researches within the last few years. Only the briefest reference to these investigations can be made here.

The existence of an antirachitic vitamin was first demonstrated by Mellanby (1918) less than fifteen years ago. Mellanby, however, identified his antirachitic vitamin with vitamin A. Hess discovered that some children having a diet rich in vitamin A developed rickets; and McCollum (McCollum, Simmons, Becker, and Shipley, 1922; McCollum and Simmonds, 1928) with his co-workers at Johns Hopkins University found that a sample of cod-liver oil in which the vitamin A had been destroyed by oxidation still retained its antirachitic power. This new vitamin, known as vitamin D, is not merely a curative and preventive of rickets; it plays an important role in the normal formation of bone in the body (Gamble, 1928).

In 1919, Huldschinsky (1928) discovered that the radiations from the quartz mercury lamp and sunlight would bring about rapid healing of rickety bones in children.

Hess, Steenbock, (Hess and Weinstock, 1924; Hess and Unger, 1920; Steenbock, 1924; Steenbock and Black, 1924) and others in 1924 discovered, further, that certain foods which were without antirachitic power developed this power when exposed to ultraviolet light. A. J. Pacini (Luckiesh and Pacini, 1926) of the General Electric Company discovered that cholesterol derived from the blood, brain, or bile of animals which have been kept in the dark is unable to support animal life, but when the animals are exposed to ultraviolet radiation, the cholesterol is activated and when extracted is valuable as a "vitalizing" agent. Pacini also showed that sterile water carrying a few dead bacteria when irradiated acquires growth producing characteristics; that water thus vitalized behaves much in the same manner as does ultraviolet radiation itself. The use of ultraviolet rays for sterilizing water thus appears to have an advantage over other methods of sterilization.

These discoveries throw new light upon the vicissitudes experienced by the spaghetti industry in New York some years ago. It was the custom of foreigners in the down-town districts to loop their spaghetti dough on broom handles and hang it out on the fire escapes to dry in the sun. When the market for home-made spaghetti was established the industry grew rapidly and hundreds of fire escapes could be seen festooned with spaghetti along certain streets on bright sunny days. Fire ordinances were eventually enacted forbidding this practice. Within three months after the substitution of indoor drying for sun drying, complaints were registered against the quality of the product. Yet only the method of drying had been altered. Luckiesh and Pacini of the General Electric Company's research staff believe that the difficulty was due to the lack of ultraviolet rays and that the complaints were well-founded.

That these discoveries should have aroused much interest in the chemical composition of vitamin D is not surprising. It was for important researches on this subject that Windaus received the Nobel Prize. The unsaponifiable portion of cod-liver oil consisting largely of sterols (solid alcohols) is strongly antirachitic. The discovery of this fact led to the hypothesis that cholesterol ($C_{27}H_{46}O$) might be the parent substance from which vitamin D is formed by ultraviolet light; but elaborate purifications of the alcohols pointed to ergosterol ($C_{27}H_{42}O$) as the chemical which is converted into vitamin D under the influence of ultraviolet light. More recently, photochemical studies of ergosterol by Kon (1928) and others (Bourdillon, Jenkins, and Webster, 1930) point to the probability that the mother substance of vitamin D is not ergosterol itself, but an impurity. Samples of ergosterol prepared by Bills (Bills and Wirick, 1930) and his associates were 400,000 times as active as ordinary cod-liver oil although the ergosterol had been transformed only partially into vitamin D. Ergosterol which has been properly irradiated is reported to be a million times as potent as ordinary cod-liver oil. A single gram would be sufficient to give positive

results with several million rachitic rats. A preparation of irradiated ergosterol known as viosterol is now prescribed by the medical profession. While its use in place of cod-liver oil has the advantage of avoiding the digestive disorders that may result from large doses of the latter, it is recognized that too much vitamin D may be even more injurious than too little. Death from overdoses has been attributed to excessive deposition of calcium salts in the blood stream. However, the experiments of Bills and Wirick on rats showed that the effect of overdosage with activated ergosterol became distinct only after about 4,000 times the minimum antirachitic dose has been administered over a period of time.

Now if vitamin D is essential to the normal activities of calcium and phosphorus in the body as appears to be certain, and if ergosterol or a kindred associate in human tissues is converted into this vitamin only under the influence of ultraviolet light, the need of pure sunshine is apparent. Ultraviolet light does not pass through ordinary window glass and it is largely absorbed by dust and smoke in the atmosphere. Using smoke similar to that of our industrial cities as a screen, Pacini proved that rats suffering from rickets failed to recover just as they would fail to recover when screened off by ordinary window glass. The Health Department, City of Knoxville, reports that 19 out of 116 children examined recently at the free clinic were suffering from rickets. The tragedy is that some of these children are deformed for life, treatment not having been taken soon enough.

In 1927, Bundesen (Bundesen, Lemon, Falk, and Coade, 1927) and his co-workers showed that the light filtered through the air over the stockyards in Chicago was low in ultraviolet light. More recently Shrader, Coblentz, and Korff (1929) made a careful series of tests to determine the effect of atmospheric pollution upon the incidence of solar ultraviolet light in the city of Baltimore, Maryland. From their observations using five different methods they conclude that only 50 per cent as much ultraviolet light reaches the city as the country surrounding it.

A study of smoke control in Pittsburgh made by Meller in 1924 to ascertain the results of ten years' enforcement showed that whereas the amount of tar was reduced 70 per cent, the total deposit had increased about 40 per cent. These observations suggested to Shrader and his co-workers the desirability of measuring the relative absorptive capacity for ultraviolet light of various types of dust. From their laboratory observations, they concluded that carbon in the form of tarry products is more inhibitive to the incidence of ultraviolet light that siliceous materials. In one series of experiments the percentages of ultraviolet light transmission were 60 for fuller's earth, 54 for street sweepings, and 14 for lamp black.

These same investigators also made determinations of the incidence of bacteria in the air. They found that the peak of bacterial contamination lies at the time of year when the incidence of ultraviolet light is least.

It is possible that the greater prevalence of disease in winter than in summer may be influenced greatly by the paucity of ultraviolet light during the winter months. When the sun is 75 degrees from the zenith, the air mass through which light rays pass in reaching us is about four times that when it is directly overhead (Luckiesh and Pacini, 1926). The ultraviolet rays are filtered out to a much greater extent than are the longer waves. Measurements on the top of Mount Wilson showed that the following relative amounts of energy reached the observer: 4000-302-117; 3800-239-74; 3600-192-49; 3400-135-26; 3200-58-8; 3000-25-2. In each series the first figure represents the wave length in angstrom[4] units, the second the relative energy when the sun was overhead, and the third the energy when the sun was 75 degrees from the zenith. The ultraviolet reaching the earth when the sun is far from the zenith is thus seen to be quite small. It follows therefore that the relative quantity of ultraviolet waves in sunlight reaching the earth must fall off rapidly as we move away from the equator. Rickets is practically unknown in the tropics. In the temperate zones, its prevalence increases rapidly with increases in latitude (Gamble, 1928).

It has been argued that if ultraviolet light is very important, the people of the tropics should be the most healthy in the world and the Eskimos should have long since perished. Nature in the course of time has adjusted peoples of different races to different climatic conditions. It appears to be certain that the negro has a different susceptibility to ultraviolet light than the whites. An imaginative mind might conceive of a race of men so changed by evolutionary processes as to thrive best in clouds of dust and chemicals, but that does not change present conditions. The negro is far more susceptible to certain diseases in America than is the white and it is unlikely that the Eskimo would be able to survive the tropics although he has not yet become perfectly acclimated to his present habitat. The migration of people to climates to which they are constitutionally ill-suited may be the cause of various diseases unknown to their ancestors. History reveals no evidence of rachitic deformities among the light-loving peoples of long ago when distant migrations were virtually unknown.

During the last few years industry has given considerable attention to the problem of good lighting. Numerous experiments have proved that proper lighting pays for itself many times in increased production and profits. Normally the eye consumes from 10 to 15 per cent of the total energy expended by the body (Anderson, 1928). Eye strain therefore causes fatigue and slower perception. As a result of this lowered efficiency production is lowered and accidents become more frequent. Definite experimental graphs, showing the relative reaction times of workmen at varying degrees of illumination, have been plotted. They show that reaction time decreases rapidly with increase of illumination. This has a definite bearing

[4]The angstrom unit is equal to approximately one-tenth of a millimicron.

upon the frequency of accidents. It is an established fact that the number of industrial accidents has increased as plants have added to their schedules more and more shifts using artificial lighting. Since our growing industrialism makes us more and more dependent upon artificial lighting, it is important that light of good quality and of the proper intensity be provided. Much improvement has been made. Not only have the use of higher candle power and better distribution of light proved to be highly beneficial, but ultraviolet lamps also are finding their place.

In smoky cities, it has been found economical to spend considerable sums for cleaning windows and light fixtures. Warren (1931) states that the depreciation in light output of lighting equipment used under average conditions runs from 5 to 10 per cent during the first month. He recommends that washing of lighting units be put on a regular monthly schedule. Littlefield (Anderson, 1928) has reported that by increasing the intensity in foot candles from 3.3 to 7.5 the U. S. Post Office showed an increase in production of 13 per cent. A towel manufacturer increased production 15 per cent by increasing the foot candles from 3.3 to 10 and by the installation of reflectors. These data are remarkable when it is remembered that the total cost of adequate and proper lighting is usually estimated at an average of only 1 per cent of the production expenses. A higher candle power than is commonly used and a better quality of light make for easier supervision, better order, cleanliness, and neatness in the plant. They make for healthier employees. All concerned are therefore happier.

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