WEATHER, CLIMATE AND POLLUTION

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Some pollutants are restricted to just one resource, air, soil or water. But many more are found in, or are dispersed through, all three.

Air pollution itself is not considered a major problem in North Dakota, but many potential pollutants are dispersed into the atmosphere before becoming problems in the soil or in water bodies. Application of chemicals for weed, disease and insect control is an example. The state of the atmosphere (weather) at the time of application is extremely important in determining how much of the material gets to the intended location and how much lands on unintended targets.

Air, that normally invisible and odorless substance which we breathe, which sustains life and fire, is the internal machinery in our weather "factory." Air in its natural state is much more than just a mixture of gases. It contains substantial amounts of liquid and solid particles which may be thought of as impurities that have vital roles in weather-making. For instance, water vapor, dust and other non-gaseous impurities in the air are common and necessary ingredients in producing clouds and, eventually, rain.

Many atmospheric pollutants originate from natural sources. Dust particles may be brought into the atmosphere by winds blowing over dry and

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barren soils. Ice crystals are whipped into the air from snow cover, while smoke and other dust particles originate from volcanic eruptions and forest fires. Sea salt nuclei are brought into the air from oceans by wind action. Bubbles of air in the ocean reach the water surface and then, bursting, eject numerous small droplets in the air. The water evaporates and salt particles are carried away by the wind. At certain times of the year huge amounts of spores and pollen are found in the atmosphere.

The more hazardous air pollutants, however, result from the activities of man. These man-made atmospheric impurities include carbon monoxide, particulate matter (particles of solid or liquid substances), sulfur oxides, hydrocarbons and nitrous oxides. These pollutants are produced through fuel combustion, solid waste disposal, industrial processes, agricultural burning and coal waste fires (1).

Historically, the atmosphere has been used as a convenient vehicle for diluting and dispersing by-products of industry and agriculture. However, its capacity to self-cleanse is limited. Ninety-nine per cent of the total mass of our atmosphere is contained just 19 miles above the earth. And since 80 per cent of this atmospheric mass is below the altitude of seven miles, it is convenient to think of the air around the earth being as thin as the rind of a melon, or possibly the coat of varnish on a classroom globe. This atmospheric shell is all-important to us; certainly we must **protect** it, and more important, we must learn to **manage** it.

THE EFFECT OF WEATHER ON THE DISPERSION OF AIRBORNE POLLUTANTS

Once air pollutants such as gaseous compounds and solid particles are deposited in the atmosphere, their dispersion is dependent upon the physical properties of the air. The prevailing air motion carries pollutants downstream. The "turbulent" fluctuations of the prevailing air stream disperses them in other directions at a rate depending upon the other properties of the atmosphere.

The desired upward dispersal of air pollutants is greatly affected by how temperature changes with height in the atmosphere. Under average conditions, temperatures decrease with height at a rate of 5.4° F per 1,000 feet (2).

Whether a parcel of air moves up or down or stays in the same position depends upon whether the actual temperature change with height is greater or less than the average temperature decrease of 5.4° F per 1,000 feet. If it is greater, a parcel of air that begins to rise with its pollutants will continue to rise. When this is the case, it is said that the atmosphere is unstable. On the other hand, if the actual temperature decrease is less than 5.4° F per 1,000 feet a parcel of air that begins to rise with its pollutants will tend to stop rising. In some cases it will even sink. This condition is known as a stable atmosphere. For disposal of air pollutants, an unstable atmosphere is clearly preferable to a stable atmosphere.

Sometimes temperatures increase with height in the atmosphere. This condition of the atmosphere is called an inversion, because the normal position of cold air above and warmer air below is reversed. The base of an inversion may be found on the earth's surface or aloft in the atmosphere. The inversion acts as a practically impenetrable lid which prevents polluted air from rising and dispersing upwards. When a surface-based or a low level inversion condition is prolonged and accompanied by low winds (the two factors usually go together), a dangerous accumulation of polluted air can build up over an area.

Temperature changes-with-height in the layer of air nearest the ground shows a large daily variation. During most nights, with light winds and clear to partly cloudy skies, the air near the ground cools faster than the air above, so that the coolest temperatures are found at ground level. This inversion of the normal temperature pattern continues throughout the night, and by dawn the inversion may extend several hundred feet into the atmosphere. This results in a very stable atmosphere with reduced vertical turbulence and increased tendency for airborne pollutants to sink or hang low over an area. The longer hours of winter darkness favor the formation and sustenance of surface-based inversions.

At sunrise, the heating of the land surface by the sun results in more rapid warming of the air near the surface than higher in the atmosphere. With continued heating of the ground surface the inversion will eventually be wiped out, causing the air to become unstable. This forces the surface air to rise and cooler air from aloft replaces the rising air. The sinking air is then warmed and rises in turn. This vigorous vertical interchange of cool air above with warm air below continues until mid-afternoon when surface heating decreases. By that time, the normal temperature decrease with height has been created. This condition facilitates upward movement of aerosols or pollutants in the atmosphere. Over deserts, this vigorous mixing of air may extend to about 10,000 feet, while over a forested lake country the mixing layer may only be 300 to 600 feet thick (3). This effect is highly seasonal. In winter the lesser solar heating and high reflection of solar radiation by snow cover greatly inhibits the vertical interchange of air.

Applicators of agricultural chemicals, or anyone dispersing potential pollutants into the air near the ground, should have some understanding of how the temperature changes with height in the air layers nearest the ground. To date, the decision of whether or not to apply agricultural chemicals has largely been based on surface wind velocities. But air pollutants can travel great distances, according to the temperature structure of the air near the ground, even if surface winds are not very strong.

Because of its major agricultural operations, North Dakota is among the major users of herbicides, pesticides and other economic poisons. It is unfortunate that measurements of the amount of these potential pollutants deposited in the air during periods of heavy applications are very inadequate, if made at all, in the state.

On a much larger scale, the temperature structure of the atmosphere can be influenced over thousands of square miles by the action of large-scale weather systems. In low pressure storm systems, the increased gradients of pressure and resulting higher wind speeds, plus the general upward atmospheric motion, create relatively good vertical mixing conditions which are conducive for faster and safer disposal of atmospheric pollutants.

In contrast, weaker gradients of pressure, slower movement, and slow downward outflow of surface air in high pressure areas result in much less vertical mixing. Here we find a descending motion of the air aloft over large areas as it replaces the outflow at the surface layers. The descending air warms, forming an inversion aloft whose base may eventually lower to 1,000 to 3,000 feet above the ground. Thus, the upward mixing of pollutants above this inversion level is inhibited. In some areas this condition may persist for a week or more. Such a situation of a stagnant high has been shown to be associated with all the major air-pollution disasters such as the incidents in 1948 in Donora, Pennsylvania (2), London in 1948, 1952 and 1962, and others (3).

Inversions produced by large scale weather systems are more critical to problems associated with discharge of waste from industrial smoke stacks. Ground-based inversions are usually eliminated during the day, while those caused by large-scale weather systems could persist for days. Furthermore, most smoke stacks are high enough to protrude above ground-based inversions, or the discharged waste is warm and buoyant enough to break through this type of inversion. It is quite certain, however, that when the effluent from a stack rises nearly straight up and then starts fanning out, leaving a plume of smoke that eventually extends for miles downwind, an inversion associated with a high pressure system is involved.

Surprisingly, perhaps, winter is not usually the time of the most persistent upper level inversions in North Dakota. Here, the usual rapid progression of high pressure systems over the state prohibits the prolonged formation of inversions which are conducive to severe pollution problems. In autumn, however, with its combination of relatively long nights and stagnation of high pressure systems over the state, prolonged inversions are most frequent and persistent.

THE ROLE OF AIRBORNE POLLUTANTS IN CLIMATIC CHANGE

Atmospheric constituents such as water vapor, carbon dioxide, dust and other impurities each have vital roles in "weather-making." Besides the fact that condensed water vapor makes up clouds and thus rain, water vapor is among the substances in the air which selectively absorb and reflect sunlight and the heat emitted by the earth, thus affecting the thermal balance of the atmosphere. Water vapor is not usually considered a pollutant except perhaps in the upper layers of the atmosphere (the stratosphere whose base is usually near 40,000 feet). Future supersonic jets have been cited as potential contributors to the amount of water vapor in the stratosphere (1).

Combustion Products, Clouds and Rain

Man's principal contribution to air pollution comes through burning. Man burns to produce heat, to generate power and to reduce solid waste. Some combustion products present in the air could serve as condensation nuclei for cloud formation and eventual precipitation. Man continually dumps foreign materials into the air through combustion, and it is conceivable that some of these materials act as seeds for promoting cloud growth and increasing precipitation. In fact, studies indicate that in recent years rainfall over and downwind from major cities is 5-10 per cent more than that observed over surrounding open country areas (1). Studies also show that precipitation appears to be more frequent on weekdays than on weekends in metropolitan areas. This is probably due to greater combustion and industrial activity on week days.

Dust and Sunlight

Wind erosion of the soil surface contributes large amounts of airborne dust. Volcanic eruptions add tons of volcanic dust to the atmosphere. Dust reflects sunlight, and an increasing dust concentration in the air could eventually reduce the intensity of sunlight around the whole globe. Anders Angstrom, one of the world's authorities on solar radiation, suggested that an increase of 2 per cent in the world's atmospheric dust would reflect enough sunlight to lower the temperature of the earth by 0.3° C (4).

Day and Sternes (2) stated that the worldwide emission of dust into the global air is estimated at about 30 million tons per year. It has been reported that over the last 10 years dustiness of the atmosphere has increased 30 per cent (5). Bryson further suggested that the tremendous increase in dust concentration in the air around us had contributed significantly to the observed decrease in the average global temperature since 1950.

There is little doubt that agriculture in North Dakota is contributing to wind-eroded dust over the Great Plain states. Proper soil conservation and management practices would help alleviate this problem.

Carbon Dioxide and The Average Global Temperature

The 2,300 billion tons of carbon dioxide in the earth's present atmosphere constitute some 0.03 per cent of its total mass (300 ppm). To be detrimental to human health, the carbon dioxide in the air has to be greater than 5,000 ppm (6). So, one might surmise that carbon dioxide is not a dangerous air pollutant. In fact, to plant life, small increases in carbon dioxide might be more beneficial than harmful. There is, however, a growing concern that carbon dioxide may have an effect on climate. There is speculation that the observed long-term warming of the average global temperature could be due to the observed increase of carbon dioxide in the air (7).

Carbon dioxide affects climatic change by altering the thermal balance of the earth through radiational exchange. Carbon dioxide in the atmosphere has a negligible effect on the incoming radiation from the sun. It is virtually transparent to sunlight. However, this particular constituent of the air is a good absorber of the heat emitted by the earth's surface. In effect, carbon dioxide permits solar heating but traps some of the heat from the earth, leading to warming of the atmosphere.

At the rate that man, through his worldwide industrial civilization, is continually emitting carbon dioxide into the air, it is estimated that by the year 2000 the increase in atmospheric carbon dioxide will be close to 25 per cent (1). This could raise the present atmospheric carbon dioxide concentration to about 450 ppm. This may be enough to produce measurable and perhaps marked changes in climate. But at present it is impossible to predict these effects quantitatively.

Not everyone agrees with the argument that the present worldwide cooling trend is associated with some form of air pollution. For instance, Jerome Namias, chief of the Extended Forecast Division of the National Weather Service, recently noted that observed changes in average ocean temperatures seem to be linked to large-scale displacements of air currents around the globe. In particular, Dr. Namias believes that it is quite possible that the observed warming in the North Pacific is responsible for the colder winters in the eastern United States and thinks it quite "unlikely" that air pollution and volcanic activity have much to do with it (8).

There was a marked warming trend in the northern latitudes from 1900 until about 1940. This subtle climatic change has been seriously attributed by scientists to man's activities. It was thought by many to have resulted from the increase in carbon dioxide release to the atmosphere during that period. But, temperatures started cooling down again after 1950 while carbon dioxide in the air continued to increase. This caused some scientists to seriously question the carbon dioxide warming theory. And yet, many others think that the theory may be right, but that the offsetting cooling effect of dust and other human-derived particulates in the air has become even more significant.

Whichever argument is correct, the fact remains that our knowledge of the atmosphere upon which our very lives depend, is still inadequate. It has also become apparent than man's involvement in the changes in his atmospheric environment, both locally and in a worldwide basis, can no longer be considered negligible.

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