

CHAPTER 19

CLIMATIC FACTORS AFFECTING POLLUTANTS IN WASTE DISPOSAL SITES IN DEVELOPING COUNTRIES

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Introduction

In many cities in the developing countries, the collection and disposal of solid wastes has become a perennial problem faced by municipal authorities. Solid wastes are being generated by the inhabitants of these cities at rates that exceed the capacities of the municipal authorities to collect, transport and safely dispose them off. The rapid increase in solid waste generation is due primarily to the high rates of growth of the population in these cities as a result of high natural growth rate and the high rates of rural-urban migration. The rapid rates of the physical expansion of these cities and their poor physical planning evident in the development of slums have made the collection, transportation and safe disposal of solid wastes a difficult exercise for the municipal authorities. The problem is compounded by the fact that many of these municipal authorities lack the necessary executive capacity because of inadequate finance and lack of adequate manpower and equipment.

Solid Wastes and Pollution

Solid wastes constitute a veritable source of air, water and land pollution in many urban areas of the developing countries because of their poor management and disposal. Open and over-filled waste dumps dot the urban landscape of many developing countries. Some of these wastes are blown about by wind while others are washed by runoff after rainstorms into urban river channels. In some cities, residents even dump their household wastes directly into urban river courses. Such wastes leading to flooding of the adjacent land often clog urban river channels. Poor solid waste disposal is the major cause of pollution of the water in the urban river courses in developing countries.

In most developing countries solid wastes are disposed off either by *incineration* or *sanitary landfill*. Often incineration takes place in open waste dumps. Whether wastes are burnt in the open or in incinerators, both gaseous and particulate pollutants are produced when wastes are burnt. Our major concern in this presentation is to examine the meteorological factors that affect the concentration in the atmosphere of pollutants generated at waste disposal sites.

Meteorological Factors Affecting Air Pollution

There are two factors that determine the level of concentration of pollutants in the air over a given location in the absence of convection. These are (i) the rates at which pollutants are generated and emitted into the atmosphere and (ii) the rates at which these pollutants are dispersed and diluted within the atmosphere. Weather and climate play an important role in both especially the latter.

With regard to solid waste generation, climate may have an effect on the composition of waste generated. The moisture content of solid wastes in wet climates may be up to 50% by weight. Organic wastes also tend to be higher in quantities during the wet season than during the dry season. Under warm moist conditions as in the humid tropics, organic wastes serve as breeding grounds for disease vectors such as flies, mosquitoes and rats.

Weather conditions may also affect the type of gaseous pollutants produced at waste dumps. When solid wastes are land-filled the organic matter initially decomposes aerobically and then degrades anaerobically when oxygen is used up. In wet climates, aerobic decomposition lasts for only a few weeks but may last up to a year in dry climates. Also, under moist conditions large quantities of leachate are produced by the decomposition of wastes at waste dumps.

Anaerobic decomposition of organic wastes in landfill generates gases such as methane and carbon dioxide. Methane is an odourless gas but it is very efficient as a greenhouse gas. It is also a combustible gas that becomes explosive when its concentration in the atmosphere exceeds 5% by volume. Carbon dioxide may combine with water under moist conditions to create an acidic environment, in which minerals such as calcium, magnesium, lead, cadmium and zinc present in the wastes or soil are dissolved giving rise to the contamination of groundwater.

However, *it is in the rate of dispersal and dilution of pollutants in the atmosphere that climatic factors play a crucial role.* The factors include the following:

- (i) Wind speed and direction;
- (ii) The vertical temperature profile of the atmosphere which determines its stability or otherwise;
- (iii) Precipitation; and
- (iv) Other meteorological and non-meteorological factors which may affect (i) and (ii) above. Such factors include *insulation, humidity, cloud cover and*

local topography including the shape, size and height of nearby structures.

The dilution of pollutants in the atmosphere is inversely proportional to the wind speed. This is because wind speed affects the volume of air that passes over a given location during a given period of time. If the wind-speed over a location doubles, the volume of air passing over the location also doubles. Thus, the greater the wind speed the more the volume of air within which the pollutants will be diluted. Pollutants whether gaseous or particulate are carried in the atmosphere by wind. Hence, the direction of a airflow is also of significance as wind direction determines where the pollutants will be advected. Airflow is determined primarily by the pattern of atmospheric pressure. Pollutants emitted by point sources like waste dumps are normally carried downwind of the prevailing wind. In a perfectly smooth airflow, pollutants would travel downwind in a narrow plume with nearly uniform level of pollution concentration within the plume. However, because of the effect of turbulence airflow is never smooth. There is usually turbulence both in the horizontal and vertical directions. The plume consequently usually spreads out in form of a cone with the level of pollutant concentration decreasing progressively downwind. It is turbulence that ensures the mixing of the plume air with the surrounding air ultimately. There are two types of turbulence namely mechanical and thermal turbulence. Mechanical turbulence is caused by obstructions to airflow by buildings, trees and rough terrain. In other words, the friction between the atmosphere and the underlying surface of the earth generates it. Thermal turbulence is the stronger turbulence and is caused by thermal instability in the atmosphere.

Within the troposphere, temperature generally decreases with height at the average rate of 6.5 degC per km. This is what is known as the **Environmental Lapse Rate** (ELR). If a parcel of unsaturated air is lifted in the atmosphere as a result of convection, orographic or frontal displacement, it expands as atmospheric pressure decreases and cools at the **Dry Adiabatic Lapse Rate** (DALR) of about 9.8 degC per km of ascent. When the rising air parcel is cooled to its dew point temperature, the moisture it is holding starts condensing and the latent heat of condensation is released to the air parcel. The rate at which the rising air parcel cools then decreases to between 4 and 9°C per km depending on its moisture content and temperature. This is what is known as the **Saturated Adiabatic Lapse Rate** (SALR). The relationships amongst the three types of lapse rates described above determine the stability condition of the atmosphere over a given location at a given time.

Three stability conditions are the most relevant in air pollution assessment, These are the conditions in which the atmosphere is *unstable* (ELR>DALR), *neutral* (ELR=DALR) and *stable* (ELR<DALR). These conditions will now be briefly described.

- ❑ **In an unstable atmosphere**, the vertical dispersion or spread of pollutants is rapid and efficient because pollutants are mixed in a deep layer of the atmosphere and are consequently well diluted. Conditions of atmospheric instability occur mainly near the earth's surface in the lower layers of the atmosphere and are associated with sunny daytime conditions or the advection of cold air over warm surface. The former conditions occur regularly in most parts of the tropics particularly during the dry season or in semi-arid areas where the sky is usually cloud free.

- ❑ **Neutral stability** conditions occur during cloudy, windy weather or briefly after sunrise before the onset of thermal convection and just before sunset when thermal convection ceases. These conditions do not encourage vertical dispersion of pollutants in the atmosphere. Air pollution problems usually occur during period of stable atmosphere characterised by temperature inversion in which temperature increases with height. Inversion acts as a lid preventing vertical motion of air. Pollutants therefore cannot rise in the atmosphere. Rather they concentrate at the base of the inversion layer. Air pollution potential is very high under inversion conditions especially if such conditions are also accompanied (as they are often are) by calm winds. Temperature inversions can occur in the tropics under a variety of conditions of which the following are the most common:
 - (i) Near the earth's surface at night when the sky is cloud free and winds are light;
 - (ii) After afternoon rain showers when the earth's surface is cooled by evaporation;
 - (iii) When there is advection of warm air over a colder surface;
 - (iv) When there is drainage of cold air from mountain slopes to the valley bottom or depression; and
 - (v) In areas under warm subtropical anticyclone trade wind inversion occurs at a height of between 1000 to 5000 metres in the middle troposphere.

Precipitation is another weather element relevant in air pollution studies and assessment. *Precipitation removes pollutants from the atmosphere by the physical processes of washout and rainout.* Washout is the term used to describe scavenging by rain while the process of scavenging by cloud droplets that eventually grow into precipitation is called rainout. Precipitation also removes pollutants from the atmosphere by the chemical processes of oxidation and hydrolysis. Acid rain commonly occurs within or downwind of industrial areas where sulphur dioxide and oxides of nitrogen are emitted in large

quantities. These gases are transformed in the atmosphere into sulphate and nitrate particles. These combine with water vapour to form mild sulphuric and nitric acids that are precipitated on to the earth's surface as acid rain.

Assessing Air Pollution Potential

Given a certain quantity of pollutants, the chances of the atmosphere getting polluted are determined by the prevailing meteorological conditions that control the atmosphere's dispersive capability or what is known as its air pollution potential. As mentioned earlier, air pollution potential is primarily controlled by the stability status of the atmosphere and wind speed. The main meteorological indicators of air pollution hazard are temperature inversions and low wind speeds. These are often characteristic of anticyclonic weather conditions. Such synoptic weather conditions also tend to suppress precipitation.

In contrast, *thunderstorms form when the atmosphere is very unstable. Heavy downpours that help "wash" down pollutants accompany these storms. Thus, conditions that favour the occurrence of thunderstorms also favour low pollution potential. The frequency of thunderstorms is highest in the tropics because of the intensity of solar radiation that encourages convection. Compared to the middle latitudes, air pollution potential in the tropics is generally low. However, air pollution potential could be high in the night and early morning in areas with little or no cloud when low-level temperature inversions develop. The trade wind inversion also occurs in many areas of the tropics although not close to the earth's surface. Radiosonde data are needed to assess the stability of the atmosphere, to calculate the thickness and height of any inversion layer and to calculate the height of the afternoon mixing layer, a major determinant of air pollution potential. Unfortunately, radiosonde data are few and are not available for most parts of the developing world, which is also practically synonymous with the tropics.*

Summary and Conclusion

In this chapter, attempts have been made to highlight those meteorological factors that affect the dispersal and dilution of pollutants in the atmosphere. They are basically the vertical temperature profile of the atmosphere and wind speed. These are themselves controlled by other meteorological processes. The process of precipitation helps to wash out many pollutants from the atmosphere. It is quite clear from the preceding discussion that meteorological factors need to be taken into account in the location of waste disposal sites by the municipal authorities. Waste dump sites like industrial sites should be located downwind of the residential areas. Incineration of wastes should take place only when the atmosphere is unstable and wind is appreciable to ensure quick dispersal and

dilution in the atmosphere of pollutants that will be generated by incineration. Studies have shown that the maximum concentration of air pollutants at ground level varies inversely as the square of the height of a chimney stack. Also that the effective height of a chimney stack can be increased if the temperature of the effluent gases is greater than the ambient air temperature. It is therefore recommended that incinerator stacks should be high and that open burning of solid wastes should be discouraged. Also, incineration should be done at very high temperatures to make the resulting gaseous pollutants buoyant and destroy their odours. This may require refuse sorting/drying before burning since refuse materials are not homogeneous and vary widely in their fuel value.

Finally, *there is need to estimate the air pollution potential of the atmosphere in and around waste dump sites, existing and potential.* This will assist in the choice of suitable sites for waste dumps as well as the best time for waste incineration. This exercise requires data not only on wind speed but also on the vertical temperature profile in the atmosphere, which only data from radiosonde can provide. It is therefore recommended that weather stations in the major urban centres should be equipped to send radiosondes into the atmosphere regularly to provide the necessary data to assess the stability status of the atmosphere and hence its air pollution potential.