CHAPTER THREE

AIR POLLUTION CLIMATOLOGY

What happens to pollution after being released into the atmosphere depends on local climate and weather. Pollution levels fluctuate in response to the changing state of atmospheric stability, which determines the mixing depth and the wind system which causes horizontal dispersion.

3.1 The Relationship between Stability and Pollution

Remember our definition of stability – the tendency of an air mass to fall back to its original position after being forced upward by an external force. When this occurs, diffusion of the polluted air is inhibited at the boundary layer between the stable airs above and the polluted air underneath, trapping the pollutants. Residents trapped in the polluted air will suffer. This generally happens during the early morning hours and in winter because the nights are cool. Occasionally during some winter mornings, a cloud layer is observed over parts of the South Durban basin as evidence of an inversion layer trapping pollution below. In summary then, stability has a direct relationship as increased stability results in an increase in pollution concentration.

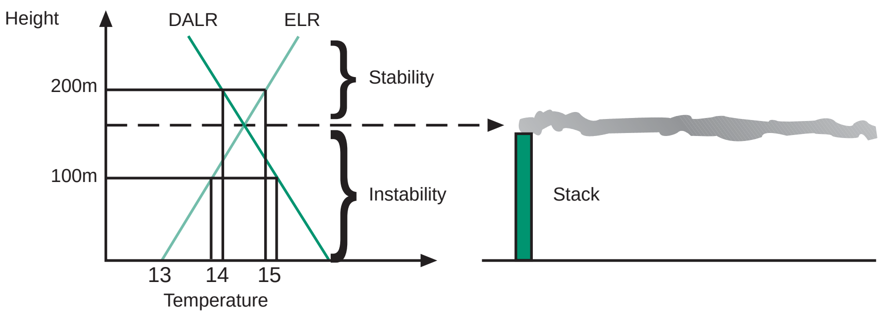


Figure 3.1: Fanning, stability and pollution

As figure 3.1 above show, at 100m, the temperature of the rising air parcel (DALR) is greater than that of the environmental air (ELR), indicating instability. At 200m altitude, the temperature of the rising air parcel is now less than that of the surrounding air indicating stability, which blocks the escape of pollutants. Under these circumstances, air pollutants move horizontally below the stable layer as indicated by the stack plume.

3.2 The Relationship between Instability and Pollution

Instability relates to a rising air mass, with a temperature that is higher than that of the surrounding air. The release of atmospheric pollutants into such an expanding air mass leads to diffusion of the pollutants reducing its concentration. This occurs most effectively under conditions of free convection, when the mixing layer is deep, and in summer during the day. Unlike stability, instability has an inverse relationship with pollution, as it disperses or dilutes air pollution.

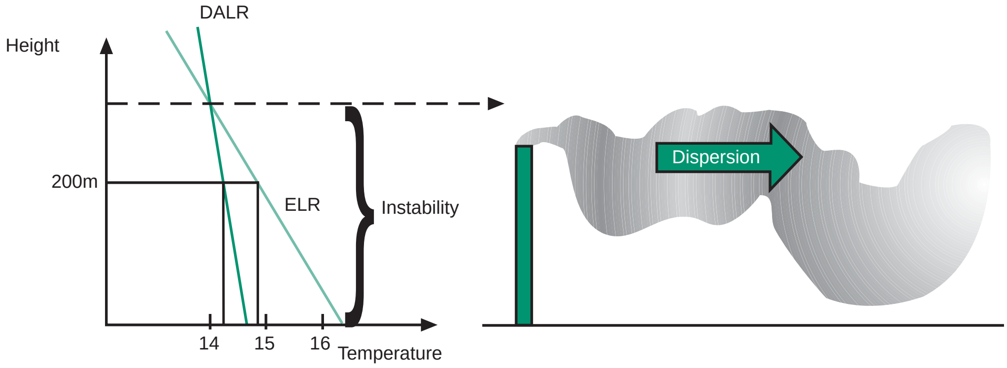


Figure 3.2: Looping, instability and pollution

Figure 3.2 above illustrates a turbulent or unstable atmosphere. To make this clear, if we draw a line 100m altitude to intersect with the two lapse rates (ELR and DALR), it would be realised that the lapse rate of the surrounding air is more negative than the adiabatic lapse rate. This creates a very unstable windy atmosphere resulting in pollutants being well mixed and quickly dispersed, therefore reducing the concentration of pollutants that the people breathe.

3.3 Inversions and Pollution

Temperature inversions are simply defined as a layer of air or a region within the troposphere where temperature increases with height.

In a normal situation, temperature decreases with an increase in height in the top sphere. You may be familiar with the expression, "the higher you go, the colder it becomes". This common saying describes the behaviour of air temperature as it ascends into the atmosphere. Temperature inversion depicts the opposite of the normal scenario. It is a situation where temperature instead increases with height, "the higher you go the hotter in becomes". During temperature inversions, cooler air is found at lower levels with hot air sitting above it.

Their origin is frequently related to different atmospheric conditions, such as, radiational cooling near the surface (radiation inversions), subsidence regions (subsidence inversions), or the vertical distribution of different air masses. Other types of inversions are frontal inversion and valley inversion. The existence of these conditions restrain the diffusion of pollutants with negative repercussions on the cities and residents trapped underneath.

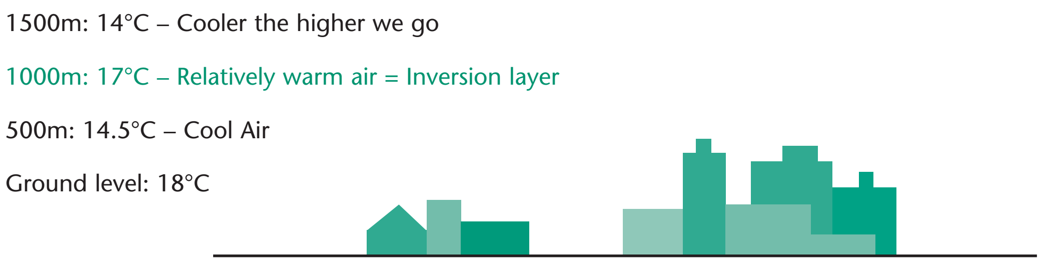


Figure 3.3: Temperature Inversion in the atmosphere

3.3.1 Surface Inversions and Atmospheric Pollution

Overnight radiative cooling of surface air often results in a nocturnal temperature inversion. Clear skies, low relative humidity, low wind speeds and calm nights are perfect for the formation of a temperature inversion at the earth's surface.

These inversions form because the ground is a much better emitter of heat radiation than the air. In other words, the ground cools much more rapidly during clear, calm nights than the air above it. The layer of air touching the ground also cools more rapidly than the air above it because it is in contact with a cooler surface. As these conditions continue into the night, this process creates a layer of air where the coolest temperatures are found closest to the surface and the temperature increases with height for up to several metres. These inversions are known as nocturnal or radiation inversions. During this period, polluted air released from stacks below the inversion are trapped since it is less buoyant and cannot penetrate the warmer, lighter air above. Residential areas suffer from peak pollution at this time. This scene is depicted by Figure 3.4 below.

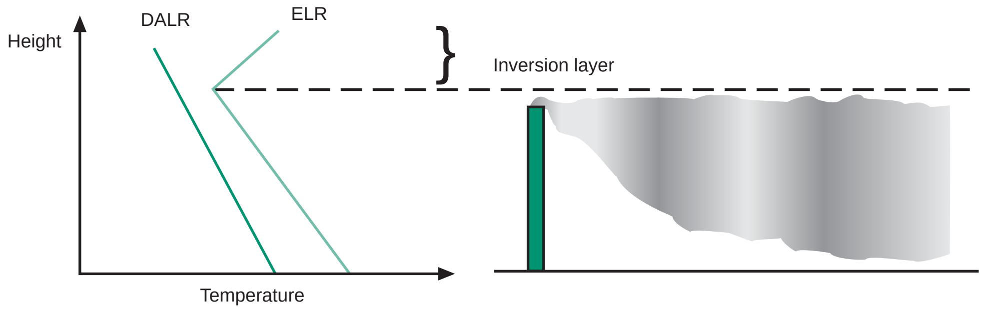


Figure 3.4: Surface inversion and pollution

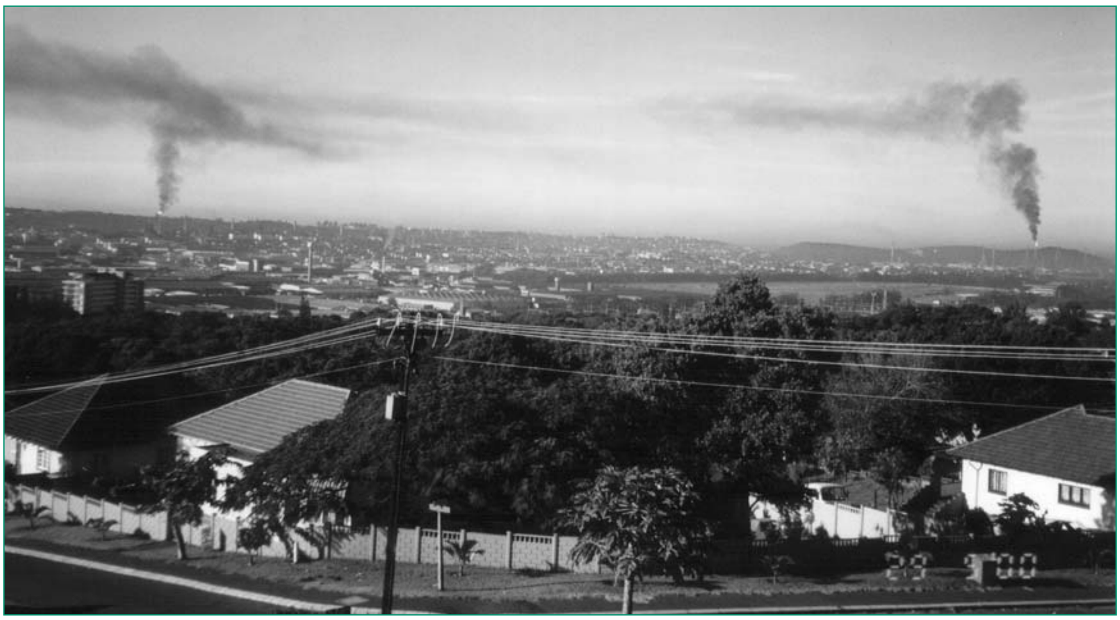


Figure 3.5: Temperature inversion blocks the escape or dispersion of pollutants

Source: GroundWork

In the South Durban basin, this corresponds to the time when residents complain the most. The areas which recorded the most complaints probably, showing they suffer more from pollution episodes, are shown in the map below.

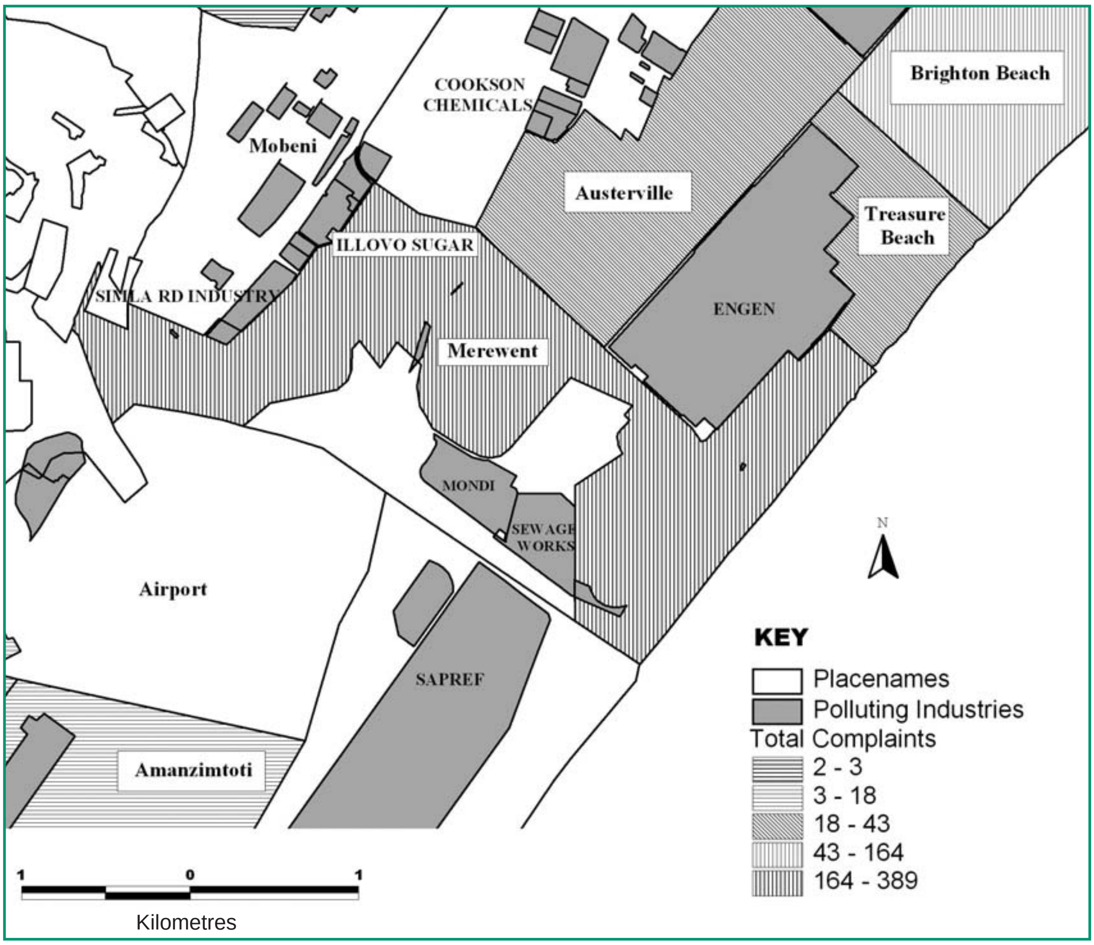


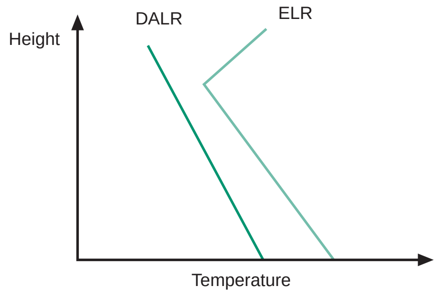
Figure 3.6: Part of South Durban showing Merewent with most complaints

The air near the ground often cools to its dew point temperature during the earth's radiative process and as a result, water vapour condenses into liquid droplets. These liquid droplets form what is known as radiation fog. The calm conditions prevent the fog from mixing with the drier air above it during the night time and early morning hours. This is common in valleys resulting in valley fog.

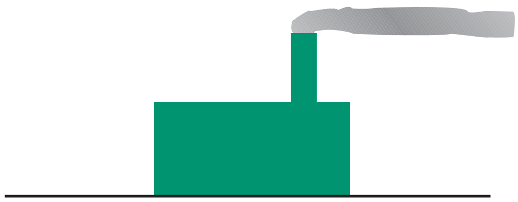
Preston-Whyte, (1980) has indicated that in Durban, these conditions occur during the winter months, re-enforced by the intensification of anti-cyclonic circulation over South Africa. Between May and August, such surface inversions occur with frequency greater than 60%, with high inversion depth. During the remainder of the year (October to March), weaker anti-cyclonic activity reduces the surface inversion frequency to 30%, with a lower inversion depth. The notion of inversion depth is an important factor in air pollution climatology because it defines the layer in which the accumulation of pollutants can be expected (Preston-Whyte, 1980).

Exercises

1. Sketch the behaviour of an industrial plume under the atmospheric conditions illustrated in the graph below.



2. The figure below shows the behaviour of emissions from a stack. Draw a graph showing the atmospheric conditions determining such behaviour.



3. Explain the effects of pollution on the South Durban communities under the conditions illustrated in number 1 and 2 above.

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4. What do you understand by surface inversion?

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5. When does inversion occur most frequently in South Durban?

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6. Explain how it occurs in South Durban. Discuss its effect on pollution and residential communities.

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7. Which places in South Durban are most affected when this happen?

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8. What is the situation marked by x in the figure below?

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   a) How does it affect pollution?

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   b) Sketch a plume behaviour under the conditions illustrated.