AN INTRODUCTION TO AIR QUALITY

— BACKGROUND

Air quality is influenced by a variety of factors and is a complex issue. The term air quality refers to the degree to which the air in a particular place is free from pollutants. Air pollutants are substances present in the atmosphere at concentrations above their normal background levels which can have a measurable effect on humans, animals and vegetation.

Common Air Pollutants

The sources of air pollutants are numerous and varied and can be either natural or man-made. Common air pollutants include:

- **Sulphur dioxide (SO_2):** SO_2 is a colourless, non-flammable gas. Once released into the atmosphere, SO_2 is converted to other compounds, predominantly sulphates which is an important precursor of secondary particulate matter. The principle man-made source of SO_2 is in waste gas produced by burning fossil fuels (e.g., coal, heavy fuels) and biomass which contain sulphur. SO_2 is produced naturally by volcanic activity.

- **Nitrogen Oxides (NO_x)**: NO_x is the generic term for mixtures of nitric oxide (NO) and nitrogen dioxide (NO_2). NO_x is produced by combustion processes. Most NO_x is emitted as NO which is then converted to NO_2 by chemical reaction with ozone. NO_2 is an orange to reddish brown gas. In daylight, NO_2 decomposes back to NO so the composition of NO_x in ambient air is highly variable. Air quality limit values exist for NO_2 but not for NO or NO_x. Natural sources of NO_2 include forest fires and lightning and man-made sources include burning fossil fuels and biomass. NO_x emissions are an important precursor of secondary particulate matter.

- **Particulate Matter (PM)**: Particulate matter is classified by particle size. The key classifications are: total suspended particulate matter (i.e., dust), PM_{10} (less than 10µm in diameter), $PM_{2.5}$ (less than 2.5 µm in diameter), and ultrafine particles (less than 0.1 µm in diameter). PM is referred to as "primary" if it is directly emitted into the air as solid particles, and is called "secondary" if it is formed by chemical reactions of gases in the atmosphere. Sources of airborne particulate matter include road dust, agricultural activities, vehicle exhaust, wood burning, smoke from forest fires, and industrial activities. Secondary particulate matter is an important fraction of $PM_{2.5}$ which can be created from NO_x, SO_2 and ammonia (NH_3).

- **Carbon Monoxide (CO)**: CO is a colourless and odourless gas. A product of incomplete combustion, its sources include fossil fuel combustion, industrial processes and natural sources such as forest fires.

- **Volatile Organic Compounds (VOCs)**: VOCs are organic compounds whose composition makes it possible for them to evaporate under standard atmospheric conditions. Examples of VOCs include benzene, ethylene glycol, and formaldehyde. VOCs are the primary precursors to the formation of ground-level ozone and particulate matter which are the main ingredients of smog. Sources of VOCs can be either natural (e.g., vegetation) or man-made (e.g., chemical industries and fossil fuel combustion). Natural sources of VOCs such as forests, grasslands and swamps are estimated to be much larger than man-made sources.

- **Ozone (O_3)**: Ozone is not emitted directly into the air, but is created by chemical reactions between NO_x and VOCs in the presence of sunlight. Ozone occurs naturally and is an important chemical in the upper atmosphere where it blocks ultra-violet radiation but can have harmful effects on human health at ground-level.

- **Ammonia (NH_3)**: Ammonia is highly reactive and does not remain long in the atmosphere and emissions of NH_3 occur over very large areas. Ammonia reacts to produce ammonium sulphate and ammonium nitrate which are the main components of secondary PM. Around 94% of NH_3 emissions in Europe are from agriculture[1].

[1] European Environment Agency 2017. Air pollution from agriculture: ammonia exceeds emission limits in 2015. EEA, 2017.

The greenhouse gases Carbon dioxide (CO_2) and Methane (CH_4) are not generally considered air pollutants although they are sometimes incorrectly referred to as such.

Air Pollutant Emissions vs Ambient Air Quality Concentrations

The terms emission and concentration are sometimes confused. An emission is the amount of pollutant released into the atmosphere from a specific source and at a specific time interval, generally expressed as a mass per unit of time (e.g., kg/h). A concentration is the amount of pollutant matter in the ambient air per volume unit and is generally expressed as mass per volume (e.g., µg/m³). Ambient air concentration is the term used to express values of air quality which can be compared to air quality limit values set by regulation. In Europe, the air quality limit values are set for the protection of human health and/or the environment and are published in the Ambient Air Quality Directive[2].

The nature of an emission source (what is emitted, how much is emitted, when and how often it is emitted, how high it is emitted) together with meteorology, climate, distance from source, and terrain all affect air quality concentrations. The relationship between emission and ambient concentration is therefore not clear cut. Generally, the concentration of a pollutant in the ambient air is the sum of many contributing sources. Reducing emissions by a given percentage does not necessarily reduce ambient air concentrations by the same amount. For this reason, emission control strategies need to be adapted to local conditions and international cooperation is needed to influence background concentrations.

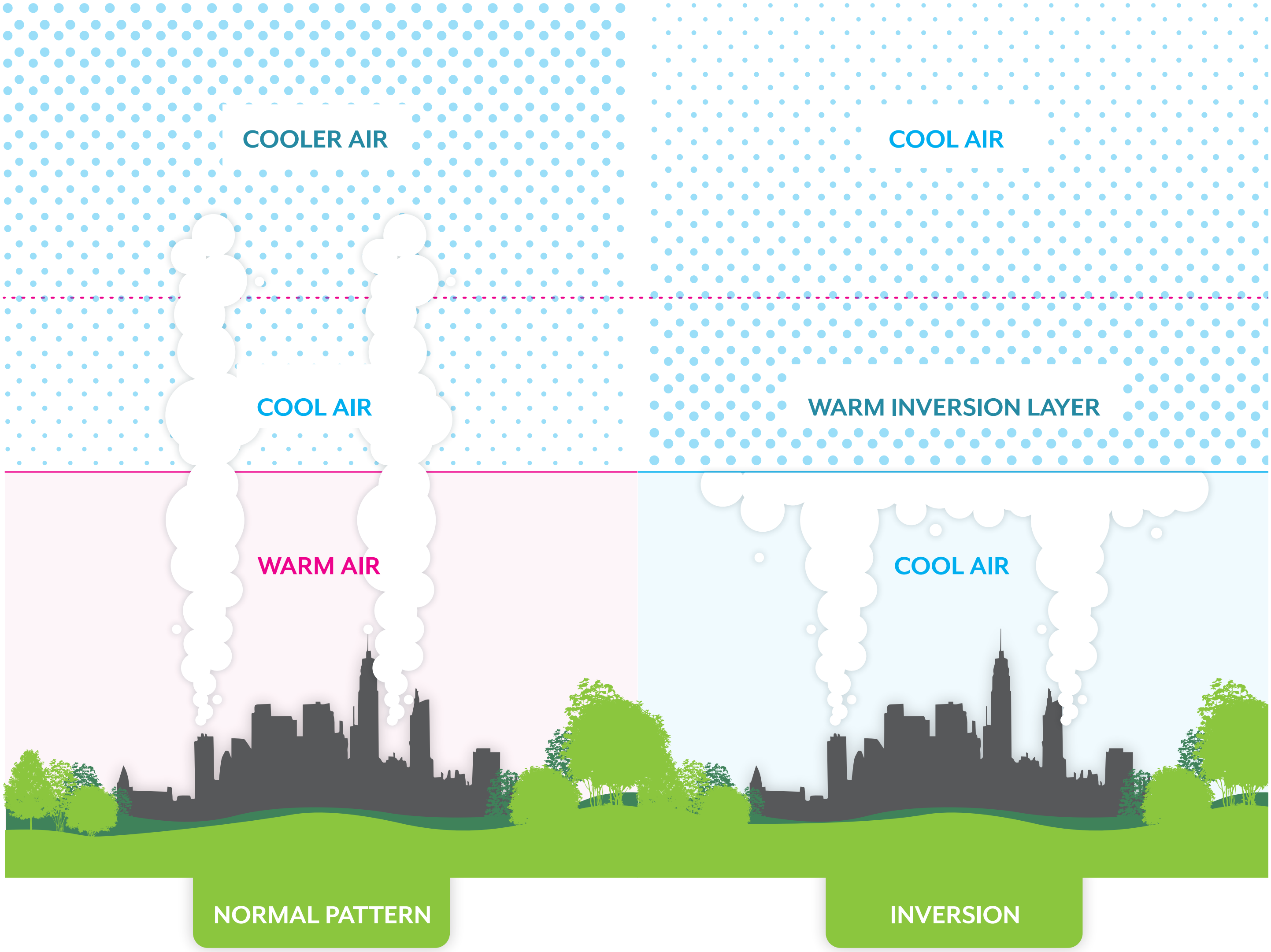
[2] Directive 2008/50/EC on ambient air quality and cleaner air for Europe: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0050&from=EN

Dispersion and Deposition

Dispersion is the distribution of air pollutants into the atmosphere and deposition is the transfer to land and water surfaces either directly (dry deposition) or by rain (wet deposition). Rates and patterns of dispersion depend to a large extent upon environmental conditions such as weather and meteorology. For example, during an inversion episode when a layer of cool air is trapped near the ground by a layer of warmer air above, air cannot rise and pollutant concentrations near the ground will be increased (see figure on the next page).

In general, higher temperatures, low winds and lack of precipitation promote chemical reactions in the atmosphere and can cause poor air quality. Pollution dispersion in the air is also affected by local and regional terrain features, the height of the emission sources, the type of emission source, and any surrounding buildings or structures[3] .

[3] European Environment Agency (EEA) website "Dispersal of air pollutants": https://www.eea.europa.eu/publications/2599XXX/page005.html



Assessment Methods

Air quality compliance refers to how close a pollutant concentration in ambient air is to an air quality limit value. Two methods commonly used to assess air quality are ambient air quality monitoring and dispersion modelling.

- **Ambient air quality monitoring**: Ambient air quality monitoring is the measurement of pollutant levels in outdoor air at a given location for a given period of time. The locations of monitoring stations and the type of monitor used will depend on the purpose of the monitoring. Monitors may be placed near busy roads, in populated areas, at a particular location of concern, or away from emission sources to determine background pollution levels. Many monitoring activities are used to assess exposure of people and therefore monitors are often placed in populated areas. Proper siting of ambient monitors is critical as station placement can greatly affect the measurements. Due to the seasonal effects of weather, long term monitoring is useful to show the differences in air quality over the course of several days, months or years.

- **Dispersion modelling**: Atmospheric dispersion models provide a mathematical simulation of how air pollutants disperse in the atmosphere. Whereas ambient monitoring can only measure existing emission sources, dispersion models are an effective tool to predict the impact of future emissions, source addition or removal on ambient air quality. Dispersion models are also useful to predict air quality concentration in areas that are not covered by ambient monitoring. Models require specific inputs in order to predict air quality concentrations which can include emission source details (source type, height, emission rate, release velocity and temperature, etc.), meteorological information and terrain data. Model predictions are only as accurate as their inputs and assumptions. Model comparison and validation exercises are an important means of checking that model predictions are consistent and reasonable. There are dispersion models tailored to different applications, such as modelling air quality at a national or city scale, an individual industrial installation, or a road.

In Europe, ambient air pollutant concentrations have been decreasing over the past several years as a result of targeted policies and implemented emission reduction measures. However, air pollution is a complex issue as air pollutants released in one country can contribute to elevated concentrations in a neighbouring country. Most air pollution issues today arise from a combination of local and long-range effects. Cumulative effects can be mitigated by international cooperation to reduce the total amount of emissions.

Helpful Links

The European Environment Agency publishes air pollution fact sheets for the EU-28 countries which provide emission trends and summaries of the national air quality situation in each country. These can be found at: **https://www.eea.europa.eu/themes/air/air-pollution-country-fact-sheets-2014/air-pollution-country-fact-sheets-2014**

For more information and other fact sheets visit **www.concawe.eu**

About Concawe

The scope of Concawe's activities has gradually expanded in line with the development of societal concerns over environmental, health and safety issues. These now cover areas such as fuels quality and emissions, air quality, water quality, soil contamination, waste, occupational health and safety, petroleum product stewardship and cross-country pipeline performance.

Our mission is to conduct research programmes to provide impartial scientific information in order to:

- Improve scientific understanding of the environmental health, safety and economic performance aspects of both petroleum refining and the distribution and sustainable use of refined products;
- Assist the development of cost-effective policies and legislation by EU institutions and Member States;
- Allow informed decision making and cost-effective legislative compliance by Association members.

Concawe endeavours to conduct its activities with objectivity and scientific integrity. In the complex world of environmental and health science. Concawe seeks to uphold three key principles: sound science, transparency and cost-effectiveness.